Spatial Sciences Project

SPAT 4009

Effect on Ground Surface Temperature of different tree species within the urban forest canopy.

Case Study:

City of Melville

Perth, Western Australia

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1 Abstract

Increasing urbanisation and its associated increase in artificial surfaces, coupled with a reduction in the urban forest canopy, has lead to the development of the urban heat island (UHI) phenomenon in and around cities worldwide. This phenomenon impacts liveability, but can also manifest itself in the form of increased infrastructure loads and maintenance, and more seriously, reduced health outcomes for the populace while increasing demand on health services.

One of the key strategies to reduce heat, and its impact in urban areas, is the implementation of revegetation strategies. The City of Melville, Perth, Western Australia is familiar with the concerns regarding increasing urban heat, and in response is implementing an urban forest strategy (City of Melville, 2017).

The aim of this report is to quantify any measurable difference in the ability of native/indigenous/exotic tree species to provide a reduction in heat accumulation, in common substrates, found within the City of Melville study area. A laser thermometer is used over a 15 hour period, per sampling day, to accurately survey ground surface temperatures, in three cycles. In this way the temperature flux beneath the tree canopy can be measured, and compared, with unshaded substrates, as well as between canopy tree species.

Table 1. Temperature reduction due to shade protection.

Surface	Sun	Shade	Change
Grass-irrigated	**32.8**	22.2	10.6
Concrete Light	**38.0**	25	13.0
Grass-Dry	**38.2**	22.6	15.6
Concrete Medium	**39.5**	26.8	12.7
Asphalt	**44.7**	27.5	17.2
Soil	**49.5**	24.4	25.1

The results demonstrate the ability of trees to provide a marked reduction in heat accumulation in urban substrates (Table 1). Additionally, the reduction in heat accumulated in artificial substrates is shown to be particularly significant, as these substrates display a measured delay in dissipating thermal energy. These materials are integral to the built environment, and hence this finding has implications for urban liveability, and comfort of the resident population. The ability of trees to moderate temperature variation, as well as the magnitude of thermal storage, in both artificial and natural surfaces is also demonstrated. There are indications that the native and indigenous species found within the study area may be more effective at reducing heat than exotic species (Table 2). Finally the importance of structure and positioning, of both individual and contiguous plantings, relative to substrate surfaces is apparent due to the localised effect of these benefits.

Averages	October	September
Exotic	25.7	22.9
Native	23.8	22.0
Indigenous	24.2	21.4

Table 2. Shaded temperatures by orgin. All substrates.

2 Introduction

Modification of natural landscapes due to urbanization has resulted in changes in local and regional climates, with associated consequences for those living within the built environment (Georgescu, Morefield, Bierwagen, & Weaver, 2014). Often referred to as the urban heat island effect (UHI), this phenomenon is related to a typical increase in artificial surfaces as urban density increases. Artificial surfaces act as heat sinks, causing additional warming through convection during the day, and reradiating latent heat back into the environment after sunset (Quattrochi & Ridd, 1994). Emissivity and conductance characteristics of artificial surfaces result in an urban region that tends to be hotter than the surrounding rural landscape.

Excessive heat in an urban environment has been linked to a series of negative outcomes ranging from increased infrastructure loads and maintenance, livability and comfort within the built environment, and serious health issues requiring hospitalization or contributing to increased morbidity.

High heat levels can produce a series of issues in residential and work situations. Table 1 provides an overview of possible heat related psycho-physiological symptoms associated with increasing temperatures. Summer temperatures within the Melville city area reach a mean maximum of approximately 30°C, while daily maximums can reach into the low 40°C range (Bureau of Meteorology, 2017). This seasonal climate characteristic already leaves residents susceptible to heat related stressors, before factoring anomalous, prolonged heat events.

Table 3. Livability and heat related health impacts (Brown, Katscherian, Carter, & Spickett, 2013).

Temperature Range (°C)	Effects	Potential outcomes
20 - 27°C	Comfort Zone	Maximum efficiency
As temperature increases	Discomfort: • Increased irritability • Loss of concentration • Loss of efficiency in mental tasks	Mental Problems
	Increase of errors: • Loss of efficiency in mental tasks • More incidents	Psycho-physiological problems
	Increase of performance of heavy work: • Disturbed water and electrolyte balance • Heavy load on heart and circulation • Fatigue and threat of exhaustion	Physiological problems
35 - 40°C	Limit of high temperature tolerance	

Particularly vulnerable are the very young, elderly or those with preexisting health issues, although under unfavorable conditions anyone can succumb to heat induced illness. Increased hospitalizations, ambulance dispatches and the associated increased demand on health services have been linked to heat events. For example the Victorian heat wave of 2009 documented a 25% increase in ambulance emergency callouts due to heat related illness, and 374 additional deaths (Department of Human Services, 2009). However, a study conducted in Toronto Canada, examining four extreme heat events spanning two years that resulted in a 12.3% increase in ambulance calls, found that calls were negatively correlated to canopy cover (Graham, Vanos, Kenny, & Brown, 2016).

Finally, increased electricity demands associated with air conditioner use can strain local supply. Air conditioner use can account for nearly one third of power consumption in Perth during summer (Brown, Katscherian, Carter, & Spickett, 2013). Trees are very effective at cooling soil substrates (Table 12), which can in turn act as heat sinks for buildings. Additionally, interception of incident solar radiation can produce a marked reduce heat accumulation, in artificial surfaces, suggesting buildings with shading trees will have a reduced need for artificial cooling.

In some instances of extreme heat events, tree canopy cover has been shown to be negatively correlated with hospitalizations due to heat stress related illness (Graham, Vanos, Kenny, & Brown, 2016). With hot dry summers and temperatures averaging in the low-mid 30's, with highs in the 40's (Bureau of Meteorology, 2017), the city of Melville, Western Australia, is familiar with the annual cycle of heat related stressors on the environment, infrastructure, and inhabitants of the city. Exacerbating these factors is the semiarid, Mediterranean climate of the location which leads to an increased susceptibility to prolonged heating (Georgescu, Morefield, Bierwagen, & Weaver, 2014).

The effectiveness of trees to ameliorate the heat island effect is the subject of a number of studies (Armson, Stringer, & Ennos, 2012). While some have focused on native versus exotic species in the context of their broader characteristics, assessments of the effectiveness of species by their origin (native, indigenous, exotic), to provide shade protection, and thereby help mitigate thermal accumulation in substrates, is lacking. Within the city of Melville approximately 57.6% of the area supports vegetative cover, with 24.1% being under local government control (MNG Survey, 2016). This study aims to address this gap in the research by investigating surface ground temperatures below native/Indigenous species, and exotics, and determine if one is more effective in preventing heat accumulation in and around the canopy shade area.

To quantify urban substrate and tree canopy interaction in response to heating events such that urban forest planning decisions effecting livability, health outcomes and infrastructure demands, can be better made.

- Quantify the behavior of common substrates, artificial and natural, found within the residential Melville study area, in terms of thermal energy accumulation and dissipation.
- Quantify the impact of the presence of a tree canopy on the most common substrates found within the study area.
- Determine if exotic, native, or indigenous species found within the urban forest population, are comparatively more effective in terms of heat mitigation.

3 Literature Review

There are many variables that affect the experienced temperature in and around city areas. With increasing urbanization an understanding of these variables has increased in importance and as such a plethora of studies exists. Increased temperatures impact the livability and infrastructure demands of a city, but more seriously the health impacts of increased and prolonged heat can be serious, and include increased hospitalization and morbidity rates due to heat stress (Graham, Vanos, Kenny, & Brown, 2016).

The tree canopies ability to mitigate heat accumulation is not simply a function of the number of trees, but the strategic placement and arrangement of vegetation, along with the selection of the most appropriate species. (Loughner, Zhang, Allen, Dickerson, & Landry, 2012) found that the inclusion of trees in the urban landscape had the ability to effectively reduce surface air temperatures in general, but was particularly effective when shading road, path and building surfaces, the surfaces that most that directly affect resident and pedestrian comfort.

Street tree cooling is localized and variable depending on geometry, substrate, vegetation stratification and meteorological conditions. The cooling effect has high spatial and temporal variability (Coutts, White, Tapper, Beringer, & Livesley, 2016). These are factors which are directly applicable to the City of Melville both at present, and in terms of future planning. Not only is local and downwind heat propagation effected by the presence of an appropriate tree canopy, but where possible, increasing the ratio of vegetation to road surfaces and 3D urban structures reduces temperatures (Loughner, Zhang, Allen, Dickerson, & Landry, 2012), and thereby reduces propagation on a wider, up to regional scale, area (Georgescu, Morefield, Bierwagen, & Weaver, 2014).

(Armson, Stringer, & Ennos, 2012) found that while grass can be effective at reducing surface temperatures, especially if a high moisture content is maintained, it is ineffective at lowering air (globe) temperatures, unlike trees, whose shade effect is what most directly effects human comfort. Tree clusters in particular influence microclimate and provide a quantifiable measure of pedestrian thermal comfort as demonstrated in Adelaide, South Australia (Thom, Coutts, Broadbent, & Tapper, 2016).

Regarding the selection of species, some studies were found that investigate the appropriateness of indigenous/native vegetation versus exotic species in the context of the overall characteristics. Almost none however evaluated the performance of native versus indigenous versus exotic trees in their ability to maintain thermal radiation protection and hence reduce temperatures. (Aguiar, 2012) is however one such study which focused on evaluating appropriate trees for the local area, in this Wollongong, central New South Wales. It was found that the difference between heat accumulation was negligible between the three categories at moderate temperatures. Indigenous species however were shown to have greater mitigation effect during extreme heat events, in addition to superior survivability within their habitat.

Trees provide their maximum cooling at times of maximum evapotranspiration which occurs at the hottest/brightest part of the day. It has been found that night cooling is also effective even though transpiration rates are low. This is due to low atmospheric turbulence around polygonal canopy structures. Again geometry is important to take advantage of this multi-stage cooling effect (Linden, Fonti, & Esper, 2016). A linear positive correlation between reduced air temperatures has been shown between polygonal vs linear vs mixed arrangements of trees, and their affect regarding heat mitigation. This is due to the clustering arrangements delaying cool air diffusion differing. While linear arrangements provide tree shaded spaces, and ground surface temperature effect, it is not as effective as a polygonal arrangement for air temperature (Park, Kim, Lee, Park, & Jeong, 2016).

Another geometric characteristic which has been shown to have a direct influence on thermal accumulation, is the Plant Area Index (PAI) of a particular species. Effectively a measure of canopy density it therefore is related to shade potential. Sanusi, Johnstone, May, & Livesley (2016) found that the PAI was the determining factor influencing thermal comfort and UHI microclimate mitigation. As this characteristic is likely to vary between species within the City of Melville study area it is likely to have an effect on the results.

Finally, as pointed out by (Sjoman, Morgenroth, Sjoman, Saebo, & Kowarik, 2016), while there is a strong drive to vegetate urban areas with indigenous or native species, exotic species should not be ignored at all costs. Exotics are able to play an important role in the local ecosystem. Additionally, urban forest resilience may be impacted if non-native species are excluded from urban greening.

This report aims to directly quantify the effect of the different species present within the streetscapes of the City of Melville, on ground surface temperatures, which is a product of the variables described above. By quantifying the thermal behavior of common substrates within the study area, assessing the impact of trees, and measuring the impact of exotic versus native versus indigenous species, it is intended that the resulting dataset will help inform decisions that improve livability, health outcomes and reduce infrastructure loads during heat events.

4 Study Area

The City of Melville is a medium density urban environment in close proximity to the Perth CBD. Landuse is dominantly residential and in private ownership (48% of land area), while 37% is under direct local government control. The population of the greater Perth region is projected to grow to 2.88M by 2031. In order to limit peri-urban development, 47% of the required housing development that will be need to house the additional residents, is expected to be provided through urban infill. The City of Melville's proximity, and medium population density make it an attractive target for redevelopment and increased population density.

As a consequence vegetative cover located on private land is expected to reduce in order to make way for additional dwellings. It is the stated policy of the local government to maintain the current urban forest canopy coverage at 24%, while the process of urban infill progresses. Necessarily this will require tree planting on government controlled land over and above attrition rates.

The study area is centered on the suburb of Bicton, within the City of Melville (**Error! Reference source ot found.**). A number of vector and raster datasets were available. Table 4 lists datasets supplied by the City of Melville. The trees point shapefile provided the tree population characteristics and locations that were needed for designing a route that incorporated as many points of interest as required to produce a valid random stratified sample set.

Table 4. Datasets supplied by City of Melville. Subsequently subsetted into sample areas, one of which is used for this report.

Date	Dataset / Report	Type	Sensor	Description
30 August 2016	Trees	Point shapefile	Ground Sampling	Tree point samples, with associated vegetation attributes
9 - 10 February	NDVI Threshold	Raster – tif		Derived NDVI image.
7 & 11 February	Thermal 99759om	Raster – tif		Derived thermal image.
		Contextural Data		
8 March 2017	Roads	Line shapefile		City of Melville road network.
8 March 2017	Parks	Polygon shapefile		Parks and reserves within the City of Melville LGA
8 March 2017	Suburbs	Polygon shapefile		Suburbs within the City of Melville LGA
8 March 2017	MelvilleLGA	Polygon shapefile		Polygon defining boundary of Melville LGA

Currently the council plants approximately 800 trees per year, with an attrition rate of 600 per year. A mix of species are planted, including indigenous varieties that naturally occur in South Western Australia, natives from others parts of Australia, and exotic introduced species. Table 5 refers to the makeup of the current tree population within the study area. It is a subset of these specimens that this study is based on. The majority of these trees occur as verge plantings along roadways. This in turn defined the substrates from which temperature measurements were to be taken, the six most common of which are asphalt roads, concrete footpaths (light coloured and dark/weathered), grass (irrigated and non-irrigated), and bare soil.

Table 5. Specimen origin.

Origin	Count	%
Exotic	195	24.3
Indigenous	212	26.4
Native	396	49.3
Total	803	

Table 5 shows the origins of the trees that makeup the population within the sample area. A representative selection, taken from an urban streetscape environment, was used for this study. Native species are dominant with the study with approximately half being from this origin.

Indigenous are predominantly represented by the species Agonis flexuosa, or Pepper Tree, ubiquitous throughout the Perth area. A characteristic of this cohort is its maturity (Table 11).

Exotic species are almost as common as indigenous varieties. In contrast to the indigenous cohort this population has a higher proportion of immature specimens (Table 11).

Fig 1. Route chosen for data collection.

As much as possible, sampling was completed on a contiguous portion of the suburban road network, centered on the suburb of Bicton within the local government area. All trees and surfaces measured form part of the local streetscape and as such are in close proximity to roads and footpaths, a typical urban arrangement. The sample area was split into two closely related zones in order to balance the number of species origins being sampled (Fig 1).

5 Methodology

Cycle	Time
Am	0430 - 0800
Early pm	1200 – 1530
Pm	1730– 2100

A random stratified sampling method was chosen to best capture the data in the project area. To provide a statistically significant sample set at least 50 points from each category (native, indigenous, exotic) were taken. Sub-classes were determined based on the most frequent surfaces found within the sample area during the first day of collecting measurements (Table 6).

Table 6. Species classes, and substrate sub-classes.

Classes	Sub-classes
Native Indigenous Exotic	Asphalt (roads) Grass: irrigated Grass: non-irrigated (common on road verge) Concrete: light Concrete: medium Soil
Additional common surfaces sampled	Pavers Artificial turf Garden mulch

Table 7. Data collection times.

Three sets of measurements were taken per sampling day; dawn, midday-early afternoon, and sunset (Table 7). This was done to maximize temperature variation and highlight the thermal characteristics of different surfaces. Each set of sample took approximately three hours to complete.

An infrared laser thermometer was used for taking spot surface temperatures under and around the shade protection of trees.

Project Site: Birdwood Circus **Description:** Mixed Species – Pepper, Cedar and Eucalyptus sp.

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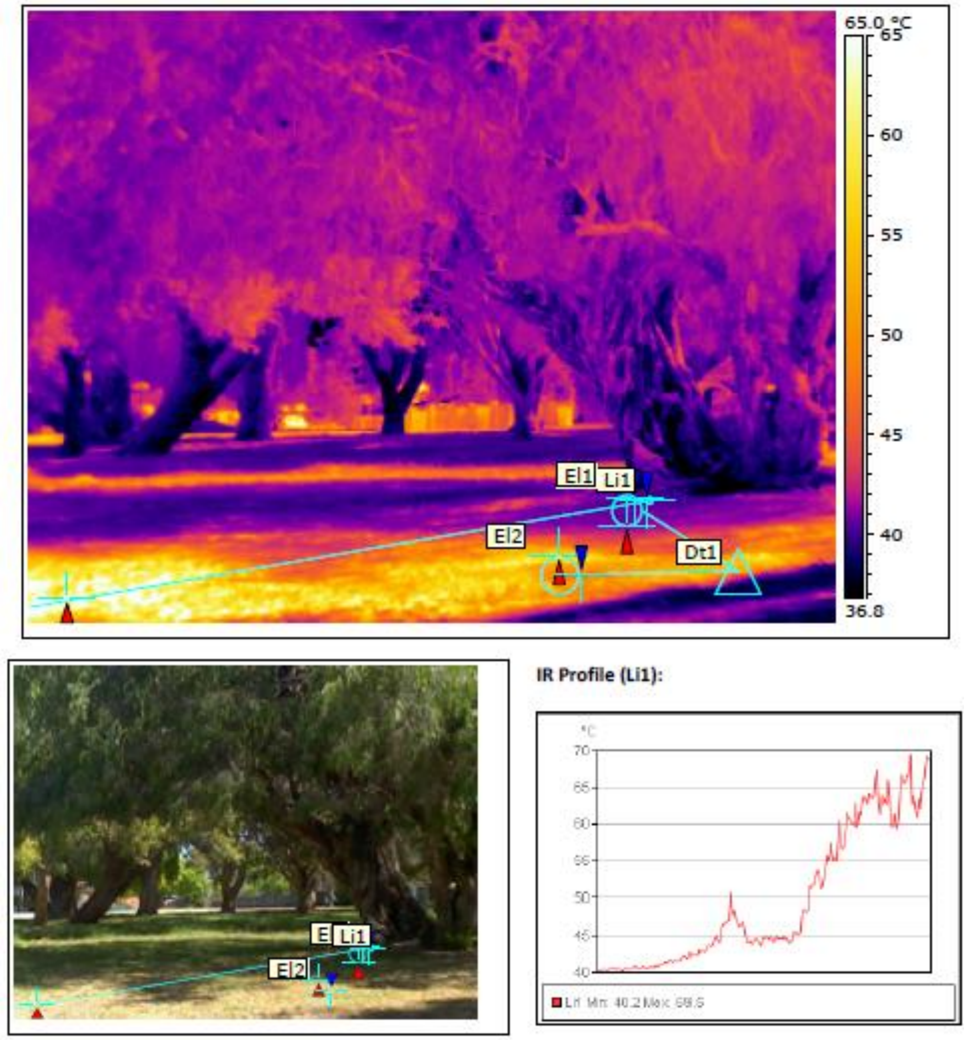

Fig 2. Thermal camera image and temperature profile.

Fig 2 shows is a thermal image containing typical species found within the sample area. The IR Profile at the bottom right demonstrates the significant difference in ground surface temperatures between shaded areas and fully exposed substrates (40 vs 65°C). The line in the image (Li1) represents the path from which the Infrared Profile was derived.

For the purposes of this report, which uses spot temperatures only, one measurement at each tree, from the deepest part of the canopy shadow, was taken. A point deep within the canopy shadow was taken to ensure the surface temperature had had time to equalize with the shade ambient temperature. Another spot temperature was taken on the fully exposed representative substrate. In this way the readings mimic the maximum and minimum profile line temperatures (Li), taken using the FLIR E60 MK-11 thermal camera during the baseline survey commissioned by the City of Melville (MNG Survey, 2016).

Some issues were encountered before this sampling. For instance, to properly represent the change in temperature across a day the same substrate had to be repeatedly at each sample point. This could be difficult due to the linear arrangement of streets and hence trees. The cast shadow could shade multiple surfaces throughout the day and may not be available for measurement at any given time. Careful selection of substrate had to be made, and substrate noted, to avoid invalid measurements.

At the time the sampling was initially undertaken many of the exotic deciduous species did not yet have their fully developed spring foliage, thereby limiting the shade potential, and invalidating any measurements. Additional samples were taken that necessitated incorporating an additional area into the sampling region. While efforts were made to collect a greater quantity of exotic samples, a full complement of measurements was not able to be collected in the initial set, and the subsequent October set was also limited.

While collecting individual surface temperatures is a rapid process, cumulatively the process is time consuming. To improve efficiency a single contiguous area for sampling was designed using QGIS. Additionally, rather than sampling sun exposed substrates at every tree location, thereby doubling the workload, substrates were sampled at half hour intervals in representative locations. These provided the control measurements against which the impact of tree shaded could be compared.

6 Results

6.1 Sampling

On each sampling day the route was planned to encompass an approximately equal number of species origins (exotic, native and indigenous), while maintaining a contiguous route (Route map, page 34). The actual number of collected measurements were less than planned due to orientation, specimen maturity, leaf phenology, surface shade transition, and incidence.

6.1.1 Sample origins

Table 8. Origins. 20 Oct sample set.

20-Oct-17	Planned	Actual
Exotic	91	46
Indigenous	104	96
Native	88	69
Total	283	211

Table 9. Origins, 14 Sep sample set.

14-Sep-17	Planned	Actual
Exotic	65	19
Indigenous	86	83
Native	80	64
Grand Total	231	166

Table 8 and Table 9 show the planned versus actual measured tree sites. Each of these measured sites was visited three times on a given day, morning, early afternoon and evening, to provide an indication of temperature flux.

In planning the route for 20 October additional exotic specimens were added. This was in response to the difficulty in collecting enough valid samples for this cohort in the 14 September sample set.

Additionally, Table 10 shows the most common substrates from those sampled, both artificial and natural, found to be measurable and ubiquitous within the sample area. Each is a single reading taken on a surface exposed to full sunlight, and distant enough from any shade protection to be temperature equalised. The difference in the number of control surfaces sampled reflects a better knowledge of the data requirement for the analysis, and increased efficiency through familiarization with the area and process.

Table 10. Control surfaces sampled.

Full Sun - surface	20 Oct '17	14 Sep '17
Concrete light	25	8
Concrete med	23	7
Grass-irrigated	27	6
Grass non-irrigated	27	8
Asphalt	26	8
Soil	24	4
Other	89	14
	241	55

Table 11. Specimen origin age.

Origin/Age	Count	%
Exotic	**46**	
Unknown	3	6.5
Mature	14	**30.4**
Semi-mat	21	45.7
Young	8	17.4
Indigenous	**96**	
Unknown	2	2.1
Mature	81	**84.4**
Semi-mat	9	9.4
Young	4	4.2
Native	**69**	
Juvenile	1	1.4
Mature	47	**68.1**
Semi-mat	15	21.7
Young	6	8.7
Total	**211**	

A high proportion of exotic trees within the sample area were found to be immature, or deciduous and without a full canopy. A count of age characteristics of the exotic population is shown in Table 11. Only the mature examples of the exotic population could be relied on to be of sufficient size to provide an effective shade potential, and then only if the seasonal canopy had developed. Additional samples were selected for surveying but only half, or less, of the planned sample sites provided useful results, impacting the analysis.

Additionally, only 68% of native trees had reached full maturity. Immature examples however, often provided a useable shade area for sampling due to their developed canopy and evergreen phenology.

Table 12. Weather conditions during sampling.

BOM	20 Oct ‘17	14 Sep ‘17
Sunshine Hours	13 hrs	11hr 50min
Lowest Temp °C	12.3	4.8
Highest Temp °C	29.7	24.6
Wind gust Max km/h	41	26

As much as practical, days of similar weather conditions were selected for sampling Table 12. Essentially cloud free and warm. This caused some delay in collecting the second sample set but conditions were comparable. The lower than average (4.8 vs 9.1°C) overnight temperature prior to the September sample collection (Bureau of Meteorology, 2017), led to lower ground surface temperatures during the morning sampling than would otherwise be expected. The net impact of this is expected to be small as the sampling day recorded no cloud cover, light wind, which in turn resulted in a rapid ground surface temperatures increase.

Additionally, the October sample set was completed on a day with significantly more wind. Ground surface temperature rise appears to be driven dominantly by incident solar radiation rather than convective air currents. While globe (air) temperatures were not measured under the tree canopy, the experienced cooling effect of these air currents is magnified, and reduced globe temperatures can propagate downwind in areas of contiguous canopies (Armson, Stringer, & Ennos, 2012).

6.1.2 Sample Surfaces

As mentioned earlier, when designing the sampling route an effort was made to select a representative and balanced number of tree sample sites. What could not be planned for was the substrate that would be available at any particular location. Therefore the number of individual substrates sampled was dictated by the arrangement of the plantings, and the type of ground surface cover that would be intersected by the canopy shadow as it transits the location throughout the day. As non-irrigated grass is the most common road verge substrate, the number of samples is high compared to other substrates.

Useable Samples 17 September 2017

	Asphalt	Dry Grass	Irrigated Grass	Light concrete	Dark Concrete	Mulch	Red Brick	Soil	Yellow Paver	Total
Exotic	4	14	1	2	6		1	3		31
Indigenous	9	33	6	4	13	1		11	1	78
Native	13	21	5	5	9			7		60
Total	26	68	12	11	28	1	1	21	1	169

Table 13. Useable samples collected 14 September 2017.

Table 13 shows the number of samples collected for each origin classification, by substrate for the September sample set. An attempt was made to collect 50 valid samples for each origin classification to provide a statistically significant set. This proved problematic for exotic trees as many were either young, or deciduous varieties had not developed their full seasonal foliage. Surfaces measured were subject to what was available on the day, and some may be underrepresented. Small sample sets should be treated with a degree of caution.

Useable Samples 20 October 2017

	Asphalt	Dry Grass	Irrigated Grass	Light concrete	Dark Concrete	Mulch	Red Brick	Soil	Yellow Paver	Total
Exotic	3	18	11	1	10		1	2		46
Indigenous	12	38	9	1	20	3		12	1	96
Native	12	24	6	3	12	4		8		69
Total	27	80	26	5	42	7	1	22	1	211

Table 14. Useable samples collected 20 October 2017.

Table 14 shows a count of the surfaces sampled under all tree origins. The six main sub-categories are shown in red.

Dry grass refers to non-irrigated grass, as found on the majority of road and footpath verges. This accounts for the high number of samples in this category as this is also the dominant location for planted trees. Irrigated grass substrates are those that are obviously watered, and/or have reticulation evident.

One of the challenges was collecting a balanced number of substrates measured in each category. The measured substrate at any particular location was often dictated by the arrangement of the plantings, and incidence angle relative to the surfaces being measured. If when taking a temperature measurement a surface other than non-irrigated grass was available, then that was measured.

Dark concrete was the second most common surface representing older, weathered footpaths and pedestrian access ways, which are often shaded by older, larger trees.

Asphalt roads are a dominant measurable substrate within the sample area, and act as a significant heat sink capable of radiating stored thermal energy back into the environment late into the evening (Fig 3). Collecting a greater number of samples from this substrate would have been valuable, but obtaining reliable samples was often difficult. Trees needed to be large enough to shelter the road, and oriented such that they provide some shade over the asphalt throughout the day. Many asphalt surfaces were shaded either in the morning, or evening, but not both.

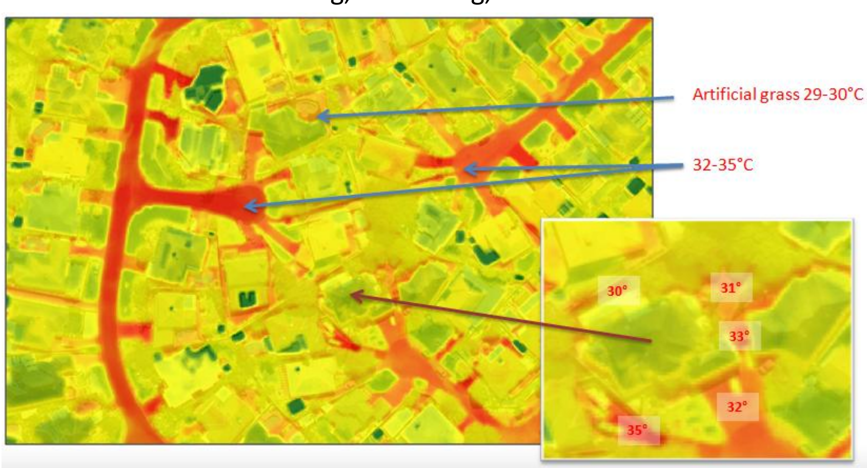

Fig 3. Asphalt heat sinks. 9pm. (MNG Survey, 2016)

Light coloured concrete, which represents a more recently laid material than the dark weathered concrete, is more common than the sampling would suggest. It often occurs in smaller sections along footpaths, or access ways to new buildings, in addition to surrounding a portion of the local shopping centre. Any canopy shadow would often transit these smaller sections, but would not provide a shaded sample at all times during the day.

Finally, irrigated grass and bare soil were also common along road and property verges.

The increase in total samples between September and October reflects an increased efficiency through familiarization with the sampling requirements, and a more efficient route design.

Over the two sampling days a total of 296 ground surface temperatures were taken on representative substrates, that were fully exposed to solar radiation, at intervals of 0.5 – 1hr, or when available for less common substrates.

6.2 Substrate Response

Sun Exposed Ground Surface Temperatures

Fig 4 & Fig 5 summarize the absolute temperatures collected for the six common substrates, measured throughout the sampling day. Boxes on the plot represent the interquartile range. The lower limit of the box is defined by 25% of the data. The upper limit is at the 75% limit. The line in the between these two limits represents where 50% of the data measurements have reached, or the median. The cross is the calculated average for the data. Finally, the whiskers represent the upper and lower 25% of the data measurements.

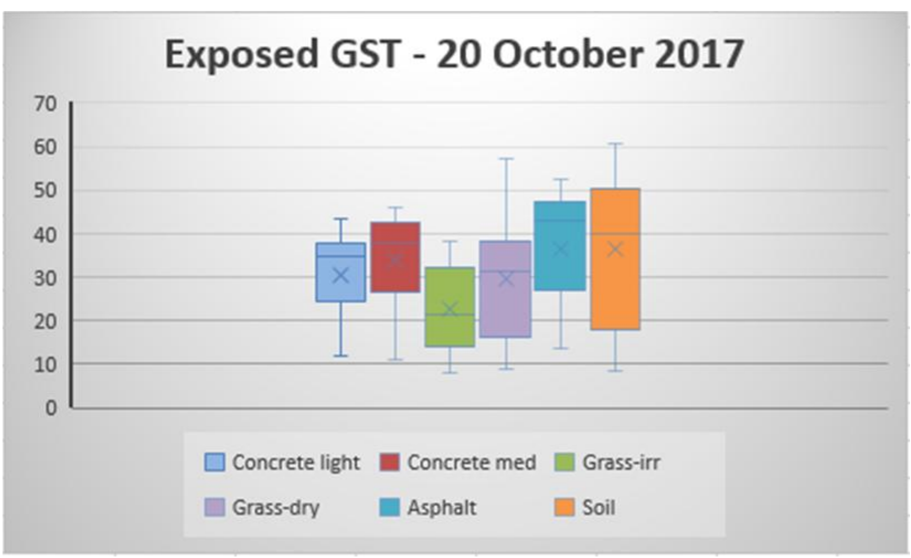

Fig 4. Early pm substrate ground surface temperatures. October.

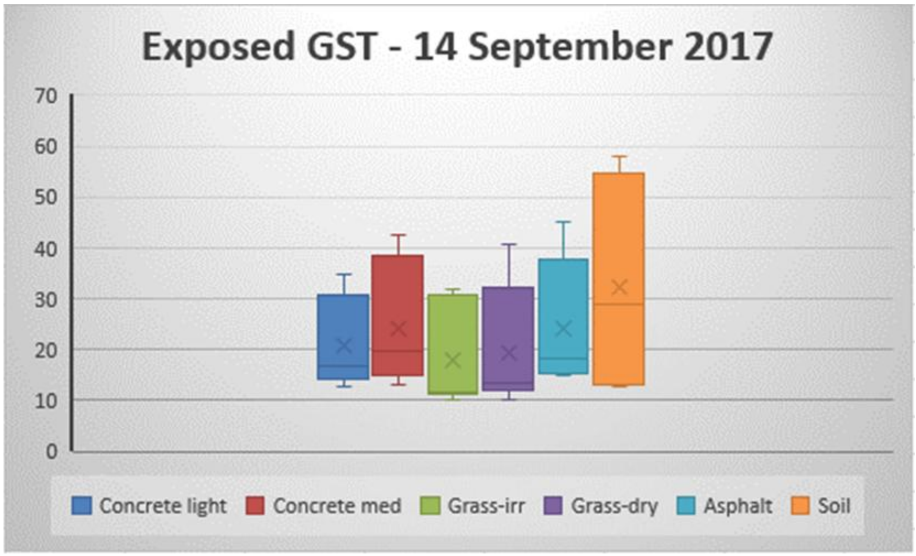

Fig 5. Early pm substrate ground surface temperatures. September.

A broad range of temperatures can be seen for each of the six substrates. The temperature relationship between the substrates, over the two months, remained consistent, in spite of the variable nature of the materials, and consequently, their thermal characteristics.

Table 15. Season mean/median temperature comparison.

	October		September	
Surface	**Mean**	**Median**	**Mean**	**Median**
asphalt	36.7	43.1	24.1	18.1
soil	36.7	40.2	32.2	29.0
concrete - light	30.7	34.6	20.7	16.8
concrete - medium	33.8	37.6	24.1	19.6
grass - irrigated	22.8	21.5	17.8	11.6
grass - non-irrigated	29.8	31.5	19.3	13.6

A seasonal shift is evident in the relative positions of the median and mean values plotted on the graphs. The September averages are above the medians, suggesting a clustering of values at the low end of the scale, while the averages for October are typically below the medians, due to a clustering of measurements higher in the temperature range (Table 15).

The September medians would have been impacted by the cooler than usual overnight temperatures prior to the collection date (Bureau of Meteorology, 2017). However this appears to have had little effect on the later GST results and does not significantly skew the data. Additionally, this is a typical seasonal characteristic that will typically be absent during summer months. As such it emphasizes the compounding scenario of longer hotter days, and higher overnight temperatures, reducing urban environment comfort and livability.

The surprising result here is the broad range, and very high temperature, attained by bare soil. Unlike other substrates which tend to have an approximately uniform composition soil is highly variable. This in turn affects its thermal capacity, and particularly its reflectance. Dry, and irrigated grass, show a consistent relationship. Notably, irrigated grass shows a significantly lower temperature in the October results, when compared to September (Table 15). This may be due to stronger wind conditions during the October sampling, resulting in greater convective cooling of the denser ground cover, as vegetation moisture is released through evapotranspiration. The often thin ground cover, and lower moisture content, of non-irrigated grass results in an increased ground temperature, and impacted cooling capacity.

Artificial substrate temperatures for September show a broader range than those taken in October. The longer night time hours and cooler overnight temperatures have allowed sufficient time for ground surface temperatures to equalize. The broad temperature range is a result of these fully exposed substrates warming rapidly once exposed to solar radiation. This suggests that high density materials are capable of accumulating thermal energy rapidly once exposed to incident solar radiation, regardless of significant overnight cooling. What is not quantified in this report is thermal storage capacity, which effects livability within the built environment.

6.2.1 Heat accumulation and subsequent cooling

Average ground surface temperatures were calculated for each substrate using the midday/early afternoon measurements, and late pm measurements, and plotted for both September (Fig 6), and October (Fig 8).

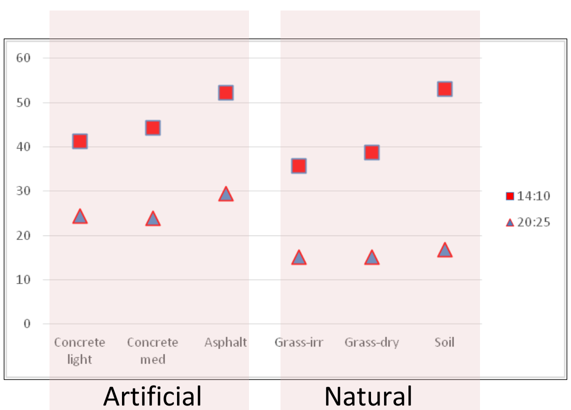

Fig 7. Cooling of exposed substrates from peak temperature 20 October 2017.

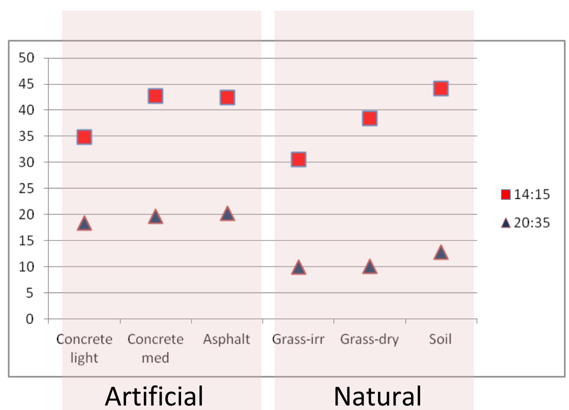

Fig 6. Cooling of exposed substrates from peak temperature 14 September 2017.

The results suggest both artificial and natural substrates are effective at accumulating thermal energy, however, natural surfaces are more effective at dissipating that energy and cooling themselves. This in turn has implications for the urban built environment, and its ability to provide relief and comfort at dusk and after sunset. Additionally, the compounding effect of greater heat accumulation during longer summer daylight hours is expected to exacerbate this effect.

The evening readings were taken at 8:35pm. All artificial surfaces display a temperature approximately double that of natural surfaces, in spite of both attaining similar daytime peak temperatures (measured at 2:15pm).

Temperature flux, or temperature change, is defined here as the difference between the average maximum, and average minimum temperatures, measured for a given substrate. It was expected that daily flux would be greater in October when compared to the September result, particularly given the longer daylight hours in October. It should be noted however, that the am temperatures in October were higher due to the warmer overnight ambient temperature, so the higher pm measurements in the October sample set provided a similar result.

Over the two sampling periods the flux appears quite similar (**Error! Reference source not found.** & Fig 10). Bare soil is the exception, which tends to show a highly variable heat accumulation, probably due to variable composition. However, as can be seen from figures Fig 7 and Fig 7, the high and low values of the temperature ranges have increased. This is to be expected as the seasonal shift to longer hotter days continues. This significant and measurable shift has occurred over a one month period during spring. It highlights the compounding effect of increasing temperatures and longer daylight hours, resulting in an elevated and prolonged daily warming cycle. This effect may be magnified as the summer month's progress. It is significant as the most effected substrates are artificial, the surfaces urban environments and living spaces are largely constructed from. Additionally, as night time temperatures increase, and night hours decrease, the opportunity for cooling is subdued further, and heating may be compounded from one day to another.

6.3 Shade Potential

6.3.1 Shade by species origin

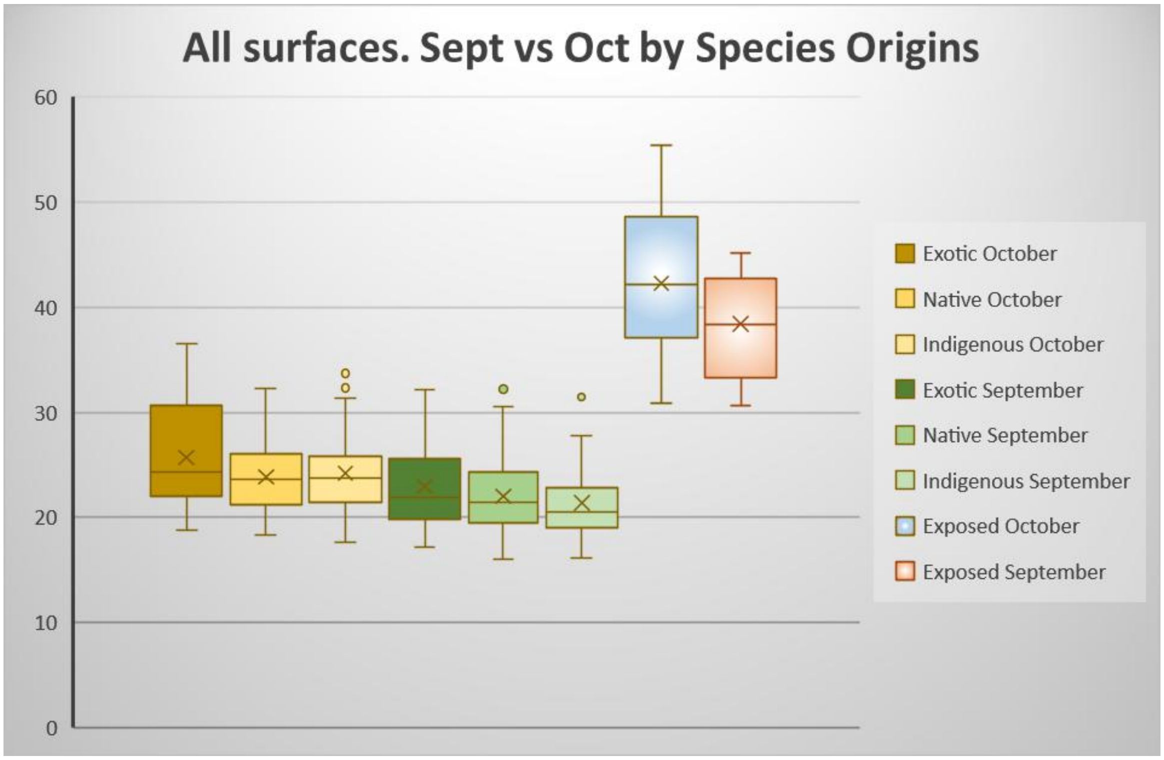

Fig 8. Temperatures for all substrates, by tree origin.

Fig 8 shows the shade effect of trees by origin, averaged over all substrate types, for both September and October, using early pm measurements. Combined early pm exposed substrate temperatures are shown for comparison.

The interquartile temperature ranges for shaded areas are more constrained than those of exposed surfaces. This appears to be feature of intercepting incident solar radiation. Heating is not only slowed across all substrates, but disparate substrates with differing thermal characteristics begin to show a similar temperature flux.

Indigenous and native trees have very similar effects, and both are more effective than exotics. This 2°C temperature difference agrees with the finding in (Aguiar, 2012). However, due to the lower number of samples for this category (46 for October, 31 for September) this result would benefit from additional measurements.

6.3.2 Comparison: Shade vs sun temperatures

Table 16 compares the effect of uninterrupted solar radiation vs shade on the six common substrates. Darker colours represent higher temperatures. These measurements are averages taken during early pm sampling on 20 October.

Table 16. Average ground surface temperatures by substrate 20 Oct '17.

Surface	Sun	Shade	Change
Grass-irrigated	**32.8**	22.2	10.6
Concrete Light	**38.0**	25	13.0
Grass-Dry	**38.2**	22.6	15.6
Concrete Medium	**39.5**	26.8	12.7
Asphalt	**44.7**	27.5	17.2
Soil	**49.5**	24.4	25.1

Notable is the change in order of the substrate temperatures. When removed from direct sunlight soil, with the largest temperature change response, returns to a value approaching the other natural surfaces, and under shade, artificial surfaces show the three highest measurements. Additionally the range of temperatures across substrates can be seen to be reduced.

6.3.3 Substrate Temperature Flux

It appears from previous results that while attaining almost equally elevated temperatures, natural surfaces are able to radiate heat away more rapidly than artificial substrates.

Fig 9 and Fig 10 show ground surface temperature changes in exposed substrates, versus shaded. The shade values were calculated using the maximum and minimum temperature for each sample site to give a temperature flux for that site, and substrate. This was done for all 396 sample sites. Averages were taken for each substrate and plotted for September and October.

Sun exposed temperatures use the maximum and minimum spot values measured on each day, for each of the six substrates, to provide a flux value.

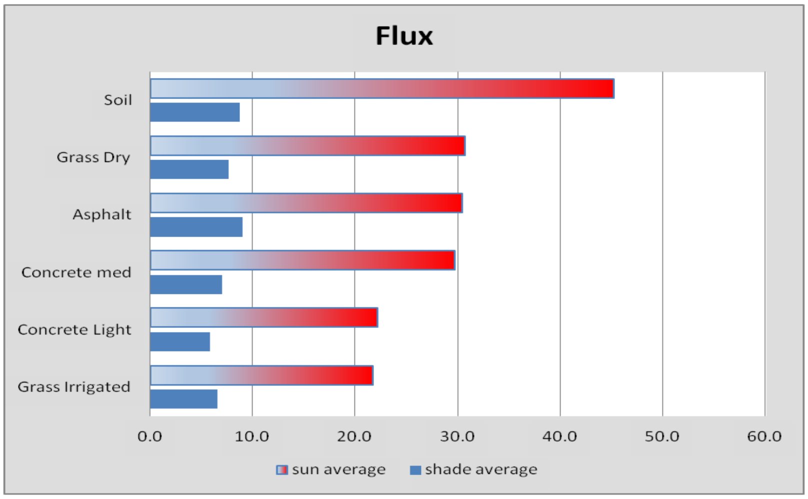

Fig 9. Temperature flux. Artificial vs shade. September.

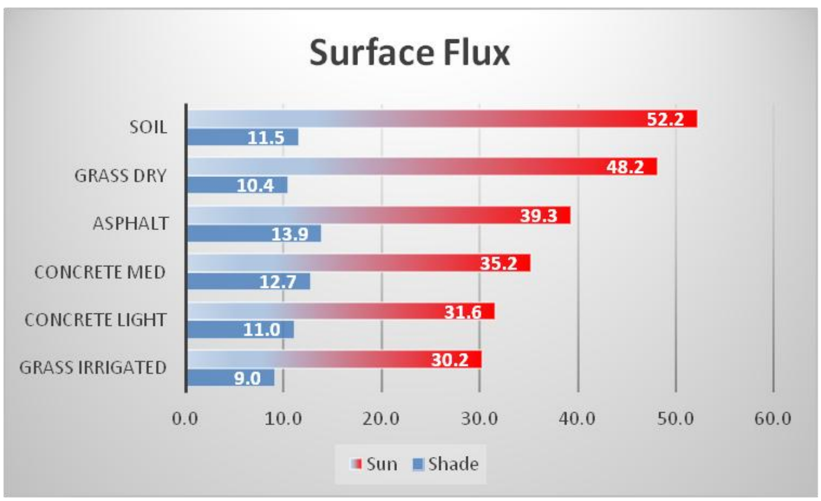

Fig 10. Temperature flux. Artificial vs shade. October.

Table 17. Temperature flux range. All substrates.

Temperature Flux °C	October	September
Sun:	22	23.5
Shade:	4.9	3.1

Fig 9, Fig 10, and Table 17, demonstrate how effective canopy derived cooling is at reducing thermal variation across disparate substrates, including artificial, high thermal capacity, materials. For sun exposed surfaces, thermal accumulation and heat dissipation in substrates is highly variable. However, under canopy shade both artificial and natural substrates are not just cooled, but the response to ambient conditions is less extreme, and artificial substrates behave similarly to natural ones.

A surprising result is the high variability of soil, and its extreme temperature. Soil composition appears to have a marked impact on its reflectivity, and this may help account for the broad range of readings. The high range reading (58°C versus 24.6 ambient) does agree with that found in the Terrestrial Data report previously commissioned by the City of Melville (MNG Survey, 2016).

Dry grass, in spite of being a natural surface, performs similarly to both dark concrete, and asphalt artificial surfaces in terms of heat flux. This perhaps demonstrates the importance of structure in the selection of vegetation, and its arrangement, where heat mitigation is the primary concern. While evapotranspiration is still taking place it is at a reduced level relative to the water/chlorophyll content. Thus the surface still provides an effective heat sink, when deprived of tree shade, and heat dissipating canopy structures.

6.3.4 Shaded artificial substrate measurements, by tree origin

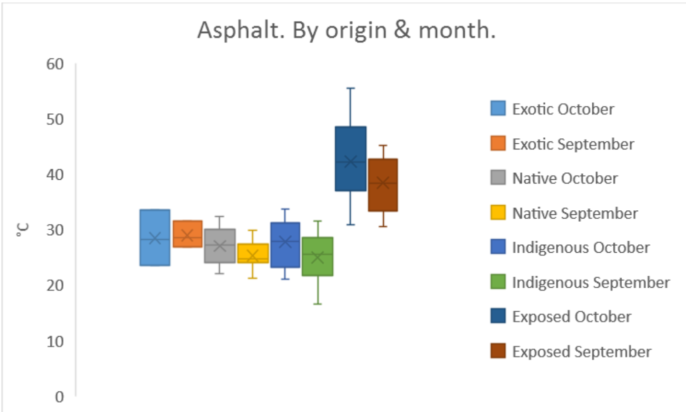

Fig 11. Ashphalt shade measurements.

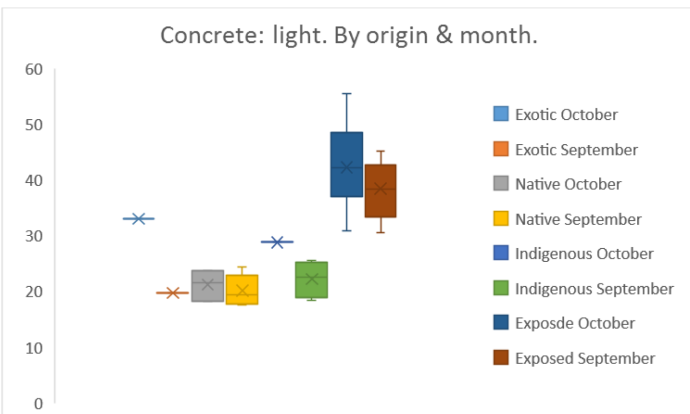

Fig 12. Light concrete shade measurements.

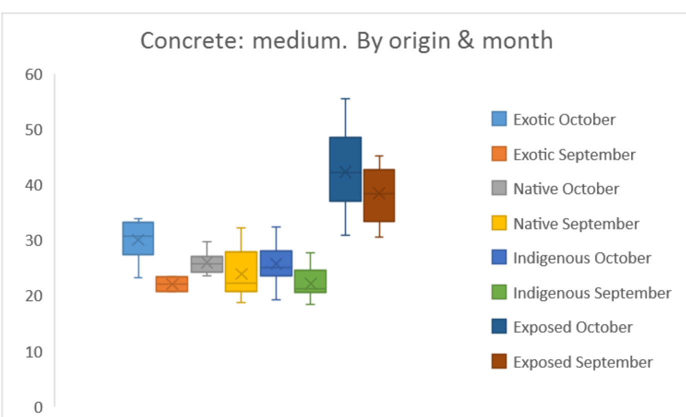

Fig 13. Medium concrete shade measurements.

As expected tree shaded artificial substrates showed a marked reduction in absolute temperature. Additionally, the wide range of variability in temperatures was reduced.

From the plots it appears that exotics are very effective at constraining temperature variation. Unfortunately this category is not statistically significant as the number of valid samples collected was less than required. This was due to two factors, phenological canopy development, and a fewer mature examples available from which to collect measurements.

The narrow range of values in the light concrete plot are a result of a limited number of samples that were able to be collected for this substrate.

6.3.5 Shaded natural substrate measurements, by tree origin

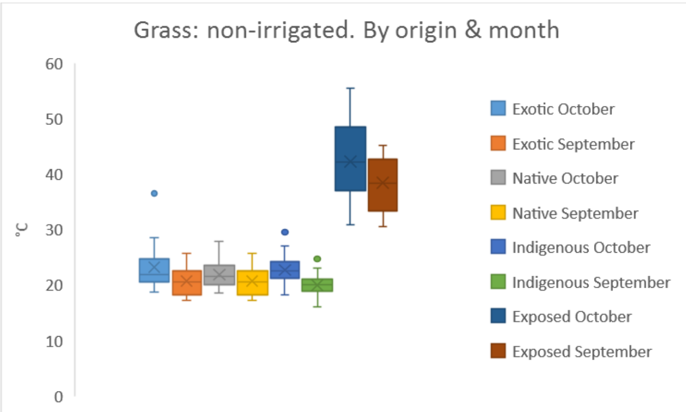

Fig 14. Non-irrigated grass shade measurements.

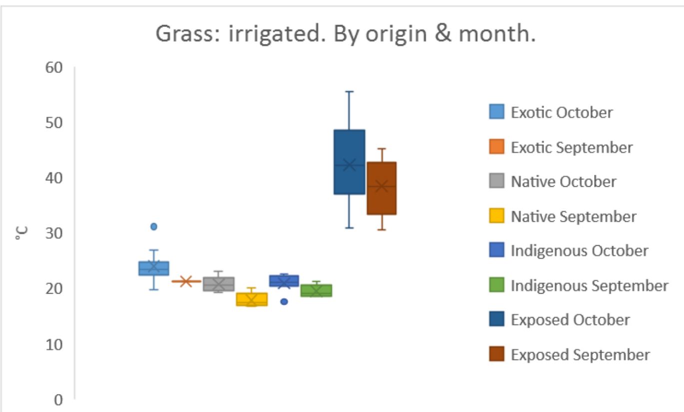

Fig 15. Irrigated grass shade measurements.

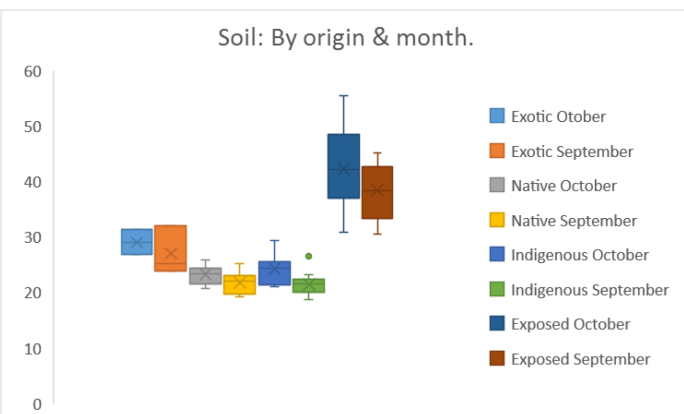

Fig 16. Soil shade measurements.

Similar to artificial substrates, tree shaded natural substrates showed a marked reduction in absolute temperature change, over the course of the 15 hour sample period. Additionally, the broad range of variability in temperatures was reduced.

For exotic species, only the dry grass plot had sufficient samples to be significant. From this it can be seen that exotic species show a marked reduction in measured temperatures, although both indigenous and exotics are slightly more effective.

7 Discussion

The samples collected in the Bicton study area amply demonstrated the ability of tree shade protection to reduce surface temperatures across a range of substrates. Further, a measurable difference in the effect of native/indigenous species versus exotics was noted. While additional sampling would be required to substantiate this result it does agree with the results of similar measurements taken in the Wollongong, New South Wales area (Aguiar, 2012). An additional consideration is the survivability of species in prolonged significant heat events, a phenomenon which will possibly be exacerbated by the Mediterranean climate (Georgescu, Morefield, Bierwagen, & Weaver, 2014). It is not known whether this result is due to structure, pigmentation, reflectivity, shade area, greater convective activity, evapotranspiration rates, or another common characteristic to these specimens.

At an individual substrate level, no difference could be discerned between the effects of native/indigenous versus exotic species, in the role of heat reduction, from this sample set. Drawing definitive conclusions is hampered by the difficulty in collecting enough samples to accurately represent the exotic cohort of the study. With further planning, and with the phenological shift towards increased foliage in deciduous species, the sample population will increase, and the results will become more significant, with any underlying trends possibly becoming evident.

Surprising results included the demonstration of natural surfaces to act as significant heat storage mediums. Bare soil recorded some of the highest temperatures on the sampling days, achieving more than 10°C above both asphalt, and concrete. This high reading for this substrate agreed with a previously completed terrestrial sampling report provided by MNG Survey (MNG Survey, 2016). The contrast with artificial surfaces however, is the time it takes for the surface to return to ambient temperature, and consequently, how much heat it continues to radiate into the surrounding environment.

Temperature variability across disparate substrates is also reduced by shade protection, another unexpected result. While a temperature reduction was expected, the resulting small 3-5°C range was not. This result is based on an average flux value for each substrate, and some outliers will exist within the data, but the result is still notable, especially considering the 23.5°C range for the non-shaded substrates.

The benefits of providing shade protection are highly localised. Areas recently emerged from shade protection showed a rapid temperature increase and quickly approached values similar to unprotected areas. However, contiguous plantings providing protection throughout the day mitigate temperature rise. Some studies have suggested that reduced ground and air temperatures can be propagated downwind in approximately unbroken canopy protected area (Coutts, White, Tapper, Beringer, & Livesley, 2016). This points to the importance of including strategic canopy design in urban planning to maximize these effects through orientation and polygonal grouping where possible (Loughner, Zhang, Allen, Dickerson, & Landry, 2012).

Finally, seasonal responses were observable in the results. By retracing the sampling route, and sampling the same substrates as defined by the initial September collection, an observable shift in measurements was documented. As observed across all criteria; substrate response, cooling, temperature flux, and shade affect measurements, both relative and absolute, showed a consistent pattern. This observable pattern occurred over a relatively short period during the spring season, and holds implications as the region progresses into a Mediterranean summer scenario, with its associated susceptibility to extreme heat events (Georgescu, Morefield, Bierwagen, & Weaver, 2014).

8 Conclusion

The ability of the current street tree population to affect heat accumulation in their immediate substrate has been shown to be strongly significant. Additionally the affect is not restricted to natural surfaces, but has a greater impact on artificial surfaces. A study by (Loughner, Zhang, Allen, Dickerson, & Landry, 2012) quantified temperature reduction on some urban artificial surfaces, and this result is in line with that study. It did not however provide a comparison with natural surfaces as has been done here. This is a particularly relevant result given the urban context of the Bicton study area.

These results indicate a greater potential for shade protection from native/indigenous species, than from exotics. This greater heat reduction agrees with a previous Australian study (Aguiar, 2012), although a greater exotic species sample population is required to confirm this result.

Seasonal changes were found to be significant over the relatively short time frame between sampling days. Measuring substrate responses provided an example of the additional thermal load imposed on the environment from a moderate temperature rise and increase in daylight hours. During September substrates showed a significant cooling between the mid day measurements, and evening readings. However, this was not necessarily the case in October. While sample times were similar, dusk temperatures could approach, and occasionally exceed, earlier measurements. This compounding effect has implications for the summer season.

In terms of the objectives of this report, quantification of natural and artificial substrates was achieved in the context of the study area. The ability of both artificial and natural surfaces to achieve similarly high ground surface temperatures was shown. In terms of substrate behavior however, natural substrates display a superior ability to dissipate heat and cool, once the source of thermal energy is removed. Natural substrates in close proximity to buildings can act as a heat sinks for materials used in construction, while shade protection for the same constructed environments reduces initial thermal accumulation. This may be an important consideration given the ongoing trend towards increasing urban infill.

Having examined the behavior of common substrates within the study area, the second objective was to assess the impact of the presence of trees, when providing shade protection over these substrates. It was found that ground surface temperatures under shade were highest in artificial substrates. This pointed to the greater capacity of these surfaces to accumulate and store thermal energy, when compared to natural surfaces. By removing the direct heating associated with incident radiation the apparently lower thermal capacity of natural surfaces, and ability to dissipate heat, results in a natural surface displaying consistently lower temperatures than artificial surfaces. Additionally, the total temperature range displayed by a surface reduced significantly for both artificial and natural surfaces Table 17. When exposed to direct sunlight the temperature flux of various substrates was markedly divergent. However, under canopy shade, while artificial and natural surfaces still behaved differently, as may be expected due to differing thermal characteristics, all substrates displayed a similar temperature variation.

In terms of the final objective, these results indicate a greater potential shade protection from native/indigenous species, over exotics. This greater heat reduction agrees with a previous Australian study (Aguiar, 2012), but it is not known whether this is due to a common characteristic with the selected species within the sample area, ie. Structure, canopy spread, leaf area index value, or maturity. As detailed Table 11 the exotic cohort contains a significantly younger population than either indigenous or native varieties. Additionally, it was noted that local, non-deciduous species, tended to display a well developed canopy, whereas canopy development in immature exotics, where present, was less well formed. Additionally, the deciduous nature of many specimens excluded them from the sample collection. Caution was taken to measure only exotic species that provided significant shade, but further investigation would be required to confirm this result.

8 Recommendations

Recommendations are formulated with the objectives of improving livability, reducing negative health outcomes for the populace, while reducing infrastructure demands associated with heating events.

Asphalt road surfaces, which receive limited canopy cover, form a large proportion of the land area under local government control. Increasing asphalt shade presents an opportunity to impact heat accumulation in this substrate. Orientating roads and/or plantings to intercept incident radiation, or introducing median planting where space allows, could significantly increase shade protection over this substrate.

Urban planning should incorporate polygonal arrangements, and vegetation stratification, where possible. This design amplifies the heat mitigation effect provided by single isolated trees, or linear arrangements.

Exotic tree species provide a good compromise between allowing light to penetrate in winter, and provide shade, and thereby summer heat mitigation, although this may be reduced when compared with native/indigenous species. A mixture of species origins should be planned for in order to maximize these characteristics.

As urban infill continues planning for shade protection of artificial surfaces should form part process. These construction materials have the greatest thermal capacity, and therefore the ability to provide a direct impact on the livability of the urban environment.

Shading pedestrian walkways from incident solar radiation provides comfort, as well as a reduction in heat accumulation in the substrate. Ensuring pedestrians are protected from the extremes of summer heat increases the usability of the urban environment. Planning should include adequate space for natural shade.

The indigenous cohort of the sample population is predominantly mature. An investigation of the structure of the canopy of mature specimens, with regard to their ability to provide effective shade should be undertaken. Aging trees with degraded canopies are less effective at providing shade, and are aesthetically less appealing. Replacing these specimens preemptively, rather than delaying until the majority of this cohort must be replaced en mass, facilitates design and planning for maximum effect, and minimal disturbance.

Canopy structural development, combined with planting arrangement appears paramount. Selection of a mixture of species, of multiple origins would be preferable to provide desired benefits, rather than being constrained by species origin.

Further investigation of the shade potential of exotic versus native/indigenous specimens should be undertaken, particularly through the high temperature summer months, to confirm the results presented here, and provide continuity to the dataset.

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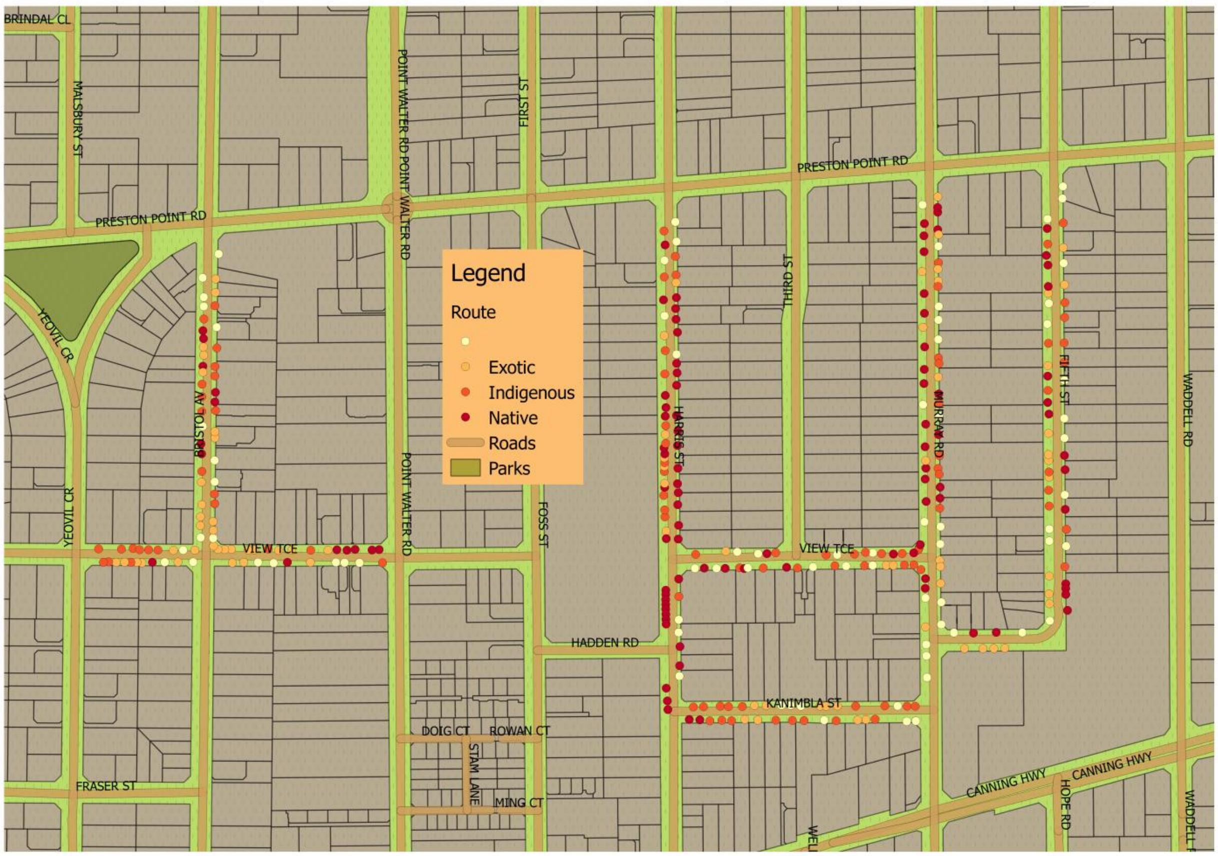
10 Appendices

10.1 Route map



10.2 Sample Sheets

10.2.1 Raw data. 20 October 2017

OID_	0500-0840	1145-1555	1720-2035	Surface	origin	species	age	height	width
804						Vacant		0	0
805						Vacant		0	0
806						Vacant		0	0
807	18.4	29.6	19.5	dgrs	Indigenous	Agonis flexuoas 2	Mature	7	16
808	18.1	26.1	14.9	dgrs	Native	Eucalyptus torquata	Young	4	4
809					Native	Corymbia ficifolia	Young	2	3
810					Exotic	Jacaranda mimosifolia	Semi-mat	8	8
811					Exotic	Jacaranda mimosifolia	Mature	8	9
812					Native	Cupaniopsis anacardioides	Semi-mat	6	8
813					Exotic	Sapium sebiferum	Juvenile	3	1
814	15.4	30.7	25.7	mcon	Indigenous	Agonis flexuosa	Mature	9	9
814	19.8	29.4	20.6	soil	Indigenous	Agonis flexuosa	Mature	9	9
815	14.8	22.2	16.2	igrs	Indigenous	Agonis flexuoas 2	Mature	9	11
816	14.3	22.2	16.2	igrs	Indigenous	Agonis flexuosa 3	Mature	10	10
817	18.6	24.6	23.5	mcon	Indigenous				
817	21.2	23.3	17.6	dgrs	Indigenous	Agonis flexuoas 2	Mature	9	11
818	17.2	25.4	17.7	dgrs	Native	Callistemon KP Special	Semi-mat	3	4
819	16.4	23.1	18.4	igrs	Native	Corymbia ficifolia	Mature	5	6
820	15.9	23.9	23	mcon	Indigenous				
820	17.5	23.5	19.5	dgrs	Indigenous	Agonis flexuoas 2	Mature	9	11
821	20.4	24.2	12.6	igrs	Exotic	Sapium sebiferum	Young	3	2
822					Exotic	Jacaranda mimosifolia	Juvenile	3	1
823	19.1	26.9	15.9	igrs	Exotic	Jacaranda mimosifolia	Young	6	6
824					Exotic	Jacaranda mimosifolia	Young	5	3
825						Vacant		0	0
853	15.8	24	18.8	igrs	Exotic	Platanus x acerifloia	Semi-mat	5	5
854	15.6	22.4	17.2	igrs	Exotic	Platanus x acerifloia	Semi-mat	6	7
855					Indigenous	Agonis flexuoas 2	Mature	8	9
856					Indigenous	Agonis flexuoas 2	Mature	5	6
857						Vacant		0	0
858						Vacant		0	0
859					Exotic	Jacaranda mimosifolia	Mature	7	6
860					Exotic	Jacaranda mimosifolia	Mature	6	6
861	14.9	21.6	18.6	dgrs	Indigenous	Agonis flexuoas 2	Mature	6	9
862	16.2	26.6	20.5	mulch	Native	Eucalyptus leucoxylon vars	Semi-mat	5	8

863	16	28.7	18.2	mulch	Native	Eucalyptus leucoxylon vars	Semi-mat	5	5
864	16.1	24.8	21.3	mulch	Indigenous	Agonis flexuoas 2	Mature	6	9
865	16.2	26.6	21.5	mulch	Indigenous	Agonis flexuoas 2	Mature	5	7
866	14.7	23.4	20.7	dgrs	Indigenous	Agonis flexuosa 3	Mature	6	9
867						Vacant		0	0
868					Indigenous	Agonis flexuosa 3	Mature	5	5
869	17.4	22.7	15.1	igrs	Exotic	Sapium sebiferum	Young	4	3
870	13.6	23.4	15.1	igrs	Exotic	Sapium sebiferum	Young	3	3
871						Vacant		0	0
108						Vacant		0	0
109	10.7	21.9	19.9	mulch	Native	Callistemon KP Special	Mature	7	7
110					Native	Eucalyptus leucoxylon vars	Mature	6	8
111						Vacant		0	0
112						Vacant		0	0
113					Exotic	Fraxinus 'Claret ash'	Juvenile	2	1
114					Exotic	Fraxinus 'Claret ash'	Juvenile	2	1
115					Exotic	Fraxinus 'Claret ash'	Juvenile	3	1
116						Vacant		0	0
117						Vacant		0	0
118	10.9	30.4	30.3	mcon	Indigenous	Agonis flexuosa 3	Mature	6	5
119	12.3	32.4	26.6	mcon	Indigenous	Agonis flexuosa 3	Mature	7	9
120	13.1	28.1	26.5	mcon	Exotic	Ulmus parvifolia	Semi-mat	8	6
121	11.3	27.1	27.3	dgrs	Indigenous	Agonis flexuosa	Mature	7	8
122	10.8	21.3	22.7	dgrs	Exotic	Ulmus parvifolia	Semi-mat	7	6
123	10.4	21.5	24	dgrs	Exotic	Ulmus parvifolia	Semi-mat	4	4
124					Exotic	Jacaranda mimosifolia	Mature	13	11
125	12.5	24.2	27.6	mcon	Native	Lophostemon confertus	Mature	10	10
126					Native	Callistemon citrinus	Young	2	2
127	10	19.4	21.1	dgrs	Indigenous	Agonis flexuosa	Young	4	4
128					Native	Callistemon citrinus	Young	2	2
129	11.3	31.3	23.6	soil	Exotic	Jacaranda mimosifolia	Semi-mat	5	6
130	10.4	20.4	22	igrs	Indigenous	Agonis flexuosa 3	Mature	6	8
131						Vacant		0	0
132	12.7	24.2	27.2	mcon	Native	Lophostemon confertus	Mature	10	10
133					Exotic	Jacaranda mimosifolia	Semi-mat	9	6
134	12.7	29.7	27.3	mcon	Native	Eucalyptus torquata	Semi-mat	5	6
135	10	21.5	20.3	igrs	Native	Eucalyptus torquata	Semi-mat	5	6
136	9.9	20.1	21.7	dgrs	Native	Callistemon sp.	Mature	2	3
137	13.1	25.5	28.9	mcon	Indigenous	Agonis flexuosa 3	Mature	9	10
138	13.8	23.8	26.6	lcon	Native	Lophostemon confertus	Mature	10	11
139	10.7	21.3	24.2	dgrs	Native	Callistemon viminalis	Young	3	3
140						Vacant		0	0
141						Vacant		0	0
142	12.1	21.2	21.7	dgrs	Indigenous	Agonis flexuoas 2	Mature	7	11

143					Exotic	Fraxinus 'Claret ash'	Young	3	1
144						Vacant		0	0
145					Exotic	Jacaranda mimosifolia	Young	6	4
146	11	21.6	22.4	dgrs	Indigenous	Agonis flexuoas 2	Mature	9	13
147	12.9	22.3	26.3	soil	Indigenous	Agonis flexuoas 2	Mature	8	12
148	11.1	24	25.1	dgrs	Indigenous	Agonis flexuoas 2	Mature	6	10
149	10.6	22.3	24.3	dgrs	Indigenous	Agonis flexuosa 3	Mature	8	11
150	11	21.3	26.7	dgrs	Indigenous	Agonis flexuosa 3	Mature	6	8
151	10.4	23.2	24	dgrs	Indigenous	Agonis flexuoas 2	Mature	7	7
152						Vacant		0	0
153	9.9	21.8	21.8	dgrs	Native	Callistemon KP Special	Mature	7	9
154	9.3	20.8	22.5	dgrs	Native	Lophostemon confertus	Mature	5	7
155						Vacant		0	0
156	10.1	18.5	20.4	dgrs	Native	Lophostemon confertus	Mature	6	7
157	10.1	21	23	igrs	Indigenous	Agonis flexuoas 2	Mature	6	8
158						Vacant		0	0
159	9.7	25	25.1	dgrs	Indigenous	Agonis flexuosa 3	Mature	6	8
160					Native	Brachychiton acerifolia	Young	4	2
161					Native	Brachychiton acerifolia	Young	2	1
162					Native	Brachychiton acerifolia	Young	3	1
163	10	24	28.5	soil	Native	Brachychiton acerifolia	Semi-mat	5	3
164					Exotic	Jacaranda mimosifolia	Juvenile	2	1
165					Exotic	Jacaranda mimosifolia	Juvenile	3	1
166					Exotic	Jacaranda mimosifolia	Juvenile	2	1
167					Exotic	Jacaranda mimosifolia	Juvenile	3	1
279						Vacant		0	0
280						Vacant		0	0
281	10.2	20.4	16.2	igrs	Indigenous	Agonis flexuoas 2	Mature	5	9
282	13.4	24.4	21.6	soil	Indigenous	Agonis flexuoas 2	Mature	5	9
283					Exotic	Unknown sp.	Young	2	1
284	11.9	24.3	21.9	dgrs	Native	Lophostemon confertus	Mature	5	8
285					Native	Eucalyptus leucoxylon vars	Semi-mat	6	5
286	13.2	23.4	22	soil	Native	Lophostemon confertus	Mature	5	8
287	14.4	26.6	24.9	mcon	Native	Lophostemon confertus	Mature	5	7
288						Vacant		0	0
289	11.5	25.6	19	dgrs	Native	Lophostemon confertus	Mature	5	8
290	14.4	26	26.1	mcon	Native	Lophostemon confertus	Mature	5	7
291	12.4	20.4	18.6	dgrs	Native	Lophostemon confertus	Mature	5	9
292	11.6	21	18.3	igrs	Native	Lophostemon confertus	Mature	5	8
293	10.9	19.3	17.5	igrs	Native	Lophostemon confertus	Mature	5	6
294	10.8	27.8	22.8	dgrs	Native	Lophostemon confertus	Mature	4	7
295	14.5	26	25.5	mcon	Native	Lophostemon confertus	Mature	5	9
296	12.4	24.6	22.9	soil	Native	Lophostemon confertus	Mature	6	8
297	13	25.9	23	soil	Native	Lophostemon confertus	Mature	7	10
298	12.9	24.4	24.2	mcon	Native	Lophostemon confertus	Mature	5	8
299	14.4	25.2	26.6	mcon	Native	Lophostemon confertus	Mature	5	10
300	13.9	23.5	27.7	mcon	Native	Lophostemon confertus	Mature	6	9
301					Exotic	Jacaranda mimosifolia	Juvenile	3	1
302	11.9	18.6	18.6	dgrs	Native	Lophostemon confertus	Mature	7	7
303	14.7	28.5	23.1	asp	Indigenous	Agonis flexuosa	Semi-mat	7	4
304					Indigenous	Agonis flexuosa	Young	4	3

305					Indigenous	Eucalyptus gomphocephala	Young	7	3
306	13.4	32.3	27.7	asp	Native	Eucalyptus sp.	Young	7	2
307					Exotic	Jacaranda mimosifolia	Juvenile	2	1
308	14.4	33.7	24.9	asp	Indigenous	Agonis flexuosa	Young	4	3
309					Exotic	Jacaranda mimosifolia	Juvenile	2	1
310	12.6	30.7	23.4	asp	Indigenous	Eucalyptus gomphocephala	Young	6	3
311					Exotic	Jacaranda mimosifolia	Juvenile	2	1
312	11.6	28.8	22.8	asp	Native	Eucalyptus sp.	Semi-mat	12	6
313					Native	Eucalyptus torquata	Young	3	4
314	11.8	23.9	21.3	soil	Indigenous	Agonis flexuosa	Semi-mat	4	6
315					Exotic	Jacaranda mimosifolia	Young	3	1
316	13.1	21.2	20.6	soil	Indigenous	Eucalyptus gomphocephala	Semi-mat	8	5
317	13.3	20.8	21	soil	Native	Lophostemon confertus	Mature	10	10
318	10.6	26.3	19	mulch	Native	Corymbia ficifolia	Juvenile	2	2
319	13.1	23.1	22	soil	Native	Lophostemon confertus	Mature	12	10
320	12.8	33.7	26.5	asp	Indigenous	Agonis flexuosa 3	Mature	7	10
321	12.3	17.6	17	igrs	Indigenous	Agonis flexuoas 2	Mature	10	11
322					Exotic	Plumeria sp.	Semi-mat	2	1
323						Vacant		0	0
324	14.5	24.2	24.5	mcon	Indigenous	Agonis flexuosa 3	Mature	0	10
325	13.9	30.4	23	asp	Native	Lophostemon confertus	Mature	6	5
326	11.8	18.3	17.6	dgrs	Indigenous	Agonis flexuoas 2	Mature	6	8
327	11.7	20.1	18.1	igrs	Native	Lophostemon confertus	Mature	6	7
328	13.7	29.1	24.9	asp	Indigenous	Agonis flexuoas 2	Mature	11	11
181						Vacant		0	0
182	14.6	25.5	20.3	mulch	Indigenous	Agonis flexuoas 2	Mature	7	8
183					Exotic	Sapium sebiferum	Juvenile	2	1
184					Exotic	Sapium sebiferum	Juvenile	2	1
185	12.3	24.1	17.6	dgrs	Indigenous	Agonis flexuoas 2	Mature	6	9
186						Vacant		0	0
187	13	21.2	17.6	dgrs	Indigenous	Agonis flexuoas 2	Mature	6	8
188	14.3	25.4	20.2	soil	Indigenous	Agonis flexuoas 2	Mature	6	7
189	12.1	27.3	22.8	yel pvr	Indigenous	Agonis flexuoas 2	Mature	5	4
190					Exotic	Sapium sebiferum	Juvenile	3	2
191					Exotic	Sapium sebiferum		3	2
192	14.5	24.7	19.3	dgrs	Indigenous	Agonis flexuoas 2	Mature	6	8
193	13.7	24.8	21.3	dgrs	Indigenous	Agonis flexuoas 2	Mature	6	11
194	12.3	25.3	20.6	dgrs	Indigenous	Agonis flexuoas 2	Mature	6	9
195					Native	Eucalyptus torquata	Juvenile	1	1
196					Native	Eucalyptus torquata	Juvenile	1	1
197	11.9	25.6	16.9	soil	Indigenous	Agonis flexuosa 3	Mature	7	7
198	12.5	24.5	18.3	soil	Indigenous	Agonis flexuosa 3	Mature	7	9
199	12.1	22.6	23.5	mcon	Indigenous	Agonis flexuosa 3	Mature	9	9
200	13.6	25.6	23.5	mcon	Indigenous	Agonis flexuoas 2	Mature	7	7
201	13.6	32.3	24	mcon	Indigenous	Agonis flexuosa 3	Mature	8	7
202	12	24.3	15.8	dgrs	Exotic	Sapium sebiferum	Semi-mat	5	5
203	12.3	30.6	26	mcon	Exotic	Sapium sebiferum	Semi-mat	4	4
204						Vacant		0	0
205						Vacant		0	0
206						Vacant		0	0
207					Exotic	Sapium sebiferum	Juvenile	2	1

208					Exotic	Sapium sebiferum	Juvenile	2	1
209	11.5	24.7	16.7	igrs	Exotic	Sapium sebiferum			
209	15.5	33.6	27.2	asp	Exotic	Sapium sebiferum			
209	12.8	33.1	26.1	mcon	Exotic	Sapium sebiferum	Mature	6	6
210	13.2	27.5	26.8	mcon	Indigenous	Agonis flexuosa 3	Mature	7	9
211	12.6	31.3	26.6	asp	Indigenous	Agonis flexuosa 3	Mature	8	9
212						Vacant		0	0
213	12.5	22.2	24.7	mcon	Indigenous	Agonis flexuosa 3	Mature	5	7
214	13.8	25.8	24.3	mcon	Indigenous	Agonis flexuosa 3	Mature	7	9
264	10.4	23.9	22.7	dgrs	Native	Melaleuca quinquenervia	Mature	5	5
265	10.5	22.9	22.7	dgrs	Native	Melaleuca quinquenervia	Semi-mat	6	5
266	9.5	28.5	23.3	dgrs	Exotic	Jacaranda mimosifolia	Semi-mat	5	6
267						Vacant		0	0
268	11.1	19.2	21.2	dgrs	Indigenous	Agonis flexuosa	Semi-mat	6	7
269	9.3	19.2	21	dgrs	Exotic	Jacaranda mimosifolia	Young	5	3
270	10.3	21.5	19.4	dgrs	Exotic	Sapium sebiferum	Semi-mat	5	4
271	9.8	21.5	20.6	dgrs	Indigenous	Agonis flexuosa	Mature	6	8
272						Vacant		0	0
273						Vacant		0	0
274						Vacant		0	0
275	12.6	21	25.3	soil	Indigenous	Melaleuca sp.	Mature	5	6
276	12.6	21	23.9	soil	Indigenous	Melaleuca sp.	Mature	6	7
277					Exotic	Oleo europaea	Juvenile	3	2
278	10	21	23	soil	Native	Vacant	Mature		
278	11.3	21	23.4	dgrs	Native	Vacant	Mature	6	9
216	9.5	21.9	18.8	dgrs	Indigenous	Agonis flexuosa	Young	3	2
217						Vacant		0	0
218	10.1	19.6	22.9	dgrs	Native	Lophostemon confertus	Mature	5	5
219	9.8	20	23	dgrs	Indigenous	Agonis flexuosa	Mature	7	8
220	9.8	23.8	20.8	dgrs	Indigenous	Agonis flexuosa	Mature	6	5
221	9.8	20.7	20.9	dgrs	Indigenous	Agonis flexuosa	Mature	6	8
222	12.4	18.3	26.9	lcon	Native	Lophostemon confertus	Semi-mat	6	7
223	12.3	21.5	26	lcon	Native	Lophostemon confertus	Mature	6	7
224	10.4	27.9	26.5	soil	Indigenous	Agonis flexuosa	Semi-mat	4	5
225						Vacant		0	0
226						Vacant		0	0
227	9.2	31.1	22	igrs	Exotic	Jacaranda mimosifolia	Semi-mat	6	7
228	9	36.5	22	dgrs	Exotic	Jacaranda mimosifolia	Semi-mat	6	6
229						Vacant		0	0
230	8.9	26.7	21.1	dgrs	Exotic	Jacaranda mimosifolia	Semi-mat	5	6
231						Vacant		0	0
232						Vacant		0	0
233						Vacant		0	0
234						Vacant		0	0
235					Exotic	Rhaphiolepis indica	Semi-mat	1	1
236						Vacant		0	0
237					Native	Eucalyptus leucoxylon vars	Mature	5	5
238					Native	Eucalyptus leucoxylon vars	Semi-mat	6	6
239					Indigenous	Corymbia calophylla	Mature	10	9
240					Native	Corymbia citriodora	Semi-mat	11	10
241	10.7	20.2	21.3	dgrs	Indigenous	Agonis flexuosa	Semi-mat	5	5

242						Vacant		0	0
243	11.4	20.4	20.2	dgrs	Native	Eucalyptus robusta	Semi-mat	10	9
244	12.3	22	24.5	asp	Native	Lophostemon confertus	Semi-mat	7	6
245	13.1	30.4	24.3	asp	Native	Eucalyptus nicholii	Semi-mat	10	6
246	11.2	23.4	25	soil	Native	Lophostemon confertus	Semi-mat	0	0
247					Exotic	Jacaranda mimosifolia	Young	3	2
248	9.8	19.7	21.8	dgrs	Native	Lophostemon confertus	Mature	9	8
249	9.7	19.6	21.9	igrs	Native	Lophostemon confertus	Mature	10	9
250						Vacant		0	0
251	13.6	23.1	26.2	asp	Native	Lophostemon confertus	Mature	11	10
252	10.7	21.7	21.4	dgrs	Native	Lophostemon confertus	Mature	9	10
253	13.7	23.9	25.4	asp	Native	Lophostemon confertus	Mature	9	9
254					Exotic	Jacaranda mimosifolia	Juvenile	3	1
255	13.2	24.8	25.7	asp	Native	Lophostemon confertus	Mature	12	10
256	14.4	25.8	25.4	asp	Native	Lophostemon confertus	Mature	7	8
257					Exotic	Jacaranda mimosifolia	Juvenile	4	1
258	13.9	26.6	25	asp	Native	Lophostemon confertus	Mature	12	10
259	13.2	28.5	24.9	asp	Native	Lophostemon confertus	Mature	9	9
260	13.7	27.8	25.8	asp	Native	Lophostemon confertus	Mature	6	5
262				dgrs	Exotic	Jacaranda mimosifolia	Semi-mat	5	6
263	10.9	22.9	22.3	dgrs	Native	Melaleuca quinquenervia	Mature	5	5
352	14.3	27.3	26.7	asp	Indigenous	Agonis flexuoas 2	Mature	7	10
353	14.7	29	27.6	mcon	Native	Acacia podalyriifolia	Mature	4	5
354	14.7	23.7	24	mcon	Indigenous	Agonis flexuoas 2	Mature	7	10
355					Native	Corymbia ficifolia	Semi-mat	6	4
356					Exotic	Delonix regia	Semi-mat	3	9
357					Indigenous	Agonis flexuoas 2	Mature	7	10
358						Vacant		0	0
359	12.4	27.2	27.3	mcon	Native	Eucalyptus leucoxylon vars	Semi-mat	4	4
360	13.6	25.4	25.3	mcon	Native	Eucalyptus leucoxylon vars	Mature	5	8
361					Native	Callistemon KP Special	Juvenile	2	1
362	14.8	26.2	31.8	mcon	Indigenous	Hakea bucculenta	Semi-mat	2	2
363					Native	Eucalyptus erythrocorys	Juvenile	2	1
364					Native	Callistemon KP Special	Young	3	1
365					Indigenous	Melaleuca sp.	Young	4	2
366	10.3	22.9	17.1	dgrs	Native	Callistemon KP Special	Young	3	2
367	9.7	22.6	16.4	igrs	Indigenous	Agonis flexuosa 3	Mature	5	6
368						Vacant		0	0
369	10.8	21.9	18.8	dgrs	Indigenous	Agonis flexuoas 2	Mature	6	9
370						Vacant		0	0
371	11.6	23.7	20.2	dgrs	Indigenous	Agonis flexuoas 2	Mature	6	8
372	12.1	25.5	22.1	dgrs	Indigenous	Agonis flexuoas 2	Mature	6	8
373					Exotic	Unknown sp.	Young	1	1
374					Exotic	Zelkova serrata	Juvenile	3	1
375	12	24.9	21.8	dgrs	Indigenous	Agonis flexuosa 3	Mature	6	6
376	13	25.5	19.3	dgrs	Indigenous	Agonis flexuoas 2	Mature	6	9
377	13.4	21.6	21.8	dgrs	Native	Callistemon KP Special	Young	2	3
378	12.6	26.1	26.4	asp	Indigenous	Agonis flexuoas 2	Mature	4	9
379	14	18.9	20.3	dgrs	Native	Callistemon KP Special	Young	2	2
380	12.4	21.9	23.6	mcon	Indigenous	Agonis flexuoas 2	Mature	7	10
381	12.6	21.1	23.6	asp	Indigenous	Agonis flexuosa 3	Mature	9	10

382	10.9	22.8	20.9	dgrs	Indigenous	Agonis flexuosa	Semi-mat	6	5
383	10.6	22.1	26.9	asp	Indigenous	Agonis flexuoas 2	Mature	6	9
384						Vacant		0	0
385	11.2	21.4	17.4	igrs	Indigenous	Agonis flexuoas 2	Mature	9	10
723	13.3	20.4	13.4	igrs	Indigenous	Agonis flexuoas 2	Mature	9	10
724	15.8	19.8	14.9	dgrs	Indigenous	Agonis flexuoas 2	Mature	8	10
725	17.5	21.3	16.1	dgrs	Indigenous	Eucalyptus gomphocephala	Semi-mat	9	7
726	13.8	22.3	20.2	asp	Indigenous	Agonis flexuosa	Mature	8	10
726	13.2	23.5	18.9	dgrs	Indigenous	Agonis flexuosa	Mature	8	10
727	13.6	20.9	12.9	dgrs	Indigenous	Agonis flexuoas 2	Mature	9	11
728	16.2	27.2	19.3	asp	Indigenous	Agonis flexuoas 2	Mature	9	10
729	14.3	28.2	27.2	asp	Exotic	Fraxinus griffithii	Young	4	4
729	12.6	22.5	17.5	igrs	Exotic	Fraxinus griffithii	Young	4	4
730	14.9	24.9	17.3	soil	Indigenous	Agonis flexuosa 3	Mature	8	10
730	14.4	28.8	21.2	lcon	Indigenous	Agonis flexuosa 3	Mature	8	10
731	14.5	19.4	14.3	dgrs	Exotic	Fraxinus griffithii	Young	5	4
732	13.1	25.2	17.1	dgrs	Exotic	?????Vacant!!!!	?	0	0
733	15	21.7	16.9	igrs	Exotic	Sapium sebiferum	Mature	4	5
733	17.3	33	24	lcon	Exotic	Sapium sebiferum	Mature	4	5
734						Vacant		0	0
735						Eucalyptus torquata	Semi-mat	5	6
736	14.4	23.4	17.4	dgrs	Exotic	Ficus carica	Mature	3	5
736	17.4	30.9	22.3	mcon	Exotic	Ficus carica	Mature	3	5
737	14.2	22.4	17.6	dgrs	Exotic	Ficus carica	Mature	4	5
737	17.3	31.7	24.4	mcon	Exotic	Ficus carica	Mature	4	5
738	14.8	28.3	23	mcon	Indigenous	Agonis flexuoas 2	Mature	5	9
739	13.1	25	18	mcon	Exotic	Unknown sp.	Mature	4	5
739	13	22.1	19.1	rd brck	Exotic	Unknown sp.	Mature	4	5
740	16.9	30.6	21.2	mcon	Exotic	Jacaranda mimosifolia	Semi-mat	7	6
741	15.5	23.5	20.4	mcon	Indigenous	Agonis flexuosa 3	Mature	7	7
742	14.3	23.7	22.3	mcon	Indigenous	Agonis flexuoas 2	Mature	7	9
826	14.1	21.5	16.5	dgrs	Exotic	Unknown sp.	Semi-mat	4	5
826	14.2	33.2	25.8	mcon	Exotic	Unknown sp.	Semi-mat	4	5
827	15.8	24.5	15.4	dgrs	Exotic	Gleditsia triacanthos	Semi-mat	4	6
827	16.1	33.9	25.6	mcon	Exotic	Gleditsia triacanthos	Semi-mat	4	6
828						Vacant		0	0
829						Vacant		0	0
830	14.8	23.6	12.6	dgrs	Native	Callistemon KP Special	Semi-mat	3	3
831	15.9	23.5	15.2	dgrs	Exotic	Jacaranda mimosifolia	Semi-mat	5	5
841	14.9	26.8	19	soil	Exotic	Jacaranda mimosifolia	Semi-mat	7	5
842	14.7	21.1	18.3	dgrs	Indigenous	Agonis flexuosa	Mature	9	9
843					Exotic	Sapium sebiferum	Juvenile	2	1
844	15	23.2	18.7	mcon	Exotic	Ulmus parvifolia	Mature	10	12
844	15.2	20.8	18	dgrs	Exotic	Ulmus parvifolia	Mature	10	12
844	17.3	23.5	21.8	asp	Exotic	Ulmus parvifolia	Mature	10	12
845	15.3	19.3	21.2	mcon	Indigenous	Agonis flexuosa	Mature	11	12
846	13.2	19.6	16.2	dgrs	Exotic	Robinia inermis 'Moptop'	Mature	5	6
847	12.8	18.8	14.9	dgrs	Exotic	Robinia inermis 'Moptop'	Mature	4	5
848					Exotic	Jacaranda mimosifolia	Mature	10	6
849					Exotic	Jacaranda mimosifolia	Mature	9	8
850	14.1	19.7	14.9	igrs	Exotic	Unknown sp.	Semi-mat	5	5

851					Exotic	Platanus x acerifloia	Semi-mat	5	5
852					Exotic	Platanus x acerifloia	Mature	6	9

10.2.2 Control surfaces. 20 October 2017.

	Footpath		Lawn		Road			
Time	Concrete light	Concrete med	Grass-irr	Grass-dry	Asphalt	Soil	Other	Other Surface
1725	34.8	37.4			44.9	31.5		
1730	36	37.6		28.4		26.6		
1740			20.9	23.5	30.5			
1745			20.7	22.3				
1800	30.4		17.6	20.2				
1800			22.4					
1820					32			
1850	26.4			15	27.2	18.5		
1900	27.2	27.5	14.2	16.3	27.8	18		
1735							30.4	Red Brick
1905		30.3						
2015					22.6			
2025	24.4	23.9	15.1	15.2	29.4	16.8	21.3	Yellow Paver
2025	24.4	26.4	13.9	16.4	25.6	16.6		
2025	22.3							
1730							30.4	Artificial Grass
1745							32.1	Red Brick
1745							36.2	Red Concrete
1750							23.2	Mulch
1750							29	Red Brick
1750							33.6	Red Brick
1815							23.6	Mulch
1815							29.4	Yellow Paver
1840							18.6	Artificial Grass
1840							21.3	Yellow Paver
1900							21.6	Artificial Grass
1900							19.6	Artificial Grass
1905							24.3	Dark Grey Paver

1910							22.2	Red Brick
1935							17.8	Artificial Grass
1950							21.8	Yellow Paver
2015							15.1	Mulch
2015							22.3	Sandstone Wall
2015							22.2	Dark Grey Paver
2020							22.2	Sandstone Wall
2025							24.5	Grey Paver
2025							22.1	Red Brick
2030							19.1	Artificial Grass
2030							18.9	Artificial Grass
2030							21.9	Slip Pad
500	13.8	12.9	10.1	9	13.4			
505			8.8					
520			9.4					
540	11.8	10.9	8.1	9.7	13.8	8.4		
630	13.9	13.6	13.9	10.8	13.7	15.5		
650			14.8			15.8		
710			15.4					
803	19.7	22.9	23.9	23.5	25.2			
815						27.1		
840	25.4	26.6	21.5	28.5	29.5	37		
1050	35.2	38.1	31.8	37.7	43.8	60.6		
1100	34.6	40.3	30.7	36.1	46.8	46.6		
1105	32.2	37	30.6	42.2	42.9	54.5		
1200	36.8	42.7	38.3	36.8	45.3	36.1		
1200	34.8	42	33.2	47	46.2	59.6		
1200				51				
1245	39	42.7	32.8	37.9	48.2	50.9		
1305	42.2	43.4	37.2	38.3	51.1	55.4		
1315	39.7	42.1	32	36.9	50.2	48.9		
1410	41.3	44.3	35.7	38.7	52.3	53		
1530		43.2		31.5	50.5			
1540	36.6	46.1	30.9	35.1	43.2	46		
1545	43.4		32.5	38.7	44.9	43.3		
1550	40.4	44.9		57.2	52.7	44.4		
500							12.9	Grey Paver

505							12.3	Red Paver
505							9.2	Mulch
530							15.6	Red Concrete
535							12	Red Brick
535							7.9	Mulch
535							12.1	Red Brick
535							12.4	Yellow Paver
535							8.2	Mulch
605							12.4	Red Brick
605							13.3	Red Paver
605							12.2	Light Grey Paver
605							12.2	Red Brick
615							13.4	Grey Paver
620							10.1	Artificial Grass
635							17.8	Sandstone Wall
650							19.4	Artificial Grass
655							15.8	Grey Paver
655							20.3	Mulch
700							14.9	Red Paver
700							13.1	Red Brick
715							15.3	Dark Grey Paver
805							30.1	Sandstone Wall
810							29.9	Mulch
810							24	Dark Grey Paver
815							26.5	Red Concrete
820							22.9	Yellow Paver
830							31	Mulch
837							26.4	Red Concrete
840							31.1	Mulch
1055							39.7	Red Brick
1058							37.7	Light Grey Paver
1100							40.3	Dark Grey Paver
1100							58.1	Mulch
1100							46	Mulch

1110							39.3	Red Paver
1110							44.7	Mulch
1110							41.1	Red Concrete
1555							43.4	Mulch
1320							36.2	Yellow Paver
1320							53.9	Artificial Grass
1340							52.2	Mulch
1355							56	Artificial Grass
1355							52.2	Artificial Grass
1415							40.5	Yellow Paver
1420							42.8	Red Paver
1420							44.9	Light Grey Paver
1420						48.7		
1435							45	Artificial Grass
1445							48.6	Mulch
1530							36.6	Grey Paver
1540							42.2	Slip Pad
1545							48.4	Artificial Grass
1545							45.6	Artificial Grass
1550							43.6	Dark Grey Paver
1110							36.6	Red Brick
1110							51.1	Mulch
1150							41.2	Slip Pad
1155							42.7	Black Paver
1200							39.6	Red Brick
1210							57.4	Mulch
1210							42.4	Red Brick
1310							46.8	Red Brick

10.2.3 Raw data. 14 September 2017

OID_	0420-0720	1305-1600	1820-2100	Surface	origin	species	age	height	width
113					Exotic	Fraxinus 'Claret ash'	Juvenile	2	1
114					Exotic	Fraxinus 'Claret ash'	Juvenile	2	1
115					Exotic	Fraxinus 'Claret ash'	Juvenile	3	1
120	15.3	23.4	21.3	mcon	Exotic	Ulmus parvifolia	Semi-mat	8	6
847	13	21.8	9.2	dgrs	Exotic	Robinia inermis 'Moptop'	Mature	4	5
846	13.1	20	9.3	dgrs	Exotic	Robinia inermis 'Moptop'	Mature	5	6
124	16	19.7	18.1	lcon	Exotic	Jacaranda mimosifolia	Mature	13	11
129	14.7	23.9	18.2	soil	Exotic	Jacaranda mimosifolia	Semi-mat	5	6
133	12.4	21.2		igrs	Exotic	Jacaranda mimosifolia	Semi-mat	9	6
143					Exotic	Fraxinus 'Claret ash'	Young	3	1
145					Exotic	Jacaranda mimosifolia	Young	6	4
164					Exotic	Jacaranda mimosifolia	Juvenile	2	1
165					Exotic	Jacaranda mimosifolia	Juvenile	3	1
166					Exotic	Jacaranda mimosifolia	Juvenile	2	1
167					Exotic	Jacaranda mimosifolia	Juvenile	3	1
183					Exotic	Sapium sebiferum	Juvenile	2	1
184					Exotic	Sapium sebiferum	Juvenile	2	1
190					Exotic	Sapium sebiferum	Juvenile	3	2
191					Exotic	Sapium sebiferum		3	2
202		no foliage			Exotic	Sapium sebiferum	Semi-mat	5	5
203		no foliage			Exotic	Sapium sebiferum	Semi-mat	4	4
207					Exotic	Sapium sebiferum	Juvenile	2	1
208					Exotic	Sapium sebiferum	Juvenile	2	1
209		no foliage			Exotic	Sapium sebiferum	Mature	6	6
731	12.9	18.8	10	dgrs	Exotic	Fraxinus griffithii	Young	5	4
729	12.8	17.6	11	dgrs	Exotic	Fraxinus griffithii	Young	4	4
831	13.3	22	11.2	dgrs	Exotic	Jacaranda mimosifolia	Semi-mat	5	5
235					Exotic	Rhaphiolepis indica	Semi-mat	1	1
247	13.4	32.1	14	soil	Exotic	Jacaranda mimosifolia	Young	3	2
254					Exotic	Jacaranda mimosifolia	Juvenile	3	1
257					Exotic	Jacaranda mimosifolia	Juvenile	4	1
262	12.2	25.7	11.3	dgrs	Exotic	Jacaranda mimosifolia	Semi-mat	5	6
266	13	23.1	11.8	dgrs	Exotic	Jacaranda mimosifolia	Semi-mat	5	6

269					Exotic	Jacaranda mimosifolia	Young	5	3
122	13.7	17.2	14.6	dgrs	Exotic	Ulmus parvifolia	Semi-mat	7	6
277					Exotic	Oleo europaea	Juvenile	3	2
283					Exotic	Unknown sp.	Young	2	1
123	14	20.5	15.8	dgrs	Exotic	Ulmus parvifolia	Semi-mat	4	4
307					Exotic	Jacaranda mimosifolia	Juvenile	2	1
309					Exotic	Jacaranda mimosifolia	Juvenile	2	1
311					Exotic	Jacaranda mimosifolia	Juvenile	2	1
315					Exotic	Jacaranda mimosifolia	Young	3	1
322					Exotic	Plumeria sp.	Semi-mat	2	1
356		no foliage			Exotic	Delonix regia	Semi-mat	3	9
373					Exotic	Unknown sp.	Young	1	1
374					Exotic	Zelkova serrata	Juvenile	3	1
227	12.8	no foliage		dgrs	Exotic	Jacaranda mimosifolia	Semi-mat	6	7
228	11.4	no foliage		dgrs	Exotic	Jacaranda mimosifolia	Semi-mat	6	6
733		no foliage		lcon	Exotic	Sapium sebiferum	Mature	4	5
736		no foliage		mcon	Exotic	Ficus carica	Mature	3	5
737		no foliage		mcon	Exotic	Ficus carica	Mature	4	5
739	14	19	14.5	rd brck	Exotic	Unknown sp.	Mature	4	5
740	15	20.8	14.8	mcon	Exotic	Jacaranda mimosifolia	Semi-mat	7	6
826		no foliage		mcon	Exotic	Unknown sp.	Semi-mat	4	5
827		no foliage		mcon	Exotic	Gleditsia triacanthos	Semi-mat	4	6
230	13	no foliage		dgrs	Exotic	Jacaranda mimosifolia	Semi-mat	5	6
841	13.7	25.2	12.1	soil	Exotic	Jacaranda mimosifolia	Semi-mat	7	5
843					Exotic	Sapium sebiferum	Juvenile	2	1
844		31.6	15.3	asp	Exotic	Ulmus parvifolia	Mature	10	12
270	12.3	no foliage		dgrs	Exotic	Sapium sebiferum	Semi-mat	5	4
301				dgrs	Exotic	Jacaranda mimosifolia	Juvenile	3	1
848		28.5	14.6	asp	Exotic	Jacaranda mimosifolia	Mature	10	6
849		26.8	14.4	asp	Exotic	Jacaranda mimosifolia	Mature	9	8
850		no foliage		asp	Exotic	Unknown sp.	Semi-mat	5	5
851					Exotic	Platanus x acerifloia	Semi-mat	5	5
118	15.9	19.9	18.9	mcon	Indigenous	Agonis flexuosa 3	Mature	6	5
119	15.9	21.2	17.2	mcon	Indigenous	Agonis flexuosa 3	Mature	7	9
121	15.1	21	18.1	dgrs	Indigenous	Agonis flexuosa	Mature	7	8
127	12.6	20.9	13.5	dgrs	Indigenous	Agonis flexuosa	Young	4	4
130	13.4	20.4	14	igrs	Indigenous	Agonis flexuosa 3	Mature	6	8
137	15.9	24.4	20.4	lcon	Indigenous	Agonis flexuosa 3	Mature	9	10

142	13.6	16.1	15.1	dgrs	Indigenous	Agonis flexuoas 2	Mature	7	11
146	14.2	19	15.7	dgrs	Indigenous	Agonis flexuoas 2	Mature	9	13
147	14.3	18.7	17.1	soil	Indigenous	Agonis flexuoas 2	Mature	8	12
148	14.1	21.1	18.1	dgrs	Indigenous	Agonis flexuoas 2	Mature	6	10
149	13.1	22.2	15.4	dgrs	Indigenous	Agonis flexuosa 3	Mature	8	11
150	13.6	23.1	17.8	dgrs	Indigenous	Agonis flexuosa 3	Mature	6	8
151	14	18.1	15	dgrs	Indigenous	Agonis flexuoas 2	Mature	7	7
157	12.4	18.8	15.3	igrs	Indigenous	Agonis flexuoas 2	Mature	6	8
159	12.7	24.7	15	dgrs	Indigenous	Agonis flexuosa 3	Mature	6	8
182	13.6	23.2	15.3	mulch	Indigenous	Agonis flexuoas 2	Mature	7	8
185	12.4	20.2	14.5	dgrs	Indigenous	Agonis flexuoas 2	Mature	6	9
187	13.6	18.8	11.2	dgrs	Indigenous	Agonis flexuoas 2	Mature	6	8
188	13.8	22.1	15.1	soil	Indigenous	Agonis flexuoas 2	Mature	6	7
189		26	17.2	yel pvr	Indigenous	Agonis flexuoas 2	Mature	5	4
192	13.5	20.4	12.6	dgrs	Indigenous	Agonis flexuoas 2	Mature	6	8
193	13.7	20.2	15.4	dgrs	Indigenous	Agonis flexuoas 2	Mature	6	11
194	13.5	20.2	14.1	dgrs	Indigenous	Agonis flexuoas 2	Mature	6	9
197	13.6	22.4	11.9	soil	Indigenous	Agonis flexuosa 3	Mature	7	7
198	13.6	20.5	13.1	soil	Indigenous	Agonis flexuosa 3	Mature	7	9
199	14.2	18.4	16	mcon	Indigenous	Agonis flexuosa 3	Mature	9	9
200	14.2	25.1	17.4	mcon	Indigenous	Agonis flexuoas 2	Mature	7	7
201		24.6	16.9	mcon	Indigenous	Agonis flexuosa 3	Mature	8	7
210	14.1	27.7	16.8	mcon	Indigenous	Agonis flexuosa 3	Mature	7	9
211		26.4	16.7	asp	Indigenous	Agonis flexuosa 3	Mature	8	9
213		18.7	15.4	mcon	Indigenous	Agonis flexuosa 3	Mature	5	7
214		22.7	16	mcon	Indigenous	Agonis flexuosa 3	Mature	7	9
216	12.1	17.1	12	dgrs	Indigenous	Agonis flexuosa	Young	3	2
219	14	19.7	12	dgrs	Indigenous	Agonis flexuosa	Mature	7	8
220	13.6	22.7	12.2	dgrs	Indigenous	Agonis flexuosa	Mature	6	5
221	13.2	20	12.4	dgrs	Indigenous	Agonis flexuosa	Mature	6	8
224	14	26.5	14.6	soil	Indigenous	Agonis flexuosa	Semi-mat	4	5
239	13.6	25.5	17.5	lcon	Indigenous	Corymbia calophylla	Mature	10	9
241					Indigenous	Agonis flexuosa	Semi-mat	5	5
268	12.5	19	11.3	dgrs	Indigenous	Agonis flexuosa	Semi-mat	6	7
271	12.5	17.3	11.8	dgrs	Indigenous	Agonis flexuosa	Mature	6	8
275	14.7	21.5	17.1	soil	Indigenous	Melaleuca sp.	Mature	5	6
276	14.7	20.4	15.4	soil	Indigenous	Melaleuca sp.	Mature	6	7
281	12.3	18.5	12	igrs	Indigenous	Agonis flexuoas 2	Mature	5	9
282	14.5	18.8	13.1	soil	Indigenous	Agonis flexuoas 2	Mature	5	9
303		30.9	19.3		Indigenous	Agonis flexuosa	Semi-mat	7	4
304		25.2	20	asp	Indigenous	Agonis flexuosa	Young	4	3
305		31.5	20.8	asp	Indigenous	Eucalyptus gomphocephala	Young	7	3
308				asp	Indigenous	Agonis flexuosa	Young	4	3
310		31.4	15.5	asp	Indigenous	Eucalyptus gomphocephala	Young	6	3
314	13.2	23.2	16.4	soil	Indigenous	Agonis flexuosa	Semi-mat	4	6
316	13.3	20.1	14.7	soil	Indigenous	Eucalyptus gomphocephala	Semi-mat	8	5
320		27.5	18.8	asp	Indigenous	Agonis flexuosa 3	Mature	7	10

321	12.4	16.6	14	dgrs	Indigenous	Agonis flexuoas 2	Mature	10	11
324	15	21.2	16.7	mcon	Indigenous	Agonis flexuosa 3	Mature	0	10
326	12.5	18.5	12.3	dgrs	Indigenous	Agonis flexuoas 2	Mature	6	8
352		24	17.6	asp	Indigenous	Agonis flexuoas 2	Mature	7	10
357	13.7	22	15.7	soil	Indigenous	Agonis flexuoas 2	Mature	7	10
362		26.6	20.9	mcon	Indigenous	Hakea bucculenta	Semi-mat	2	2
365					Indigenous	Melaleuca sp.	Young	4	2
367	11.8	21.3	12.8	igrs	Indigenous	Agonis flexuosa 3	Mature	5	6
369	13.6	20.3	15.3	dgrs	Indigenous	Agonis flexuoas 2	Mature	6	9
371		21.8	16.4	dgrs	Indigenous	Agonis flexuoas 2	Mature	6	8
375		22.2	15.4	dgrs	Indigenous	Agonis flexuosa 3	Mature	6	6
376	14.2	19.3	16.9	dgrs	Indigenous	Agonis flexuoas 2	Mature	6	9
378		18	15.3	asp	Indigenous	Agonis flexuoas 2	Mature	4	9
380		18.4	15.7	lcon	Indigenous	Agonis flexuoas 2	Mature	7	10
382	13.8	21.9	14.2	dgrs	Indigenous	Agonis flexuosa	Semi-mat	6	5
383		23	17	asp	Indigenous	Agonis flexuoas 2	Mature	6	9
385	14.1	19.2	13	igrs	Indigenous	Agonis flexuoas 2	Mature	9	10
723	12	18.6	11.2	igrs	Indigenous	Agonis flexuoas 2	Mature	9	10
724	13.9	18.9	10.2	dgrs	Indigenous	Agonis flexuoas 2	Mature	8	10
725	12.4	19	10.2	dgrs	Indigenous	Eucalyptus gomphocephala	Semi-mat	9	7
726	13.4	19.8	11.4	dgrs	Indigenous	Agonis flexuosa	Mature	8	10
727	12.6	19.4	12	dgrs	Indigenous	Agonis flexuoas 2	Mature	9	11
728	12.7	19.3	11.1	dgrs	Indigenous	Agonis flexuoas 2	Mature	9	10
738		22.5	16.8	mcon	Indigenous	Agonis flexuoas 2	Mature	5	9
741	15.1	20.7	15.5	mcon	Indigenous	Agonis flexuosa 3	Mature	7	7
742		20.7	16.7	mcon	Indigenous	Agonis flexuoas 2	Mature	7	9
842	13	20	10.8	dgrs	Indigenous	Agonis flexuosa	Mature	9	9
845		20.6	14.4	lcon	Indigenous	Agonis flexuosa	Mature	11	12
109	14.1	22.7	13.3	dgrs	Native	Callistemon KP Special	Mature	7	7
110	15	19.4	20.4	lcon	Native	Eucalyptus leucoxylon vars	Mature	6	8
125	15.8	20.8	19.4	mcon	Native	Lophostemon confertus	Mature	10	10
126					Native	Callistemon citrinus	Young	2	2
128					Native	Callistemon citrinus	Young	2	2
134	14.8	24.4	19.9	lcon	Native	Eucalyptus torquata	Semi-mat	5	6
135	11.9	17.4	13.4	igrs	Native	Eucalyptus torquata	Semi-mat	5	6
136	13.3	18	13.4	igrs	Native	Callistemon sp.	Mature	2	3
138	15.6	21.4	18.3	lcon	Native	Lophostemon confertus	Mature	10	11
153	13.7	19.5	15.4	dgrs	Native	Callistemon KP Special	Mature	7	9
154	12.9	22.6	15.4	dgrs	Native	Lophostemon confertus	Mature	5	7
156	12.6	16.2	14.2	dgrs	Native	Lophostemon confertus	Mature	6	7
160					Native	Brachychiton acerifolia	Young	4	2
161					Native	Brachychiton acerifolia	Young	2	1
162					Native	Brachychiton acerifolia	Young	3	1
163	14.3	25.2	17.1	soil	Native	Brachychiton acerifolia	Semi-mat	5	3
195					Native	Eucalyptus torquata	Juvenile	1	1
196					Native	Eucalyptus torquata	Juvenile	1	1
218	13.3	21.4	12.3	dgrs	Native	Lophostemon confertus	Mature	5	5

222	15	17.6	16.4	lcon	Native	Lophostemon confertus	Semi-mat	6	7
223	15.7	17.8	16.8	lcon	Native	Lophostemon confertus	Mature	6	7
237		27.9	16.7	asp	Native	Eucalyptus leucoxylon vars	Mature	5	5
238		27.9	16.3	asp	Native	Eucalyptus leucoxylon vars	Semi-mat	6	6
240					Native	Corymbia citriodora	Semi-mat	11	10
243	13.2	21.7	13.1	dgrs	Native	Eucalyptus robusta	Semi-mat	10	9
244	15.4	26.9	16.9	asp	Native	Lophostemon confertus	Semi-mat	7	6
245	15.5	25.8	15.5	asp	Native	Eucalyptus nicholii	Semi-mat	10	6
246	14.3	23	14.9	soil	Native	Lophostemon confertus	Semi-mat	0	0
248	13.2	19.7	11.3	dgrs	Native	Lophostemon confertus	Mature	9	8
249	13.5	20	13.2	igrs	Native	Lophostemon confertus	Mature	10	9
251	16.6	24.6	16.5	asp	Native	Lophostemon confertus	Mature	11	10
252	13.5	24.2	13.5	dgrs	Native	Lophostemon confertus	Mature	9	10
253	15.5	21.3	16.5	asp	Native	Lophostemon confertus	Mature	9	9
255	15.7	23.7	15.2	asp	Native	Lophostemon confertus	Mature	12	10
256	16	25.1	16.2	asp	Native	Lophostemon confertus	Mature	7	8
258	16.1	24.5	15	asp	Native	Lophostemon confertus	Mature	12	10
259		22.2	15.3	asp	Native	Lophostemon confertus	Mature	9	9
260		24.3	16.7	asp	Native	Lophostemon confertus	Mature	6	5
263	13.9	19.5	13.6	dgrs	Native	Melaleuca quinquenervia	Mature	5	5
264	13.6	20.8	11.3	dgrs	Native	Melaleuca quinquenervia	Mature	5	5
265	13.4	21.2	13.7	dgrs	Native	Melaleuca quinquenervia	Semi-mat	6	5
278	13.6	16	12	dgrs	Native	Vacant	Mature	6	9
284	13.8	21.6	12.6	dgrs	Native	Lophostemon confertus	Mature	5	8
285	12.7	22.4	13.2	dgrs	Native	Eucalyptus leucoxylon vars	Semi-mat	6	5
286	14.5	19.7	16.4	soil	Native	Lophostemon confertus	Mature	5	8
287	15.2	21.5	16.4	mcon	Native	Lophostemon confertus	Mature	5	7
289	13.5	21.4	15.1	dgrs	Native	Lophostemon confertus	Mature	5	8
290	15.2	24	19.8	mcon	Native	Lophostemon confertus	Mature	5	7
291	13.7	16.8	13.1	igrs	Native	Lophostemon confertus	Mature	5	9
292	12.7	18.4	13.4	dgrs	Native	Lophostemon confertus	Mature	5	8
293	12.5	21.7	13.3	dgrs	Native	Lophostemon confertus	Mature	5	6
294	13.6	21	16	dgrs	Native	Lophostemon confertus	Mature	4	7
295	15.6	18.8	18.2	mcon	Native	Lophostemon confertus	Mature	5	9
296	14.8	22.1	17.6	soil	Native	Lophostemon confertus	Mature	6	8
297	15	22.5	17.6	soil	Native	Lophostemon confertus	Mature	7	10
298	15.4	21.3	17.7	mcon	Native	Lophostemon confertus	Mature	5	8
299	15.6	22.2	19.7	mcon	Native	Lophostemon confertus	Mature	5	10
300	15.3	19.1	16.7	mcon	Native	Lophostemon confertus	Mature	6	9
302	12.5	17.5	14.2	dgrs	Native	Lophostemon confertus	Mature	7	7
306					Native	Eucalyptus sp.	Young	7	2
312		29.9	18.1	asp	Native	Eucalyptus sp.	Semi-mat	12	6
313					Native	Eucalyptus torquata	Young	3	4

317	14.4	19.3	14.9	soil	Native	Lophostemon confertus	Mature	10	10
318					Native	Corymbia ficifolia	Juvenile	2	2
319	14.3	21.1	17	soil	Native	Lophostemon confertus	Mature	12	10
325		24.8	19.2	asp	Native	Lophostemon confertus	Mature	6	5
327	11.3	17.1	14	igrs	Native	Lophostemon confertus	Mature	6	7
353					Native	Acacia podalyriifolia	Mature	4	5
359	15.6	30.5	20.9	mcon	Native	Eucalyptus leucoxylon vars	Semi-mat	4	4
361					Native	Callistemon KP Special	Juvenile	2	1
363		27.9	21.2	mcon	Native	Eucalyptus erythrocorys	Juvenile	2	1
366		23.6	14.6	dgrs	Native	Callistemon KP Special	Young	3	2
377					Native	Callistemon KP Special	Young	2	3
379					Native	Callistemon KP Special	Young	2	2
735					Native	Eucalyptus torquata	Semi-mat	5	6
830	12.4	19	9.4	dgrs	Native	Callistemon KP Special	Semi-mat	3	3
108						Vacant		0	0
111						Vacant		0	0
112						Vacant		0	0
116						Vacant		0	0
117						Vacant		0	0
131						Vacant		0	0
132	14.5	20	17.4	dgrs	Native	Lophostemon confertus	Mature	10	10
139	14.1	21	14.8	dgrs	Native	Callistemon viminalis	Young	3	3
140						Vacant		0	0
141						Vacant		0	0
144						Vacant		0	0
152						Vacant		0	0
155						Vacant		0	0
158						Vacant		0	0
181						Vacant		0	0
186						Vacant		0	0
204						Vacant		0	0
205						Vacant		0	0
206						Vacant		0	0
212						Vacant		0	0
217						Vacant		0	0
225						Vacant		0	0
226						Vacant		0	0
229						Vacant		0	0
231						Vacant		0	0
232						Vacant		0	0
233						Vacant		0	0
234						Vacant		0	0
236						Vacant		0	0
242						Vacant		0	0
250						Vacant		0	0
267						Vacant		0	0
272						Vacant		0	0
273						Vacant		0	0
274						Vacant		0	0

279						Vacant		0	0
280						Vacant		0	0
288						Vacant		0	0
323						Vacant		0	0
328		26	16.8	asp	Indigenous	Agonis flexuoas 2	Mature	11	11
354	14.8	21.1	17.1	mcon	Indigenous	Agonis flexuoas 2	Mature	7	10
355						Corymbia ficifolia	Semi-mat	6	4
358						Vacant		0	0
360		24.3	19.5	mcon	Native	Eucalyptus leucoxylon vars	Mature	5	8
364	13.5	32.2	23.5	mcon	Native	Callistemon KP Special	Young	3	1
368						Vacant		0	0
370						Vacant		0	0
372		20.5	13.6	dgrs	Indigenous	Agonis flexuoas 2	Mature	6	8
381		16.6	16.3	asp	Indigenous	Agonis flexuosa 3	Mature	9	10
384						Vacant		0	0
730	14	20.5	13.7	mcon	Indigenous	Agonis flexuosa 3	Mature	8	10
732						Vacant		0	0
734						Vacant		0	0
828						Vacant		0	0
829						Vacant		0	0
852						Platanus x acerifloia	Mature	6	9

10.2.4 Control surfaces. 14 September 2017.

	Footpath		Lawn		Road			
Time	Concrete light	Concrete med	Grass-irr	Grass-dry	Asphalt	Volc Chip	Other	Other Surface
04:05	12.7	16	11.7	13.7	14.8			
04:45	15.1	15.1		13.6	16			
06:00	14.1			12.4	15.8		13.9	soil
06:15							14.5	Artificial Grass
06:55	14.3	13	11.5	11.6	15.2			
12:55	33.3	38.4	31.7	40.8	45.2		47.5	Mulch
13:30							58	Soil
14:15	34.9	42.7	30.6	38.4	42.4		44.1	Soil
14:25							42.2	Artificial Grass
15:05							42.8	Artificial Grass
15:15							36.4	Yellow Paver
15:15							32.8	Red Brick
15:20							37.9	Mulch
16:00							39.1	Artificial Grass
16:00							33.5	Red Brick
18:15	22.8	24.2	11.5	13.6	23.4		14.8	Mulch
18:15							13.5	Artificial grass
20:35	18.4	19.6	10	10.1	20.2		12.8	Soil
							15.3	Mulch