# URBAN HEAT ISLAND MITIGATION STRATEGY

## Moorebank Precinct East Stage 2

11 JUNE 2019

# SYDNEY INTERMODAL TERMINAL ALLIANCE MOOREBANK PRECINCT EAST STAGE 2

## Urban Heat Island Mitigation Strategy


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## REVISIONS

| Revision | Date | Description | Prepared by | Approved by |
|---|---|---|---|---|
| 001 | 28/03/18 | Draft to Tactical for discussion only | [redacted] | - |
| 002 | 24/04/18 | Draft for submission to Tactical | | [redacted] |
| 003 | 14/06/18 | Draft for submission to Ground Ink and Reid Campbell | | |
| 004 | 29/06/2018 | Updated for submission to DP&E | | |
| 005 | 31/08/2018 | Updated to reflect W1P | | |
| 006 | 8/04/2019 | Updated with comments from GANSW and DP&E | | |
| 007 | 11/06/2019 | Updated with comments from DP&E | | |

# ACRONYMS AND DEFINITIONS

| Acronym/Term | Meaning |
|---|---|
| AHD | Australian Height Datum |
| Albedo | A measure of the amount of solar radiation that is reflected from a surface |
| Anthropogenic heat | Heat released as a result of human activities including machinery use, particularly engines and air conditioning. |
| ANZECC | Australian and New Zealand Environment and Conservation Council |
| Atmospheric UHI | Typically a result of urban geometry (i.e. the dimensions and spacing of buildings within an urban area). Urban geometry influences wind flow, energy absorption and how effectively radiation can be emitted back to space. Heat from energy use in human activities is a further contributor to the atmospheric UHI. |
| BOM | Bureau of Meteorology |
| Boundary layer | Layer that extend from the rooftop and treetop level and up to the point where urban landscapes no longer influence the atmosphere |
| Canopy layer | Layer of air where people live, from the ground to below the tops of trees and roofs |
| CBD | Central Business District |
| CCoA | Commonwealth Concept Approval Conditions |
| CEFC | Clean Energy Finance Corporation |
| CEMP | Construction Environmental Management Plan |
| CoCs | Conditions of Consent |
| Current design | The current design is as of 7 June 2019 as shown in drawing title “Combined UDLP Site Layout Plan” submitted 5 June 2019. |
| DJLU | Defence Joint Logistics Unit |
| DNSDC | Defence National Storage and Distribution Centre |
| DP&E | NSW Department of Planning and Environment |
| EIS | Environmental Impact Statement |
| EP&A Act | *Environmental Planning and Assessment Act 1979* |
| ESD | Ecologically sustainable development |
| FCMM | Final Compilation of Mitigation Measures |
| GANSW | Government Architect New South Wales |
| GBCA | Green Building Council of Australia |
| GFA | Gross floor area |
| H:W | Height to width ratio |

| Acronym/Term | Meaning |
|---|---|
| HVAC | Heating and cooling, ventilation, air conditioning |
| ISCA | Infrastructure Sustainability Council of Australia |
| km | Kilometre |
| LED | Light-emitting diode |
| LSE | Land surface emissivity |
| LSP | Lighting Sub Plan |
| LST | Land surface temperatures |
| m | Metre |
| MLP | Moorebank Logistics Park |
| mm | Millimetre |
| MPE | Moorebank Precinct East |
| MPW | Moorebank Precinct West |
| MW | Megawatts |
| NSW | New South Wales |
| OEH | Office of Environment and Heritage |
| OEMP | Operational Environmental Management Plan |
| OSD | On-site detention |
| PAC | Planning Assessment Commission |
| RL | Reduced levels |
| RSoC | Revised Statement of Commitments |
| RtS | Response to Submissions |
| SIMTA | Sydney Intermodal Terminal Alliance |
| SMP | Stormwater Management Plan |
| SSD | State significant development |
| Surface UHI | Generally caused by the sun heating dry, exposed surfaces, such as roofs and pavement to temperatures hotter than the air. Surface UHI are therefore typically strongest during the day when the sun is shining. |
| SVF | Sky view factor |
| The Project | MPE Stage 2 Project, namely Stage 2 of the MPE Concept Approval (MP 10_0193) including construction and operation of warehousing and distribution facilities on the MPE site within the Moorebank Precinct as approved under SSD 7628. |

| Acronym/Term | Meaning |
|---|---|
| Thermal emittance | Also known as thermal emissivity.<br>How much heat a material will radiate per unit area at a given temperature and is a measure of how readily the surface will shed heat. |
| UDLP | Urban design landscape plan |
| UHI | Urban heat island |
| UHIMS | Urban Heat Island Mitigation Strategy |
| Urban geometry | Dimensions and spacing of buildings within a city, referred to as urban geometry, influences how solar radiation and anthropogenic heat is absorbed and re-emitted (Oke 1981; Bärring *et al* 1985; Eliasson 1996). |
| WSUD | Water sensitive urban design |

# EXECUTIVE SUMMARY

The Urban Heat Island (UHI) effect refers to the phenomena whereby urban regions typically experience warmer temperatures than their rural and natural surroundings. A contributing factor to the UHI effect is when buildings and hard surfaces absorb the sun's heat and then radiate it back into their surroundings. There are two broad types of UHI: atmospheric and surface UHIs. These two heat island types differ in the ways they are formed, the techniques used to identify and measure them, their impacts, and to some degree, the methods available to mitigate them (U.S. Environmental Protection Agency, 2008).

This Urban Heat Island Mitigation Strategy (UHIMS) has been developed for the entire MPE Stage 2 site (SSD 7628) specifically addressing CoC B139 and provides recommendations to mitigate the UHI effect of the Project during operation. The details of the mitigation strategies to be implemented are included within the Urban Design and Landscape Plan (UDLP), Development Layout Plans and Architectural Plan. This UHIMS focuses on strategies to mitigate the UHI effects within the surface and canopy layers and includes a goal to achieve a 4°C decrease in temperature on the Project site compared to neighbouring industrial developments. This UHIMS considers options for design choices, including landscaping and materials selection and that have been shown to have a difference in temperature.

The potential UHI mitigation strategies discussed are those that are widely recognised as having a positive impact on the UHI effect and for which peer reviewed literature is available. Advantages and disadvantages of each potential UHI mitigation strategy are presented within an industrial context, taking into consideration other aspects of the strategies (i.e. maintenance requirements, other environmental benefits / costs etc.). The strategies deemed appropriate for an industrial context are then analysed further with respect to the Project and site-specific information.

A review of the Project, as described in the Response to Submissions (RtS) report was completed and considered the potential UHI effect on each aspect of the development. Following this analysis, mitigation factors already incorporated in the design and recommendations for other potential mitigation factors to mitigate the UHI effect were summarised. The mitigation factors that would minimise heat effects and promote cooling of the Project site at a level appropriate to an industrial development, while meeting the Project operational requirements and maintaining consistency with the approved Project included:

**Mitigation Factors Incorporated in Design**

- Water sensitive urban design (WSUD)
- On-site detention (OSDs)
- Landscaping
- Green space
- Minimisation of heat generation from operations.

**Mitigation Recommendations**

- Additional landscaping and green space
- Cool roofs
- Solar panels
- Cool building materials
- High albedo pavement types
- Minimisation of heat generation from operations.

The UHIMS provides a site analysis and comparison for the Project and neighbouring industrial sites for the mitigation of the UHI effect. An Australian UHI mapping study, undertaken as part of the broader study titled *Where should all the trees go? Investigating the impact of tree canopy cover on socioeconomic status and wellbeing in LGA's* (Amati, 2017) has been used to inform the analysis of the existing UHI effect in neighbouring industrial areas to the Project site. An assessment was also completed of the UHI performance of neighbouring industrial sites and a review of the surface area features of the site that may contribute, beneficially or adversely, to local UHI effects.

Modelling was undertaken to determine if a 4°C decrease in temperature for the entire MPE Stage 2 Project site could be achieved in comparison to neighbouring industrial developments with the incorporation of select mitigation strategies. The modelling was undertaken for the entire MPE Stage 2 Project site for the RtS design plan on 29 March 2019 and reissued on 6 June 2019 for the current design plan. The difference in the site surface areas for the RtS design plan and the current design plan was determined to be less than 1% with the primary change being the layouts of On-Site Detention (OSD) 1 and OSD9. As such, the results for both reports concluded a 1°C reduction in canopy temperature during the middle of the day across the year when compared to adjacent industrial facilities. According to a study (Azevedo et al, 2016), a 1°C difference in canopy temperature correlates to approximately a 4°C difference in surface temperature.

Recommendations from this UHIMS have been incorporated into other various Project documents in accordance with CoC B139(d). The UHIMS has been incorporated into the Updated Final Development Layout Plans, WSUD Plans and the UDLP.

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# 1 BACKGROUND

The Sydney Intermodal Terminal Alliance (SIMTA) received approval for the construction and operation of Stage 2 of the Moorebank precinct East (MPE) Project (SSD 7628), which comprises the second stage of development under the MPE Concept Consent (MP10_0193). This Urban Heat Island Mitigation Strategy (UHIMS) has been developed to provide a strategy for the mitigation of potential urban heat island (UHI) effects associated with the Moorebank Precinct East Stage 2 Project (the Project).

This UHIMS addresses the relevant requirements of the Development Consent (CoC B139).

## 1.1 Introduction

The MPE site, including the Project site, is located approximately 27 kilometres (km) south-west of the Sydney Central Business District (CBD) and approximately 26 km west of Port Botany and includes the former Defence National Storage and Distribution Centre (DNSDC) site. The MPE site is situated within the Liverpool Local Government Area (LGA), in Sydney's South West subregion, approximately 2.5 km from the Liverpool City Centre.

Stage 2 of the MPE Project (the Project) involves the construction and operation of warehousing and distribution facilities on the MPE site and upgrades to approximately 1.5 km of Moorebank Avenue from approximately 35 metres (m) south of the northern boundary of the MPE site to approximately 185 m south of the southern MPE site boundary.

Key components of the Project include:

- Earthworks including the importation of 600,000 $m^3$ of fill and vegetation clearing
- Approximately 300,000 $m^2$ gross floor area (GFA) of warehousing and ancillary offices
- Freight village, 8,000 $m^2$ GFA of ancillary retail, commercial and light industrial land uses
- Internal road network and hardstand across the site
- Ancillary supporting infrastructure within the site, including:
  - Stormwater, drainage and flooding infrastructure
  - Utilities relocation/installation
  - Fencing, signage, lighting, remediation and landscaping
- Moorebank Avenue upgrade including:
  - Raising by about 2 m and some widening
  - Embankments and tie-ins to existing Moorebank Avenue road levels
  - Signalling and intersection works
- Intersection upgrades along Moorebank Avenue including:
  - Moorebank Avenue/MPE Stage 2 access
  - Moorebank Avenue/MPE Stage 1 northern access
  - Moorebank Avenue/MPE Stage 2 central access
  - Moorebank Precinct West (MPW) Southern Access/MPE Stage 2 southern emergency access.

The Project will interact with the MPE Stage 1 Project (SSD 6766) via the transfer of containers between the MPE Stage 1 Intermodal Terminal and the Project's warehousing and distribution facilities.

## 1.2 Development Consent

The Project has been assessed by the Department of Planning and Environment (DP&E) under Part 4, Division 4.1 (now Division 4.7 as of 1 March 2018) of the *Environmental Planning and Assessment Act 1979* (EP&A Act) as State significant development (SSD). The Planning Assessment Commission (PAC) granted approval for the MPE Stage 2 Project on 31 January 2018 subject to the Conditions of Consent (CoCs) (SSD 7628).

## 1.3 Purpose and Application

This UHIMS has been developed to address CoC B139 for the whole MPE Stage 2 Project site. This UHIMS provides recommendations to mitigate the UHI effect of the Project during operation. This UHIMS focuses on strategies to mitigate the UHI effects within the surface and canopy layers and includes a goal to achieve a 4°C decrease in temperature on the Project site compared to neighbouring industrial developments. This UHIMS considers options for design choices, including landscaping, materials selection and anthropogenic heat generation mitigation that have been shown to have a difference in temperature. The structure of this UHIMS is as follows:

- **Section 2**: Includes consideration of the government policy and strategic planning reports referenced within the MPE Stage 2 State Significant Development Assessment Report (NSW Department of Planning and Environment, 2017) and the PAC Determination Report (NSW Planning Assessment Commission, 2018). The specific requirements of the CoCs for the compilation of this UHIMS, as identified in the CoCs are identified in the Compliance Matrices in Section 2.3.
- **Section 3**: Potential UHI mitigation strategies are identified, based on peer-reviewed literature. Advantages and disadvantages of each potential UHI mitigation strategy are presented within an industrial context, taking into consideration other aspects of the strategies (i.e. maintenance requirements, other environmental benefits / costs etc.). The strategies deemed appropriate for an industrial context are then analysed further in Section 4 with respect to the Project and site-specific information.
- **Section 4**: Includes a review of the Project design, as described in the Response to Submissions (RtS) report and an assessment of the likely development impacts in the context of UHI. Mitigation factors already incorporated in the design and recommendations on mitigation factors to mitigate the UHI effects generated by the operation of the Project are included for each mitigation strategy deemed appropriate for an industrial context.
- **Section 5**: Summarises the mitigation factors that would minimise heat effects and promote cooling of the Project site at a level appropriate to an industrial development, while meeting the Project operational requirements and maintaining consistency with the approved Project.
- **Section 6**: Includes an assessment of the UHI performance of neighbouring industrial sites and a review of the surface area features of the site that may contribute, beneficially or adversely, to local UHI effects.
- **Section 7**: Summarises the UHI mitigation strategies that have been incorporated into the overall design after completing a site analysis and comparison of adjacent neighbouring sites. A modelling tool was used to determine if a 4°C decrease in temperature at the Project site could be achieved in comparison to neighbouring industrial developments with the incorporation of the mitigation strategies outlined in this section. Modelling was undertaken for the entire MPE Stage 2 Project site in relation to the RtS and current design plan to demonstrate design progression and compliance with CoC B139(c) based on the recommendations made within this UHIMs.
- **Section 8**: Outlines where the UHI mitigation strategies will be incorporated into the other plans, as required by CoC B139(d).

This UHIMS is a strategy document and will not be staged as it considers the entire MPE Stage 2 Project site. This UHIMS is not intended to demonstrate the detailed design of the Project however, provides recommendations for strategies to be implemented to minimise the UHI impacts. Recommendations of this UHIMS have been incorporated into the following documents:

- Development Layout Plans, Water Sensitive Urban Design (WSUD) plans and architectural details as required by CoC A22, A23 and A24 respectively
- Urban Design and Landscape Plan (UDLP) as required by CoC B140 and B141
- Construction Environmental Management Plan (CEMP) as required by CoC C1
- Operational Environmental Management Plan (OEMP) as required by CoC C3.

The most recent, approved version of this UHIMS will be implemented to provide recommendations for design choices to reduce the impacts of UHI generated by the development of the Project.

### 1.3.1 Objectives and Targets

Table 1 outlines the objectives and targets to reduce UHI effects of the Project.

*Table 1 Objectives and Targets*

| Objective | Target | Timeframe | Accountability |
|---|---|---|---|
| Provide recommendations to mitigate the UHI effect generated by the development | Incorporate recommended mitigation strategies into the detailed design of the Project to reduce the UHI effect | During detailed design | SIMTA |
| Provide a design strategy to reduce the UHI effect | Demonstrate that the design strategy can achieve a 4°C decrease in temperature when compared to neighbouring industrial developments | During detailed design | SIMTA |

## 1.4 Consultation

This UHIMS was submitted by the Secretary to the Government Architect NSW (GANSW) for consultation, in accordance with CoC B139. A summary of the consultation undertaken for this UHIMS through DP&E is provided in Table 2. Appendix D provides the response to GANSW comments in relation to the UHIMS.

*Table 2 Consultation Summary*

| Agency | Date | Person Contacted | Comment | Status |
|---|---|---|---|---|
| DP&E and GANSW | 27/08/2018 | [redacted] | Request to review UDLP in conjunction with UHIMS | UDLP supplied |
| | 28/08/2018 | DP&E (on behalf of GANSW) | Presentation on UHIMS and UDLP at DP&E office | Presentation completed |
| | 05/09/2018 | DP&E (on behalf of GANSW) | Draft UHIMS focusing on W1P and directly link with UDLP | Closed |
| | 19/10/2018 | SIMTA | Email with reviewed plan | Closed |
| | 23/10/2018 | SIMTA | Email with requested plans and drawings to be updated for next week’s meeting | Closed |
| | 24/10/2018 | SIMTA | Email requesting additional information regarding modelling of 4 degrees temperature | Closed |
| | 30/10/2018 | SIMTA | Email with GANSW figure mark ups and comments | Closed |
| | 21/11/2018 | DP&E (on behalf of GANSW) | Email responding to GANSW comments | Closed |
| | 28/11/2018 | DP&E (on behalf of GANSW) | Email responding to GANSW comments and figures | Closed |
| | 29-30/11/2019 | DP&E (on behalf of GANSW) | Email with UHIMS modelling demonstrating 4 degrees temperature | Closed |

| Agency | Date | Person Contacted | Comment | Status |
|---|---|---|---|---|
| | 6/12/2018 | DP&E (on behalf of GANSW) | Follow up email regarding meeting on 02/12/2018 and response to comments | Closed |
| | 15/01/2019 | SIMTA | Email with GANSW response to comments from 11/28/2018 | Closed |
| | 23/01/2019 | DP&E (on behalf of GANSW) | Presentation on UHIMS | Presentation completed |
| | 26/02/2019 | SIMTA | Email with reviewed plan and comments | Closed |
| | 9/04/2019 | DP&E | Updated UHIMS | Closed |
| | 22/05/2019 | SIMTA | Email with reviewed plan and comments | Closed |
| | | | | |

# 2 ENVIRONMENTAL MANAGEMENT

There are few government policies within NSW that address UHI mitigation for private developments and none which specifically consider the UHI effect within an industrial context. The following sections outline the points of consideration during the assessment process for Project approval and the requirements of CoC B139, which was included within the CoCs as a result of these considerations.

## 2.1 Government Policy and Assessment Report Considerations

The PAC Determination Report (NSW Planning Assessment Commission, 2018) and the State Significant Development Assessment Report (NSW Department of Planning and Environment, 2017) recognise that UHI effects can be reduced through initiatives like *Greener Places* and *Five Million Trees*.

*Greener Places* is a draft Green Infrastructure policy issued by the GANSW to guide planning, design and delivery of green infrastructure in urban areas throughout NSW, with a focus on the provision of publicly accessible green space. *Greener Places* focuses on improving community access to recreation and exercise, supporting walking and cycling connections, and improving the resilience of urban areas (Government Architect New South Wales , 2017). Although the Project site is not a public space, this policy has been considered where appropriate to inform this strategy.

The *Urban Tree Canopy Guide* is a draft guide issued by the GANSW to provide information on the importance of urban tree canopy and its capacity to improve urban climate. The Urban Tree Canopy sits underneath the Greener Places guide and prescribes percentage targets for urban tree canopy cover in CBD areas (>15%), light commercial / high to medium density residential areas (>25%) and suburban areas (>40%). These targets have been nominated based on international and national best practice to assist climate mitigation and adaptation and reduce the urban heat island effect. There is no prescribed target for industrial / heavy commercial sites under the guide. The actions prescribed under the guide are for implementation by State and local government and the development of Urban Tree Canopy Plans which are to be prepared concurrently with plans for open space and/or bushland and waterway management.

The *Five Million Trees* (New South Wales Government Architect, 2018) initiative announced by the NSW Government on 11 April 2018, proposes five million trees will be planted in Sydney by 2030, in order to increase the tree canopy in Sydney from 16.8% to 40% (NSW Department of Planning and Environment, 2018). The target aims to provide more shade, and improve the community's quality of life, biodiversity habitat and visual amenity. Individuals and organisations can register a tree they have planted on the NSW Government's website to meet the goal of five million trees.

The *Western Sydney District Plan* identifies that climate change is likely to result in more extremely hot days. In addition, the plan recognises that highly developed parts of the Western Sydney District can be exposed to extreme heat conditions as a result of the urban heat island effect. The plan notes that existing planning controls focus on cooling the landscape by retaining water and protecting, enhancing and extending the urban tree canopy to mitigate the urban heat island effect.

It is noted that the State Significant Development Assessment Report states that the GANSW identified Planning Priority W18 - 'Delivering High Quality Open Space' within the *Western Sydney District Plan* as applicable to the Project. The approved Project is industrial in nature and, while the Project includes improvement to transport links, including cycling and walking infrastructure as a means to access the Project site, the Project does not include the creation of public open space. Access to the Project site would be restricted to employees and persons using the Project site to maintain site security; hence this planning priority is not considered applicable to the Project and reference to 'open space' within the context of the Project is inappropriate.

For the preparation of this UHIMS, the following resources were reviewed:

- *State Significant Development Assessment Report: Moorebank Intermodal Terminal, Moorebank Precinct East, Moorebank Avenue, Moorebank, SSD 7628* (NSW Department of Planning and Environment, 2017)
- *Greener Places* (Government Architect New South Wales , 2017)
- *Urban Tree Canopy Guide* (Government Architect NSW, 2018)
- *Five Million Trees* (NSW Department of Planning and Environment, 2018)
- *Green Star* (Green Building Council Australia, 2015)

- *Cooling the City Strategy* (Penrith City Council, 2015)
- *Guide to Urban Cooling Strategies* (Sharifi, 2017)
- *Reducing urban island heat islands: Compendium of strategies* (U.S. Environmental Protection Agency, 2008)
- *Western Sydney District Plan* (Greater Sydney Commission, n.d.)
- *Turn Down the Heat* (Western Sydney Regional Organisation of Councils, 2018)
- *Where Should All the Trees Go? An analysis of urban canopy cover in Australia* (Amati, 2017)
- *Urban Heat and Energy Demand: Application of an urban meteorological network.* (Azevedo et al, 2016).*)*

Currently, there is no guidance document for the mitigation of the UHI effect within private or industrial developments in NSW. The preparation of this UHIMS has therefore drawn from international examples as well as peer-reviewed, scientific papers (refer to Section 9 for full list of references).

## 2.2 Project Sustainability Initiatives

Industrial design and sustainability measures consistent with industry standards have been considered in the development of the detailed design for the Project. These measures include energy efficiency design and use of machinery, minimising heating and cooling, ventilation, air conditioning (HVAC) demand and other ecologically sustainable design (ESD) principles.

In June 2017, Qube Logistics entered into an agreement with the Clean Energy Finance Corporation (CEFC) for the provision of $150 million in low interest financing for the installation of a solar photovoltaic (PV) cells and other energy efficiency technologies. CEFC have awarded this funding subject to a number of conditions being met. These conditions can broadly be categorised into three key areas:

- CEFC mandated conditions: These conditions include a range of requirements specified by the CEFC on specific elements of the Moorebank Logistics Park (MLP), which includes the Project site (e.g. minimum requirements for solar power system size, or requirements to investigate use of low embodied energy materials). Conditions also include regular reporting on sustainability delivery and outcomes
- Implementation of the Infrastructure Sustainability (IS) Rating tool: CEFC have specified that a Design, As Built and Operation IS Rating performance level must be achieved for the various packages of the MLP
- Minimum implementation of a minimum of a 4 Star Green Star rating for each of the warehouse buildings.

There are a number of initiatives within the CEFC agreement that relate to the sustainability performance of the Project, and are listed below:

- Register components of the Project for which an ISCA rating is achievable with ISCA and undertake assessment, verification and certification process to achieve as a minimum a "Commended" rating
- Register components of the Project with the Green Building Council of Australia (GBCA) and undertake assessment, verification, and certification process to achieve a minimum Design and As-Built v1.1 3[1] star Green Star rating for warehouses
- Consider embodied energy over the life cycle of pavements when comparing pavement types for incorporation within the Project
- Increase of solar panels to at least 30 megawatts (MW)
- Provisioning for precinct power storage to support renewable energy sources
- Monitoring and reduction opportunity identification of greenhouse gas emissions and energy use sufficient to achieve a minimum ISCA Energy and Carbon Monitoring and Reduction credit rating of Level 1

[1] Note that 3-Star rating for Green Star is not applicable for Design and As-built requirements, as such a 4-Star rating is being targeted.

- Minimisation of heating and cooling for warehouses.

Most of these initiatives will impact upon the Project's energy demand, overall detailed design and reduce the UHI effect during operation of the Project. The Project's sustainability targets form an integral part of the Project and have been taken into consideration when recommending strategies to mitigate the UHI effects generated by the Project.

The design and operation of the warehouses and freight village will also be required to meet ESD principles, in accordance with CoC B142. The ESD principles which have the potential to influence the UHI effect include:

- Passive solar design
- Use of energy efficient plant and equipment
- Use of renewable energy resources
- Cross ventilation
- Rainwater capture and reuse.

## 2.3 Compliance Matrices

This UHIMS has been prepared to comply with CoC B139. Table 3 contains the requirements of CoC B139 and demonstrates where within the UHIMS the requirement has been addressed and summarises how it has been addressed.

*Table 3 Conditions of Consent (CoCs)*

| CoC | Requirement | Document Reference | How Addressed |
|---|---|---|---|
| B139 | Prior to commencement of permanent built surface works and/or landscaping, or as otherwise agreed by the Secretary, an **Urban Heat Island (UHI) Mitigation Strategy** must be prepared and submitted to the Secretary for approval, in consultation with the NSW Government Architect. The UHIMS must be prepared by a suitably qualified and experienced person(s). | This plan | This UHIMS has been prepared by personnel with environmental science and management qualifications with inputs from an architect and landscape architect, as identified on the sign-off page of the UHIMS. |
| | (a) review the current architectural details, building layout, landscaping provision, shading provision, landscape irrigation, stormwater water detention and WSUD, as well as building and paving material specifications; | Section 4 | Review of nominated design content confirms suitability of design to enable UHI effect management strategies to be incorporated without amendment to structural design or layout. |
| | (b) make recommendations to mitigate the UHI effects generated by the development including but not limited to: | Section 5 | Measures to mitigate the effects of UHI are discussed in Section 3.2, and include consideration of the recommendations listed.<br>Analysis of the appropriateness of each of the measures in the context of an industrial site are discussed in Section 3.3.<br>The potential and recommendation options for the mitigation strategies that are appropriate for an industrial site are outlined in Section 4. |
| | (i) provision of WSUD elements; | Section 3.2.1<br>Section 3.3.1<br>Section 4.7 | |
| | (ii) street tree planting; | Section 3.2.2<br>Section 3.3.2<br>Section 4.5 | |

| CoC | Requirement | Document Reference | How Addressed |
|---|---|---|---|
| | (iii) landscape coverage and screening; | Section 3.2.3<br>Section 3.3.3<br>Section 4.4 | |
| | (iv) use of building material including reflectivity; | Section 3.2.4<br>Section 3.3.4<br>Section 4.8 | |
| | (v) use of pavement material including reflectivity; | Section 3.2.5<br>Section 3.3.5<br>Section 4.9 | |
| | (vi) improved green space maintained by independent, climate resilient water supplies, to achieve increased amenity and urban cooling; and | Section 3.2.2<br>Section 3.2.3<br>Section 4.6 | A discussion of the mitigation of the UHI effect through the provision of landscaping of green space, maintained through climate resilient water supplies is discussed in Section 3.2.2 and 3.2.3.<br>Section 4.6 discusses considerations of green space and irrigation requirements for landscaping. |
| | (vii) heat generation from operations; and | Section 3.2.7<br>Section 4.10 | Measures to mitigate heat generation from Project site operations is discussed in Section 3.2.7 and Section 4.10 |
| | (c) include a design strategy with the goal to achieve a 4°C degree decrease in temperature compared to neighbouring industrial developments; | Section 5.4<br>Section 6<br>Section 7<br>Section 7.1<br>Appendix B | Section 5.4 provides potential temperature reductions based on literature review for the mitigation strategies incorporated into the design and the strategies that are recommended.<br>The site analysis and comparison in Section 6 identifies neighbouring sites for comparison and presents UHI imagery as a baseline of neighbouring sites.<br>The design strategy, including the final mitigation strategies in Section 7, identifies the potential effect of a suite of mitigation strategies that are projected to achieve the goal of a 4°C degree decrease in temperature compared to neighbouring industrial developments.<br>Section 7.1 includes a description of the UHI mitigation strategy modelling that was undertaken. Refer to Appendix C for further detail of the UHIMS modelling. |
| | d) details of where and how recommendations from the UHI Mitigation Strategy have been incorporated into the: | Section 8 | Section 8 identifies where and how recommendations of this UHIMS will be incorporated into the plans and drawings. The following sections provide specific detail where the recommendations have been incorporated into the plans and drawings. |

| CoC | Requirement | Document Reference | How Addressed |
|---|---|---|---|
| | (i) updated final Development Layout Plans and WSUD Plans required by conditions A22 and A23; | UDLP - Appendix H1: Development Layout Plans<br><br>UDLP – Appendix H2: WSUD Plans<br><br>SMP – W1P<br><br>SMP – Balance of Site | The Updated Final Architectural details and Development Layout Plans incorporate the following in relation to minimising the UHI effect including:<br>• Use of cool roofs (i.e. translucent sheeting)<br>• Installation of solar panels<br>• Use of cool building materials and finishes<br>• Large awning roof over receiving and / or loading docks<br>• Incorporation of a bioretention structure as part of the stormwater management controls<br>• Incorporation of landscaping within car parking and provision of canopy trees throughout the perimeter of the site.<br><br>The Stormwater Management Plan (SMP) – W1P and SMP – Balance of Site describe the stormwater quality management devices that will be incorporated into the design to minimise the UHI effect throughout the site, include:<br>• Installation of a bio-retention systems, OSDs and GPTs<br>• On-site collection and re-use of stormwater and recycled water will be considered where reasonable and feasible and will be consistent with the Stormwater Management Plan. |
| | (ii) updated final architectural details required by condition A24; | Final Architectural details | Refer to comment above regarding Development Layout Plans (A22) |
| | (iii) UDLP required by condition B141; | UDLP | The UDLP incorporates the following in relation to minimising the UHI effect including:<br>• LED lighting<br>• Provision of translucent sheeting<br>• Installation of solar panels on roofs of warehouses for energy efficiency<br>• Use of light-coloured building materials and finishes<br>• Building walls to minimise large blank walls with light coloured materials and finishes<br>• Integration of WSUD elements including OSDs, GPTs and bio-retention systems |

| CoC | Requirement | Document Reference | How Addressed |
| --- | --- | --- | --- |
| | | | • Greens space including garden beds, planter boxes, canopy trees and other vegetation<br>• Perimeter screening to utilise advanced endemic shrubs and canopy trees to optimise shade provision from establishment. |
| | (iv) CEMP required by condition C1; and | CEMP | The Construction Environmental Management Plan (CEMP) will be implemented during the construction phase of the Project, including construction of warehouses, during which time UHI mitigation strategies will be constructed or installed in accordance with relevant design drawings and specifications. |
| | (v) OEMP required by condition C3. | OEMP | Details on the maintenance and operation of the UHI mitigation strategies that are adopted will be incorporated into the Operational Environmental Management Plan (OEMP). Specifically, into OEMP sections as follows:<br>• C3(d) – Identification of infrastructure, including UHI mitigation strategies<br>• C3(e) – Roles and responsibilities for maintenance of UHI mitigation strategies<br>• C3(g) – OEMP sub-plans, specifically:<br>- (iii) Stormwater Infrastructure Operation and Maintenance Plan<br>- (viii) Operational Flora and Fauna Management Plan. |

There are no Final Compilation of Mitigation Measures (FCMMs), Revised Statement of Conditions (RSoC) and Commonwealth Concept Approval Conditions (CCoA) related to this UHIMS.

# 3 UHI AND POTENTIAL MITIGATION STRATEGIES

## 3.1 UHI Effect

The UHI effect refers to the phenomena whereby urban regions typically experience warmer temperatures than their rural and natural surroundings. A contributing factor to the UHI effect is when buildings and hard surfaces absorb the sun's heat and then radiate it back into their surroundings.

This atmospheric influence results largely from modification of surface properties (for example replacing vegetated areas with paved surfaces) which leads to greater absorption of solar radiation, reduced convective cooling and lower water evaporation rates. Heat emissions associated with human activities also influence the net positive thermal balance that gives rise to the UHI. In general, human activities increase the quantity of thermal energy released to the atmosphere, while weather, urban and geographical features vary the intensity and distribution of this release. The main urban features that modify radiant heat levels relate to the change of nature and composition of surface materials within the built environment.

There are two broad types of UHI: atmospheric and surface UHIs. These two heat island types differ in the ways they are formed, the techniques used to identify and measure them, their impacts, and to some degree, the methods available to mitigate them (U.S. Environmental Protection Agency, 2008). Refer to Appendix A for further details on the types of UHI and UHI contributors.

The following sections outline strategies that are available to mitigate the UHI effect. The strategies discussed are those that are widely recognised as having a positive impact on the UHI effect and for which peer reviewed literature is available. Analysis of the appropriateness of adoption of these strategies within the industrial context is included in Section 3.3.

## 3.2 Potential Mitigation Strategies

### 3.2.1 WSUD and Stormwater Management

In dry climates, surface water can use the heat for evaporation, therefore reducing air temperatures. The cooling depends on the size of the surface water body, dry / humid climate and wind flow / direction (Osmond & Sharifi, 2017). It has been shown that the ambient air temperature within the vicinity of a water body can be reduced between 3 to 8°C when the relative humidity is less than 50% (Osmond & Sharifi, 2017). In areas with high humidity, surface water and other evaporative cooling strategies may have low or reverse effects on reducing temperatures nearby.

Surface water in urban areas could include designs such as constructed wetlands, ponds and water features (e.g. fountains).  Studies on surface water bodies (Coutts, Tapper, Beringer, & Loughnan, 2012) indicate areas near or downwind of surface water bodies have reduced air temperatures by around 1 to 2°C compared to surrounding areas. This results from the evaporation of the water body (Coutts, Tapper, Beringer, & Loughnan, 2012).

#### 3.2.1.1 WSUD

WSUD for the use of mitigation UHI effect is generally used to assist with irrigation for vegetation (i.e. green spaces), use of treatment wetlands (i.e. bio-retention) and open water bodies (discussed further below). Using WSUD methods can increase evapotranspiration and infiltration, resulting in reduced air temperatures (Coutts, Tapper, Beringer, & Loughnan, 2012).

Bio-retention systems, such as those that will be established for the Project, reduce stormwater runoff, by using vegetated basins or trenches with porous filtration media. Bio-retention systems have the ability to increase infiltration and evapotranspiration. However, additional research is required to fully understand the relationship between bio-retention systems and the UHI effect (Coutts, Tapper, Beringer, & Loughnan, 2012).

Infiltration systems reduce stormwater runoff without the use of vegetation. A porous pavement is an example of an infiltration system and can reduce surface temperatures and increase evaporation when compared to conventional pavement (refer to Section 3.2.5) (Coutts, Tapper, Beringer, & Loughnan, 2012). Other examples of bioretention and infiltration systems include raingardens, bio-swales and wetlands.

Green roofs are another commonly studied WSUD technology in the context of UHI mitigation (Coutts, Tapper, Beringer, & Loughnan, 2012) and is discussed in Section 3.2.3.4.

#### 3.2.1.2 Stormwater Management

Stormwater detention and on-site detention (OSDs) basins can provide a means of heat reduction through evaporative cooling and absorption and dispersal of heat throughout water bodies, which allows water bodies to maintain relatively stable temperatures throughout the diurnal cycle (Gunawardena, Wells, & Kershaw, 2017). The evaporative cooling effect of water bodies is experienced adjacent to the water body and downwind from the water body. Smaller, regularly shaped water bodies, distributed evenly within an area generate smaller temperature effects than a single larger body of a similar volume, but influence a larger area. The study concluded that several smaller regularly shaped water bodies have the most beneficial effect when it comes to lowering extreme temperatures during the day. The study also found that the cooling effect of water bodies occurs predominantly during the daytime and that water bodies may have a warming effect at night time (Theeuwes N. S., 2013).

Smaller, shallow OSD basins with a longer fetch have been shown to utilise the entire column of the water body to provide thermal capacity, while deeper basins are likely to experience stratification and therefore not utilise the available thermal capacity of the water body (Gunawardena, Wells, & Kershaw, 2017). It is noted that one limitation of shallow OSD basins as a cooling mechanism is that they require frequent inputs of water to maintain water within the basin and may be dry when evaporative cooling is most needed, for example, during a summer heat wave.

#### 3.2.1.3 Evaporative Spray Cooling

Evaporative spray cooling is the process of misting fans producing fine water droplets (<10 μm) through forced mixing between the airstream and water. Reduction of air temperature occurs when the fine water droplets absorb ambient heat from the atmosphere (Osmond & Sharifi, 2017). Air temperature within the immediate area can be reduced by 5 to 15°C depending on the weather conditions and humidity (Osmond & Sharifi, 2017).

Misting fans are a common method of evaporative spray cooling and are most effective when installed approximately 2.4 to 3 m above ground surface (Osmond & Sharifi, 2017). Harvested rainwater and grey water are unsuitable means of water supply for evaporative spray cooling as water has the potential to come in contact with people and must therefore meet the water quality guidelines for primary contact prescribed within the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (Australian and New Zealand Environment and Conservation Council, 2000) (ANZECC Guidelines).

### 3.2.2 Street Tree Planting

Vegetation provides reduced air temperatures through the shading and the process of evapotranspiration. Evapotranspiration is the cooling from water evaporation, which occurs when trees absorb water through their roots and emit the water back into the air. Evapotranspiration cools the air by using ambient heat to evaporate the water (U.S. Environmental Protection Agency, 2008). Evapotranspiration is more beneficial in dry climates than in wet climates, as humidity restricts the process of evaporative cooling (Hoverter, 2012).

Tree canopies intercept and dissipate the incoming solar radiation through reflection, absorption and transmittance. The obstruction of solar radiation from the street trees, results in a smaller SVF and a decrease in the UHI effect.  Approximately 10 to 30% of solar radiation reaches the area under the tree, while the remainder is absorbed by the plants' leafs for photosynthesis or reflected back into the environment (U.S. Environmental Protection Agency, 2008).The amount of shade provided by the tree canopy depends on the planting and high branching density, placement, number of canopy layers, canopy height, canopy ventilation, albedo and leaf size and structure. (Norton, et al., 2014) (Hunter Block, Livesley, & Williams, 2012).

The tree canopy can increase shading, cooling and energy saving benefits. Selection of tree species and placement of the trees relative to a building can influence the shading and cooling effect. Overall, the tree canopies should be placed near a building to create shade near the building wall and window. In warm climates, tree canopies are best placed to shade the roof and the north or western walls (Hunter Block,

Livesley, & Williams, 2012). The maximum effect of surface air temperature around street trees is around 4 to 15°C, and a maximum effect of precinct scale air temperature is 2°C (Osmond & Sharifi, 2017).

In addition, the effect of the tree canopy depends greatly on the surfaces underneath the tree canopy. If the canopy layer is above a region containing hot surfaces, than temperatures may increase. However, if the tree canopy is above areas of cool surfaces (i.e. shaded and wet soil), temperatures may be lowered (Kurn, Bretz, Huang, & Akbari, 1994).

An analysis conducted in 2013 by Coutts and Harris for street trees planted in Melbourne. The study found that canyons with a height to width ratio (H:W ratio) less than 0.8 were effective at reducing surface air temperatures. When the H:W ratio was above 0.8, the reduced air temperatures were not as significant (Norton, et al., 2014). As the H:W ratio increase, the sunlight levels decrease and wind flow increases (Norton, et al., 2014). Trees should also be planted at least 1.5 to 3 m away from the building to allow for ground, but shade trees should be planted no more than 9 to 15 m away (U.S. Environmental Protection Agency, 2008).

## 3.2.3 Landscaping Coverage and Screening

### 3.2.3.1 Urban Green Spaces

Urban greens spaces include grassed areas with reduced tree canopy. These spaces have the potential to reduce temperatures as compared to areas covered with pavement. Air temperatures are reduced in urban green spaces due to the process of evapotranspiration and the irrigation provided for the vegetation. When an urban green space has a relatively cool temperature, it is known as the park cool island effect. The park cool island effect depends on the amount and type of vegetation and irrigation used (Osmond & Sharifi, 2017). Cooling also occurs, when urban areas are located downwind of urban green spaces (Norton, et al., 2014).

The available studies have shown the following for urban green spaces:

- Parks were found to be 1 to 3°C cooler than the surrounding urban landscapes (Hunter Block, Livesley, & Williams, 2012)
- Temperatures over grass sports fields are 1 to 2°C cooler than over bordering areas (U.S. Environmental Protection Agency, 2008).

While urban green spaces have been shown to provide a cooling effect it is noted that, grassed areas also contribute to the UHI effect as they have been shown to contribute 12°C of heat to the air mass during the diurnal cycle within the Western Sydney context  (Samuels, 2017), when not shaded by canopy trees. Also, in areas with high humidity, surface water and other evaporative cooling strategies may have low or reverse effects on reducing temperatures nearby.

### 3.2.3.2 Green Facades

Traditional direct green facades feature woody or herbaceous climbing plants usually planted at the base of a wall. A review of studies on direct green facades (Hunter Block, Livesley, & Williams, 2012) found that all studies showed an improvement in the thermal performance of the building. The level of improvement varied depended on location, climate, direction and type/material of wall, type of vegetation and other factors. The reviewed studies measured a range of variables, making direct comparisons difficult. Cited studies described results including:

- Reduced summer daytime indoor air temperatures between 1 and 5°C
- Reductions in cooling energy demands between 7 and 28%.

More recently, 'double-skin' green facades or 'green curtains' consist of a support structure on which plants grow and provide an insulating layer of air between the vegetation and the building wall. A review of studies on 'double skin' green facades (Hunter Block, Livesley, & Williams, 2012) cited studies that showed the following temporal improvements:

- Higher ventilation rates were achieved
- Reduced daytime interior ambient temperature by 3.6°C, up to a maximum of 9.9°C

- Relative humidity in the intermediate space was 7% higher than that measured outside, demonstrating effects of evapotranspirative cooling
- Microclimates can be developed in the air cavity delivering:
  - Increased winter air temperatures 3.8°C higher, with lower relative humidity
  - Reduced summer air temperatures by 1.36°C, with higher relative humidity than the outside air.

### 3.2.3.3 Green Walls

Green walls may either by constructed from prefabricated, modular panels or planters containing a lightweight growing medium or from geotextile felts. The green walls provide additional thermal insulation and passive energy savings to the building. The green walls can also provide shading and increased evaporative cooling depending on the orientation of the plant density and water content of the green walls.

A review of the limited available studies on green walls (Hunter Block, Livesley, & Williams, 2012) (Osmond & Sharifi, 2017) indicates dramatic cooling potential including:

- Surface temperatures of a green wall and building wall were found to be around 5°C
- Maximum wall temperature was reduced by 16°C when modular panels that were pre-plated with Zoysia japonica were used
- Reduce building surface temperature between 5 and 15°C
- Mean annual air temperature was reduced by 2°C in spaces located immediately adjacent to the green walls.

### 3.2.3.4 Green Roofs

Green roofs reduce the UHI effect by shading heat absorbing materials, increasing albedo (when compared to dark, conventional roofs) and increasing evapotranspiration. There are two types of green roofs including:

- **Extensive green roofs** involve a thin layer of soil and vegetation with planted grasses, wildflowers and other native plants which require low maintenance
- **Intensive green roofs** require more structural support than extensive green roofs due to the large amounts of vegetation that can be planted (e.g. full grown trees) (Osmond & Sharifi, 2017).

The substrate and drainage layer of the green roof are important aspects in maintaining moisture levels and reducing air temperatures. The substrate affects the energy efficiency of a green roof due to the substrate's insulating properties. Studies have shown, that in hot, arid climates, a substrate layer of 500 to 1000 mm is required to prevent heat transfer to the building. However, a substrate depth of only 100 mm was required in Hong Kong (Hunter Block, Livesley, & Williams, 2012). More research is required in Australia to determine an optimum substrate depth; however, 150 mm would be required for vegetation to survive (Hunter Block, Livesley, & Williams, 2012).

Studies have shown a reduction of near surface day time temperature by 4°C when comparing a dark, conventional roof to a green roof (U.S. Environmental Protection Agency, 2008). Other studies have resulted in a surface temperature of a green roof to range from 33 to 48°C, in comparison to a dark conventional roof at 76°C (U.S. Environmental Protection Agency, 2008).

Irrigation is another major component of green roofs. The opportunity to use stormwater capture and grey water systems for irrigation may be integrated into the green roof design. Also, there is the potential for water retention in the drainage layer of the green roof to provide an increase in evapotranspiration (Hunter Block, Livesley, & Williams, 2012).

## 3.2.4 Building Materials

### 3.2.4.1 Cool Roofs

Cool roofs absorb less incoming solar radiation than conventional styled roofs, which reduces the air temperature and provides a cooling effect. The two categories of cool roofs are low sloped and steep-sloped roofs. In addition, there are different types of cool roof coatings, which include coatings and membranes. Coatings include liquid applied coatings which are applied to the roof and vary in different colours (i.e. white or pigmented). There are cool versions on a wide range of coloured coatings which can be applied to the roof, instead of using the 'coolest' colour, white (Global Cool Cities Alliance, 2012). Single-ply membranes are a pre-fabricated sheet that is applied in a single layer to a low sloped roof (U.S. Environmental Protection Agency, 2008).

Figure 3-1 shows relationship of surface temperature and solar reflectance when comparing different roofing material for steep sloped roof.

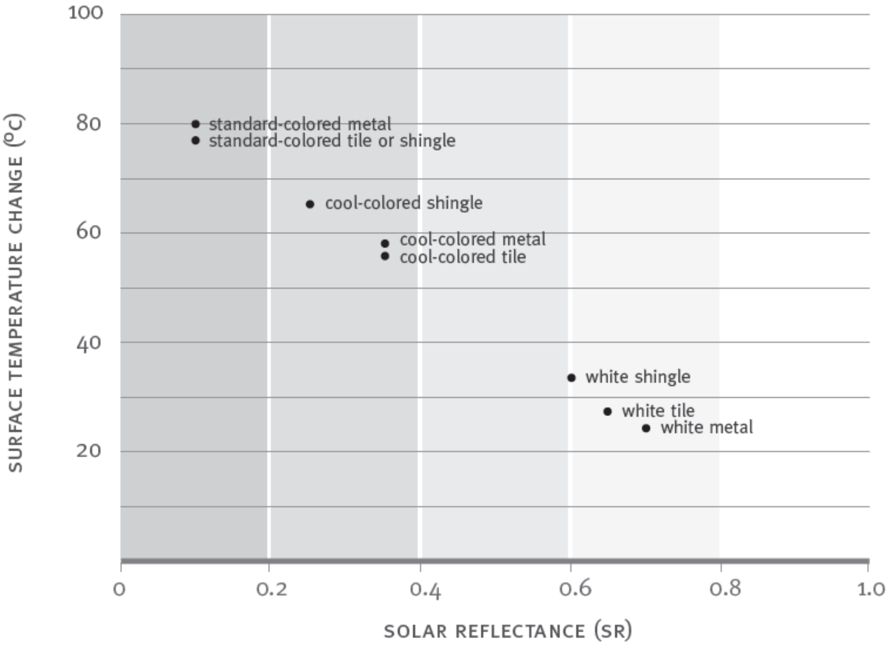



*Figure 3-1 Solar Reflectance of Common Roofing Materials (Global Cool Cities Alliance, 2012)*

Cool roofs work by using high albedo and high emissivity surfaces to reflect more than 65% of the incoming solar radiation (U.S. Environmental Protection Agency, 2008). Traditional roofing material with low albedo and emissivity properties (e.g. black asphalt roofs), absorb 85 to 95% of the incoming solar radiation instead of reflecting the energy aback into the atmosphere (U.S. Environmental Protection Agency, 2008).

A review of studies on cool roofs showed the following temporal improvements:

- Reduced surface temperatures up to 33°C, resulting in a reduced indoor temperature directly below the cool roof from between 1.2 to 4.7°C (Osmond & Sharifi, 2017)
- Reduced ceiling surface temperatures by about 2.6°C, with daily maximum room air temperatures dropped by 1.3°C (Osmond & Sharifi, 2017)
- Maximum coverage rate scenario (100%) (Salamanca, Georgescu, Mahalov, Moustaoui, & Martilli, 2016)
  - Reduced near-surface day time temperatures by 0.4 to 0.8°C
  - Reduced near surface night time temperatures by 0.1 to 0.4°C.
- Minimum coverage rate scenario (25 and 50%) (Salamanca, Georgescu, Mahalov, Moustaoui, & Martilli, 2016)
  - Reduced near-surface day time temperatures by 0.2 to 0.4°C
  - Reduced near surface night time temperatures by 0.1 to 0.3°C.

### 3.2.4.2 Photovoltaic Cells / Solar Panels

A cooling effect occurs as the energy from the solar panels absorbs energy which would have otherwise heated urban sources. This energy is used to generate electricity.

Photovoltaic (PV) cellsSolar panels contain an albedo of approximately 11 to 16% (Keetels). The change in temperature of using a PV solar panel roof system is caused by the changes in surface energy balance, i.e. heat energy that would have otherwise been re-radiated is transferred to power generation.

Studies have shown large-scale use of solar panels on roofs PV roof systems can mitigate the UHI effect. Salamanca et a. (2016) completed a study in two cities in the United States to determine the reduction of near surface temperatures with the use of solar panels (Salamanca, Georgescu, Mahalov, Moustaoui, & Martilli, 2016). The following was concluded:

- Maximum coverage rate scenario (100%) of PV cells
  - Reduced near-surface day time temperatures by 0.2 to 0.4°C
  - Reduced near surface night time temperatures by 0.4 to 0.8°C.
- Minimum coverage rate scenario (25 and 50%) of PV cells
  - Reduced near-surface day time temperatures by 0.1 to 0.3°C
  - Reduced near surface night time temperatures by 0 or 0.1 to 0.4°C.

A study in Sydney showed that cooling for solar panels with 30% efficiency, occurring over medium to high intensity urban areas, was around 0.3°C, reaching to 0.15 °C for low intensity urban areas in January. In July, the cooling was reduced to around 0.3°C. As the efficiency of solar panels increases (40 to 60%), cooling was increased, and can approach 1°C in January and July in medium to high intensity urban sources, and 0.4 to 0.5°C, over low intensity urban surfaces (Ma, Goldstein, Pitman, Haghdadi, & Macgill, 2017).

### 3.2.4.3 Cool Building Materials

In addition to roofs, other building materials can contribute significantly to the surface and air temperatures around a building. The use of cool building materials has the potential to conduct less heat into the interior of the building, thereby storing less heat. As such, using high albedo materials for the building exterior walls has the potential to reduce temperatures. The urban geometry of buildings is also a factor that should be considered when implementing cool building materials.

A review of available studies showed the following:

- External walls of an enclosure were painted black and were found to be 7°C warmer than a similar white painted enclosure during hours of maximum daylight, while the enclosures showed nearly the same temperature during the night time (Al-hafiza, 2017)
- Studies in Israel determined white-covered walls on small buildings were approximately 3°C cooler in summer when compared to grey-painted walls (Mansouri, Belarbi, & Bourbia, 2017)
- White electrometric coatings with a reflectivity of 0.72 could be as high as 45°C cooler than black coatings with a reflectivity of 0.08 (Mansouri, Belarbi, & Bourbia, 2017).

### 3.2.4.4 Shading Devices and Insulation

External shading devices (i.e. eaves, awnings, and verandahs) have the potential to improve the thermal performance of the building. The external shading devices restricts sunlight from reaching the external faces of the building, thereby reducing the heat absorbed into the walls (University of Melbourne, 2013).

Insulation also has the potential to improve the thermal performance of the building. Insulation prevents significant amount of heat transfer through the ceiling, walls and floor (University of Melbourne, 2013). There are a variety of insulation types including: bulk, reflective and foam insulation, which can be used in the ceilings, walls and under-floor.

## 3.2.5 Pavement Treatments

Cool pavements refer to paving materials which reflect more solar energy and increase water evaporation, resulting in reduced surface and air temperatures. Cool pavements include permeable pavement and high albedo pavement.

### 3.2.5.1 High Albedo Pavement

Conventional paving materials (e.g. concrete and asphalt) reflect solar radiation by only 5 to 40% and can reach temperatures of 50 to 65°C (U.S. Environmental Protection Agency, 2008). High albedo pavement is a technique used to increase the amount of solar radiation that is reflected rather than absorbed. High emissivity is also an important characteristic as high emissivity allows the pavement to give heat away more readily to the surrounding environment (U.S. Environmental Protection Agency, 2008).

Using lighter aggregates, pigments and binders in asphalt and concrete and lighter surface coatings, are effective methods to cool paved surfaces through increased albedo (Osmond & Sharifi, 2017). The most popular light-coloured pavement is Portland cement concrete (Hoverter, 2012). Types of high albedo pavements include:

- Resin-based concrete / asphalt
  - Uses clear tree resins in place of petroleum-based elements to bind aggregate.
- Chip seals
  - Aggregate bound in liquid asphalt
  - Used to resurface asphalt used for low traffic volumes.
- Whitetopping / Ultra-thin whitetopping
  - Layer of concrete (varied thickness) containing fibres
  - Used to resurface portions of road, parking lots and intersections.

A study was completed in an urban park in Athens, Greece, where a 4,500 $m^2$ area was paved with reflective material, comprising concrete blocks of light yellow colour (Santamouris, Giatani, Spanour, Saliari, & Gianopoulou, 2012). The findings of the study concluded:

- Reduced summer ambient temperature by 1.9 °C
- Surface temperature in the park was reduced by up to 12 °C.

The case study concluded the use of cool pavements is an efficient method to reduce the strength of heat island in urban areas (Santamouris, Giatani, Spanour, Saliari, & Gianopoulou, 2012). The US EPA has estimated that an increase in the surface albedo of paved areas by 20% would reduce air temperatures by approximately 0.6°C (U.S. Environmental Protection Agency, 2008; Pomerantz, 2000).

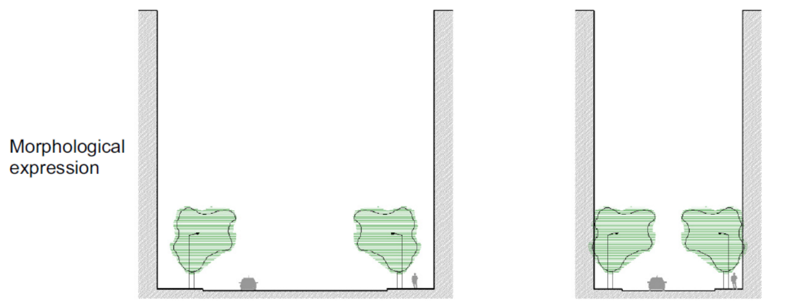
### 3.2.5.2 Permeable Pavement

Permeable pavements include voids in the surface for air, water and water vapour to pass through and allow evaporation to occur following infiltration. This type of pavement uses rubber or open-grade aggregate for asphalt, and foam or open-grade aggregate for concrete to provide more void spaces to drain water. The surface temperature is reduced as moisture is readily available for evaporative cooling ultimately drawing heat out of the pavement, depending on humidity levels (Osmond & Sharifi, 2017). Types of permeable pavements include (Osmond & Sharifi, 2017) (U.S. Environmental Protection Agency, 2008):

- Non-vegetated permeable pavement
  - Void in pavement to drain water through the surface into the sub-layers and ground below
  - Used in areas of lower traffic volumes
  - Examples: Porous asphalt, pervious concrete, brick/block pavers.
- Vegetated permeable pavement
  - Uses lattices to support grass (and other vegetation) to grow in the interstices
  - Used in areas of lower traffic volumes.

## 3.2.6 Urban Geometry

Several studies have been undertaken to assess the impact of urban geometry on the UHI effect. (Ruiz, 2015) analysed the UHI effect within the semi-arid city of Mendoza, Argentina, with an aim to identify the best configuration to minimise the UHI effect. Figure 3-2 shows the best and worst configurations for buildings with a height of 30 m; demonstrating that the difference in configuration has an impact on air temperatures of 3°C. As can be seen, the best cross section allows for 30 m between buildings, with street trees between the buildings. The building orientation has the ability to affect the wind direction and impact the effectiveness that the wind has on reducing the temperature in the area.




| | | | |
|---|---|---|---|
| MBH (m) | | 30 | |
| UCW (m) | 30 | | 16 |
| H/W | 1.00 | | 1.88 |
| Valb | 0.30 | | 0.96 |
| T/m (trees/m) | 0.23 | | 0.13 |
| Halb | 0.54 | | 0.22 |
| DTwall (ºC) | | 31 | |
| **DTair (ºC)** | **27.3** | | **31.8** |
| ΔDTair (ºC) | | **4.5** | |
| **NTair (ºC)** | **25.1** | | **28.1** |
| ΔNTair (ºC) | | **3.0** | |

*Figure 3-2 Best and Worst Cross-Section's Configuration in High Building Density According to Thermal Behaviour for Buildings with Walls Between 15 & 30 m in Height (Ruiz, 2015)*

## 3.2.7 Anthropogenic Heat

Anthropogenic heat is released as a result of human activities for the use of lighting, machinery use for heating and cooling (i.e. air conditioning) and transportation. Heat generated by human activities is trapped within the urban canopy layer and by the urban geometry of an area, which may prevent it from dissipation and lead to increased urban temperatures.

A review of a study completed on the effects of air temperature with the demand for air conditioning in an urban area (Salamanca, Georgescu, Mahalov, Moustaoui, & Wang, 2014) found the following:

- Increased night time temperature of 1 to 1.5°C when total floor area was air conditioned
- Increased night time temperature of 0.5 to 1°C when 65% of total floor area was air conditioned
- Increased night time temperature of 0.25 to 0.5°C when 35% of total floor area was air conditioned.

In addition to air conditioners, conventional vehicles have also been shown to emit heat. A study was conducted in Beijing, China, which showed electric vehicles emit only 19.8% of the total heat emitted by conventional vehicles per mile (Li, et al., 2015).

## 3.3 Advantages and Disadvantages of Potential UHI Mitigation Strategies

The advantages and disadvantages of potential UHI mitigation strategies vary depending on factors such as climate and land use. The potential UHI mitigation strategies will have variable effects if applied to an

industrial, residential, commercial or parkland context. Also, the effectiveness of the mitigation strategies vary depending on the climate of the area (i.e. hot, cold, humid or dry conditions).

For example, use of evaporative sprays to provide cooling is an effective strategy to reduce air temperatures for areas used regularly by the public as the cooling provided by these strategies is only experienced at a personal level, however, is not a reasonable strategy for an industrial or commercial site where outdoor thoroughfare would be low. In addition, if an area has high humidity compared to a drier climate, the rate of evapotranspiration is lowered and the effectiveness of mitigating the UHI effect is also reduced.

The following presents advantages and disadvantages of each of the UHI mitigation strategies within an industrial context while taking into consideration other aspects (e.g. maintenance requirements, other environmental benefits, costs, space requirements etc.). ESD principles and sustainability initiatives should also be considered during the analysis, as presented in CoC B142.

## 3.3.1 WSUD and Stormwater Management

### 3.3.1.1 WSUD

Table 4 below presents advantages and disadvantages for WSUD within an industrial context.

*Table 4 Advantages and Disadvantages – WSUD*

| Advantages | Disadvantages |
|---|---|
| Reduce energy use by lowering surrounding air temperatures, thereby reducing demand on cooling systems | Require additional maintenance |
| Improve air quality by up taking air pollutants and deposition of particulate matter | Less effective at UHI mitigation than green space strategies (Gunawardena, Wells, & Kershaw, 2017) |
| Reduce stormwater runoff due to increased infiltration, and increase in groundwater input | Increase in humidity levels leading to an increase in thermal discomfort |
| Depending on type of WSUD, can be aesthetically appealing to workers and public (i.e. bio-retention systems) | May provide a warming effect during night time and towards end of summer (Gunawardena, Wells, & Kershaw, 2017) |
| Vegetation used for infiltration and bio-retention systems provides habitat and increases biodiversity | - |
| Increase water quality | - |

On review of the advantages and disadvantages for the use of WSUD elements, adoption of these measures to mitigate the UHI effect and achieve water quality outcomes is considered appropriate within an industrial context. As such, WSUD elements will be analysed further as a Project specific mitigation strategy in this UHIMS.

### 3.3.1.2 Stormwater Management

Table 5 presents advantages and disadvantages for stormwater management, including OSD basins within an industrial context.

*Table 5 Advantages and Disadvantages – Stormwater Management*

| Advantages | Disadvantages |
|---|---|
| Mitigate flood impacts | Requires additional maintenance |

| Advantages | Disadvantages |
|---|---|
| Provide cooling effect for areas adjacent and downwind of stormwater management | Less effective than green space strategies (Gunawardena, Wells, & Kershaw, 2017) |
| Reduce energy use by lowering surrounding air temperatures, thereby reducing demand on cooling systems | Rain dependent to maintain effectiveness of cooling and may be dry when cooling is needed most |
| - | Increase in humidity levels leading to an increase in thermal discomfort |
| - | May provide a warming effect during night time and towards end of summer (Gunawardena, Wells, & Kershaw, 2017) |

On review of the advantages and disadvantages for the use of OSD structures for stormwater management, adoption of these measures to mitigate the UHI effect, collect stormwater runoff and achieve water quality outcomes is considered appropriate within the industrial context. As such, stormwater management will be analysed further as a Project specific mitigation strategy in this UHIMS.

#### 3.3.1.3 Evaporative Spray Cooling

Table 6 presents advantages and disadvantages for evaporative spray cooling within an industrial context.

*Table 6 Advantages and Disadvantages – Evaporative Spray Cooling*

| Advantages | Disadvantages |
|---|---|
| Aesthetically appealing to workers and public | Requires maintenance of misting fans |
| Reduce energy use by lowering surrounding air temperatures, thereby reducing demand on cooling systems | Less effective than green space strategies (Gunawardena, Wells, & Kershaw, 2017) |
| Improve comfort, health and sense of well-being for workers and public | Temporary effect only experienced by workers walking under / past the spray coolers |
| Provide workers opportunities for recreation and leisure | Requires treated water supply (harvested stormwater and grey water are unsuitable for this application unless treated) |
| - | Not suitable in areas where workers spend majority of their time (i.e. warehouses / work places) |
| - | Not cost effective for an industrial site |

On review of the advantages and disadvantages for the use of evaporative spray cooling, adoption of these measures to mitigate the UHI effect is considered inappropriate within an industrial context due to the intended recreational / leisure purpose of evaporative spray cooling. As such, evaporative spraying will not be analysed further as a Project specific mitigation strategy in this UHIMS.

## 3.3.2 Street Tree Planting

Table 7 presents advantages and disadvantages for street tree planting within an industrial context.

*Table 7 Advantages and Disadvantages – Street Tree Planting*

| Advantages | Disadvantages |
|---|---|
| Reduce energy use by lowering surrounding air temperatures, thereby reducing demand on cooling systems within the warehouses | Heat trapped in canopy boundary if improper ventilation (Norton, et al., 2014), thereby increasing the temperature |
| Provide shade to workers, public, pavements and buildings during the day time | Increase in humidity levels leading to an increase in thermal discomfort |
| Reduce air pollution and greenhouse gas emissions emitted | Loss of space |
| Improve air quality by up taking air pollutants and deposition of particulate matter | Increase in solid waste from weeding and pruning of vegetation |
| Increases property value | Possible damage to sidewalks, power lines and other nearby infrastructure |
| Improve comfort, health and sense of well-being for workers | Maintenance of street trees required (i.e. weeding, pruning and watering) |
| Provide workers opportunities for recreation and leisure | Increase in water demand for irrigation of vegetation |
| Reduce site stormwater runoff due to increased infiltration, thereby reducing flood impacts and increase groundwater input | - |
| Reduce pavement maintenance costs due to tree canopy providing protection to roads and footpaths located near the trees | - |
| Reduce noise for nearby sensitive receivers | - |
| Provide and improve habitat and biodiversity benefits | - |
| Greatest cooling effects during high UHI intensity and heatwaves (Gunawardena, Wells, & Kershaw, 2017) | - |

On review of the advantages and disadvantages for the use of street trees, planting of street trees and canopy trees as a measure to mitigate the UHI effect is considered appropriate within the landscaped areas of an industrial site. As such, street trees will be analysed further as a Project specific mitigation strategy in this UHIMS.

## 3.3.3 Landscaping Coverage and Screening

### 3.3.3.1 Urban Green Spaces

Table 8 presents advantages and disadvantages for urban green spaces within an industrial context.

*Table 8 Advantages and Disadvantages – Urban Green Spaces*

| Advantages | Disadvantages |
| --- | --- |
| Reduce energy use by lowering surrounding air temperatures, thereby reducing demand on cooling systems | Increase in humidity levels, thereby an increase in thermal discomfort |
| Provide shade to workers, public and nearby buildings during day time | Increase in water demand for irrigation of vegetation |
| Reduce air pollution and greenhouse gas emissions emitted | Increase in solid waste from pruning of vegetation |
| Improve air quality by up taking air pollutants and deposition of particulate matter | Potential damage to sidewalks and other nearby infrastructure due to vegetation root growth |
| Reduce noise for nearby sensitive receivers | Maintenance of urban green space required (i.e. mowing, pruning and watering) |
| Improve comfort, health and sense of well-being for workers and public | Loss of space |
| Provide workers opportunities for recreation and leisure | Expensive to install and maintain |
| Reduce site stormwater runoff due to increased infiltration, thereby reducing flood impacts and increase groundwater input | Relies on availability of water for irrigation |
| Reduce pavement maintenance costs due to tree canopy providing protection to roads and footpaths located near trees | - |
| Provide and improve habitat and biodiversity benefits | - |
| Greatest cooling effects during high UHI intensity and heatwaves (Gunawardena, Wells, & Kershaw, 2017) | - |

On review of the advantages and disadvantages for the use of green spaces, adoption of these measures to mitigate the UHI effect is considered appropriate within the defined landscaped areas of an industrial site, including the employee outdoor meal break areas. As such, green spaces will be analysed further as a Project specific mitigation strategy in this UHIMS.

### 3.3.3.2 Green Facades

Table 9 presents advantages and disadvantages for green facades within an industrial context.

*Table 9 Advantages and Disadvantages – Green Facades*

| Advantages | Disadvantages |
|---|---|
| Reduce energy use by lowering surrounding air temperatures, thereby reducing demand on cooling systems | Expensive to install and maintain |
| Provides shade canyon surfaces | Increase in solid waste from pruning and weeding of vegetation |
| Aesthetic appealing to workers and public | Increase in water demand for irrigation of vegetation |
| Opportunity to use captured stormwater for irrigation of vegetation | Maintenance required (i.e. weeding, pruning and watering) |
| Provide and improve natural habitat | Increase in humidity levels, thereby an increase in thermal discomfort |
| Reduce air pollution and greenhouse gas emissions emitted | - |
| Improve comfort, health and sense of well-being for workers and public | - |
| Greatest cooling effects during high UHI intensity and heatwaves (Gunawardena, Wells, & Kershaw, 2017) | - |

On review of the advantages and disadvantages for the use of green facades, adoption of these measures to mitigate the UHI effect is considered inappropriate within an industrial context and will not be analysed further in this UHIMS.

### 3.3.3.3 Green Walls

Table 10 presents advantages and disadvantages for green walls within an industrial context.

*Table 10 Advantages and Disadvantages – Green Walls*

| Advantages | Disadvantages |
|---|---|
| Reduce energy use by lowering surrounding air temperatures, thereby reducing demand on cooling systems | Expensive to install and maintain (i.e. not cost effective for an industrial site context) |
| Provides shade canyon surfaces | Increase water demand for irrigation of vegetation |
| Aesthetic appealing to workers and public | Increase in solid waste from pruning and weeding of vegetation |
| Opportunity to use captured stormwater for irrigation of vegetation | Maintenance required (i.e. weeding, pruning and watering) |
| Provide and improve natural habitat | Increase in humidity levels, thereby an increase in thermal discomfort |

| Advantages | Disadvantages |
|---|---|
| Reduce air pollution and greenhouse gas emissions emitted | - |
| Improve comfort, health and sense of well-being for workers and public | - |
| Greatest cooling effects during high UHI intensity and heatwaves (Gunawardena, Wells, & Kershaw, 2017) | - |

On review of the advantages and disadvantages for the use of green walls, adoption of these measures to mitigate the UHI effect is considered inappropriate due to the overall purpose of an industrial site and the high maintenance requirements. As such, green walls will not be analysed further as a Project specific mitigation strategy in this UHIMS.

#### 3.3.3.4 Green Roofs

Table 11 presents advantages and disadvantages for green roofs within an industrial context.

*Table 11 Advantages and Disadvantages – Green Roofs*

| Advantages | Disadvantages |
|---|---|
| Reduce energy use by lowering surrounding air temperatures, thereby reducing demand on cooling systems | Maintenance required for watering, fertilising and weeding (U.S. Environmental Protection Agency, 2008):<br>– Extensive: low water requirements, low maintenance<br>– Intensive: requires irrigation, higher maintenance. |
| Reduce total air pollution and greenhouse gas emissions emitted | Increase of water supply for irrigation of vegetation |
| Improve air quality by up taking air pollutants and deposition of particulate matter | Fire risk due to potentially dry vegetation |
| Opportunity to use as recreational space for workers | Increase in solid waste from weeding and pruning of vegetation |
| Improve comfort, health and sense of well-being for workers and public | Higher upfront costs than conventional roof |
| Improve stormwater management by reducing stormwater run-off and improving water quality | Structural components of warehouse design may not support added weight of green roof |
| Noise reduction for nearby sensitive receivers | Relies on availability of water for irrigation |
| Provide and improve natural habitat | Conflicts with the sustainability initiatives and ESD principles for solar power generation as green roofs and solar panels cannot be combined |
| Opportunity to use captured stormwater and grey water for irrigation of vegetation | - |
| Aesthetically appealing to workers and public | - |
| Longer life spans than conventional roofs | - |

| Advantages | Disadvantages |
|---|---|
| Greatest cooling effects during high UHI intensity and heatwaves (Gunawardena, Wells, & Kershaw, 2017) | - |

On review of the advantages and disadvantages for the use of green roofs, adoption of these measures to mitigate the UHI effect is considered inappropriate within an industrial context as the use would conflict with the sustainability initiatives and ESD principles to include solar power generation (i.e. solar panels) on the warehouse roofs. As such, green roofs will not be analysed further as a Project specific mitigation strategy in this UHIMS.

## 3.3.4 Building Materials

### 3.3.4.1 Cool Roofs

Table 12 presents advantages and disadvantages for cool roofs within an industrial context.

*Table 12 Advantages and Disadvantages – Cool Roofs*

| Advantages | Disadvantages |
|---|---|
| Reduce energy use by lowering surrounding air temperatures, thereby reducing demand on cooling systems | Maintenance of high albedo surface over time |
| Longer life spans than conventional roofs | Increase glare to workers and public |
| Reduce material and labour costs over time due to extended life of cool roof compared to traditional roof | - |
| Efficient in hot and sunny climates | - |
| Improve human health and comfort for workers and public | - |
| Provides a synergistic effect when combined with the use of solar panels | - |

On review of the advantages and disadvantages for the use of cool roofs, adoption of these measures to mitigate the UHI effect is considered appropriate within an industrial context due to the potential for a large surface area of roofs and the possibility to combine the use of cool roofs with solar panels. As such, cool roofs will be analysed further as a Project specific mitigation strategy in this UHIMS.

### 3.3.4.2 Solar Panels

Table 13 presents advantages and disadvantages for solar panels within an industrial context.

*Table 13 Advantages and Disadvantages – Solar Panels*

| Advantages | Disadvantages |
|---|---|
| Reduce energy use by lowering surrounding air temperature, thereby reducing demand on cooling systems | Higher upfront costs than traditional roof |
| Reduce total air pollution and greenhouse gas emissions emitted | Maintenance of solar panels |
| Improve health and comfort for workers and public | Require large amounts of space for installation |

| Advantages | Disadvantages |
| --- | --- |
| Generate electricity which can be used for electricity | Potential to increase glare to workers and public |
| Reduce dependence on fossil fuel consumption | - |
| Incorporates sustainability initiatives and ESD principles | - |

On review of the advantages and disadvantages for the use of solar panels, adoption of these measures to mitigate the UHI was considered in conjunction with sustainability initiatives and ESD principles. Use of solar panels is considered appropriate due to the potential of large surface areas of the roofs. Solar panels in addition, provide an opportunity for an industrial site to generate its own electricity. As such, solar panels will be analysed further as a Project specific mitigation strategy in this UHIMS.

#### 3.3.4.3 Cool Building Materials

Table 14 presents advantages and disadvantages for cool building materials within an industrial context.

*Table 14 Advantages and Disadvantages – Cool Building Materials*

| Advantages | Disadvantages |
| --- | --- |
| Reduce energy use by lowering surrounding air temperatures, thereby reducing demand on cooling systems | Relies on urban geometry (i.e. distance between buildings and surrounding area land uses) |
| Efficient in hot and sunny climates | Maintenance of high albedo surface over time |
| Improved health and comfort to workers and public when used in public areas | Increase glare of building material to workers and public |
| Does not depend on water supply | - |
| Does not require additional space to implement | - |

On review of the advantages and disadvantages for the use of cool building materials, adoption of these measures to mitigate the UHI effect is considered appropriate within an industrial context due to the potential of a large number and size of buildings at the site, and will be analysed further as a Project specific mitigation strategy in this UHIMS.

### 3.3.5 Pavement Treatments

#### 3.3.5.1 High Albedo Pavement

Table 15 presents advantages and disadvantages for high albedo pavement within an industrial context.

*Table 15 Advantages and Disadvantages – High Albedo Pavement*

| Advantages | Disadvantages |
| --- | --- |
| Reduce energy use by lowering surrounding air temperature, thereby reducing demand on cooling systems | Increase glare of pavement to workers and public |
| Lower temperature of stormwater runoff, thereby improving stormwater runoff quality | Albedo may decrease over time due to soiling from traffic |

| Advantages | Disadvantages |
|---|---|
| Increase pavement life due to decreased heat stress and may be less likely to rut | Higher upfront costs than conventional pavement types |
| Increase visibility of road and footpaths at night time | Cement (with a higher albedo) has a higher embodied energy content than asphalt |
| Opportunity to be combined with permeable pavement | Maintenance of high albedo surface over time |
| Improve health and comfort for workers and public | - |

On review of the advantages and disadvantages for the use of high albedo pavement, adoption of these measures to mitigate the UHI effect is considered appropriate within the industrial context due to the potential of large surface areas of pavement and the high potential for temperature reduction.

### 3.3.5.2 Permeable Pavement

Table 16 presents advantages and disadvantages for permeable pavement within an industrial context.

*Table 16 Advantages and Disadvantages – Permeable Pavement*

| Advantages | Disadvantages |
|---|---|
| Reduce energy use by lowering surrounding air temperatures, thereby reducing demand on cooling systems | Relies on water supply to provide cooling benefits |
| Reduce noise to sensitive receivers by increasing street porosity | Higher upfront costs than conventional pavement types |
| Reduce site stormwater runoff due to increased infiltration, thereby reducing flood impacts and increase groundwater input | Most permeable pavements are not suitable for use in high truck / heavy vehicle or machinery traffic areas and can only support light traffic loads |
| Opportunity to be combined with lighter coloured paving material | Maintenance required to prevent clogging of sediment and pollutants, thereby decreasing effectiveness of permeability |
| Increase pavement life of roads and footpaths | - |
| Increase safety of workers and public due to improved drainage and increased traction | - |
| Improve health and comfort for workers and public | - |
| Reduce glare of pavement to workers and public | - |
| Aesthetically appealing to workers and public accessing the area | - |
| Lower temperature of stormwater runoff, thereby improving stormwater runoff quality | - |

On review of the advantages and disadvantages for the use of permeable pavement, adoption of these measures to mitigate the UHI effect is considered inappropriate within an industrial context to the unsuitability of permeable pavement in high traffic areas and areas with high heavy vehicle use. As such, permeable pavements will be analysed further as a Project specific mitigation strategy for areas of low traffic volume only.

# 4 PROJECT REVIEW

In accordance with CoC B139(a), a review of the development details for the entire Project is outlined below, as provided in the RtS design plan. The review describes the approved Project, as per the RtS design plan and considers the potential UHI effect on each aspect of the development. Recommendations are described to mitigate the potential UHI effect from the Project, including those already captured within the Project design and planning, and those recommended for inclusion in future design stages.

As discussed above, the Project is aiming to demonstrate best practice design through the implementation of Green Star for the warehouses and other sustainability considerations (i.e. reduced embodied energy). In determining the appropriateness of the potential UHI effect, consideration was given to the objectives and targets of the Project as a whole, including those for sustainability, Green Star initiatives and operability of the overall Project design. It is important that the overall Project considers all these targets and objectives when providing recommendations for the Project. The following were considered when developing the recommendations for the Project:

- UHI effectiveness
- Industrial context of the Project
- Project sustainability commitments (i.e. ISCA, Green Star and ESD principles)
- Consistency with the approved Project design.

## 4.1 Site Context

The MPE site, including the Project site, is located approximately 27 km south-west of the Sydney Central Business District (CBD) and approximately 26 km west of Port Botany. The MPE site is situated within the Liverpool Local Government Area (LGA), in Sydney's south west sub-region, approximately 2.5 km from the Liverpool City Centre. The MPE site is located approximately 800 m south of the intersection of Moorebank Avenue and the M5 Motorway. The regional context of the Project is shown on Figure 4-1**.**

The Project site is located approximately 2.5 km south of the Liverpool City Centre, 800 m south of the Moorebank Avenue/M5 Motorway interchange and one kilometre to the east of the Southern Sydney Freight Line providing convenient access to and from the site for rail freight (via a dedicated freight rail line) and for trucks via the Sydney Motorway Network. The local context of the Project is shown on Figure 4-2**.**

For further detail on the regional and local environmental values of the Project, refer to Section 2 of the UDLP.

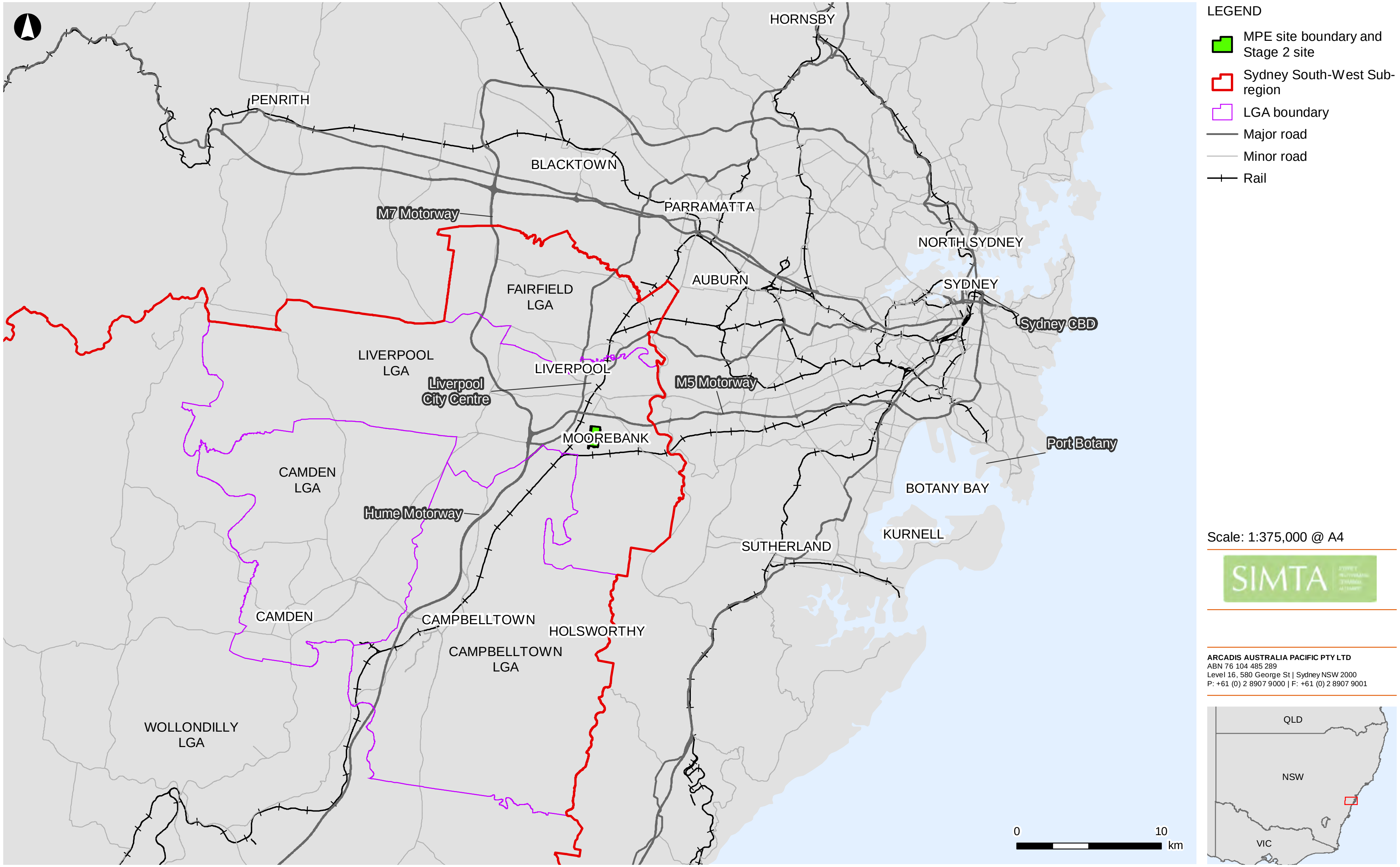



Figure 4-1: Regional Context of the Project

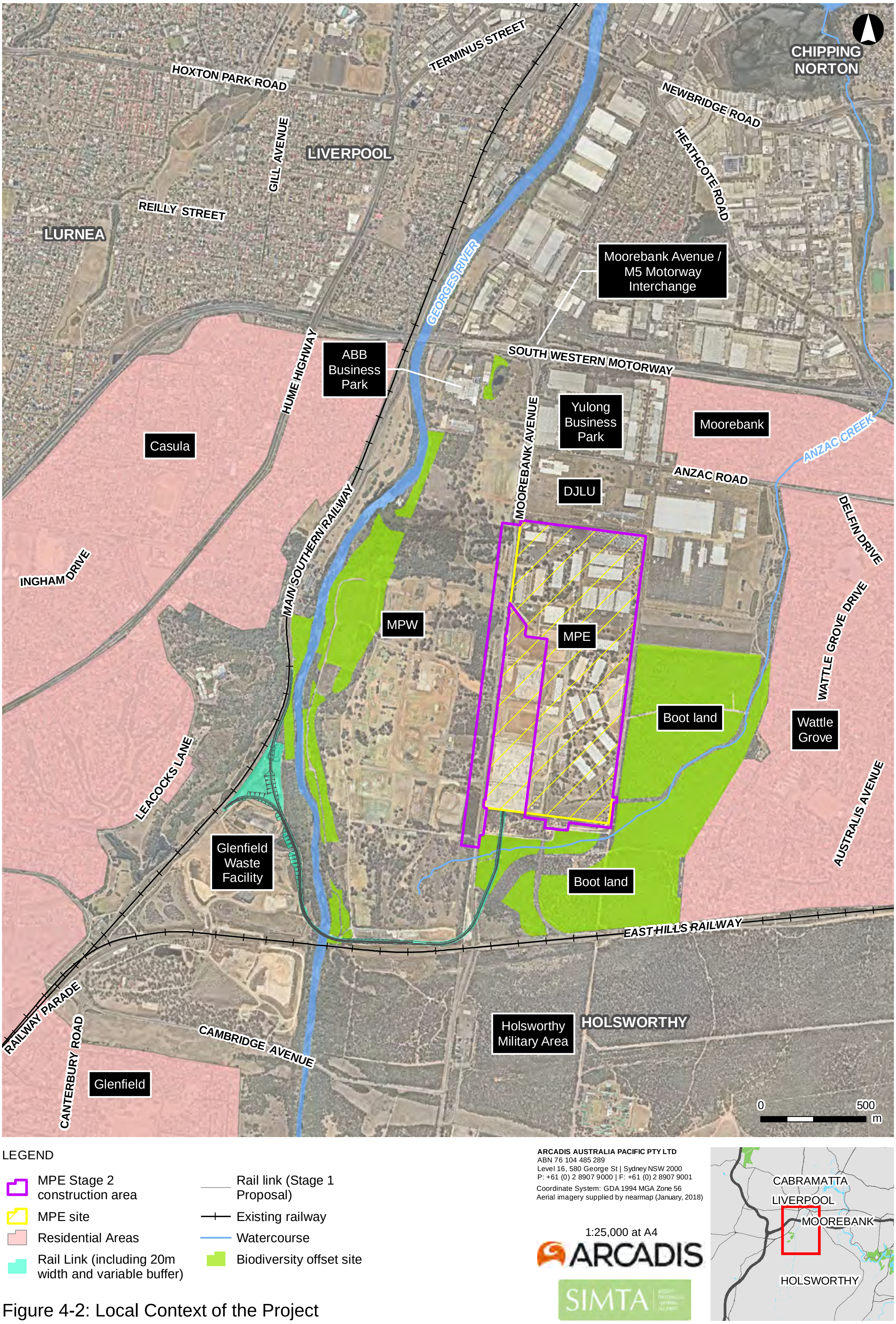



Figure 4-2: Local Context of the Project

**Surrounding Land Uses**

The majority of land surrounding the Project site is owned and operated by the Commonwealth and comprises:

- The MPW site, formerly the School of Military Engineering (SME), on the western side of Moorebank Avenue directly adjacent to the Project site (subject to the MPW Concept Plan Approval)
- The Holsworthy Military Reserve, to the south of the Project site on the southern side of the East Hills Rail Corridor, which is owned and operated by Sydney Trains
- Residual Commonwealth Land (known as the Boot Land), to the east of the Project site between the Project site boundary and the Wattle Grove residential area
- Glenfield Waste Services, southwest of the Project is proposing to develop a Materials Recycling Facility on land owned by the Glenfield Waste Services Group within the boundary of the current landfill site at Glenfield.

The area immediately south of the Project site, known as the Southern Boot Land, includes an existing rail spur within heavily vegetated remnant bushland. The Southern Boot Land includes a range of vegetation, varying from remnant bushland to the north-east of the Sydney Trains East Hills Rail Corridor. This area and two other areas to the west of the Project site will be protected as biodiversity offset areas for the Moorebank Precinct and provide a vegetated buffer between the Project and adjacent residential areas.

A number of residential suburbs are located in proximity to the Project site including:

- Wattle Grove – 360 m to the northeast
- Moorebank – 1300 m to the north
- Casula – 820 m to the west
- Glenfield – 1830 m to the southwest.

The closest industrial precinct to the Project is at Moorebank, comprising approximately 200 ha of industrial development. This area includes (but is not limited to) nine neighbouring industrial sites such as the Yulong and ABB sites to the south of the M5 Motorway and the Goodman M5 Business Park and miscellaneous industrial and commercial development to the north of the M5 Motorway (Figure 4-1 and Figure 6-2). The majority of this development is located to the north of the M5 Motorway between Newbridge Road, the Georges River and Anzac Creek. The Moorebank Industrial Area supports a range of industrial and commercial uses, including freight and logistics, heavy and light manufacturing, offices and business park developments.

**Site Drainage**

The topography of the Project site is relatively flat, with reduced levels (RL) ranging between 14 and 16 m Australian Height Datum (AHD). Along the eastern boundary of the Project site, the land rises from about RL14 m AHD at each end to a localised peak of RL22 m AHD about midway along the length.

There are three internal catchments within the Project site and a number of small external catchments that discharge into the Project site. There are three existing stormwater culvert outlets from the Project site. Two outlets discharge eastward to Anzac Creek and cross under the Greenhills Road formation via pipes and headwalls. Stormwater to these two culvert outlets is conveyed through the site via formal open grass lined channels, while from Greenhills Road to Anzac Creek the channels appear less formalised.

On the western portion of the Project site, water from both the Project site and the eastern side of Moorebank Avenue is collected in a formal concrete lined channel which runs within the site parallel to Moorebank Avenue. These channel flows discharge via a culvert under Moorebank Avenue into a channel which leads to Georges River.

**Climate and Prevailing Winds**

Monthly mean temperatures range between 5°C to 18°C, with monthly mean maximum temperatures of 17°C to 28°C. The highest temperatures are typically experienced during the summer months, while the lowest are generally experienced between May and September. According to the Australian Government, Bureau of Meteorology (BOM), the annual mean humidity levels for the Liverpool areas at 9am and 3pm are between 51 and 72% (Australian Government Bureau of Meteorlogy, 2018).

Historical data recorded at Bankstown Airport since 1968 indicates the region is characterised by moderate rainfall, with a mean annual rainfall of 870mm, and an annual rainfall range between 493 and 1,398mm.

There is typically significant variation in monthly rainfall within the area, with the wettest periods usually during the summer and autumn months.

An annual wind rose of recorded wind speed and direction data from the Office of Environment and Heritage's (OEH) Liverpool station during 2013 is shown in Figure 4-3. The annual recorded wind pattern is dominated by the southwest to westerly airflow.

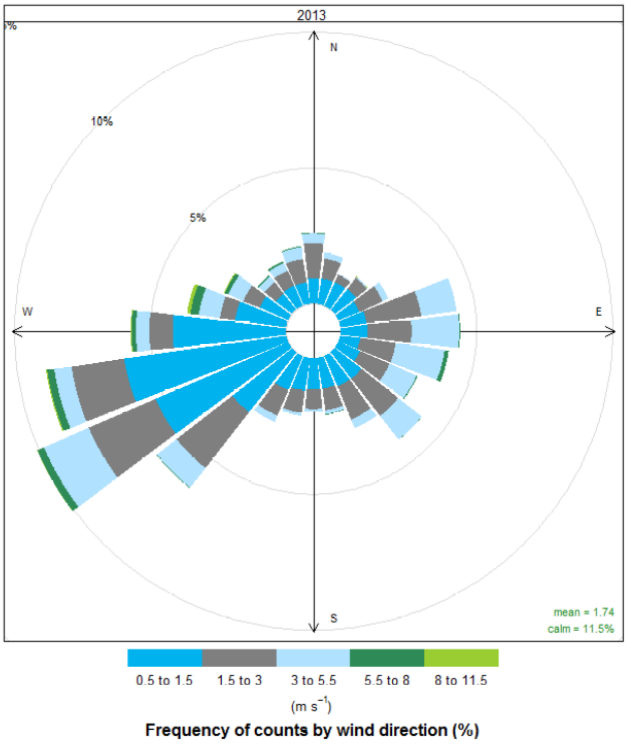



*Figure 4-3 Annual Wind Rose for 2013 – OEH Site at Liverpool (Rambol Environ Australia Pty Ltd, 2016)*

### 4.1.1 Potential and Recommended Mitigation Factors

As described above, the adjacent sites south and east of the Project site is the Southern Boot Land, which includes heavily vegetated remnant bushland. The Project site is also adjacent to two water bodies, Georges River and Anzac Creek. Prevailing winds across the Project site are from the southwest and will provide cool air from within the surrounding vegetated areas and water bodies. As such, the surrounding vegetation land and water bodies play a significant role in minimising the UHI effect experienced on the Project site.

Table 17 includes the mitigating factors for minimising the UHI effect which are incorporated into the design already with respect to the site context. No recommendations to the Project design are proposed in response to UHI effect and the surrounding land uses and site context.

*Table 17 UHI Mitigation Aspects – Site Context*

| Mitigating Factors Already Incorporated in Design | Mitigation Recommendations |
|---|---|
| Vegetation immediately south and east of the Project site | - |
| Water bodies located to the south and west of the Project site | - |
| Prevailing winds from the south-west to provide cool air from the surrounding vegetated land and water bodies | - |

## 4.2 Building Layout

Setbacks being integrated to promote the formation of landscaped areas enables environmentally sustainable measures and streetscape elements to achieve a satisfactory and attractive outcome from the view of the public domain, acting to break down bulk and scale. The appropriate building setbacks also contribute to and enhance the ability for the estate roads to self-cross-ventilate to lessen the solar absorbance of the pavement areas as well as reducing spans of heat retentive material, such as pavements or hardstands.

The key building elements of the Project include the warehouses, freight village, internal site roads and Moorebank Avenue. The Project provides up to 300,000 $m^2$ of warehousing across the Project site, with a total of eight warehouses. The warehouses will be up to 21 m in height and be oriented northeast to southwest. The warehouse building spaces are approximately 40 to 110 m in the north to south direction and 20 to 70 m in the east to west direction. The buildings in the freight village will be between one and four stories in height.

Refer to Development Layout Plans in Appendix H1 of the UDLP for the GFA of each warehouse, as well as building setbacks allowing for cross ventilation.

### 4.2.1 Potential and Recommended Mitigation Factors

Warehouse buildings within the Project site are generally orientated north to south, while the annual recorded wind pattern is in the southwest to westerly direction. As such, the orientation of the warehouse buildings is considered poor for encouraging the flow of the prevailing winds through the Project site. As noted above, the warehouse buildings are spaced between 40 and 110 m apart in the north to south direction and 20  to 70 m in the east to west direction; and generally conform to the best cross section identified in *"Suitable configurations for forested urban canyons to mitigate the UHI in the city of Mendoza, Argentina"* (Ruiz, 2015). Refer to the Development Layout Plans in the Appendix H1 of the UDLP for the distances between each warehouse allowing for cross ventilation.

However, while the orientation of the warehouse buildings is poor for encouraging the flow of the prevailing winds, the spacing between the warehouses is generally greater than the 'very wide' canyon category prescribed in (Norton, et al., 2014). The 'very wide' canyon of the warehouse buildings permits wind movement across the paved areas which facilitates heat transfer. As such, the impact of the warehouse orientation on prevailing winds is therefore considered to be low.

The layout of the Project site has been approved (SSD 7628) and changes to the geometry of the Project site are not proposed or considered necessary to mitigate potential UHI effects. Table 18 outlines the mitigating factors already incorporated into the Project design that have the potential to minimise the UHI effect experienced at the Project site.

*Table 18 UHI Mitigation Aspects – Building Layout*

| Mitigating Factors Already Incorporated in Design | Mitigation Recommendations |
|---|---|
| Warehouses are generally greater than the 'very wide' canyon category, permitting wind movement across the Project site | - |
| Warehouses setbacks allow for cross-ventilation | - |

## 4.3 Architectural Details

Architectural details include a variety of aspects such as building layout, building materials and finishes, and building features. The follow sections outline principles of architectural design that can be implemented to help mitigate the UHI effect. Generally, adoption of considered urban design principles should, when combined, amount to substantial reductions to contributory factors relating to this environmental issue. This information is not intended to be prescriptive or constraining, particularly with concern to range of materials suggested or formation of building envelopes.

Urban design principles can be incorporated into all facets of proposed buildings within the estate where practical and possible. Through this, the development can integrate with and improve the existing site character to form a high performance and quality development.

Materials that are recycled or considered of high environmental sustainability standard will be encouraged to be used where practical and possible. The selection of building materials and colours for the Project site will be appropriate for intended use according to the land use and development initiatives. An indicative colour and material palette introduced in RtS provides an assortment of values that contribute to achieving the Project's objectives, including the mitigation of the UHI effect. Materials of high albedo will be encouraged to be used in the development of the warehouses. Refer to Appendix B for a list of building properties.

Refer to Section 3.2 of the UDLP and the Architectural Details in Appendix H1 of the UDLP for further information on the architectural details of the Project.

### 4.3.1 Potential and Recommended Mitigation Factors

Table 19 below outlines the mitigating factors already incorporated into the Project design that have the potential to minimise the UHI effect and mitigation recommendations.

*Table 19 UHI Mitigation Aspects – Architectural Design*

| Mitigating Factors Already Incorporated in Design | Mitigation Recommendations |
|---|---|
| Incorporate colour and material palette introduced in the RtS | All warehouses on the Project site should be designed to meet a minimum of 4 star rating for design and as-built under the Green Star accreditation system |

## 4.4 Landscaping Provision

The use of local and endemic species will provide habitat capable of supporting native fauna as well as providing adequate understory to help support habitat values and integration with the surrounding vegetation areas. Planting will incorporate a range of local species that have been selected for their unique forms, colours and textures. The soil used for landscaping purposes will be low in phosphorous content as required by native plant varieties to promote optimum growing conditions. Further detail of the soil depths, soil horizons and irrigation method is provided in Section 4.1 of the UDLP and Appendix A3 – Typical Garden Depth of the UDLP.

The landscape of the main site entrance from Moorebank Avenue will include features to enhance the arrival experience of the public through the use of native plants. The trees planted at the front entrance will provide shade for the public who are entering the Project site. Vegetation will include a range of local species that have been selected for their unique forms, colours and textures.

The landscaped setback along the Moorebank Avenue frontage provides a visual screen to the Project site from the roadway while reinforcing the identity of the area with the use of local plantings. The vegetation will be native tree species and will provide a dense tree canopy and lower screen planting.

Landscaping along the northern, western and southern boundaries will visually connect the Project site with the greater landscape and provide a biological connection. All planting will be informal, with groups of trees, shrubs and swathes of groundcovers. Landscaping will consist of mixed tree planting used to create a natural feeling through landscape zones and mixed under-storey planting consisting of native shrubs and ground covers to form a virtually impenetrable visual barrier and shading when mature.

Refer to the Landscape Drawings in Appendix A3 and Appendix G of the UDLP for further detail on the soil depth, canopy, and provision of landscaping at ground level, soft landscaping, and linkages for workers to landscaped areas throughout the site throughout the site. Refer to Section 3.1 and 4.1 of the UDLP for specific details on landscaping and green space for the Project.

### 4.4.1 Potential and Recommended Mitigation Factors

The approved Project incorporates landscaped areas throughout the Project footprint and has a minimum of 15% of the Project site landscaped at ground level as a requirement of the CoCs, 10% of which must include soft landscaping. The landscaped areas have the potential to reduce temperatures as compared to areas covered with pavement, through evapotranspiration and evaporation of water used for irrigation, when establishing vegetation.

Table 20 below, outlines the landscaping aspects of the Project that have the potential to mitigate the UHI effect as well as those which are recommended for the detailed design.

*Table 20 UHI Mitigation Aspects – Landscaping Provision*

| Mitigating Factors Already Incorporated in Design | Mitigation Recommendations |
|---|---|
| Minimum of 15% of the site to be landscaped at ground level | Preference should be given to provision of green space within the outdoor meal break areas and breakout areas |
| 10% of the Project site to be soft landscaping | Preference should be given to drought tolerant species |
| Perimeter site screening using shrubs and trees | - |

## 4.5 Shading Provision

Street tree planting has been designed to create tree canopy cover throughout the Project site to provide shade. A mix of large native canopy trees will be planted throughout the car parking areas and pedestrian pathways to provide shade, therefore reducing the UHI effect.

Section 3.1 and 4.1 of the UDLP provides detail of the landscaping throughout the site. Appendix A3 in the UDLP provides shadow diagrams which have been developed demonstrating winter and summer shadows from buildings and vegetation in 5 years and 15 years' time at 3pm in comparison to the location of car parking spaces.

### 4.5.1 Potential and Recommended Mitigation Factors

The use of street trees in the Project site is for visual amenity and to provide shade for the workers accessing the Project site. Street trees have the potential to reduce air temperatures through shading and the process of evapotranspiration, depending on the humidity. As stated in above, street trees will be planted throughout the Project site, specifically in the car parking areas.

Table 21 below, outlines the UHI mitigation aspects for landscaping at the Project site which have already been incorporated in the Project design and those that are recommended for the detailed design.

*Table 21 UHI Mitigation Aspects – Shading Provision*

| Mitigating Factors Already Incorporated in Design | Mitigation Recommendations |
|---|---|
| Inclusion of canopy trees at a minimum rate of one per 30 $m^2$ of landscaped area | Use of advanced shrubs and canopy trees within car parking areas for shade, as deemed appropriate by Landscape Architects. |
| Incorporation of landscaping within car parking | - |
| For car parking that directly adjoins landscaping, canopy trees that overhang car parking would be integrated into that landscaping area | - |
| Planting of all street trees throughout the Project site, once mature, will provide significant shading to the area | - |

## 4.6 Landscape Irrigation

Minimal irrigation will be required at the Project site, due to the incorporation of native vegetation which require less water than non-native species. Minimal irrigation at the Project site will both improve the visual amenity of the Project site and reduce site demand for water.

Nonetheless, a low-volume drip irrigation system will be installed to support establishment and maintenance of proposed site landscaping. The position of a control box, solenoids and irrigation conduits will be designed by qualified irrigation engineers and is discussed in detail within Section 4.1 of the UDLP.

Water reuse will be implemented on the Project site through rainwater harvesting at each warehouse in accordance with CoC B40 and B142. Concept options for rainwater capture and reuse were considered within the Stormwater Management Plan as required by CoC B40.

Refer to Section 4.1 of the UDLP for details relating to the irrigation used at the site. Appendix A3 of the UDLP provides a typical garden depth figure outlining the different soil horizons and depths, and further detail on irrigation. In addition, Appendix A3 of the UDLP provides detail of the canopy tree shading, approximate width of tree canopies and species selection.

The Landscape Vegetation Management Sub Plan (LVMSP) also provides site-specific information concerning the maintenance and monitoring of landscaping at the site.

### 4.6.1 Potential and Recommended Mitigation Factors

Landscaping for the Project has been designed to minimise the demand for water on the Project site in order to create and maintain a drought resilient landscape. As such, use of irrigation for the purposes of UHI mitigation on the Project site is not deemed appropriate. Landscaped areas will contribute to UHI reduction through evapotranspiration (depending on humidity), without the need for the installation of additional climate resilient water supplies.

## 4.7 WSUD and Stormwater Management

OSDs will be constructed throughout the Project site for operational purposes. The Stormwater Management Plan outlines the strategy for stormwater management, which includes the development of OSDs. OSDs have been designed to have minimal longitudinal grade on the base and multiple inflow locations along the length of the OSDs, resulting in low flow velocities (i.e. the OSDs have been designed to convey waters at a low velocity over a wide, flat area). The OSD outlets are to be freely discharging up to the 100 year average recurrence interval (ARI) event and water will not be stored in the basins for prolonged periods of time. The extended detention depth is approximately 300 mm and it is not anticipated that water above this depth will be held within the OSDs for longer than a few hours.

To address potential impacts on stormwater quality, WSUD principles and a treatment train approach have been applied. Two key treatment measures are proposed for the Project to meet the performance targets are:

- Gross pollutant traps
- Raingardens (including bioretention systems).

WSUD measures for the Project include the provision of bioretention systems (raingardens) comprising a combination of vegetation and filter substrate within the OSDs. The bioretention systems will be placed in the base of each OSD to maximise the catchment area draining to the bioretention systems. The bioretention systems provide treatment of stormwater through the processes of settling, filtration and biological uptake and are very effective in the removal of fine sediments and nutrients. Unlike conventional raingardens, by incorporating multiple inlets over large flat areas within the OSDs the risk of flows short circuiting within the raingarden to the outlet is significantly reduced thereby maximising the amount of stormwater treated by the bioretention systems.

In addition to these treatment measures, rainwater harvesting and reuse will also be implemented for each warehouse in accordance with CoC B40 and B142.

For further site-specific details on WSUD elements and stormwater management, refer to Section 3.2.3 of the UDLP and WSUD Plans in Appendix H2 of the UDLP.

### 4.7.1 Potential and Recommended Mitigation Factors

The WSUD design for the Project utilises OSD basins, gross pollutant traps, bioretention and rain garden systems to achieve treatment of stormwater to meet the Project operational stormwater requirements and will have a positive impact on reducing the UHI effect. The WSUD design has the potential to provide a cooling effect through increasing evapotranspiration and infiltration of stormwater, and through the use of vegetation.

Table 22, outlines the UHI mitigation aspects for WSUD and stormwater management at the Project site which have already been incorporated in the Project design. No additional mitigation recommendations are proposed for the detailed design of the Project.

*Table 22 UHI Mitigation Aspects – WSUD and Stormwater Management*

| Mitigating Factors Already Incorporated in Design | Mitigation Recommendations |
|---|---|
| Bio-retention / rain garden systems with the use of vegetation | - |
| Gross pollutant (GPTs) will be located on all major stormwater drainage lines from non-roof areas prior to flows discharging into the OSD | - |
| Large underground OSD tank with topsoil and vegetation on top of the lid | - |

## 4.8 Building Material Specifications

The following are design principles for the building materials and colours:

- Prominent building facades fronting public interface areas and main internal roads will consist of a specified building materials and colours
- Colour selections follow a development colour palette, with adaptation to tenant corporate colours where specified to highlight entries or building focal points
- Building materials will generally reflect the robustness of industrial and business park developments
- High quality materials will be used at building entry or focal points
- Materials that are recycled or considered of high environmental sustainability standard are encouraged to be used where practical and possible.

The buildings and structures at the Project site will be of a high design quality. The building colours and finishes will be compatible and blend with the surrounding landscaping, including non-reflective colours. An indicative colour palette for buildings and structures, as presented in the RtS, is included in Table 23. Refer to Appendix B for a list of building properties.

*Table 23 Project Site Building Materials*

| Infrastructure | Item | Indicative Materials | Indicative Colour Palette |
|---|---|---|---|
| Warehouse | Roof | Metal or translucent sheeting | • Shale Grey<br>• Light Grey<br>• Windspray<br>• Dark Grey<br>• Highlights of:<br>– Yellow<br>– Dark Green<br>– Mid Green<br>– Light Green |
| | Structural posts | Steel | |
| | Wall | Cladding | |
| | Feature wall | Precast panel | |

| Infrastructure | Item | Indicative Materials | Indicative Colour Palette |
|---|---|---|---|
| Freight village | Roof | Metal, translucent sheeting or fritted glass | • Light Grey<br>• Mouse Grey<br>• Mid-tone Grey<br>• Windspray<br>• Dark Grey<br>• Highlights of:<br>– Red<br>– Light Grey<br>– Mid Grey<br>– Dark Grey |
| | Windows | Aluminium framed glazing<br>Metal framed louvres | |
| | Features | Colour backed glass | |
| | Structural posts | Steel | |
| | Walls | Aluminium composite panels | |
| | Footing walls | Concrete | |

Refer to Section 3.2.1 of the UDLP and Development Layout Plans in Appendix H1 of the UDLP for site specific details on cool building materials used at the site.

### 4.8.1 Potential and Recommended Mitigation Factors

An indicative colour and material palette introduced in the RtS provides an assortment of values that contribute to achieving the Project's objectives, including the mitigation of the UHI effect. While dark colours are included in the colour palette, the use of light coloured materials are also incorporated. For example, shale grey (WC1) which is classified as 'light' and is therefore used as the primary colour of cladding on the warehouse to minimise solar absorption.

Solar panels have been included as a mitigation recommendation for building materials, as this UHI mitigation strategy should be combined with cool roofs to maximise their efficiency and minimise the UHI effect. Solar panels work to provide cooling as energy from the solar panels absorb energy which would have otherwise heated the nearby urban environment.

The design principles for building materials and colours, as presented in the RtS should generally be maintained; however, the following recommendations in Table 24 should be adopted during development of the detailed design.

*Table 24 UHI Mitigation Aspects – Building Materials*

| Mitigating Factors Already Incorporated in Design | Mitigation Recommendations |
|---|---|
| Buildings and structures will be of a high design quality | Incorporate the use of high albedo materials for the building exterior walls, where glare to the public will not be an issue |
| Design principles for building materials and colours will generally be maintained, including the incorporation of light coloured materials | Select roofing materials with high albedos and high emissivity properties, such as white roof coatings |
| - | Incorporate the use of solar panels for provision of energy to warehouses, offices and the freight village |

## 4.9 Pavement Specifications

No information is provided in the EIS or RtS about pavement types for the Project site. The type of pavement material for the Project site will progress as part of the detailed design for the Project. In terms of the design requirements for the pavements, the pavement type will need to be hard wearing with a design life of approximately 40 years.

### 4.9.1 Potential and Recommended Mitigation Factors

High albedo pavement increases the amount of solar radiation that is reflected rather than absorbed by the pavement, while pervious pavement has the potential to increase evapotranspiration resulting in a cooling effect. The use of conventional paving material will have the potential to increase the UHI effect of the Project site. Table 25 includes recommendations to be implemented during the detailed design to mitigate this potential effect.

*Table 25 UHI Mitigation Aspects – Pavement Specifications*

| Mitigating Factors Already Incorporated in Design | Mitigation Recommendations |
| --- | --- |
| - | Use of high albedo pavements, such as white-topping of asphalt or concrete, for high traffic areas |
| - | Use of permeable pavements for low traffic areas, such as pedestrian footpaths |

## 4.10 Anthropogenic Heat

Anthropogenic heat released as a result of human activities at the Project site includes the use of lighting, HVAC requirements and engine types used for machinery (i.e. combustible and electric). The RtS and EIS provides minimal information on these activities which may potentially produce anthropogenic heat. However, the Project is aiming to demonstrate best practice design through the implementation of Green Star for the warehouses and other sustainability considerations (i.e. reduced embodied energy), which will influence the amount of anthropogenic heat released into the atmosphere from the Project.

Refer to Section 3.2.1 and Development Layout Plans in Appendix H1 of the UDLP for details on the building details. The Lighting Sub Plan (LSP) also details information on the lighting used throughout the Project.

### 4.10.1 Potential and Recommended Mitigation Factors

The heat generated by human activities can become trapped within urban areas, leading to increased temperatures. However, there are a number of initiatives within the CEFC agreement that relate to the sustainability performance of the Project which would reduce the Project's overall energy demand. The reduction of the Project's energy demand would reduce the HVAC requirements, resulting in a reduction in temperature as discussed in Section 3.2.7.

The following mitigation recommendations in Table 26 should be incorporated into the design and operation of the Project.

*Table 26 UHI Mitigation Recommendations – Anthropogenic Heat*

| Mitigating Factors Already Incorporated in Design | Mitigation Recommendations |
| --- | --- |
| LED lighting, opposed to incandescent light bulbs | All warehouses should be designed to meet a minimum of 4 star rating for design and as-built under the Green Star accreditation system |
| - | Achieve a minimum ISCA energy and carbon monitoring and reduction credit rating of Level 1 |
| - | Selection of operational machinery should preference machinery with electric engines over combustible engines |

# 5 SUMMARY OF MITIGATION FACTORS

The approved Project is a SSD for the purpose of warehousing and freight logistics, with the purpose of supporting the operation and use of the MPE Intermodal Terminal (as approved under SSD 6766). In assessing the applicability of UHI mitigation strategies, consideration has been given to those measures that would minimise heat effects and promote cooling of the Project site at a level appropriate to an industrial development, while meeting the Project operational requirements and maintaining consistency with the approved Project.

## 5.1 Mitigating Factors Incorporated in the Design

The mitigating factors already incorporated into the design of the Project, and promote a cooling effect at the Project site include the following:

- **WSUD:** The WSUD design for the Project utilises bioretention and rain garden systems to achieve treatment of stormwater to meet the Project operational stormwater requirements.
- **OSDs:** Multiple, free draining and elongated OSDs are incorporated into the design to maximise the potential for cooling effects and collect stormwater runoff at the Project site.
- **Landscaping:** The following design strategies are incorporated into the landscape plans, in accordance with the Project approval:
    - Inclusion of canopy trees at a minimum rate of one per 30 $m^2$ of landscaped area
    - Provision of landscape bays within car parking areas at a rate of a 2.5 m wide bay every 6 to 8 parking bays (or equivalent)
    - Use of advanced shrubs and canopy trees within car parking areas for screening of warehouses and to provide shade, as deemed appropriate by Landscape Architects.
- **Green space:** The Project incorporates landscaped areas throughout the Project site and has a minimum of 15% of the site landscaped at ground level as a requirement of the CoCs, 10% of which must include soft landscaping.
- **Minimisation of heat generation from operations**: The use of LED lighting throughout the Project has been considered to minimise heat generation across the Project site.

## 5.2 Mitigation Recommendations

The following UHI mitigation recommendations proposed for the Project site will be considered during the detailed design:

- **Additional landscaping and green space:** Preference should be given to provision of green space within the outdoor meal break areas and breakout areas
- **Cool roofs**: Detailed design of buildings should select roofing materials with high albedo and high emissivity properties, such as white roof coatings
- **Solar panels**: Detailed design of buildings should incorporate the use of solar panels for provision of energy to warehouses, offices and the freight village. Solar panels should be used in conjunction with cool roofs to maximise their efficiency and minimise the UHI effect
- **Cool building materials**: Detailed design of buildings should incorporate the use of high albedo materials for the building exterior walls, where glare to the public will not be an issue
- **Pavement types**: Detailed design of pavements should consider the use of high albedo pavements, such as white-topping of asphalt, throughout the Project site for high traffic areas. For areas of low traffic (i.e. pedestrian footpaths and parking lots), permeable pavement types should be considered
- **Minimisation of heat generation from operations**: The following considerations should be incorporated into the detailed design and operation of the Project:
    - All warehouses on the Project site should be designed to meet a minimum of 4 star rating for design and as-built under the Green Star accreditation system. Meeting this requirement will decrease the demand for heating and cooling of the warehouses

- Project should achieve a minimum ISCA energy and carbon monitoring and reduction credit rating of Level 1Selection of operational machinery for the Project site should preference machinery with electric engines over combustible engines.

## 5.3 Selection of Appropriate UHI Mitigation Strategies

The detailed design of each warehouse and structural element of the Project should take into consideration the recommendations listed above. When determining the appropriate mitigation strategies to be adopted for each Project site element the following should also be taken into account:

- **UHI effect:** Certain mitigation strategies are more effective at maximising the cooling effect than others when considering the industrial context of the Project
- **Cost:** The full life cycle cost of the selected mitigation strategy should be analysed within the context of the Project, including costs for the on-going maintenance. Cost savings, resulting from reduced energy demand and increase durability / product life span should also be analysed.
- **Sustainability commitments:** The commitments within the CEFC sustainability agreement should be considered and the sustainability credentials of materials and resources associated with implementation of the mitigation strategies should be taken into account (e.g. embodied energy).
- **Synergies between mitigation strategies:** Opportunities for synergies between mitigation strategies should be investigated. For example, the placement of WSUD measures within OSD basins and the combination of cool roofs and solar panels, to maximise the positive impacts of the strategies adopted. Deleterious impacts between strategies should also be considered, for example increased glare from highly reflective pavements and buildings materials (e.g. walls) may impact on the amenity of site users.

## 5.4 Analysis of Project Mitigation Strategies

Table 27 identifies the mitigation strategies that have been demonstrated to have the most significant measurable effect at reducing the UHI effect for the Project. The mitigation strategies are separated into those that are already incorporated into the design and those that are recommended to be adopted across the Project site, Table 27 also presents the anticipated day time temperature reduction anticipated through the adoption of the Project mitigation strategies, where such information was found within published and peer reviewed literature. It is noted that for some of the Project UHI mitigation strategies, reliable information on daytime temperature reduction was not available and these strategies have not been included within the design strategy presented in Table 27.

Other strategies that may be adopted on the Project site to reduce temperatures include shading devices, awnings and insulation, however have not been included in Table 27 due to availability of information. In particular, limited studies and information are available on the cooling effect in relation to human activities producing anthropogenic heat. As such, anthropogenic heat has not been evaluated within this design strategy for reducing the UHI effect for the Project. The mitigation strategies will be adopted as appropriate, to minimise anthropogenic heat. Reduction in anthropogenic heat will further improve the effectiveness of the mitigation strategies in the design strategy described below in Table 27.

*Table 27 Summary of UHI Strategies*

| Strategy | Where it is / or where it would be Implemented on the Project Site | Anticipated Day Time Temperature Reduction in Canopy Layer (°C) | % of Site Affected (RtS Design Plan) | Reference(s) | Comments |
|---|---|---|---|---|---|
| **Mitigation Factors Incorporated in Design** | | | | | |
| WSUD and Stormwater Management | • Bioretention systems (i.e. raingardens)<br>• Stormwater detention systems<br>• OSD basins | 1.0 – 2.0*<br>1.4** | 3.6 to 3.7 % | (Coutts, Tapper, Beringer, & Loughnan, 2012)<br>(Theeuwes N. S., 2013) | Water provided from WSUD for vegetation irrigation, reduces air temperatures through increased evapotranspiration, depending on humidity. In addition, the water bodies provide evaporative cooling, and absorption, depending on humidity.<br>The OSDs on the Project site have been designed to drain freely up to the 100 year ARI event and will not store water for prolonged periods of time. Cooling benefits from the OSDs will only be experienced while there is water within the structures; however it is not deemed appropriate to prolong stormwater detention times on the Project site sue to safety considerations. |
| Street Trees | • Landscaping | 2.0 | 7% | (Osmond & Sharifi, 2017) | Increasing the amount of street trees in the public areas and car parks will provide shade, thereby reducing the exposure of surfaces to solar radiation. Solar energy is also used through the use of photosynthesis and evapotranspiration, resulting in a cooling effect experienced at the Project site. |
| Urban Greenspace | • Landscaping | 1.5 | 10% | (Osmond & Sharifi, 2017) | Increasing turf can achieve a cooling effect through evapotranspiration, but is dependent on water for irrigation and does not provide shade for the public.<br>Combination of street trees and turf can reduce air temperatures by approximately 1.5 °C depending on the green space's extent and proportion of trees. |

| Strategy | Where it is / or where it would be Implemented on the Project Site | Anticipated Day Time Temperature Reduction in Canopy Layer (°C) | % of Site Affected (RtS Design Plan) | Reference(s) | Comments |
|---|---|---|---|---|---|
| **Mitigation Factors Recommended for Inclusion in Detailed Design** | | | | | |
| Cool roofs | • Warehouse roofs | 0.4 – 0.8*** | 40% | (Salamanca, Georgescu, Mahalov, Moustaoui, & Martilli, 2016)<br>(Osmond & Sharifi, 2017) | Use of high albedo material can radiation up to 75% of solar radiation reaching the surface. Combining cool roofs with solar panels would maximise the cooling effect experienced at the Project site. |
| Solar panels on roofs | • Warehouse roofs | 0.2 – 0.4*** | 20%<br>(Approx. 50% of warehouse roofs could utilise solar panels) | (Salamanca, Georgescu, Mahalov, Moustaoui, & Martilli, 2016)<br>(Osmond & Sharifi, 2017) | Solar panels can be integrated with cool roofsto generate energy for the Project site and reduce the temperatures experienced at the Project site. Utilising solar panels with a covered white roof reduces total sensible flux by up to 50%. |
| Pavement types (e.g. high albedo and permeable pavement) | • Pavement for internal roads, car parks and footpaths | 0.6**** | 14% - bitumen<br>24% - concrete | (Santamouris, Giatani, Spanour, Saliari, & Gianopoulou, 2012; Pomerantz, 2000) | Increasing the pavement reflectance by 20% can be achieved by applying a coating layer to asphalt with a high albedo. This approach would minimise the embedded energy of pavements on the Project site while allowing for an increase in albedo. |

Notes:
* Downwind and adjacent to water bodies
** Based on small, regularly shaped and distributed water bodies with a water temperature of 15°C
*** Based on maximum cover rate scenario
**** Based on an increase in pavement albedo of approximately 20%

# 6 SITE ANALYSIS AND COMPARISON

The following sections of the UHIMS provide a site analysis and comparison for the Project and neighbouring industrial sites for the mitigation of the UHI effect. The goal of the site analysis and comparison is to achieve a 4°C decrease in temperature compared to neighbouring industrial developments through the implementation of design choices that have been shown to provide measurable differences in temperature. The site analysis and comparison draws upon the literature research discussed in Section 3.2 and Appendix A, where studies have been conducted to demonstrate the heat reduction potential for specific mitigation strategies, and a review of heat generation from neighbouring industrial developments.

The following steps were undertaken to assess the likely performance of the Project site, with and without the adoption of the Project mitigation strategies, in terms of the UHI effect:

- The study *Where should all the trees go? Investigating the impact of tree canopy cover on socioeconomic status and wellbeing in LGA's* (Amati, 2017) was reviewed to identify the UHI effect experienced on neighbouring industrial developments and sites
- An analysis was undertaken of percentage breakdown of surface area features of the neighbouring industrial sites that were considered likely to contribute to, or mitigate, the UHI effect on those sites
- A comparison of the surface area features of the Project site with those of neighbouring industrial sites was undertaken to determine the likely performance of the Project site in terms of the UHI effect, without the implementation of the Project mitigation strategies, when compared to the adjacent sites
- The predicted temperature reductions associated with the Project mitigation strategies, where such temperature reductions have been quantified in peer reviewed literature, were reviewed along with the percentage site coverage for each of the strategies to determine whether the goal of 4°C is likely to be achieved through the implementation of the strategies.

The analysis concludes that adoption of the UHI mitigation strategies for the Project, in line with the design strategy presented within this section of the UHIMS, should achieve a 4°C decrease in temperature compared to neighbouring industrial developments.

## 6.1 Neighbouring Site UHI Effect Analysis

It should be noted, that understanding of UHI originated in temperate arable environments such as the United Kingdom and the United States of America, and caution should be used when using the information from these climates within the Australian context. For example, it is not generally appropriate within the semi-arid Australian context to compare urban areas with arable land as in the middle of the summer, grazed arable land in dry areas is often hotter in the morning than urban areas because it is unshaded. Earth or sand takes less time to heat up than materials associated with urban areas such as concrete or asphalt, which may lead to an underestimation of the UHI effect in semi-arid Australian cities (Amati, 2017). This differs from the European and United States of American experience where arable land remains cooler than adjacent urban areas during the day.

For this reason, an Australian UHI mapping study, undertaken as part of the broader study titled *Where should all the trees go? Investigating the impact of tree canopy cover on socioeconomic status and wellbeing in LGA's* (Amati, 2017) has been used to inform the analysis of the existing UHI effect in neighbouring industrial areas to the Project site.

### 6.1.1 Urban Heat Mapping – Amati et al, 2017

Mapping of the UHI effect within they Sydney area was undertaken in 2017 by (Amati, 2017). Land surface temperature (LST) estimates were calculated from the Landsat 8 satellite thermal infrared data and atmospheric parameterization, suing data from the BOM and an estimate of land surface emissivity (LSE). Estimation of LSE required Landsat 8 surface reflectance data (specifically bands 4 and 5) and data was sourced from the Australian Reflectance Grid 25 (ARG25) (Geoscience Australia, 2015). The final LST was calculated using measurements of top of atmosphere radiance, at sensor temperature and provided constants.

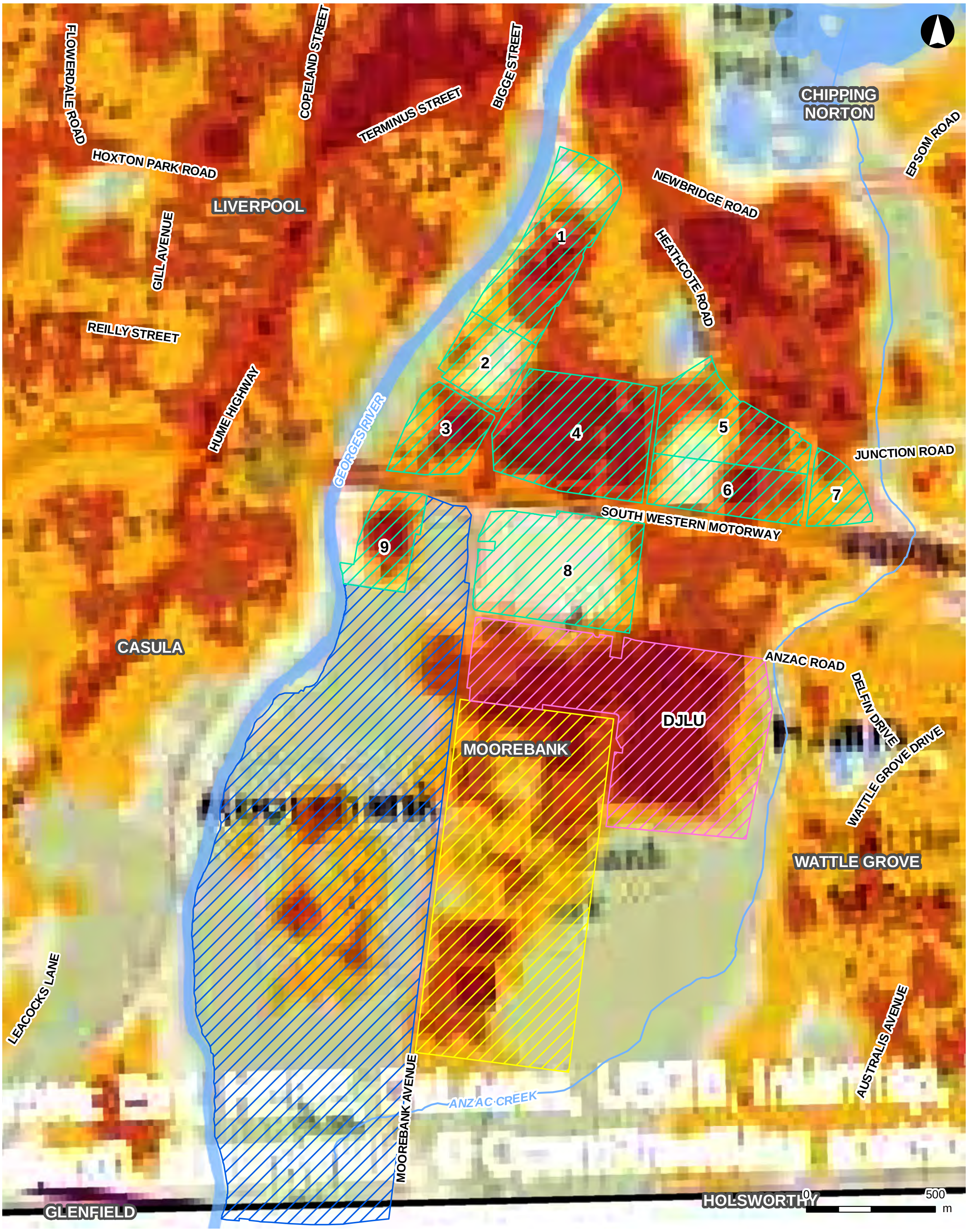
The individual LST images for each area assessed were joined together into a single LST image covering the extent of the project's targeted area. Where multiple LST images overlapped, the images were averaged to produce a central value that was more representative of seasonal temperature rather than the temperature of any particular day.

To calculate the UHI effect, a modelled estimate of the LST in the absence of urbanization was subtracted from the actual LST. For this project, a temperature gradient was fitted to forested areas within the areas analysed, while excluding forest boundaries, areas with high slope and areas with elevation that considerably differed to the urban area under consideration. This gradient is a first order correction that captures broad temperature trends independent of urbanization, such as those attributable to changes in latitude, elevation or distance from the coast. After subtracting this from the LST, the residuals are finer scale, localised temperature variations, some of which are attributable to urbanization (Amati, 2017). Figure 5-1 shows the UHI effect as mapped by (Amati, 2017) for the Fairfield and Liverpool area.

The UHI effect mapping identified a number of key features that are commonly associated with UHI 'hot spots', being:

- Impact of large areas of infrastructure, including certain roofs of warehouses: the mapping shoes that these areas generally generate hot spots that are more than 13°C hotter than equivalent native vegetation and have an impact on surroundings.
- Native bushland: mapping shows that areas of green and blue space, such as native bushland and river corridors provide a cooling effect.

Figure 6-1identifies the boundaries of the neighbouring industrial areas to the Project site. As can be seen, a number of these areas were identified as hot spots, with a mapped temperature of 13°C above the equivalent native areas of vegetation. Two of the neighbouring industrial sites, Sites 2 and 8, have a minimal contribution to the UHI effect, with no measurable increase to land surface temperatures above natural vegetation. The DJLU site, located immediately to the north of the Project site, is also mapped as having a temperature of 13°C above the equivalent native areas of vegetation. Section 6.1.2 provides an analysis of the land surface types within the neighbouring industrial areas, as well as and the DJLU site to understand the potential contributors to the UHI effect for these areas.




LEGEND

- Neighbouring industrial site
- DJLU site
- MPW Site
- MPE Site
- Watercourse

Degrees above native bushland

- 9.1 - 11.2
- 11.2 - 13.3
- Over 13.3

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Coordinate System: GDA 1994 MGA Zone 56
Source: Amati et at. 2017[NK1]

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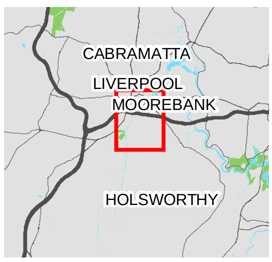


Figure 6-1: Urban Heat Island Effect: Fairfield NSW as Mapped by Amatic et al. 2017

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Created by : RM
QA by : RB

### 6.1.2 Analysis of Neighbouring Industrial Areas Surface Area Features

An analysis was undertaken of the percentage breakdown of surface area cover of the neighbouring industrial areas to the Project site as well as DJLU to identify surface area features that may contribute to the UHI effect within those areas. High resolution imagery and LiDAR elevation data was used to digitise the surface area features into the following categories:

- **Building**: Building areas / roof tops
- **Bitumen**: Roads and car park areas
- **Concrete**: Built up areas excluding buildings with a higher surface albedo
- **Landscape**: Green spaces and soil, excluding tree canopy cover
- **Tree cover**: Tree canopy cover.

Nine industrial sites were identified within the vicinity of the Project site, which have been identified by their cadastral lot boundaries. The Defence Joint Logistics Unit (DJLU), identified as defence land is located to the north of the Project site.

The surface area feature percentage of each site and total are given below in Table 28. The digitised surface area features for each site are shown in Figure 6-2. Sites 2 and 8, which were analysed as having a low contribution to the UHI effect are highlighted grey within Table 28. No water features were observed on the neighbouring industrial sites.

*Table 28 Surface Area Feature Percentage for Neighbouring Industrial Sites*

| Site | Building | Pavement | | Green Cover | |
|---|---|---|---|---|---|
| | | Bitumen | Concrete | Landscape | Tree Cover |
| 1 | 44.3 | 16.5 | 22.1 | 8.9 | 8.2 |
| 2 | 58.5 | 4.9 | 27.2 | 3.1 | 6.3 |
| 3 | 41.8 | 10.1 | 30.1 | 9.4 | 8.6 |
| 4 | 33.2 | 43.9 | 14.1 | 3.8 | 5.1 |
| 5 | 37.2 | 24.6 | 21.6 | 8.9 | 7.7 |
| 6 | 57.1 | 10.3 | 26.2 | 2.0 | 4.4 |
| 7 | 40.4 | 1.5 | 49.7 | 6.1 | 2.4 |
| 8 | 47.4 | 12.3 | 21.0 | 11.1 | 8.1 |
| 9 | 29.7 | 36.4 | 7.2 | 14.2 | 12.7 |
| **Total Surface Area Percentage for Neighbouring Industrial Sites** | **42.9** | **20.1** | **21.4** | **14.1** | **7.1** |

#### 6.1.2.1 Defence Joint Logistics Unit

Analysis was also undertaken of the DJLU site, immediately to the north of the Project site. As can be seen in Figure 6-1, the DJLU site generates significant heat when compared to natural bushland. The analysis of the DJLU site includes the operation boundary of the site, and excludes the area of parkland to the east of the site. Table 29 provides an analysis of the surface area features on the DJLU site.

*Table 29 Surface Area Feature Percentage for DJLU*

| Site | Building | Pavement | | Green Cover | |
|---|---|---|---|---|---|
| | | Bitumen | Concrete | Landscape | Tree Cover |
| DJLU | 14.8 | 23.8 | 6.8 | 51.8 | 2.7 |

### 6.1.2.2 Discussion

The following general observations can be made about the surface area features of the neighbouring industrial sites:

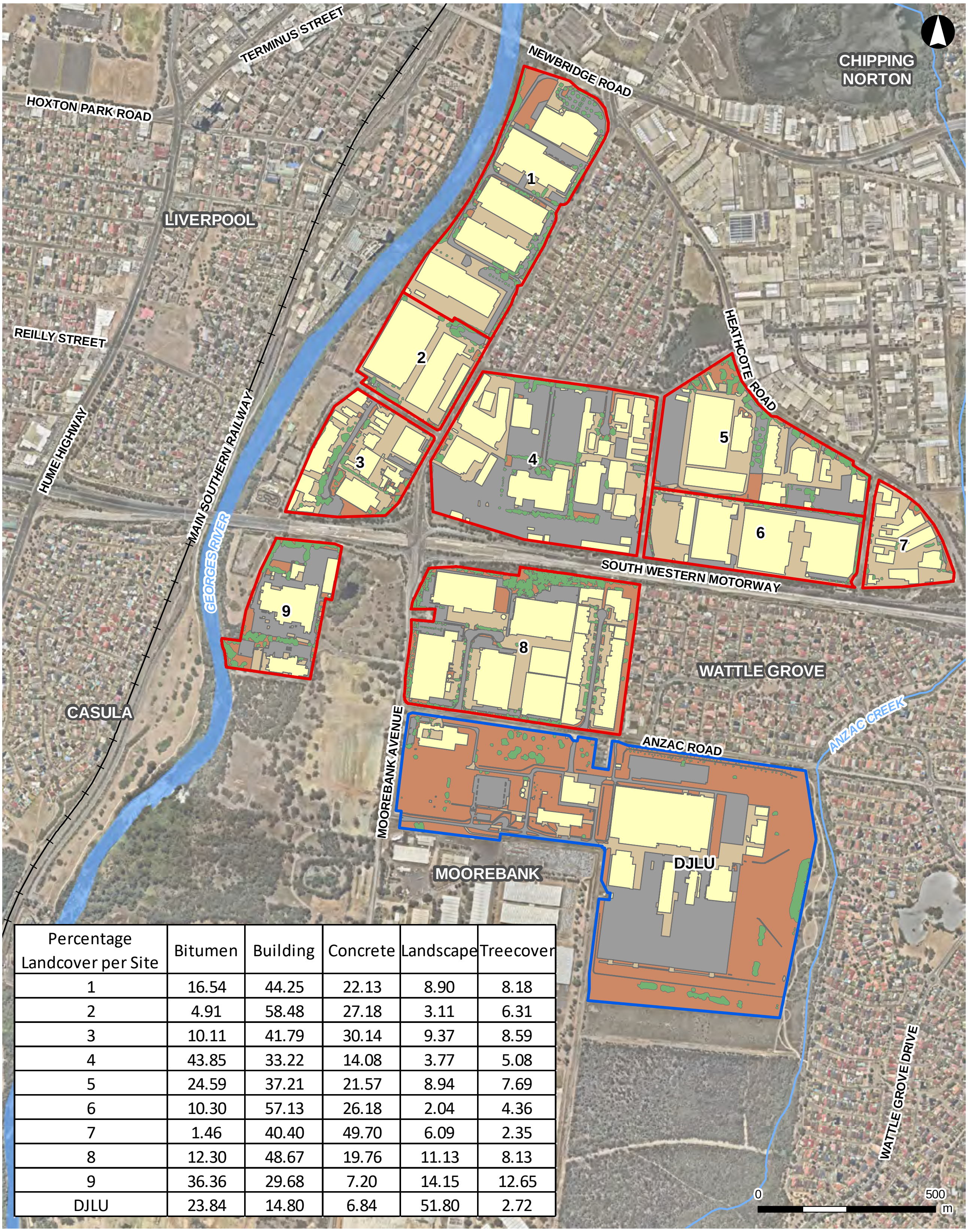
- **Buildings**: Percentage of building cover for buildings ranges from 30 to 58%, with the total surface area covered by buildings comprising 43%. Sites 2 and 8 have a relatively high percentage of building cover, at 58 and 47%. It is noted that the roof colour of buildings within Sites 2 and 8 have lighter coloured roofs than some buildings within the neighbouring industrial areas.
- **Pavement**: Percentage of bituminous pavement on the neighbouring industrial sites range from 1.5 to 44%, with the total surface area covered by pavements comprising 42%, equally split between concrete and bitumen. Sites 2 and 8 have comparatively low percentages of bituminous covering the surface area, at 5 and 12%. The percentage of concrete covering ranges from 7 to 50%. Sites 2 and 8 are have concrete surface coverings of 27 and 21%.
- **Green cover**: Landscaping cover (exclusive of canopy cover) on the sites ranges between 3 and 14%, with the total surface area covered by landscaping comprising 7.6%. Sites 2 accounts for the minimum percentage cover of 2%, while Site 8 has the second highest percentage cover of 11%. Tree cover on the sites range from 2 to 13%, with a total surface area covered by tree cover comprising 7.1%. Sites 2 and 8 have canopy cover of 6 and 8%, which is consistent with the average canopy cover for the industrial sites.

The DJLU site has a high proportion of landscape areas, at 51.8%, comprising largely grassed areas. Bitumen cover on the site is 23.8% of the DJLU site, while tree canopy cover accounts for only 2.7% of the DJLU site.

The following observations can be made in relation to the contribution to UHI effect from land surface cover for the adjacent sites:

- Both Sites 2 and 8 have a high proportion of roof cover and have used light coloured roofing. This appears to contribute to a reduction in the UHI effect which may be due to increased albedo.
- Sites 2 and 8 have comparatively low percentages of bitumen covering the surface area, which also appears to contribute to a reduction in the UHI effect. This may be due to the higher albedo of the concrete paving used, in preference to bitumen.
- The DJLU site has a comparatively high percent of bitumen covering which appears to contribute to the UHI effect on the DJLU site.
- The DJLU site has a high percentage of landscaping but a low percentage of tree cover, which appears to contribute to the UHI effect.

It is assumed that the neighbouring industrial sites and the DJLU have not adopted any strategies to mitigate UHI effects.




| Percentage Landcover per Site | Bitumen | Building | Concrete | Landscape | Treecover |
|---|---|---|---|---|---|
| 1 | 16.54 | 44.25 | 22.13 | 8.90 | 8.18 |
| 2 | 4.91 | 58.48 | 27.18 | 3.11 | 6.31 |
| 3 | 10.11 | 41.79 | 30.14 | 9.37 | 8.59 |
| 4 | 43.85 | 33.22 | 14.08 | 3.77 | 5.08 |
| 5 | 24.59 | 37.21 | 21.57 | 8.94 | 7.69 |
| 6 | 10.30 | 57.13 | 26.18 | 2.04 | 4.36 |
| 7 | 1.46 | 40.40 | 49.70 | 6.09 | 2.35 |
| 8 | 12.30 | 48.67 | 19.76 | 11.13 | 8.13 |
| 9 | 36.36 | 29.68 | 7.20 | 14.15 | 12.65 |
| DJLU | 23.84 | 14.80 | 6.84 | 51.80 | 2.72 |

LEGEND

- Cadastral boundary of neighbouring industrial sites
- Operational Defence Area
- Existing railway
- Watercourse

Total Landcover Percentage (Sites 1 to 9)

- Bitumen - 20.94
- Building - 42.92
- Concrete - 21.43
- Landscape - 7.60
- Treecover - 7.11

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Aerial imagery supplied by nearmap (January, 2018)

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Figure 6-2: Digitised Land Surface Areas of Neighbouring Industrial Sites

## 6.1.3 Surface Area Feature Comparison with Project Site

Analysis was undertaken to calculate percentage breakdowns of surface area features of the Project site. Digitisation of land cover types from the landscape plan were provided in the RtS (Appendix B2: Revised Landscape Design Statement and Plans). The following surface area features were identified and digitised from the landscape plan:

- Buildings, including:
  - Office
  - Warehouse.
- Bitumen, including:
  - Car park
  - Road.
- Landscaping, including:
  - OSD basins
  - Landscape areas (excluding tree cover)
  - Tree cover.

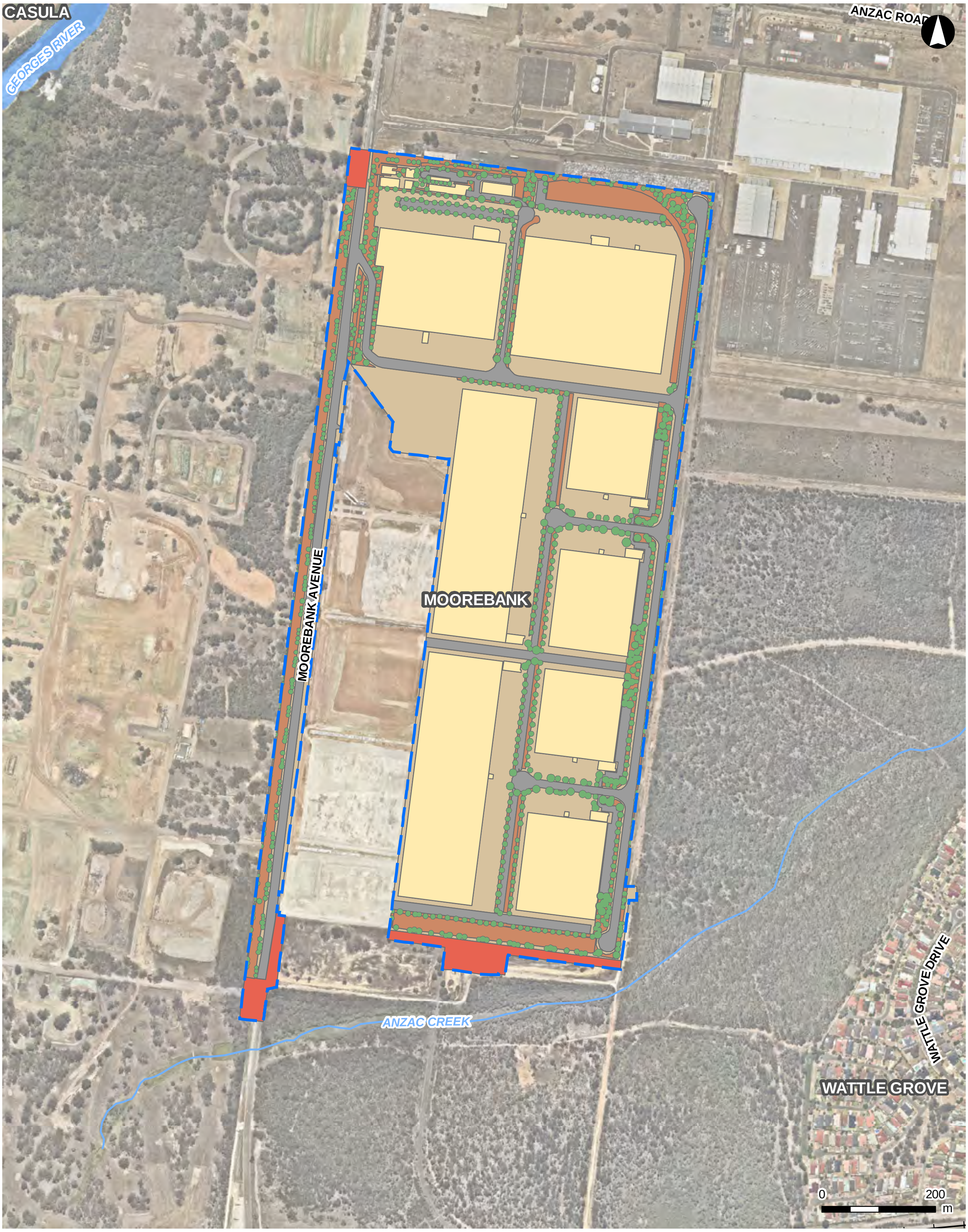
To adopt a consistent analysis approach with the neighbouring area analysis, the surface area feature classes are grouped as described below in Table 30. The surface area feature percentage breakdown for the Project site is also provided below in Table 30.

The majority of the Project site is covered with buildings (i.e. warehouses and offices), while pavement (i.e. concrete and bitumen) covers 38% of the Project site. Green cover accounts for 17% of the land cover at the Project site. Refer to Figure 6-3 for the surface area features of the Project site (according to the RtS design plan).

*Table 30 Total Surface Area Feature Cover for the Project Site*

| Land Cover Type | Total Land Cover Percentage (%) |
|---|---|
| | **RtS Design Plan** |
| **Building Space** | |
| Building (Warehouse and office) | 40.1 |
| **Pavement** | |
| Bitumen (Road and car park) | 13.6 |
| Concrete | 24.0 |
| **Green Cover** | |
| Landscape and OSD basins | 10.1 |
| Tree cover | 7.3 |
| Future Landscape Area | 3.8 |

# Urban Heat Island Mitigation Strategy




LEGEND

- MPE Stage 2 operational area
- Existing railway
- Watercourse

Total Landcover Percentage

- Bitumen - 13.85
- Building - 42.51
- Concrete - 24.61
- Landscape - 9.73
- Treecover - 6.68
- Future landscape area - 2.61

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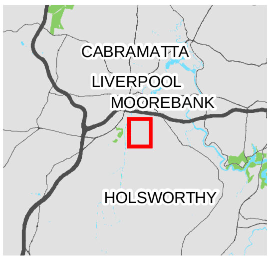


Figure 6-3: Surface Area Features of the Project Site (as per the RtS)

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QA by : RB

Table 31 shows a comparison of the percentage cover of surface area features for the neighbouring industrial areas, the DJLU site and the Project site. The Project site has a very similar surface area feature coverage to the neighbouring industrial sites, with a lower proposed bitumen covering and slightly higher tree cover.

*Table 31 Comparison of Surface Area Feature Percentage*

| Site | Building | Pavement | | Green Cover | |
|---|---|---|---|---|---|
| | | Bitumen | Concrete | Landscape | Tree Cover |
| Total Surface Area Percentage for Neighbouring Industrial Sites | 42.9 | 20.1 | 21.4 | 14.1 | 7.1 |
| DJLU | 14.8 | 23.8 | 6.8 | 51.8 | 2.7 |
| RtS Design Plan* | 40.1 | 13.6 | 24.0 | 10.1 | 7.3 |

* As per the Project described in the RtS.

# 7 FINAL MITIGATION STRATEGIES

To achieve the greatest cooling effect, a combination of mitigation strategies is required as this will have a synergistic effect across the Project site. The following UHI mitigation strategies have been incorporated into the overall design:

- **Provision of landscaping and green space**: Landscaping and the use of green space includes canopy trees along the Project boundary and the car parking areas, with garden beds or planter boxes included within the outdoor employee eating areas. Refer to UDLP Section 3.1 and 4.1 for details on landscaping and green space for the Project
- **Incorporation of a bioretention structures as part of the stormwater management controls:** Raingardens maintain a saturated zone, allowing vegetation established within the rain garden access to water during dry periods. Refer to the UDLP Section 3.2.3 and WSUD Plans in Appendix H2 of the UDLP for details on WSUD elements throughout the Project
- **Use of cool roofs:** Roofing materials will be made of translucent sheeting such as Zincalume (or equivalent) to minimise solar absorption. Refer to UDLP Section 3.2.1 and Development Layout Plans in Appendix H1 of the UDLP for details on the warehouse roofs.
- **Use of solar panels:** Solar panels will be installed on warehousing roofs to reduce dependency on fossil fuels and align with the Projects sustainability requirements. Refer to UDLP Section 3.2.2 and Development Layout Plans in Appendix H1 of the UDLP for details on the solar panels.
- **Use of cool building materials**: Use of light-coloured building materials will be incorporated into the colour palette and used as the primary colour of cladding on warehouses to minimise solar absorption. Refer to UDLP Section 3.2.1 and Development Layout Plans in Appendix H1 of the UDLP for details cool building materials.
- **Large awning roof over receiving docks**: Large awning roofs will be incorporated to provide additional shade and reduce solar absorption by pavements over the receiving / loading docks. Refer to Development Layout Plans in Appendix H1 of the UDLP for details on the awning roofs.
- **Minimisation of heat generation from operations:** The warehouses will achieve a minimum 4 star – Green Star rating for design and as built under the Green Star accreditation system, achieving a demonstrable reduction in energy demand from a reference warehouse. Energy efficiency of the building will be achieved through the use of LED lighting and provision of translucent sheeting to allow for natural lighting. Refer to UDPL Section 3.2.1 and Development Layout Plans in Appendix H1 of the UDLP for building details. The LSP also details information on the lighting used throughout the Project.

High albedo pavement was not considered as a final mitigation strategy for the development. High albedo pavement was not considered a feasible option due to the high embodied energy required for production of high albedo concrete. Large amounts of concrete for the Project site would contradict the Project's ability to meet the greenhouse gas emissions required for obligations under CEFC.

UHI mitigation measures to be implemented specific to each warehouse will be included within the relevant staged submission of the UDLP.

## 7.1 UHI Mitigation Strategies Modelling

### 7.1.1 RtS Design Plan

UHI mitigation strategies modelling was undertaken by Integral Group on 29 March 2019 (refer to Appendix C). The modelling was conducted based on the RtS design plan for the entire MPE Stage 2 Project site. The modelling tool used information presented in this UHIMS to determine if a 4°C decrease in temperature at the Project site is achieved in comparison to neighbouring industrial developments. The modelling incorporated the following Project design details:

- Landscaping and green space
- Cool roofs
- Solar panels

- Pavement types (e.g. concrete and asphalt)
- Minimisation of heat generation from operations (4-star Green star as-built and design rating)
- Current building layout.

The results concluded a 1°C reduction in canopy temperature during the middle of the day across the year when compared to adjacent industrial facilities. According to a study (Azevedo et al, 2016), a 1°C difference in canopy temperature correlates to approximately a 4°C difference in surface temperature. As such, the 1°C canopy temperature reduction that is currently predicted correlates to a 4°C surface temperature reduction. This temperature reduction aligns with the 4°C decrease in temperature required by CoC B139(c).

### 7.1.2 Current Design Plan

UHI mitigation strategies modelling was also undertaken by Integral Group on 6 June 2019 for the current design plan of the entire MPE Stage 2 project site (refer to Appendix C). The modelling was conducted based on the current design plan as shown in Figure 7-1. The difference in the site surface areas for the RtS design plan and the current design plan was determined to be less than 1% and is due to the change in design of OSD1 and OSD9.

The modelling was undertaken to determine if a 4°C decrease in temperature at the Project site is achieved for the current design plan in comparison to neighbouring industrial developments. As there was no significant difference in the site surface area from RtS to current design plan, the results were not substantially different from the 29 March 2019 report. In summary, the results concluded a 1°C reduction in canopy temperature during the middle of the day across the year when compared to adjacent industrial facilities. As such, the 1°C canopy temperature reduction that is currently predicted correlates to a 4°C surface temperature reduction.

A further sensitivity analysis was undertaken that showed that there are diminishing returns in further increasing the density of vegetation across the site. Hence, no additional vegetation is required, as the current landscaping presents sufficient UHI reduction and no further modelling will be required should additional vegetation be planted.

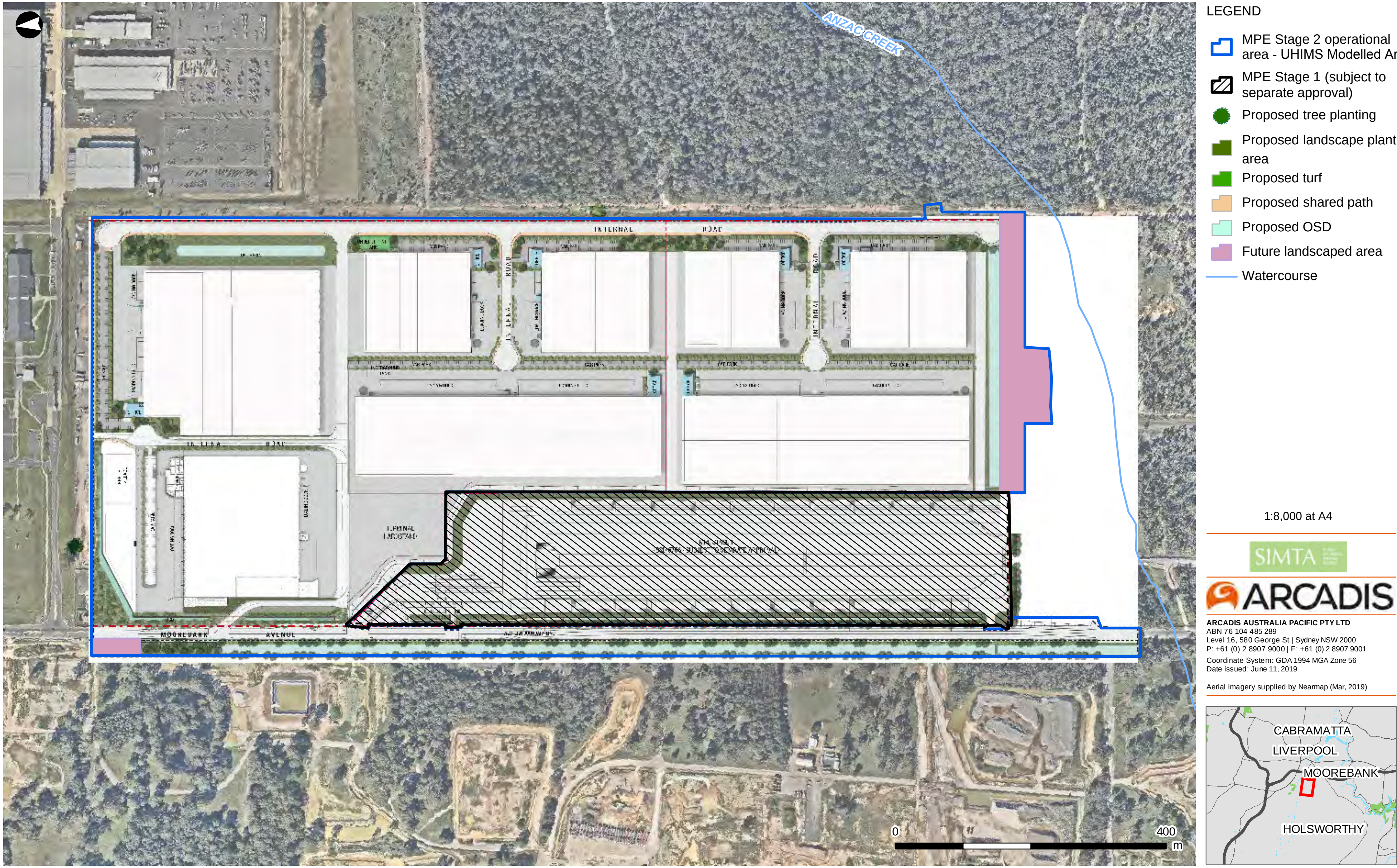


Figure 7.1: UHIMS modelling area and site characteristics

# 8 INTEGRATION OF UHIMS INTO PLANS

Table 32 describes the information and recommendations of this UHIMS that have been incorporated into other various Project documents in accordance with CoC B139(d).

*Table 32 UHI Integration with Other Project Documents*

| CoC | Requirement | Where | How Addressed |
|---|---|---|---|
| A22 | Updated final Development Layout Plans | UDLP – Appendix H1 | The Updated final Architectural details and Development Layout Plans incorporate the following in relation to minimising the UHI effect including:<br>• Use of cool roofs (i.e. translucent sheeting)<br>• Installation of solar panels<br>• Use of cool building materials and finishes<br>• Large awning roof over receiving and / or loading docks<br>• Incorporation of bioretention structures as part of the stormwater management controls<br>• Incorporation of landscaping within car parking and provision of canopy trees throughout the perimeter of the site. |
| A23 | WSUD Plans | UDLP – Appendix H2<br>SMP – W1P (Section 6)<br>SMP – Balance of Site | The SMP – W1P and SMP – Balance of Site describe the stormwater quality management devices that will be incorporated into the design to minimise the UHI effect throughout the site. Relevant information has also been included within the Development Layout Plan and include:<br>• Installation of a bio-retention systems, OSDs and GPTs<br>• On-site collection and re-use of stormwater and recycled water. These will be considered where reasonable and feasible and be consistent with the Stormwater Management Plan |
| A24 | Updated final Architectural details | Refer to A22 | Architectural details are incorporated within the Development Layout Plans. Refer to A22. |
| B140 | Urban Design and Landscape Plan | UDLP<br>UDLP – Appendix H1<br>UDLP – Appendix G<br>LSP | The UDLP incorporates the following in relation to minimising the UHI effect including:<br>• LED lighting<br>• Provision of translucent sheeting<br>• Installation of solar panels on roofs of warehouses for energy efficiency<br>• Use of light-coloured building materials and finishes<br>• Building walls to minimise large blank walls with light coloured materials and finishes<br>• Integration of WSUD elements including OSDs, GPTs and bio-retention systems |

| CoC | Requirement | Where | How Addressed |
|---|---|---|---|
| | | | • Greens space including garden beds, planter boxes, canopy trees and other vegetation<br>• Perimeter screening to utilise advanced endemic shrubs and canopy trees to optimise shade provision from establishment. |
| C1 | Construction Environmental Management Plan | N / A | The Construction Environmental Management Plan (CEMP) will be implemented during the construction phase of the Project, during which time the UHI mitigation strategies will be constructed or installed in accordance with relevant design drawings and specifications. |
| C3 | Operational Environmental Management Plan | OEMP (under preparation) | Details on the maintenance and operation of the UHI mitigation strategies that are adopted within and throughout the Project site will be incorporated into the Operational Environmental Management Plan (OEMP). Specifically into OEMP sections as follows:<br>• C3(d) – Identification of infrastructure, including architectural and stormwater management UHI mitigation strategies<br>• C3(e) – Roles and responsibilities for maintenance of UHI mitigation strategies<br>• C3(g) – OEMP sub-plans, specifically:<br>- (iii) Stormwater Infrastructure Operation and Maintenance Plan<br>- (viii) Operational Flora and Fauna Management Plan. |

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# APPENDIX A UHI INFORMATION

# 1 TYPES OF UHI

There are two broad types of UHI: atmospheric and surface UHIs. These two heat island types differ in the ways they are formed, the techniques used to identify and measure them, their impacts, and to some degree, the methods available to mitigate them (U.S. Environmental Protection Agency, 2008).

## 1.1 Atmospheric UHI

Atmospheric UHI is typically a result of urban geometry (i.e. the dimensions and spacing of buildings within an urban area). Urban geometry influences wind flow, energy absorption and how effectively radiation can be emitted back to space. Heat from energy use in human activities is a further contributor to the atmospheric UHI.

Atmospheric heat islands vary much less in intensity than surface heat islands. On an annual mean basis, air temperatures in large cities might be 1 to 3°C warmer than those of their rural surroundings. Atmospheric UHIs can be detected by measuring the ambient air temperature in urban areas and comparing this to the ambient air temperatures in adjacent rural and natural areas. Atmospheric UHIs are commonly divided into two different types being, canopy layer UHIs and boundary layer UHIs. The urban climate should be understood as constituting both the UHI beneath the urban canopy and the urban boundary layer above the rooftops (Samuels, 2017).

### 1.1.1 Canopy Layer UHI

Canopy layer UHIs exist in the layer of air where people live, from the ground to below the tops of trees and roofs. Anthropogenic features and human activities within the canopy layer are the main influence on the net positive thermal balance that gives rise to the UHI experienced in the canopy layer (Oke, 1987). The canopy layer UHI is the most commonly observed and experienced atmospheric UHI as it is where people generally experience the increased atmospheric temperatures.

Canopy layer UHIs are often weak during the late morning and increase throughout the day and become more pronounced after sunset, due to the slow release of heat from urban infrastructure. Buildings and hard surfaces store more latent heat than rural and vegetated areas. The timing of this peak, however, depends on the properties of urban surfaces, the season, and prevailing weather conditions.

### 1.1.2. Boundary Layer UHI

Boundary layer UHIs extend from the rooftop and treetop level and up to the point where urban landscapes no longer influence the atmosphere. This region typically extends approximately 1.5 km from the surface. The boundary layer UHI covers whole cities and their immediate surrounds and affects the urban, regional and ultimately the global climate (Samuels, 2017).

## 1.2 Surface UHI

Surface UHI is generally caused by the sun heating dry, exposed surfaces, such as roofs and pavement to temperatures hotter than the air. Surface UHI are therefore typically strongest during the day due to the direct sunlight. On average, the temperature difference between an undeveloped, vegetated area and a developed area is 10 to 15°C during the day and 5 to 10°C during the night (Roth, 1989).

The magnitude of surface UHIs varies with seasons, due to changes in the sun's intensity as well as ground-cover and weather. As a result of such variation, surface UHIs are typically largest in the summer. Surface UHI is influenced by reduced vegetation, with associated reduced shading and reduced evapotranspiration, and the characteristics of urban materials, which affects how the sun's energy is reflected, emitted, and absorbed. Surface UHIs can be remotely sensed using thermal infrared sensors that sense land surface temperatures. Usually, a close relationship between the near surface air temperatures (e.g. the canopy layer UHI) and land surface temperatures can be established. As such, surface UHIs are a reliable indicator of the atmospheric UHI.

# 2 UHI CONTRIBUTORS

The urban landscape differs from the natural landscape in the way it absorbs short and longwave radiation, allows for transpiration, releases of anthropogenic heat and blocks prevalent winds. The energy absorbed by urban surfaces from solar radiation and generated by anthropogenic activity is physically balanced by warming the air above the surface (convection and radiation), the evaporation of moisture, and storage of heat in surface materials (Gunawardena, Wells, & Kershaw, 2017). The urban energy balance can be expressed as comprising consideration of:

- Incoming solar radiation (absorbed and longwave)
- Anthropogenic heat generated within the urban area
- Fluxes of sensible and latent heat within the atmosphere
- Storage heat flux, representing all energy storage mechanisms within the urban area, including air, trees, building fabrics and soils
- Net advection through the lateral sides of the volume or the urban area (Haghighat, 2010) (Oke T. , 1988).

The amount of latent and sensible heat within the urban environment is a function of the city location and atmospheric characteristics (Haghighat, 2010). The weather, and in particular wind and cloud cover, affects the intensity of heat islands, with the magnitude of UHI effects generally found to be the greatest under calm and clear weather conditions.

(Pijpers-van Esch, 2015) summarises the key factors that influence the UHI as follows:

- Decreased evaporation and transpiration from urban areas due to less permeable materials and less vegetation compared to rural areas. As a consequence, more energy is put into sensible heat and less into latent heat.
- Absorption of short-wave radiation from the sun in low albedo and high emissivity of materials. The absorption is even more stimulated by multiple reflections between buildings and street surface.
- Decreased long-wave radiation heat loss from street canyons, caused by obstruction of the sky by buildings, trees and other objects (i.e. smaller sky view factor [SVF]). The heat is intercepted by the obstructing surfaces and absorbed or radiated back to the canopy layer.
- Increased heat storage by building materials with large thermal admittance. Cities have a larger surface area compared to rural areas and therefore store more heat.
- Decreased turbulent heat transport from within urban canyons caused by a reduction of wind speed.
- Absorption and re-emission of long-wave radiation by air pollution in the urban atmosphere.
- The release of anthropogenic heat by combustion processes, such as traffic, machinery and industrial processes.

The UHI effect is a complex occurrence, due to the complexity of urban settings, weather patterns and the interplay between its contributing factors. For example:

- The roughness of urban surface covers and their heat capacity cause temperature variations across the urban environment and create local air turbulence, which has the potential to decrease the UHI effect
- Hard urban surfaces store more heat; however, their heat loss rate is higher than permeable and greened surfaces
- Anthropogenic heat sources, such as exhaust from air-conditioning, transport and industry is a highly contextual contributor, which can significantly magnify the UHI effect (Osmond & Sharifi, 2017).

Urban and rooftop planting in some major cities decreases air temperature; however it also results in an increase in air humidity, which has a negative effect on thermal comfort in warm climates and an increase in outgoing latent heat during the daytime (Samuels, 2017). Overall, humidity reduces the effectiveness of some strategies to mitigate the UHI effect and reduce temperatures. The following sections provide a brief discussion of the key contributing factors to the UHI. As discussed above, the factors work together to create the UHI effect and are further influenced by the existing climate and topography of the area.

Figure A1 below outlines how the UHI contributors (i.e. anthropogenic heat, loss of vegetation) affect the surrounding area, specifically with regards to surface and canopy layers.

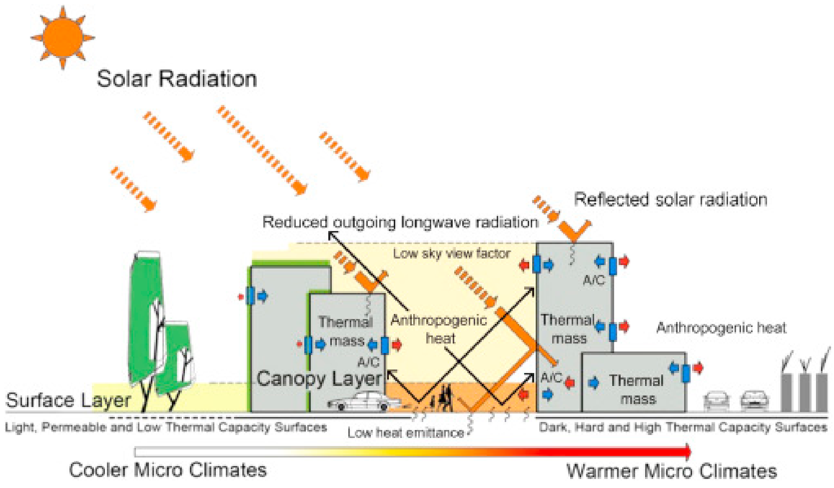



*Figure A1 Urban Structure, Cover, Fabric and Metabolism Contribute to the UHI Effect in Highly Developed Areas (Modified based on: Sharifi and Lehmann (2014, p. 25)) (Soltani & Sharifi, 2017)*

## 2.1 Loss of Vegetation

Vegetation, and in particular trees, cools microclimates in many ways, such as:

- Shading heat-absorbing materials
- Providing evapotranspirative cooling
- Altering wind patterns (Oke T. C., 1989) (McPherson 1994) (Taha, 1997).

Tall vegetation, such as trees and some bushes, also affects microclimates by establishing a canopy layer. Wind speeds in the canopy layer are greatly reduced, causing canopy-layer air to be confined longer than in areas without canopies. The effect on air temperature within this canopy layer depends on the surfaces within the region of confinement: if canopy layer air is confined to a region containing hot surfaces, such as bitumen warmed in the sun, canopy-layer air temperatures may be raised. However, if canopy layer air is confined a region containing cool surfaces (for example shaded, wet soils) temperatures may be lowered (Dan M. Kum, 1994).

Vegetation also alters the 'equivalent albedo' of an area as, while the surface of vegetation may be darker in colour than an urban surface, the energy released by vegetation through evapotranspiration lowers temperatures. This energy loss can be converted to the energy equivalent of the average incident solar radiation that would be reflected (but is instead lost through transpiration).

Within the urban context, as development occurs, vegetation is generally replaced with materials of high thermal conductivity, heat storage capacity and low albedo values, such as roofs, bitumen and areas landscaped with grasses and low shrubs. It is noted that grassed areas also contribute to the UHI effect as they have been shown to contribute 12°C of heat to the air mass during the diurnal cycle within the Western Sydney context. This is due to the typical lack of shading of grassed areas which allows the soil to absorb heat (Samuels, 2017). Loss of vegetation, and in particular trees and shrubs, leads to a loss of the cooling effects of provided by vegetation and an increase in land covers, including pavement, buildings, and other surfaces that absorb and retain heat, contributing to the UHI effect.

## 2.2 Reduction in Evaporation and Infiltration

As areas are developed and vegetation is replaced by impervious surfaces, water infiltration rates decrease dramatically. Where rainfall is rapidly drained via stormwater pipes it leaves little available moisture in the urban landscape, which reduces evapotranspiration and increases sensible heating of the local atmosphere (Norton, et al., 2014). This results in the drier soil conditions common in urban environments (Walsh, 2005) which mean that less incoming solar energy is used to drive plant transpiration and soil evaporation, leaving more of this energy to warm urban surfaces (Coutts A. B., 2007) (Oke T. , 1988).

Vegetation and moist soil profiles assist in cooling surfaces through evapotranspiration, which uses heat from the air to evaporate water.

## 2.3 Urban Materials and Changes in Albedo

Thermal emittance (or thermal emissivity) of a material determines how much heat it will radiate per unit area at a given temperature and is a measure of how readily the surface will shed heat. Any surface exposed to radiant energy will heat up until it reaches thermal equilibrium (i.e. gives off as much heat as it receives). When exposed to solar radiation a surface with high emittance will reach thermal equilibrium at a lower temperature than a surface with low emittance, because the high-emittance surface gives off its heat more readily (U.S. Environmental Protection Agency, 2008).

The albedo of a surface is defined as it's hemispherically and wavelength-integrated reflectivity (Taha, 1997) providing a measure of the amount of solar radiation that is reflected from that surface. The albedo of the surface ranges from value 0 to 1, where zero indicates that all the energy is absorbed and therefore no energy is reflected by the surface (Pourshams-Manzouri, 2013). Typically, urban albedos are in the range 0.10 to 0.20, which is less than the 'equivalent albedo' of an area vegetated with trees of 0.40 (Dan M. Kum, 1994). The decrease in albedo leads to an increase in the absorption of solar radiation during the day time, and subsequent re-radiation as heat during the night. This results in higher surface temperatures of buildings and pavements with lower albedos and higher temperatures within the canopy layer (Al-hafiza, 2017). Examples of the albedos of some commonly used urban materials are:

- Freshly installed asphalt pavement: 0.05
- Aged asphalt pavements: 0.10 to 0.18
- Light-colour concrete: 0.35 to 0.40
- Aged concrete: 0.25 to 0.30
- Dark, flat roofs: 0.1 to 0.2.

Figure A2 shows the correlation between the albedo of materials typically used on roads and surface temperature. The figures shows that as albedo decreases, surface temperature increases.

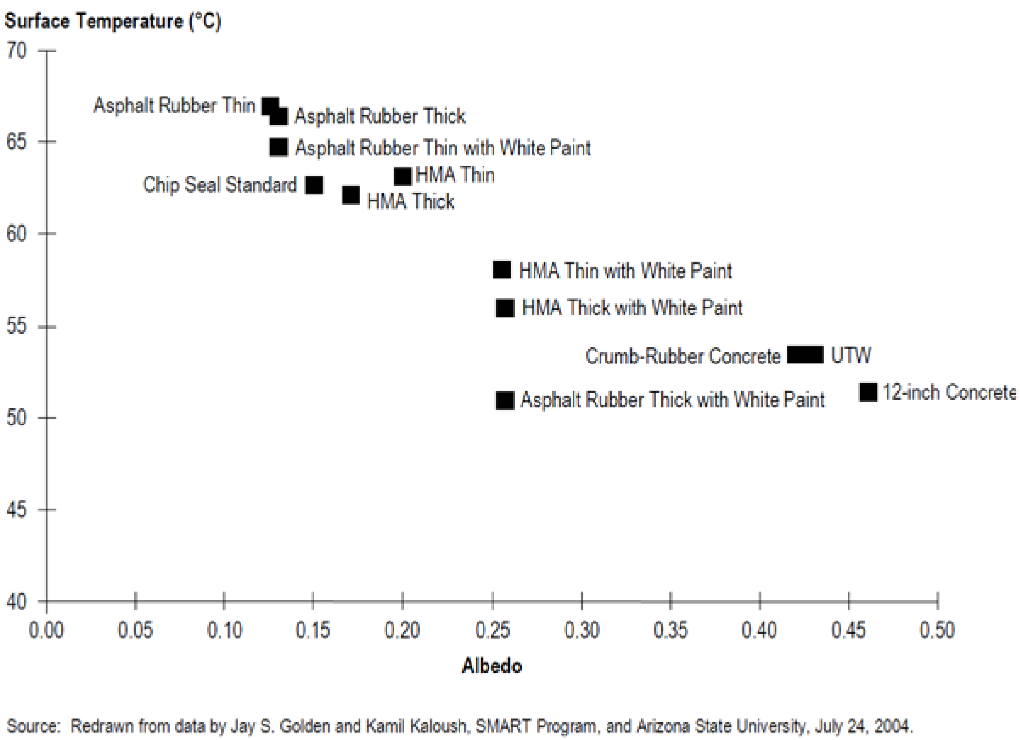



*Figure A2 Surface Temperature vs. Albedo* (U.S. Department of Transportation Federal Highway Administration, 2017)

Research has shown that thermal emittance and surface albedo work together to affect temperatures within the urban environment and the best-performing construction materials for surface temperature and air temperature reduction have both high albedo and high emittance (Al-hafiza, 2017). For example, research

suggests albedo and emittance have the greatest influence on determining how a conventional pavement cools down or heats up, with albedo having a large impact on maximum surface temperatures, and emittance affecting minimum temperatures (U.S. Environmental Protection Agency, 2008).

Other properties of urban materials that are contributing factors in the UHI effect include:

- **Thermal conductivity**: materials with low thermal conductivity may heat up at the surface but will not transfer that heat throughout the other pavement layers as quickly as pavement with higher conductivity.
- **Heat capacity**: many urban materials, such as pavement, can store more heat than natural materials, such as dry soil and sand. As a result, urban areas typically capture more solar radiation, sometimes retaining twice as much as their rural surroundings during daytime. The higher heat capacity of conventional urban materials contributes to UHI at night, when materials in urban areas release the stored heat.
- **Thickness**: the thickness of a materials influences how much heat they will store, with thicker materials typically storing more heat (U.S. Environmental Protection Agency, 2008).

## 2.4 Urban Geometry

The dimensions and spacing of buildings within a city, referred to as urban geometry, influences how solar radiation and anthropogenic heat is absorbed and re-emitted (Oke 1981; Bärring *et al* 1985; Eliasson 1996). For example, tall buildings along narrow streets create an urban canyon which can limit heat gain to the pavement during the day, when the buildings provide shade. These same buildings may also absorb and trap the heat that is reflected and emitted by the pavement, which prevents the heat from escaping and exacerbates the UHI effect at night (U.S. Environmental Protection Agency, 2008). Buildings may also slow wind speeds that otherwise would help to reduce the temperature in urban areas. The overall impact of urban geometry on the UHI effect is therefore dependent on a number of factors including:

- Urban form impacts on the SVF
  - Reductions in the SVF due to tall buildings and other urban forms affect heat loss potential to the sky, in particular at night
- Height and width of urban canyons
  - Tall buildings provide shade to adjacent buildings and may reduce temperatures during the day. It is thought that wider canyons permit greater convective and radiative cooling exchange (Ruiz, 2015)
  - (Norton, et al., 2014) categorises urban canyons into four categories being: narrow (10 m), medium (20 m), wide (30 m) and very wide (40 m)
- Compactness index
  - Ratio of building surface area to the surface area of a cube which has the same volume as the building
- Linearity / sinuosity ratio of urban canyons (Samuels, 2017)
- Vegetation within urban canyons (Ruiz, 2015)
- Dominant wind direction and building orientation.

The distance between buildings also determines whether radiation energy reflected from one building is absorbed by surrounding buildings and consequently reradiated to the surface of other buildings, consequently increasing the surface temperature (Al-hafiza, 2017).

## 2.5 Anthropogenic Heat

Anthropogenic heat represents the heat generated from an area by human activity, which includes both stationary and mobile sources. The contribution of anthropogenic heat to the UHI effect differs across different land use types (Sharifi, 2017). Sources of anthropogenic heat include burning of fossil fuels for heating and cooling, manufacturing, transportation and lighting.

The contribution of anthropogenic heat to the urban energy balance is largely a function of latitude and season of the year (Shahmohamadi, 2011). Sources vary in its influence on UHI effect; for example:

- (Oke T. , 1988) reported that anthropogenic heat release could be related to the population and its per capita energy use
- (Taha, 1997) found that the effects of anthropogenic heating were found to be relatively small in comparison to surface albedo and vegetation cover, and negligible in commercial and residential areas
- (Offerle, Grimmond, Fortuniak, Klysik, & and Oke, 2006) found that anthropogenic heating is significant to UHI in winter.

This means that it is difficult to draw conclusions on the contribution of anthropogenic heat to the UHI effect as, depending on the area and its energy use, anthropogenic heat could be significant or negligible and it could have varying diurnal, seasonal and even weekly trends (Shahmohamadi, 2011).

# APPENDIX B BUILDING MATERIAL PROPERTIES

| Material Code (refer to SSD 7628) | Example | Notes/Comments |
|---|---|---|
| C1 | 'Cottage Green', Colorbond | By limiting the use of the dark coloured finishes with high absorption and low reflectivity values, the material's ability to reflect solar heat is maximised. |
| C2/C3 | 'Intensity Evergreen', Dulux<br>'Intensity Leaf', Dulux | The use of these materials having low 'Light Reflectance Values' are minimised to reduce solar gain. |
| C4 | 'Intensity Moonlight', Dulux | The lighter colour of the C4 material assists in reducing the solar gain of the warehouse. Its particular use on the north façade for example, will minimises the absorption of prolonged solar exposure. |
| WC1/RF1 | 'Shale Grey', Colorbond | The colour of WC1 is classified as 'light' and was therefore used as the primary colour of cladding on the warehouse to minimise solar absorption. |
| WC2 | 'Windspray', Colorbond | WC2 is not as effective as WC1 in terms of solar absorption, however is used sparingly to respond to issues of solar gain. |
| WC3 | 'Monument', Colorbond | This dark metal sheeting colour is used sparingly to minimise the overall solar absorption of the warehousing envelopes. |
| RF2 | 'Gun Metal' Laserlite 3000, Polycarbonate | The product specifically performs to reduce light transmission and minimise solar gain. As the U Value is high and does not perform well as an insulating element, its limited application and ability to reflect light should assist in mitigating the urban heat island effect. |
| RF3 | 'Checkerboard' ScalaSeraphic, Viridian | The use of a fritted glass allows the awning to provide a certain amount of shading, and the selected pattern further assists in reducing light transmission to the ground below it. Selection and design of the pattern in the glass is crucial to reducing solar access to the ground below. |
| PC1 | 200mm Precast Concrete panel<br>Painted 'Monument' | Although the finish is of a dark colour, overall solar absorption is controlled through the limited use of the PC1 finish and appropriate shading through design. |
| PC2 | 200mm Off-form Concrete<br>Unpainted | Off-form concrete finishes are used sparingly to limit direct exposure to 'thermal mass' elements. In addition to limiting the use of PC2, lighter pigments selected for the composite could decrease solar absorption. |
| CL1 | 'Beige' #103, Alucobond | The main colour selected for composite panel cladding on Freight Village buildings is considered high in terms of its luminance reflectance value, resulting in less solar absorption into the buildings. |

| Material Code (refer to SSD 7628) | Example | Notes/Comments |
|---|---|---|
| CL2 | 'Mouse Grey' #125, Alucobond | The secondary composite panel cladding colour is used sparingly, with its dark colour and assumed low reflectivity performance taken into consideration. |
| GL1 | 'SuperBlue' EVantage, Viridian<br>Alternative:<br>'Clear 82' ComfortPlus, Viridian | In addition to specifying glass with low emission and higher insulation properties, sun shading devices and awnings have been implemented to the façade to control direct solar access to the glass elements. |
| GL2 | 'Slate' SpectraColour, Viridian<br>Similar colour: 'Windspray', Colorbond | Spandrel colour-backed glass is implemented to maintain the desired appearance across entire facades. While the selected colour has a low luminance reflectance value, the reflective nature of glass and limited use of GL2 to contribute to controlling solar gain into the building. |
| L1 | Metal framed louvres<br>Colour: Windspray | Although a dark colour, the louvres are limited in allocation and are assigned with intention to limit solar absorption to other elements. |

# APPENDIX C UHIMS MODELLING (INTEGRAL GROUP 2019)

**Integral Group**
Level 7 16 Spring Street
Sydney, NSW 2000

# Moorebank Intermodal
# Urban Heat Island Mitigation Strategies Modelling

06.06.2019

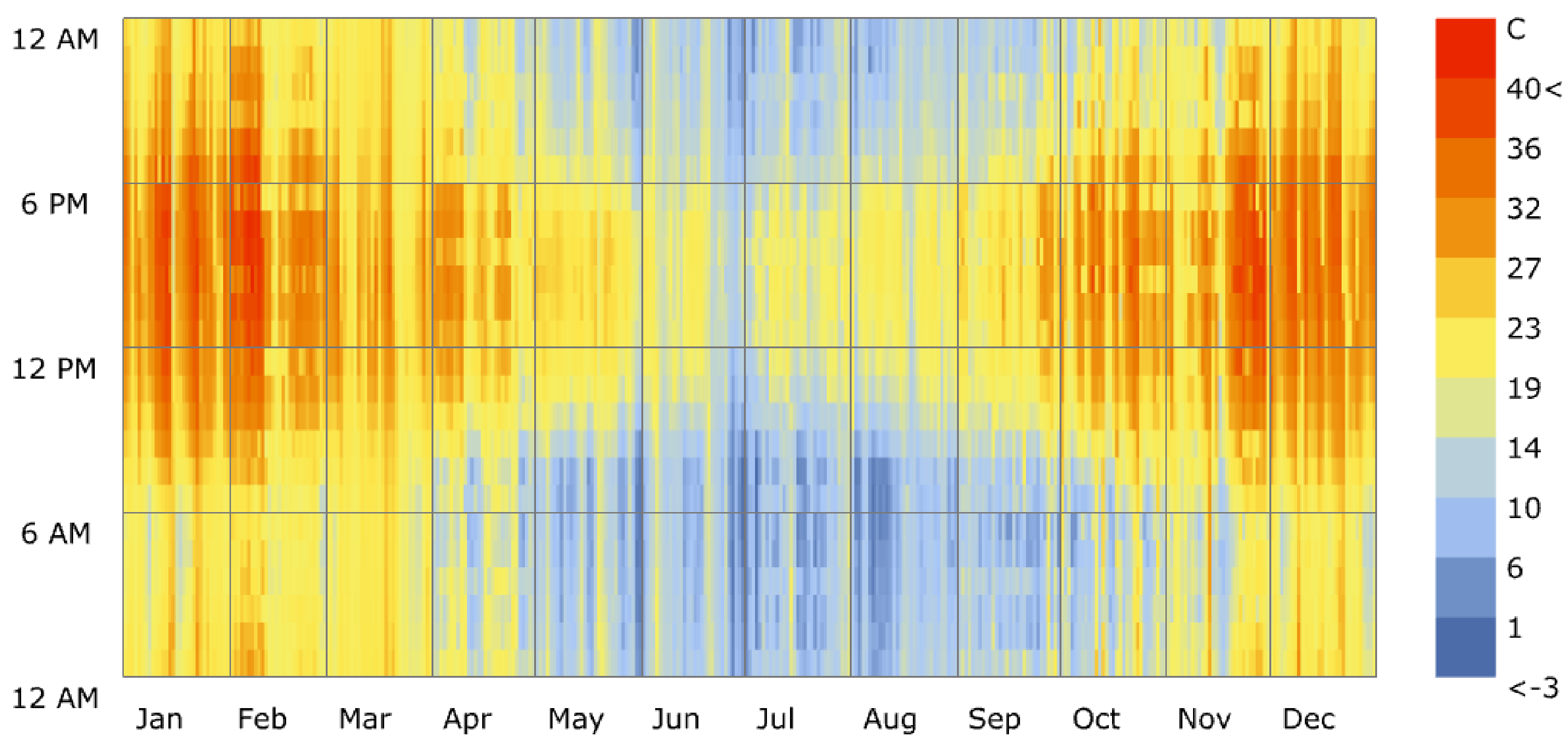
## Introduction

Arcadis produced the Urban Heat Island Mitigation Strategy MPE Stage 2 report to address the condition of consent in terms of Urban Heat Island (UHI). In the report, they examined different UHI mitigation strategies.
Several strategies were modelled by Integral Group to get a more realistic understanding of the strategies achieving the outcomes specified in the condition of consent – a 4°C degree decrease in temperature compared to neighbouring industrial developments.

Integral Group built a model of the MPE site based on the local weather data, using the Grasshoper software and Urban Weather Generator engine, to compare it to the neighbouring industrial sites and measure the impact of the UHI Mitigation Strategies.

## Site Context / Weather Data

- The project site is the new Moorebank Precinct East
- This report iteration uses the newest site layout (as of 06-06-2019) as indicated by the dotted line across the northeast site corner.
- This analysis uses local weather data from the Holsworthy weather station




Dry Bulb Temperature (C) - Hourly
Holsworthy Control Range_NSW_AUS
1 JAN 1:00 - 31 DEC 24:00

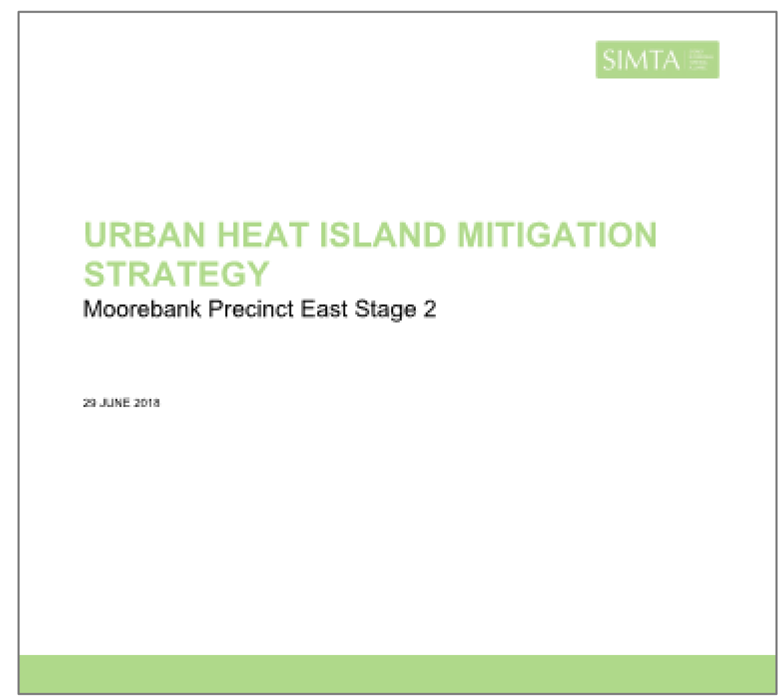

Weather Station in Holsworthy, NSW

## Methodology

- Integral Group has analyzed the Moorebank Precinct East Stage 2 Site using the state-of-the-art Urban Heat Island analysis tool

- The model is built in Grasshopper and uses the Urban Weather Generator (created by MIT) to predict UHI conditions based on a variety of site inputs

- A major input into this analysis was the documentation included in the UHIMS report generated by Arcadis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URBAN HEAT ISLAND MITIGATION STRATEGY

Moorebank Precinct East Stage 2

29 JUNE 2018

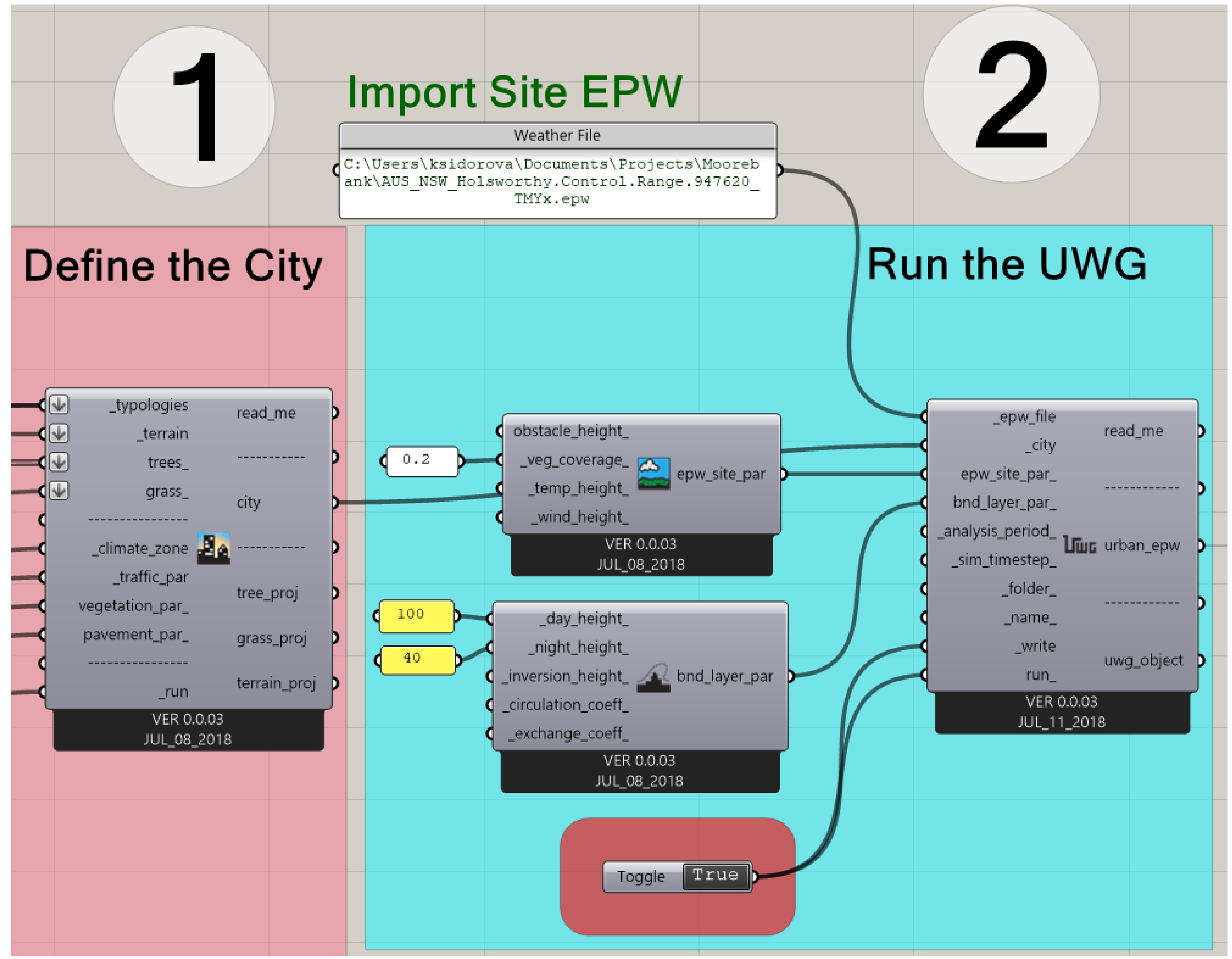
## Modeling Inputs

Currently Model includes following UHI Mitigation Strategies:

- 17% of site is Vegetation
    - 7% Trees (one canopy tree every 30m²)
    - 10% landscaping
- High Albedo Roof (0.65)
- Energy efficient building design (4-star Green Star equivalent)
- Current building layout

Additional Key Parameters in model:

- 40% of site is Building footprint
- 38% of site is Pavement (concrete and asphalt)



## UHI, Surface and Canopy Temperature

When discussing Urban Heat Island, there are two predominant temperatures that are considered:

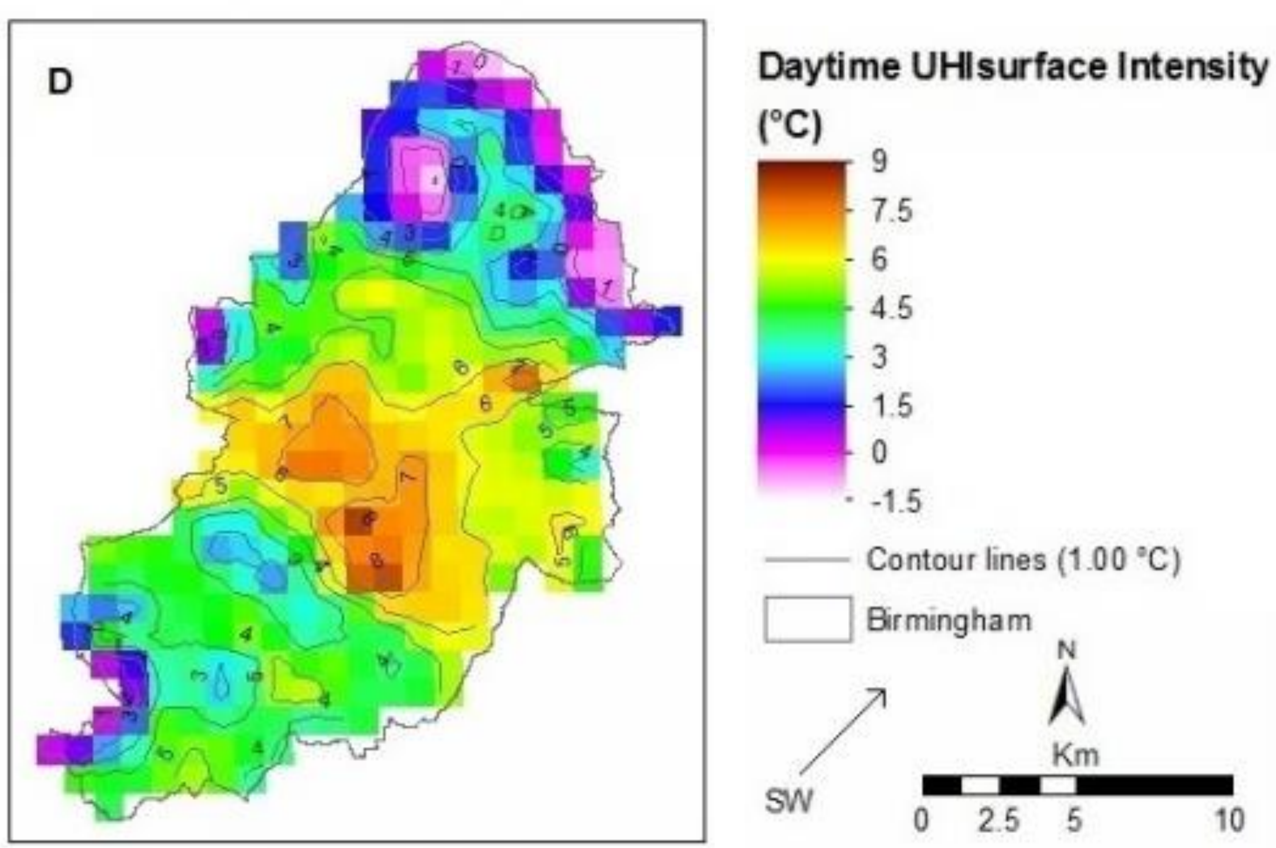
1. **Surface Temperature** – this is the temperature of the surface, often captured by satellite images and also called Land Surface Temperature. Typical Intensity can vary by **+/- 10°C** due to UHI effects


2. **Canopy Temperature** – when looking at models of urban areas, climate scientists will typically model the air temperature within the urban canopy (the height capped by the tallest buildings). It has a smaller Intensity, given the nature of air temperature, and can vary by **+/- 1 to 2°C** due to UHI effects.

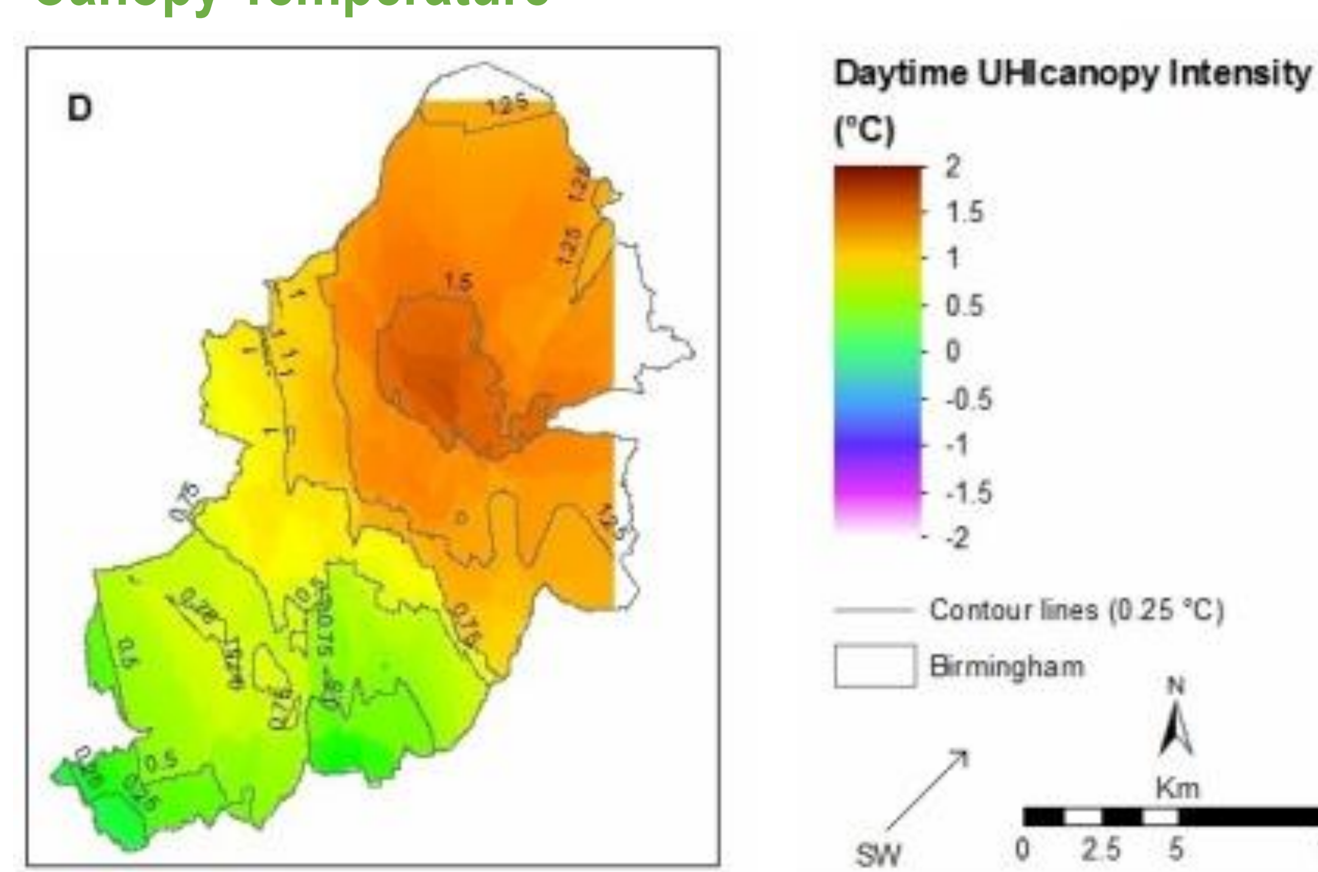
The following data has been pulled from a UHI study performed by Azevedo et al 2016 at the School of Geography, Earth and Environmental Sciences, University of Birmingham found the following correlation between Land Surface Temperature (LST) and Canopy Air Temperature:

**a 1°C difference in UHI Canopy Temperature correlated to approximately a 4°C difference in UHI Surface Temperature**.

### Surface Temperature




### Canopy Temperature

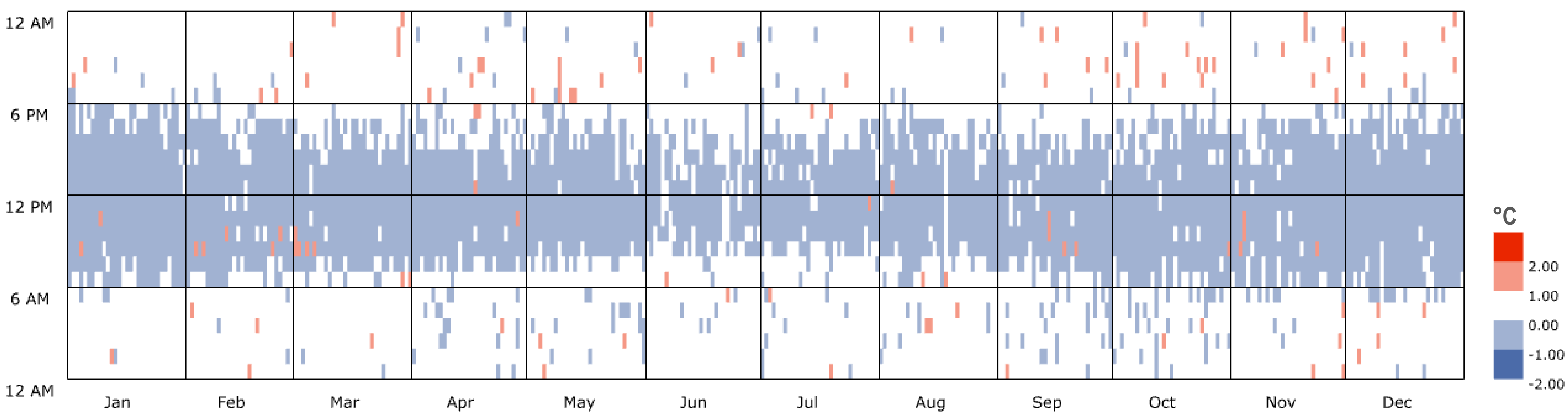


## UHI Mitigation Strategies Impact on Surface Temperature

Integral Group have built a model of the MPE site to show the benefit of adding UHI Mitigation Strategies.

This chart shows the temperature difference for each hour of the year for a design with no UHI MS versus a design including UHI MS.

The blue band throughout the centre of the graph indicates that there is a 1°C temperature reduction in canopy temperature for most hours throughout the year between 6am and 6pm due to the inclusion the UHI MS. **This 1°C canopy temperature reduction correlates to a 4°C reduction in Surface Temperature.**




MPE without UHI MS versus MPE with UHI MS

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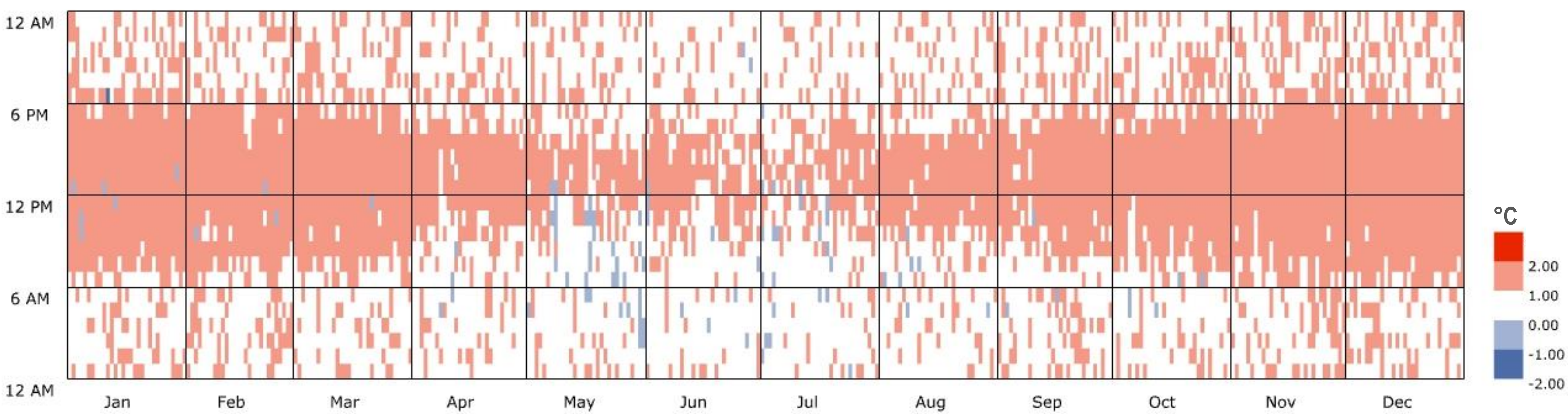
## MPE Site with the Mitigation Strategies vs Adjacent Site DJLU

Integral Group have built a model of the DJLU site, including the landscape, tree and building coverage, and compared it to the MPE site with the UHI Mitigation Strategies.

The light pink colour in the graph demonstrates that the MPE site performs 1°C warmer than DJLU over summer months.



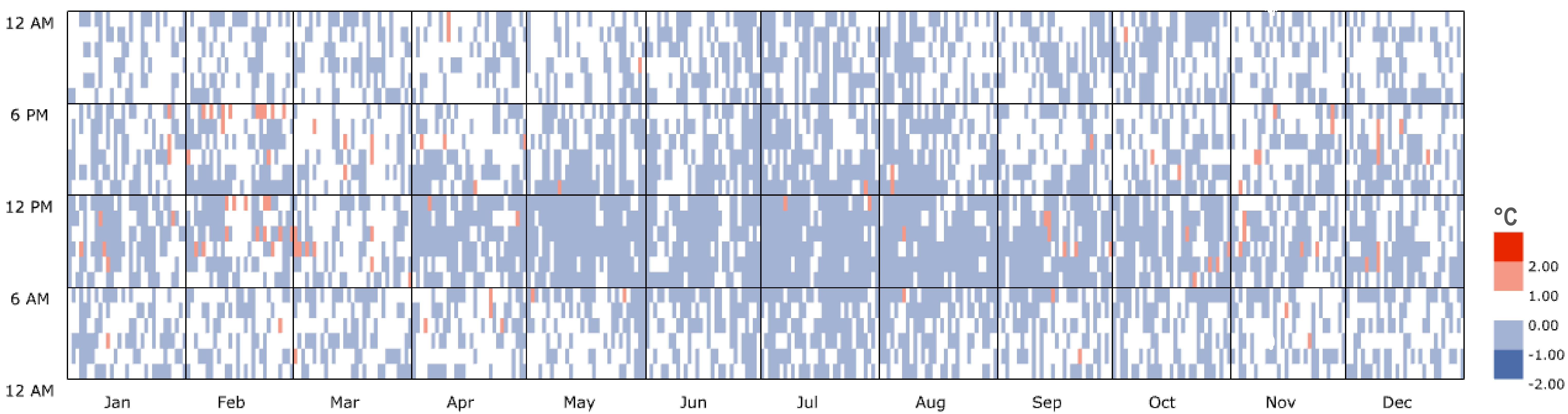

**MPE UHI MS versus DJLU**

## MPE Site with the Mitigation Strategies vs Adjacent Site Goodman

Integral Group have built a model of an additional neighbouring industrial site (Goodman) and compared it to the MPE site with the UHI Mitigation Strategies. The peak temperature reduction between these two sites shows a 1°C reduction in canopy temperature at the MPE site.

The Goodman site layout is more similar to MPE, and is good comparison point for the MPE site performance.

This magnitude of temperature reduction is greater between these two similar sites (as compared to the previous slide showing MPE versus DJLU).




MPE UHI MS versus Goodman

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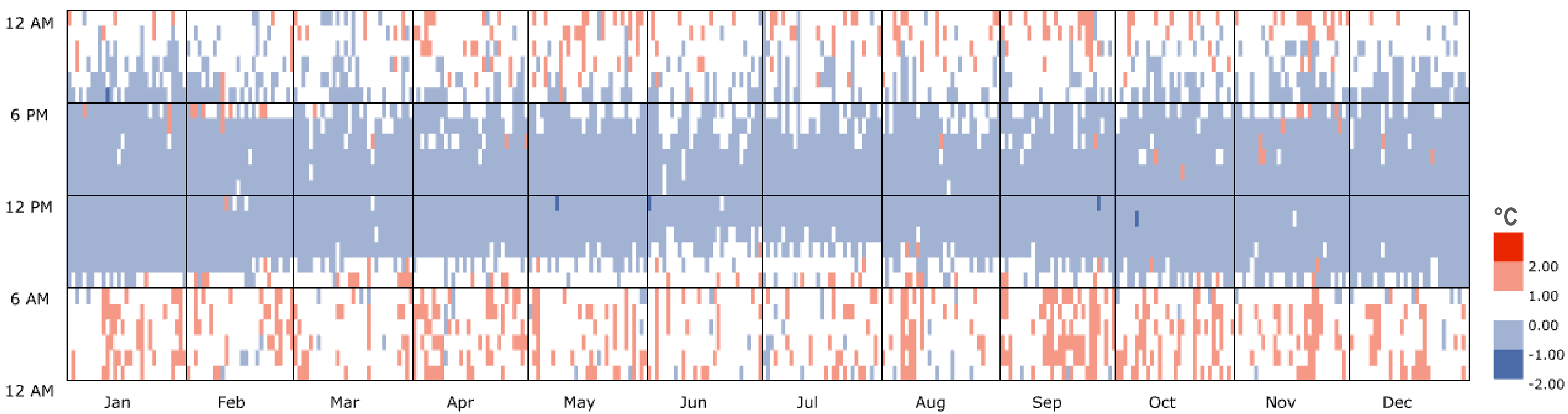
## Sensitivity Analysis (Greenfield Site vs Developed Site)

A sensitivity analysis has been undertaken at the outset to determine which means of measurement should be applied. Based on the modelling efforts (including full tree and grass coverage of the site with no buildings) and referenced literature, a 4°C Canopy Temperature reduction is not achievable.

However, **the 1°C canopy temperature reduction correlates to a 4°C surface temperature reduction** which aligns with the project goals.

This correlation is based on the study by Azevedo et al 2016 described on slide 6.




Greenfield versus MPE UHI MS

## Conclusion

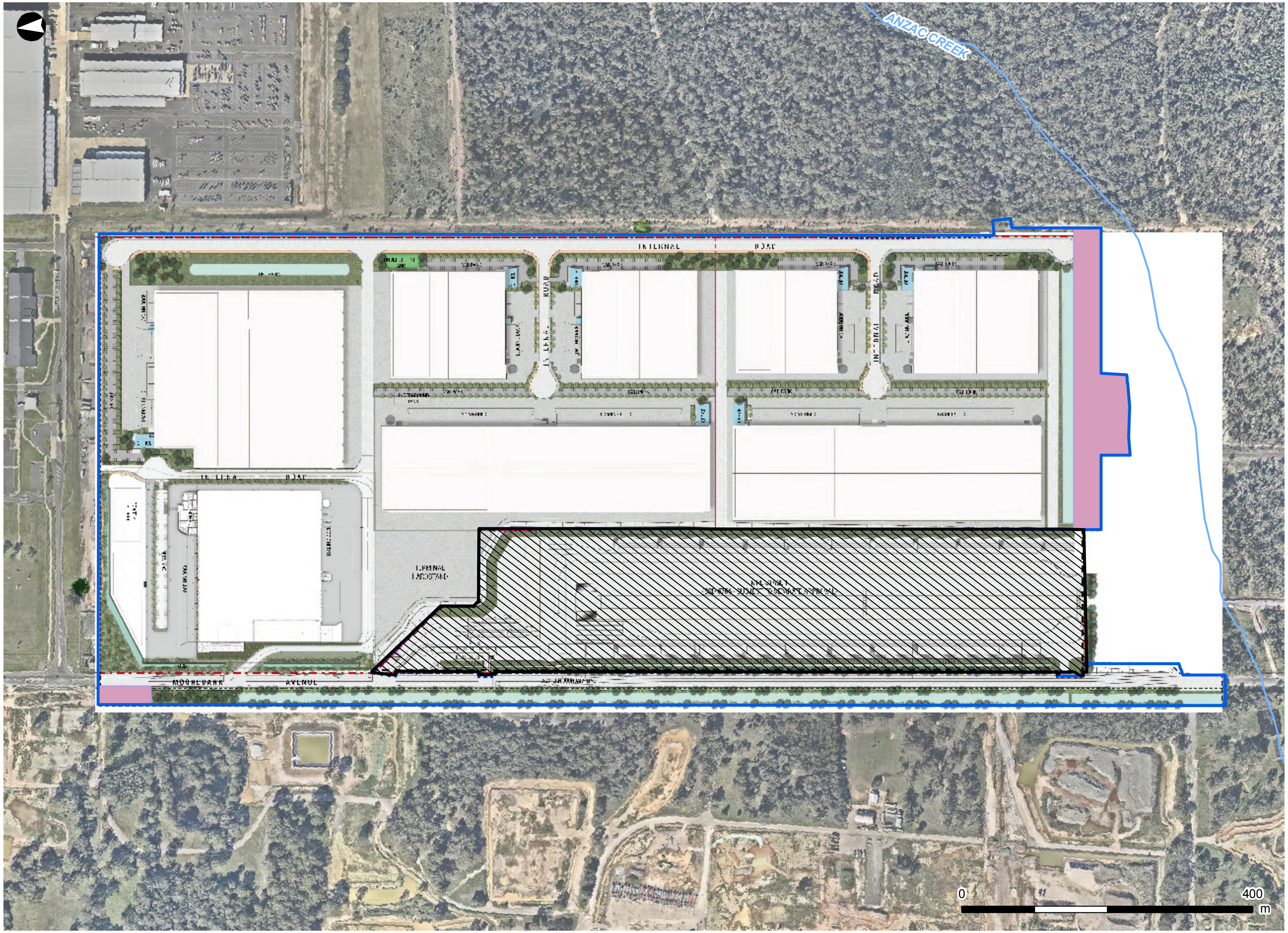
1. The modelling shows that the Mitigation strategies that have been incorporated into the MPE Stage 2 design have contributed to achieving a 4°C reduction in surface temperature.

2. Current MPE Stage 2 design achieves 4°C reduction in comparison to the neighbouring industrial site, based on the examined and modelled strategies.

3. A further sensitivity analysis shows that there are diminishing returns in further increasing the density of vegetation across the site. Hence, no additional vegetation is required, as the current landscaping presents sufficient reduction.

4. These results are based on the latest site layout (dated 06-06-2019). The change in site area from previously issued results is less than 1%. The results were not substantially different from the last iteration.

# Urban Heat Island Mitigation Strategy




LEGEND

- MPE Stage 2 operational area - UHIMS Modelled Area
- MPE Stage 1 (subject to separate approval)
- Proposed tree planting
- Proposed landscape planting area
- Proposed turf
- Proposed shared path
- Proposed OSD
- Future landscaped area
- Watercourse

1:8,000 at A4

SIMTA

ARCADIS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Coordinate System: GDA 1994 MGA Zone 56
Date issued: June 11, 2019

Aerial imagery supplied by Nearmap (Mar, 2019)


UHIMS modelling area and site characteristics

# APPENDIX D EVIDENCE OF CONSULTATION

## DPE/GANSW/GP review comments - Condition B139 Urban Heat Island Mitigation Strategy, Rev 5 W1P dated 29/06/2018

| Condition No. | Section in plan | GANSW Comments (Consolidated, with GP's comments) (Rev 5)<br>DPE Comments | Consolidated comments |
|---|---|---|---|
| **A14**<br>With the approval of the Secretary, the Applicant may submit any strategy, plan or program required by this consent on a staged basis. | Section 1.5 | The strategy is staged into Warehouse 1 Precinct, and Remainder of site. UHIMS W1P has been submitted to prior to the construction of built surface works in the Warehouse 1 Precinct (WIP), with a commitment for this stage to not constrain the delivery of a compliant design for the future stage. The Department notes that design and construction of the Freight Village will occur once there is sufficient demand for this site.<br>**1. Please update section 1.5 with staging of W1P to note that an updated UHIMS W1P will be prepared to address Freight Village, to be submitted to the Secretary for approval together with a request for approval of the revised staged UHIM W1P (incl. Freight Village) from the Secretary. The Stormwater Management Plan under condition B40 which has been staged for W1P will also need to be updated with details of stormwater management pertaining to the Freight Village and submitted to the Secretary for approval.** | 1. Section 1.5 has been updated to include the following:<br>"The UHIMS is a strategy document and will not be staged as it considers the Project holistically. The UHIMS is not intended to demonstrate the detailed design of the Project however, provides recommendations for strategies that could be implemented to minimise the UHI impacts. Recommendations of this UHIMS have been incorporated into the following documents:<br>• Development Layout Plans, Water Sensitive Urban Design (WSUD) plans and architectural details as required by CoC A22, A23 and A24 respectively<br>• Urban Design and Landscape Plan (UDLP) as required by CoC B140 and B141<br>• Construction Environmental management Plan (CEMP) as required by CoC C1<br>• Operational Environmental management Plan (OEMP) as required by CoC C3." |
| **A15**<br>If the submission of any strategy, plan or program is to be staged, then the relevant strategy, plan or program must clearly describe the specific stage of the development to which the strategy, plan or program applies, the relationship of the stage to any future stages and the trigger for updating the strategy, plan or program. | Section 1.5 | The strategy is staged into Warehouse 1 Precinct, and Remainder of site. UHIMS W1P has been submitted to commence construction of Warehouse 1, with a commitment for this stage to not constrain the delivery of a compliant design for the future stage.<br><br>The UHIMS – Remainder of Site will be submitted prior to commencement of permanent built surface works/and or landscaping for the remainder of the Project site as a whole. DPE notes that this stage excludes the permanent built surface works of the freight village, with an update proposed "or as incorporated into the UHIMS – Remainder of Site". DPE notes that at this stage of the project, there is insufficient demand for the design and construction of the freight village.<br>**2. As queried in the UDLP, please clarify the staging for the UHIMS, as the current version does not contain strategies for the freight village. It appears that the freight village update is essentially another stage that should be articulated in the plan including an update to Section 1.5.4 – Triggers. See comment 1 above. DPE notes that**<br>**3. Please prepare figures which shows areas within each stage (W1P, W1P (inc Freight Village), Remainder of Site etc), at appropriate scale (1:500).**<br><br>**4. Please also include a Whole of Site figure for MPE Stage 2 depicting the relationship to each stage.** | 2. See comment #1<br><br>3. See comment #1. No figured required. The UDLP has been staged and clearly articulates this information.<br><br>4. See comment #1. No figure required. |
| **B139**<br>Prior to commencement of permanent built surface works and/or landscaping, or as otherwise agreed by the | This plan | Proponent submitted staged UHIMS for GANSW consultation on 29/06/2018. A meeting was held with DPE, GANSW and the Proponent to discuss next steps required for the UHIMS. The Proponent was advised to pursue a staged approach. An updated, staged Urban Heat Island Mitigation Strategy – Moorebank Precinct East Stage 2 – Warehouse 1 Precinct (Rev 5) was | *5.* See comment #1 |

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| Secretary, and **Urban Heat Island (UHI) Mitigation Strategy** must be prepared and submitted to the Secretary for approval, in consultation with the NSW Government Architect. The UHIMS must be prepared by a suitably qualified and experienced person(s) | | submitted to the Department on 19/10/2018 to reflect the Warehouse 1 Precinct and has been prepared by Arcadis in consultation with Reid Campbell (Architects) and Ground Ink (Landscape Architects).<br>**5. See comments above regarding staging of the freight village.** | |
| The **UHI Mitigation Strategy** must<br>(a) review the current architectural details, building layout, landscaping provision, shading provision, landscape irrigation, stormwater water detention and WSUD, as well as building and paving material specifications; | Section 4 | *Site Context..*<br>*Response to context is limited.*<br>**6. Update the UHIMS to demonstrate consideration for the MPE site as a whole, as well as a high-level discussion of the UHIMS issues for the precinct (MPE+MPW).**<br><br>*Building Layout*. Very wide canyon of the warehouses permits wind movement across the paved areas facilitating heat transfer. Impact of warehouse orientation on prevailing winds is considered to be low.<br>Building layouts offer limited landscape opportunities and good street opportunity.<br><br>*Architectural Details*. Further details required.<br>Section 4.3 does not provide sufficient review of the architectural details as required by the condition. The statements made are broad in nature and do not specifically relate to the architectural detail proposed. Condition B142 requires that warehouses and the freight village must be designed and operated to meet ESD principles. DPE notes that Section 2.2 discusses the sustainability initiatives (PV cells installation "and other energy efficient technologies"), implementation of the ISCA Rating tool with the Clean Energy Finance Corporation must achieve a design, As Built and Operation IS rating. The CEFC agreement that relate to sustainability performance are listed.<br><br>**7. This section will need to be updated once the UDLP architectural details have been updated. Provide figures that demonstrate relevant architectural details that will contribute to UHIM. For instance, include detail in a drawing or figure (and consistent with the UDLP) that demonstrates how the warehouse setbacks allow for cross ventilation. What design features will be incorporated to meet a minimum of 3 star Green Star rating? Section 2.2 states that the conditions of the CEFC financing include minimum implementation of a minimum 4 Star Green Star rating for each warehouse. Please clarify which rating will be achieved.**<br><br>4.4 *Landscaping Provision*. Minimum of 15% of the site will be landscaped at ground level. 10% of the project site will be soft landscaping. Trees and shrubs will be used as perimeter screening. The strategy recommends that preference should be given to green space within the outdoor meal break areas and breakout areas, and preference given to drought tolerant species.<br>Query the stated provision of landscape at ground level, soft landscaping, opportunity for people to have landscape space to enjoy meal breaks.<br>Grassed area offers no shade.<br>-The size and long-term width of the tree canopy is a critical determinant on the ultimate tree species selection. Currently this list has not been provided in this report. | 6. The UHI mitigation strategies in the UHIMS have been recommended for the entire MPE S2 site. UHI mitigation strategies for MPW have not been considered as it is not a requirement in the CoCs. MPW Stage 2 is still in assessment and has not yet been approved.<br>***NOTE: The UHIMS is a strategy document which provides recommendations of UHI mitigation strategies that could be implemented. The details of the mitigation strategies to be implemented are included within the UDLP and Development Layout Plans. These have not been replicated within the UHIMS.***<br><br>7. Section 4.3 of the UHIMS includes the architectural details that can be implemented to help mitigate the UHI effect. The UDLP (Appendix H1) includes the architectural details that are implemented throughout the site.<br><br>Refer to Section 4.2.1 of the UHIMS for further information on cross ventilation. Appendix H1 (Proposed Amended Warehouse 1) has also been updated to include the distances between each of the warehouses on the site.<br><br>The UHIMS and UDLP do not provide specific detail of the Green Star rating for the Project as this aspect of the Project is being managed separately for the internal features of the warehouse. However, the following design features in the UDLP which relate to Green Star credits include:<br>- Solar panels<br>- Bicycle parking facilities<br>- Rainwater harvesting tank<br>- OSDs, GPTs, bio-retention system<br>- Warehouse and shared path lighting<br><br>The Project is aiming for a 4 star rating and not 3 star, as 3 star is not applicable to the As-Built requirements rating. |

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| | | - Suggest minimum soil depth for all trees be 700mm and 1200mm as per stated in car parking areas. This depth should be at time of installation at least 70% of the ultimate Dia of the proposed canopy<br>**8. Please address comments in UDLP review table regarding minimum soil depth, canopy, and provision of landscaping at ground level, soft landscaping, and linkages for workers to landscaped areas. Update the UHIMS accordingly.**<br><br>*Shading Provision*. A mix of large canopy trees will be planted throughout the car parking areas and pedestrian pathways to provide shade. The plan proposes that car parking that directly adjoins landscaping, canopy trees that overhang parking would be integrated into that landscaping area, mixed tree planting will occur in carparking over the OSD basins with a minimum soil depth of 1.2 m, turfed office breakout areas, and street trees at the main site entrance from Moorebank avenue. The strategy recommends the use of advanced shrubs and canopy trees within car parking areas for screening of warehouse and to provide shade, creating an immediate shading effect (as opposed to waiting for seedlings to mature).<br><br>4.6 *Landscape Irrigation*<br>Landscaping for the Project has been designed to minimise the demand for water on the Project site to create and maintain a drought resilient landscape. The Plan states that irrigation for the purposes of UHI mitigation on the Project is not deemed appropriate. Climate resilient water supplies will not need to be installed as landscaped areas will contribute to UHI reduction through evapotranspiration. Water reuse will be implemented on the Project site through rainwater harvesting at each warehouse in accordance with CoC B40 and B142.<br>The proposed plans offer limited opportunity for shading.<br>The proposed grassed area is not shaded. Canopy trees not adequately defined in scale and span.<br>-The size and long-term width of the tree canopy is a critical determinant on the ultimate tree species selection. Currently this list has not been provided in this report.<br>- Suggest minimum soil depth for all trees be 700mm and 1200mm as per stated in car parking areas. This depth should be at time of installation at least 70% of the ultimate Dia of the proposed canopy<br>**9. Please address comments in UDLP regarding shading, size and long term width of tree canopy, species selection, and soil depth, and update UHIMS accordingly.**<br><br>*WSUD and Stormwater Management*,<br>The design of the Project incorporates multiple, free draining and elongated OSD basins which will maximise the potential for cooling effects experienced at the Project site. Cooling benefits from the OSDs will only be experienced while there is water within the structures; however, it is not deemed appropriate to prolong stormwater detention times on the Project site due to safety considerations. No new mitigation measures included in the strategy apart from those already incorporated in the design. Raingardens noted as only relating to OSDs and not broader WSUD opportunities within the site.<br>The applicant should explore using tree species that can live in a semi inundated state in suitable rain gardens in order to increase the potential growth of a variety of different tree species throughout the site. To mimic low lying swamp like vegetation common in this area. | As outlined in Section 4, Green Star was mentioned in the UHIMS because:<br>"In determining the appropriateness of the potential UHI effect, mitigation strategies consideration were given to the objectives and targets of the Project as a whole, including those for sustainability, Green Star initiatives and operability of the overall Project design. It is important that the overall Project considers all these targets and objectives when providing recommendations for the Project."<br><br>8. The UHIMS is recommendation document only. Site specific details are provided in the UDLP. Section 4.4 of the UHIMS has been updated to include the following:<br>"Refer to the Landscape Drawings in Appendix A3 and Appendix G of the UDLP for further detail on the soil depth, canopy, and provision of landscaping at ground level, soft landscaping, and linkages for workers to landscaped areas throughout the site. Refer to Section 3.1 and 4.1 of the UDLP for specific details on landscaping and green space for the Project."<br><br>9. The UHIMS is recommendation document only. Site specific details are provided in the UDLP. Section 4.6 of the UHIMS has been updated to include the following:<br>"Refer to Section 4.1 of the UDLP for details relating to the irrigation used at the site. Appendix A3 of the UDLP provides a typical garden depth figure outlining the different soil horizons and depths, and provides further detail on irrigation. In addition, Appendix A3 of the UDLP provides detail canopy tree shading, expected canopy spread and species selection.<br><br>The Landscape Vegetation Management Sub Plan (LVMSP) also provides site specific information on the maintenance and monitoring of landscaping at the site.<br><br>10. WSUD elements discussed and approved in the Stormwater Management Plan include GPTs, OSDs and raingardens. As such, no other options were considered appropriate for the facility due to size restrictions, industrial site context, cost and maintenance requirements. There is no requirement under B139 to provide an options assessment for WSUD elements; any assessment would be academic and not possible to be implemented due to the issues raised above. |

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| | | **10. The UHIMS lack discussion or consideration of other WSUD elements that do not relate to OSDs and raingardens. Please clarify if there are other options / opportunities that have been explored and if not, why.**<br><br>*Building Material Specifications*<br>Incorporated into the design are building structures that will be of a high design quality, and that building materials and colours should generally be maintained, including the incorporation of light coloured materials. The strategy recommends incorporating the use of high albedo materials for exteriors, reducing glare. Rooves should be designed with high albedo and high emissive materials, such as white roof coatings. PV cells for provisions of energy to warehouse, offices (and the freight village) is also recommended. Satisfactory.<br><br>*Pavement Specifications*<br>The strategy recommends the use of high albedo pavements, such as white-topping of asphalt, for high traffic areas, and to consider the use of permeable pavements for low traffic areas.<br>- Agree with the suggested mitigation of high albedo pavements for high traffic areas and permeable pavements in low traffic areas. Satisfactory. | |
| (b) make recommendations to mitigate the UHI effects generated by the development including but not limited to<br>(i) provision of WSUD elements; | Section 3.3.1<br>Section 3.4.1<br>Section 4.7 | The strategy explains the UHI effect of each element (Section 3.2), and then provides a literature review and description of potential UHIM strategies (Section 3.3). The advantages and disadvantages for each potential UHI Mitigation strategy within an industrial context are assessed in Section 3.4.<br>Recommendations for each element/treatment measure are detailed in Section 4.<br>The plan does not contain sufficient green infrastructure considerations considering the size of the development and the opportunities for improvement that it creates. Include green infrastructure elements in the plan and demonstrate how this will be implemented and what effect this will have on mitigating UHI Effect.<br>DPE notes GA comments.<br>The strategy commits to adopting WSUD elements to mitigate UHI effects and will be analysed further. Lacks detail on other WSUD elements that are not OSD or rain gardens.<br>**11. See comment 9 above regarding provision of other WSUD elements and provide further discussion of options.** | 11. See above |
| (ii) street tree planting | Section 3.3.2<br>Section 3.4.2<br>Section 4.5 | Section 3.3.2 contains information on the effect of street tree planting on UHIM through a literature review, but lacks clarity on what recommendations recommendations from the review will be included in the project. | 12. Yes, reference has been added to Section 2.1. |

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| | | | **12. Is this section consistent with the modelling references (Birmingham Study) undertaken for B139 (c)?**<br>The strategy considers planting of street trees and canopy trees to be an appropriate<br>**13. Describe where these considerations are being included within the W1P and update relevant drawing/figures.** | 13. Sections 3.3.2 and 3.3.3 of the UHIMS are only intended to provide information on the strategies available to mitigate UHI effect. Section 4.4 and 4.5 provides mitigating factors already incorporated into the design as well as mitigation recommendations incorporating shade. Section 6 lists the mitigation strategies which have been incorporated into the design.<br><br>Refer to Section 3.1.1 of the UDLP for the incorporation of canopy trees through the site, including the following: "Planting will comprise of mixed tree planting, as discussed in Section 4.1 and shown in Appendix A3 (Area 1 Masterplan and Landscape Sections). Examples of trees to be considered for along the northern and western boundaries of Area 1 include: Acacia decureens, Eucalyptus ampilfolia and Melaleuca linariifolia."<br><br>Refer to Appendix A3 in the UDLP for detail on the landscape design and inclusion of canopy trees throughout Area 1. |
| (iii) | landscape coverage and screening | Section 3.3.3<br>Section 3.4.3<br>Section 4.4 | The strategy considers it appropriate to further analyse green spaces (i.e. employee outdoor meal break areas).<br>GANSW considers the justification of the exclusion of the following not acceptable:<br><br>- Evaporative Spray Cooling. *Inappropriate due to the need for water treatment and the intended recreation/leisure purpose of this mitigation strategy. As such, evaporative spraying will not be analysed further as a Project specific mitigation strategy in this UHIMS.*<br>- Green Facades, *Inappropriate due to maintenance required (i.e. weeding, pruning watering) and increase in humidity levels, thereby an increase in thermal discomfort. Will not be analysed further.*<br>- Green Walls. *Inappropriate due to the overall purpose of the industrial site and high maintenance requirements. Expensive to install and maintain, increased water demand for irrigation of vegetation, increase in solid waste from pruning and weeding of vegetation.*<br>- Green Rooves. *Inappropriate as their use would conflict with the sustainability initiatives and ESD principles to include solar power generation on the warehouse rooves.*<br>- Permeable Pavement. *Inappropriate due to unsuitability of permeable pavement in high traffic areas and areas with high heavy vehicles use and will only be analysed for areas of low traffic volume.*<br>DPE notes GA comments.<br>**14. Update plan to reflect the outcomes of the UDLP review, and to demonstrate that in the absence of these strategies, temperature reduction would still occur. Include analysis of what the temperature difference would be if these measures were included as a comparison.** | 14. Section 5.3 and Appendix B of the UHIMS describes the modelling undertaken. The modelling completed by Integral Group (Appendix B) did not include the following:<br>- evaporative spray cooling<br>- green facades<br>- green walls<br>- green rooves<br>- permeable pavements<br><br>The modelling demonstrated a 4°C cooling against neighbouring industrial facilities and is therefore considered compliant with CoC B139 (c) as described in Section 5.3 of the UHIMS. No other modelling will be undertaken. |
| (iv) | use of building material including reflectivity | Section 3.3.4<br>Section 3.4.4<br>Section 4.8 | The strategy considers it appropriate to adopt cool rooves, and considers combining with PV cells. The strategy considers it appropriate to include cool building materials. DPE considers this acceptable. | 15. Section 4.8 of the UHIMS describes the approved Project, as per the RtS Design Plan and provides mitigation recommendations for building material specification specific |

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| | | | **15. Describe which structure are being built within the W1P with these considerations and update the relevant drawing/figures.** | to the Project as a whole. As required by the condition, this section is not intended to provide details on building material specification, and is only intended to provide recommendations to mitigate the UHI effects generated by the development. Section 6 lists the mitigation strategies which have been incorporated into the design including cool rooves and solar panels. Full details for Warehouse 1 is included within the staged submission of the UDLP which includes specific UHI mitigation measures to be implemented. These are also nominated on Development Layout Plans included within Appendix H1 of the UDLP.<br><br>For information purposes, Warehouse 1 will be built from light coloured building materials, translucent sheeting and solar panels. Refer to Section 3.2.1 and 3.2.2 of the UDLP for specific information on building materials. Refer to Appendix A2 (Solar Panels) in the UDLP for detail on the solar panels and roofing colour for Warehouse 1. |
| (v) | use of pavement material including reflectivity | Section 3.3.5<br>Section 3.4.5<br>Section 4.9 | The strategy considers high albedo pavement to be an appropriate measure and will be analysed further.<br>**16. Describe which structures within the W1P will be designed as high albedo pavements and include on the relevant drawings/figures.** | 16. Section 4.9 of the UHIMS describes the approved Project, as per the RtS Design Plan and provides mitigation recommendations for pavement specifications specific to the Project. As required by the condition, this section is not intended to provide details on high albedo pavement, and is only intended to provide recommendations to mitigate the UHI effects generated by the development.<br><br>Section 6 of the UHIMS lists the mitigation strategies which have been incorporated into the design. It is not proposed to use high albedo pavements within the development. High albedo pavement was not considered a feasible option in the UDLP due to the high embodied energy required for production of concrete. This is the only UHIMS recommendation that the UDLP does not incorporate due to sustainability considerations. |
| (vi) | improved green space maintained by independent, climate resilient water supplies, to achieve increased amenity and urban cooling; and | Section 3.3.2<br>Section 3.3.3<br>Section 3.4.3<br>Section 4.6 | The project has been designed to minimise the demand for water on site in order to create and maintain a drought resilient landscape. Irrigation is not deemed appropriate, and considers that there is no need for the installation of additional climate resilient water supplies.<br>**17. This section will need to be updated to reflect the comments in the UDLP regarding viability of plantings and how these will be sustained long-term. Are there opportunities for stormwater capture and reuse in order to sustain plantings that will provide improved UHIM outcomes?** | 17. Section 4.6 of the UHIMS has been updated to include further detail on the low drip irrigation system. For information on the connection of the rainwater harvesting tanks to the irrigation systems, refer to Section 4.1 and Appendix A3 (Typical Garden Detail) of the UDLP. This also provides further details on soil depth and plant varieties. |

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| (vii) heat generation from operations; and | Section 3.3.7<br>Section 4.10 | The strategy recommends that the following considerations sho0uld be incorporated in to the detailed design and operation of the Project:<br>*Anthropogenic Heat*.<br>The Project is aiming to demonstrate best practice design through the implementation of Green Star for the warehouses and other sustainability consideration which will influence the amount of anthropogenic heat released into the atmosphere from the Project. The strategy recommends that all warehouses on the Project site should be designed to meet a minimum of 3-star rating for design and as-built under the Green Star accreditation system. The project should achieve a minimum ISCA energy and carbon monitoring and<br>reduction credit rating of Level1. The Project should consider the use of light emitting diode (LED) lighting, opposed to incandescent light bulbs. Machinery should preference those with electric engines over combustible engines.<br>**18. Provide consideration of LED lighting, and low anthropogenic heat producing engines as per the GA comment above.**<br>- **Demonstrate these commitments on an indicative drawing/Figure.** | 18. Refer to the Lighting Sub Plan which demonstrates the LED lighting located throughout the site. It is not possible to demonstrate the use of low anthropogenic heat producing engines on a figure; further this is only a recommendation and not a commitment for the UHIMS. The use of renewable energy rather than combustion engines to power warehouses will also provide a reduction in anthropogenic heat. |
| **18.** include a design strategy with the goal to achieve a 4°C degree decrease in temperature compared to neighbouring industrial developments; | Section 5 | **19. Update this section to reflect the modelling undertaken by Integral, demonstrating that the difference in air and surface temperature is across the whole Warehouse 1 Precinct (and also whether this includes the freight village in the calculations).** | 19. Section 5.3 has been included to summarise the modelling undertaken by Integral Group. Appendix B includes the UHIMS Modelling Report by Integral Group. |
| **19.** details of where and how recommendations from the **UHI Mitigation Strategy** have been incorporated into the: | Section 0. | **20.** Update the strategy to include the design plans (when these are available), clearly demonstrating the UHIM treatments incorporated into the design | 20. The Development Layout Plans and Architectural Plans have been updated to demonstrate the integration of UHIMS, including:<br>• Use of cool rooves (i.e. translucent sheeting)<br>• Installation of solar panels<br>• Use of cool building materials and finishes<br>• Large awning roof over receiving and / or loading docks<br>• Incorporation of a bioretention structure as part of the stormwater management controls<br>• Incorporation of landscaping within car parking and provision of canopy trees throughout the perimeter of the site.<br><br>The plans are included in Appendix H1 of the UDLP. The plans are not included in this UHIMS. |
| (i) updated final Development Layout Plans and WSUD Plans required by conditions A22 and A23 | Updated final Development Layout Plans | **21. See comment 7 above.** | 21. The Development Layout Plans have been updated and are included in the UDLP (Appendix H1). The WSUD plans are also attached to the UDLP in Appendix H2. |

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| (ii) | updated final architectural details required by condition A24 | Final Architectural details | **22. Updated final architectural details will need to demonstrate how the UHIM mitigation strategies have been applied** | 22. The Architectural Plans have been updated and are included in Appendix H1 of the UDLP. See comment #20 for the UHI strategies incorporated into the Architectural Plans. |
| **(iii)** | **UDLP required by condition B141;** | **UDLP** | **23. Please ensure that the interdependencies between the UHIMS and UDLP are addressed, and that both clearly reference the other, and reflect the same commitments following consultation with GA and DPE review.** | 23. UHIMS is a recommendations document. Recommendation from the UHIMS (Section 6) have been incorporated into the UDLP where applicable, such as the incorporation of canopy trees, light coloured building materials, translucent sheeting and LED lighting. |
| (iv) | CEMP required by condition C1; and | CEMP | **24. When final design has been developed, ensure that CEMP sub-plans that reference specific design elements or contain the plans are updated to reflect the final design.** | Noted. |
| (v) | OEMP required by condition C3. | OEMP | **25. When final design has been developed, ensure that OEMP sub-plans that reference specific design elements or contain the plans are updated to reflect the final design. Ensure that Long and short-term landscape maintenance management measures are included in the LVMP sub-plan.** | Noted. |