THE STAR ENTERTAINMENT GROUP LTD

The Star, Sydney

MODIFICATION 14 - MARINE IMPACT ASSESSMENT

PUBLIC

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The Star, Sydney

MODIFICATION 14 - MARINE IMPACT ASSESSMENT

The Star Entertainment Group Ltd

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ABBREVIATIONS

AHD	Australian Height Datum
ANZECC	Australian and New Zealand Environment Conservation Council
EAC	Eastern Australian current
EIS	Environmental Impact Statement
EP&A Act	NSW *Environmental Planning and Assessment Act 1979*
EPBC Act	Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*
EPI	Environmental Planning Instrument
EPL	Environmental protection licence
ESD	Ecologically sustainable development
FM Act	NSW *Fisheries Management Act 1994*
KTP	Key threatening process
L/s	Litres per second (flow rate)
LAT	Lowest astronomical tide
m	Metre (distance)
mm	Millimetre (distance)
MNES	Matter of national environmental significance
m/s	Metre per second (speed)
NSW EPA	NSE Environment Protection Authority
NSW OEH	NSW Office of Environment and Heritage
^{o}C	Degrees Celsius
ppm	parts per million
ppt	Parts per thousand
PSU	Practical salinity units
SEARs	Secretary’s Environmental Assessment Requirements
TSC Act	NSW *Threatened Species Conservation Act 1995*
WQO	Water quality objectives

EXECUTIVE SUMMARY

Modification 14 Overview

The Star Entertainment Group is a leading operator of integrated resorts catering to both local and international visitors, and is the operator of The Star Sydney (The Star). Consistent with The Star's licence obligation to operate the site to an international standard, The Star Entertainment Group (TSEG) is proposing to advance a revitalisation of the existing complex.

The Star is embarking on a five year redevelopment journey to create a landmark, exemplar integrated resort within the City of Sydney. This proposed redevelopment will occur through the lodgement of two S75W applications with the Department of Planning and Environment, identified as Modification 13 and Modification 14. All works pertaining to Modification 14 are detailed below. Modification 13 will involve the design of a new Ritz-Carlton Hotel Tower and associated podium treatment and will be detailed at a future time.

The Star is proposing to attain the highest standard of built form outcomes for the site through the proposed redevelopment by encouraging innovation and best practice approaches in order to achieve an environmentally sustainable development that positively contributes to the overall architecture of both Pyrmont and the City of Sydney. This will be done through the implementation of advanced ESD initiatives, improved people and movement connections, upgrades to the external appearance and presentation of the facility and improved integration with the adjacent urban fabric.

Modification 14 includes the following proposed works:

1. **Level B4 Infrastructure Upgrades** - Upgrades to existing generators, existing harbour heat rejection system, natural gas system, existing domestic cold water system and an additional sewer connection.
2. **Level 00 – Porte Cochere and Astral Lobby Upgrade** - Realignment of Porte Cochere to accommodate expanded and upgraded Astral Lobby, upgraded Astral Lobby Bar and retail expansion and upgrades of the Main Casino Entry, including valet improvements to the Porte Cochere.
3. **Level 00 Back of House Upgrades** - Internal upgrades and improvements to multiple aspects of the back of house space at Level 00.
4. **Level 00 Astral Luxury Retail Zone** - New luxury retail zone connecting from Astral Hotel Lobby out to Jones Bay Road. Change of use from office / back of house to retail.
5. **Level 00 - SELS Fitout** - Refurbish existing SELS Level 00 toilets at the southern end of the building to allow for adjacent lift lobby circulation areas. Upgrades and tenancy improvements to existing retail tenant at northern end of SELS building along Jones Bay Road. No external changes to SELS are proposed, with internal alterations only.
6. **Level 00 SELS Lighting** - External lighting of the SELS building along Pyrmont Street to celebrate the heritage elements of the building.
7. **Level 00 Darling Café** - New café within the existing Darling Hotel Lobby at Level 00.
8. **Level 00 to 01 - G-Star Raw Escalators** - Replace existing G-Star Raw retail shop at Level 00 with new escalators providing access from Level 00 to Main Gaming Floor at Level 01. Includes new arrival bar adjacent to escalators at Level 01.
9. **Level 01 - Main Gaming Floor Slab Infill** - Slab expansion off the Main gaming Floor at Level 01 over the existing main entry foyer facing Pirrama Road. No facade works are proposed.
10. **Level 02 – Oasis Gaming Area** - Minor external alterations to the Oasis unenclosed gaming area at Level 02.

11. **Level 03 - Sovereign Expansion** - Expansion to the existing Sovereign Room at Level 03. This includes refurbishment of existing food, beverage and gaming locations, expansion of food and beverage opportunities an VIP gaming and unenclosed gaming areas.
12. **Level 03 - Event Centre Pre-function Space** - New pre-function space adjacent to the MUEF at Level 03, to allow for circulation changes from the level 03 expansion.
13. **Vertical Transportation Drum** - New escalators as part of a vertical transport arrival strategy from Level 00 to Level 03.
14. **Level 04 – Star Administrative Offices** - Fitout of existing administrative offices within Astral Residences tower. Internal improvements only.
15. **Level 05 – VIP Lobby & Check-In** - Conversion of existing pool plant space and enclosed pool deck at Level 05 to a lobby for the VIP hotel guest lounge.
16. **Level 05 - Astral Residences Reception** - Conversion of meeting room to Reception and check-in lobby. Includes minor expansion to existing enclosed space.
17. **Northern Porte Cochere Canopy** - Removal of a section of the current glazing (retaining the canopy structure) of the current porte cochere canopy and include a new ceiling at a lower height over a section of the new slab (NW Gaming slab infill).

The proposal

As part of the Modification 14 redevelopment of The Star, the existing harbour heat rejection (HHR) system will be upgraded such that the system has the capacity to reject additional heat when required.

The current system has been operating continuously since 1998 and is now approaching the end of its serviceable life. The Star proposes to upgrade the system to allow for the following:

- Installation of high efficiency pumps utilising modern pump technology
- Increased level of redundancy within the system for improved reliability
- Increased pumping capacity to allow pumps to run more efficiently for greater periods
- Future proofing the site for any site changes in the future
- Minimising disruption by completing the works in conjunction with other works on the site

The HHR system upgrade includes a 50% increase in the volume of seawater to be pumped via existing pipework from the head of Jones Bay in Sydney Harbour and transferred to a heat exchanger, where it would be used to cool condenser water from the centralised cooling system. The seawater is then discharged into the Pyrmont Bay via infrastructure presently installed at the southern shore.

The current system works on the basis of regularly varying flow of seawater through the heat exchanger and through this process, the maximum temperature differential (DT) of the discharged water relative to the ambient water is limited to +6ºC at all times, inclusive of peak conditions. Under typical conditions however, the temperature increase of the discharged water will be approximately +3 to +4ºC.

The proposed system will have the capacity to reject more heat than the existing system and the increase in loads is expected to occur over a number of years, without the need for further HHR system upgrades in the foreseeable future. As such it may be a number years before the system is operated beyond its current capacity. The additional capacity will be achieved by increasing the sea water flow through the system; the additional water will allow the transfer of the additional energy without increasing the temperature differential. The maximum flow will increase from 850 L/s to approximately 1,300 L/s. Under typical conditions however, the system operates with a flow of approximately 80% of the maximum.

The existing system was approved in 1998 and no modifications have been made to the system since then. This report is specifically concerned with assessing marine impacts due to the incremental increase in the properties of the thermal plume created by the increased flow of water through the heat exchanger associated with the upgrade.

The proposal seeks to increase intake and discharge water volumes through existing piping and structures and no construction works are proposed as part of the heat rejection system upgrade.

This assessment has considered the physical and ecological environment of Sydney Harbour to understand how the marine environment would be impacted under this component of the proposal. Through this process the following has been concluded:

Hydrodynamic and physical properties

The following conclusions have been drawn from an assessment into changes that may occur to the hydrodynamic and physical properties of the receiving waters of Pyrmont Bay.

TEMPERATURE EFFECTS

- Under both the summer and the rest of year conditions, the existing discharge plume reaches the surface within approximately 2.2 m and the temperature at the edge of the nearfield is approximately 3.6 ºC above ambient.
- The proposed system discharge plume has an increased velocity and undergoes a greater degree of mixing over a greater area prior to reaching the surface. Under both the summer and the rest of year conditions the proposed system discharge reaches the surface over a distance of approximately 3.2 m and the temperature at the edge of the nearfield is approximately 3.3 ºC above ambient.
- The nearfield zone of the proposed discharge plume is larger in area than that of the existing discharge plume, and due to this, has a lower modelled temperature at the edge of the nearfield zone. The incremental differences in temperature and size of the nearfield zone of the existing plume compared to the proposed can be considered negligible.
- An assessment against the ambient 80th percentile was carried out to establish if the temperature effects of the discharge plume are confined to the nearfield mixing zone in accordance with the ANZECC (2000) approach. The analysis confirms that the predicted median temperature post increased discharge is less than the 80th percentile ambient temperature and the proposal is therefore not considered to have an adverse impact on the receiving waters either in terms of the ANZECC Guidelines.

EROSION AND SCOUR

- Modelled discharge velocities for the existing and proposed discharge plumes under summer and rest of year conditions were assessed. Due to the dimensions of the outlet and the flow rate, the discharge velocities can be considered negligible when the plume exits the outlet at 0.14 m/s for the existing system and 0.22 m/s for the proposed system.
- The incremental increase in discharge velocity due to the proposal is estimated to be less than 0.1 m/s and, as such, there will be negligible risk of additional potential erosion or scour due to the proposal.

MARINE GROWTH

- There will be no change to the fouling management plan currently in place for the existing system and as such there will no incremental impact to the marine environment.
- The fouling management plan currently in place for the existing system entails the use of Mexel 432, an amine based dispersant. Mexel 432 has been approved for use in seawater cooling systems by the Australian Pesticides and Veterinary Medicines Authority (APVMA) to prevent corrosion, biofilm formation and the attachment of seawater organisms. The current dosage is 2 to 3 parts per million (ppm) every day and this is anticipated to remain the same for use in the proposed system.

- The dilution factors associated with the discharge plume were applied to the use of antifouling product, Mexel 432, at an initial dosage of 3 ppm. Modelling shows that the predicted concentration of Mexel 432 at the edge of the nearfield mixing zone is approximately 1.7 ppm for the existing system and 1.6 ppm for the proposed system.
- For both the existing and proposed systems the addition of Mexel 432 occurs once a day for one hour so the concentrations shown in Figure 6.6 will exist only during the one hour dosing period before being diluted to undetectable levels.
- The use of an APVMA approved amine based biocide is considered to pose a negligible risk of impact. Providing the correct concentrations, treatments and controls are introduced and the plant is operated within manufacturer specifications the risk of any impact can be managed to acceptable levels.
- The active constituents in Mexel 432 Dispersant will largely be consumed within the cooling system and are unlikely to persist in the marine environment following discharge because of their strong sorptive characteristics and biodegradability (APVMA, 2012). Due to this, cumulative impacts of other local systems using this product are unlikely to cause unacceptably high concentrations in receiving waters.

ACCIDENTAL AND EMERGENCY DISCHARGES

- There will be no additional risk of overdose or emergency discharge due to the proposal as the operational procedures associated with the system, including automated biocide dosing, will remain unchanged.

FAR FIELD MODELLING

- The predicted modelling results confirm that there would be sufficient initial mixing and dilution in the nearfield such that the water temperature would return close to ambient conditions within the near field zone. The modelling also confirms that the discharge would be below the trigger value in the near field calculated in accordance with the ANZECC Guidelines (ANZECC, 2000). As such, there would be no need to consider the impacts across the far field.

Marine ecology

The following conclusions have been drawn from an assessment into potential changes and impacts relating to marine ecology that may occur within Jones Bay and Pyrmont Bay.

EXISTING DISCHARGE OPERATIONS

The following observations have been made from a visual inspection from the shore and a review of footage from an underwater survey conducted by a marine ecologist:

- A variety of marine biota was observed in Pyrmont Bay on wharf structures within the existing region of elevated temperature due to the existing discharge plume.
- The species diversity and abundance of the observed assemblage is considered typical of those in urbanised estuarine environments dominated by built structures and vertical surfaces.
- Barnacles, oysters, mussels and the encrusting assemblage including filamentous algae occupied almost 100% of the surfaces of wharf piles with no apparent effect of the biocide on their abundance or growth. There were no pest species observed on the wharf piles.
- Overall, the impacts of the discharge from the existing heat exchange system are undiscernible on a marine assemblage that appears to be typical of its location on an estuarine, urbanised foreshore.

ADDITIONAL THERMAL IMPACTS

- The visual inspection and review of the underwater survey footage shows that there is no evidence of impact of the existing thermal plume and estuarine organisms in general are well adapted to changes in temperature and salinity (McLusky and Elliott, 2004). It can therefore be concluded that any marine life that is currently just outside of the current plume footprint (mainly oysters in the intertidal zone and mussel at deeper depths) are likely to easily tolerate the effects of the predicted increase in plume footprint due to the proposal.

- Sydney rock oysters form bands around the wharf piles at mid-tide level in Pyrmont Bay. Research on this common estuarine species indicates that the temperature increase associated with the existing and proposed discharge plumes are well within its temperature tolerance over the range of salinities likely to occur in the study area (O'Connor *et al*., 2008).
- Little is known about the temperature tolerances of most of the other common species found in the intertidal and subtidal sections of the wharf piles. However, the predicted temperature effects due to the increased plume footprint under the proposal can be considered negligible in comparison to the seasonal temperature fluctuation recorded in the intertidal habitats in which the organisms occur.

ADDITIONAL CHEMICAL IMPACTS

- The current low concentration of discharged biocide is rapidly and thoroughly diluted with no evidence of deleterious impacts on marine biota on wharves within the existing discharge plume. It is therefore unlikely that the same rate of dosing would have a discernible impact on marine biota due to rapid mixing in the water column. After the point of discharge at the culvert, the biocide's residual concentration would be diluted within the nearfield zone before reducing to undetectable levels due to the action of waves and ambient currents.
- Levels of dissolved oxygen in the water currently discharged would be lower than those in the ambient seawater due to the elevated temperature of the discharged water. The increased velocity of the discharge under the proposal (0.22 m/s compared to 0.14 m/s) would increase initial mixing, which would result in the re-oxygenation of the water within approximately 3 m of the outlet channel. Given that no effects of deoxygenation on stationery or mobile marine biota were observed, no physiological changes in marine biota are likely to be detectable under the proposal due to initial lower dissolved oxygen in discharge water.

INTAKE OPERATIONS

- Maintenance procedures include clearing the structures using a high-pressure hose with an angled nozzle that is pulled along the pipe. Screens inside the cooling plant are manually cleaned with freshwater, without the use of chemicals once per year.

ENTRAINMENT AND IMPINGEMENT

- The proposed inlet velocity would increase from 1.8 to 2.8 m/s into the intake pit and from 2.3 to 3.6 m/s at the inlet pipe. While the magnitude of the current entrainment of fish is not quantified, their occasional presence within the inlet system suggests that entrainment occurs occasionally under the existing inlet velocities.
- The increased inlet velocity under the proposal may, if unmitigated, represent an additional impact on adult and juvenile fish. Table ES.1 shows that the installation of a mesh screen across the culvert openings will mitigate this impact.
- Because both the existing and proposed systems use very small water volumes in comparison to the volume of Port Jackson, impacts on ecological primary production are likely to be negligible.

IMPACTS ON THREATENED SPECIES, COMMUNITIES, POPULATIONS AND HABITATS

- No threatened or protected marine species, populations or ecological communities listed under the EPBC Act, TSC Act and FM Act were observed within the spatial extent of the proposed discharge, and their occurrence in Pyrmont Bay or Jones Bay is either unlikely or transient in duration (seabirds).

MARINE PEST SPECIES

- The existing inlet structures are regularly cleaned and the main organisms removed to date have been two native mussel species. As removal of fouling organisms will continue under the proposal, via physical cleaning and the use of a biocide, the increased volume of water under the proposal is unlikely to result in an increased risk of the occurrence of marine pest species within the HHR infrastructure.

OPERATIONAL NOISE

- Given the distance of the inlet and outlet infrastructure from the plant room, the associated operational noise is considered to be within the limit of the variance in ambient conditions considering boat movements and other activities within Jones Bay and Pyrmont Bay. There will be no change to this infrastructure under the proposal and as such, there is assessed to be no operational impact or risk due to noise.

In summary, the operation of the upgraded HHR system is unlikely to have any material impact on the physical or ecological environment of Jones Bay or Pyrmont Bay. This has been demonstrated through modelling predictions and a review of relevant data. Effectively, the potential impacts due to the proposal would be insufficient to materially affect the marine environment in these locations.

Mitigation measures

The following potential mitigation measures could be adopted to mitigate against the predicted impacts.

Table ES.1 Mitigation measures

IMPACT	MITIGATION
Operation	
Temperature effects	None required as the modelled temperature effects are shown to be within the tolerances of the marine organisms present and are below the trigger value calculated as per ANZECC (2000).
Water velocity impacts at inlet (Entrainment of fish)	Install 100 mm mesh screen across culvert openings in the sea wall at Jones Bay as this location can be easily accessed to maintain and replace the screens.
Fouling management	Maintain current dosage rate of biocide Mexel 432 to deter biofouling. Continue physical cleaning of fouled screens on as-needed basis. Physical cleaning of any additional mesh screens

1. INTRODUCTION

This Section introduces the purpose of the marine impact assessment and its relationship to the proposed Modification 14 proposal at The Star, 80 Pyrmont Street, Pyrmont NSW 2009.

1.1 Background

As part of the plan to redevelop The Star, the existing harbour heat rejection (HHR) system is required to be upgraded such that the system has an increased heat rejection capacity.

The current system has been operating continuously since 1998 and is now approaching the end of its serviceable life. The Star proposes to upgrade the system to allow for the following:

- High efficiency pumps utilising modern pump technology
- Increased level of redundancy within the system for improved reliability
- Increased capacity to allow pumps to run more efficiently for greater periods
- Future proofing the site for any site changes in the future
- Minimising disruption by completing the works in conjunction with other works on the site

The HHR system would require a 50% increase in the volume of seawater to be pumped via existing pipework from the head of Jones Bay in Sydney Harbour and transferred to a heat exchanger, where it would be used to cool condenser water from the centralised cooling system. The seawater is then discharged into the Pyrmont Bay via existing infrastructure installed at the southern shore.

The current system works on the basis of the regular flow of seawater through the heat exchanger and through this process, the maximum temperature differential (DT) of the discharged water relative to the ambient water is up to +6ºC during peak loading. Under typical conditions however, the temperature increase of the discharged water is approximately +3 to +4ºC.

The proposed system will have the capacity to reject more heat than the existing system. The increase in loads is expected to occur over a number of years, without the need for further harbour heat rejection system upgrades. As such it may be a number years before the system is operated beyond its current capacity. The additional capacity will be achieved by increasing the sea water flow through the system; the temperature differential will not increase. The maximum flow will increase from 850 L/s to approximately 1,300 L/s. Under typical conditions however, the system operates with a flow of approximately 80% of the maximum.

The existing system was approved in 1998 and has not changed since then. This report is specifically concerned with assessing marine impacts due to the incremental increase in the properties of the thermal plume created by the increased flow of water through the heat exchanger associated with the upgrade.

The proposal seeks to increase intake and discharge water volumes through existing piping and structures and no construction works are proposed as part of the heat rejection system upgrade.

This assessment has addressed reasonably anticipated requirements based on SEARs issued for the Barangaroo South and Sydney Modern Project HHR systems.

1.1.1 Local harbour heat rejection systems

A number of other HHR systems are currently in use along the foreshore of Sydney Harbour. Examples include:

- Sydney Opera House – Circular Quay
- AMP Building – Circular Quay

- Park Hyatt Hotel – Circular Quay
- Museum of Contemporary Art – Circular Quay
- Sydney Convention & Exhibition Centre – Darling Harbour
- Power House Museum – Darling Harbour
- King Street Wharf – Darling Harbour
- Workplace 6 – Pyrmont Bay
- Barangaroo (under construction) – Darling Harbour

Source: Sydney Harbour Foreshore Authority (2012)

1.2 Report structure

This report is structured as follows:

- Section 1: introduces the purpose of the assessment.
- Section 2: describes how the proposal would operate.
- Section 3: describes the environmental planning instruments (EPIs) and water quality guidelines adopted in the assessment.
- Section 4: describes the assessment method and approach to modelling.
- Section 5: describes the existing environment of the study area.
- Section 6: describes the predicted incremental impacts that may occur from operating the proposal.
- Section 7: describes the stakeholder engagement that has been carried out as part of the marine impact assessment.
- Section 8: describes the proposed mitigation measures that would be used to avoid and reduce the predicted impacts.
- Section 9: summarises the key conclusions of the assessment.

1.3 Terms commonly used in this report

The following terms have been used throughout this report:

- The ‘proposal’ or ‘proposed system’ refers to the increase in the capacity of the existing heat water exchange system which takes in water from Jones Bay and discharges it to Pyrmont Bay. The proposal forms part of the wider plan to renovate the Star City Resort. It also represents ‘development’ for the purposes of Part 4 of the EP&A Act.
- The ‘existing system’ refers to that which is currently operational and has already been approved and is therefore not the focus of this impact assessment.
- The ‘study area’ covers the extent of the existing environment described in Section 5. It represents the area that may be both directly and indirectly impacted by the proposal.
- The ‘locality’ represents a wider area where information has been gathered to describe the environment of the study area and proposal footprint. The locality would not be impacted by the proposal.
- ‘Summer’ refers to the December to February period.
- ‘Rest of year’ refers to the March to November period.

2. HARBOUR HEAT REJECTION SYSTEM DESCRIPTION

This section describes the HHR system and the aspects of the design that have been taken into consideration in this assessment.

2.1 System Overview

The HHR system uses some of the pipework infrastructure constructed for the Pyrmont Power Station, which occupied The Star site prior to the station's decommissioning and demolition in 1993. The location of The Star and the inlet and discharge points are shown in Figure 2.1.

An underwater survey was conducted on 3 August 2016 to ascertain the nature and dimensions of the inlet and outlet infrastructure that is accessible from the seaward side. Based on the findings of the underwater survey and 'approved for construction' plans (Connell Wagner 1995), a schematic of the inlet and outlet infrastructure has been produced as shown in Figures 2.2 and 2.3 respectively.

The inlet, outlet and operation of the HHR system are described in the following sections.

Figure 2.1 Location map showing The Star and inlet and discharge locations

2.2 Inlet System

The inlet system extracts seawater from the south east corner of Jones Bay. The seawall is divided into a series of chambers, which are open to the sea as shown in Figure 2.2. A pipe installed in the seawall allows water to flow into a flooded chamber situated landward of the seawall. The inlet pipe runs from the flooded chamber and delivers seawater to the heat exchanger. The seawater passes through a penstock (sluice) valve that can be opened and closed to regulate/prevent the flow of seawater into the exchanger. There will be no change to this infrastructure as part of the proposal.

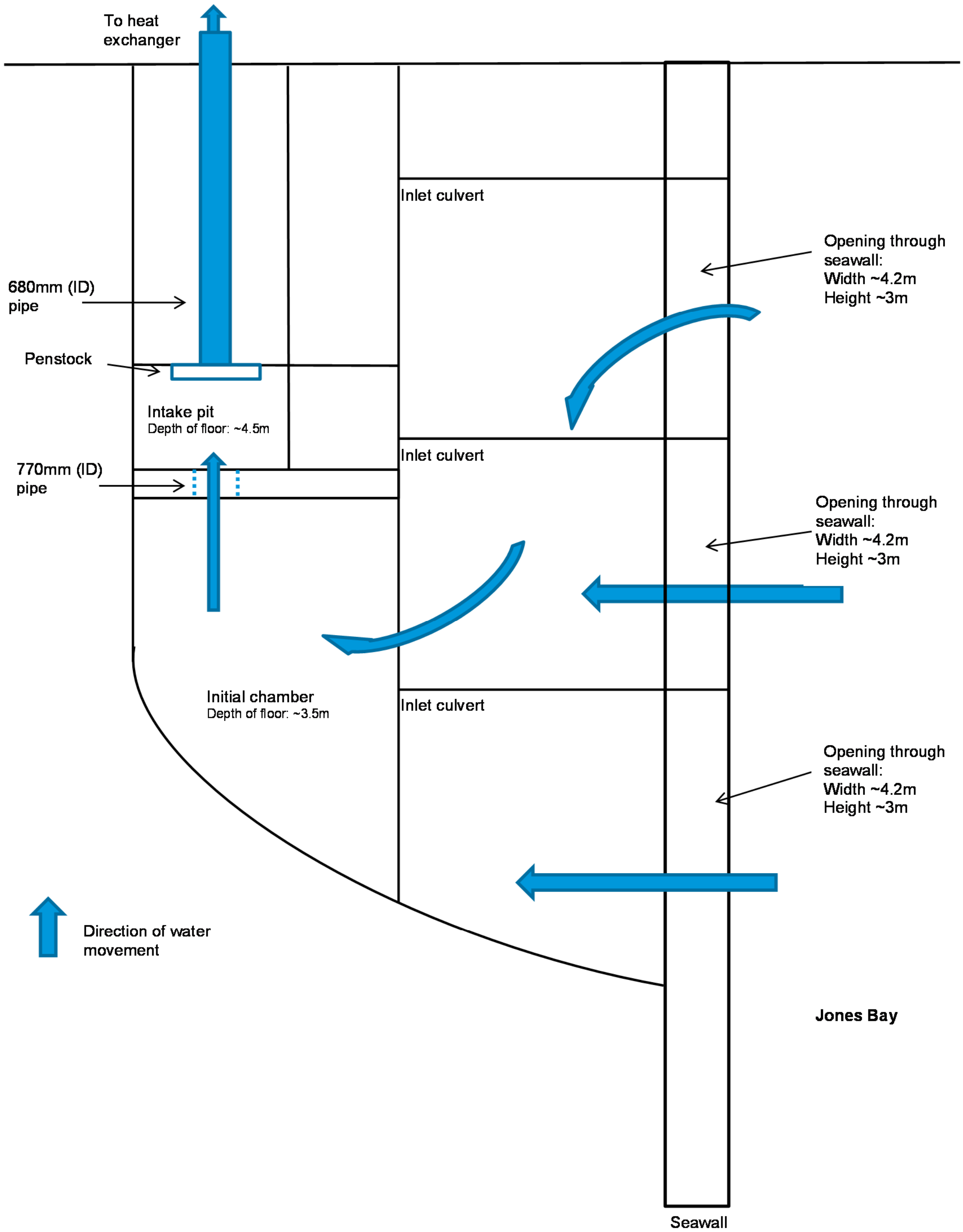


Figure 2.2 Inlet schematic produced from underwater survey observations

Table 2.1 shows the inlet parameters that have been used to undertake the assessment described in Section 5.

Table 2.1 Inlet system parameters

PARAMETER	EXISITNG SYSTEM	PROPOSED SYSTEM
Inlet pipe diameter (mm)[a]	680	680
Water intake velocity (m/s)[b]	2.34	3.58
Intake rate (L/s) [b]	850	1,300
Orientation of inlet pipe relative to the seabed[a]	Horizontal	Horizontal
Water depth at inlet pipe location (m)[a]	~4.5	~4.5
Inlet pipe location	Refer to Figures 2.1 and 2.2	Refer to Figures 2.1 and 2.2

a) Measured during underwater survey
b) Calculated

2.3 Outlet System

The returned seawater flows through a 900 mm diameter pipe to the harbour wall on the southern shore of Pyrmont Bay (Figure 2.3) where it discharges into two box culverts that run adjacent to each other and discharge into Pyrmont Bay beneath the suspended wharf. Measurements taken during an underwater survey conducted on 3 August 2016 showed that the mouth of each the culvert is approximately 1.5m wide by 2m high (from the seabed) and the separation between adjacent culverts is approximately 0.4 m. The length of the box culverts is approximately 40 m, which is expected to provide sufficient volume for full mixing of the discharge with ambient sweater to occur within the box culvert. Therefore, a uniform discharge of returned seawater flow is assumed at the month of the box culvert.

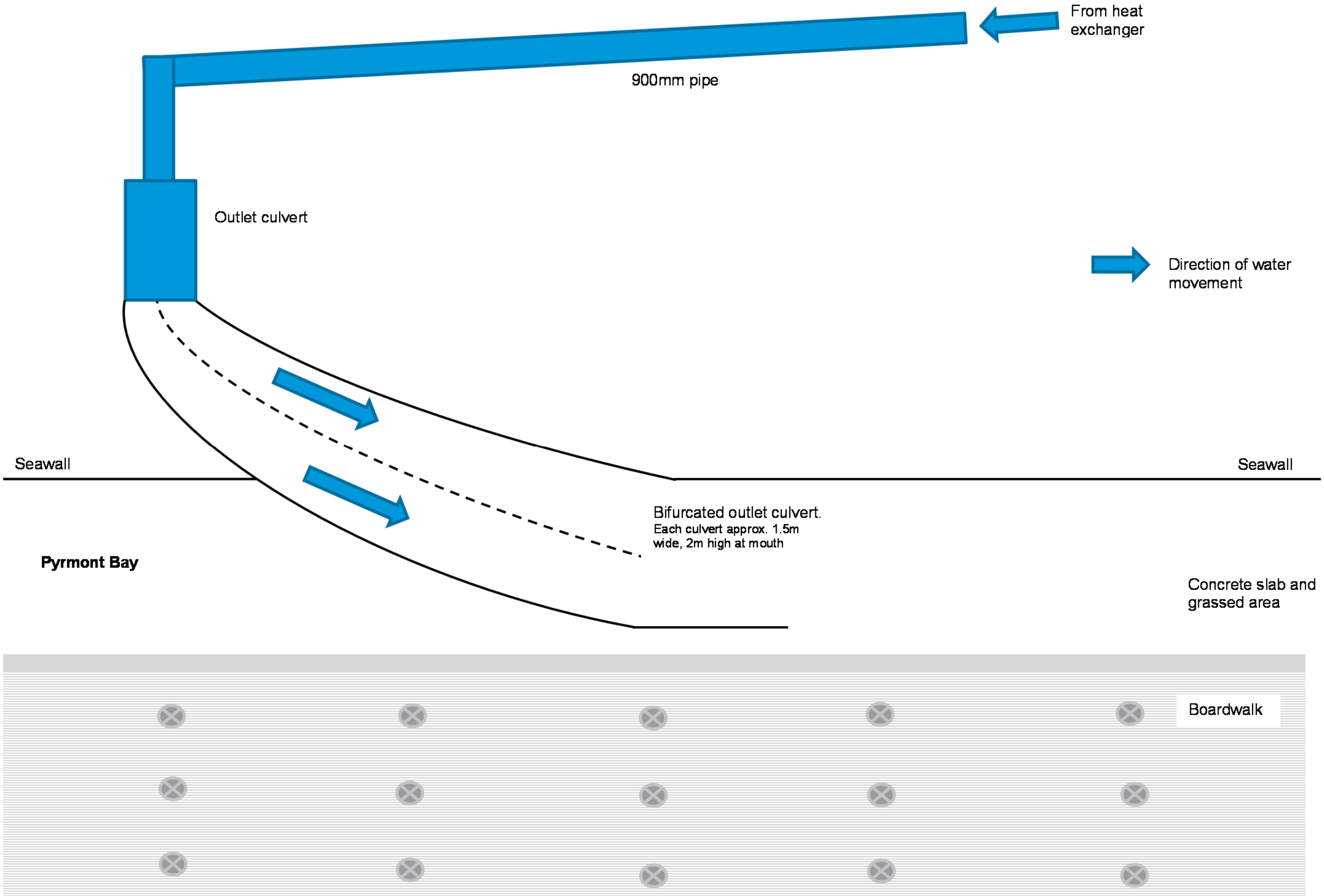


Figure 2.3 Outlet schematic produced from underwater survey observations

Table 2.2 shows the parameters that have been used to undertake the numerical modelling described in Section 6.

Table 2.2 Discharge system parameters

PARAMETER	EXISITNG SYSTEM	PROPOSED SYSTEM
Discharge rate (L/s)[a]	850	1,300
Discharge velocity (m/s)[a]	0.14	0.22
Differential temperature (°C)[a]	6	6
Outlet pipe dimensions (mm)[b]	Height: 2000, Width: 1,500	Height: 2000, Width: 1,500
Number of outlets[b]	2	2
Height of culvert base from seabed (m)[b]	0	0
Water depth at outlet pipe location (m)[b]	2.15	2.15
Outlet pipe location	Refer to Figures 2.1 and 2.3	Refer to Figures 2.1 and 2.3

a) Pers. Coms The Star
b) The Diving Company, 2016

2.4 System Operation

The cooling demand of The Star would vary over the course of a day, week and across the seasons. Typically, there would be greatest demand on the system during the summer months across the middle part of the day. Also, there would be more demand during periods of high visitor numbers, as they generate hi internal loads within the building.

As such, the system has a maximum operational demand, which, along with a range of other seasonal conditions, has been adopted in the modelling assessment to ensure the assessment is conservative. This maximum operational demand is likely to only occur for short periods during the day in February, which is typically the hottest month. For the other months, it is estimated that the system would typically operate at approximately:

- 80% of its maximum operational demand during the summer months
- 25% to 60% of its maximum operational demand during the autumn, winter and spring months

2.4.1 Fouling management

The fouling management plan currently in place for the existing system entails the use of Mexel 432, an amine based dispersant. Mexel 432 has been approved for use in seawater cooling systems by the Australian Pesticides and Veterinary Medicines Authority (APVMA) to prevent corrosion, biofilm formation and retard the attachment of seawater organisms. The current dosage is 2 to 3 parts per million (ppm) every day and this is anticipated to remain the same for use in the proposed system.

3. LEGISLATION AND GUIDELINES

This section describes the EPIs and water quality guidelines adopted in the assessment.

3.1 Development

3.1.1 NSW Environmental Planning and Assessment Act 1979

The proposal forms part of a modification application submitted under the Environmental Planning and Assessment (EP&A) Act 1979. Refer to the modification application for more information.

3.2 Ecology

3.2.1 NSW Threated Species Conservation Act 1995

The NSW *Threatened Species Conservation Act 1995* provides for the protection of vulnerable and endangered flora, fauna, communities and populations and their associated habitat. The Act is administered by the Office of Environment and Heritage and includes provisions to declare threatened species, populations, ecological communities and key threatening processes (KTP).

Species, populations and communities identified as:

- "Endangered" are listed in Schedule 1.
- "Critically endangered" are listed in Schedule 1b.
- "Vulnerable" are listed in Schedule 2.

Marine birds, mammals and reptiles are included in the Schedules of the above Act whereas all fish and marine vegetation are listed under the NSW *Fisheries Management Act 1994* (see below). The above Act also provides for the identification and listing of habitat that is critical to the survival of an endangered species, population or ecological community.

Section 109 to Section 113 of the above Act requires The Star to prepare a species impact statement in instances where the proposal would have significant effect either on: terrestrial critical flora and fauna habitat or terrestrial threatened species, populations and ecological communities and their habitat. The proposal is not expected to have any material impact on communities and species protected in under the above Act (refer to Section 6) within the meaning and definitions of the supporting impact assessment guideline. This removes the need to prepare species impact statements.

3.2.2 NSW Fisheries Management Act 1994

The NSW *Fisheries Management Act 1994* aims to protect the fish stocks, key fish habitats and threatened species, populations and ecological communities of fish and marine vegetation for current and future generations.

Species, populations and communities identified:

- Endangered are listed in Schedule 4.
- Critically endangered" are listed in Schedule 4A.
- Vulnerable are listed in Schedule 5.

The Fisheries Management (FM) Act also lists KTP that may threaten the survival of listed species, populations and ecological communities. Section 19 of the FM Act allows for the declaration of specified species as protected to prevent them from becoming threatened in the future. Nominated aquatic habitats and aquatic reserves are protected under provisions of Part 7 of the Act, under which permits for activities that may damage protected habitats, flora and fauna are administered. Habitats that are critical to the survival of an endangered species, population or ecological community are identified under Division 3 of the above Act.

Section 221J and section 221K of the above Act require a species impact statement to be prepared in instances where the proposal would have significant effect either on: critical aquatic flora and fauna habitat, or aquatic threatened species, populations and ecological communities and their habitat. In the case of the proposal, it would have no material impact that would trigger the provisions of the above Act such that it would require Star Entertainment Group Ltd to prepare a species impact statement (refer to Section 6). The Act also sets out a number of permitting provisions for certain work activities where it is likely to impact on key fish habitat. The proposal is not expected to have any material impact on communities and species protected in under the above Act (refer to Section 6) within the meaning and definitions of the supporting impact assessment guideline. This removes the need to prepare species impact statements.

3.2.3 Commonwealth Environment Protection and Biodiversity Conservation Act 1999

The Commonwealth Environment Protection Biodiversity Conservation Act 1999 aims to:

- Provide for the protection of the environment, especially Matters of National Environmental Significance (MNES).
- Promote ecologically sustainable development (ESD) through conservation and ecologically sustainable use of natural resources.
- Promote conservation of biodiversity.

In the aquatic environment, the above Act lists the following MNES relevant to this study:

- Nationally threatened and listed marine species, ecological communities and critical habitats.
- Migratory species.
- Wetlands of national significance (termed Ramsar sites after the 1971 Convention on Wetlands).

Under the above Act a referral is required to the Australian Government for proposed “actions that have the potential to significantly impact on matters of national environmental significance or the environment of Commonwealth land”.

3.3 Water quality and pollution

3.3.1 NSW Protection of the Environment Operations Act 1997 (as amended)

Environmental protection is provisioned under the above Act. The underlying objective of the Act is to reduce pollution and manage the storage, treatment and disposal of waste. A key feature of the Act is the issuing of environmental protection licences (EPLs) for certain (scheduled) activities. Until 2001, seawater exchange was considered a scheduled activity within the meaning and definition of the above Act. As such, a proponent needed an environmental protection licence to operate a seawater exchange. Environmental protection licences issued to allow the NSW Environment Protection Authority (NSW EPA) to set conditions to control potentially polluting activities. While the de-scheduling of seawater exchange from under the above Act occurred in 2001, the Trust would still introduce controls to ensure the seawater exchange operated in accordance with the pollution prevention controls and requirements of the above Act.

Under Section 120 of the above Act, is it an offence to pollute any waters (including tidal waters and the sea) within the State. Water pollution under the Act is defined as causing a ‘physical, chemical or biological’ change to the condition of the water. It also includes making the water ‘unclean, noxious, poisonous, impure, or detrimental to health, safety, welfare or property’. This includes making the water unsuitable for fauna, livestock, fish, irrigation, or human consumption. Schedule 5j of the supporting NSW Protection of the Environment Operations (General) Regulation 2009 describes ‘thermal waste’ as being a potential source of water pollution. Thermal waste is defined as being “any liquid which, after being used in, or in connection with any activity, is more than two degrees Celsius hotter or colder than the water into which it is discharged".

While the Regulation defines thermal waste for it to pollute Pyrmont Bay it would need to trigger the provisions under Section 120 of the Act. To determine if this risk is likely, threshold criteria have been developed under the Guidelines for Marine and Fresh Water Ecology 2000 (refer to section 3.3.2).

The Act also requires The Star to notify the NSW EPA, which is responsible for administering the provisions of the Act, in instances where any pollution incident has the potential to "cause or threaten material harm to the environment" (refer to section 148 of the Act).

Waste discharge and pollution

The National Environmental Protection Measure (NEPM) and the NSW *Waste Classification Guidelines 2009* describe types of waste in terms of their environmental risk. Under the NEPM waste biocide is deemed a 'controlled waste' meaning that it must be tracked and disposed to a licenced facility. The NEPM and above guidelines also consider the discharge of stormwater (or freshwater) into the marine environment as a waste discharge. The above Act as supported by the Protection of the Environment Operations (General) Regulation 2009 prescribes certain matters for the purpose of water pollution one of which is the discharge of 'waste' that may materially harm the water quality values. As such, the proposal would be subject to the same discharge controls as general stormwater runoff to the Harbour as set in the context of the above Act. With regards to the use of biocides, only residual concentrations would be discharged in accordance with their approved use by Australian Pesticides and Veterinary Medicines Authority. This would ensure that any biocide flushing would not trigger the waste and/or pollution triggers of the above environmental planning instruments.

3.3.2 Guidelines for Marine and Fresh Water Ecology 2000 (ANZECC guidelines)

Australian and New Zealand Environment Conservation Council (ANZECC) published its revised Australian and New Zealand guidelines for fresh and marine water quality in 2000. These guidelines provide Government and the community, especially regulators, industry, consultants, community groups and catchment and water managers, with a framework for conserving ambient water quality in Australian rivers, lakes, estuaries and marine waters. Commonly referred to as the ANZECC Guidelines, they provide a framework for defining and assessing water quality, based on whether the physical, chemical and biological characteristics of a waterway support community environmental values including:

- Protection of aquatic ecosystems
- Drinking water
- Primary and secondary recreation
- Visual amenity
- Agricultural water for irrigation, livestock and growing aquatic foods.

The environmental values (and uses) of water apply to waterways such as natural rivers, creeks, lagoons, wetlands, lakes, groundwater, and estuarine and marine waters. The quality of artificial waterways such as reservoirs, where the waters are valued by the community for aquatic ecosystems or human uses, are also addressed by the guidelines, but enclosed and piped waters are excluded.

3.3.3 NSW water quality objectives

The NSW Water Quality Objectives (WQOs) are the environmental values and long-term goals for consideration when assessing and managing the likely impact of activities on waterways. They are not intended to be applied directly as regulatory criteria, limits or conditions but are one factor to be considered by industry, the community, planning authorities or regulators when making decisions affecting the future of a waterway.

The policy in NSW is that the level of protection applied to most waterways is the one suggested for 'slightly-to-moderately disturbed' ecosystems. Sydney Harbour (Port Jackson) and it component bays, however, may be considered as highly disturbed waterways and reduced level of protection may be appropriate as a pragmatic short-term goal, with the aim of eventually restoring it to the status of 'slightly-to-moderately disturbed'. However, it is not acceptable to allow poor environmental management or water pollution, simply because a waterway is currently degraded.

3.3.4 NSW Pesticides Act 1999

The above Act controls the use of pesticides in NSW. The Act aims to reduce the risks associated with the use of pesticides to human health, the environment, property, industry and trade. It also aims to promote collaborative and integrated policies for the use of pesticides. The proposal includes for the occasional use of biocides, a form of pesticide that falls under the Act.

The Act sets controls on the use, application, storage, and disposal of certain pesticides given their ability to cause ecological damage. The proposal intends to continue to use Mexel ® 432, which has been approved for use by the Australian Pesticides and Veterinary Medicines Authority (APVMA). This approval is consistent with the provisions of the above Act. Providing the biocide is used in accordance with the specifications, and controls are introduced to regulate its use then the risk of causing direct environmental harm or pollution, within the meaning and definition of NSW *Protection of the Environment Operations Act 1997 (as amended)* is reduced to acceptable levels by way of its approved use.

4. ASSESSMENT METHOD

This section describes the three broad stages of the impact assessment methodology.

4.1 Collation of available information and data

The following data and information sources were used in this assessment:

4.1.1 Study area definition

The marine assessment study area focusses on the water quality, marine ecology and hydrodynamic conditions of Jones Bay (inlet location) and Pyrmont Bay (discharge location), and where required, the wider locality of Sydney Harbour.

4.1.2 Available data and information

- The existing hydrodynamic, bathymetric and temperature conditions in Jones Bay and Pyrmont Bay were identified by referring to:
  - Admiralty chart data
    - Hydrographic and bathymetric data
  - Sydney Harbour Hydrodynamic Model
    - Bottom, middle and surface water current data
  - University of Sydney
    - Temperature data collected in 2013
  - Ocean Technology Group, University of Sydney
    - Water salinity data collected in 2013
- The existing marine ecology environment in Jones Bay and Pyrmont Bay was identified by referring to:
  - NSW National Parks and Wildlife Services wildlife atlas database (NSW Office of Environment and Heritage (NSW OEH), 2016) covering NSW Threatened Species Conservation (TSC) Act listings.
  - Commonwealth Government Environmental Protection and Biodiversity Conservation (EPBC) Act protected matters search tool (Australian Government Department of the Environment, 2016) covering Australian Government EPBC Act listings.
- Discussion with The Star facilities staff to confirm the fouling management plan and obtain anecdotal information on the nature and frequency of fouling and marine life entrainment.
- ‘Approved for construction plans’ of the HHR infrastructure produced by Connell Wagner (1995).

4.1.3 Site walkover

A walkover of the shoreline adjacent to the study area (Figure 2.1) was undertaken during mid tide (0.38 metres above Australia Height Datum (AHD)) on 26 July 2016. The purpose of the walkover was to observe and record sedentary and mobile biota occurring in the intertidal and shallow subtidal structures adjacent to the proposal.

A second site visit was undertaken on 3 August 2016 during high tide (1.44 m above Australia Height Datum (AHD)). The purpose of this site visit was to liaise with divers as they completed the underwater survey.

4.1.4 Underwater survey

An underwater survey was conducted on 3 August 2016 by The Diving Company to ascertain the nature and dimensions of the inlet and outlet infrastructure and conduct an ecological survey within the vicinity of the inlet and outlet.

4.2 Hydrodynamic Modelling

The hydrodynamic modelling comprised the following broad stages:

- Development of a three dimensional nearfield model to predict plume dispersion characteristics
- Confirmation of the design parameters, operating conditions and limits of the proposed harbour heat rejection system
- Assessment of the discharge and nearfield mixing that would take place in the receiving environment using the above modelling in the context of the provided design parameters
- A number of scenarios have been investigated (Table 2.3) to analyse the sensitivity of the dilution rate to seasonal fluctuation in ambient water temperature and salinity. These parameters determine the buoyancy of the discharge relative to the ambient waters and influence the degree of mixing.

The modelling domain, which defines the limits of the modelling, was initially restricted to the nearfield environment to assess if impacts are confined to within this region. Where necessary, modelling can be extended outside of this region into the far-field environment to assess further reaching impacts. These two environments are defines as follows:

- The nearfield environment, an area within which the thermal plume reaches neutral buoyancy or the surface, also known as the mixing zone. The edge of the nearfield is where any site specific trigger values regarding temperature will need to be met.
- The far field environment is the area outside of the nearfield where the wider values of the receiving environment may need to be considered in relation to the proposal. Consideration of the far field environment is only required where the impacts are not confined to the nearfield.

For the near-field modelling, the PC-based interactive flow visualisation tool VISJET was used which incorporates the Lagrangian jet model JETLAG (Lee et al, 1997). This model was developed by Professor Joseph Lee and his colleagues at the University of Hong Kong and provides 3D flow visualization of the predicted path and mixing of arbitrarily inclined buoyant plumes in moving receiving waters which may be density-stratified.

JETLAG has been validated against extensive analytical, laboratory experiments and field data and is widely used in design and assessment of marine outfalls including sites in NSW and specifically in Sydney Harbour. Examples of sites where JETLAG has been used are Barangaroo South District Cooling Plant, Sydney Sewage Treatment Plant Effluent Outfalls and the Sydney Modern Project.

Based on the results of the nearfield modelling it was concluded that no far-field modelling was required; this is explained further in Section 6 and detailed in the modelling report (Appendix A), which comprises details of the modelling inputs, assumptions and results.

4.3 Impact assessment

The marine impact assessment addresses the following:

- Assessment as to whether the ambient temperature and velocity in the nearfield environment would remove any potential thermal pollution and water velocity-related risk in the context of the adopted site-specific triggers and within the meaning and definition of the NSW *Protection of Environment Operations Act 1997* (as amended).

- Assessment of the impact on the marine environment of increasing the flow through the existing heat rejection system including the increased loading of antifouling product.
- Identification of adverse impacts that would need mitigation under the proposal.

4.3.1 Marine ecology

The marine ecology assessment focussed on assessing the impact on:

- Intertidal and subtidal habitat, flora and fauna due to the effects of increased seawater intake and discharge.
- Listed protected species, populations, communities and habitats.
- Adult and larval marine biota due to entrainment in the inlet pipes.
- Marine ecology due to the discharge of heated seawater.

4.3.2 Assessing ecological significance

Impact significance was assessed in accordance with the following guidelines:

- Threatened Species Assessment Guidelines: The Assessment of Significance (DECCW, 2007)
- Significant Impact Guidelines 1.1: Matters of National Environmental Significance (Commonwealth Department of Environment, 2013).

The above two guidelines define the processes for determining if a proposal's impacts are significant within the statutory meaning and definition of the corresponding Acts. They provide a statutory basis for defining the project's impacts by simply defining if a proposal's is predicted to have a significant impact, which would trigger additional legal and statutory requirements and provisions.

5. EXISTING ENVIRONMENT

This section describes the existing environment of the study area in terms of the hydrodynamic, physical and ecological conditions.

5.1 Hydrodynamic and physical conditions

5.1.1 Sydney Harbour

Sydney Harbour, along with Middle Harbour, North Harbour and the Lane Cove and Parramatta Rivers collectively form Port Jackson which covers an area of 55 km^2, comprises 317 km of shoreline, and at high tide, contains about 650 million cubic metres of water.

The majority of Port Jackson's shoreline is fronted by urban development. The associated catchment, including Sydney Harbour, receives high volumes of stormwater runoff from the surrounding urban environment. This runoff is mostly discharged by Council, Roads and Maritime and Sydney Water drainage infrastructure. Typically, the only stormwater pollution prevention controls in place regionally are gross pollutant (litter) traps. As a result "Sydney Harbour's water quality is graded 'poor' as the result of ongoing gross pollutant, sediment, suspended solid, nutrient, organic material, heavy metal and hydrocarbons discharges" (Sydney Harbour Catchment Water Quality Improvement Plan, WaterNSW, 2010). Despite this, Sydney Harbour supports a number of endangered species, communities and migratory species (Sydney Harbour Catchment Water Quality Improvement Plan, WaterNSW, 2010).

As a result, the surrounding councils, Roads and Maritime, and Sydney Water have developed stormwater management plans that are being implemented to improve the Sydney Harbour water quality.

5.1.2 Water quality

5.1.2.1 OBJECTIVES

The State Government has developed water quality objectives (WQO) for each catchment in NSW. These objectives were adopted following public consultation in 1998 (NSW DEC, 2006). The Sydney Harbour WQO are to protect:

- Aquatic ecosystems
- Visual amenity
- Primary and secondary contact recreation
- Aquatic food production (aquaculture).

5.1.2.2 CHEMISTRY

The salinity of seawater affects its density and hence buoyancy. In coastal and estuarine areas the salinity of the seawater will affect how well it mixes and exchanges with the freshwater. In low energy environments the saline seawater and fresh water do not mix. The fresh water overlies the saline water (a process known as stratification), which can lead to anoxic conditions.

Offshore of Sydney Harbour, the salinity is about 35 practical salinity units (PSU) which is typical of open ocean conditions (Sydney Institute of Marine Science, 2016). Salinity data collected from Darling Harbour by the University of Sydney in 2013 confirmed that the seawater's average salinity in the summer months is 34.12 parts per thousand (ppt) (which is broadly comparable to PSU) and during the rest of the year is 33.50 ppt. The corresponding annual minimum in 2013 was 24.6 ppt while the maximum was 35.2 ppt. The data confirms that the seawater within the Darling Harbour area is slightly less saline than the offshore seawater. This reflects the limited, but still present, mixing of fresh and saline water, which is a result of stormwater runoff and freshwater discharge via the Parramatta River.

5.1.3 Physical characteristics

5.1.3.1 TIDES

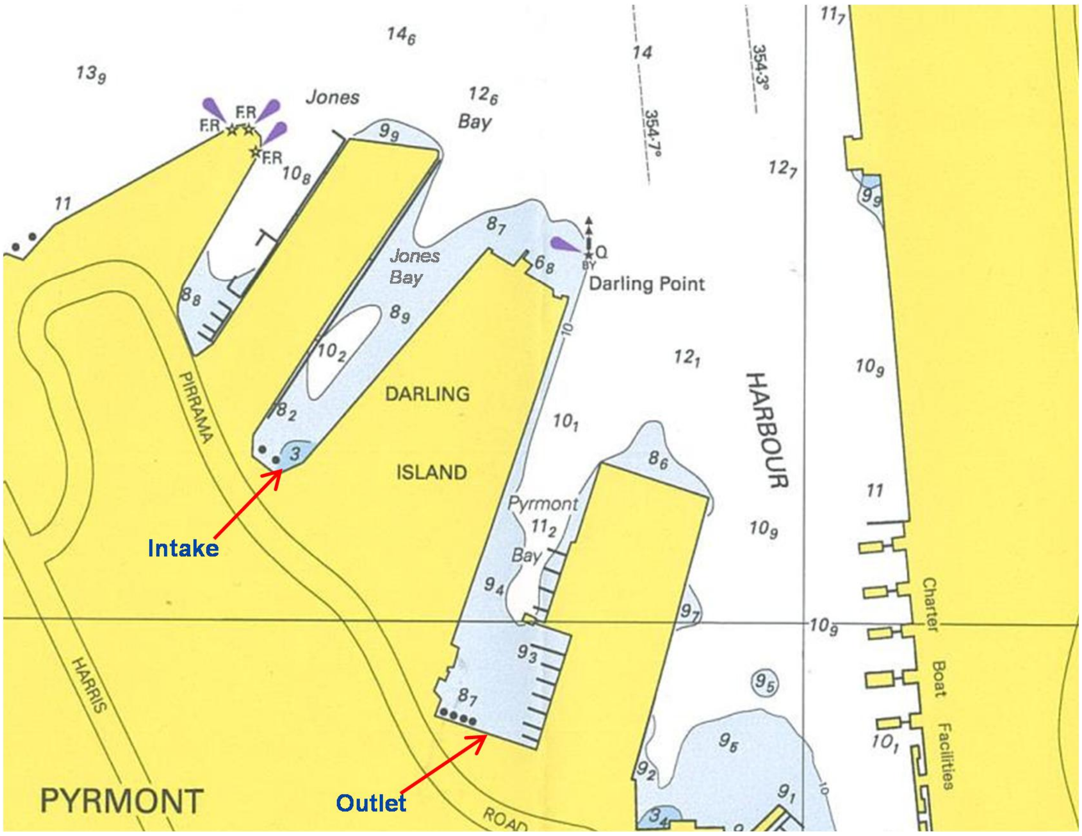
Sydney Harbour is tidally influenced, and the cycle is semi-diurnal meaning there is approximately 12.5 hours between high tides. At Fort Denison the tidal conditions are as follows:

- Mean spring tide is 1.23 metres above AHD.
- Mean neap tide is 0.75 metres above AHD.
- Mean high water is approximately 0.5 metres above AHD.
- Mean low tide can be approximately one metre below AHD.
- Highest high tide that would occur approximately once every 50 years is about 1.6 mAHD

5.1.3.2 BATHYMETRY

There is a complex bathymetry across Sydney Harbour. The natural seabed has been heavily modified in locations through dredging for shipping and navigation channels. A number of deep areas are present across the middle of the harbour with depths of up to 45 m separated by shoals as shallow as 3 m (Sydney Institute of Marine Science, 2016).

The Port Jackson Admiralty Chart displayed in Figure 5.1 shows that the seabed around Jones Bay is up to 10.2 m deep (based on lowest astronomical tide (LAT)) with a small shelf at 3 m deep adjacent to the inlet structure. The seabed around Pyrmont Bay is 8.7 to 11.2 m deep.



Source: Sydney Ports Corporation, Waterways Authority

Figure 5.1 Bathymetric data around Jones and Pyrmont bays

5.1.3.3 CURRENTS AND CIRCULATION

Sydney Harbour is influenced by the East Australian Current (EAC), which generally provides a nutrient depleted sub-tropical water mass (Sydney Institute of Marine Science, 2016). Average offshore current speeds are approximately 1.5 m/s so the water flowing past the heads is being constantly renewed, facilitating mixing, flushing and seawater exchange.

Hydrodynamic data including flow fields and components of water velocity adjacent to the outlet location were derived from the Sydney Harbour Hydrodynamic Model (Tanner *et al.* 2016). The actual average current velocities from the Sydney Harbour Hydrodynamic Model (Tanner *et al.* 2016) were used in the model to represent the degree of mixing that would occur within Pyrmont Bay.

The average velocities ranged from 0 (slack water) to 0.03 m/s, which reflect the sheltered and enclosed environment of Pyrmont Bay. The velocity is towards the main channel as the discharge from the Parramatta River, seaward groundwater movement and land run-off result in a net current towards the heads.

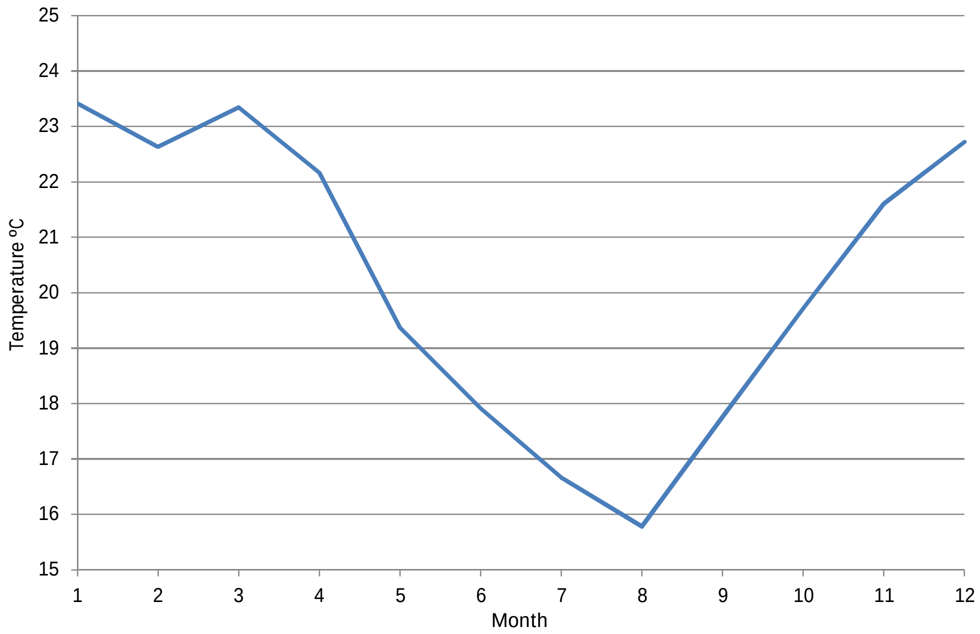
5.1.3.4 WIND AND WAVE CONDITIONS

Three dominant wind patterns affect Sydney Harbour. The strongest winds occur for about 17% of the time and come from the south. These affect the northern shoreline with the southern shoreline, which includes Pyrmont, being comparatively sheltered. The most frequently observed wind pattern comes from the north east (about 22% of the time), and the third most common pattern are winds coming from the west, which occur for about 17% of the time on average but are more prominent during winter (Sydney Institute of Marine Science, 2016).

Sydney Harbour is largely an enclosed system. This means the waves generated in the Harbour are typically only wind-generated. The maximum wave heights are closer to the heads and across the main channels; with wavelengths typically of less than 2 m. However, the low energy and sheltered nature of the many bays, including Pyrmont and Jones Bays, means that the wave conditions are further limited, resulting in very small waves and typically calm to still conditions.

5.1.3.5 TEMPERATURE CONDITIONS

The data collected by Harrison (2013) shows that during 2013; summer water temperature ranged from 21.6 ºC to 23.9 ºC, while the temperature range during the rest of the year is 15.7 ºC to 24.0 ºC. Figure 5.2 displays average monthly temperature during 2013.



Source: Harrison, 2013

Figure 5.2 Average monthly water temperature during 2013

5.1.3.6 FLUSHING AND ANOXIA

Broadly, the harbour can be divided into a main channel of deeper water surrounded by a number of large shallow bays. As a result, the main tidal mixing occurs in the main deep channel. Current speeds are typically higher in the main channel, which facilitates flushing. The bay areas, which are more sheltered, typically have lower current speeds, however, the currents and tides are considered sufficient to allow reasonable water exchange over a tidal cycle. The tidal movement will reduce the risk of stagnation leading to anoxic water (Sydney Institute of Marine Science, 2016).

5.1.3.7 GEOLOGY AND SEDIMENTOLOGY

Sydney Harbour is located in the Sydney Basin which comprises Hawkesbury Sandstone typically overlain by Quaternary deposits. The sandstone comprises cross-bedded, medium-to-coarse quartz sand with minor shale and laminate beds. The Quaternary deposits are up to 160 metres deep and comprise sand, silty-sand, clayey-sand and clay with peat lenses.

Sandstone underlays Sydney Harbour including Pyrmont. While occasionally exposed at surface, the sandstone is either directly overlain by up to seven metres of sub-benthic sediment or a sequence of Quaternary deposits, which in turn are overlain by sub-benthic sediments.

These sub-benthic sediments comprise occasional stiff-clay lenses, peat deposits and silty sands. There is also variability across Sydney Harbour, with the main channel and seabed close to the heads comprising sediments formed of a mixture of modern and relict sand and biogenic material (gastropod shells, bivalve shells and rock fragments) transported from offshore.

In the bay areas, including Jones Bay and Pyrmont Bay, the low energy means that finer marine sediment have settled comprising find sand, muddy deposits and even occasional peat lenses.

5.2 Marine ecology

5.2.1 Marine Habitats

The study area includes the heads of Jones Bay (seawater inlet location) and Pyrmont Bay (seawater discharge location). These bays, like much of Sydney Harbour have undergone extensive modification through reclamation and construction of extensive foreshore structures. Land uses adjacent to the bays are dominated by maritime activities (small boat marinas) backed by a mixture of commercial and residential developments.

The following information is summarised from land-based observations (26 July 2016) and underwater video footage recorded on 3 August 2016 at Jones Bay:

- The foreshore of Jones Bay area consists entirely of built structures (seawalls, pontoons, wharves and piles).
- The intertidal habitat in the vicinity of the existing seawater inlet pipes consists of an artificial concrete wall perforated by nine openings with stormwater drainage pipes at either end.
- The intertidal portion of the seawall is populated by a typical estuarine biotic assemblages dominated by Sydney rock oysters.
- Subtidal structures (wharf piles, headstock) were covered with algal and invertebrate growth typical of the Sydney estuary with distributions consistent with variations in tidal height (refer to Table 5.2).
- No introduced marine pest species were observed.

Figure 5.3 Location of existing seawater inlet culverts at the head of Jones Bay

The following information is summarised from land-based observations (26 July2016) and underwater video footage recorded on 3 August 2016 at Pyrmont Bay:

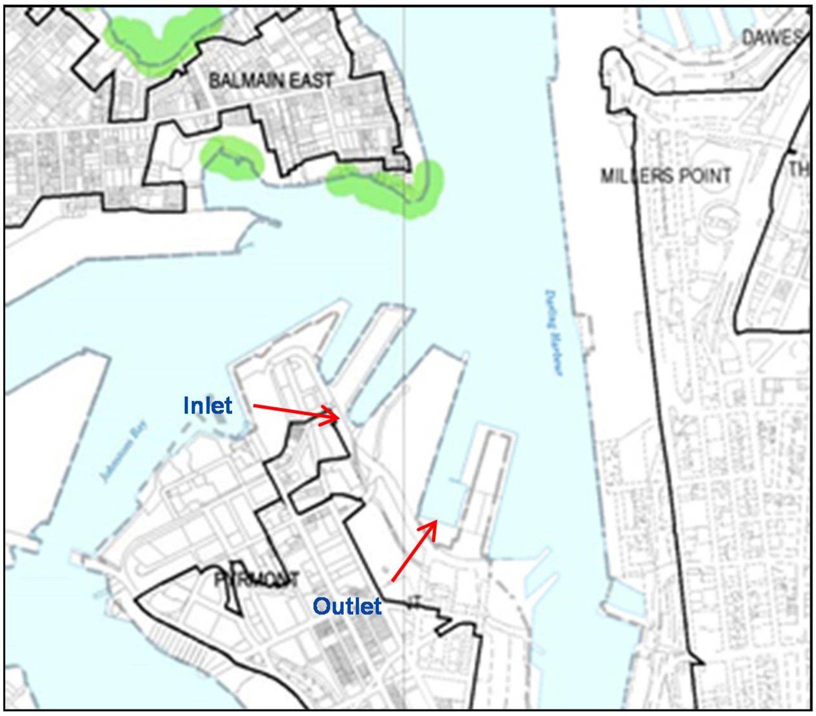
- The existing seawater discharge pipes are located beneath the wharf and grassed area at the head of Pyrmont Bay.
- Like Jones Bay, Pyrmont Bay retains few unaltered marine habitats and is dominated by built structures including seawalls, wood and steel wharf piles and a small vessel marina immediately seaward of the HHR outlet.
- Vertical artificial structures such as seawall, ladders, pontoon piles and wharf piles are populated by Sydney rock oysters and the associated invertebrate assemblage.
- Subtidal structures (wharf piles and headstock) were covered with algal and invertebrate growth typical of the Sydney estuary with distributions consistent with variations in tidal height (Table 5.2).
- Native algae was observed growing below mean water level on wooden wharf piles.

- No introduced marine pest species were observed.

Figure 5.4 Marine algae below Sydney rock oyster assemblage on wooden wharf piles near the outlet location at the head of Pyrmont Bay

5.2.2 Protected areas

Both Jones Bay and Pyrmont Bay have no listed wetland protected areas along their foreshores. The closest mapped wetland protected area is at Peacock Point the south-east portion of the Balmain peninsula, located 600 m to 800 m north west of the inlet and outlet locations.



Source: Sydney Regional Environmental Plan (Sydney Harbour Catchment) 2005 Wetlands Protection Area Map Sheets 4 and 10, DIPNR 2005

Figure 5.5 Map of Wetland Protection areas in the vicinity of the proposal

5.2.3 Protected biodiversity

Searches of relevant databases of listed threatened species under the EBPC Act, TSC Act and FM Act (refer to section 4.1) returned a list of threatened species, populations and communities that occur within 10 kilometres of the proposal, however the majority of which are land based and therefore not relevant to this assessment.

A summary of the threatened marine species, population and communities that are recorded in the locality of the proposal are listed in Table 5.1.

Table 5.1 Protected species

COMMON NAME	SUMMARY
State and Commonwealth protected species	
Fish	Four species, one endangered population of fish, and up to 23 species of seahorses (Syngnathiformes)
Marine mammals	Six species
Marine turtles	Five species
Birds	26 species and one population of birds
Ecological communities/population	The seagrass *Posidonia australis* meadows of the Manning-Hawkesbury ecoregion and populations in Port Hacking, Botany Bay, Sydney Harbour, Pittwater, Brisbane Waters and Lake Macquarie.

The relevance of the activities associated with operating the proposal and the likelihood of the species to occur in the immediate vicinity of the inlet and outlet were considered to determine which species, communities and populations require further assessment. The following key project-specific considerations were taken into account:

- The proposal affects small bays within Sydney Harbour which consist of modified and urbanised intertidal and subtidal habitats that have relatively low habitat diversity and low biotic diversity. Intertidal habitats consist mainly of artificial structures such as seawalls, wharf piles and (in Pyrmont Bay) pontoons and as such are unlikely to afford an appropriate habitat for the majority of protected species that may occur in the locality of the proposal.
- No construction activity is proposed and hence any minor disturbance to existing marine habitats would be restricted to the installation of mitigation structures such as screens at the inlet location.
- The proposed increase in water flow through the system is unlikely to have any incremental impact on deeper soft bottom habitats.
- The increased volume of seawater used for operation of the proposed heat exchange system would be small relative to the volume of Sydney Harbour (refer to section 5.1.1) making the loss of planktonic life forms of protected biota insignificant and unlikely to alter the ecology of intertidal or subtidal habitats.

No threatened or protected species required formal tests of significance (refer to section 4.3) due to one or more of the above considerations. Appendix B, Table 1, lists the specific reasons applicable to each of the relevant threatened or protected marine species, community or population. The main reason for the lack of threatened species in Jones Bay and Pyrmont Bay is that the type of habitats that threatened marine faunal species require, such as well-developed seagrass beds (habitat for seahorses and their allies and feeding grounds for turtles) and open sandy beaches (nesting habitats for some threatened shorebirds and turtles) are absent, minimal or have been largely replaced by artificial structures thus reducing the likelihood of finding threatened or protected species in the inner reaches of Jones Bay and Pyrmont Bay.

5.2.4 Flora and Fauna

Flora and fauna observed at intertidal levels on seawalls, wharf piles and pontoons at the head of Jones Bay and Pyrmont Bay were dominated by attached invertebrates such as barnacles, oysters and their associated small, mobile invertebrates (limpets, periwinkles, snails and whelks) and included encrusting and foliose algae.

On wharf and inlet and outlet structures below intertidal height barnacles, oysters, mussels and a variety of encrusting organisms (tube worms, bryozoans, encrusting sponges and filamentous algae) were observed. Barnacles and oysters occupied vertical structures at the shallowest water depth, with oysters also occurring on the bottom surface of the concrete wharf pile headstock at the Pyrmont Bay discharge location. Mussels became denser toward the seabed at the bottom of wharf piles at both locations. Consistent with the availability of light, macroalgae such as kelp were more abundant on exterior structures and were replaced by short, filamentous algal species in encrusting growth under the wharves and within inlet and outlet structures.

Table 5.2 lists the flora and fauna observed during the site walkover and underwater survey.

Table 5.2 Intertidal and subtidal flora and fauna observed at the head of Jones and Pyrmont Bays

COMMON NAME	SCIENTIFIC NAME
Marine Algae (flora)	
Brown algae	*Zonaria* spp.
Green algae	Low turfing forms
Funnel weed	*Padina elegans*
Bubble weed	*Sargassum linearifolium*
Kelp	*Ecklonia radiata*
Brown forkweed	*Dictyota dichotoma*
Encrusting red algae	Various species
Turf forming coralline algae	*Corallina* spp., *Jania* spp.
Marine Invertebrates (fauna)	
Sydney Rock oyster	*Saccostrea glomerata*
Barnacles	*Elminius modestus, Catomerus polymerus, Tetraclitella purpurascens, Chthamlus antennatus,*
Limpets	*Patelloida mimula, Spihonaria* spp.
Periwinkles and snails	*Bembicium* spp.,*Littorina* spp., *Austrocochlea porcata, Nerita atramentosa*
Whelk	*Morula marginalba*
Common edible mussel	*Mytilus edulis planulatus*
Hairy Mussel	*Trichomya hirsuta*
Eastern Australian scallop	*Scaeochlamys livida*
Bryozoans	Various erect and encrusting species
Encrusting sponges	Various species, yellow to orange in colour
Tubeworms	Various species with hard, white tubes
Finfish (fauna)	
Eastern hulafish	*Trachinops taeniatus*
Bait fish, Schooling fish	Young of several species
Freshwater eel (Longfin eel)	*Anguilla reinhardtii*
Birds (fauna)	
Silver gull	*Larus novaehollandia*

Figure 5.3 Left: Two species of mussel, tubeworms and encrusting assemblage typical of subtidal growth at Jones Bay and Pyrmont Bay. Right: Eastern Australian scallop *Scaeochlamys livida* from Jones Bay.

The flora and fauna in Table 5.2 and Figure 5.3 are typical of estuarine assemblages common in sheltered bays dominated by built structures in Sydney Harbour (Chapman, 2003). The observed biodiversity of the intertidal and shallow subtidal areas can be considered moderate to low, likely due to the restricted marine habitats available. A visual inspection of the Mussels, tubeworms and scallop shown in Figure 5.3 by a marine ecologist has determined that these can be considered healthy specimens.

No pest marine species were observed at either the inlet or outlet location.

5.2.5 Key Threatening Processes

Key threatening processes (KTP) are actions that have the capability to threaten the survival or evolutionary development of any species, population or community protected under State legislation. A series of standard processes have been defined under State legislation (refer to section 4.1). No KTPs were identified that may adversely affect the identified threatened species within Jones Bay and Pyrmont Bay and hence no consideration of KTPs is required in this assessment.

No threatened or protected species required formal tests of significance (refer to section 4.3) due to one or more of the considerations listed in section 5.2.4 above.

6. MARINE IMPACT ASSESSMENT

This section describes the predicted incremental impacts that would occur on the marine environment from operating the HHR system with a water flow increase of approximately 50%.

An approved heat exchange system is currently in operation and the proposal is limited to increasing the volume of water taken up and the volume of water discharged. Although the frequency of system maintenance may increase under the proposal, no changes to the differential temperature or chemical composition of the discharge water are anticipated. Because typical assemblages of marine biota are present at both the inlet and outlet locations it is assumed that they are adapted to the existing conditions.

The potential direct and indirect impacts on the marine environment are summarised below:

- Hydrodynamic and water quality
  - Temperature changes (Pyrmont Bay): small increase in the spatial extent of the thermal plume due to increased discharge volume and velocity compared to the existing system (Section 6.1.1).
  - Erosion and scour: potential small additional increase above present conditions due to marginal increase in discharge velocity in Pyrmont Bay. No additional impact on scouring at inlet (Jones Bay) associated with increased inlet velocity due to depth of seabed adjacent to inlet culverts (Section 6.1.2).
  - Water quality changes (Pyrmont Bay): No additional impacts due to no change in chemistry of discharged water compared to present operation (Section 6.1.3).
  - Accidental and emergency discharges (Pyrmont Bay): no additional impact due to no relevant changes in maintenance or operational procedures compared to existing regime (Section 6.1.4).
- Marine ecology
  - Thermal pollution (Pyrmont Bay): no additional impacts due to no increase in discharge temperature and small increase in the spatial extent of the thermal plume (Section 6.2.1).
  - Chemical impacts (Jones Bay): no incremental impact on marine growth in the immediate vicinity of the outlet due to no change in concentration of antifouling chemical dosing (Section 6.2.1).
  - Operational maintenance impacts: no additional impact on marine biota due to no change in maintenance procedures.
  - Entrainment and impingement (Jones Bay): no additional impact (and potential to reduce existing impact) associated with entrainment due to installation of screens on inlet structures as mitigation measures (Section 6.2.2).
  - Changes in primary production: negligible additional impact due to no increase in discharge temperature and small increase in the spatial extent of the thermal plume (Pyrmont Bay). Negligible additional impact due to increase in seawater intake volume (Jones Bay) (Section 6.2.2).
  - Operational noise: no additional impact
  - Impacts on threatened species, communities, populations and habitats: no additional impacts mainly due to low likelihood of occurrence, generally as a consequence of lack appropriate habitat (Pyrmont Bay and Jones Bay) (Section 6.2.2).

6.1 Hydrodynamic and physical properties

A number of scenarios have been investigated to assess the properties of the existing and proposed discharge plumes such that the incremental change due to the upgrade can be determined and assessed against an appropriate trigger value.

Further scenarios have been carried out to analyse the sensitivity of the dilution rate to seasonal fluctuation in ambient water temperature and salinity. These parameters determine the buoyancy of the discharge relative to the ambient waters and influence the degree of mixing.

The modelling considers the system operation during two broad periods:

- Summer months (December to February) as this is when there will be the greatest demand on the system.
- Rest of year (March to November) to provide an assessment of the remainder of the year under the typical associated ambient conditions such as salinity and temperature.

All scenarios incorporate the following conservative assumptions:

- Due to the relatively shallow depth of the water column, it is not appropriate to model the water column as density stratified; therefore the ambient salinity applies to the entire water column.
- All modelled scenarios represent the maximum flow rate through the system (Table 2.2) with the maximum DT of +6°C.
- The ambient current velocity is varied with depth according to the following inputs, the model linearly interpolates between the data points:
  - Surface current: 0 m deep
  - Mid-depth current: 1.1 m deep
  - Bottom current: 2.2 m deep

6.1.1 Temperature effects

Figures 6.1 and 6.2 show the temperature decay with distance from the outlet for the existing and proposed systems under the summer condition and rest of year condition respectively. Under both conditions, the existing discharge plume reaches the surface within approximately 2.2 m and the temperature at the edge of the nearfield is approximately 3.6 ºC above ambient.

The proposed system discharge plume has an increased velocity and undergoes a greater degree of mixing over a greater area prior to reaching the surface. Under both summer and rest of year conditions the proposed system discharge reaches the surface over a distance of approximately 3.2 m and the temperature at the edge of the nearfield is approximately 3.3 ºC above ambient.

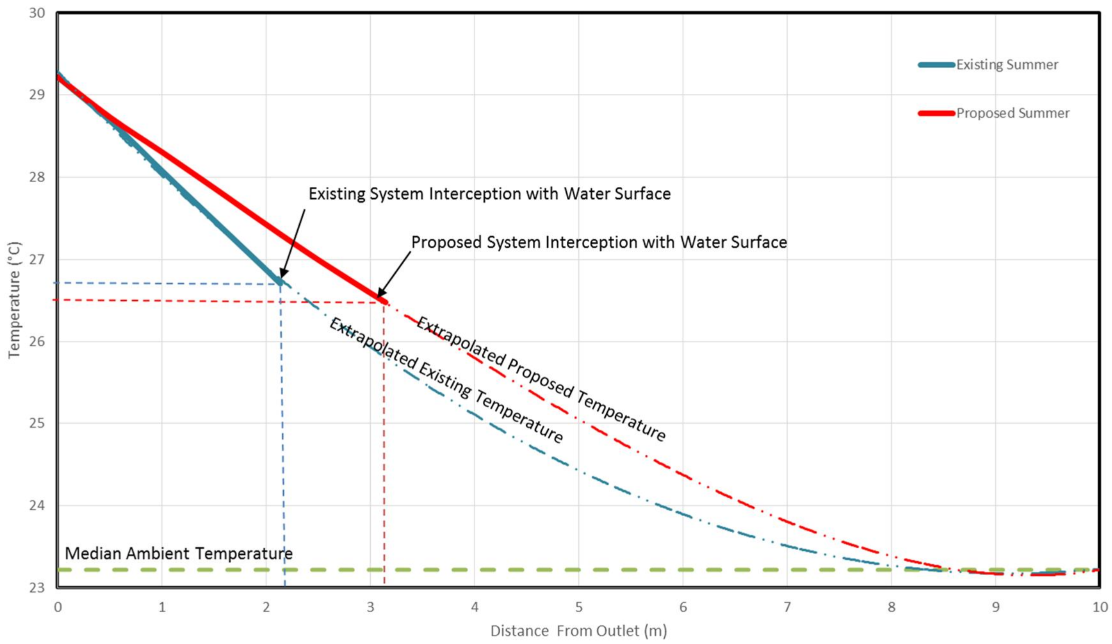


Figure 6.1 Temperature dilution with distance from the outlet summer condition

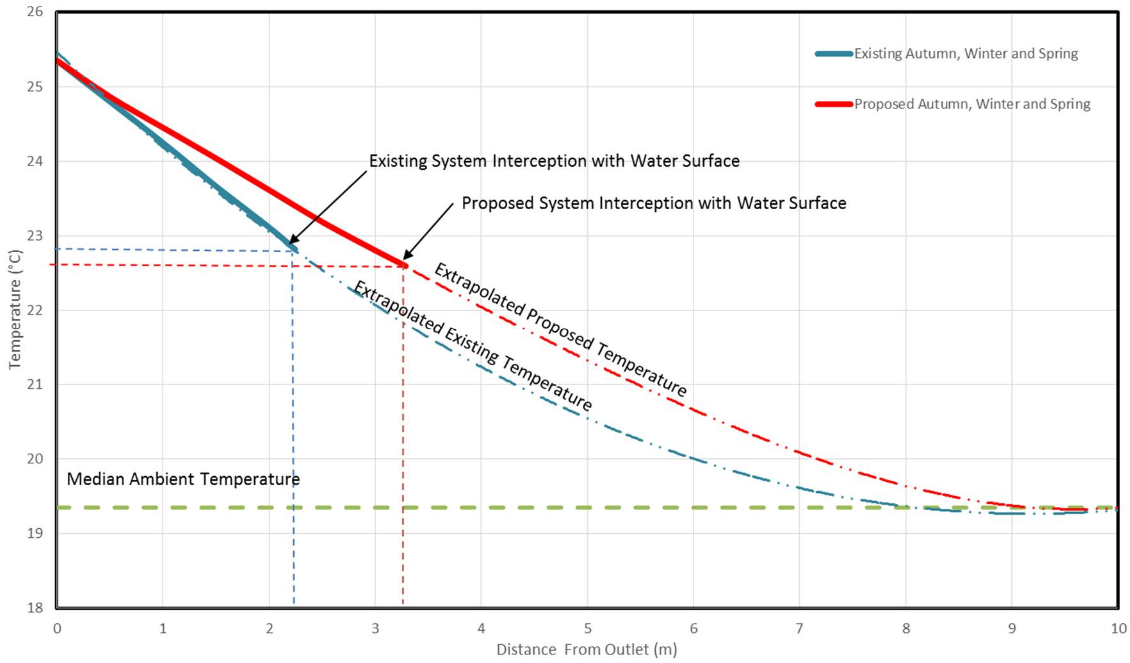


Figure 6.2 Temperature dilution with distance from the outlet rest of year condition

The nearfield zone of the proposed discharge plume is larger in area than that of the existing discharge plume, and due to this, has a lower modelled temperature at the edge of the nearfield zone. The incremental differences in temperature and size of the nearfield zone of the existing plume compared to the proposed can be considered negligible.

The temperature dilution has been extrapolated beyond the nearfield zone to provide an indication of the distance over which the plume would equilibrate to ambient temperature. Note that the modelled data is nearfield only and the extrapolation is assumed.

6.1.1.1 ASSESSMENT AGAINST AMBIENT 80TH PERCENTILE

As noted in section 3.3.1, if the temperature of the discharge is greater than 2 ºC above ambient this is deemed ‘thermal waste’ within the meaning and definition of the NSW Protection of the Environment Operations (General) Regulation 2009.

The above regulation does not provide the specific conditions under which ‘thermal waste’ would result in ‘water pollution’ other than defining the resultant environmental impact. This is defined with the ANZECC Guidelines (refer to section 3.3.2), through the concept of assessing the potential exceedance of ‘trigger values’. These are values above which there is an increased risk of causing water pollution that must be investigated further.

Section 7.4.4.1 of the ANZECC Guidelines contain a summary of the approach recommended for comparing results from a test site with a guideline trigger value. It is emphasised that trigger values are an ‘early warning’ mechanism of a potential problem. They are not intended to be an instrument to assess ‘compliance’ and should not be used in this capacity. The recommended trigger-based approach for physiochemical stressors (changes in the natural environment that can cause an impact on marine values) such as temperature is stated as follows, “a trigger for further investigation will be deemed to have occurred when the median concentration of independent samples taken at a test site exceeds the 80th percentile of the same indicator at a suitably chosen reference site”.

The assessment against the ambient 80th percentile was carried out to establish if the temperature effects of the discharge plume are confined to the nearfield mixing zone in accordance with the ANZECC (2000) approach detailed in Section 2.2.3.

The trigger value must represent the ambient 80th percentile temperature of the receiving water, which will include the existing approved HHR system. This is compared against the median temperature at the edge of the nearfield zone associated with the proposed system to understand if the degree of warming that is taking place in the receiving waters due to the proposed system is within acceptable limits.

The approach firstly requires the establishment of a suitable trigger value against which the temperature effects of the proposed system can be compared. The trigger value is calculated as the 80th percentile ambient condition, including the existing system, as measured at the edge of the nearfield mixing zone (where the plume meets the surface). The trigger value has been calculated to be 26.8ºC. A detailed account of this process is provided in Appendix A.

COMPARISON AGAINST THE PROPOSAL

The proposed system operating under standard conditions during summer (Figure 6.1) has been compared against the trigger value. Figure 6.3 shows that the temperature at the edge of the nearfield mixing zone due to the proposed system does not exceed the trigger value.

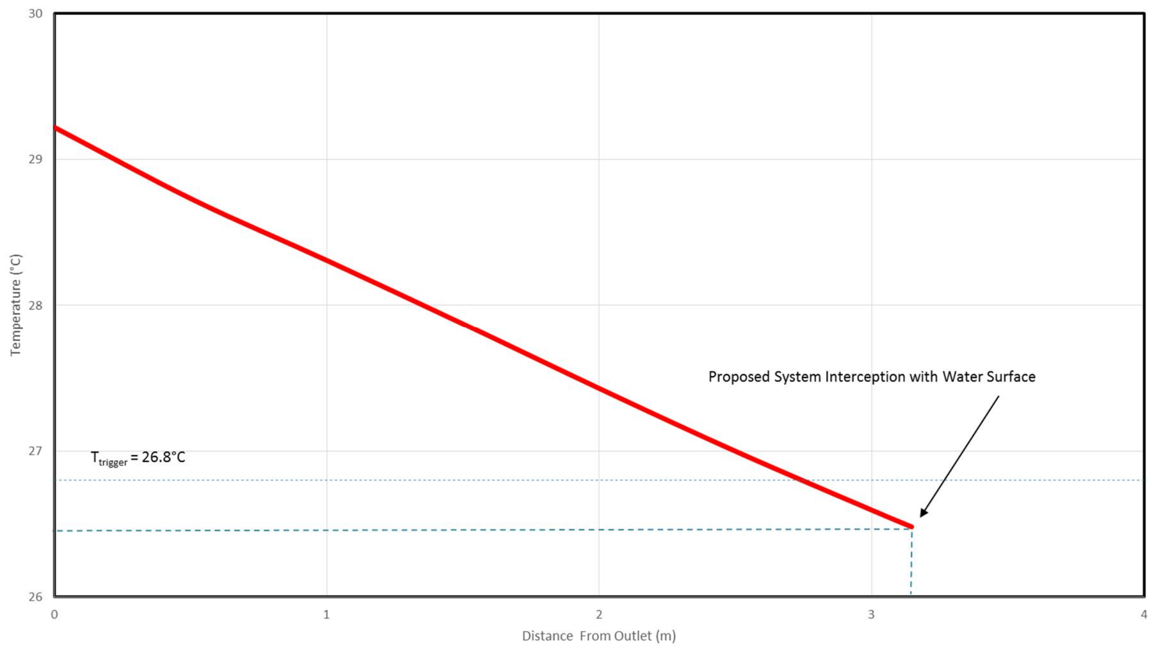


Figure 6.3 Assessment of proposal against 80th percentile trigger value

The above analysis confirms that the predicted median temperature post increased discharge is less than the 80th percentile ambient temperature and the proposal is therefore not considered to have an adverse impact on the receiving waters either in terms of the ANZECC Guidelines.

6.1.2 Erosion and scour

Modelled discharge velocities for the existing and proposed discharge plumes under summer and rest of year conditions are presented in Figures 6.4 and 6.5 respectively. Due to the dimensions of the outlet and the flow rate, the discharge velocities can be considered negligible when the plume exits the outlet at 0.14 m/s for the existing system and 0.22 m/s for the proposed system.

The modelling shows that the velocities rapidly decrease within 3 m from the outlet. Furthermore, due to the buoyancy of the discharge plume, it is immediately directed towards the surface, which will restrict the interaction with the seabed to the area immediately outside of the outlet and hence reduce the risk of increased erosion and scour. Upon reaching the surface the action of waves, wind and surface current will be the dominant force controlling the plume dilution.

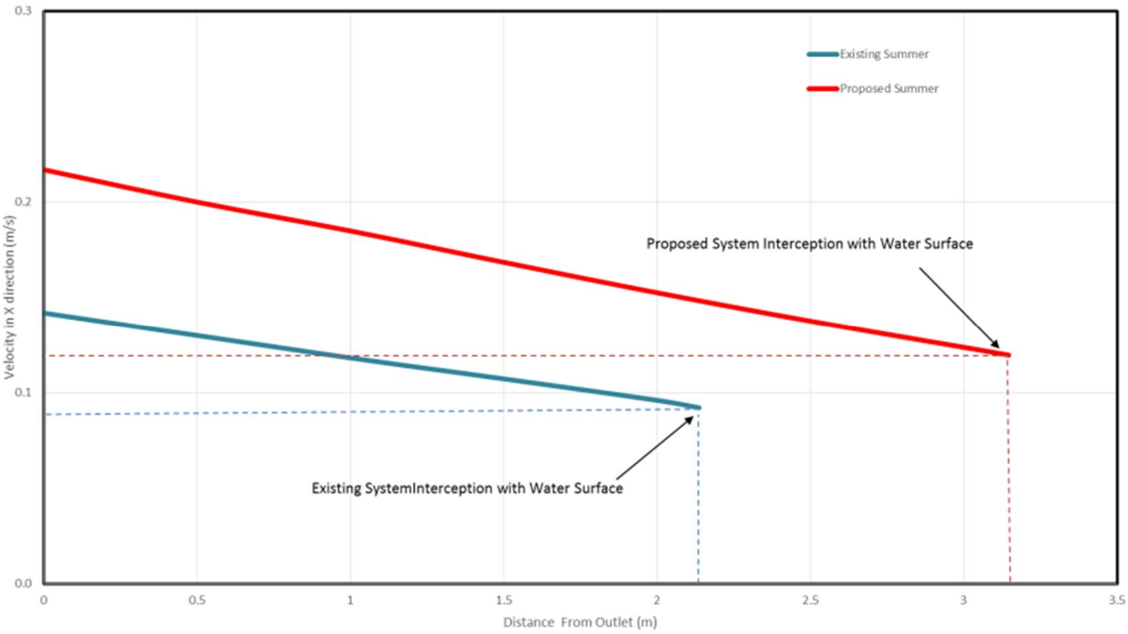


Figure 6.4 Velocity dilution with distance from the outlet summer condition

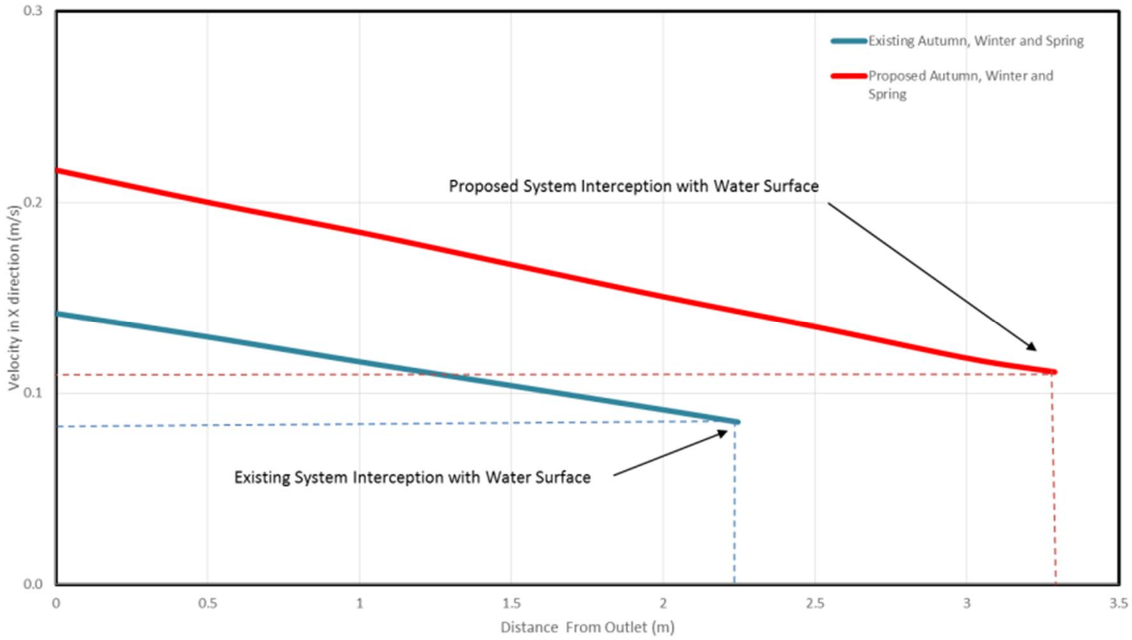


Figure 6.5 Velocity dilution with distance from the outlet rest of year condition

The incremental increase in discharge velocity due to the proposal is estimated to be less than 0.1 m/s and, as such, there will be negligible risk of additional erosion or scour due to the proposal.

6.1.3 Marine growth

There will be no change to the fouling management plan currently in place for the existing system and as such there will no incremental impact to the marine environment.

The strainers are cleaned twice a year using freshwater, and pipework cleaned once per year using a high pressure fresh water hose for 8 hours over 2 to 3 days. The associated sudden drop in salinity caused by introducing freshwater can lead to osmotic shock, which can be an effective way to inhibit marine growth.

The fouling management plan currently in place for the existing system entails the use of Mexel 432, an amine based dispersant. Mexel 432 has been approved for use in seawater cooling systems by the Australian Pesticides and Veterinary Medicines Authority (APVMA) to prevent corrosion, biofilm formation and the attachment of seawater organisms. The current dosage is 2 to 3 parts per million (ppm) every day for one hour and this is anticipated to remain the same for use in the proposed system.

6.1.3.1 MEXEL 432 DILUTION ASSESSMENT

The dilution factors associated with the discharge plume were applied to the use of antifouling product, Mexel 432, at an initial dosage of 3 ppm. Figure 6.6 shows the difference in the concentration gradient of the existing and proposed systems under summer conditions.

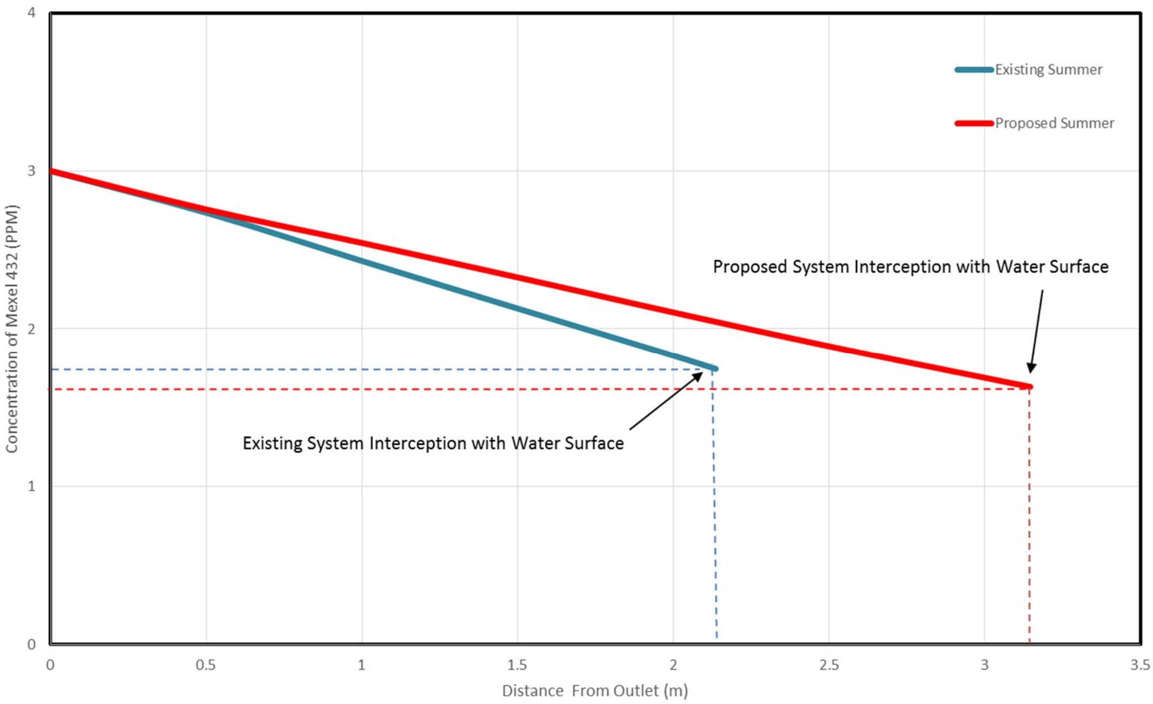


Figure 6.6 Mexel 432 dilution

Figure 6.6 shows that the predicted concentration of Mexel 432 at the edge of the nearfield mixing zone is approximately 1.7 ppm for the existing system and 1.6 ppm for the proposed system. The proposed system has a lower concentration at the edge of the nearfield due to the increased size of the nearfield zone associated with the greater discharge; the proposed discharge plume undergoes a greater degree of mixing with ambient waters prior to reaching the surface. Upon reaching the surface, the action of wind and waves will disperse the plume more rapidly than when the plume is submerged.

For both the existing and proposed systems the addition of Mexel 432 occurs once a day for one hour so the concentrations shown in Figure 6.6 will exist only during the one hour dosing period before being diluted to undetectable levels.

6.1.3.2 IMPACTS TO MARINE GROWTH

The use of an APVMA approved amine based biocide in conjunction with freshwater flushing is considered to pose a negligible risk of impact. Providing the correct concentrations, treatments and controls are introduced and the plant is operated within manufacturer specifications the risk of any impact can be managed to acceptable levels.

The active constituents in Mexel 432 Dispersant will largely be consumed within the cooling system and are unlikely to persist in the marine environment following discharge because of their strong sorptive characteristics and biodegradability (APVMA, 2012). Due to this, cumulative impacts of other local systems using this product are unlikely to cause unacceptably high concentrations in receiving waters.

The Commonwealth Department of Environment (DCoE) has recommended that the APVMA be satisfied that the proposed use of Mexel 432 Dispersant in accordance with good practice would not be likely to have an unintended effect that is harmful to animals, plants or things, or to the environment (APVMA, 2012).

The only other potential risk would be one of an accidental overdose. This risk would be managed through automated dosing or dosing only by suitably qualified personnel. All personnel involved in the dosing would be required to have been trained in the dosing equipment. Furthermore, the system would be monitored and shut down in such an event.

6.1.4 Accidental and emergency discharges

There will be no additional risk of overdose or emergency discharge due to the proposal as the operational procedures associated with the system will remain unchanged.

6.1.5 Far field modelling

The predicted modelling results confirm that there would be sufficient initial mixing and dilution in the nearfield such that the water temperature would return close to ambient conditions within the near field zone. The modelling also confirms that the discharge would be below the trigger value in the near field calculated in accordance with the ANZECC Guidelines (ANZECC, 2000). As such, there would be no need to consider the impacts across the far field.

6.2 Marine ecology

6.2.1 Existing discharge operations

The heat exchange system has been in operation since 1998 with maximum possible intake of 850 L/s. Water is discharged from the system at up to 6 $^{\circ}$C above ambient seawater temperature at a discharge velocity of 0.14 m/s at the culvert opening. The existing discharge plume, modelled at full flow capacity indicates that the discharge plume intercepts the water surface 2.2 m away from the culvert outlet. This location corresponds to approximately half the distance between the suspended wharf and the nearest pontoon to the wharf in Pyrmont Bay. The discharged water contains a biocide (Mexel) dosage of 2 to 3 ppm delivered for one hour every day at random times.

A variety of marine biota was observed in Pyrmont Bay on wharf structures within the existing region of elevated temperature due to the existing discharge plume (section 5.2.1). The species diversity and abundance of the observed assemblage is considered typical of those in urbanised estuarine environments dominated by built structures and vertical surfaces. The vertical distribution of marine biota on wharf piles within the existing region of elevated temperature due to the discharge plume can be explained by the combined factors of height with respect to the tide and decreasing distance from light. Barnacles, oysters, mussels and the encrusting assemblage including filamentous algae occupied almost 100% of the surfaces of wharf piles with no apparent effect of the biocide on their abundance or growth. There were no pest species observed on the wharf piles.

Overall, the impacts of the discharge from the existing heat exchange system are undiscernible on a marine assemblage that appears to be typical of its location on an estuarine, urbanised foreshore.

6.2.2 Additional Thermal Impacts

Modelling indicates that the proposed discharge plume would exit the culverts at a rate of 0.22 m/s. This would result in the discharge plume intercepting the water surface 3.2 m away from the outlet near the pontoons closest to the suspended wharf, 1 m closer to the pontoons than the current discharge. Marine habitats affected by the proposed discharge plume include wharf piles currently outside the existing plume and potentially the pontoons closest to the wharf.

The visual inspection and review of the underwater survey footage shows that there is no evidence of impact of the existing thermal plume and estuarine organisms in general are well adapted to changes in temperature and salinity (McLusky and Elliott, 2004). It can therefore be concluded that any marine life that is currently just outside of the current plume footprint (mainly oysters in the intertidal zone and mussel at deeper depths) are likely to easily tolerate the effects of the predicted increase in plume footprint due to the proposal.

Sydney rock oysters form bands around the wharf piles at mid-tide level in Pyrmont Bay. Research on this common estuarine species indicates that the temperature increase associated with the existing and proposed discharge plumes are well within its temperature tolerance over the range of salinities likely to occur in the study area (O'Connor *et al*., 2008). Little is known about the temperature tolerances of most of the other common species found in the intertidal and subtidal sections of the wharf piles, but the marginal predicted temperature elevation is well within the maximum range recorded in intertidal habitats in which the organisms occur and would occur over a few additional wharf piles.

6.2.3 Additional Chemical Impacts

As noted above, the system is currently flushed with biocide (Mexel) at a rate of 2 to 3 ppm for one hour every day at random times to reduce marine biofouling of pipework. Under the proposal the rate of biocide dosing would remain the same resulting in a net increase in the biocide load in receiving water due to greater volume of seawater discharged. The current low concentration of discharged biocide is rapidly and thoroughly diluted with no evidence of deleterious impacts on marine biota on wharves within the existing discharge plume. It is therefore unlikely that the same rate of dosing would have a discernible impact on marine biota due to rapid mixing in the water column. After the point of discharge at the culvert, the biocide's residual concentration would be diluted within the nearfield zone as per Figure 6.6 before reducing to undetectable levels due to the action of wind and waves and ambient currents.

Cold water can hold more dissolved oxygen than warm water, therefore the levels of dissolved oxygen in the water currently discharged would be lower than those in the ambient seawater due to the elevated temperature of the discharged water. The increased velocity of the discharge under the proposal (0.22 m/s compared to 0.14 m/s) would increase initial mixing, which would result in the re-oxygenation of the water within approximately 3 m of the outlet channel. Given that no effects of deoxygenation on stationery or mobile marine biota were observed, no physiological changes in marine biota are likely to be detectable under the proposal due to initial lower dissolved oxygen in discharge water.

6.2.4 Intake Operations

The existing system draws in seawater horizontally from the south east corner of Jones Bay at the rate of 1.8 m/s into the intake pit with the intake rate increasing to 2.3 m/s at the inlet pipe (Figure 2.2). There are currently no screens on the entrances to either the initial chambers or the inlet pipe. In the past there have been anecdotal reports by maintenance workers of entrainment of medium, and (infrequently) large fish into the cooling plant, however no such entrainment has been reported in the past few years (Source: The Star maintenance personnel).

The intake pit and inlet pipe are cleaned once per year, usually during cooler months of the year so that while the system is offline, building cooling requirements can be met by alternative means. Maintenance procedures include clearing the structures using a high-pressure hose with an angled nozzle that is pulled along the pipe. Screens inside the cooling plant are manually cleaned with freshwater, without the use of chemicals. The main marine species removed are mussels, and video evidence of broken mussel shells was captured during the underwater survey on 3 August 2016. Mussels are common fouling organisms in cooling systems (Holmes, 1970).

6.2.4.1 ENTRAINMENT AND IMPINGEMENT

Entrainment is the process whereby marine plankton is taken up into the cooling system and killed in the process. The entrainment process removes microscopic floating plants as well as larval and adult marine animals (including fish) from the ecosystem. As such, it affects the most vulnerable life stages (eggs and larvae) of familiar marine biota such as fish, crabs and shellfish (oysters, clams, snails) (Dixon *et al.*, 2001). The planktonic phase of the reproductive cycle of many marine animals is the most precarious and marine biota have evolved reproductive strategies that can produce eggs and larvae far in excess of the numbers required for population replacement to counteract the significant mortality experienced in early life stages (Underwood and Chapman, 1995).

Impingement is the process whereby larger marine biota (commonly fish) are trapped against a screened inlet structure because their burst swimming speed is not sufficient to escape the force of the inlet velocity current. Fish may escape from temporary or short periods of impingement; however impingement can lead to injury or fatality.

The proposed inlet velocity would increase to 2.8 m/s into the intake pit and to 3.6 m/s at the inlet pipe. While the magnitude of the current entrainment of fish is not quantified, their occasional presence within the inlet system suggests that entrainment occurs occasionally under the existing inlet velocities. This entrainment is consistent with current best practice that suggest that inlet velocities in the order of 0.5 feet per second (0.15 m/s) conform to best practice mortality performance standards that minimise entrainment of most juvenile and adult fish (Water Reuse Association, 2011). Given that the existing inlet velocity exceeds the entrainment threshold velocity, the increased inlet velocity under the proposal may, if unmitigated, represent an additional impact on adult and juvenile fish.

As there are no practical mitigation measures that avoid or minimise entrainment of plankton, the magnitude of impacts on primary production due to entrainment of plankton is proportional to the volume of water used. Because both the existing and proposed systems use very small water volumes in comparison to the volume of Port Jackson, impacts on primary production are likely to be negligible. The volume of water taken up in the existing system is relatively small (approximately 26.8 million cubic metres per year) compared to the volume of Port Jackson (650 million cubic metres). When operating at the anticipated 25% to 80% capacity the proposed increased volume of seawater uptake represents a relatively small increase of up to 6 million cubic metres per year) or a total of 0.9% of the water volume in Port Jackson. This minor increase is unlikely to significantly affect net primary productivity and the population of plankton in Port Jackson.

6.2.4.2 IMPACTS ON THREATENED SPECIES, COMMUNITIES, POPULATIONS AND HABITATS

No threatened or protected marine species, populations or ecological communities listed under the EPBC Act, TSC Act and FM Act were observed within the spatial extent of the proposed discharge, and their occurrence in Pyrmont Bay or Jones Bay is either unlikely or transient in duration (seabirds). This is due largely to the lack of appropriate habitat in the bays that provide food or shelter for protected species, communities or populations.

6.2.4.3 MARINE PEST SPECIES

Artificial marine structures such as wharves and submerged inlet screens can provide habitat that marine pest species can exploit at the expense of native species (Hedge et al 2013, Glasby and Lobb 2008, NIMPIS 2002). Introduced via vectors including ship's ballast water and hull fouling, pest species such as Asian green mussels (*Perna viridis*) and Brown mussels (*Perna perna*) can multiply quickly, block pipe openings and form founder colonies from which the pest species can disperse. The existing inlet structures are regularly cleaned and the main organisms removed to date have been two native mussel species (Edible mussels and Hairy mussels). As removal of fouling organisms will continue under the proposal, the increased volume of water under the proposal is unlikely to result in an increased risk of the occurrence of marine pest species.

6.2.5 Operational noise

Given the distance of the inlet and outlet infrastructure from the plant room, the associated operational noise is considered to be within the limit of the variance in ambient conditions considering boat movements and other activities within Jones Bay and Pyrmont Bay. There will be no change to this infrastructure under the proposal and as such, there is assessed to be no operational impact or risk due to noise. By comparison, studies into the underwater noise from a high-pressure operational gas pipeline (Zykov, *et al.,* 2013) confirm the low risk to marine fauna and mammals. This is a pipeline where the operating pressures (and noise levels) would far exceed those experienced under this proposal.

7. CONSULTATION

The following government authorities have been consulted regarding the proposal:

7.1 Environment Protection Authority

Through discussion with the NSW Environment Protection Authority (NSW EPA) regarding the proposal the advice is that such systems do not require an environmental protection licence (EPL) and that the authority would not be involved in a regulatory capacity. It may however provide technical advice if requested by the NSW Department of Planning and Environment.

7.2 Department of Primary Industries – Water

The NSW Department of Primary Industries – Water has advised that they would not be involved in a seawater heat exchange project as it is concerned with freshwater in the environment and anything involving seawater would not require their input as a stakeholder.

8. MITIGATION MEASURES

This section describes potential mitigation measures that could be adopted to mitigate against the impacts discussed in Section 6. Mitigation measures are shown in Table 8.1.

Table 8.1 Mitigation measures

IMPACT	MITIGATION
Operation	
Temperature effects	None required as the modelled temperature effects are shown to be within the tolerances of the marine organisms present and are below the trigger value calculated as per ANZECC (2000).
Water velocity impacts at inlet (Entrainment of fish)	Install 100 mm mesh screen across culvert openings in the sea wall at Jones Bay as this location can be easily accessed to maintain and replace the screens.
Fouling management	Maintain current dosage rate of biocide Mexel 432 to deter biofouling. Continue physical cleaning of fouled screens on as-needed basis. Physical cleaning of any additional mesh screens

9. CONCLUSIONS

This report has considered the impacts of operating a harbour heat rejection system with a 50% increase in flow required as part of the Modification 14 redevelopment of The Star. The system operates by providing heat rejection for the central cooling system for the site.

This assessment has considered the physical and ecological environment of Sydney Harbour to understand how the marine environment would be impacted under this component of the proposal. Through this process the following can be concluded:

9.1 Hydrodynamic and physical properties

The following conclusions have been drawn from an assessment into changes that may occur to the hydrodynamic and physical properties of the receiving waters of Pyrmont Bay.

TEMPERATURE EFFECTS

- Under summer and rest of year conditions, the existing discharge plume reaches the surface within approximately 2.2 m and the temperature at the edge of the nearfield is approximately 3.6 ºC above ambient.
- The proposed system discharge plume has an increased velocity and undergoes a greater degree of mixing over a greater area prior to reaching the surface. Under both summer and rest of year conditions the proposed system discharge reaches the surface over a distance of approximately 3.2 m and the temperature at the edge of the nearfield is approximately 3.3 ºC above ambient.
- The nearfield zone of the proposed discharge plume is larger in area than that of the existing discharge plume, and due to this, has a lower modelled temperature at the edge of the nearfield zone. The incremental differences in temperature and size of the nearfield zone of the existing plume compared to the proposed can be considered negligible.
- An assessment against the ambient 80th percentile was carried out to establish if the temperature effects of the discharge plume are confined to the nearfield mixing zone in accordance with the ANZECC (2000) approach. The analysis confirms that the predicted median temperature post increased discharge is less than the 80th percentile ambient temperature and the proposal is therefore not considered to have an adverse impact on the receiving waters either in terms of the ANZECC Guidelines.

EROSION AND SCOUR

- Modelled discharge velocities for the existing and proposed discharge plumes under summer and rest of year conditions were assessed. Due to the dimensions of the outlet and the flow rate, the discharge velocities can be considered negligible when the plume exits the outlet at 0.14 m/s for the existing system and 0.22 m/s for the proposed system.
- The incremental increase in discharge velocity due to the proposal is estimated to be less than 0.1 m/s and, as such, there will be negligible risk of additional potential erosion or scour due to the proposal.

MARINE GROWTH

- There will be no change to the fouling management plan currently in place for the existing system and as such there will no incremental impact to the marine environment.
- The fouling management plan currently in place for the existing system entails the use of Mexel 432, an amine based dispersant. Mexel 432 has been approved for use in seawater cooling systems by the Australian Pesticides and Veterinary Medicines Authority (APVMA) to prevent corrosion, biofilm formation and the attachment of seawater organisms. The current dosage is 2 to 3 parts per million (ppm) every day and this is anticipated to remain the same for use in the proposed system.
- The dilution factors associated with the discharge plume were applied to the use of antifouling product, Mexel 432, at an initial dosage of 3 ppm. Modelling shows that the predicted concentration of Mexel 432

at the edge of the nearfield mixing zone is approximately 1.7 ppm for the existing system and 1.6 ppm for the proposed system.

- For both the existing and proposed systems the addition of Mexel 432 occurs once a day for one hour so the concentrations shown in Figure 6.6 will exist only during the one hour dosing period before being diluted to undetectable levels.
- The use of an APVMA approved amine based biocide in conjunction with freshwater flushing is considered to pose a negligible risk of impact. Providing the correct concentrations, treatments and controls are introduced and the plant is operated within manufacturer specifications the risk of any impact can be managed to acceptable levels.
- The active constituents in Mexel 432 Dispersant will largely be consumed within the cooling system and are unlikely to persist in the marine environment following discharge because of their strong sorptive characteristics and biodegradability (APVMA, 2012). Due to this, cumulative impacts of other local systems using this product are unlikely to cause unacceptably high concentrations in receiving waters.

ACCIDENTAL AND EMERGENCY DISCHARGES

- There will be no additional risk of overdose or emergency discharge due to the proposal as the operational procedures associated with the system, including automated biocide dosing, will remain unchanged.

FAR FIELD MODELLING

- The predicted modelling results confirm that there would be sufficient initial mixing and dilution in the nearfield such that the water temperature would return close to ambient conditions within the near field zone. The modelling also confirms that the discharge would be below the trigger value in the near field calculated in accordance with the ANZECC Guidelines (ANZECC, 2000). As such, there would be no need to consider the impacts across the far field.

9.2 Marine ecology

The following conclusions have been drawn from an assessment into potential changes and impacts relating to marine ecology that may occur within Jones Bay and Pyrmont Bay.

EXISTING DISCHARGE OPERATIONS

The following observations have been made from a visual inspection from the shore and a review of footage from an underwater survey conducted by a marine ecologist:

- A variety of marine biota was observed in Pyrmont Bay on wharf structures within the existing region of elevated temperature due to the existing discharge plume.
- The species diversity and abundance of the observed assemblage is considered typical of those in urbanised estuarine environments dominated by built structures and vertical surfaces.
- Barnacles, oysters, mussels and the encrusting assemblage including filamentous algae occupied almost 100% of the surfaces of wharf piles with no apparent effect of the biocide on their abundance or growth. There were no pest species observed on the wharf piles.
- Overall, the impacts of the discharge from the existing heat exchange system are undiscernible on a marine assemblage that appears to be typical of its location on an estuarine, urbanised foreshore.

ADDITIONAL THERMAL IMPACTS

- The visual inspection and review of the underwater survey footage shows that there is no evidence of impact of the existing thermal plume and estuarine organisms in general are well adapted to changes in temperature and salinity (McLusky and Elliott, 2004). It can therefore be concluded that any marine life that is currently just outside of the current plume footprint (mainly oysters in the intertidal zone and mussel at deeper depths) are likely to easily tolerate the effects of the predicted increase in plume footprint due to the proposal.

- Sydney rock oysters form bands around the wharf piles at mid-tide level in Pyrmont Bay. Research on this common estuarine species indicates that the temperature increase associated with the existing and proposed discharge plumes are well within its temperature tolerance over the range of salinities likely to occur in the study area (O'Connor *et al*., 2008).
- Little is known about the temperature tolerances of most of the other common species found in the intertidal and subtidal sections of the wharf piles. However, the predicted temperature effects due to the increased plume footprint under the proposal can be considered negligible in comparison to the seasonal temperature fluctuation recorded in the intertidal habitats in which the organisms occur.

ADDITIONAL CHEMICAL IMPACTS

- The current low concentration of discharged biocide is rapidly and thoroughly diluted with no evidence of deleterious impacts on marine biota on wharves within the existing discharge plume. It is therefore unlikely that the same rate of dosing would have a discernible impact on marine biota due to rapid mixing in the water column. After the point of discharge at the culvert, the biocide's residual concentration would be diluted within the nearfield zone before reducing to undetectable levels due to the action of wind and waves and ambient currents.
- Levels of dissolved oxygen in the water currently discharged would be lower than those in the ambient seawater due to the elevated temperature of the discharged water. The increased velocity of the discharge under the proposal (0.22 m/s compared to 0.14 m/s) would increase initial mixing, which would result in the re-oxygenation of the water within approximately 3 m of the outlet channel. Given that no effects of deoxygenation on stationery or mobile marine biota were observed, no physiological changes in marine biota are likely to be detectable under the proposal due to initial lower dissolved oxygen in discharge water.

INTAKE OPERATIONS

- Maintenance procedures include clearing the structures using a high-pressure hose with an angled nozzle that is pulled along the pipe. Screens inside the cooling plant are manually cleaned with freshwater, without the use of chemicals.

ENTRAINMENT AND IMPINGEMENT

- The proposed inlet velocity would increase from 1.8 to 2.8 m/s into the intake pit and from 2.3 to 3.6 m/s at the inlet pipe. While the magnitude of the current entrainment of fish is not quantified, their occasional presence within the inlet system suggests that entrainment occurs occasionally under the existing inlet velocities.
- The increased inlet velocity under the proposal may, if unmitigated, represent an additional impact on adult and juvenile fish. Table ES.1 shows that the installation of a mesh screen across the culvert openings will mitigate this impact.
- Because both the existing and proposed systems use very small water volumes in comparison to the volume of Port Jackson, impacts on ecological primary production are likely to be negligible.

IMPACTS ON THREATENED SPECIES, COMMUNITIES, POPULATIONS AND HABITATS

- No threatened or protected marine species, populations or ecological communities listed under the EPBC Act, TSC Act and FM Act were observed within the spatial extent of the proposed discharge, and their occurrence in Pyrmont Bay or Jones Bay is either unlikely or transient in duration (seabirds).

MARINE PEST SPECIES

- The existing inlet structures are regularly cleaned and the main organisms removed to date have been two native mussel species. As removal of fouling organisms will continue under the proposal, via physical cleaning and the use of a biocide, the increased volume of water under the proposal is unlikely to result in an increased risk of the occurrence of marine pest species within the HHR infrastructure.

OPERATIONAL NOISE

- Given the distance of the inlet and outlet infrastructure from the plant room, the associated operational noise is considered to be within the limit of the variance in ambient conditions considering boat movements and other activities within Jones Bay and Pyrmont Bay. There will be no change to this infrastructure under the proposal and as such, there is assessed to be no operational impact or risk due to noise.

In summary, the operation of the upgraded HHR system is unlikely to have any material impact on the physical or ecological environment of Jones Bay or Pyrmont Bay. This has been demonstrated through modelling predictions and a review of relevant data. Effectively, the potential impacts due to the proposal would be insufficient to materially affect the marine environment in these locations.

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Appendix A

THERMAL AND CHEMICAL DISCHARGE MODELLING

THE STAR ENTERTAINMENT GROUP LTD

The Star, Sydney

MODIFICATION 14 - MARINE IMPACT ASSESSMENT MODELLING REPORT

PUBLIC

SEPTEMBER 2016

The Star, Sydney

MODIFICATION 14 - MARINE IMPACT ASSESSMENT MODELLING REPORT

The Star Entertainment Group Ltd

Public

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1 INTRODUCTION

The following technical report is written as an appendix to The Star, Sydney, Modification 14 - marine impact assessment (WSP | Parsons Brinckerhoff, 2016) which describes the proposal to increase the capacity of the existing seawater heat rejection system, a component of The Star's central cooling system.

This report is specifically concerned with numerical modelling of the incremental increase in the properties of the thermal plume created by the discharge of additional water used to provide the additional air conditioning cooling capacity as part of the Modification 14 redevelopment of The Star.

The modelling is intended to provide thermal, velocity and additive concentration gradients for use in the assessment of ecological impacts associated with the upgrade.

This modelling assessment has been carried out using operational data of the existing system and publicly available hydrodynamic data. It is not based on the collection of focussed temperature, velocity and bathymetric datasets of the ambient waters. The datasets used are from within Pyrmont Bay and Darling Harbour and, where required, conservative assumptions have been made such that the use of more focussed data will likely lead to a reduction in the predicted temperature and velocity effects, and hence reduced impacts.

1.1 Modification 14 overview

The Star Entertainment Group is a leading operator of integrated resorts catering to both local and international visitors, and is the operator of The Star Sydney (The Star). Consistent with The Star's licence obligation to operate the site to an international standard, The Star Entertainment Group (TSEG) is proposing to advance a revitalisation of the existing complex.

The Star is embarking on a five year redevelopment journey to create a landmark, exemplar integrated resort within the City of Sydney. This proposed redevelopment will occur through the lodgement of two S75W applications with the Department of Planning and Environment, identified as Modification 13 and Modification 14. All works pertaining to Modification 14 are detailed below. Modification 13 will involve the design of a new Ritz-Carlton Hotel Tower and associated podium treatment and will be detailed at a future time.

The Star is proposing to attain the highest standard of built form outcomes for the site through the proposed redevelopment by encouraging innovation and best practice approaches in order to achieve an environmentally sustainable development that positively contributes to the overall architecture of both Pyrmont and the City of Sydney. This will be done through the implementation of advanced ESD initiatives, improved people and movement connections, upgrades to the external appearance and presentation of the facility and improved integration with the adjacent urban fabric.

Modification 14 includes the following proposed works:

1. **Level B4 Infrastructure Upgrades** - Upgrades to existing generators, existing harbour heat rejection system, natural gas system, existing domestic cold water system and an additional sewer connection.
2. **Level 00 – Porte Cochere and Astral Lobby Upgrade** - Realignment of Porte Cochere to accommodate expanded and upgraded Astral Lobby, upgraded Astral Lobby Bar and retail expansion and upgrades of the Main Casino Entry, including valet improvements to the Porte Cochere.
3. **Level 00 Back of House Upgrades** - Internal upgrades and improvements to multiple aspects of the back of house space at Level 00.
4. **Level 00 Astral Luxury Retail Zone** - New luxury retail zone connecting from Astral Hotel Lobby out to Jones Bay Road. Change of use from office / back of house to retail.
5. **Level 00 - SELS Fitout** - Refurbish existing SELS Level 00 toilets at the southern end of the building to allow for adjacent lift lobby circulation areas. Upgrades and tenancy improvements to existing retail

tenant at northern end of SELS building along Jones Bay Road. No external changes to SELS are proposed, with internal alterations only.

6. **Level 00 SELS Lighting** - External lighting of the SELS building along Pyrmont Street to celebrate the heritage elements of the building.
7. **Level 00 Darling Café** - New café within the existing Darling Hotel Lobby at Level 00.
8. **Level 00 to 01 - G-Star Raw Escalators** - Replace existing G-Star Raw retail shop at Level 00 with new escalators providing access from Level 00 to Main Gaming Floor at Level 01. Includes new arrival bar adjacent to escalators at Level 01.
9. **Level 01 - Main Gaming Floor Slab Infill** - Slab expansion off the Main gaming Floor at Level 01 over the existing main entry foyer facing Pirrama Road. No facade works are proposed.
10. **Level 02 – Oasis Gaming Area** - Minor external alterations to the Oasis unenclosed gaming area at Level 02.
11. **Level 03 - Sovereign Expansion** - Expansion to the existing Sovereign Room at Level 03. This includes refurbishment of existing food, beverage and gaming locations, expansion of food and beverage opportunities an VIP gaming and unenclosed gaming areas.
12. **Level 03 - Event Centre Pre-function Space** - New pre-function space adjacent to the MUEF at Level 03, to allow for circulation changes from the level 03 expansion.
13. **Vertical Transportation Drum** - New escalators as part of a vertical transport arrival strategy from Level 00 to Level 03.
14. **Level 04 – Star Administrative Offices** - Fitout of existing administrative offices within Astral Residences tower. Internal improvements only.
15. **Level 05 – VIP Lobby & Check-In** - Conversion of existing pool plant space and enclosed pool deck at Level 05 to a lobby for the VIP hotel guest lounge.
16. **Level 05 - Astral Residences Reception** - Conversion of meeting room to Reception and check-in lobby. Includes minor expansion to existing enclosed space.
17. **Northern Porte Cochere Canopy** - Removal of a section of the current glazing (retaining the canopy structure) of the current porte cochere canopy and include a new ceiling at a lower height over a section of the new slab (NW Gaming slab infill).

1.2 System overview

As part of the Modification 14 redevelopment of The Star, the existing harbour heat rejection (HHR) system will be upgraded such that the system has the capacity to reject additional heat when required. The HHR system requires seawater to be pumped from Jones Bay and through a heat exchanger, where it would be used to cool condenser water from the centralised cooling system. The seawater is then discharged back into Pyrmont Bay. The system works on the regularly varying flow of seawater through the heat exchanger and through this process, the maximum temperature differential (DT) of the discharged water relative to the ambient water is expected to be +6°C at all times, inclusive of peak conditions. Under typical conditions however, the temperature increase of the discharged water will be approximately +3° to +4°C.

The proposed system will have the capacity to reject more heat than the existing system. The increase in loads is expected to occur over a number of years, without the need for further harbour heat rejection system upgrades in the foreseeable future. As such it may be a number years before the system is operated beyond its current capacity. The additional capacity will be achieved by increasing the sea water flow through the system; the temperature differential will not increase. The maximum flow will increase from 850 L/s to approximately 1,300 L/s. However, on average throughout a typical year, the system would typically operate at approximately:

→ 80% of its maximum operational demand during the summer months (December to February)

→ 25% to 60% of its maximum operational demand during the autumn winter and spring months (March to November)

1.3 Discharge overview

The increase in the discharge water temperature will increase the buoyancy of the discharge water relative to the cooler ambient water. As the water exits through the outlet, the plume will rise towards the surface. In this region mixing and dilution is rapid and mainly caused by the turbulence generated by the discharge flow rate and velocity. This initial mixing region is called the nearfield zone where the impact of the heated discharged water on the ambient environment is at its highest.

The density of the receiving waters increases with depth, i.e. the receiving waters are density-stratified. The resulting buoyancy force deflects the discharge plume upwards whilst being transported by ambient currents. The plume entrains ambient seawater as it rises, causing it to be diluted, reducing the density difference with the ambient waters.

Depending on the density stratification of the receiving water the rising plume may reach a level of neutral buoyancy where it stops rising and begins to spread laterally. This spreading field drifts with any currents present and is diffused by turbulence in a wider region called the far field. The rate of dilution in the nearfield is greater than the far field.

1.3.1 Fouling management

The antifouling management plan currently in place for the existing system entails the use of Mexel 432, an amine based dispersant. Mexel 432 has been approved for use in seawater cooling systems by the Australian Pesticides and Veterinary Medicines Authority (APVMA) to prevent corrosion, biofilm formation and the attachment of seawater organisms. The current dosage is 2 to 3 parts per million (ppm) every day and this is anticipated to remain the same for use in the proposed system.

2 NUMERICAL MODEL

For the nearfield modelling, the PC-based interactive flow visualisation tool VISJET was used which incorporates the Lagrangian jet model JETLAG (Lee et al, 1997). This model was developed by Professor Joseph Lee and his colleagues at the University of Hong Kong and provides 3D flow visualization of the predicted path and mixing of arbitrarily inclined buoyant plumes in moving receiving waters which may be density-stratified.

JETLAG has been validated against extensive analytical, laboratory experiments and field data and is widely used in design and assessment of marine outfalls including sites in NSW and specifically in Sydney Harbour. Examples of sites where JETLAG has been used are Barangaroo South District Cooling Plant, Sydney Sewage Treatment Plant Effluent Outfalls and the Sydney Modern Project seawater exchange system.

2.1 Model set up and input data

The modelling approach has been designed to assess the incremental impact of the proposed system compared to the already approved existing system. This will be achieved by modelling the proposed and the existing system separately and subtracting the existing from the proposed to understand the additional effects of the upgrade.

The modelling considers the system operation during two broad periods:

- Summer months (December to February) as this is when there will be the greatest demand on the system.
- Rest of year (March to November) to provide an assessment of the remainder of the year under the typical associated ambient conditions such as salinity and temperature.

The model input parameters are shown in Tables 2.1 and 2.2.

2.1.1 System operation

The operational data used to model the impacts have been assumed to be the maximum flow with the maximum DT with continuous operation throughout the year. This is a conservative assumption as the system operates at less than its maximum capacity for a major portion of the year (Section 1.1) and is not in constant operation as the system is occasionally shut down for maintenance.

2.1.2 Outlet design

The returned seawater flows through a 900 mm diameter pipe to the harbour wall on the southern shore of Pyrmont Bay where it discharges into two culverts that run adjacent to each other and discharge into Pyrmont Bay beneath the suspended wharf. The dilution of the discharged sea water would begin at the discharge from the pipe into the two box culverts. Measurements taken during an underwater survey conducted on 03 August 2016 showed that the mouth of each culvert is approximately 1.5 m wide by 2 m high and the separation between the adjacent culverts is approximately 0.4 m. The length of the box culverts is approximately 40 m, which is expected to provide sufficient volume for full mixing of the discharge with ambient sweater to occur within the box culvert. Therefore, a uniform discharge of returned seawater flow is assumed at the month of the box culvert.

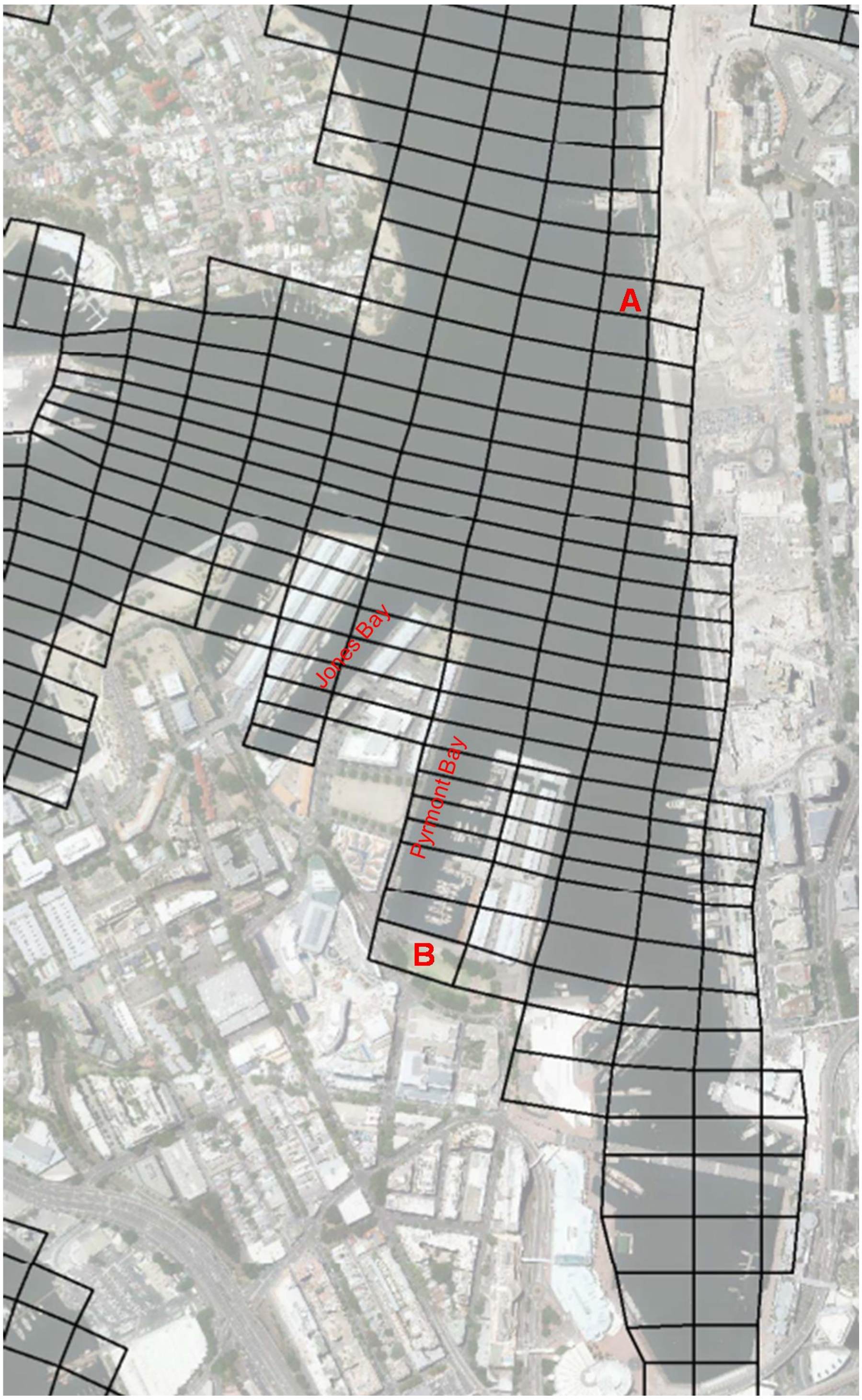
The outlet configuration in the model has been represented as two adjacent cylindrical culverts, of cross sectional area equal to that of a 1.5 x 2 m rectangular culvert. The mouth of the culvert is situated on the seabed at a depth of 2.15 m relative to mean sea level (MSL)[1].

In the scenarios modelled in this investigation the depth of the outlet is less than 3 m in an environment that is sufficiently energetic to reduce the density stratification to such an extent that the plume will reach the surface and will not reach neutral buoyancy below the surface.

2.1.3 Flow fields

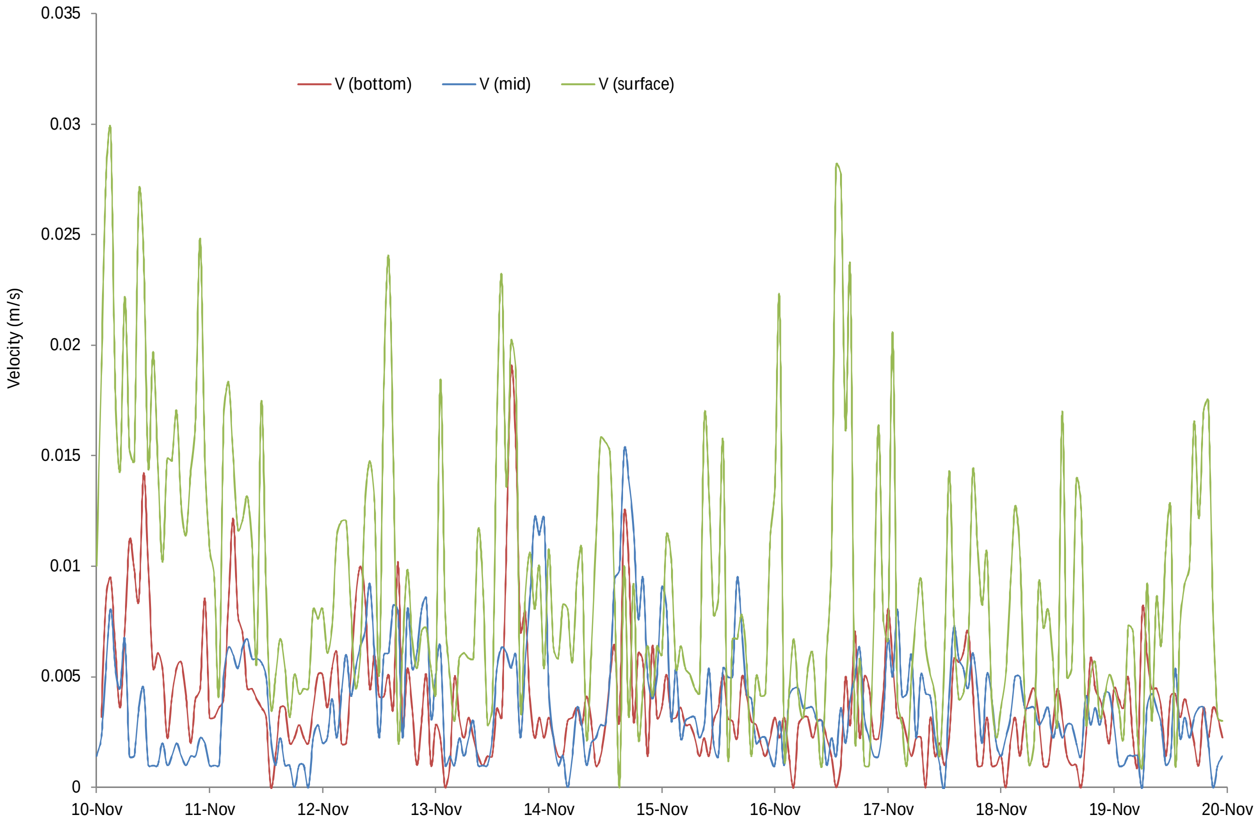
Hydrodynamic data including flow fields and components of water velocity in the vicinity of the outlet location were derived from the Sydney Harbour Hydrodynamic Model (Tanner *et al*, 2016) at three depths (bottom, middle and surface) from location B shown in Figure 2.1. The derived flow field velocities used are for summer months as the cooling system is considered to be in peak usage at this time of the year. The data is displayed in Figure 2.2. For use in the model this data was averaged to provide a net velocity within Pyrmont Bay.

1 Mean seal level has been taken from Fort Denison tide gauge data



Source: Tanner et al. 2016

Figure 2.1 Hydrodynamic data locations

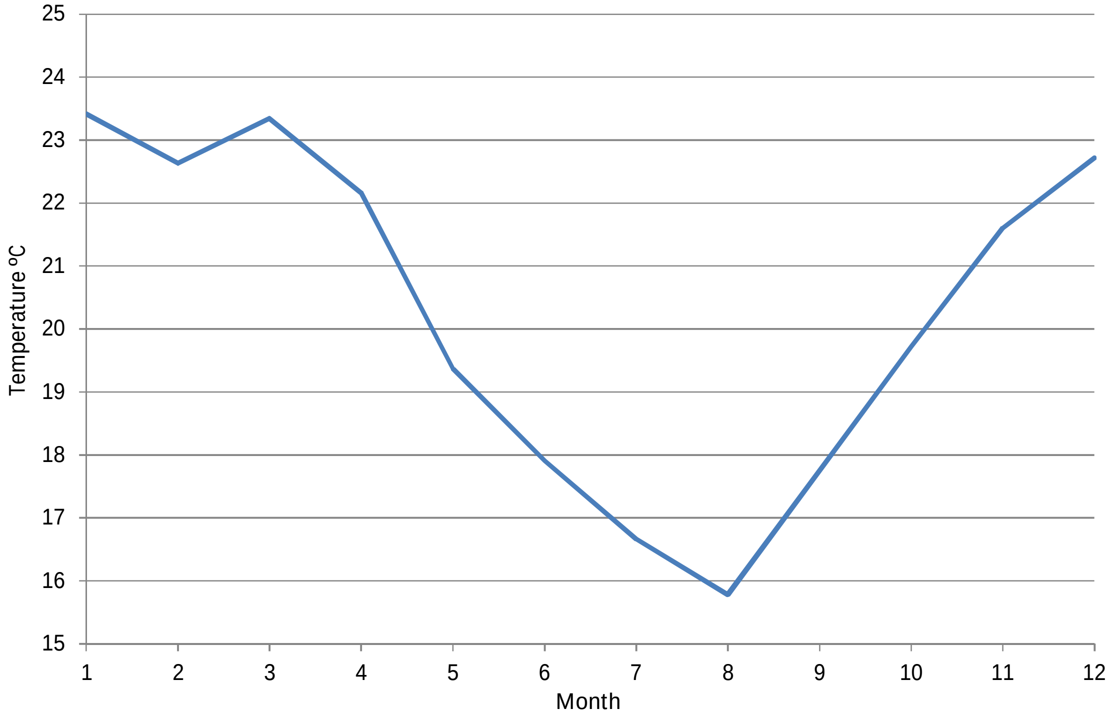


Source: Tanner et al. 2016

Figure 2.2 Derived flow velocity data

2.1.4 Temperature conditions

The closest available water temperature data to the outlet was collected from location A, shown in Figure 2.1, by the University of Sydney during 2013 (Harrison, 2013). This data is based on monthly surveys and is shown in Figure 2.3.

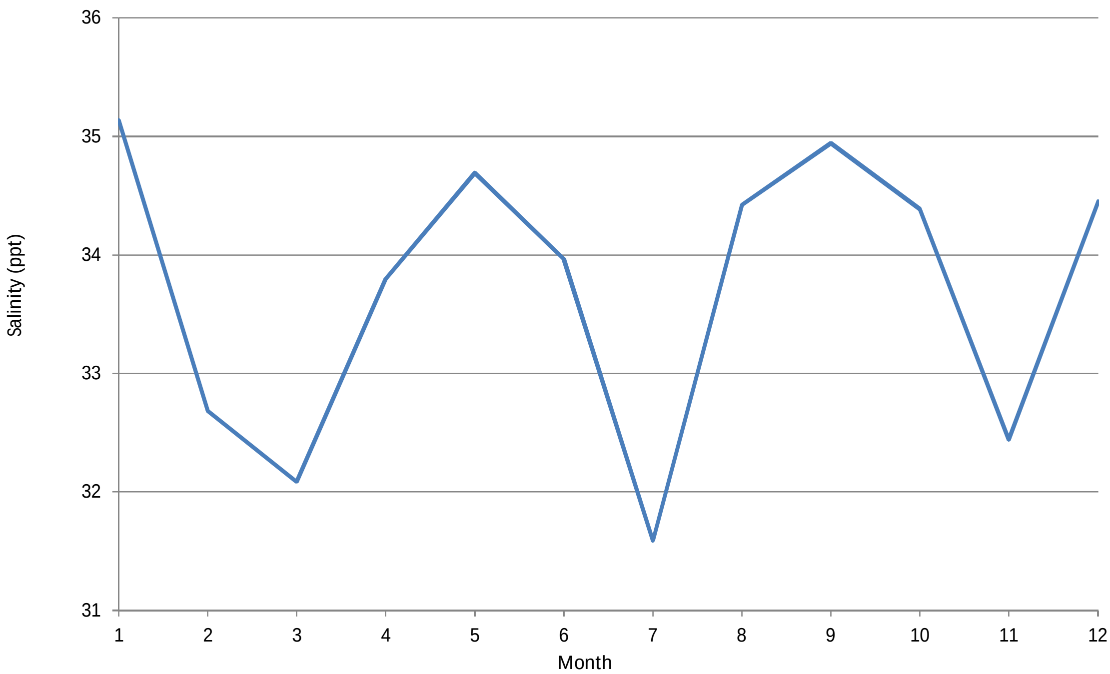


Source: Harrison, 2013

Figure 2.3 Seasonal variation of average water temperature

2.1.5 Water salinity

The closest available salinity data to the outlet was collected from location A, shown in Figure 2.1, by the University of Sydney during 2013 (Harrison, 2013). This data is based on monthly surveys and is shown in Figure 2.4.



Source: Harrison, 2013

Figure 2.4 Annual variation in seawater salinity in the vicinity of the outlet

2.1.6 Adopted parameters

The adopted model parameters for the discharge, outlet and receiving waters are shown in Tables 2.1 and 2.2.

Table 2.1 Adopted ambient water parameters used as model inputs

AMBIENT WATER PARAMETER	VALUE
Mean current velocity[a]	0.009m/s (surface), 0.004m/s (mid-depth), 0.004m/s (bottom)
Salinity[b]	34.12 ppt (summer), 33.50 ppt (spring, autumn and winter)
Temperature[b]	Summer: 21.59°C (min), 23.22°C (median), 23.90°C (max), 23.53°C (80%ile) Spring, Autumn, Winter: 15.67°C (min), 19.35°C (median), 24.03°C (max), 22.24°C (80%ile)

a) Tanner *et al.* 2016
b) Harrison, 2013

Table 2.2 Adopted outlet parameters used as model inputs

OUTLET PARAMETER	VALUE
Discharge rate (L/s)[a]	850 (existing) 1,300 (proposed)
Discharge velocity	0.14 (existing) 0.22 (proposed)
Temperature differential (°C) [a]	6
Dimensions of outlets[b]	Height: 2 m, Width: 1.5 m
Number of outlets[b]	2
Height of culvert base from seabed (m)[b]	0
Depth of culvert base (relative to msl) (m)[b]	2.15

a) Pers. Coms The Star
b) The Diving Company, 2016

2.2 Modelled scenarios

A number of scenarios have been investigated (Table 2.3) to assess the properties of the existing and proposed discharge plumes such that the incremental change due to the upgrade can be determined and assesses against an appropriate trigger value.

Further scenarios have been carried out to analyse the sensitivity of the dilution rate to seasonal fluctuation in ambient water temperature and salinity. These parameters determine the buoyancy of the discharge relative to the ambient waters and influence the degree of mixing.

All scenarios incorporate the following assumptions:

→ Due to the relatively shallow depth of the water column, it is not appropriate to model the water column as density stratified; therefore the ambient salinity applies to the entire water column.

→ All modelled scenarios represent the maximum flow rate through the system (Table 2.2) with the maximum DT of 6°C.

→ The ambient current velocity is varied with depth according to the following inputs, the model linearly interpolates between the data points:

  - Surface current: 0 m deep
  - Mid-depth current: 1.1 m deep
  - Bottom current: 2.2 m deep

Table 2.3 Modelled scenarios

SCENARIO DESCRIPTION	SEASON	EXISTING (E) PROPOSED (P)	DISCHARGE RATE (L/S)	INTAKE TEMPERATURE (°C)	DISCHARGE TEMPERATURE (°C)	DT(°C)	RECEIVING WATER TEMPERATURE (°C)	AMBIENT SALINITY (PPT)	CONCENTRATION OF MEXEL 432 (PPM)
Incremental impact assessment	Summer	E	850	23.22	29.22	6	23.22	34.12	N/A
	Summer	P	1300	23.22	29.22	6	23.22	34.12	N/A
	Rest of year	E	850	19.35	25.53	6	19.35	33.50	N/A
	Rest of year	P	1300	19.35	25.53	6	19.35	33.50	N/A
Sensitivity of model to ambient temperature	Rest of year	E	850	15.67	21.67	6	15.67	33.50	N/A
	Rest of year	E	850	24.03	30.03	6	24.03	33.50	N/A
Assessment against 80%ile ambient conditions	Summer	E	850	23.22	29.22	6	23.53	34.12	N/A
	Summer	P	1300	23.22	29.22	6	23.22	34.12	N/A
Mexel 432 dilution	Summer	E	850	23.22	29.22	6	23.22	34.12	3
	Summer	P	1300	23.22	29.22	6	23.22	34.12	3

2.2.1 Incremental impact assessment

This scenario is designed to show the difference between the existing and proposed systems to quantify the incremental increase in plume temperature and velocity. The scenario is modelled using median temperatures during summer (3 months) and the rest of the year (9 months) to show how the properties of the discharge plume vary with the annual variation in ambient water temperature and salinity.

2.2.2 Sensitivity to ambient temperature

The sensitivity of the dilution characteristics to ambient temperature variation was assessed whilst maintaining constant ambient salinity and constant temperature differential. This was done by running the rest of year (9 months excluding summer) scenarios using minimum, mean and maximum ambient temperatures (Table 2.1). The purpose of this scenario is to optimise scenario selection such that parameter variation is focused on parameters that materially affect the modelled outputs.

2.2.3 Assessment against ambient 80th percentile

The purpose of this scenario is to compare the incremental increase in discharge plume temperature to a trigger value. A method by which to calculate trigger values for ambient chemical and physico-chemical parameters is provided by the Australiana and New Zealand Environment and Conservation Council (ANZECC) in their guidelines for fresh and marine water quality (ANZECC, 2000). This was applied in this scenario, as follows.

ANZECC RECOMMENDED APPROACH

It is the responsibility of the operator of heat rejection systems to demonstrate compliance with the Protection of the Environment Operations (POEO) Act 1997.

The method to quantify an adverse effect and demonstrate compliance with the POEO Act is provided in Section 7.4.4.1 of ANZECC (2000). A summary of the approach recommended for comparing results from a test site with a guideline trigger value (details of the method are contained in Appendix 7 of Volume 2 and Section 6.4.3 of the Monitoring Guidelines). It is emphasised that trigger values are an ‘early warning’ mechanism to provide an alert of a potential problem, and are not intended to be an instrument to assess ‘compliance’ and should not be used in this capacity.

The recommended trigger-based approach for physio-chemical stressors such as temperature is stated as follows: “A trigger for further investigation will be deemed to have occurred when the median concentration of independent samples taken at a test site exceeds the eightieth percentile of the same indicator at a suitably chosen reference site”.

MODELLED SCENARIO

Based on this approach, 80th percentile ambient temperatures have been calculated for summer and the rest of the year using the data from Harrison (2013) and presented in Table 2.1. Since this data is not collected at the existing outlet, it does not incorporate the temperature effects of the existing system. Therefore, in order to provide, an 80th percentile trigger value that best represents the actual conditions, the existing plume temperature (modelled data from the edge of the nearfield) must be added on to the ambient 80th percentile data.

The proposed system discharging into ambient waters of mean temperature will provide mean temperature effects associated with the proposed system operation (at the maximum flow rate). This may then be compared to the 80th percentile of the ambient waters to provide a representative comparison.

2.2.4 Mexel 432 dilution

The dilution of the antifouling product, Mexel 432, will be assessed for the existing and proposed system under summer median conditions.

3 MODEL RESULTS

The following section details the modelled predictions using the input parameters and scenarios discussed in Section 2.

Modelled predictions are presented as plume temperature, velocity and Mexel 432 decay against lateral distance from the outlet.

3.1 Incremental impact assessment

The incremental velocity and temperature effects have been modelled for summer and rest of year conditions as per Table 2.3.

3.1.1 Temperature effects

Figures 3.1 and 3.2 show the temperature decay with distance from the outlet for the existing and proposed systems under the summer condition and rest of year condition, respectively. Under both conditions, the existing discharge plume reaches the surface within approximately 2.2 m and the temperature at the edge of the nearfield is approximately 3.6ºC above ambient.

The proposed system discharge plume has an increased velocity and undergoes a greater degree of mixing over a greater area prior to reaching the surface. Under both summer and rest of year conditions the proposed system discharge reaches the surface over a distance of approximately 3.2 m and the temperature at the edge of the nearfield is approximately 3.3ºC above ambient.

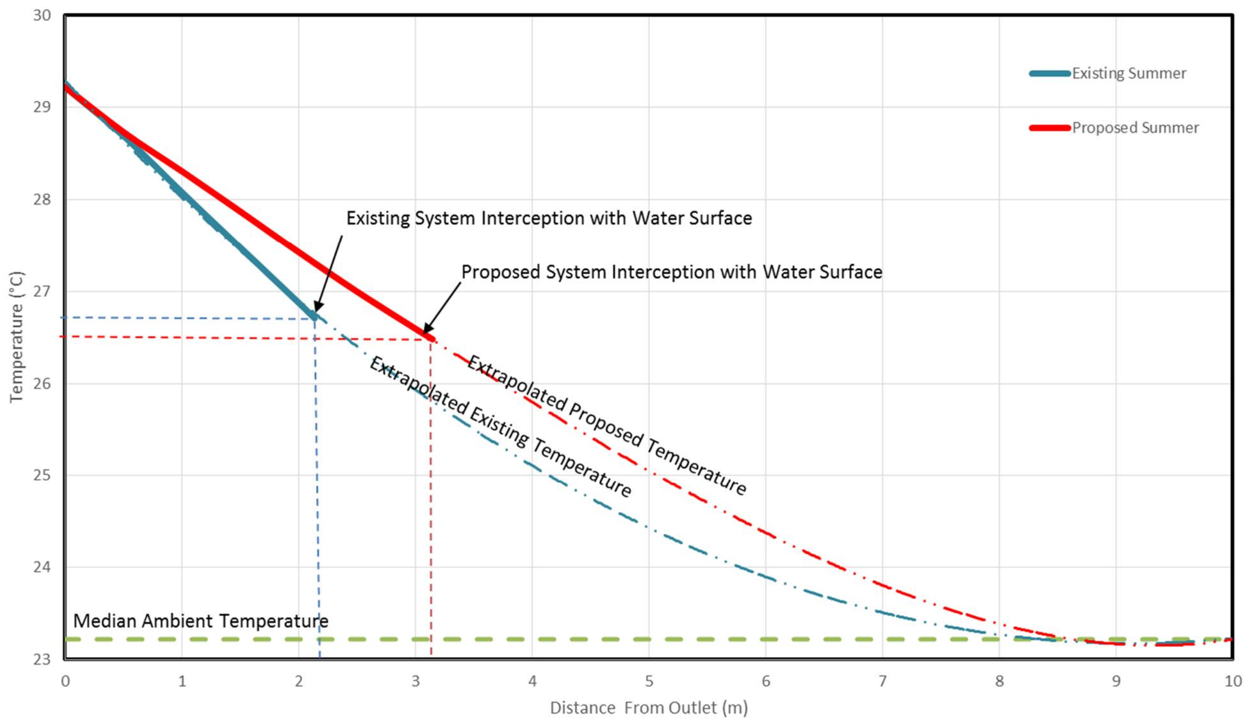


Figure 3.1 Temperature dilution with distance from the outlet: *Summer condition*

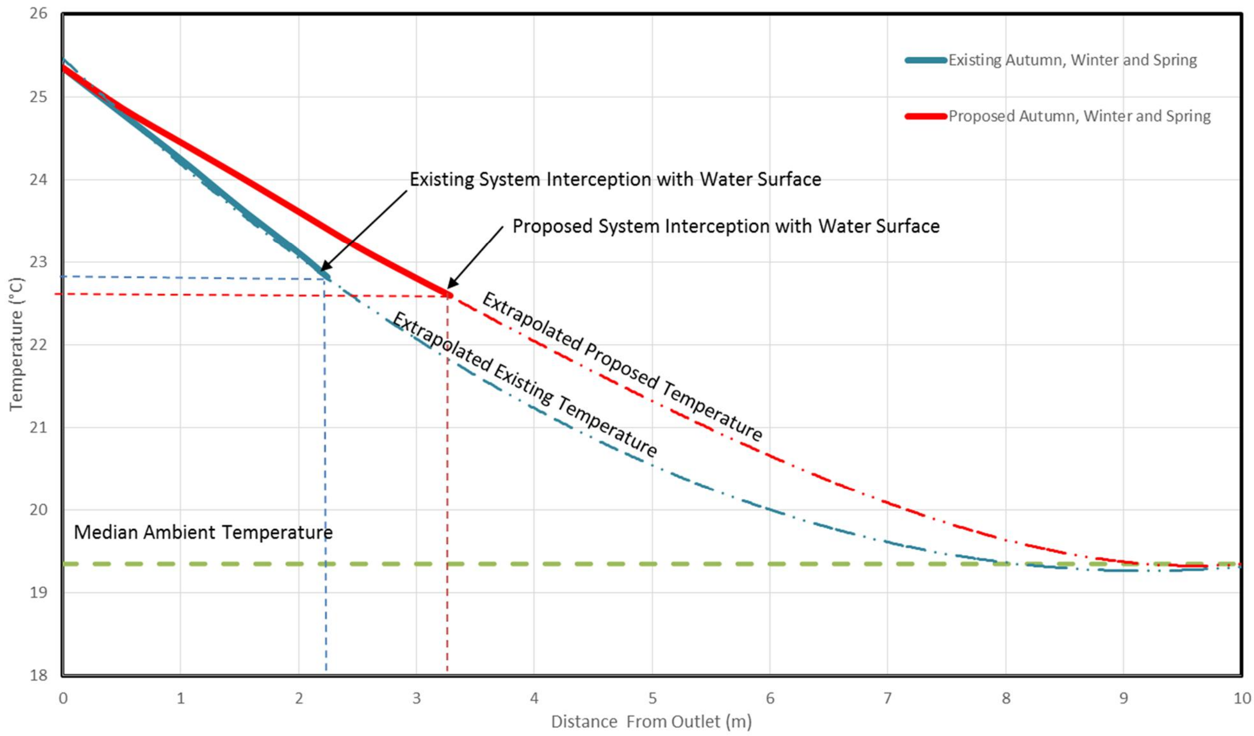


Figure 3.2 Temperature dilution with distance from the outlet: ***Rest of year condition***

The nearfield zone of the proposed discharge plume is larger in area than that of the existing discharge plume, and as a result, has a lower modelled temperature at the edge of the nearfield zone. The incremental differences in temperature and size of the nearfield zone of the existing plume compared to the proposed can be considered negligible.

The temperature dilution has been extrapolated beyond the nearfield zone to provide an indication of the distance over which the plume would equilibrate to ambient temperature. Note that the modelled data is nearfield only and the extrapolation is assumed.

3.1.2 Velocity effects

Modelled discharge velocities for the existing and proposed discharge plumes under summer and rest of year conditions are presented in Figures 3.3 and 3.4 respectively. Due to the size of the outlet and the flow rate, the discharge velocities can be considered negligible when the plume exits the outlet at 0.14 m/s for the existing system and 0.22 m/s for the proposed system. The modelling shows that the velocities rapidly decrease within 3 m from the outlet. Upon reaching the surface the action of waves and surface currents will be the dominant force controlling the plume dilution.

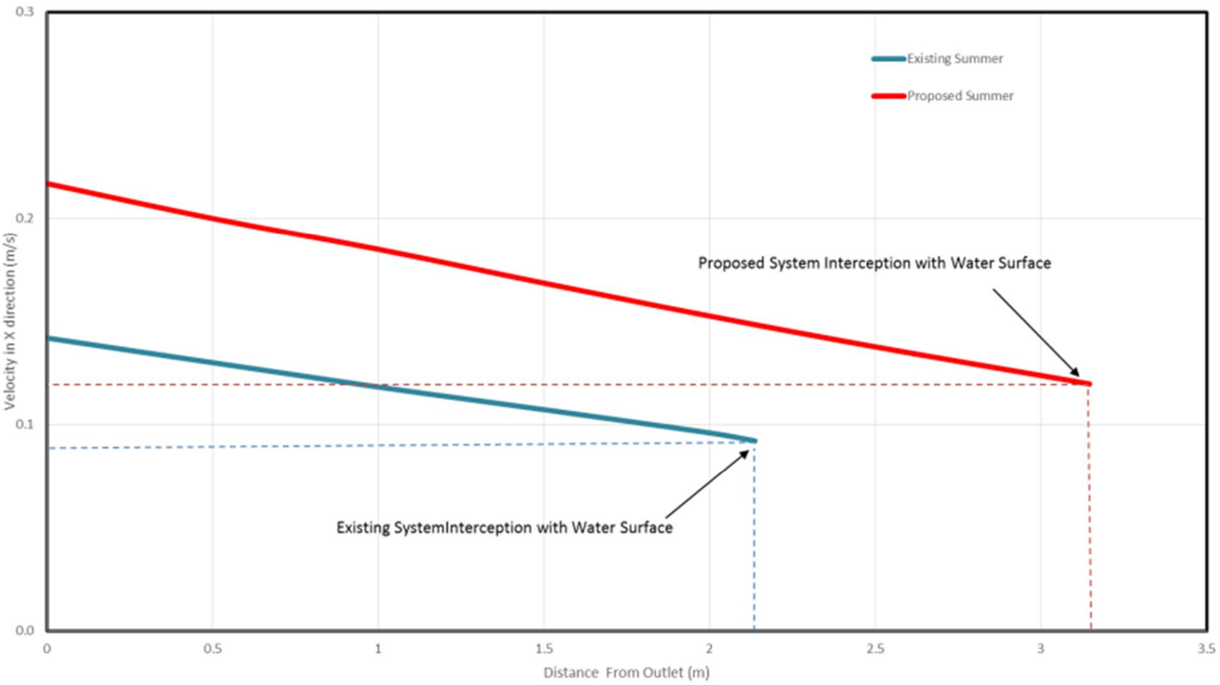


Figure 3.3 Velocity dilution with distance from the outlet: ***Summer condition***

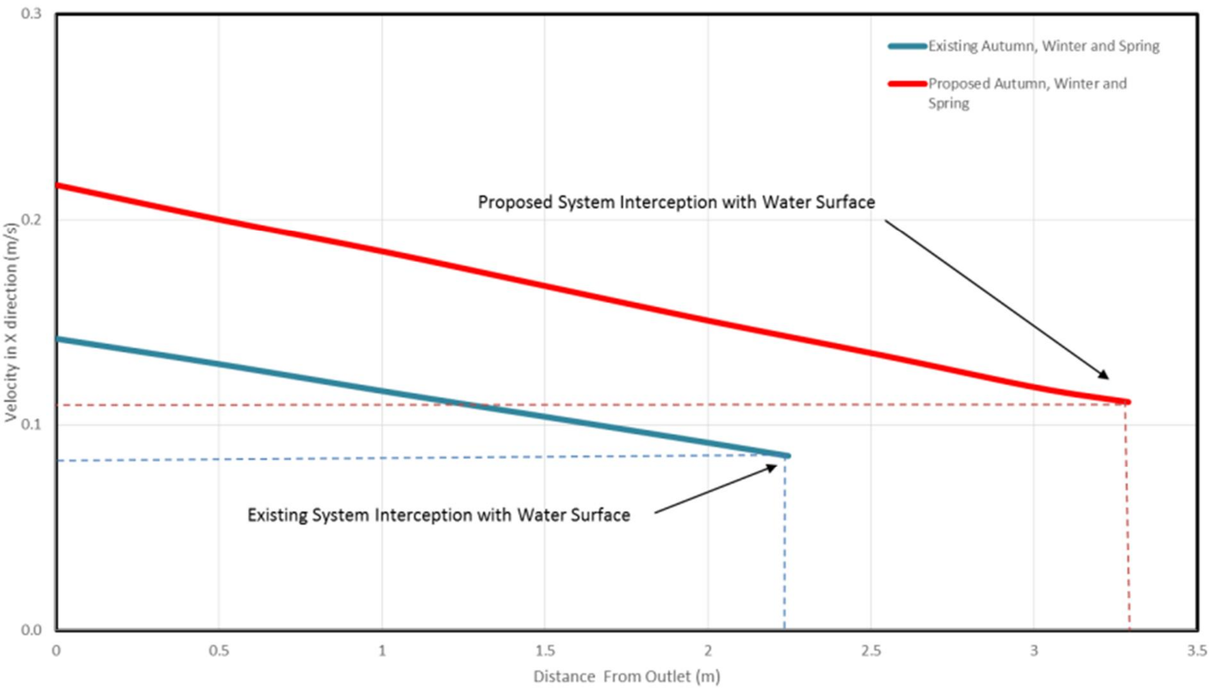


Figure 3.4 Velocity dilution with distance from the outlet: ***Rest of year condition***

3.2 Sensitivity to ambient temperature

Figure 3.5 shows that when the ambient temperature is varied between minimum and maximum for the rest of year condition, the effect on the temperature gradient of the discharge plume is negligible. Due to the insensitivity of the model to ambient temperature variation, modelling scenarios use median ambient temperature only. This can be either summer median or rest of year median to represent seasonal changes in salinity.

In this scenario, DT remained constant at 6°C. Modelling has shown that variation in DT has a greater effect on the modelled results than ambient temperature.

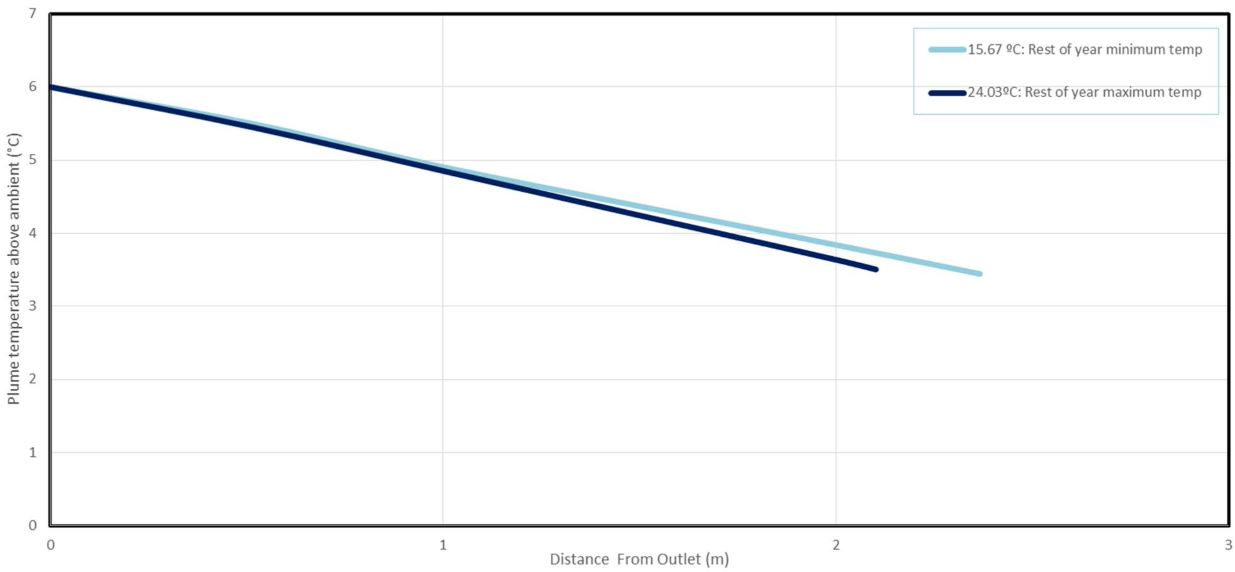


Figure 3.5 Sensitivity of temperature gradient to variation in ambient temperature

3.3 Assessment against ambient 80th percentile

The assessment against the ambient 80th percentile was carried out to establish if the temperature effects of the discharge plume are confined to the nearfield mixing zone in accordance with the ANZECC (2000) approach detailed in Section 2.2.3.

The trigger value must represent the ambient 80th percentile temperature of the receiving water, which will include the existing approved HHR system. This is compared against the median temperature at the edge of the nearfield zone associated with the proposed system to understand if the degree of warming that is taking place in the receiving waters due to the proposed system is within acceptable limits.

The approach firstly requires the establishment of a suitable trigger value against which the temperature effects of the proposed system can be compared.

3.3.1 Establishment of trigger value

A shown in Figure 2.1, the nearest available temperature data was collected at a site sufficiently distant to the outlet such that this data would not incorporate the temperature effects of the existing system. Therefore, the temperature effects of the existing system were added to the 80th percentile ambient temperature data by modelling a scenario in which the existing discharge using median intake water temperature discharges into receiving waters of a temperature equal to the 80th percentile ambient temperature. The results are shown in Figure 3.6.

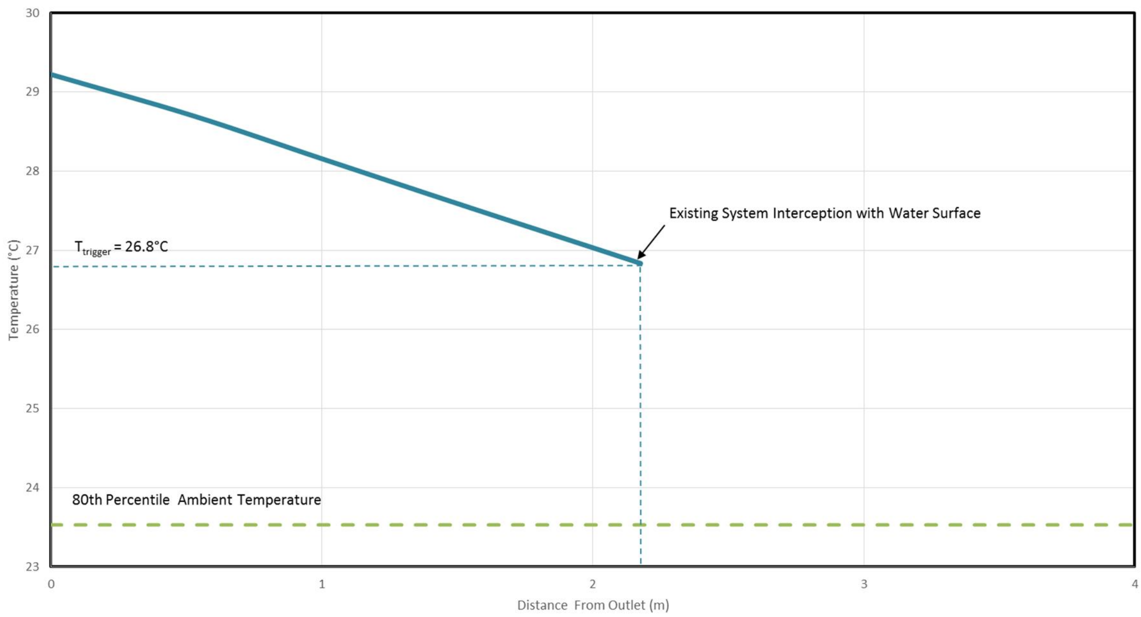


Figure 3.6 80th percentile trigger value establishment

The trigger value is calculated as the 80th percentile ambient condition, including the existing system, as measured at the edge of the nearfield mixing zone (where the plume meets the surface). The trigger value is 26.8ºC.

3.3.2 Comparison against the proposal

The proposed system operating under standard conditions during summer (Figure 3.1) may then be compared against the trigger value. Figure 3.7 shows that the temperature at the edge of the nearfield mixing zone due to the proposed system does not exceed the trigger value.

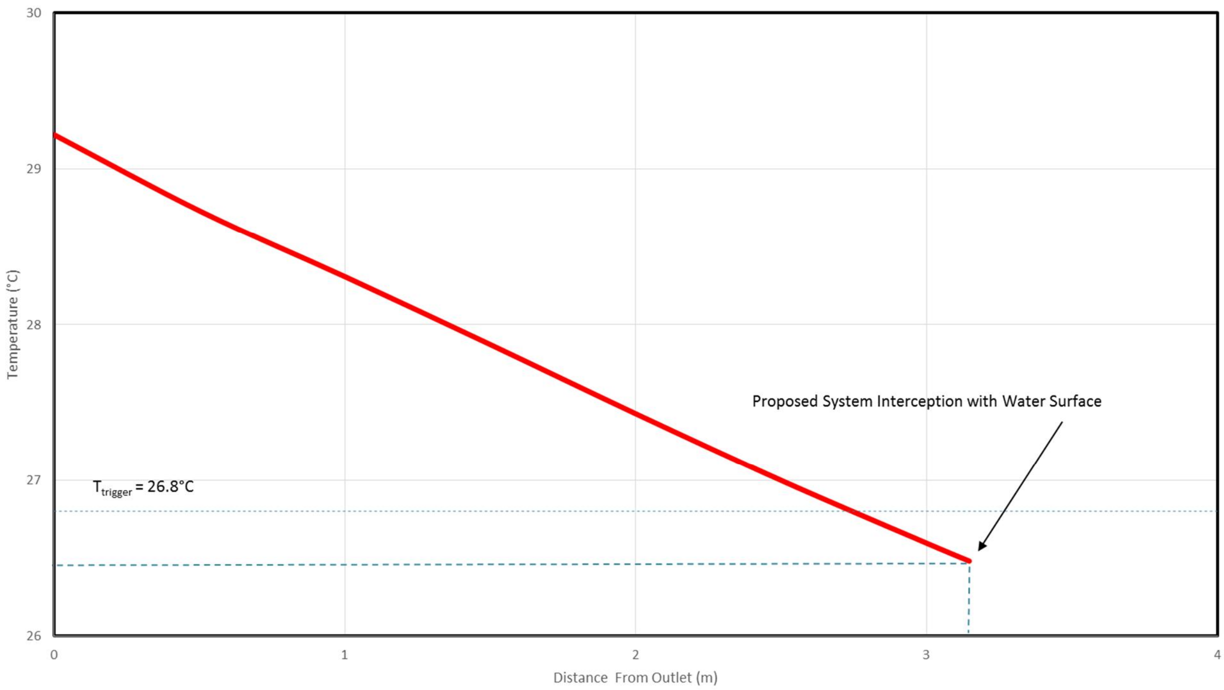


Figure 3.7 Assessment of proposal against 80th percentile trigger value

3.4 Mexel 432 dilution

The dilution factors associated with the discharge plume were applied to the use of antifouling product, Mexel 432, at an initial dosage of 3 ppm. Figure 3.8 shows the difference in the concentration gradient of the existing and proposed systems under summer conditions.

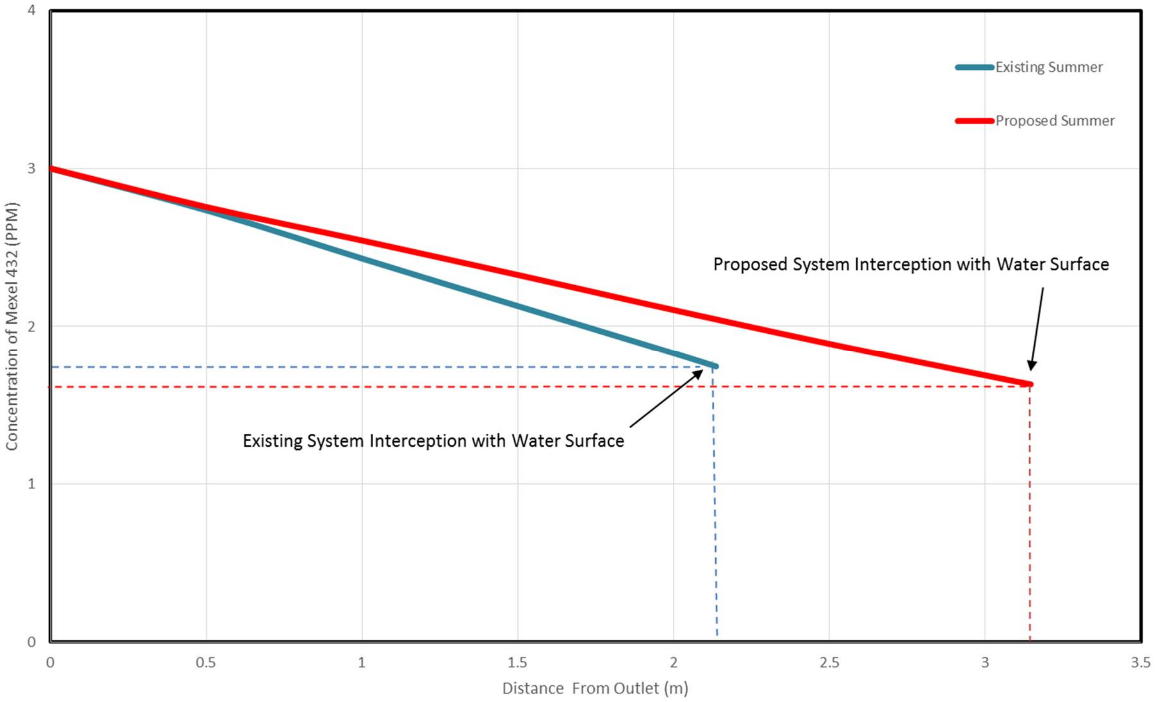


Figure 3.8 Mexel 432 dilution

Figure 3.8 shows that the concentration of Mexel 432 at the edge of the nearfield mixing zone is approximately 1.7 ppm for the existing system and 1.6 ppm for the proposed system. The proposed system has a lower concentration at the edge of the nearfield due to the increased size of the nearfield zone associated with the greater discharge; the proposed discharge plume undergoes a greater degree of mixing with ambient waters prior to reaching the surface. Upon reaching the surface, the action of wind and waves will disperse the plume more rapidly than when the plume is submerged.

For both the existing and proposed systems the addition of Mexel 432 occurs once a day for an hour so the concentrations shown in Figure 3.8 will exist only during the dosing period before being diluted to undetectable levels.

3.5 Far-field modelling

Based on the results of the nearfield modelling it is concluded that no far-field modelling is required for the discharge as the impact of the discharge on the greater Sydney harbour is deemed to be negligible.

4 CONCLUSIONS

The following conclusions are drawn from the modelling detailed in this report. This modelling assessment has been carried out using publicly available data and is not based on the collection of focussed temperature, velocity and bathymetric datasets. The datasets used are within Darling Harbour and Pyrmont Bay and, where required, conservative assumptions have been made such that the use of more focussed data will likely lead to a reduction in the modelled temperature and velocity effects.

4.1 Temperature effects

INCREMENTAL IMPACTS

- → The modelling predicts that the existing system discharge plume will reach the surface within 2.2 m of the outlet and the temperature at the edge of the nearfield zone will be 3.6 ºC above ambient under both summer and rest of year conditions.
- → The proposed system discharge plume has an increased velocity and undergoes a greater degree of mixing over a greater area prior to reaching the surface. Under both summer and rest of year conditions the proposed system discharge plume reaches the surface over a distance of approximately 3.2 m and the temperature at the edge of the nearfield is approximately 3.3ºC above ambient.
- → The nearfield zone of the proposed discharge plume is larger in area than that of the existing discharge plume, and due to this, has a lower modelled temperature at the edge of the nearfield zone. The incremental differences in temperature and size of the nearfield zone of the existing plume compared to the proposed can be considered negligible.

SENSITIVITY ANALYSIS

- → An assessment of the sensitivity of the model to ambient temperature showed that the effect on the temperature gradient of the discharge plume is negligible. Due to the insensitivity of the model to ambient temperature variation, modelling scenarios use median ambient temperature only.

TRIGGER VALUE ASSESSMENT

- → An appropriate 80th percentile ambient temperature trigger value was calculated in accordance with ANZECC (2000) by using measured seawater temperature data and incorporating the temperature effects of the existing approved system discharge. Comparison against the modelled temperature effects of the proposed discharge shows that the proposed system does not exceed the adopted trigger value.

4.2 Velocity effects

- → Discharge velocities for the existing and proposed discharge plumes have been modelled under summer and rest of year conditions. Due to the size of the outlet and the flow rate, the discharge velocities can be considered negligible when the plume exits the outlet at 0.14 m/s for the existing system and 0.22 m/s for the proposed system.
- → The modelling shows that the velocities quickly decrease within a few metres. Upon reaching the surface the action of waves, wind and surface current will be the dominant force controlling the plume dilution.
- → The mean ambient velocities are negligible and have negligible effect on the plume dispersion. The use of mean velocity is a conservative assumption and in reality the effects of wind, waves and tides will facilitate plume dispersion and most likely reduce the predicted effects.

4.3 Mexel 432 dilution

- → The dilution factors associated with the discharge plume were applied to the use of antifouling product, Mexel 432, at an initial dosage of 3 ppm to assess the difference in the concentration gradient of the existing and proposed systems under summer conditions.

- The modelling shows that the concentration of Mexel 432 at the edge of the nearfield mixing zone is approximately 1.7 ppm for the existing system and 1.6 ppm for the proposed system.
- The proposed system has a lower concentration at the edge of the nearfield due to the increased size of the nearfield zone associated with the greater discharge; the proposed discharge plume undergoes a greater degree of mixing with ambient waters prior to reaching the surface. Upon reaching the surface, the action of wind and waves will disperse the plume more rapidly than when the plume is submerged.
- For both the existing and proposed systems, the addition of Mexel 432 occurs once a day so the modelled concentration in the receiving waters will exist instantaneously before being diluted to undetectable levels.

5 REFERENCES

ANZECC, 2000. Australian and New Zealand guidelines for fresh and marine water quality. Volume 1, The guidelines / Australian and New Zealand Environment and Conservation Council, Agriculture and Resource Management Council of Australia and New Zealand.

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Appendix B

CONSIDERATION OF IMPACTS ON THREATENED AND PROTECTED MARINE SPECIES

CONSIDERATION OF IMPACTS ON THREATENED AND PROTECTED MARINE SPECIES

To determine the potential impact on threatened species and ecological communities searches were made of marine species listed under the EPBC Act, the NSW Threatened Species Conservation Act 1995 (TSC Act) and the Fisheries Management Act that may occur in a 5 km radius of the proposed heat exchange system. Appendix B Table 1 compiles the listing from those conservation instruments and presents justification for the need to complete a formal significance assessment for each species. Key project-specific considerations in determining whether a species, community or population listed below require further assessment include:

- The proposal affects small bays within Sydney Harbour which consist of modified and urbanised intertidal and subtidal habitats that have relatively low habitat diversity and low biotic diversity. Intertidal habitat consists mainly of artificial structures such as seawalls, wharf piles and (in Pyrmont Bay) pontoons and as such are unlikely to afford appropriate habitat for the majority of protected species that may occur in the bays.
- No construction activity is proposed and hence any minor disturbance to existing marine habitats would be restricted to the installation of mitigation structures (screens at the intake location in Jones Bay).
- The proposed operation of inlet and outlet pipes is unlikely to have any incremental impact on deeper soft bottom habitats.
- The increased volume of seawater used for operation of the proposed heat exchange system would be small relative to the volume of Sydney Harbour (refer to section 5.1.1) making the loss of planktonic life forms insignificant and unlikely to alter the ecology of intertidal or subtidal habitats
- The marginal increase in warm temperature resulting from the increased system capacity is negligible in comparison to the existing system operation.
- The installation of mesh screens over the existing pipe opening would mitigate impacts of entrainment of large mobile marine species at the intake location.

Appendix B Table 1 Listing of relevant threatened and protected species and justification for further assessment of significance

P = Protected; V = Vulnerable; CE = Critically Endangered, E = Endangered; M = Migratory, L = Listed Marine

[1] = the entire east coast population of grey nurse sharks, [2] = the population of little penguins at Manly

Common Name	Scientific Name	Conservation listing status EPBC	TSC	FM	Project-specific considerations relevant to requirement for significance assessment	Formal assessment required?
Finfish						
Grey nurse shark	*Carcharias taurus*	E[1]		CE	Water at project site too shallow for species to occur, no resting habitat available (i.e. lack of caves) and very little availability of foraging area. Potential for occurrence in Project area very low.	No
Black cod	*Epinephelus daemelii*	V		V	Relevant habitats Black cod require (caves, complex rocky reef) are absent or sub-optimal. Potential for occurrence very low.	No
Estuary cod	*Epinephelus coioides*			P	Relevant habitats Estuary cod require (caves, complex rocky reef) are absent or sub-optimal. Potential for occurrence very low.	No
Elegant wrasse	*Anampses elegans*			P	Adults are not likely to occur in the study area as they usually occupy deeper and more complex habitats (e.g. rocky reefs). Juveniles school in seaweed and rocky reefs habitats which are not present in the project area. Potential for occurrence is low.	No
Eastern blue devil	*Paraplesiops bleekeri-*			P	Usually occupies deeper and more complex habitats such as rocky reefs with crevices and caves. Juveniles are found in rocky reefs habitats which are not present in the study area. Potential for occurrence in Project area is low.	No
Up to 23 species of seahorses, seadragons, pipefish, pipehorses, ghostpipefish and seamoths	Syngnathiformes	L		P	No seagrass and limited macrophyte or other suitable habitat available. Potential for occurrence is low and disturbance of algal habitat is minimal.	No
Marine Mammals						
Common dolphin	*Delphinus delphis*	L	P		Very little foraging area available. Uncommon in shallow and intertidal habitats.	No
Indian Ocean Bottlenose Dolphin, Spotted	*Tursiops aduncus*	M, L	P			No

Common Name	Scientific Name	Conservation listing status EPBC	TSC	FM	Project-specific considerations relevant to requirement for significance assessment	Formal assessment required?
Bottlenose Dolphin						
Dusky dolphin	*Lagenorhynchus obscurus*	M,L	P			No
Marine Reptiles						
Loggerhead turtle	*Caretta caretta (M)*	E,M,L	E,P		The Project area represents an unlikely foraging area due to the lack of seagrass beds or extensive algae mats. Potential for occurrence is very low.	No
Green turtle	*Chelonia mydas (M)*	V,M,L	V,P			
Leatherback turtle	*Dermochelys coriacea (M)*	E,M,L	E,P		Highly pelagic species occurring near shore manly during the nesting season. It requires sandy beaches to nest which are near absent in the Project area. Potential for occurrence is very low.	No
Hawksbill turtle	*Eretmochelys imbricata (M)*	V,M,L	V,P		Highly pelagic species occurring near shore mainly during the nesting season and occasionally for foraging in seagrass habitats. Requires sandy beaches to nest which are absent in the Project area. Potential for occurrence is very low.	No
Flatback turtle	*Natator depressus (M)*	V,M,L	P		Adults inhabit soft bottom habitat over the continental shelf of northern Australia and occur nearshore mainly during the nesting season. Requires sandy beaches to nest which are nearly absent in the Project area. Potential of occurrence is very low.	No
Marine Birds						
Little penguin	*Eudyptula minor*	L	E[2], P		Little penguins spend most of their time foraging in open coastal waters. The only known breeding colony in NSW is in the Manly area of Sydney Harbour. Potential of occurrence in the Project area is very low.	No
Little pied cormorant	*Microcarbo melanoleucos*	L	P		Could occur in the Project area, but Project area is not key roosting site for any of this group of birds. These species readily move away from disturbed habitats, or readily acclimate to them (e.g. pelicans). There are no proposed construction activities would directly impact on birds temporarily using the foreshore to roost, and there is high availability of other roosting	No
Great cormorant	*Phalacrocorax carbo*	L	P			
Little black	*Phalacrocorax*	L	P			

Common Name	Scientific Name	Conservation listing status EPBC	TSC	FM	Project-specific considerations relevant to requirement for significance assessment	Formal assessment required?
cormorant	*sulcirostris*				habitats.	
Pied cormorant	*Phalacrocorax varius*	L	P			
Australian pelican	*Pelecanus conspicillatus*	L	P			
White-bellied sea eagle	*Haliaeetus leucogaster*	M,L	P		Occurs mainly in large areas of open water (larger rivers, swamps, lakes, sea). Forages over in-shore waters and large expanses. The project area is not suitable for nesting. Potential occurrence is very low.	No
Black noddy	*Anous minutus*	L	P		Could occur incidentally in the Project area but Project area does not represent key roosting, nesting or foraging habitat. Potential occurrence is very low.	No
Common noddy	*Anous stolidus*	L	P			
Kelp gull	*Larus dominicanus*	L	P			
Silver gull	*Chroicocephalus novaehollandiae*	L	P		Could occur incidentally in the Project area but Project area does not represent key roosting, nesting or foraging habitat. Potential occurrence is very low.	No
Pacific gull	*Larus pacificus*	L	P			
Franklin's gull	*Leucophaeus pipixcan*	L	P			
Whiskered tern	*Chlidonias hybrida*	L	P			
White-winged black tern	*Chlidonias leucopterus*	L	P		Could occur incidentally in the Project area but Project area does not represent key roosting, nesting or foraging habitat. Potential occurrence is very low.	No
Gull-billed tern	*Gelochelidon nilotica*	L	P			

Common Name	Scientific Name	Conservation listing status			Project-specific considerations relevant to requirement for significance assessment	Formal assessment required?
		EPBC	TSC	FM		
White tern	*Gygis alba*	L	P			
Caspian tern	*Hydroprogne caspia*	L	P			
Sooty tern	*Onychoprion fuscata*	L	P			
Grey ternlet	*Procelsterna cerulea*	L	P			
Common tern	*Sterna hirundo*	L	P			
Arctic tern	*Sterna paradisaea*	L	P			
White-fronted tern	*Sterna striata*	L	P			
Little tern	*Sternula albifrons*	L	P			
Fairy tern	*Sternula nereis*	L	P			
Crested tern	*Thalasseus bergii*	L	P			
Ecological Communities						
	Posidonia australis seagrass meadows, population	T (Manning-Hawkesbury ecoregion)		EP (Port Hacking, Botany Bay, Sydney Harbour, Pittwater, Brisbane Waters and Lake Macquarie)	No seagrasses present in the project area	No