

Harbour Heat Rejection Impact

Assessment report

Contents

1. Objectives of assessment	3
1.1 Background	3
1.2 Purpose and scope	3
1.3 Report structure	4
2. Site and project descriptions	5
2.1 The Site and surrounds	5
2.2 The Project	7
3. Site analysis	10
3.1 Climate	10
3.2 Harbour hydrodynamics	11
3.3 Waves	12
3.4 Ambient air and water temperature	13
3.5 Proposed sea-water cooling system	13
4. Hydrodynamic Model	15
4.1 Introduction	15
4.2 Sydney Harbour MIKE3 FM Model	15
4.2.1 Model Mesh and Bathymetry	15
4.2.2 Boundary Conditions	19
4.2.3 Bottom Friction	19
4.2.4 Eddy Viscosity	19
4.2.5 Heat Exchange	19
4.2.6 Walsh Bay Heat Rejection System	19
4.3 Model Verification	20
5. Thermal Plume Scenario Modelling	25
5.1 Assessment Criteria	25
5.2 Modelled Scenarios	25
5.3 Model Results	26
6. Conclusions	29
7. References	30
Appendix A. Temperature Impact Maps	31

1. Objectives of assessment

1.1 Background

Infrastructure New South Wales (INSW) is acting as Principal for the design services of the Walsh Bay Arts Precinct (WBAP) project on behalf of the client, Arts New South Wales. The project will integrate the WBAP into Sydney's Cultural Ribbon, and will complement other cultural initiatives in the surrounding areas, such as at Barangaroo. WBAP will provide facilities for world-class arts and cultural tenancies in order to activate the area with a unique cultural offering and visitor experience. In addition, the upgrade will revitalise an important landmark of Sydney's waterfront cultural heritage.

Walsh Bay consists of four wharves, three of which have been upgraded within the past 30 years. The WBAP will consist of two of these wharves, Pier 2/3 and Pier 4/5 (plus the shoresheds, creating Wharf 4/5), as well as the waterfront in between these piers. It is proposed that the new facilities will feature an air conditioning system that utilises a closed loop sea water cooling system to reject heat. The closed loop sea water cooling system will transfer heat to adjacent sea-water without discharging any effluent. Jacobs was commissioned by INSW to undertake an assessment of the potential thermal impacts of the closed loop sea water cooling system on the receiving waters of Walsh Bay and Sydney Harbour. This report documents the outcomes of this assessment.

1.2 Purpose and scope

The purpose of this report is to assess the potential thermal impacts of the closed loop sea water cooling system associated with the Walsh Bay Arts Precinct project in accordance with the assessment requirements of condition B21 of the Conditions of Consent for the Stage 1 State Significant Development Application (SSDA), which states:

“Any future application which includes the installation of a harbour heat rejection system is to be accompanied by an environmental impact assessment report which includes an assessment of the following:

(a) seawater abstraction (if any); and

(b) associated water pollution (including thermal pollution) and use of antifoulants.”

Task components of the scope included:

- Develop a numerical model that can simulate the key dispersion processes within Walsh Bay and Sydney Harbour;
- Model the likely maximum thermal impacts of the proposed closed loop sea water cooling system operations; and
- Assess the potential thermal impacts of the sea water cooling system on the receiving water environment.

1.3 Report structure

The heat rejection impact assessment involved a number of technical analyses and modelling investigations as detailed in the following section of the report:

- **Section 2** provides a description of the study area and a summary of the proposed heat rejection system;
- **Section 3** describes the hydrodynamic model used to simulate currents and heat exchange processes;
- **Section 4** details the results of the heat rejection scenario modelling; and
- **Section 5** discusses and summaries the key findings of the study.

2. Site and project descriptions

2.1 The Site and surrounds

The Walsh Bay Arts Precinct (WBAP) (the “site”) generally comprises Pier 2/3, Pier 4/5 and its shore sheds which make up Wharf 4/5, as well as the adjoining waterway. The site has a street frontage to Hickson Road. The site is shown in Figures 1 and 2. The site is part of the Walsh Bay area which is located adjacent to Sydney Harbour within the suburb of Dawes Point. The site is located within the City of Sydney Local Government Area.

Walsh Bay is strategically located to the north of Sydney’s CBD in the vicinity of major tourist destinations including the Sydney Harbour Bridge, the historic areas of Millers Point and The Rocks, Circular Quay and the Sydney Opera House. The Barangaroo redevelopment precinct is located immediately to the south-west.

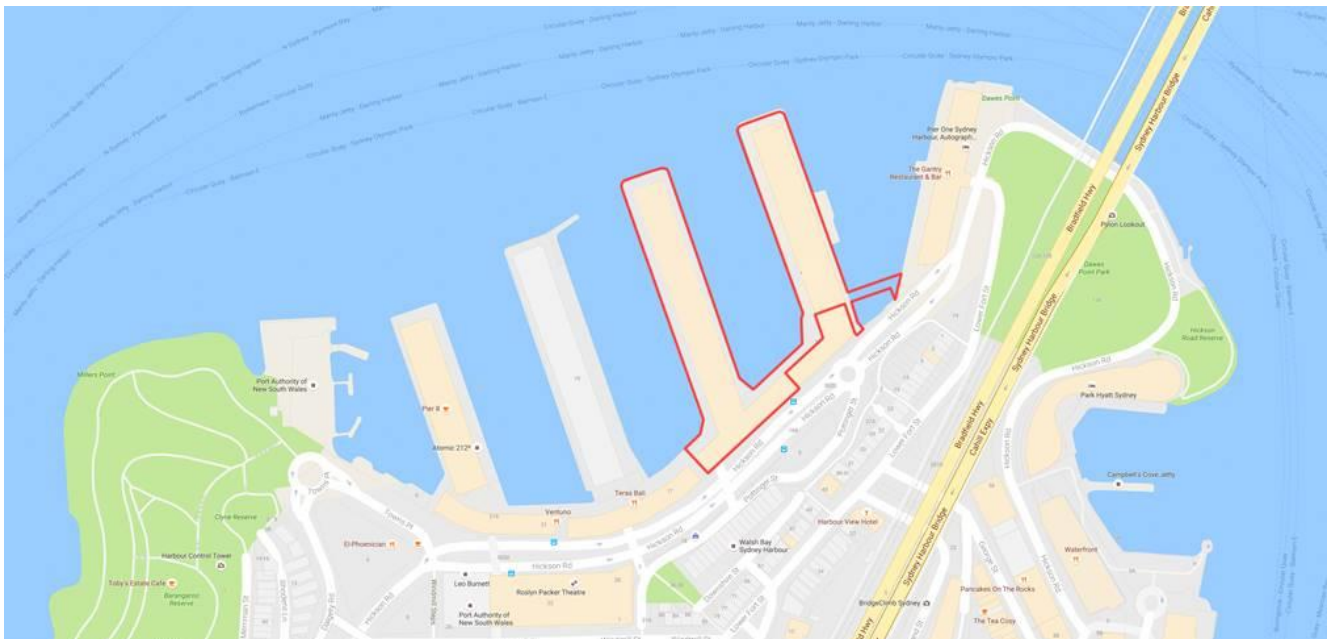


Figure 1: Site Location (Source: Google Maps)

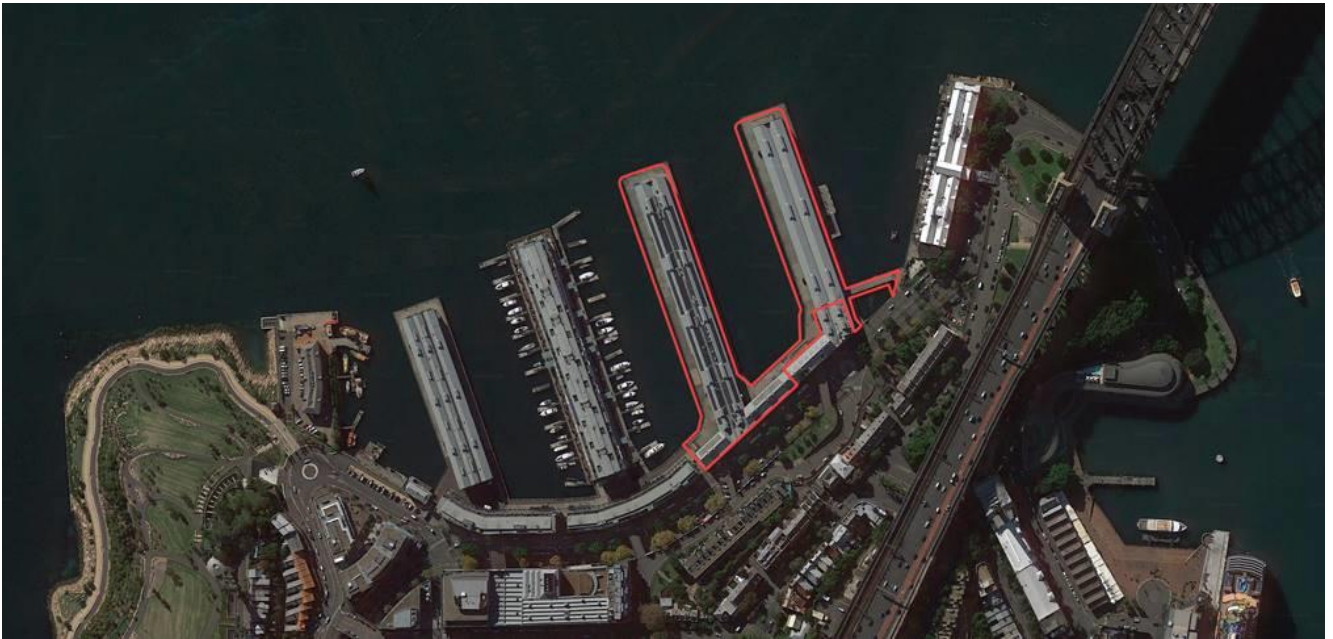


Figure 2: Aerial view (Source: www.nearmap.com)

Pier 2/3 is legally described as Lot 11 in DP 1138931 and Wharf 4/5 is legally described as Lot 65 in DP 1048377. The total area for these lots is 18,090sqm.

The land owner of the site is the Roads and Maritime Services (RMS). Both Pier 2/3 and Wharf 4/5 are occupied under various lease arrangements with Arts NSW, Department of Justice, primarily for arts and cultural uses.

The area of water that the project proposes to build over is also owned by RMS. Its land title description is Lot 12 in DP 1138931.

Walsh Bay comprises ten berths constructed between 1908 and 1922 for international and interstate shipping. These are collectively known as the Walsh Bay Wharves. The Walsh Bay Wharves Precinct is listed as an item on the State Heritage Register.

Bathymetry within the bay is typically around -10.0mCD, with Chart Datum relative to the Lowest Astronomical Tide (Source: Navionics).

The Walsh Bay Wharves comprise the following:

- Pier One which contains the Sebel Pier One Sydney Hotel;
- Pier 2/3 the last remaining undeveloped pier (has previously received approval for cultural uses, temporary arts events and some commercial events);
- Wharf 4/5 which is occupied by the Sydney Theatre Company (STC), the Australian Theatre for Youth Program (ATYP), Sydney Dance Company (SDC), Bangarra Dance Theatre and the choirs comprising Gondwana, the Song Company and Sydney Philharmonia;
- Pier 6/7 which has been redeveloped for residential apartments and associated boat marina;

- Pier 8/9 which has been redeveloped for office uses; and,
- Shore sheds aligning Hickson Road which contain a range of commercial activities, including restaurants, bars, shops and offices.

2.2 The Project

The approved Stage 1 development application comprised:

- A new waterfront public square between Pier 2/3 and Wharf 4/5;
- A series of new stairs and balconies on Pier 2/3 and Wharf 4/5 and modification to the roof of Pier 2/3;
- The inclusion of new tenancy spaces in Pier 2/3 and Wharf 4/5 for arts and cultural activities; and,
- The use of the precinct for arts festivals, events and pop-ups and associated uses, including restaurants, cafes and bars.

The WBAP Stage 2 State Significant Development Application seeks consent for construction works for the above to realise the WBAP project, as well as the proposed external alterations and additions to all of Wharf 4/5. It also seeks consent for new commercial and event uses in the precinct. Key aspects of the proposed development are outlined below:

Early works

- Early construction works comprising infrastructure upgrades, demolition, hazmat removal and sub structure works.

Pier 2/3

- Internal alterations and reconfiguration to provide for the following:
 - Performance venues;
 - Rehearsal rooms, production workshops, back of house facilities and offices;
 - Function spaces, bars, cafes and foyer spaces extending onto external gantry platforms (balconies) providing breakout space for internal foyers and allowing views of outdoor performances;
 - Mezzanine spaces for offices and back of house facilities;
 - Upgrades to meet compliance with current BCA, DDA and fire codes;
 - New lifts and stairs;
 - Creation of new commercial tenancies and public toilets;
 - Removal of some storey posts and beams to facilitate internal reconfiguration and new uses; and
 - Retention of a large proportion of the ground floor in its existing 'raw' heritage state for events and festivals including Sydney Writers' Festival and Biennale including venue and commercial hire.
- External alterations and additions comprising:

- New balconies and external stairs for fire egress;
- New external lift for access;
- Installation of glazing in existing cargo sliding door openings and other solid panels on the eastern, western and northern elevations to allow for views into and out of the building;
- Roof penetrations within the central valley at the southern and northern end to accommodate new performance spaces and associated structural modifications including truss strengthening;
- Installation of ESD elements, such as photovoltaic panels and seawater heat exchange systems; and
- Raising of the external floor level on the eastern side by introducing a new raised deck and continuous set of stairs beyond the existing column line.

Wharf 4/5

- Internal alterations and reconfiguration to the Bangarra Dance Theatre (BDT) tenancy to provide for the following:
 - Upgrade of the main rehearsal and performance spaces;
 - Upgraded foyer and exhibition space along the eastern frontage;
 - Improved office space at mezzanine level including a new lift and stairs;
 - Provision of a function space at ground level of the northern end of wharf with associated kitchen facilities; and
 - New entrance and new glazing in bays of sliding cargo doors, opening up the foyer and main studio to the Pier 4 apron.
- Minor internal alterations and additions to the SDC tenancy comprising:
 - Reducing the existing workshop space to create a fifth dance studio; and
 - Upgrading office and reception areas.
- External alterations and additions to SDC tenancy comprising:
 - Raising of the timber wharf deck adjoining the SDC café and opening of the facade with new glazing to activate the waterfront square.
- Creation of new commercial tenancies and public toilets;
- External fabric alterations around the Sydney Theatre Company (STC) tenancy comprising:
 - Improved street entry at Hickson Road involving relocation of the stairs to allow for an improved landing and point of arrival to the STC;
 - New 'gantry' balconies, stairs and lifts mid-wharf and at the end of the wharf to provide for improved accessibility and compliance with fire engineering solutions;
 - Minor amendments to the existing façade to accommodate new entries and exits along the wharf;

- Roof penetrations within the central valley at two locations to accommodate theatre and workshop spaces and associated structural modifications including truss strengthening; and
- Reinstallation of existing photovoltaic panels where applicable.

Wharf 4/5 Shore Sheds

- Internal alterations to reconfigure the choir spaces, including provision of a mezzanine for choir administration;
- Creation of new commercial tenancies at ground and mezzanine levels; and
- Provision of office space at ground level.

Public Domain

- Construction of a new waterfront square comprising a deck on piled structure;
- Shaded informal performance space on piled structure; and
- Changes to existing levels and steps down to facilitate access between the existing apron and new waterfront square.

New Uses

- Use of the precinct for arts festivals, events and pop ups as well as a range of activating uses such as retail, restaurants, cafes and bars.

3. Site analysis

3.1 Climate

The climate of Sydney is temperate, having warm sometimes hot summers and mild winter, with moderate extreme seasonal differences. The maximum and minimum air temperature varies from occasionally more than 40 °C in summer to just below 0°C in winter. The daily average temperature is typically in the high twenties during summer and low tens during winter (Refer to Figure 3).

Rainfall is fairly evenly spread through the year, with moderate to low variability. Precipitation is slightly higher during the first half of the year when easterly winds dominate (February–June), and lower in the second half (mainly July–September).

Figure 4 presents a wind rose for Sydney Airport, located approximately 11 km south-southwest of the site, derived from measurements spanning a 70-year period. The wind rose shows that the region is affected by three dominant wind directions, namely southerlies, westerlies and north easterlies. The strongest and most frequent winds are from the south. All wind speeds presented in this report are 10-minute average values.

These general wind characteristics are also evident in the wind data from the Sydney Observatory Hill station, located less than a kilometre south-southwest of the site (Figure 5). The wind data of this station shows that ambient winds around the site are typically below 6 m/s.

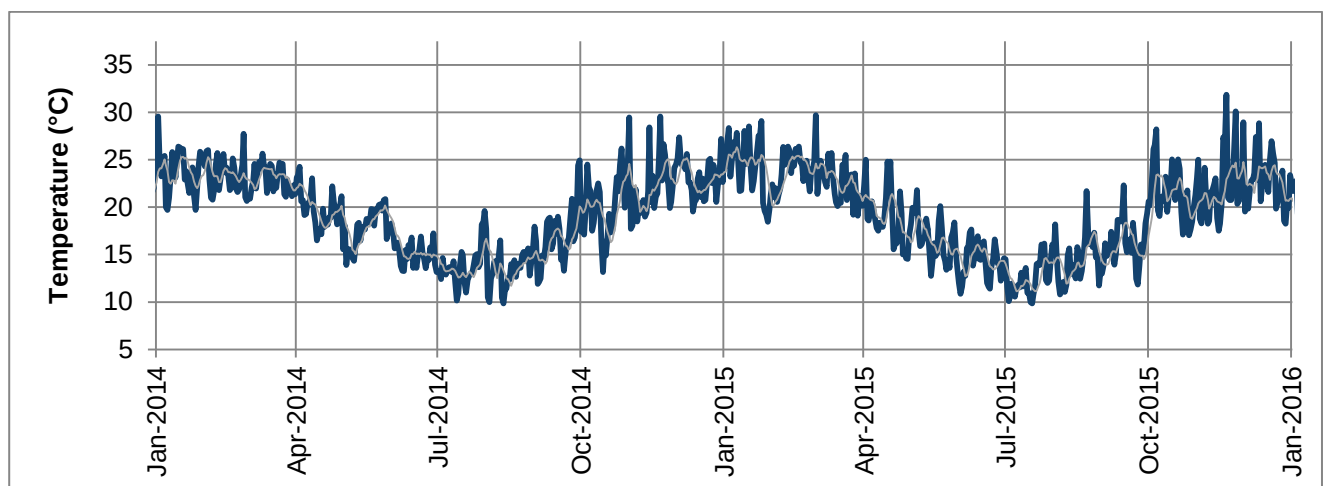


Figure 3 Daily Mean Air Temperature Observed at Sydney Observatory Hill Station

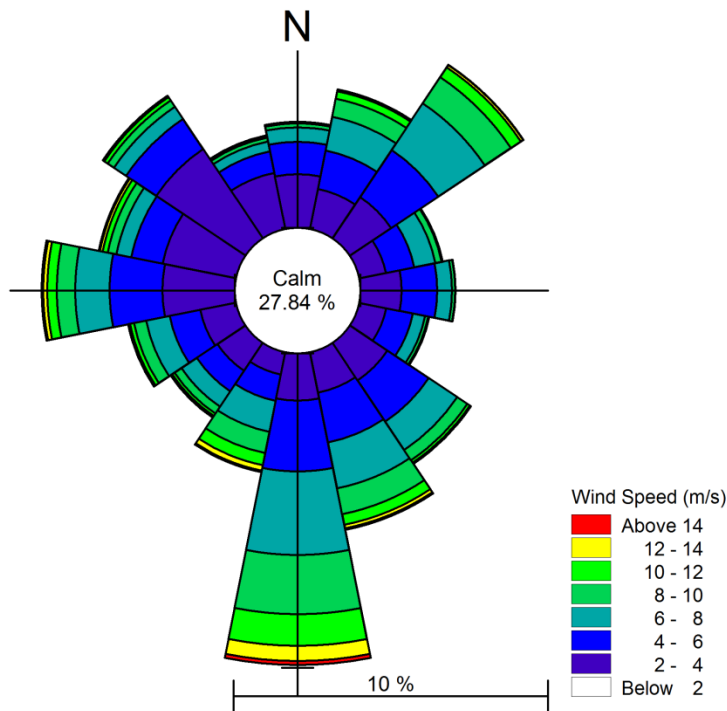


Figure 4 Sydney airport wind rose (1939 – 2009)

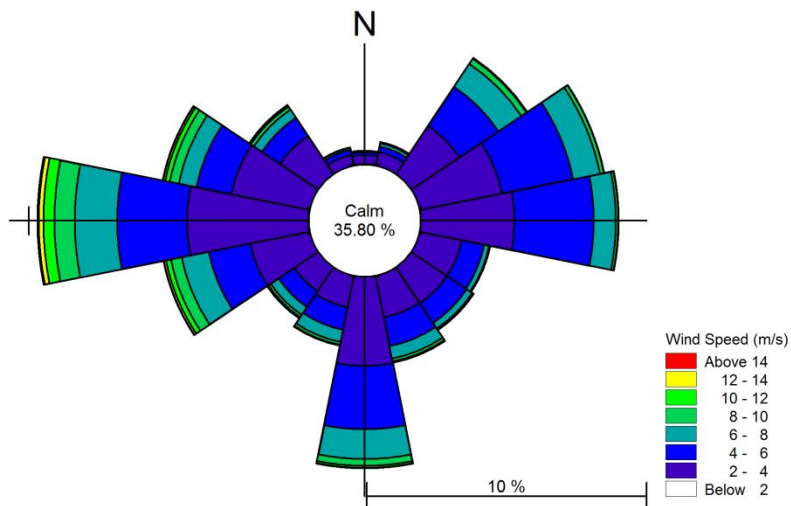


Figure 5 Sydney Observatory Hill wind rose (1997 – 2006)

3.2 Harbour hydrodynamics

Circulation within Sydney Harbour is dominated by the tides, with some influence from prevailing winds (Hedge *et al.* 2013). Tides within Sydney Harbour are semi-diurnal with a typical range of approximately two metres. Figure 6 presents tidal water level predictions for Sydney Harbour for the period February 2016 – March 2016. Tides propagate into the connected embayments and rivers, and their tidal tributaries. The speed of propagation of the tide up the estuary is primarily dependent on:

- Depth of the estuary; and
- Friction losses due to the roughness of the bed and banks and the non-uniformity of the cross section.

The tidal prism at a particular location is the volume of water that passes this location during the rise or fall of a tide. Therefore the tidal prism decreases from a maximum at the mouth of the embayment to zero at the limit of tidal influence.

Das *et al.* (2000) estimated discharge volumes to be up to 6,000 m³/s across the Heads at the peak of the ebb tide, with more than 4,000 m³/s coming from the main branch of Port Jackson and less than 1,500 m³/s coming from Middle Harbour (Hedge *et al.* 2013).

Tidal currents within Port Jackson flow in a general east-to-west direction during flood tide and a general west-to-east direction during ebb tide. Tidal flow velocity between Clyne Reserve (approximately 500m west of Pier 2/3) and the Sydney Harbour Bridge is typically less than 0.5 m/s. Locally, tidal currents within Port Jackson are influenced by the coves and points along the coast, resulting in the generation of weak eddies (National Geospatial Intelligence Agency, 2014).

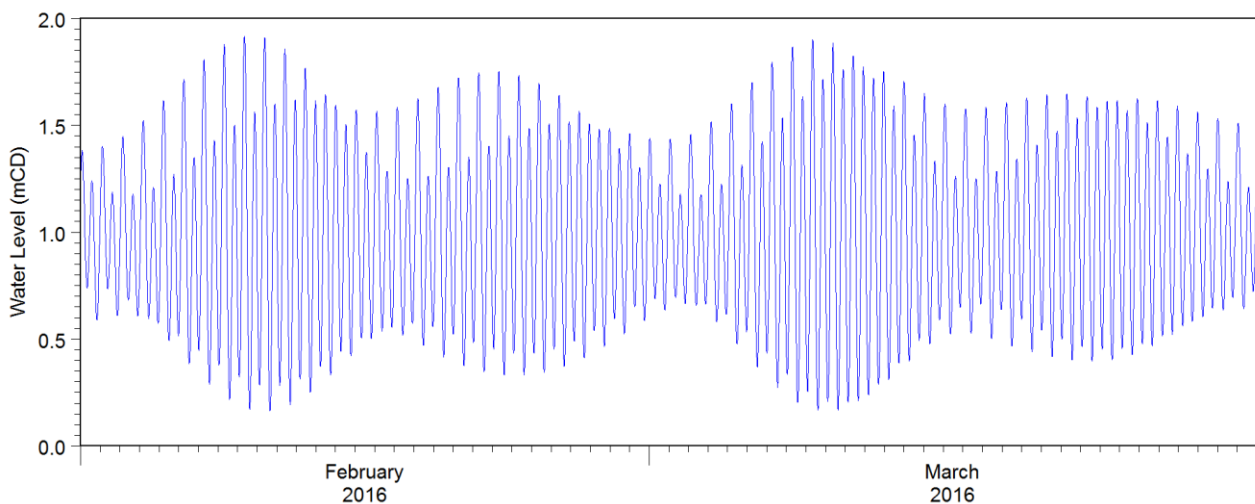


Figure 6 Tidal water level predictions for Feb/Mar 2016 at Sydney Harbour (Source: Australian Hydrographic Office, 2012)

3.3 Waves

The waves affecting Walsh Bay are dominated by waves generated within Sydney Harbour by local winds. Ocean swell entering Sydney Harbour through the Heads is considered to have no significant influence on coastal processes at the western part of the Harbour (Cardno, 2015).

Waves at Walsh Bay are generally of low height and relatively short period (generally less than four seconds) although occasionally larger waves associated with strong wind events may occur.

3.4 Ambient air and water temperature

Water temperature measurements taken at the mouth of the Parramatta River have been obtained from the Hornsby Shire Council. In addition, data has been extracted from the HYCOM global dataset, at an ocean location close to the mouth of the Sydney Harbour. These are provided in Figure 7.

Water temperature measurements taken at the mouth of the Parramatta River show a greater annual variation than re-analysis predictions from the HYCOM dataset.

Daily mean air temperature measurements obtained from the Bureau of Meteorology show that there is a strong correlation between ambient air and water temperature measurements taken inside the harbour. The 5th and 95th percentile water temperature values were derived from the Parramatta River dataset as a proxy of the typical annual ambient water temperature variation within Walsh Bay. The 5th and 95th percentile temperatures are 13.2°C and 26.8°C respectively.

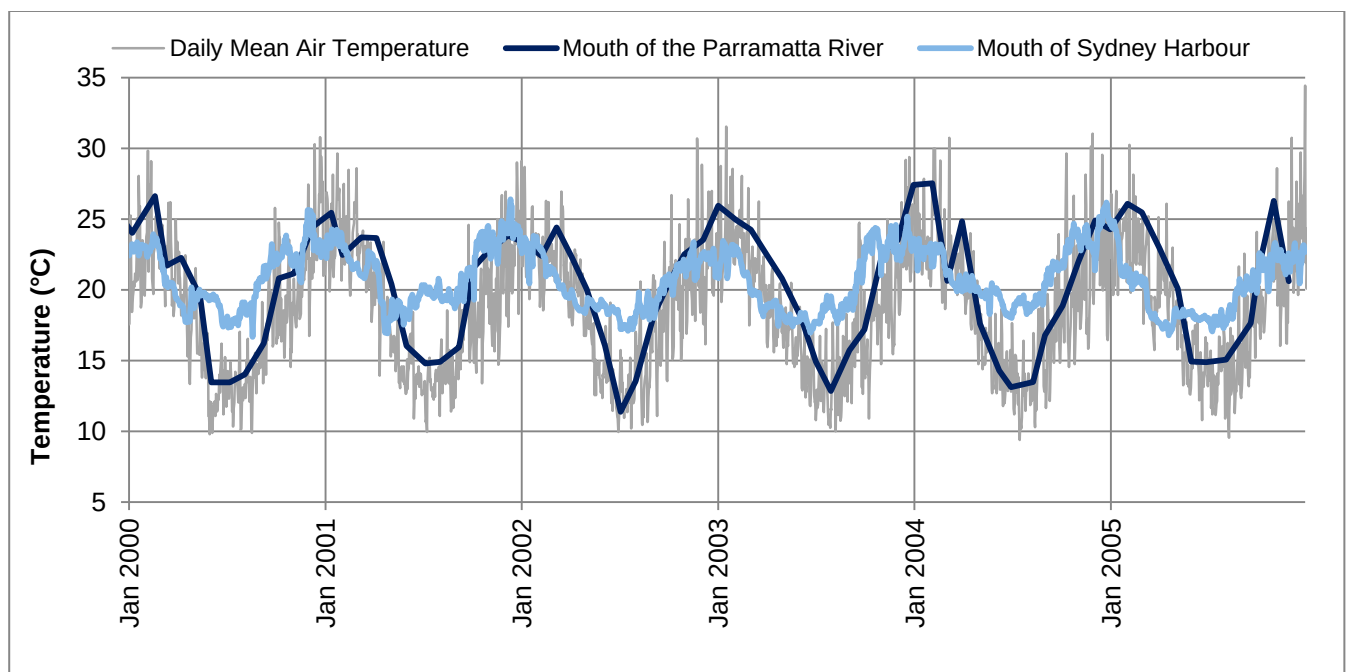


Figure 7 Ambient temperature measurements inside the Sydney Harbour estuary at the mouth of the Parramatta River (Hornsby Shire Council) and at the mouth of Sydney Harbour (HYCOM)

3.5 Proposed sea-water cooling system

The Walsh Bay Arts Precinct will feature an air conditioning system that utilises a closed loop sea water cooling system to reject heat. The heat rejection system will transfer heat to adjacent sea-water via a network of submerged coiled chillers.

At the time of writing, the design of the heat rejection system was not yet finalised, however preliminary details have been provided to Jacobs.

The heat rejection system will consist of a network of PEX Piping, coiled and mounted underneath the southern end of Pier 2/3, approximately 2m below low water mark. The system will have a capacity of approximately 1.2MW, and operate with cooling liquid at approximately 30-35°C. An example of a similar closed-loop Heat Rejection System being installed in Sydney Harbour is presented in Figure 8.



Figure 8 Photograph taken during installation of closed loop geexchange system at Woolloomoolloo Wharves, Sydney Harbour (Source: GEOEXCHANGE Australia)

4. Hydrodynamic Model

4.1 Introduction

A numerical modelling system was used to simulate the key dispersion processes operating within the Sydney Harbour estuary and to assess the potential thermal impacts of the Walsh Bay Heat Rejection System.

The numerical modelling system was developed using DHI's MIKE hydrodynamic modelling software, and comprises of a three-dimensional (3D) model of Sydney Harbour (Refer to Figure 9).

MIKE hydrodynamic modelling software is a commonly used tool to simulate hydrodynamic (water level variation and flow) and heat exchange processes in oceanic, coastal and estuarine environments. MIKE3 HD solves the 2D/3D Non-Linear-Shallow-Water-Equations (NLSWE) on a flexible mesh using a finite-volume numerical scheme. The model is based on the numerical solution of the 3D incompressible Reynolds averaged Navier-Stokes equations subject to the assumptions of Boussinesq and hydrostatic pressure (DHI, 2011).

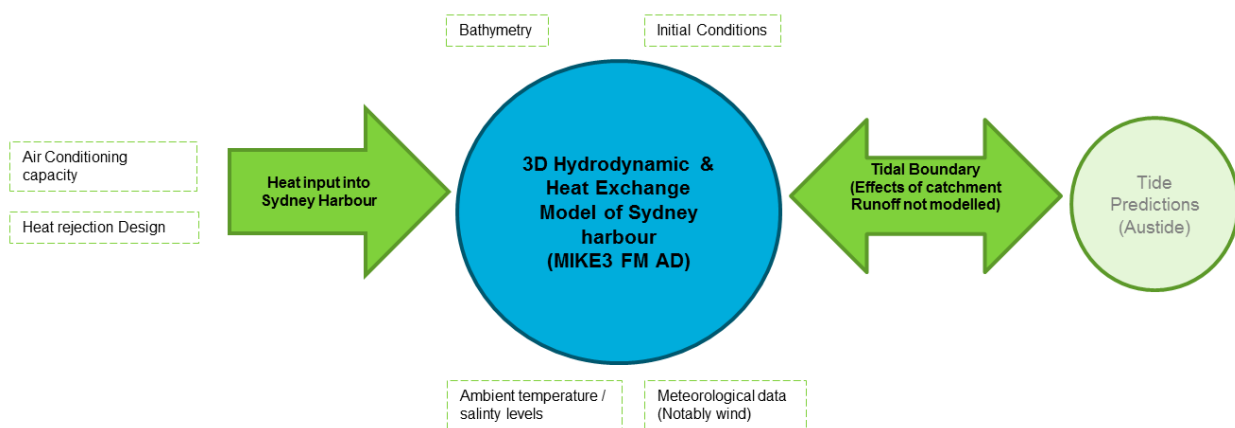


Figure 9 Structure of the Sydney Harbour Modelling System

4.2 Sydney Harbour MIKE3 FM Model

4.2.1 Model Mesh and Bathymetry

The model domain covers the entire estuarine section of Sydney Harbour and extends from the tidal limits of the Parramatta River to its outflow location, the Pacific Ocean. A layered flexible mesh approach was adopted to resolve the model in the vertical and horizontal domain (see also Figure 10). In the horizontal domain an unstructured mesh was adopted as shown below in Figure 11 and Figure 12 (all figures are displayed in MGA Zone 56 projection). In the vertical domain, the model uses a combined sigma / z-layer formulation with up to 10 discrete layers. The thickness of the z-layers varies over the depth, as shown in Table 1.

The model resolution was varied from approximately 1.0km element lengths around the offshore boundaries to approximately 20m by 20m in the vicinity of Walsh Bay.

A Digital Elevation Model (DEM) was developed by interpolating data extracted from Jeppesen Norway's C-MAP Professional+ electronic navigation database. Model bathymetry levels relative to chart datum were defined by sampling the digital elevation model at mesh nodes throughout the domain.

Table 1 Vertical mesh definition of the Sydney Harbour MIKE3 FM Model

Layer Type	Layer	Layer Thickness (m)	Location
Sigma	1 & 2	Varying: 2 equidistance layers	Surface to -2.0m
Z-Layer	3	2	-2.0m to -4.0m
	4	2	-4.0m to -6.0m
	5	2	-6.0m to -8.0m
	6	2	-8.0m to -10.0m
	7	5	-10.0m to -15.0m
	8	5	-15.0m to -20.0m
	9	10	-20.0m to -30.0m
	10	50	-30.0m to -80.0m

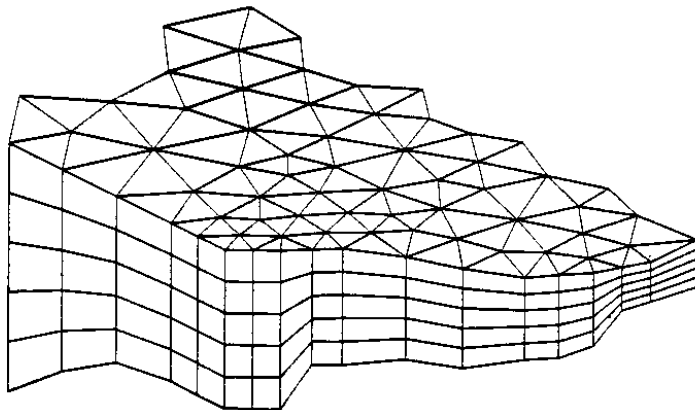


Figure 10 Principle of a 3D Flexible Mesh solution technique (Source: DHI, 2013)

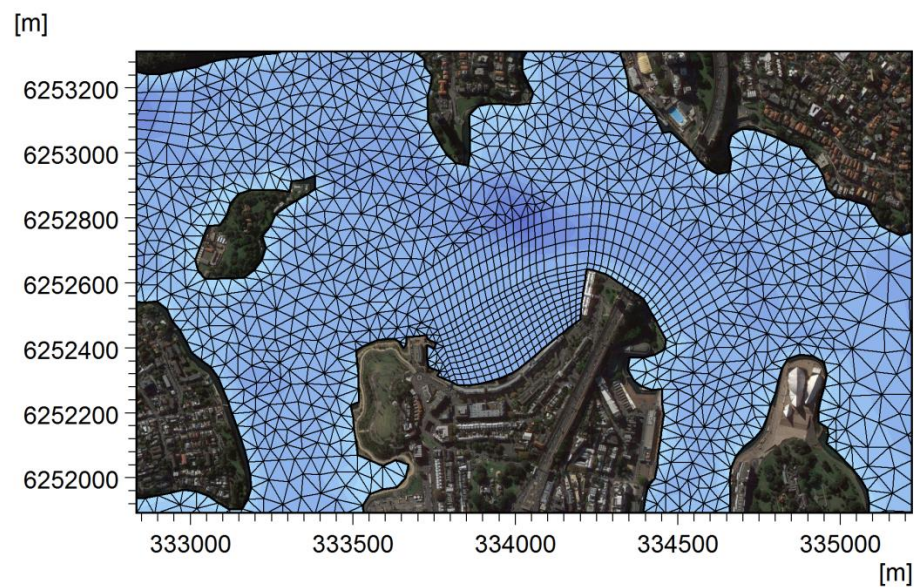


Figure 11 Model mesh adopted at Walsh Bay (MGA 56 projection)

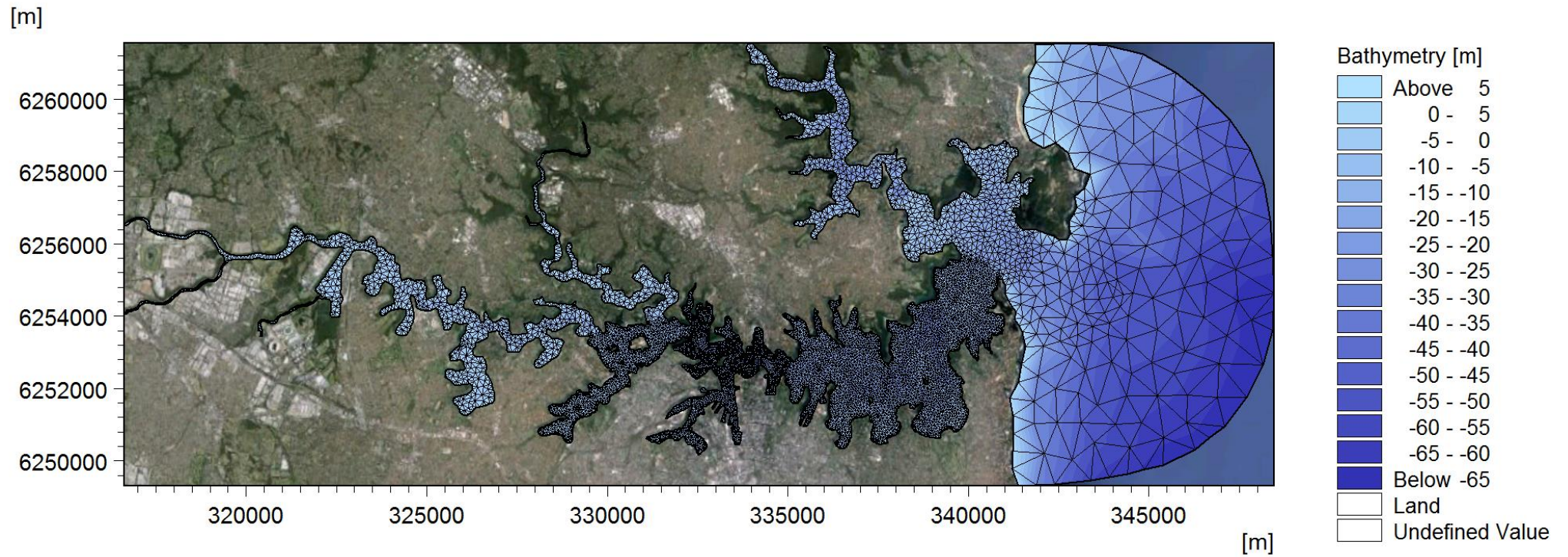


Figure 12 Model mesh and bathymetry of the Sydney Harbour model (MGA56 projection)

4.2.2 Boundary Conditions

Tidal constituents for Sydney (Fort Denison) were obtained from the Australian Hydrographic Service AusTide software (2012) and used to generate tidal height prediction levels for Sydney Harbour. These tidal levels were applied along the model's open boundary to drive tidal flows across the model domain.

4.2.3 Bottom Friction

Hydraulic bed friction was applied in the model as effective bed roughness length. A constant value of 0.066m was adopted throughout the wet domain with the exception of Walsh Bay. A value of 0.25m was adopted at the elements that intersect with the piled foundations of the piers at Walsh Bay.

4.2.4 Eddy Viscosity

A scaled eddy viscosity formulation was used to simulate dispersion processes in the model. The Smagorinsky model has been used to represent horizontal eddy-viscosity and a log-law formulation for vertical eddy-viscosity.

In lieu of site specific data, horizontal and vertical scaling factors of 1.0 have been adopted and a horizontal eddy viscosity coefficient of 0.28.

4.2.5 Heat Exchange

The seawater heated by the Heat Rejection unit will experience heat loss to the atmosphere where the heated water contacts the water surface.

In the model, atmospheric heat exchange has been simulated using the sensible heat flux module. The heat loss coefficient is a representation of the rate of heat loss per area for a given temperature differential between the surface water temperature and the air temperature. The value of the heat loss coefficient depends on the ambient water temperature and wind speed.

The heat loss coefficients recommended by Adams et al. (1981) have been adopted in this study. The adopted coefficient for each model scenario is presented in Table 2 in Section 5.2.

4.2.6 Walsh Bay Heat Rejection System

As aforementioned, the design of the WBAP Heat Rejection System is yet to be finalised and only preliminary information has been provided to Jacobs.

In the modelling, it is assumed that the Heat Rejection System will have a length of less than 20m and the heat emission of the Heat Rejection System can be represented by a point source.

At the location presented in Figure 13, at an elevation of -3mCD, a flow discharge was applied with a temperature of 35°C to represent the heat influx of each scenario (1.2 or 0.96MW depending on the season, refer to Table 2 in Section 5.2).

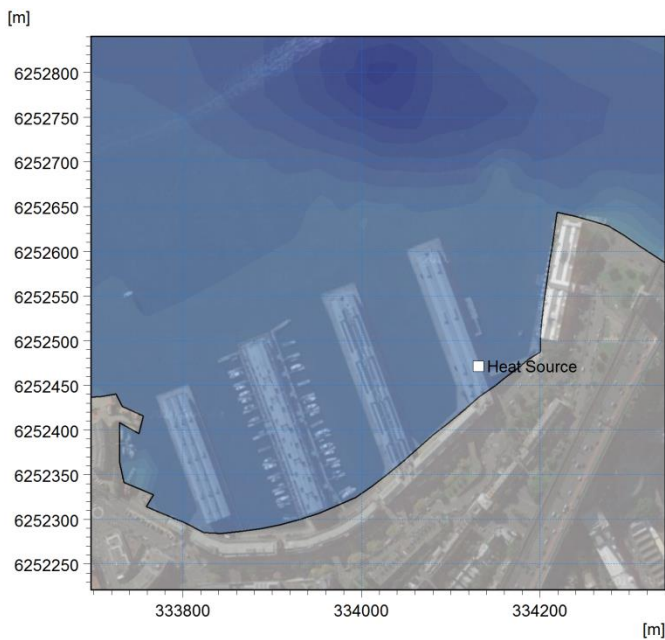


Figure 13 Modelled heat influx location

4.3 Model Verification

No current measurements were available in the vicinity of Walsh Bay, hence the model was verified using tidal survey data measured on 19 March 1992, as reported in the Manly Hydraulics Laboratory Report MHL 1988 (2010). This survey data consisted of tidal discharge and water level measurements taken across 10 transects within Sydney Harbour. The location of these transects are shown in Figure 14.

Calibration plots of predicted and modelled water levels and tidal flow discharges during the measurement period are presented in Figure 15 to Figure 16 for each of the transects. These plots show good agreement between the model results and the measured water levels and flows. The performance of the model was verified by simulating the period 28 February to 2 March 2016 and comparing model predictions against current measurements from a bottom mounted ADCP installed near Balls Head. Figure 17 compares the model predictions of the current magnitude and direction against ADCP measurements averaged over the top 12m. This plots shows that the model predicts current speed and direction with a high correlation against measurements made at the Balls Head ADCP.

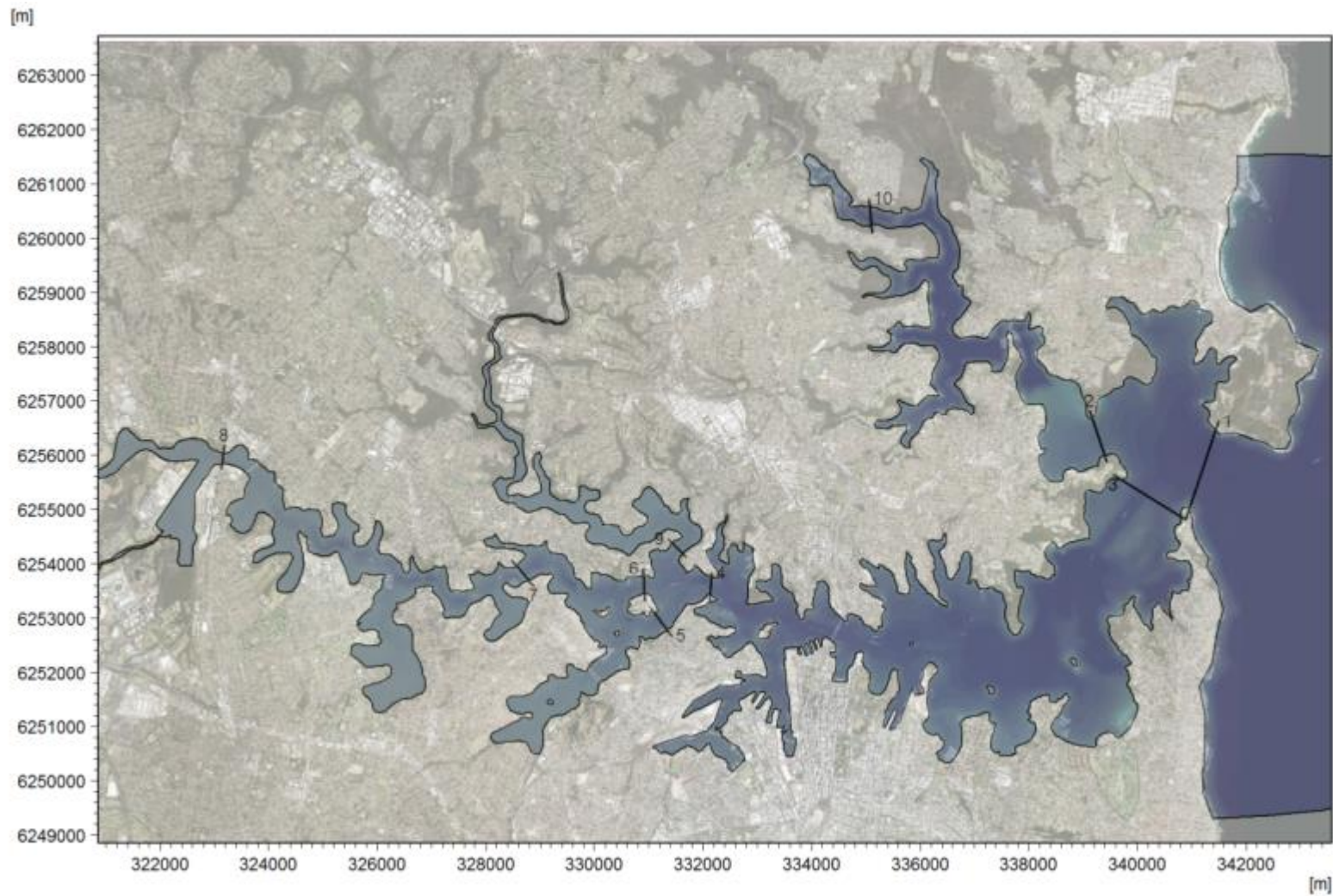


Figure 14 Location of tidal survey transects for 19 March 1992 (MHL, 2010)

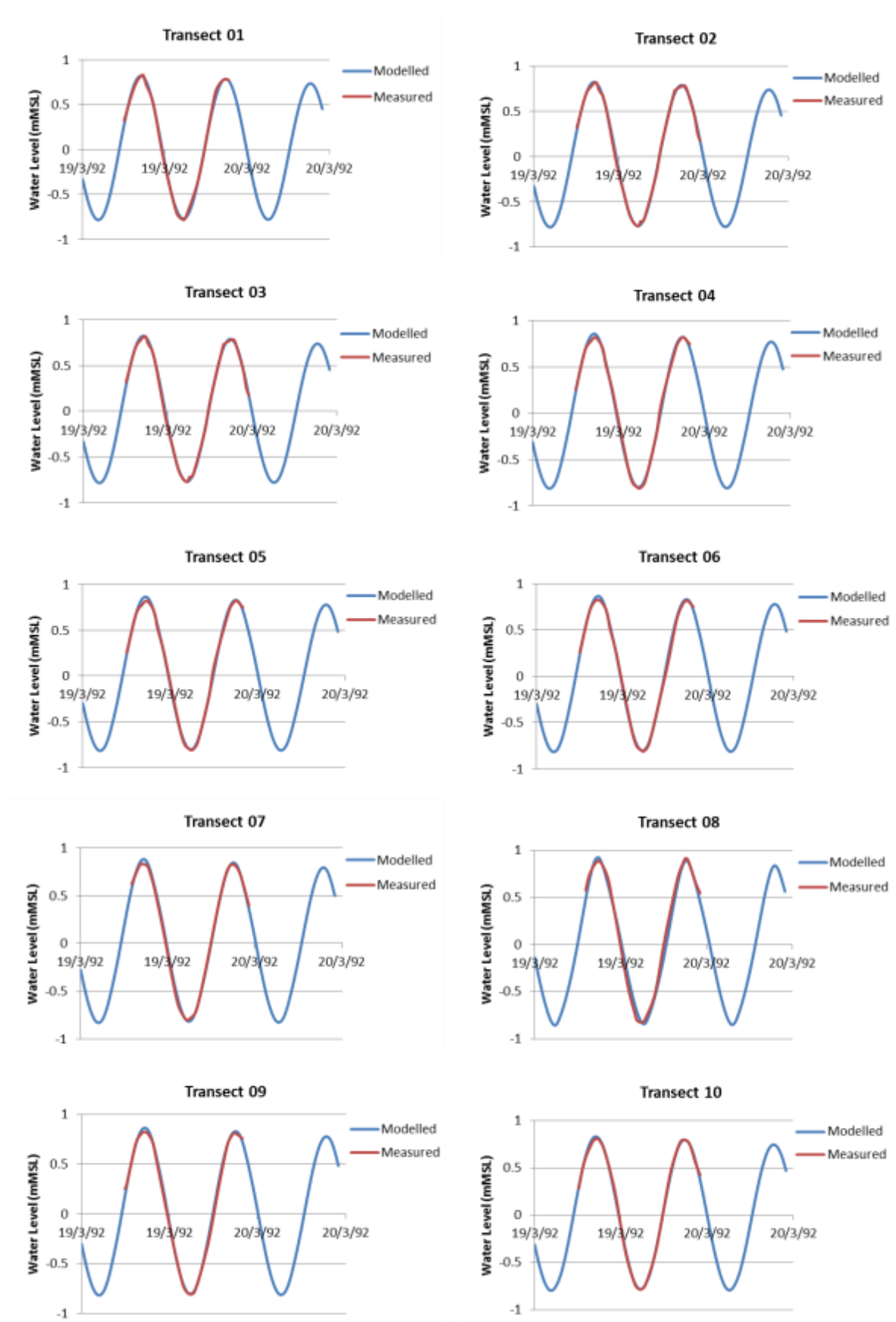


Figure 15 Hydrodynamic model water level calibration

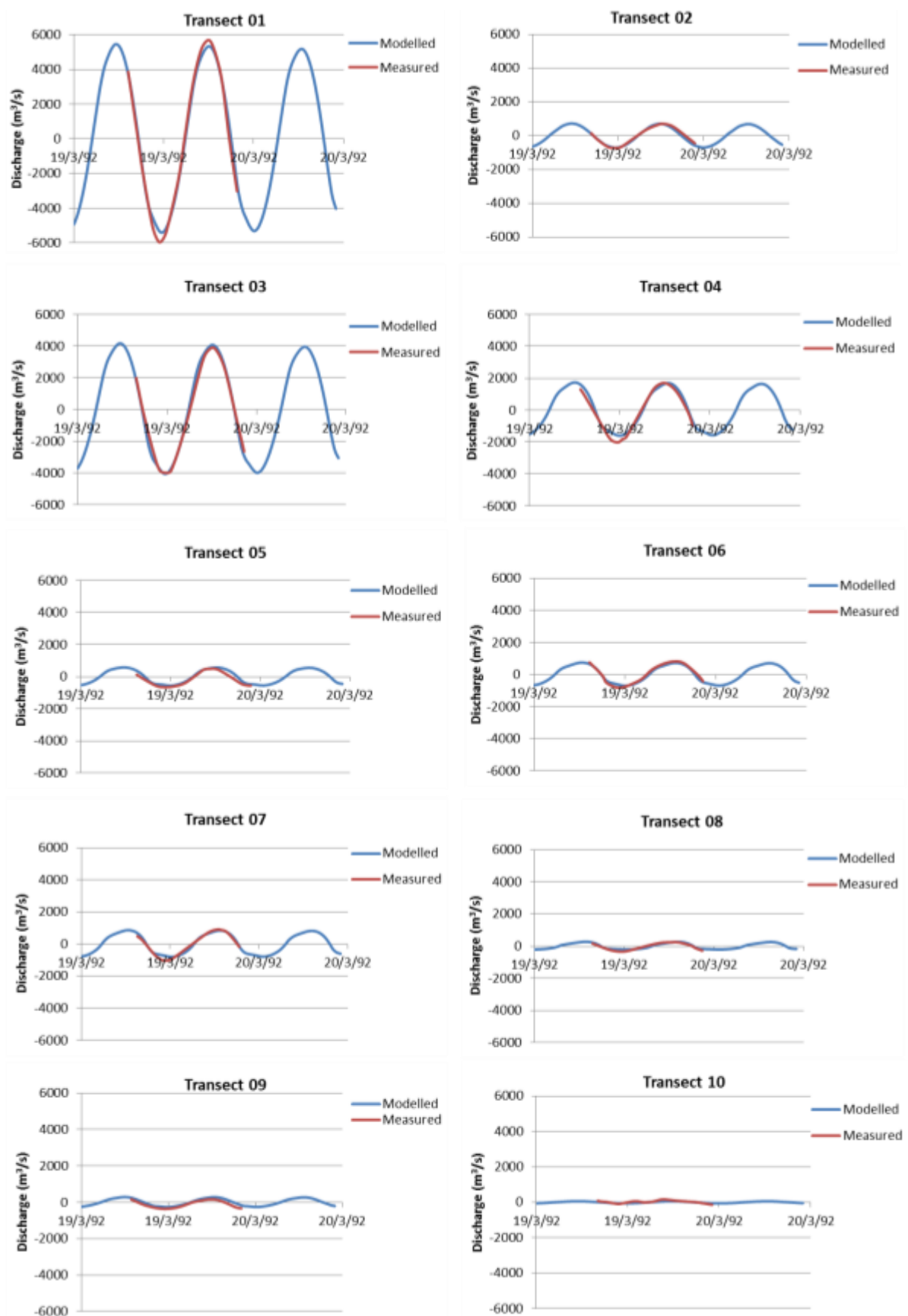


Figure 16 Hydrodynamic tidal discharge calibration

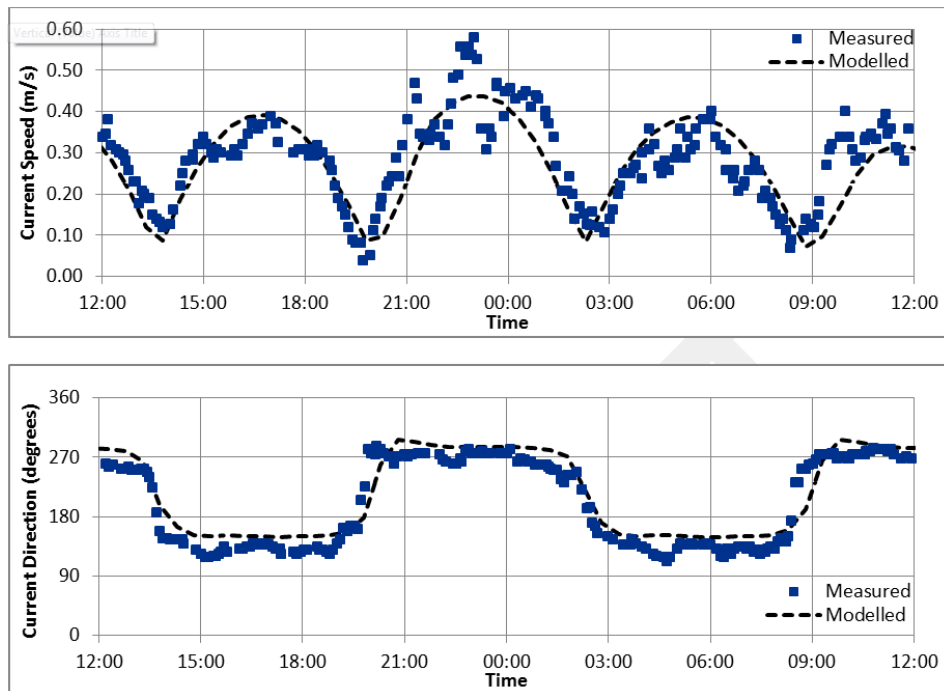


Figure 17 Model verification against Balls Head ADCP over period February 29th to March 1st, 2016

5. Thermal Plume Scenario Modelling

5.1 Assessment Criteria

Aquatic ecosystem functioning is closely regulated by temperature with aquatic organisms, and water quality sensitive to temperature changes (ANZECC/ARMCANZ 2000). An organism's growth metabolism, reproduction mobility and migration patterns may all be altered by changes in ambient water temperature.

There is limited data available on the thermal responses of Australian organisms to enable meaningful predictions of the effects of thermal alterations on Australian aquatic ecosystems and the provision of guidelines (ANZECC/ARMCANZ 2000). However for the purposes of this assessment, a temperature increase limit of 2°C has been adopted, based upon the Marine Water Quality Objectives for NSW Ocean Waters (1999).

5.2 Modelled Scenarios

The size and impact of a thermal plume is dependent on a number of factors. The most important factors that influence these are the hydrodynamics of the estuary, ambient air and water temperature, as well as wind magnitude and direction.

A number of model simulations were performed to simulate the thermal plume behaviour under a range of ambient conditions. The scenarios modelled are summarised in Table 2. These scenarios were chosen to represent the likely maximum variability at the site (excluding extreme conditions) in terms of heat emission and meteorological conditions, and represent expected worst case scenarios in terms of consequence from heat rejection:

Three ambient air and water temperature scenarios have been adopted to correspond to a typical summer, winter and yearly average temperature (Refer to Section 3.4). Wind forcing has been included in four directional bands with a constant wind speed of 5m/s, as well as a scenario without wind. Magnitudes of greater than 5m/s have not been modelled as such wind conditions will provide significantly enhanced atmospheric cooling and therefore results in a smaller thermal plume, compared to lower wind conditions.

The Heat Rejection System (described in Section 4.2.6) will provide up to 1.2MW of energy into the water during summer. During winter, it is unlikely that the air conditioning system will operate at capacity, hence a heat emission of 80% of the installed capacity (0.96MW) was adopted in the modelled winter scenarios.

In all model scenarios, the heat emission was assumed to be present during the entire simulation period (ie. a constant source energy input was applied 24/7), which is considered to be a conservative representation of the system.

Table 2 Thermal Plume Modelling Scenarios

Scenario Name	Ambient Conditions	Heat Emission from Heat Rejection System	Heat loss coefficient (W/m ² /°C)
Summer No Wind	Water temperature: 26.8°C Air Temperature 26.8°C Wind Condition: 0 m/s	1.2MW	17
Summer Wind	Water temperature: 26.8°C Air Temperature 26.8°C Wind Condition: 5m/s Directions: NN, EE, SS, WW	1.2MW	85
Winter No Wind	Water temperature: 13.2°C Air Temperature 13.2°C Wind Condition: 0 m/s	0.96MW	11
Winter Wind	Water temperature: 13.2°C Air Temperature 13.2°C Wind Condition: 5m/s Directions: NN, EE, SS, WW	0.96MW	55

5.3 Model Results

The MIKE3 HD model was run for a two week period during the transition from a spring tidal cycle into a neap cycle. Thermal plume impacts have been assessed by creating percentile maps (95th percentiles) of the temperature impacts relative to ambient water temperature. The sea spatial maps depict the levels of increased temperature above ambient water temperature that are exceeded only 5% of the time.

Percentile maps for the complete range of scenarios are presented in **Appendix A**. Figure 18 and Figure 19 present the 95th Percentile Maps for the winter and summer - no wind scenarios respectively, which were found to be the model scenarios resulting in the largest thermal impacts.

The highest 95th percentile temperature impact is modelled to occur during the “winter - no wind” scenario, where a temperature impact of up to approximately 0.8°C is predicted in the vicinity of the heat rejection system.

The addition of wind significantly decreases the thermal impact and size of plume for all wind directions, due to an increased rate of heat transfer from the water to the atmosphere. The maps demonstrate that the footprint of the thermal plume is small for all scenarios modelled, with the thermal impacts of up to 0.1°C confined to an area within approximately 50m from the source on Pier 2/3.

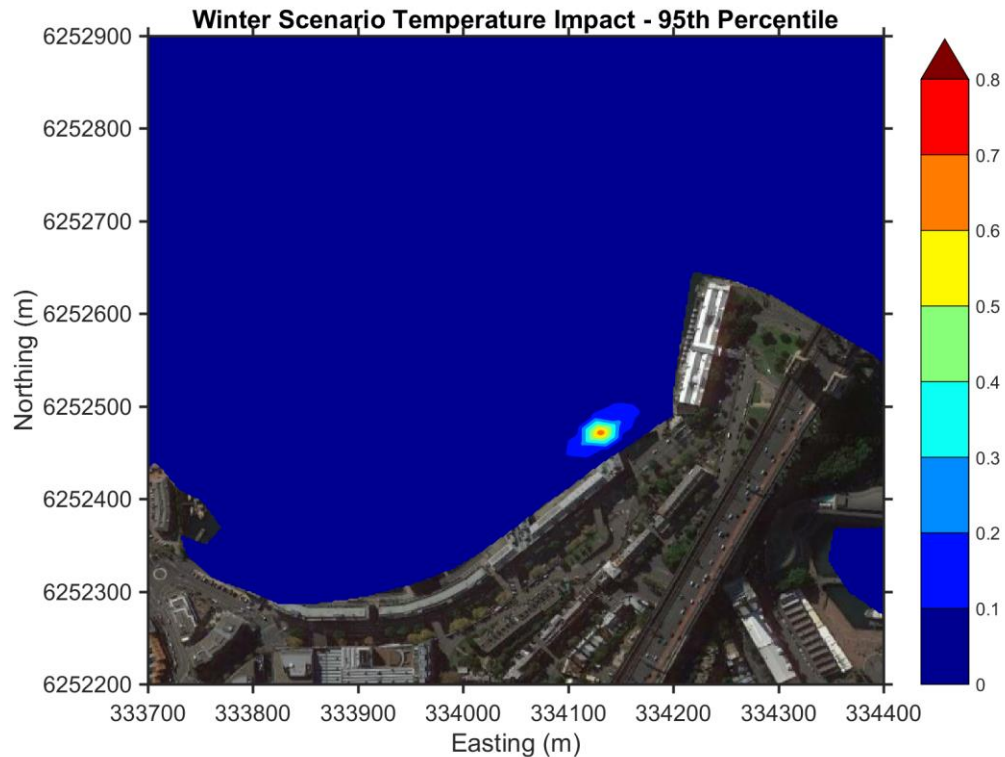


Figure 18 Modelled 95th Percentile Temperature Impact - Winter, No Wind Scenario

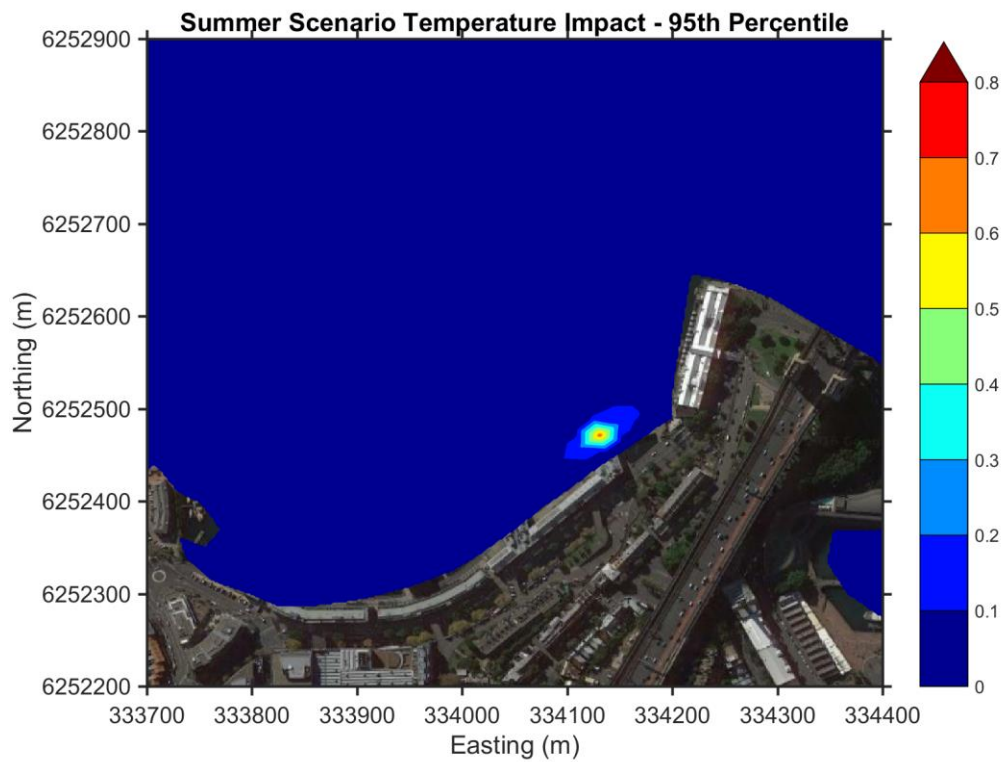


Figure 19 Modelled 95th Percentile Temperature Impact – Summer, No Wind Scenario

6. Conclusions

Modelling has been undertaken to investigate the likely maximum thermal impact of the installation of a Heat Rejection System at Pier 2/3 in Walsh Bay. The likely maximum thermal impacts were determined by simulating the thermal plume behaviour under a range of model scenarios. The model scenarios adopted for assessment are considered to be conservative; it is more likely that less extreme conditions will prevail and as such thermal impacts are likely to be less than that shown in the model results.

The model results demonstrate that the footprint of the thermal plume will be small, with a temperature impact of greater than 0.1°C confined to an area of approximately 50m from the Heat Rejection System. The highest 95th percentile impact (approximately 0.8°C) is significantly below the temperature increase limit of 2°C.

7. References

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Appendix A. Temperature Impact Maps

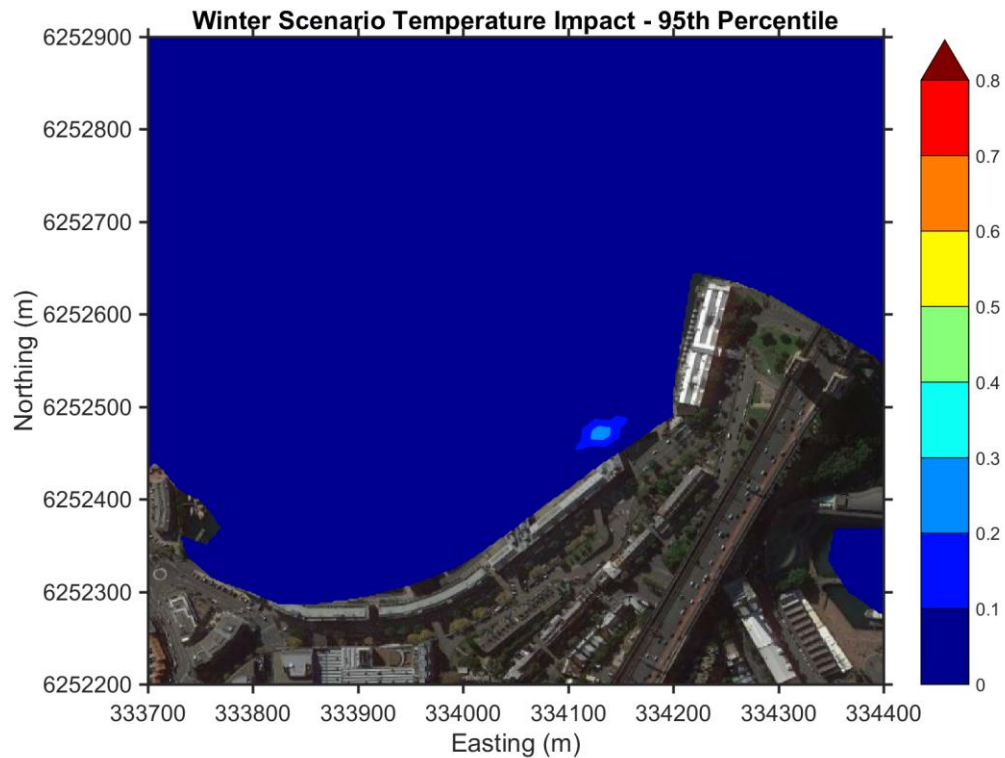


Figure 20 Modelled 95th Temperature Impact – Winter, 5m/s Easterly Wind Scenario

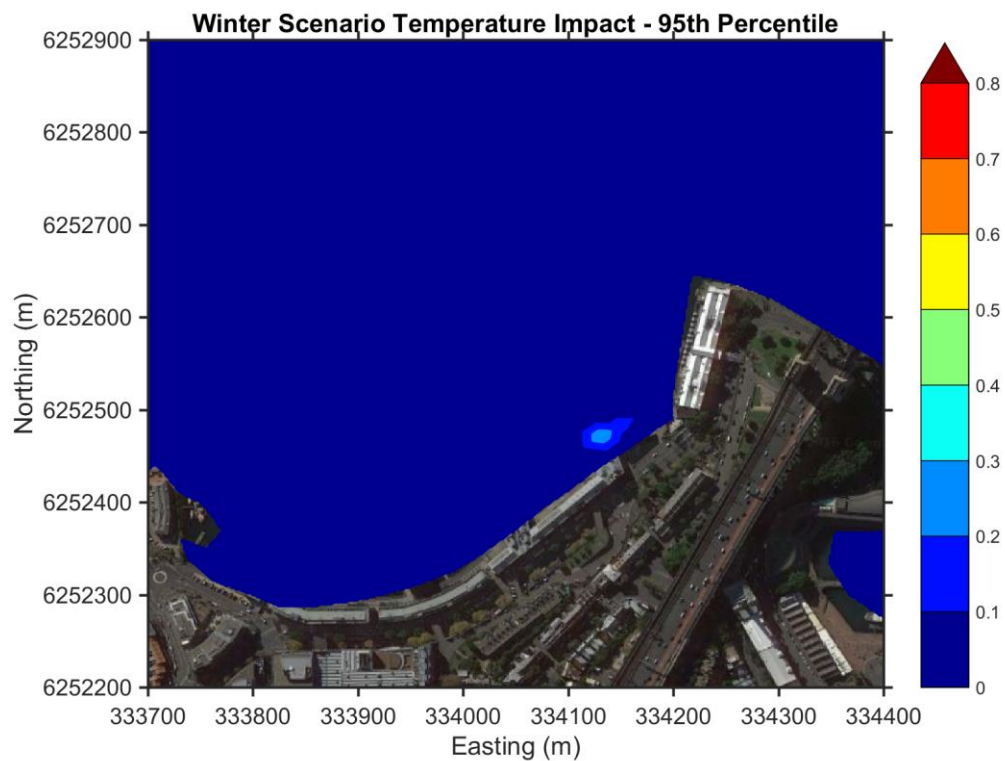


Figure 21 Modelled 95th Temperature Impact – Winter, 5m/s Northerly Wind Scenario

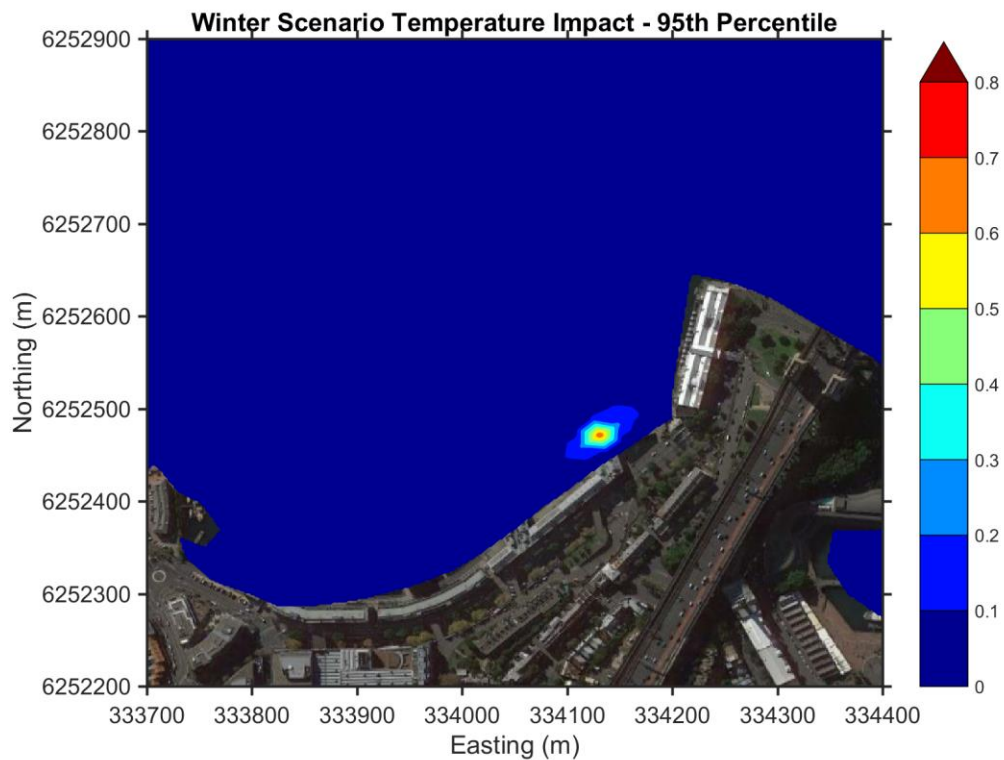


Figure 22 Modelled 95th Temperature Impact – Winter, No Wind Scenario

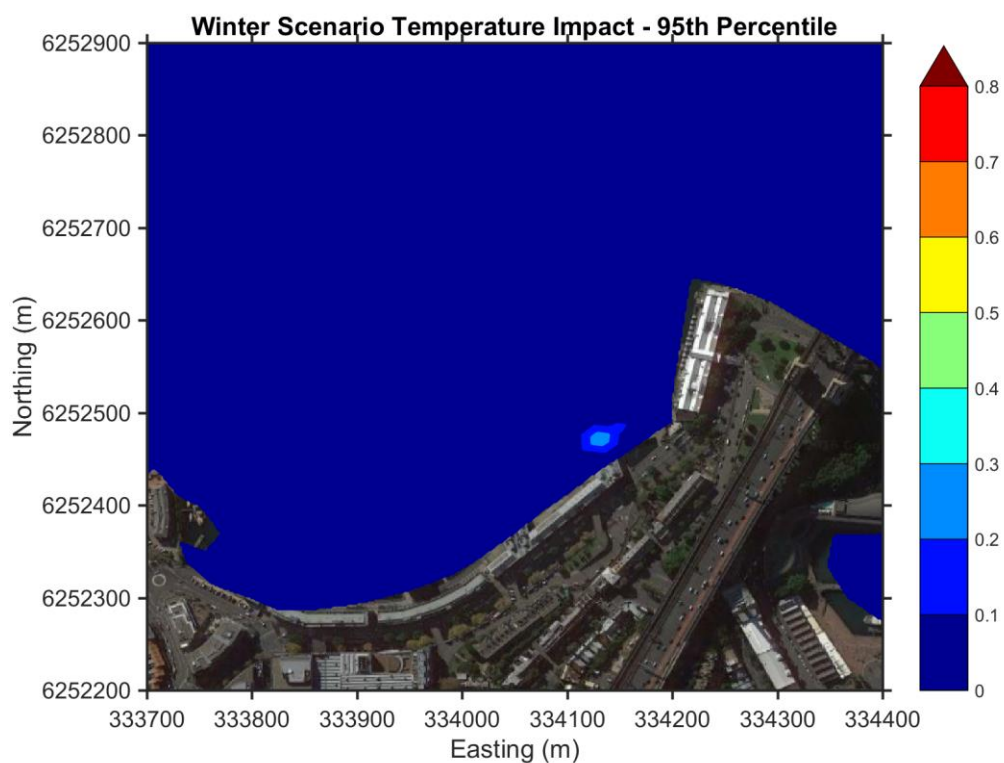


Figure 23 Modelled 95th Temperature Impact – Winter, 5m/s Southerly Wind Scenario

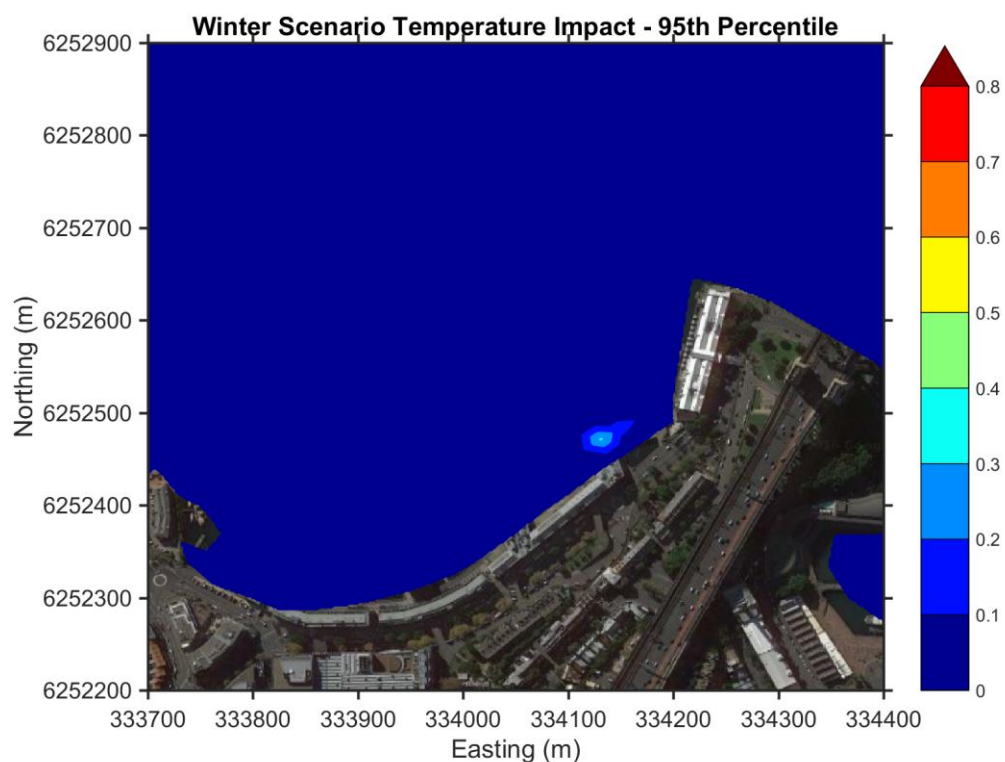


Figure 24 Modelled 95th Temperature Impact – Winter, 5m/s Westerly Wind Scenario

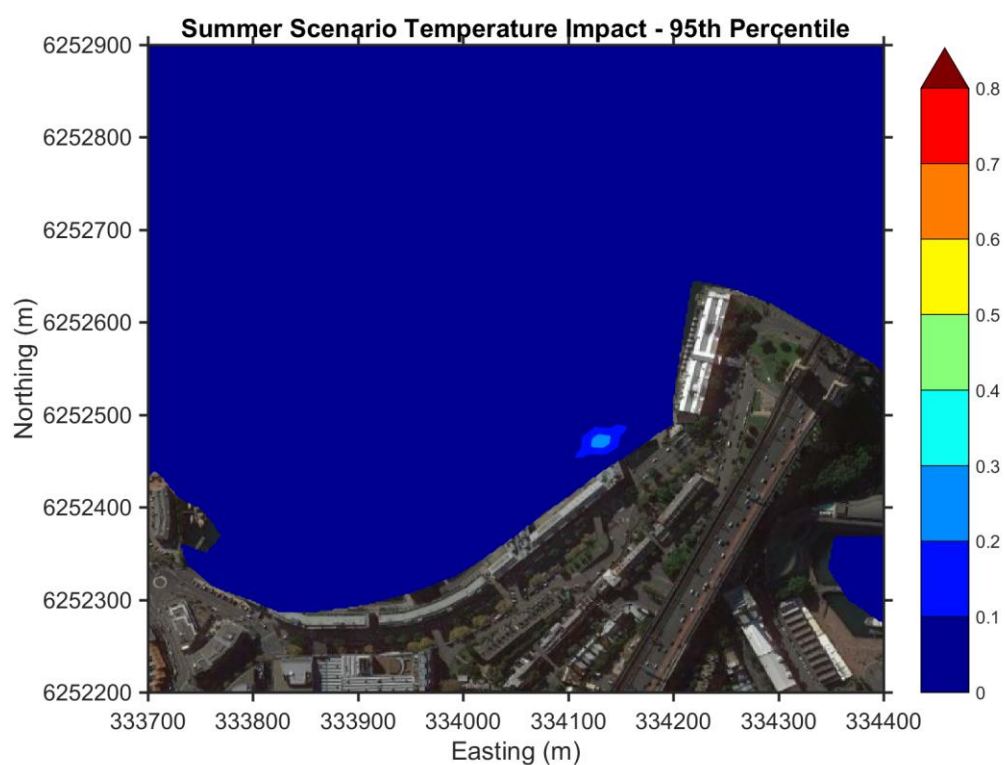


Figure 25 Modelled 95th Temperature Impact – Summer, 5m/s Easterly Wind Scenario

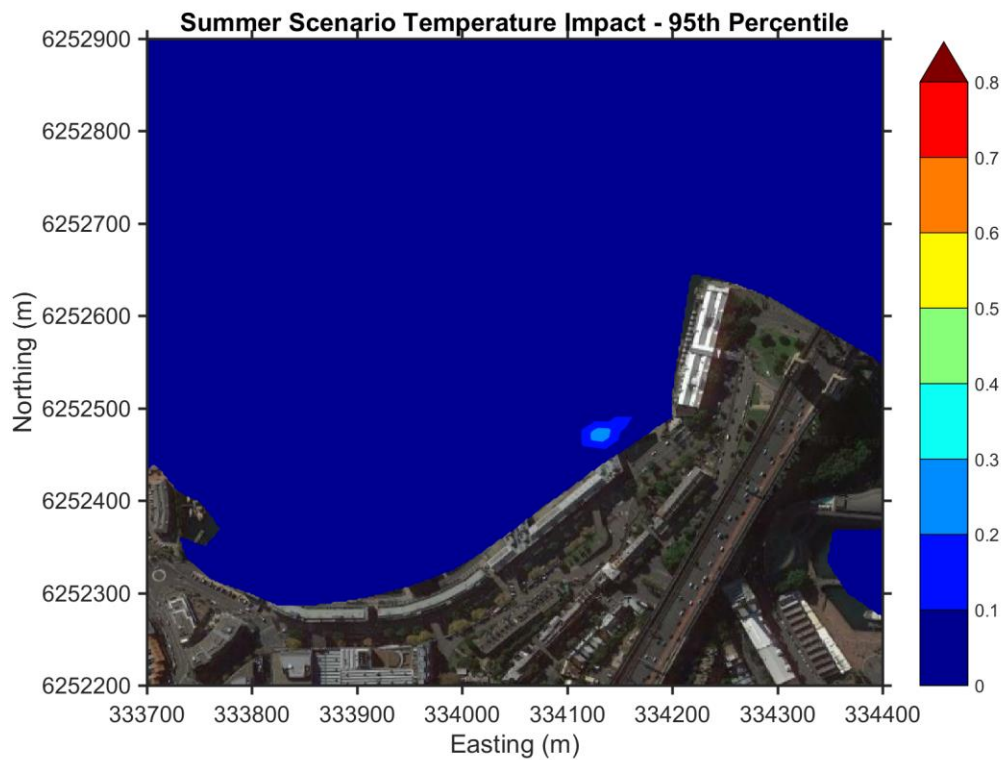


Figure 26 Modelled 95th Temperature Impact – Summer, 5m/s Northerly Wind Scenario

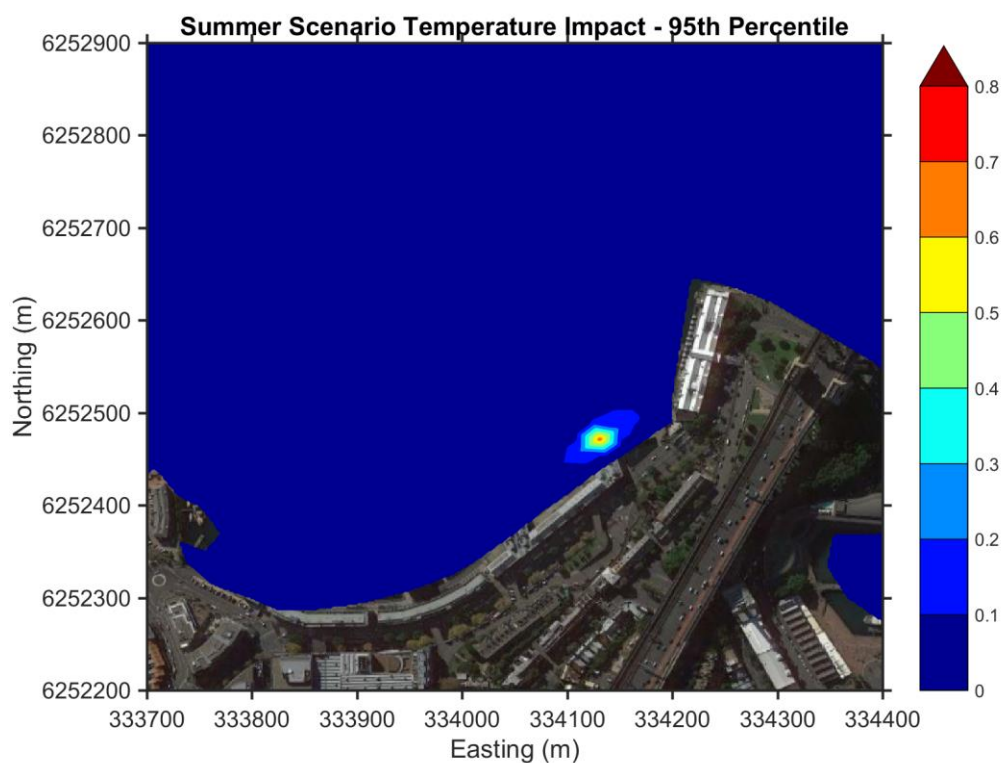


Figure 27 Modelled 95th Temperature Impact – Summer, No Wind Scenario

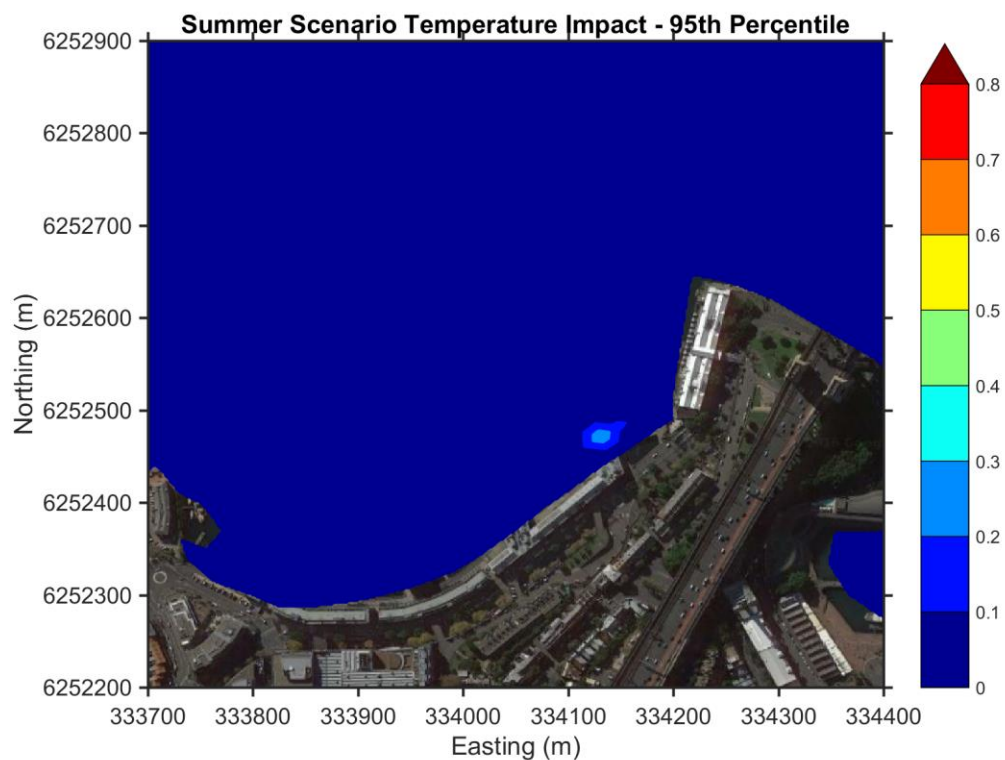


Figure 28 Modelled 95th Temperature Impact – Summer, 5m/s Southerly Wind Scenario

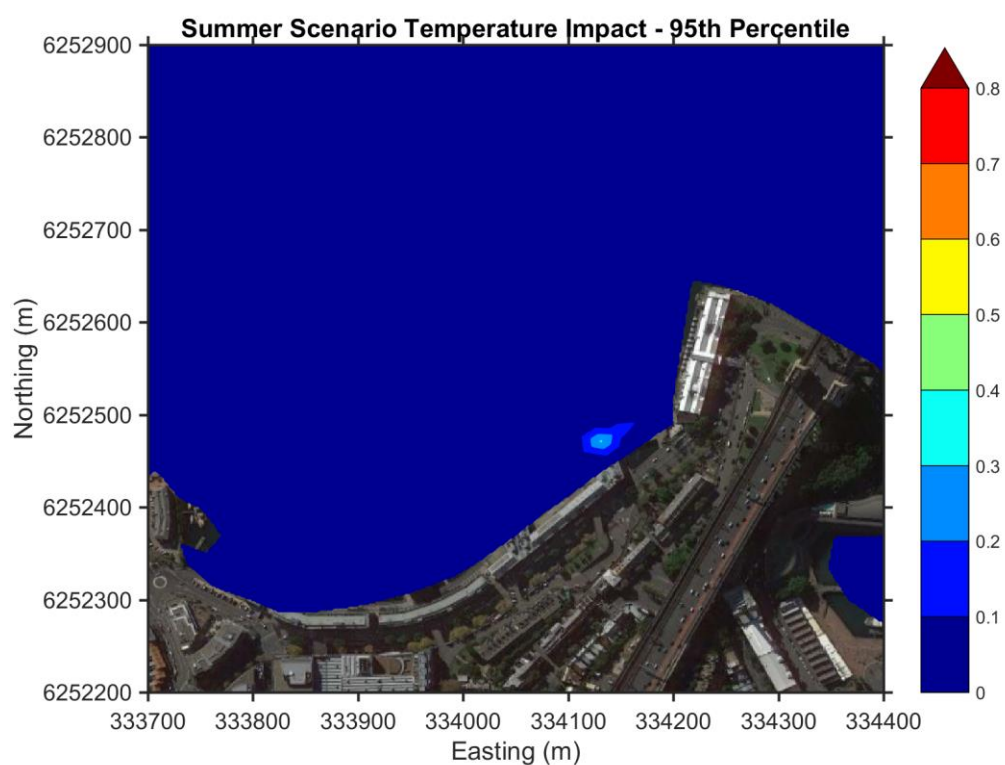


Figure 29 Modelled 95th Temperature Impact – Summer, 5m/s Westerly Wind Scenario