Marine Water Quality

Appendix B

Technical Report

Near Field and Far-Field Modelling of Discharge From the Twofold Bay Biomass fired Power Plant

9 DECEMBER 2009

Prepared for

South East Fibre Exports Ltd

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Appendix A Incorporation of the Diffuser Design into CORMIX

Abbreviations

Abbreviation	Description
°C	Degrees Celsius
ANZECC	Australia and New Zealand Environment and Conservation Council
cm/s	Centimetres per second
DECC	Department of Environment and Climate Change
EFDC	Environmental Fluid Dynamics Code
EP&A Act	Environmental Planning and Assessment Act 1979
g/L	Grams per litre
kg/m^3	Kilograms per cubic metre
l/s	Litres per second
mm	Millimetres
MW	Mega Watts
MWh	Mega Watt hours
MWQO	Marine Water Quality Objectives
NSW	New South Wales
%ile	Percentile
POEO Act	Protection of the Environment Operations Act 1997
SEFE	South East Fibre Exports Pty Ltd
t	Tonnes
USEPA	United States Environmental Protection Agency

Executive Summary

URS Australia Pty Ltd has been commissioned by South East Fibre Exports Pty Ltd to investigate the dilution characteristics of cooling water discharge from a proposed biomass fuelled Power Plant to be located at Munganno Point, Twofold Bay, New South Wales.

The assessment has focused on the water quality and mixing zone requirements utilising a combination of near-field and far-field modelling. A number of scenarios have been considered including the discharge of cooling water to the marine environment via the outlet under typical and extreme conditions.

Study Objectives

The purpose of the far-field modelling was to:

- Develop three dimensional hydrodynamics of Twofold Bay.
- Provide a characterisation of the depth average, alongshore currents for use in the near-field modelling.
- Provide a conservative estimate of the potential for accumulation of temperature in the vicinity of the discharge.

The purpose of the near-field modelling was to:

- Determine the characteristics of the discharge plume as it disperses within the first few meters of the marine environment.

Water Quality Objectives

The key pollutant of concern associated with the cooling water discharge for aquatic ecosystem protection is temperature. The water quality guidelines for aquatic ecosystem protection require that hot water discharges should not be permitted to increase the temperature of the aquatic ecosystem above the 80th percentile temperature value obtained from the seasonal distribution of temperature data from the reference.

Based on the monthly averaged temperature data for Eden, a temperature differential trigger value of 2.4ºC was considered to be an appropriate criterion for assessing the extent of the mixing zone.

Far Field Modelling

Three-dimensional, far-field modelling was undertaken using the software package Environmental Fluid Dynamics Code which is USEPA approved and supported.

The results of the far-field modelling suggest that:

- There is the potential for a background accumulation of temperature in the vicinity of the diffuser outlet of 0.25°C.
- The hydrodynamic simulations have provided a time series of depth average along shore current velocities in the vicinity of the diffuser outlet that suggests the currents range in velocity from 0.03 m/s to 0.23 m/s.

Near-Field Modelling

Near-field modelling was undertaken using the plume dispersion model CORMIX.

A preliminary assessment of design options was undertaken for winter and summer scenarios in order to provide input into the design selection process.

Table 0-1 Design Configuration Options

Scenario	Units	Case 1		Case 2	
		1A	1B	2A	2B
		Summer	Winter	Summer	Winter
Seawater temperature in	°C	23	13	23	13
Temperature rise	°C	10	21.1	8	19.1
Seawater temperature out	°C	33	34.1	31	32.1
Flow rate	litres/s	333	158	416	174

The results of the preliminary assessment of Case 1 and Case 2 design options suggested that:

- In order to optimise the path length of the discharge plume prior to reaching the surface of the water column, an angled diffuser outlet configuration is preferable to a horizontal configuration.
- A diffuser configuration with an outlet angle of 30 degrees with respect to the horizontal was selected.
- Case 2 was found to be associated with marginally better environmental outcomes compared with Case 1.
- Based on communications with South East Fibre Exports Pty Ltd, it was concluded that the differences in the environmental outcomes between Case 1 and Case 2 did not warrant the large operational cost differential between these two design options. Case 1 will require lower flow rates than Case 2 and result in a significant reduction in pump running costs.
- Case 1 was selected as the preferred option and was the focus of the detailed assessment.

A detailed near-field assessment using CORMIX was conducted for Case 1.

A total of twelve uniform water column scenarios and (due to the limited availability of more detailed information) one stratified water column scenario were considered.

Results of the detailed assessment suggests that the trigger value for temperature of a temperature differential of less than 2.4ºC will be achievable within a distance of less than 3.5 m from the diffuser outlet.

Summary of Findings

Results of the cooling water discharge assessment suggest the following:

- An accumulation of temperature in the vicinity of the diffuser outlet of 0.3ºC is considered to be a conservative estimate of the potential for the localised elevation of background temperatures.
- Water quality objectives associated with trigger values for temperature can be achieved within 3.5 m from the outlet of the diffuser.

Introduction

URS Australia Pty Ltd has been commissioned by South East Fibre Exports Pty Ltd (SEFE) to investigate the dilution characteristics of cooling water discharge from a proposed biomass fuelled Power Plant to be located at Munganno Point, Twofold Bay, New South Wales (NSW).

The assessment has focused on the water quality and mixing zone requirements utilising a combination of near-field and far-field modelling. A number of scenarios have been considered including the discharge of cooling water to the marine environment via the outlet under typical and extreme conditions.

The purpose of the far-field modelling was to:

- Develop three dimensional hydrodynamics of Twofold Bay.
- Provide a characterisation of the depth average, alongshore currents for use in the near-field modelling.
- Provide a conservative estimate of the potential for accumulation of temperature in the vicinity of the discharge.

The purpose of the near-field modelling was to:

- Determine the characteristics of the discharge plume as it disperses within the first few meters of the marine environment.

1.1 Background

SEFE operates a woodchip mill and export facility at Munganno Point NSW (**Figure 1-1**), approximately 400 km south of Sydney. The Munganno Point mill site is located on the southern shoreline of Twofold Bay (**Figure 1-2**) and has been in operation for 40 years. The existing facility includes the receiving of logs and their storage, debarking and chipping, an associated process plant, and a wharf / ship-loading facility for the export of woodchips.

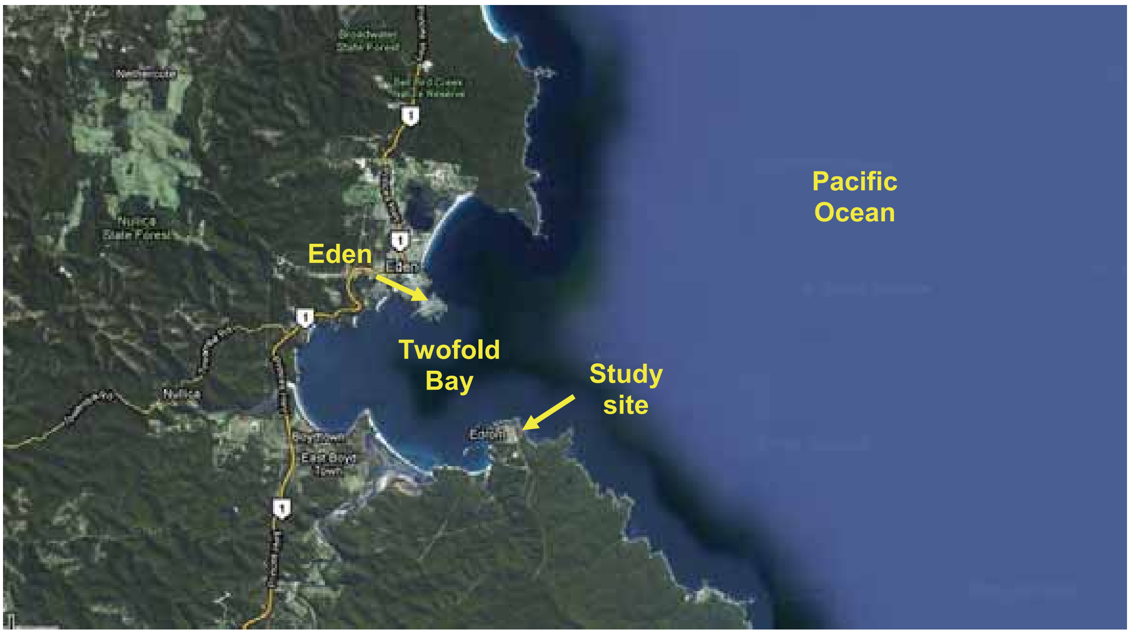

Figure 1-1 Location of Study Site on Munganno Point (Source: Google Maps)

1 Introduction

Figure 1-2 Proposed Power Station Site (Source: Google Maps)

SEFE generates approximately 35,100 tonnes (t) of wood waste each year which is currently being disposed of in the burner or sold as mulch to markets in Sydney and Canberra.

SEFE plans to construct a Wood Waste to Energy (biomass) facility (power plant) within their existing Munganno Point mill site. SEFE would use the wood waste generated from its operations together with a further 22,600 t of wood waste available from local timber processing operations. The Power Plant would have a capacity of around 5.5 MW and would burn around 57,700 tonnes of wood waste to produce around 31,000 MWh of electricity per annum. A seawater cooling system was selected as the most feasible solution to provide cooling to the proposed Power Plant. Seawater will be drawn from Twofold Bay via an intake suspended from SEFE's existing wharf. Cooling water from the Power Plant will also be discharged from the wharf.

Ambient Environment

2.1 Local Topography and Bathymetry

Presented in **Figure 2-1** are the bathymetry and topography contours for Twofold Bay with a close up of the study site provided in **Figure 2-2**. Twofold Bay is seen to reach depths in excess of 30 m (AHD). The study site is located on a peninsula with steep topography and at an elevation of over 10 m (AHD) overlooking the Bay.

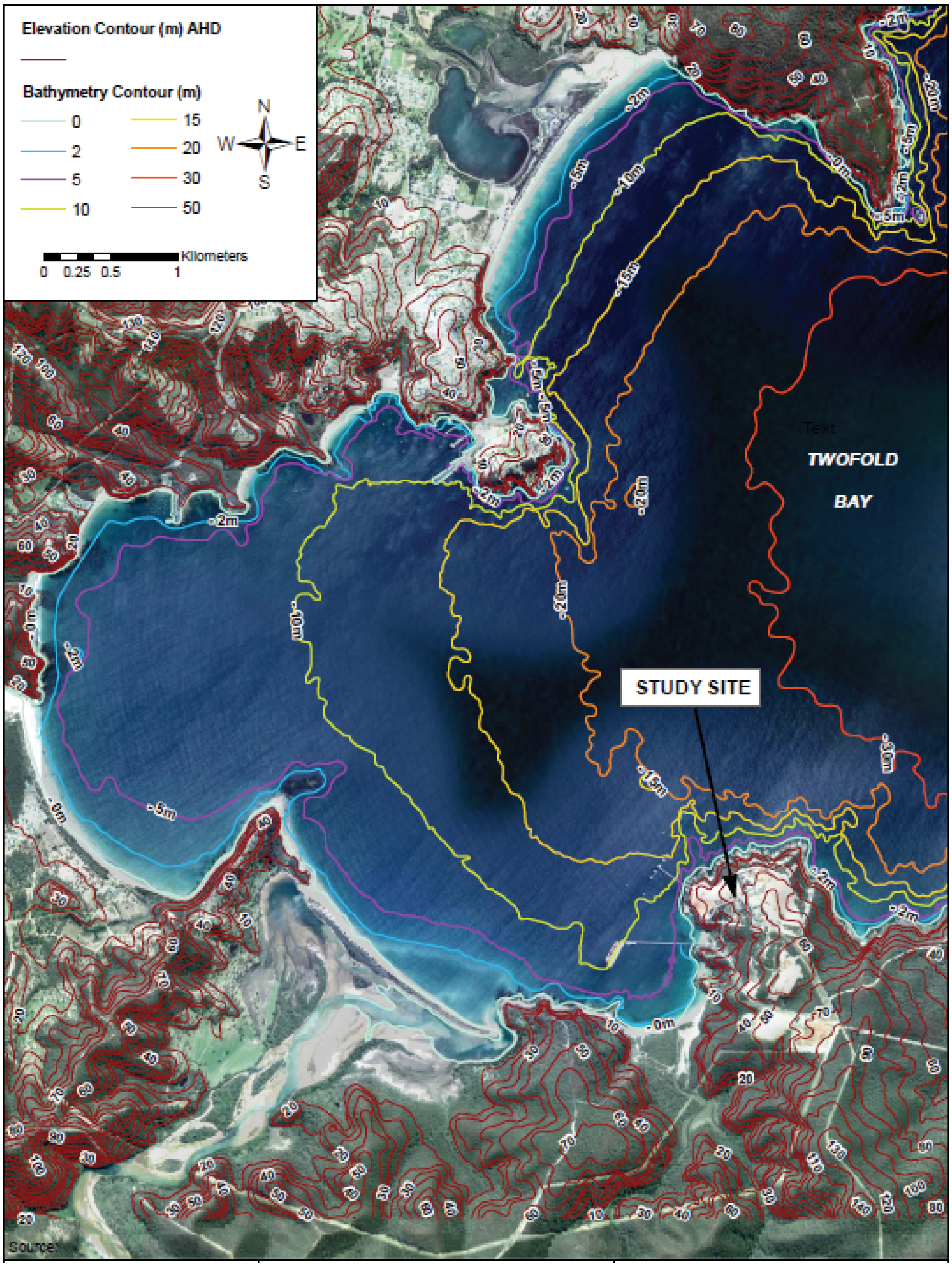

Figure 2-1 Topography and Bathymetry of Twofold Bay

2 Ambient Environment

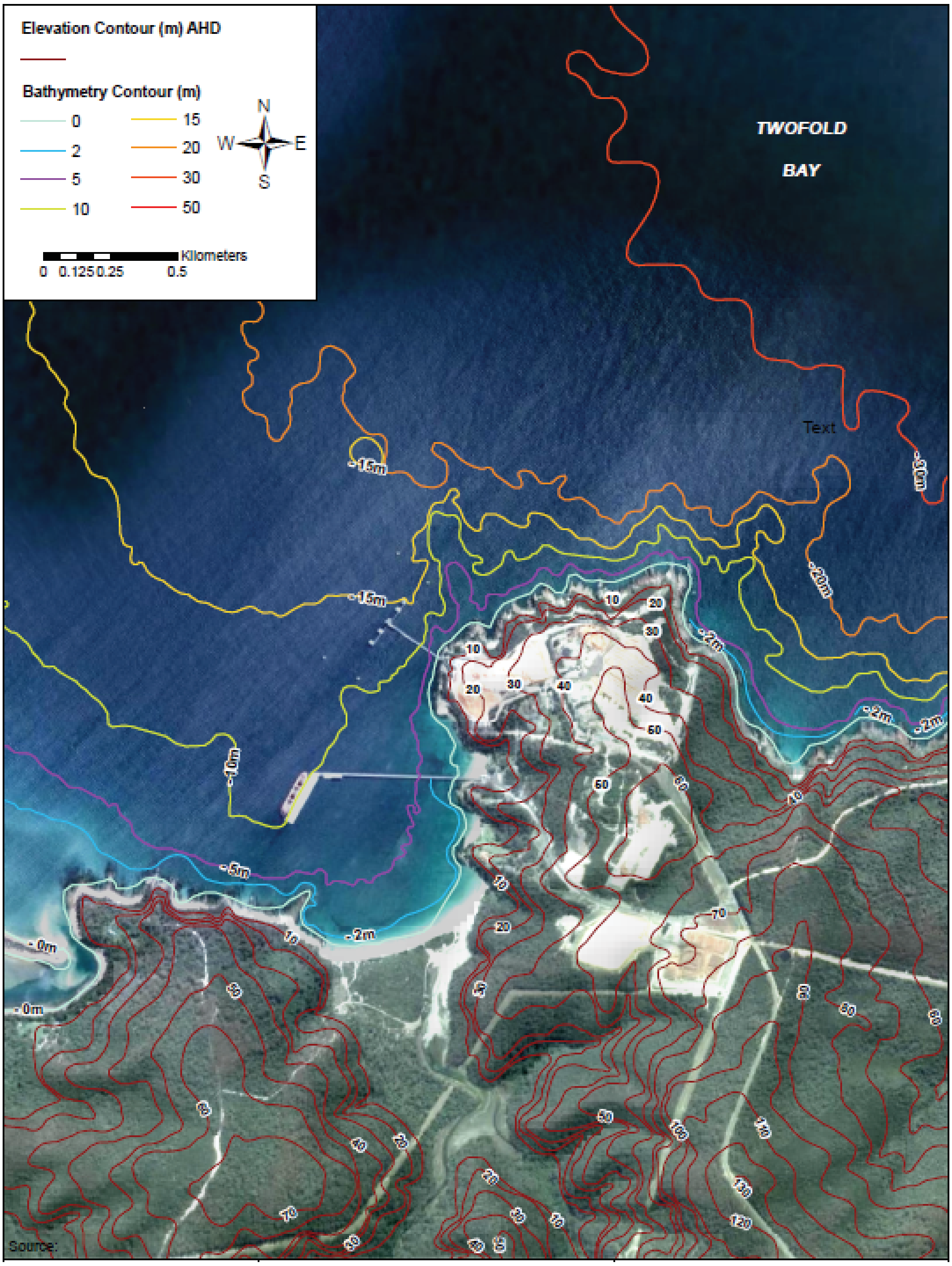

Figure 2-2 Topography and Bathymetry of Twofold Bay in the Vicinity of the Project Site

2.2 Meteorology

Due to the absence of site-specific meteorology, the Air Pollution Model (TAPM) developed by the CSIRO was used to construct a year of hourly wind fields at a location over Twofold Bay (37.099 ºS, 155.899 ºE). A summary of wind speeds generated by TAPM over Twofold Bay (2007) is presented in **Table 2-1**. The annual wind rose is presented in **Figure 2-3** and indicates that the predominant wind directions are from the northeast and the southwest.

Table 2-1 Summary of Wind Speeds, TAPM 2007

Parameters	Unit	Min	1%	10%	50%	90%	99%	Max
Wind speed	m/s	0	1.2	1.8	2.7	3.9	5.7	11.7

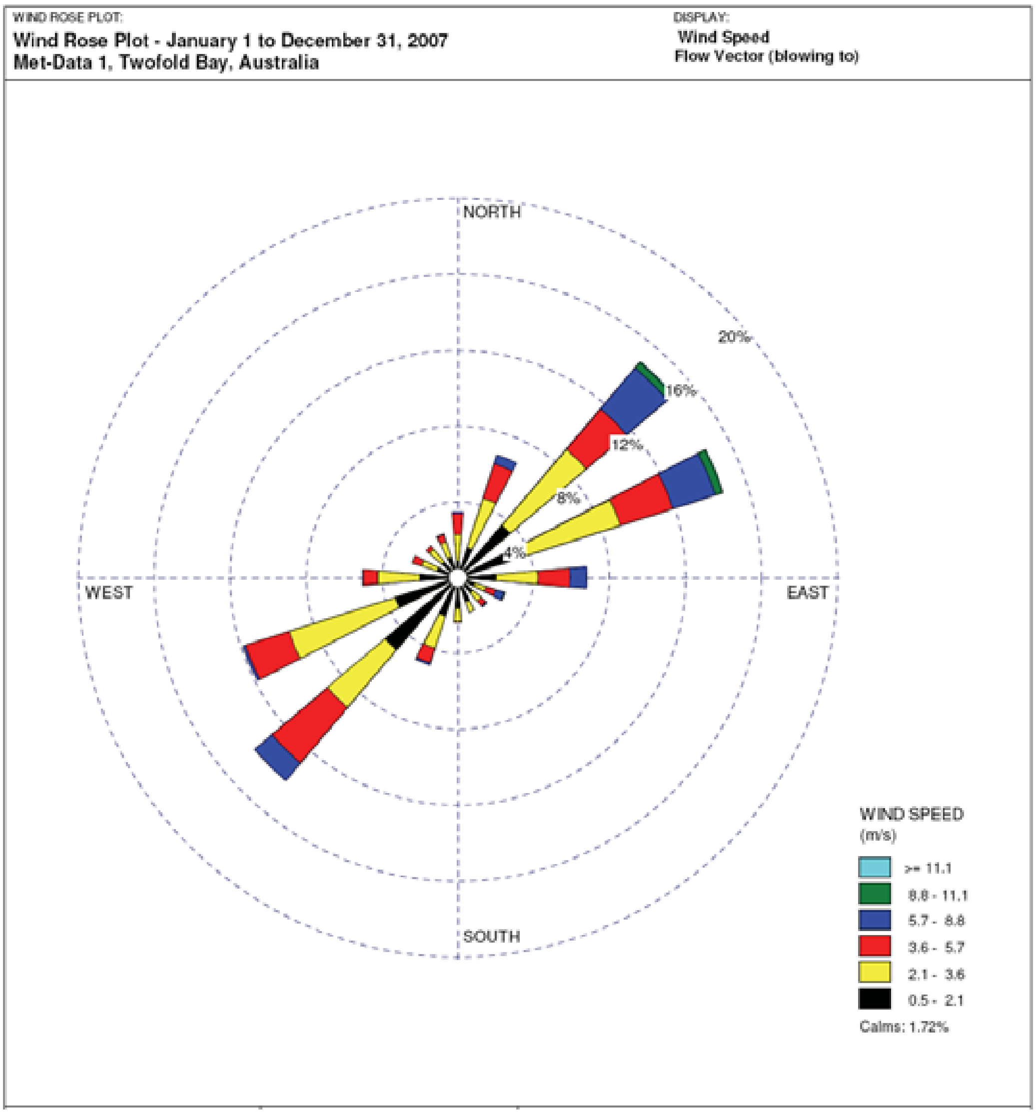

Figure 2-3 Annual Wind Rose Generated by TAPM, 2007

2.3 Oceanography

2.3.1 Tides

Hourly tide records were obtained for the Eden tide gage for the period 17/09/1986 through 1/5/2009. Tide elevations for 2007 are presented in **Figure 2-4**. The data indicates a low frequency annual period for a small amplitude variation in water elevation, in the order of 0.25 m, peaking in January. Also evident is a spring neap tide cycle. A shorter period record for May 2007 is shown in **Figure 2-5**. The spring neap cycle is evident, and the tides are semi-diurnal, with two high tides of differing amplitude each day. The peak spring tide amplitude is approximately 1.75 m.

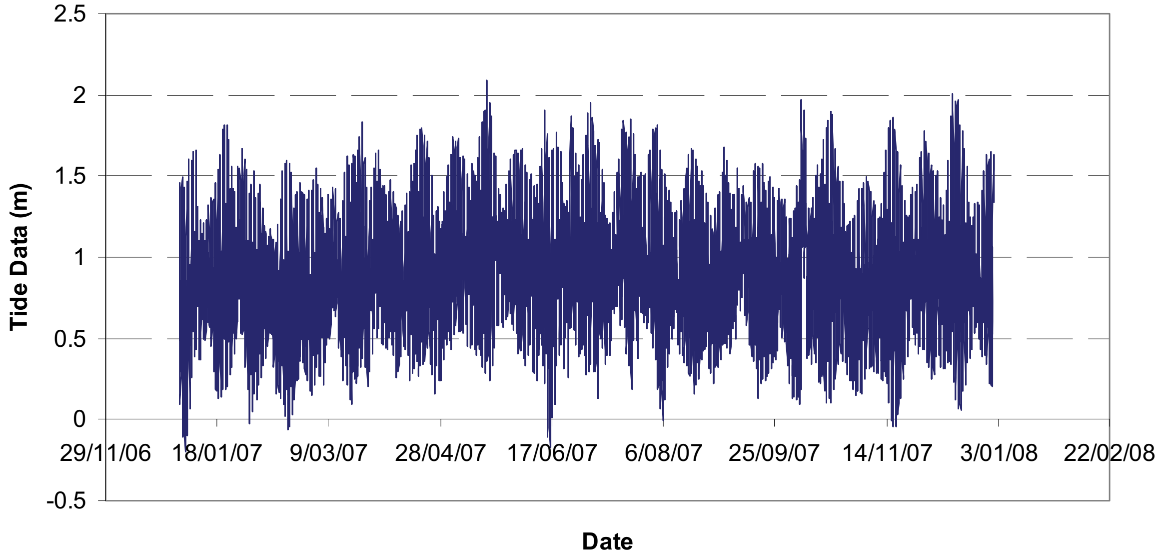

Figure 2-4 Tide Data from Eden Gauge, 2007

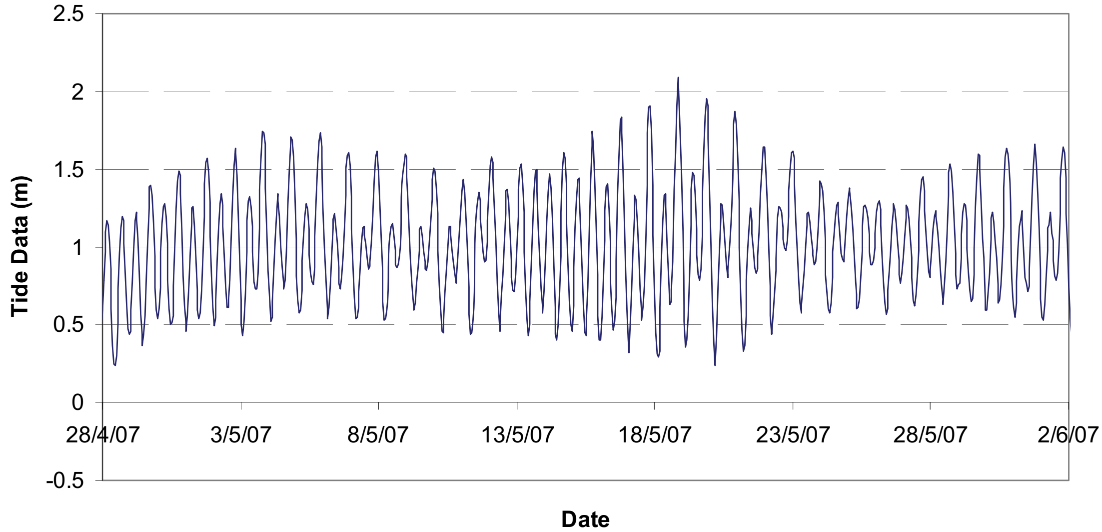

Figure 2-5 Tide Data from Eden Gauge, May 2007

2.3.2 Currents

There was no current data available at the time of the assessment. Therefore, for the purposes of the characterisation of the ambient current environment, numerically simulated current information will be presented and has been developed using the methodology outlined in **Section 5.3**.

Presented in **Figure 2-6** and summarised in **Table 2-2** is the depth-averaged, alongshore current speeds extracted from the hydrodynamic modelling (**Section 5.3**) at the location of the diffuser outlet.

Table 2-2 Statistics for the Depth Averaged Alongshore Current Speeds

Parameters	Unit	Min	10%	25%	50%	75%	90%	Max
Current speed	m/s	0.027	0.105	0.118	0.130	0.144	0.158	0.229

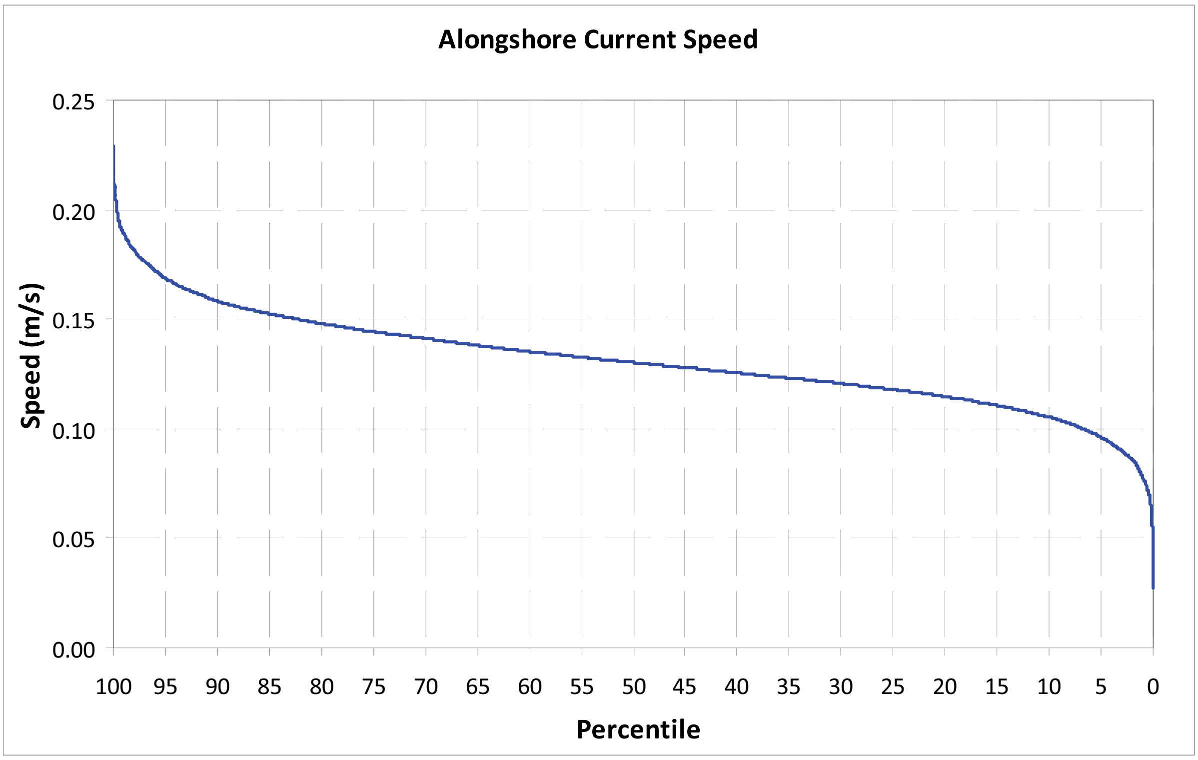

Figure 2-6 Statistics for the Depth-Averaged Alongshore Current Speed as Developed using EFDC

2.3.3 Ambient Water Quality

To assess the effects of effluent from the diffuser discharge on the marine environment, it is necessary to consider the characteristics of the ambient environment likely to influence the dilution rate and plume behaviour.

The mean annual sea-surface temperature (17.5°C) reflects the influence of warmer waters brought into Bass Strait by the East Australian Current (EAC) (IMCRA, 1998). The monthly average seawater temperature varies between 14.2 and 20.2°C (DOM, 2009). The 80th percentile temperature is 20.0°C with a median (50th percentile) temperature of 17.6°C.

The annual salinity range at Eden is 35.6 g/l to 35.7 g/l (DOM, 2009), with an annual average salinity of 35.65 g/l (**Table 2-3**).

Table 2-3 Temperature and salinity monthly averages (DOM, 2009)

	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**
Temperature (°C)	19.6	20.1	20.2	20.1	18.3	16.4
Salinity (g/L)	35.7	35.7	35.7	35.7	35.7	35.7
	Jul	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Temperature (°C)	15.2	14.2	14.8	16.2	17.2	18
Salinity (g/L)	35.6	35.6	35.6	35.6	35.6	35.6

Legislative Context and Water Quality Objectives

3.1 Regulatory Framework

The key legislation regulating discharges to the marine environment within 3 nautical miles (5.5km) of the coastline are:

- *Environmental Planning and Assessment Act 1979*

The *Environmental Planning and Assessment Act 1979* (EP&A Act) and the *Environmental Planning and Assessment Regulation 2000* provide the framework for the assessment of, and planning for, development in NSW.

- *Protection of the Environment Operations Act 1997*

The *Protection of the Environment Operations* Act 2005 (POEO Act) is the primary environment protection legislation in NSW. The Act requires the consideration of the impacts of discharges on the environmental values of receiving waters when deciding whether to licence a discharge.

3.2 Water Quality Guidelines

The Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000 establish the water quality standard necessary to support the identified environmental values. The guidelines provide instructions for translating the desired environmental values into water quality management criteria and also provide a framework for assessing the risks of each pollutant in the proposed discharge and how it affects each environmental value.

3.2.1 Environmental Values and Water Quality Objectives

Environmental values represent the characteristics or qualities of a waterway that support healthy ecosystems and the community's livelihoods and lifestyles. In ocean waters adjacent to the NSW coastline environment values are defined within the Marine Water Quality Objectives (MWQO) for NSW ocean waters (2005). The environmental values which apply to marine waters at the location of the proposed discharge are shown in **Table 3-1**.

Water quality criteria and guideline levels have been specified for each environmental value within the MWQO (2005). Together these represent the water quality objectives that must be maintained to achieve the specified environmental values.

Table 3-1 Environmental Values

Environmental values	Twofold Bay
Protection of high ecological value aquatic habitat	X
Protection of slightly to moderately disturbed aquatic habitat	✓
Protection of highly disturbed aquatic habitat	X
Suitability for human consumers of aquatic food	✓
Suitability for primary contact recreation (e.g. swimming)	✓
Suitability for secondary recreation (e.g. boating)	✓
Suitability for visual (no contact) recreation	✓
Protection of cultural and spiritual values	✓
Suitability for industrial use (including manufacturing plants, power generation)	✓
Suitability for aquaculture	✓
Suitability for drinking water supplies	X
Suitability for crop irrigation	X
Suitability for stock watering	X
Suitability for farm use	X

Table Notes:
✓: Bay is suitable for the environmental value.
X: Bay is not suitable for the environmental value.

3.2.2 Trigger Values for Temperature

The level of aquatic ecosystem protection for Twofold Bay is "slightly to moderately disturbed". The key pollutant of concern associated with the cooling water discharge for aquatic ecosystem protection is temperature. The water quality guidelines for aquatic ecosystem protection require that hot water discharges should not be permitted to increase the temperature of the aquatic ecosystem above the 80%ile temperature value obtained from the seasonal distribution of temperature data from the reference.

In relation to other studies of heated discharges to the marine environment, Department of Environment and Climate Change (DECC) has advised (NSW DECC reference number 282151A7:WOF13617:PW Attachment B) that:

Results of modelling scenarios should also be presented as differences between water temperatures with and without the thermal loading in order to illustrate the extent of the thermal disturbance above ANZECC (2000) trigger criteria. That is, the simulated 50th percentile temperatures must be compared with the 80th percentile natural ambient temperatures. This analysis can be undertaken for a summer period (eg 1st Jan to 28th Feb) and an equivalent winter period when ambient water temperatures are at a minimum.

Based on the monthly averaged temperature data presented in Table 2-3, the 80th percentile ambient temperature is 20.0ºC with a 50th percentile temperature of 17.6ºC. Interpreted in accordance with the comments of DECC, this suggests that the temperature differential (i.e. water temperature less the ambient temperature) should not exceed 2.4ºC. This temperature differential trigger value of 2.4ºC will be used to assess the extent of the mixing zone predicted by the near-field modelling.

Diffuser and Discharge Characteristics

4.1 Diffuser Characteristics

A concept design for the cooling water diffuser was prepared by URS and details of the design can be found in *Design of Seawater Intake and Outlet System - Preliminary Work* (URS, 2009). Information that is relevant to the assessment of the cooling water discharge is summarised in the following sections.

4.1.1 Geometry of the Diffuser

The Power Plant will use seawater cooling. Seawater will be pumped to the condenser via an above ground delivery pipeline, will pass once through the condenser, and will return via a return pipeline to the discharge point. The intake and outlet structures will be installed on the existing jetty. Marine surveys were undertaken to identify suitable intake and outfall locations. A schematic of the cooling system is shown in **Figure 4-1**.

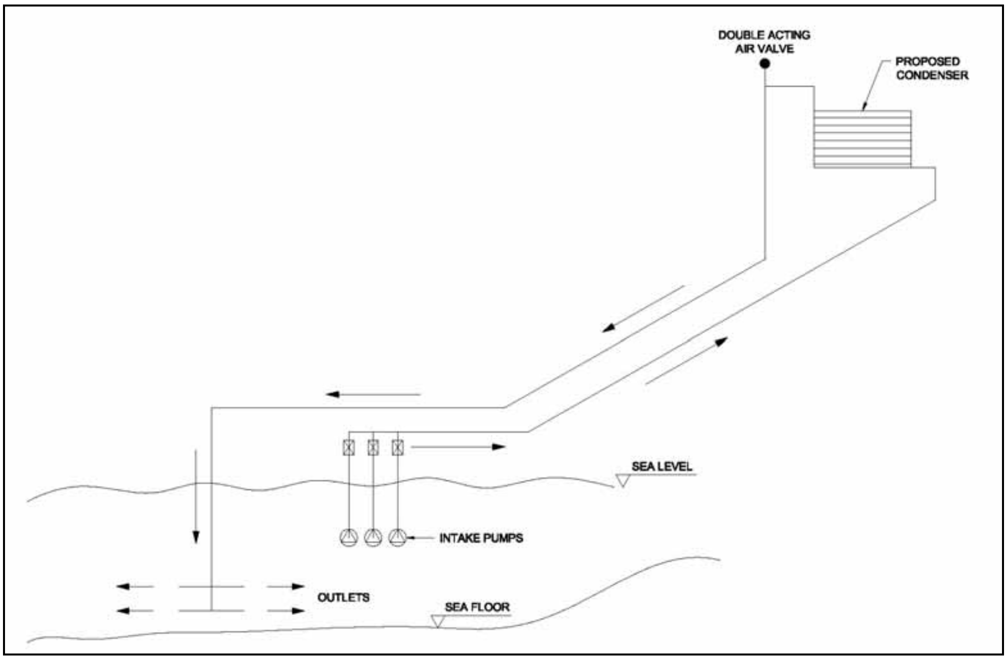

Figure 4-1 Schematic of cooling system (URS, 2009)

The inlets will be positioned approximately 90m from the shore where the average sea floor is at -9.2m datum level. The outlet will be located approximately 190m from the shore where the average sea floor is at -14m. The outlet pipeline will end with a vertical section down to the sea floor with two 150mm outlets at 2m from sea bed and another two at 1m from the sea bed. The orientation of the diffuser outlets have been interpreted as parallel to the jetty and thus perpendicular to the coastline with one pair of outlets directed towards the shore, the other pair directed away from the shore. Thus the axis of the outlets has been taken is perpendicular to the alongshore currents. The diffuser geometry is summarised in **Table 4-1** and depicted in **Figure 4-2**.

4 Diffuser and Discharge Characteristics

Table 4-1 Diffuser Characteristics (URS, 2009)

Parameters(1)	**Units**	**Value**
Length	m	190
Diameter	mm	400
Number of outlets	-	4
Port diameter	mm	150
Port orientation	Degrees above horizontal	0(1), 30
Port direction	Relative to the shore	perpendicular
Port spacing	M	1
Port alignment	-	Alternating opposing orientation

Note (1): The concept design considered a 0 degree port orientation. Results of the near-field dispersion modelling suggested the use of a 30 degree port orientation to ensure that the plume does not impact the sea floor.

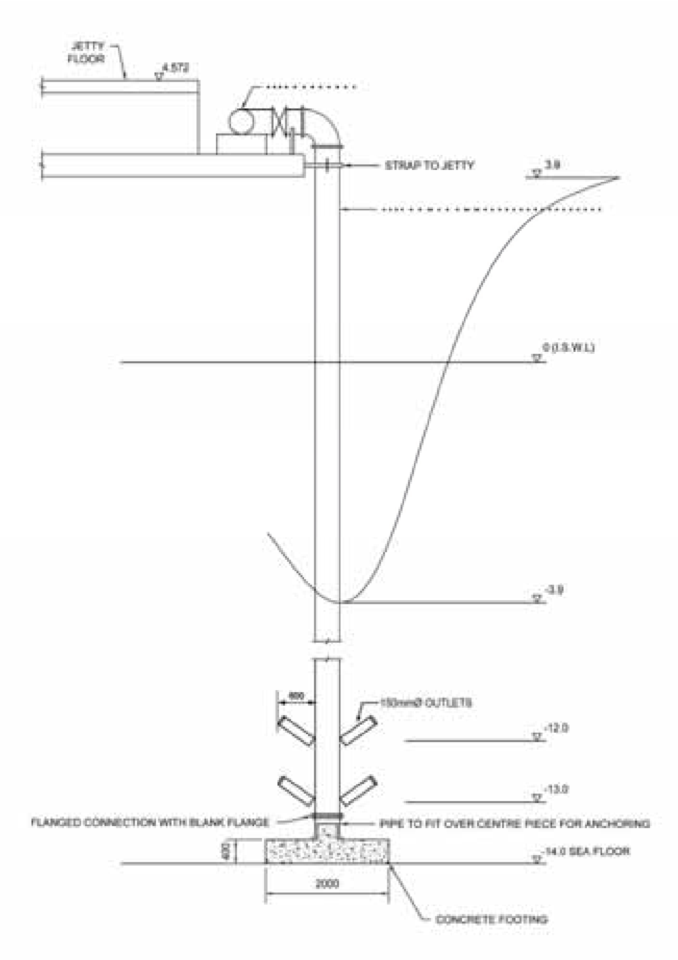

Figure 4-2 Diffuser Concept Design (Adapted from URS, 2009)

4.2 Effluent Characteristics

Consideration has been given to two cooling system designs options denoted as Case 1 and Case 2, with cooling water discharge characteristics for each case summarised in **Table 4-2**. The Case 1 summer and winter scenarios involve a larger ambient to discharge temperature differential and a lower flow rate when compared with Case 2.

Although the summer and winter temperature differential (i.e. discharge temperature minus the ambient temperature) is 21.1°C (case 1) or 19.1 °C (Case 2) during winter, and 10°C (Case 1) or 8°C (Case 2) during summer, the estimated heat load to the ambient environment (Q) which is proportional to the mass flow (m) and the temperature differential (ΔT), is constant throughout the year.

$$Q \propto m(\Delta T)$$

Table 4-2 Cooling Water Quality Characteristics

Scenario	Units	Case 1		Case 2	
		1A	1B	2A	2B
		Summer	Winter	Summer	Winter
Seawater temperature in	°C	23	13	23	13
Temperature rise	°C	10	21.1	8	19.1
Seawater temperature out	°C	33	34.1	31	32.1
Flow rate	litres/s	333	158	416	174

4.2.1 Anti-Fouling System

A number of methods are available for anti-fouling. The recommended solution is called the Vandervelde Protection anti-fouling system and involves the use of copper ions (URS, 2009). With this system, metallic cupper is oxidised to cupro ions (Cu^+). These cupro ions dissolve and create a temporary toxic medium for fouling, and because they hinder the growth and development of micro organisms they are effective in anti-fouling. The cupro ions are unstable and react rapidly with oxygen dissolved in water to cupper(I)oxides and oxidise in water spontaneously and precipitate. Research measurements in a fish pool with copper sensitive trout have proven that there were no hazardous effects (URS, 2009).

Far-Field Modelling

As the results of the far-field modelling play an integral role in providing both the currents and accumulation potential for the near-field modelling, the methodology and results of the far-field modelling are presented ahead of those for the near-field (**Section 6**).

5.1 Software

The model selected for the far-field modelling was the Environmental Fluid Dynamics Code (EFDC) which is supported and approved by the US Environmental Protection Agency (USEPA). The EFDC model solves the three-dimensional, vertically hydrostatic, free surface, turbulent averaged equations of motion for a variable density fluid. The model uses a stretched, or sigma, vertical coordinate and Cartesian, or curvilinear, orthogonal horizontal coordinates. Dynamically coupled transport equations for turbulent kinetic energy, turbulent length scale, salinity and temperature are also solved. In general, it includes forcing due to tides, winds, and river discharges. The EFDC model is supported with a graphical user interface, EFDC-View, which provides graphical tools and menus to facilitate the model setup, execution and post-processing.

5.2 Data Requirements

The EFDC model configuration and implementation requires the following data:

- Bathymetry.
- A one-year wind record (hourly or 3-hourly).
- A one-year tide record (hourly).
- The discharge locations and design flow rate.
- The discharge temperature.
- The ambient temperature.
- Data characterising the vertical stratification due to vertical salinity and temperature gradients.

At the time of model set up, there was no data available to characterise the vertical density profiles in the bay. However, since the bay is relatively open, deep and does not have much freshwater discharge, it is reasonable to assume that the water column is fairly uniform in the vertical. Due to computational constraints and lack of supporting data it was not feasible to conduct a sensitivity analysis for the 3D model. Since the model is intended to simulate the background build-up of excess temperature, and it is likely that the bay is well mixed vertically most of the time, the assumption of a well mixed ambient water column is not considered to be limiting.

5.3 Model Configuration

The EFDC model grid was configured to provide detailed resolution in the vicinity of the discharge locations and provide reasonable simulation times. A stretched grid was developed with 20 meters horizontal cell spacing in the vicinity that slowly increased to a maximum of 500 meters spacing in directions away from the discharge location (**Figure 5-2**) based on the bathymetry depicted in **Figure 5-1**.

5 Far-Field Modelling

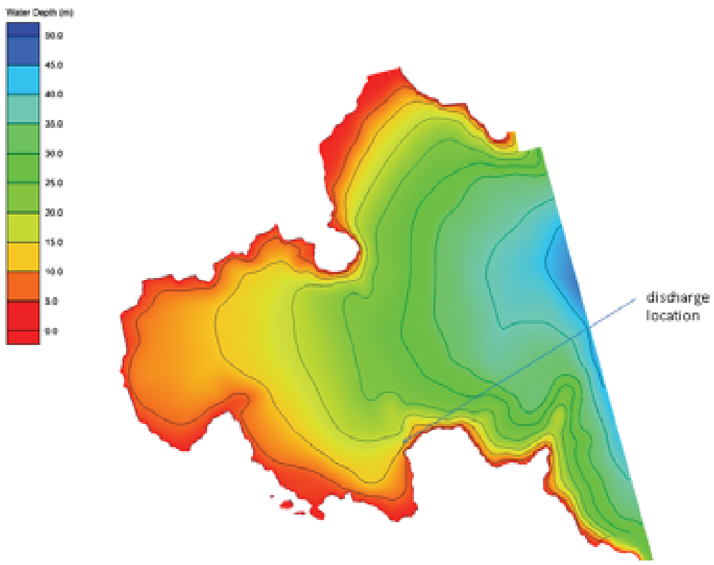

Figure 5-1 Bathymetry of Twofold Bay as Incorporated into EFDC

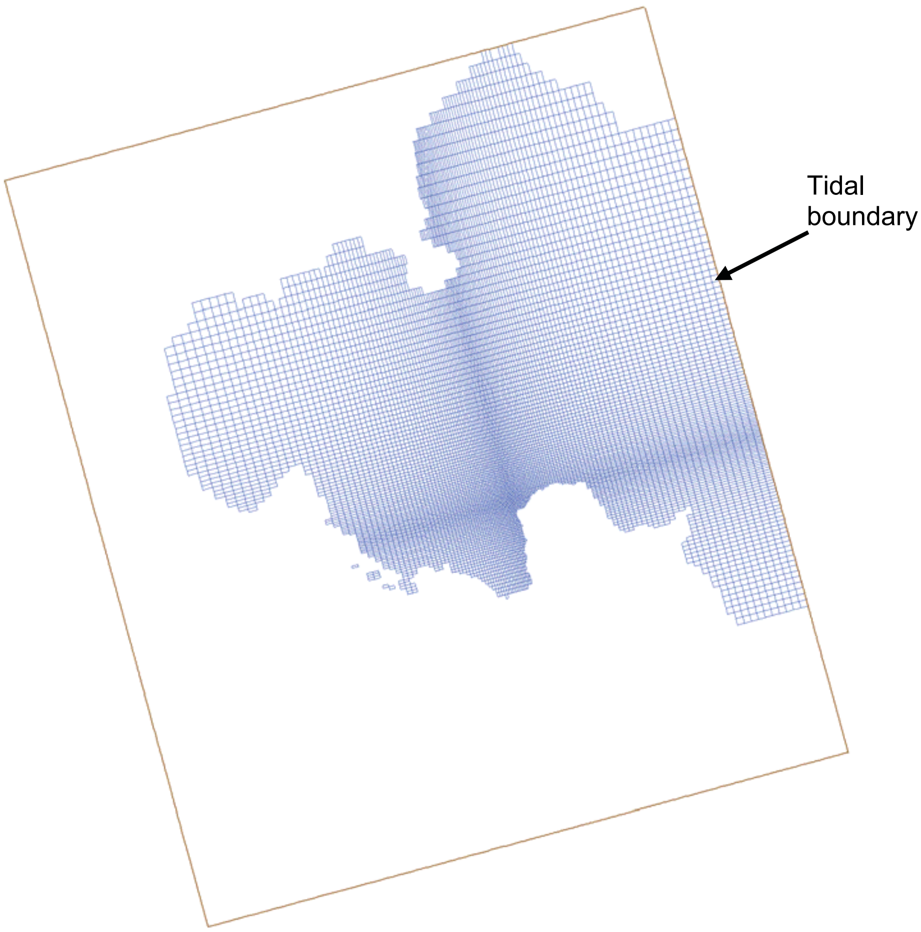

Figure 5-2 EFDC Model Grid Showing High Resolution in the Vicinity of the Discharge Outlet

Five vertical layers were used to represent the vertical version in current speed and temperature. The layer depths varied as the water depth varied. In the vicinity of the discharge, with a water depth of approximately 12 meters, the layer thicknesses were on the order of 2.4 meters.

The model was forced at the tidal boundary using the hourly tide data presented in **Section 2.3.1** and depicted in **Figure 2-4**.

The hourly wind data presented in **Section 2.2** and **Figure 2-3** was applied as a spatially uniform wind forcing on the surface layer across the entire model grid.

For all simulations, the sub-grid scale Smagorinsky lateral mixing scheme and the k-epsilon vertical mixing schemes were used. The explicit simulation mode was used with a time step of 8 seconds.

5.4 Modelling Analysis

Two 1-year model simulations were conducted. The first simulation consisted of tide and wind forcing using the data for the 2007 period. The second simulation consisted of the same tide and wind forcing as the first simulation and included the proposed discharge (and associated constant heat loading). The simulation period is 01/01/07 through 31/12/07.

5.4.1 Hydrodynamic Simulation Results

The results of the 1-year hydrodynamic simulation are shown in **Figure 5-3** through **Figure 5-5**. **Figure 5-3** shows the near surface velocity vectors in the vicinity of the discharge site during an ebb tide on 18/05/07.

A time series of the depth average velocity at the discharge location is shown in **Figure 5-4** for the month of May, 2007. The velocities in the area reflect the spring neap cycle, but are generally low, ranging from 1 to 10 cm/s. The corresponding velocity directions are shown in **Figure 5-5**. They range from 50 degrees (approximately NE) to -100 degrees (approximately WSW). The direction plot indicates a slight bias in the velocity to the west, indicating a counter-clockwise residual circulation in the bay. A frequency diagram of the depth-averaged velocity for the velocity magnitude at the proposed discharge location was presented as **Figure 2-6**. These data were used to characterise the velocity range for use in the near-field modelling (**Table 2-2**).

5 Far-Field Modelling

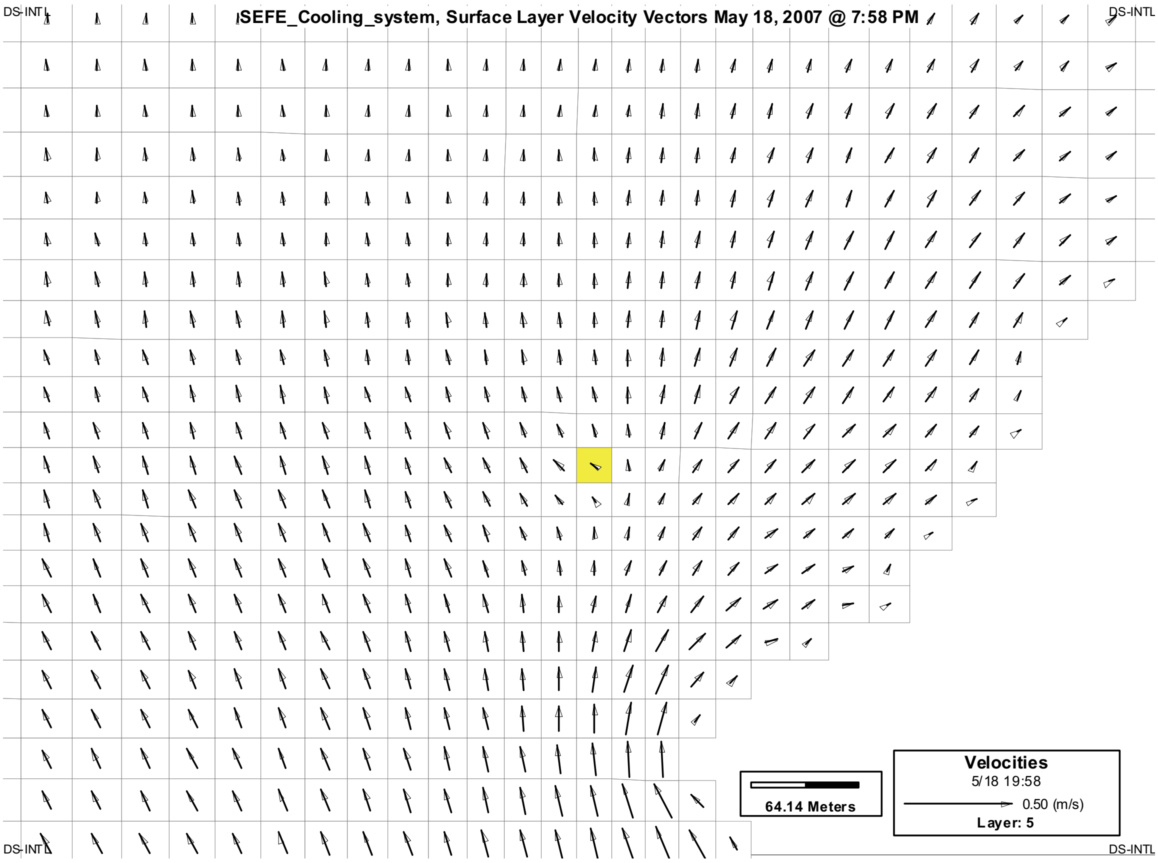

Figure 5-3 Surface Velocity Vector Distribution in the Vicinity of the Discharge outlet, May 18, 2007

5 Far-Field Modelling

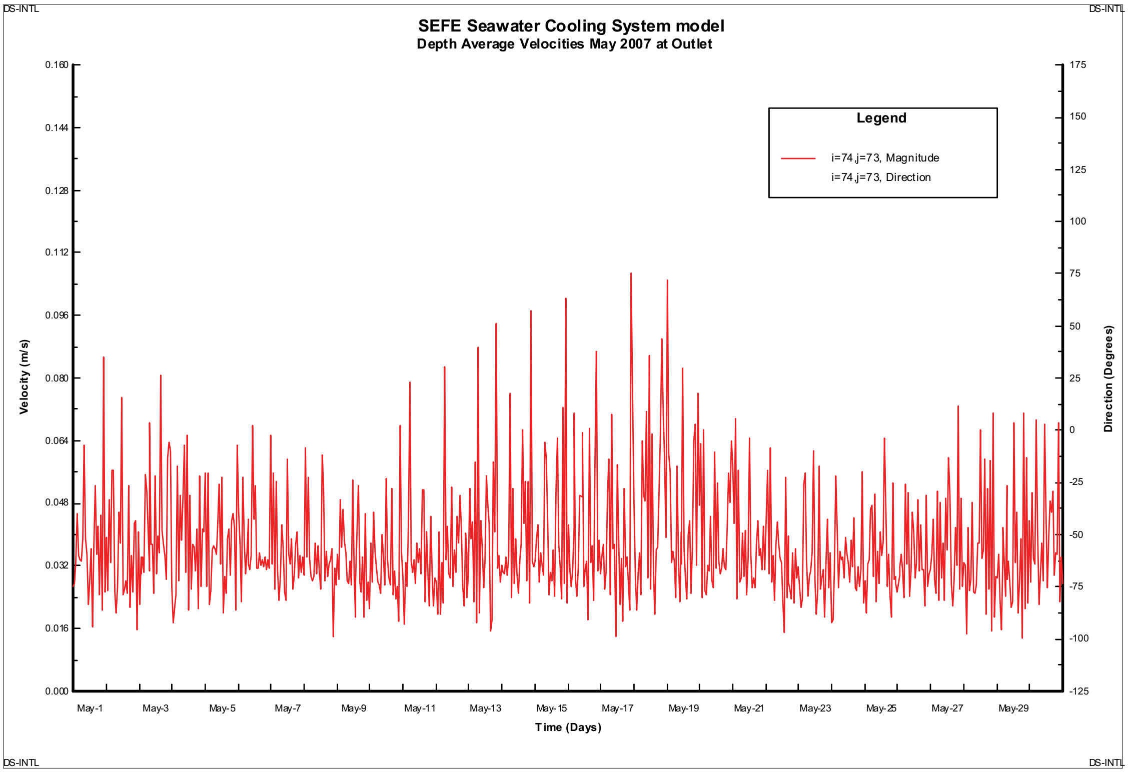

Figure 5-4 Magnitude of Depth Averaged Velocity at the Proposed Discharge Location, May 2007

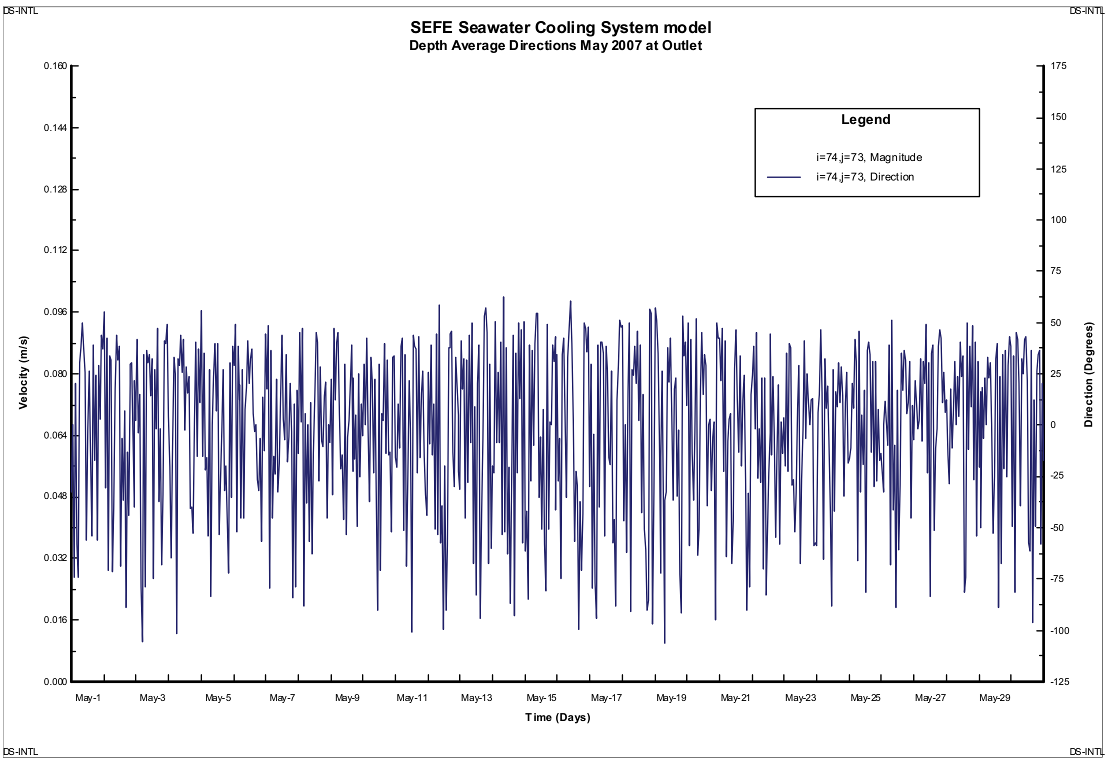

Figure 5-5 Direction of Depth Averaged Velocity at the Proposed Discharge Location, May 2007

5.4.2 Thermal Discharge Simulation Results

The constant heat load to the environment is an important characteristic of the discharge as the implications of the constant loading provide additional confidence in the interpretation of the results of the far-field modelling in the absence of detailed ambient temperature data.

The thermal discharge was represented in the model as an intake/discharge with a temperature increase of 10ºC added to the intake temperature. Since the discharge is expected to be a constant value above ambient (i.e. the intake value) the actual ambient temperature is not critical for the modelling analysis. Therefore, the ambient temperature was set to 17.5 ºC, which is an approximate average value for the bay.

Thermal exchanges between the water column and the atmosphere were not represented in the model. This represents a conservative estimate of the thermal plume background build-up because typically the heated discharge will rise to the surface and loose energy to the atmosphere. Thus the simulated influence of the thermal discharge will indicate temperatures that are higher than what will actually occur.

The intake was located sufficiently far from the discharge so that the influence of the discharge was not affecting the ambient water near the intake. A discharge of 0.416 m^3/s was applied at the proposed discharge locations in the bottom layer.

The results of the 1-year simulation are shown in **Figure 5-6** through **Figure 5-8**. A contour plot of the instantaneous temperature distribution in the bottom layer of the EFDC model is shown in **Figure 5-6**. The plume near the discharge location is starting to flow to the northeast consistent with the ebb flow velocity field. There is some evidence of a small temperature build-up along the southern coast of the bay, which is due to the residual circulation. However, the temperature increase in this area averages less than 0.25 ºC.

5 Far-Field Modelling

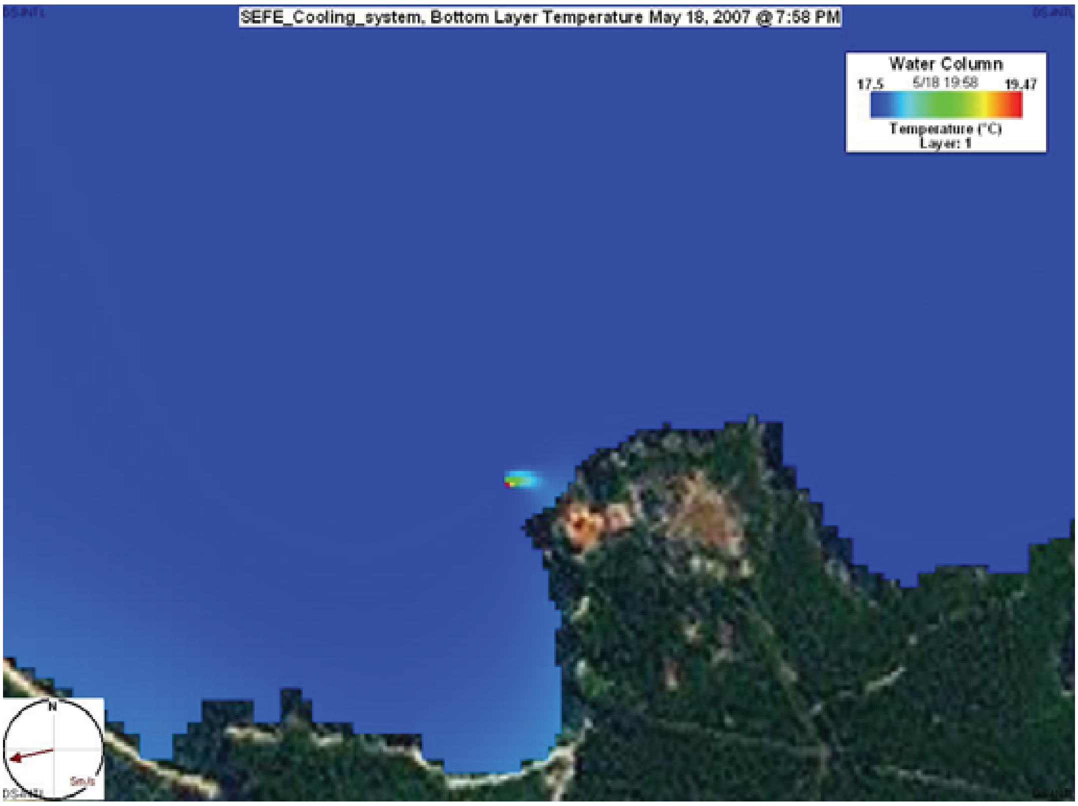

Figure 5-6 Instantaneous Bottom Layer Temperature Distribution, 18/05/07

A contour plot of the instantaneous temperature distribution in the surface layer of the EFDC model is shown in **Figure 5-7** for 18/05/07. The temperature build-up is more prominent in the surface layer, since the buoyant (heated) discharge rises to the surface layer and thermally spreads laterally. The effect of the residual tidal current is also evident, with a warming of the surface layer in the order of 0.5ºC mostly west of the discharge location. The surface layer thermal plume is still oriented towards the southwest despite the tide having started to ebb (depth average flow to the northeast). This is due to the wind, which is blowing to the southwest at just under 5 m/s and delaying the transition from flood to ebb tide in the surface layer.

5 Far-Field Modelling

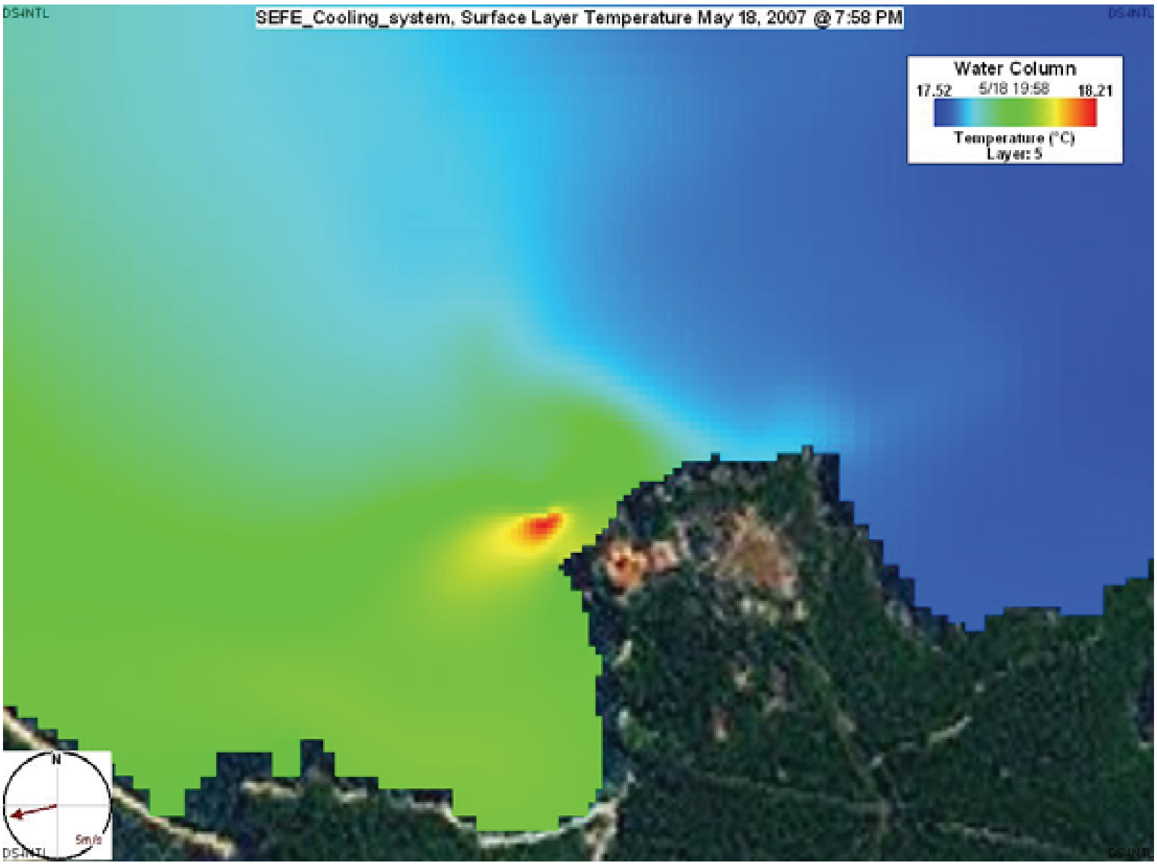

Figure 5-7 Instantaneous Surface Layer Temperature Distribution, 18/05/07

A time series of the depth averaged temperature at about 120 m southwest of the discharge location is shown in **Figure 5-8** for the one year period. The time series indicates that the effect of the thermal discharge is an increase in ambient temperature of about 0.25ºC (17.75ºC relative to the ambient temperature of 17.5ºC). The temperature oscillates with the tidal excursion, but with very small amplitude, in the order of 0.05ºC. This small value indicates a very low spatial gradient in the background build-up. These data, and specifically, the value of 0.25ºC, are representative of the background build-up of temperature in the vicinity of the discharge location. This value should be considered a conservative estimate since the heat loss to the atmosphere was not included in the analysis.

5 Far-Field Modelling

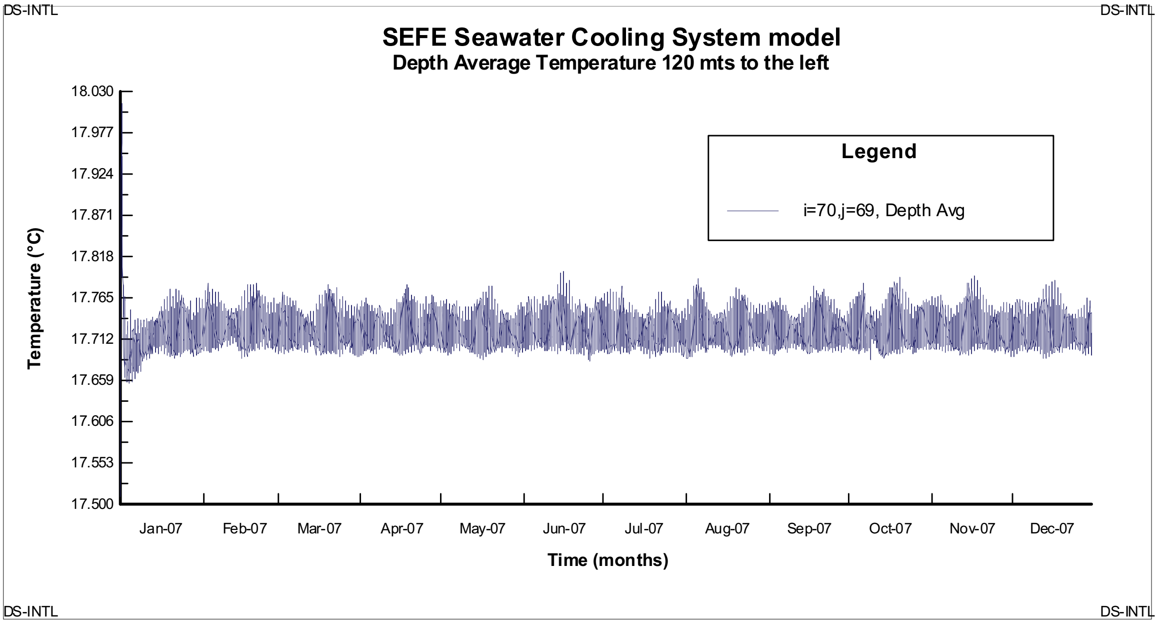

Figure 5-8 Depth Average Temperature 120 m to the Southwest of the Discharge

5.4.3 Summary of Findings and Outcomes of the Far Field Modelling

In summary, the results of the far-field modelling using EFDC suggest that:

- There is the potential for a background accumulation of temperature in the vicinity of the diffuser outlet of 0.25°C.
- The hydrodynamic simulations have provided a time series of depth average along shore current velocities in the vicinity of the diffuser outlet that suggests the currents range in velocity from 0.03 m/s to 0.23 m/s.

In relation to the far-field modelling the following should be noted:

- Data were not available with which to characterise seasonal water column characteristics of temperature and salinity and thus a uniform water column (i.e. well mixed) has been assumed.
- The monthly averaged temperature and salinity data presented in **Table 2-3** was not available at the time of the EFDC model set up and thus simulations were conducted using a fixed temperature and constant thermal loading throughout the year. This is not believed to have a significant impact on the results presented here for the far-field modelling however, a sensitivity analysis has not been conducted.

Near-Field Modelling

6.1 Software

The CORMIX modelling system is a software system for the analysis, prediction and design of pollutant discharges into diverse water bodies. The key focus of the assessment is on the geometry and dilution characteristics of the initial mixing zone, including compliance with regulatory constraints as well as predicting the behaviour of the discharge plume with distance from the diffuser. The CORMIX modelling system consists of four integrated hydrodynamic models:

- CORMIX 1 for single port discharges.
- CORMIX 2 for multi-port diffuser discharges.
- CORMIX 3 for buoyant surface discharges.
- DHYDRO for the analysis of dense and/or sediment discharges in coastal environments.

CORMIX predicts the geometry and dilution characteristics of effluent flow resulting from a single or multi-port discharge or arbitrary density, location, and geometry into an ambient receiving water body that may be stagnant or flowing and have ambient density stratification of different types. The plume is assumed to be at steady state, which means that successive elements follow the same trajectory. Predictions include dilution, plume diameter, plume elevation, and other plume properties. Once the effluent plume surfaces, the far-field solution calculates dilution due to horizontal turbulent mixing of the plume with ambient water.

6.2 Model Assumptions and Limitations

CORMIX has been widely used elsewhere in the world for near-field dispersion modelling studies and describes water dispersion on the scale of minutes to hours after discharge from the diffuser.

However, CORMIX is based upon a number of assumptions that need to be considered when interpreting the data from the model including (but not limited to):

- CORMIX is a simplified simulation of a complex process. It is most robust in simulation of the initial mixing of a plume. The model calculates far-field dispersion based on depth specified data at a single port, and as such cannot capture circulation or ambient conditions that change with distance from the diffuser.
- In general, it is recommended that the dilution and path predictions provided by CORMIX should only be treated with confidence within approximately 100 m from the diffuser. While dilutions at greater distances can be obtained using the model, these should be treated as indicative only.
- CORMIX assumes that the area available for dilution is unconstrained by changing bathymetry. This assumption may be a significant simplification of the true environment.
- CORMIX does not cope well with a “bottom hit” of the plume. In reality, a bottom hit will also constrain the entrainment into the plume, and should result in decreased rate of dilution.

6.3 Data Requirements

The CORMIX model configuration and implementation requires the following data:

- Diffuser characteristics (**Table 4-1**).
- Discharge characteristics (**Table 4-2**).
- Currents (**Table 2-2**).
- Wind speeds (**Table 2-1**).
- Ambient temperature and salinity information (**Table 2-3**).

6.4 Configuration of CORMIX

The configuration of the diffuser as designed is not directly incorporable into the near-field model as the vertical alignment of the diffuser outlets is not a standard configuration alignment within CORMIX.

The methodology for the development of the discharge geometry as assessed using CORMIX is outlined in Appendix A.

When developing the modelling scenarios, consideration was given to a wide range of inputs including:

- Range of current speeds.
- Impact of wind on dispersion.
- Density characteristics of the ambient environment.
- Density characteristics of the discharge.
- The potential frequency of discharge.
- Depth of the water column.

It was concluded that for the purposes of a preliminary assessment of the Case 1 and Case 2 Design options, the following would apply:

- Wind speed of 0 m/s
- Current speed of 0.105 m/s based on the 10th percentile (although current speeds of 0.027 m/s and 0.229 m/s have also been considered for some scenarios)
- Ambient and discharge salinity of 35.65 g/l
- Water column depth of 14 m at the location of the diffuser
- Manning number of 0.025 (a measure of seabed roughness).

6.5 Preliminary Assessment of Case 1 and Case 2 Design Options

6.5.1 Discharge Scenarios

Initial investigations into the dispersion characteristics of the proposed diffuser design configuration associated with Case 1 and Case 2 (**Figure 6-1**) indicated that under certain conditions, the plume would impact the sea bottom immediately after discharging into the marine environment.

In order to minimise impacts of the discharge plume alterations to the diffuser design were proposed including:

- Increasing the height of the diffuser outlets above the sea floor. The outlet heights were originally proposed for heights of 1 m and 3 m (**Figure 6-1**).
- Increasing the horizontal angle of the diffuser outlets. The diffuser outlets were originally proposed to extend outward, parallel to the seafloor.

In order to maximise the path length of the plume prior to reaching the water surface, the option to keep the diffuser outlets near the bottom but angle the outlets upward at an angle of 30º has been adopted for the purposes of this assessment (**Figure 6-2**). This angle was selected based on CORMIX results to ensure that the discharge plume does not impact the sea floor immediately after exiting the diffuser. Refinement of the diffuser design is anticipated at latter stages in the project during detailed design.

6 Near-Field Modelling

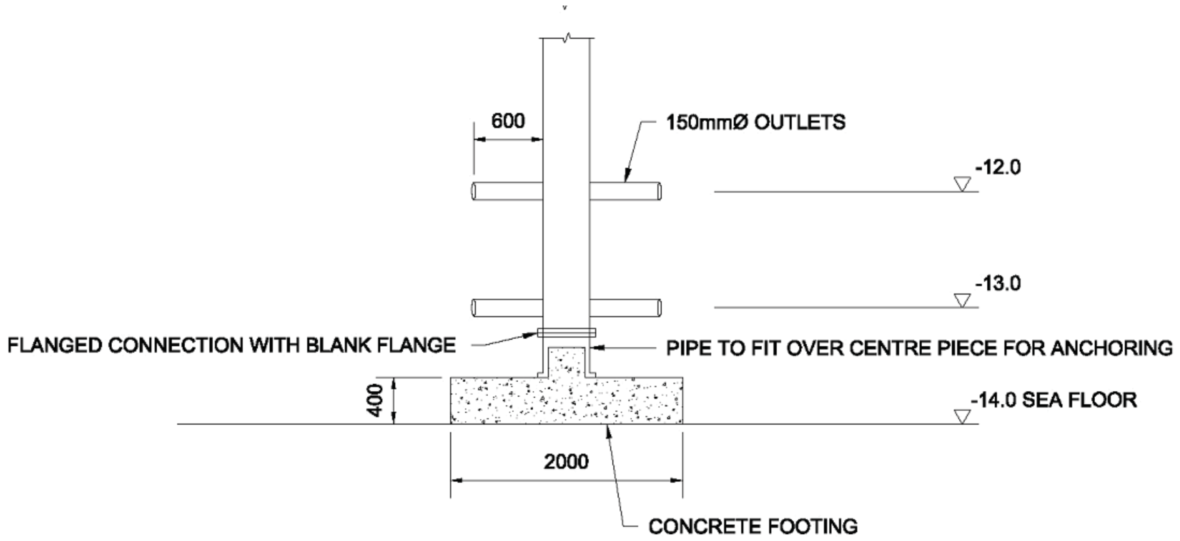

Figure 6-1 Diffuser outlets oriented parallel to the seafloor (URS, 2009)

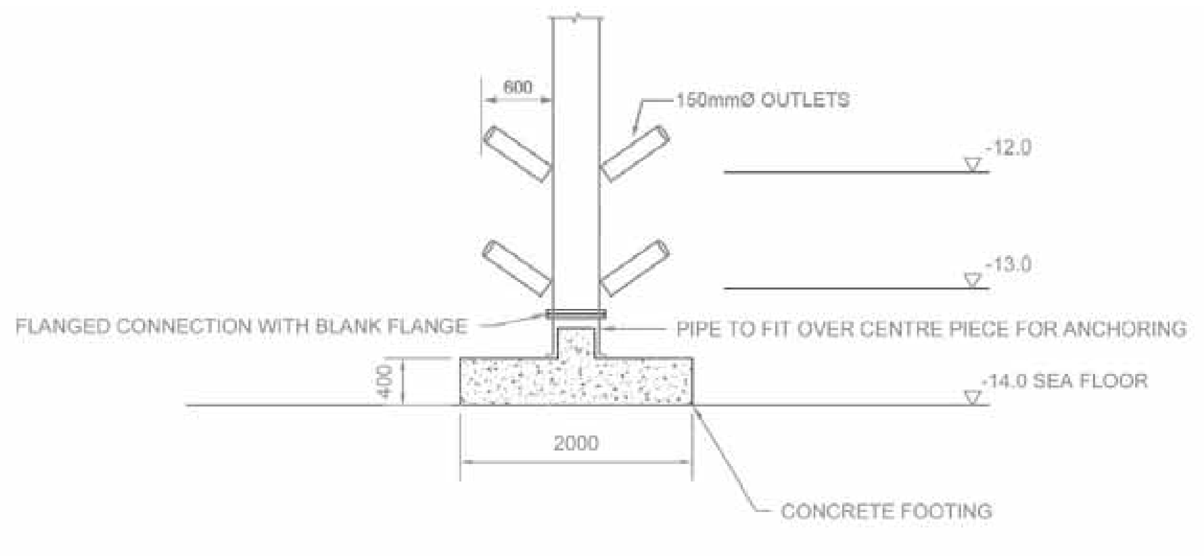

Figure 6-2 Diffuser outlets oriented upward at an angle of 30º with respect to horizontal (adapted from URS, 2009)

In order to assess the two cooling system design options Case 1 and Case 2, four discharge scenarios were modelled with parameter values summarised in **Table 6-1**.

Table 6-1 Discharge Characteristics

Scenario	Units	Case 1		Case 2	
		1A	1B	2A	2B
		Summer	Winter	Summer	Winter
Seawater temperature in	°C	23	13	23	13
Temperature rise	°C	10	21.1	8	19.1
Seawater temperature out	°C	33	34.1	31	32.1
Flow rate	litres/s	333	158	416	174
Outlet angle wrt horizontal	degrees	30	30	30	30
Ambient current(1)	m/s	0.105	0.105	0.105	0.105
Salinity (ambient & discharge)(2)	ppt	35.65	35.65	35.65	35.65

Note (1): Based on the 10th percentile current velocity, Table 2-2
(2): Based on the average value, Table 2-3

6.5.2 Results of the Preliminary Assessment

Summarised in **Table 6-2** are the results of the near-field assessment for the four scenarios presented in **Table 6-1**. Included in the table are the discharge temperature, the temperature differential, and the dilution at a downstream distance of 10 m from the diffuser as well as the temperature differential and dilution at 100 m. Results include an accumulation of 0.3°C based on the findings of the far-field modelling (**Section 5.4.2**).

Table 6-2 Results of the Near-Field Assessment at 10 m and 100 m from the Outlet

Parameter	Units	Case 1		Case 2	
		Summer	Winter	Summer	Winter
		1A	1B	2A	2B
Ambient temperature	ºC	23.0	13.0	23.0	13.0
Discharge temperature	ºC	33.0	34.1	31.0	32.1
Temperature @ 10 m	ºC	23.6	13.8	23.6	13.8
Temperature differential @ 10 m	ºC	0.6	0.8	0.6	0.8
Temperature differential @ 100 m	ºC	0.5	0.5	0.5	0.5
Dilution @ 10 m		18.1	29.1	16.0	29.6
Dilution @ 100 m		22.2	50.6	18.1	49.2
Distance to 2.4ºC temperature differential	m	0.43	2.34	0.23	1.71

Presented as **Figure 6-3** and **Figure 6-4** are the results for water temperature as a function of the downstream distance from the diffuser for Case 1 and Case 2 respectively. Included in the figures are the corresponding ambient temperatures for the summer (A) and winter (B) scenarios. The results suggest a rapid decay of temperature with distance downstream from the diffuser.

6 Near-Field Modelling

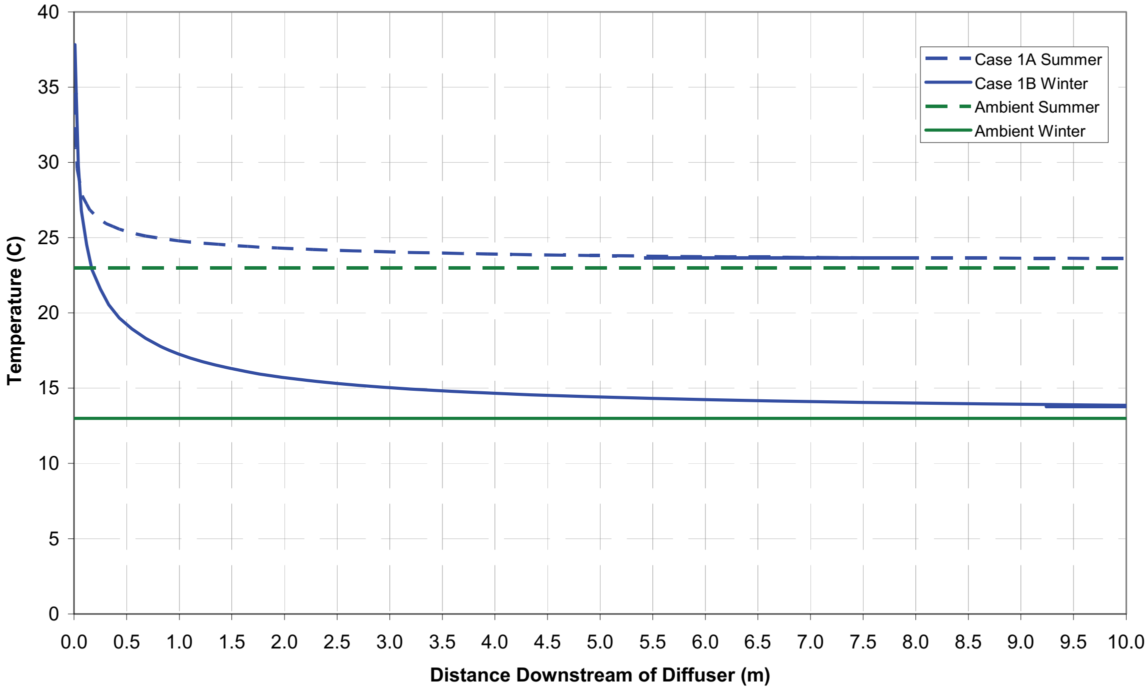

Figure 6-3 Case 1 Water Temperature as a Function of the Downstream Distance from the Diffuser

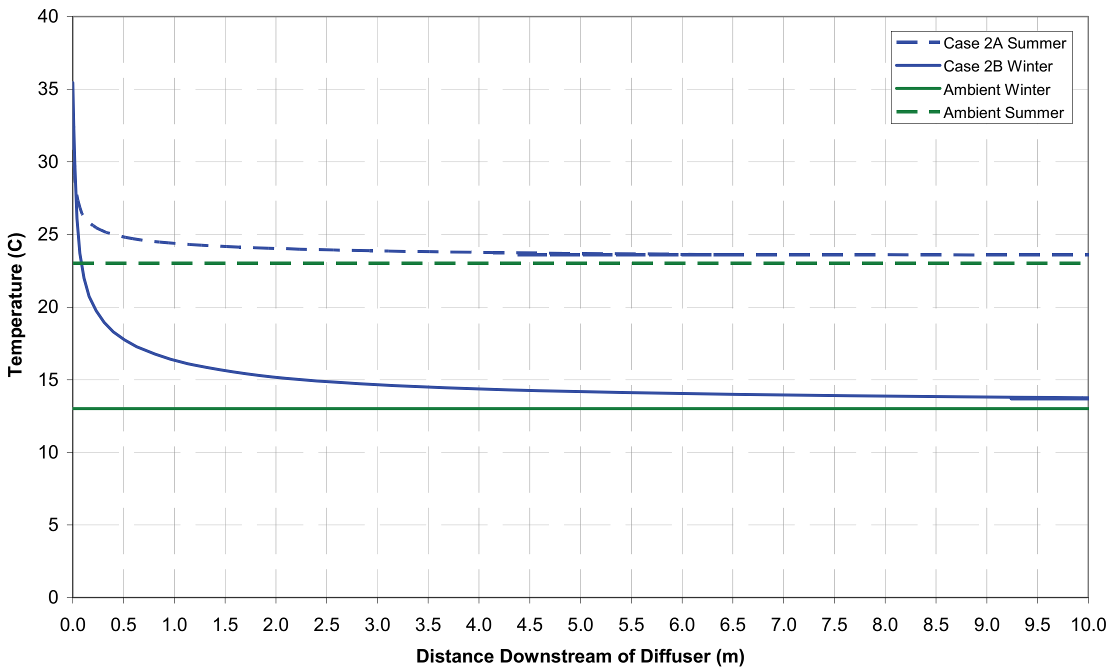

Figure 6-4 Case 2 Water Temperature as a Function of the Downstream Distance from the Diffuser

For ease of comparison with the trigger value for temperature of 2.4ºC (discharge water to ambient water temperature differential, **Section 3.2.2**), results for the summer and winter scenarios of Case 1 and Case 2 are presented in **Figure 6-5** as the temperature differential.

6 Near-Field Modelling

Results suggest that the centreline temperature differential between the discharge plume and the ambient environment will fall below the trigger value of 2.4ºC within 0.5 m (summer scenarios) and 2.5 m (winter scenarios) from the diffuser. Not surprisingly, winter scenarios (Case 1B and Case 2B) are associated with a larger zone of exceedence of the 2.4ºC trigger value.

Case 2 which is associated with smaller initial temperature differential and an increased flow rate compared with Case1 is found to be associated with a slightly smaller area of exceedance for both the summer and winter scenarios.

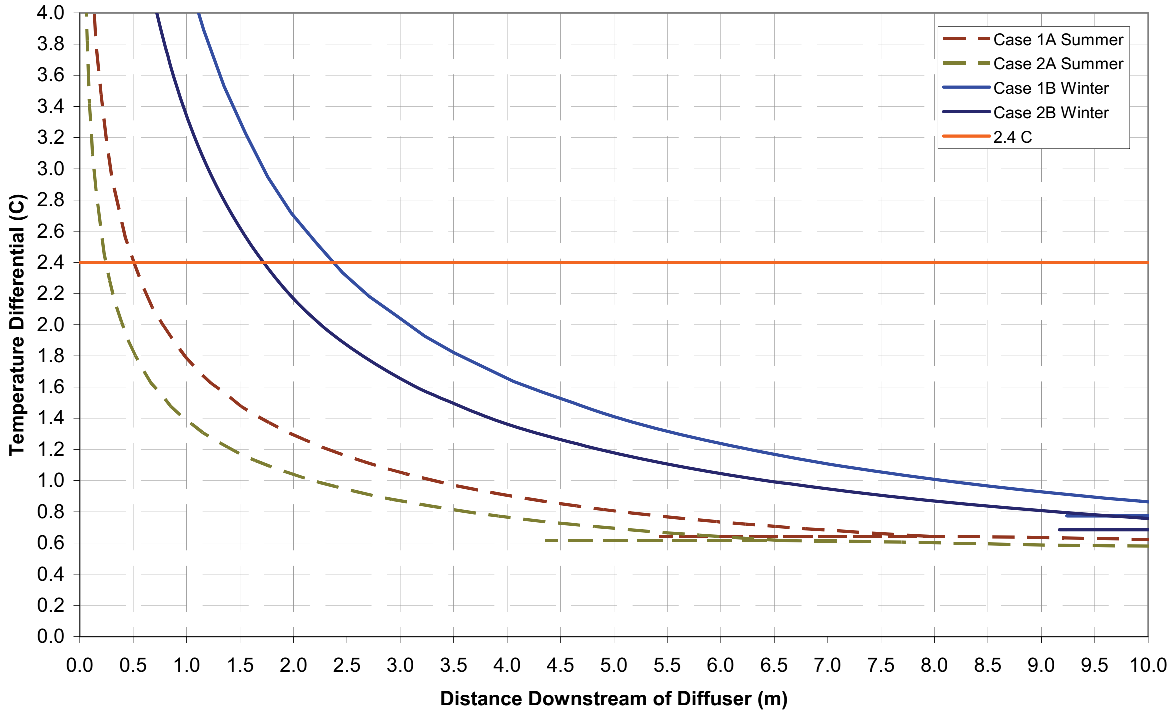

Figure 6-5 Temperature Differential for Case 1 and Case 2 as a Function of Distance Downstream of Diffuser

It should be noted that the discontinuities in **Figure 6-5** (for example Case 2A) are the result of the use of multiple solution techniques by CORMIX where the selection of the theoretical model is based on the stage of plume development and its location within the marine environment. The discontinuity indicated by Case 2A and Case 2B are associated with the discharge plume reaching the surface of the water column.

Presented in Figure 6-6 through **Figure 6-8** is an example of the plume behaviour predicted for summer (specifically Case 2A though these are indicative of all plumes associated with a current speed of 0.105 m/s i.e. the 10th percentile). The rapid rise of the discharge plume to the surface of the water column driven by buoyancy flux is highlighted in Figure 6-6. The deflection of the plume from the centreline is evident in both **Figure 6-7** and **Figure 6-8**.

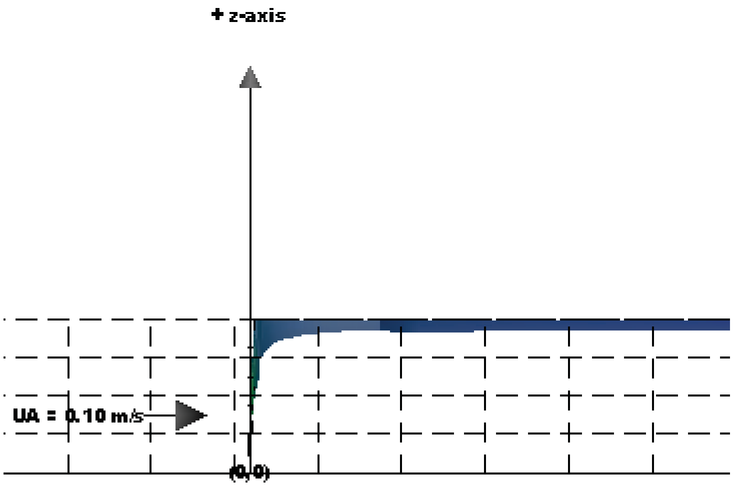

Figure 6-6 Side View of the Discharge Plume with Distance Downstream of the Diffuser

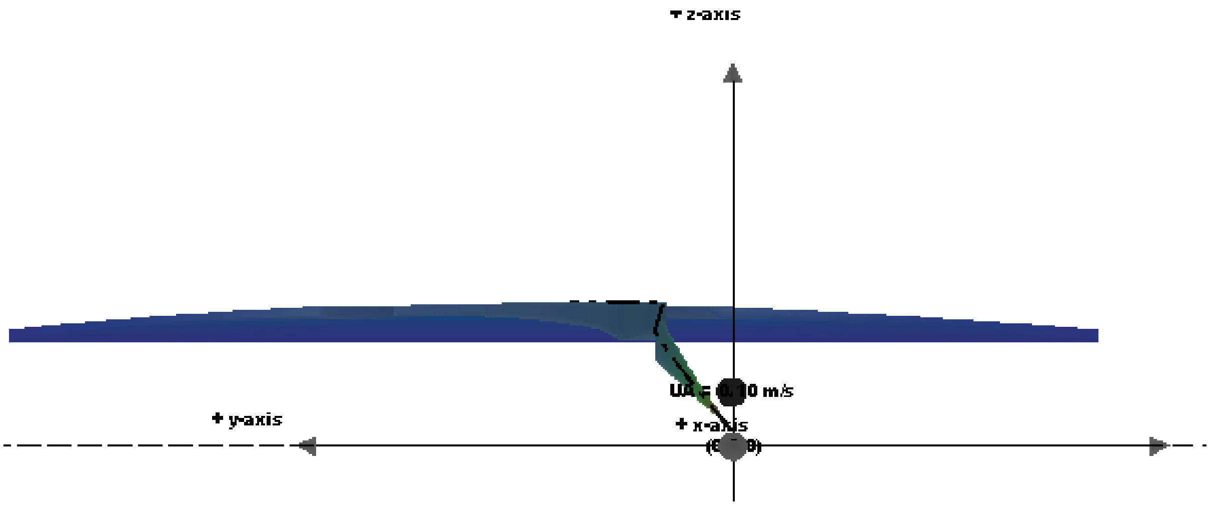

Figure 6-7 End View of the Discharge Plume Looking Downstream

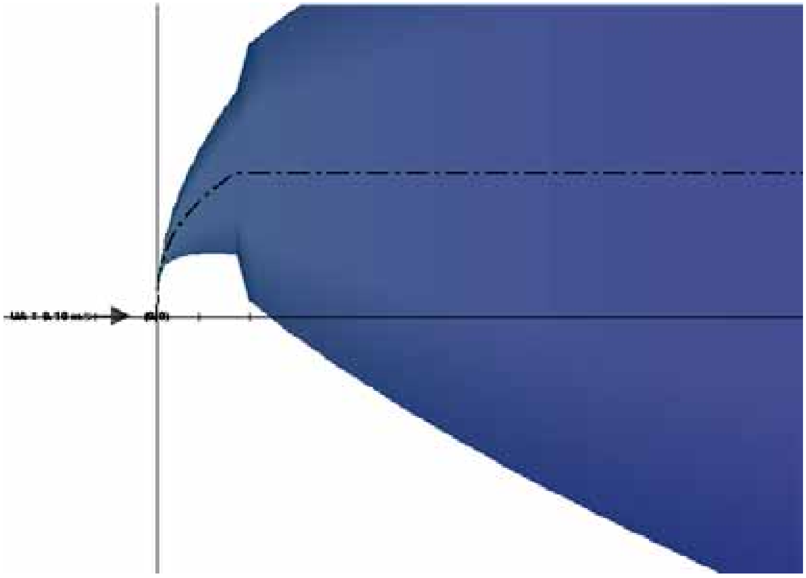

Figure 6-8 Top View of the Discharge Plume

6.5.3 Summary of Findings and Outcomes of the Preliminary Assessment

In summary, the results of the preliminary assessment of Case 1 and Case 2 design options suggest that:

- A horizontal diffuser outlet configuration at 1 m and 2 m from the bottom may lead to a discharge plume that impacts the seafloor immediately after discharging under certain conditions.
- A horizontal diffuser outlet configuration would require a minimum height above the seafloor of 3 m to 3.5 m in order to ensure that the discharge plume does not impact the seafloor under a wide range of ambient conditions.
- In order to optimise the path length of the discharge plume prior to reaching the surface of the water column, an angled diffuser outlet configuration is preferable to a horizontal configuration.
- The assessment will focus on a diffuser configuration with an outlet angle of 30 degrees with respect to the horizontal.
- Case 2 is associated with marginally better environmental outcomes compared with Case 1
- Based on communications with SEFE, it was concluded that the differences in the environmental outcomes between Case 1 and Case 2 did not warrant the large operational cost differential between these two design options. Case 1 will require lower flow rates than Case 2 and result in a significant reduction in pump running costs.
- Case 1 has been selected as the preferred option and will be the focus of the detailed assessment.

6.6 Detailed Assessment of Diffuser Design Option Case 1

6.6.1 Discharge Scenarios

Based on the continuous nature of the proposed discharge, scenarios relating to the cooling water discharge via the diffuser focused on the worst, typical and extreme current and wind velocities scenarios within both a uniform and stratified ambient environment.

6 Near-Field Modelling

Parameter values associated with each of the scenarios are summarised in **Table 6-3**.

In relation to the representativeness of the scenarios the following applies:

- Calm conditions (current & wind) – scenario 1.
- Typical conditions (current & wind) – scenario 8.
- Worst-case conditions (current & wind) – scenario 12.

Table 6-3 Modelled Scenarios for the Detailed Assessment

Scenario	Vertical Structure(0)	Current Speed (m/s)	Wind Speed (m/s)	Comments	
				Currents	Winds
1	U	0.027	0.0	Minimum	Minimum
2	U	0.027	2.7	Minimum	Median
3	U	0.027	14.7	Minimum	Maximum
4	U	0.105	0.0	10^{th} percentile	Minimum
5	U	0.105	2.7	10^{th} percentile	Median
6	U	0.105	14.7	10^{th} percentile	Maximum
7	U	0.130	0.0	Median	Minimum
8	U	0.130	2.7	Median	Median
9	U	0.130	14.7	Median	Maximum
10	U	0.229	0.0	Maximum	Minimum
11	U	0.229	2.7	Maximum	Median
12	U	0.229	14.7	Maximum	Maximum
13	S[1]	0.027	0.0	Minimum	Minimum

Note (0): U (Uniform ambient environment), S (stratified ambient environment)
(1): Stratified conditions are associated with periods for which both current velocities and wind speeds are minimal and a minimum of 3 °C temperature difference between the near surface and the bottom water.

6.6.2 Results of the Detailed Assessment

Presented in **Table 6-4** are the results of the detailed near-field assessment which includes a range of current velocities and wind speeds.

A single stratified scenario (#13) has been considered which assumes a constant salinity profile with depth and a temperature differential between near surface and bottom temperatures of 3ºC.

Results of the detailed assessment suggests that the trigger value for temperature of ΔT less than 2.4ºC will be achievable within a distance of less than 3.5 m from the diffuser outlet.

Table 6-4 Results for the Discharge Scenarios

Case	Distance to ΔT = 2.4°C	ΔT @ 10 m	Dilution @10 m	Dilution @ 100 m
Summer				
1	<0.5	0.45	24.25	28.25
2	<0.5	0.45	24.25	28.34
3	<0.5	0.45	24.25	34.52
4	<0.5	0.64	18.06	22.18
5	<1	0.62	18.67	22.20
6	<1	0.62	18.67	27.69
7	<1	0.60	19.52	24.06
8	<1	0.60	19.52	24.12
9	<1	0.60	19.52	28.15
10	<1	0.66	18.13	32.21
11	<1	0.66	18.13	32.21
12	<1	0.66	18.13	32.79
13	<0.5	0.49	22.69	27.17
Winter				
1	<1	1.31	17.7	26.5
2	<1	1.31	17.8	27.6
3	<1	0.92	30.9	70.4
4	<2.5	0.80	29.1	50.6
5	<2.5	0.86	28.7	50.6
6	<2.5	0.86	28.7	59.1
7	<3	0.92	27.0	55.0
8	<3	0.92	27.0	55.0
9	<3	0.92	27.0	60.5
10	<3.5	1.14	22.3	63.6
11	<3.5	1.14	22.3	63.6
12	<3.5	1.14	22.3	65.0
13	<1	1.37	16.9	25.9

Presented in **Figure 6-9** is the temperature differential as a function of downstream distance from the diffuser for Scenario 12 which represents worst-case conditions and is associated with a maximum current velocity of 0.229 m/s and maximum wind speed of 14.7 m/s.

The trigger value of 2.4°C has been included for ease of comparison. Results suggest that the trigger value is able to be satisfied outside a region approximately 3.2 m from the outlet of the diffuser.

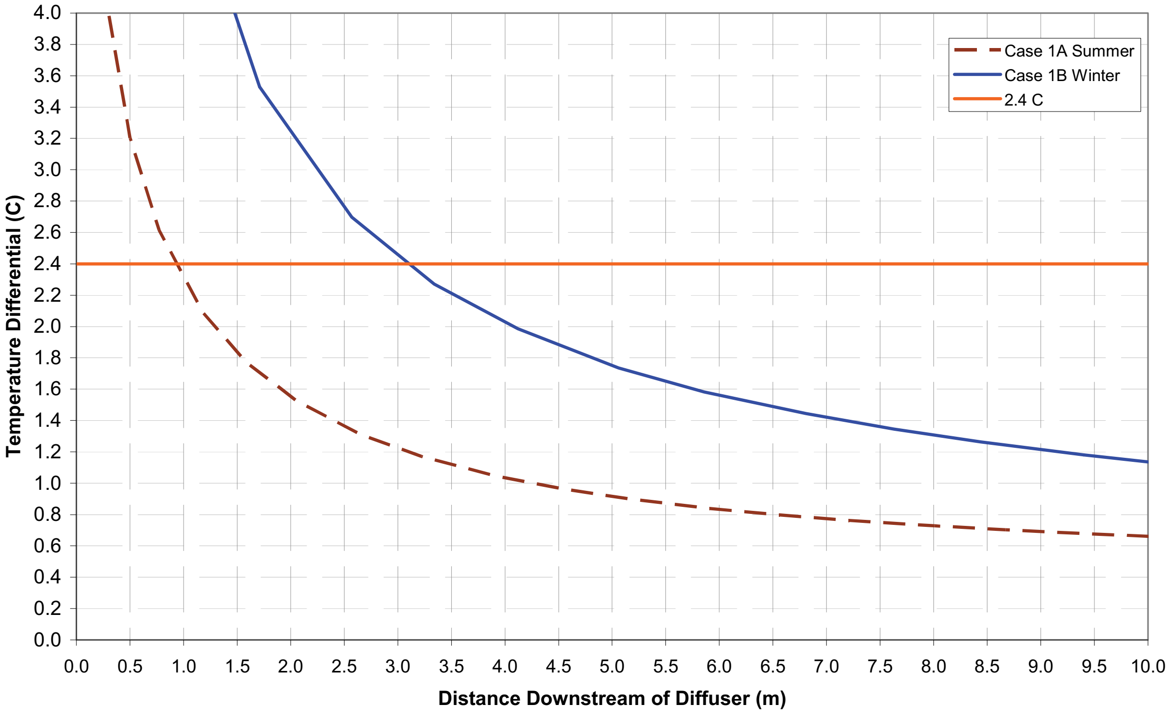

Figure 6-9 Scenario 12 Temperature Differential as a Function of Distance Downstream of Diffuser

Presented in **Figure 6-10** are views of the plume development for Scenario 12 including a side view, a plan view and a 3-dimensional view. Note that the plume is predicted to make contact with the bottom at a distance greater than 800 m from the outlet.

6 Near-Field Modelling

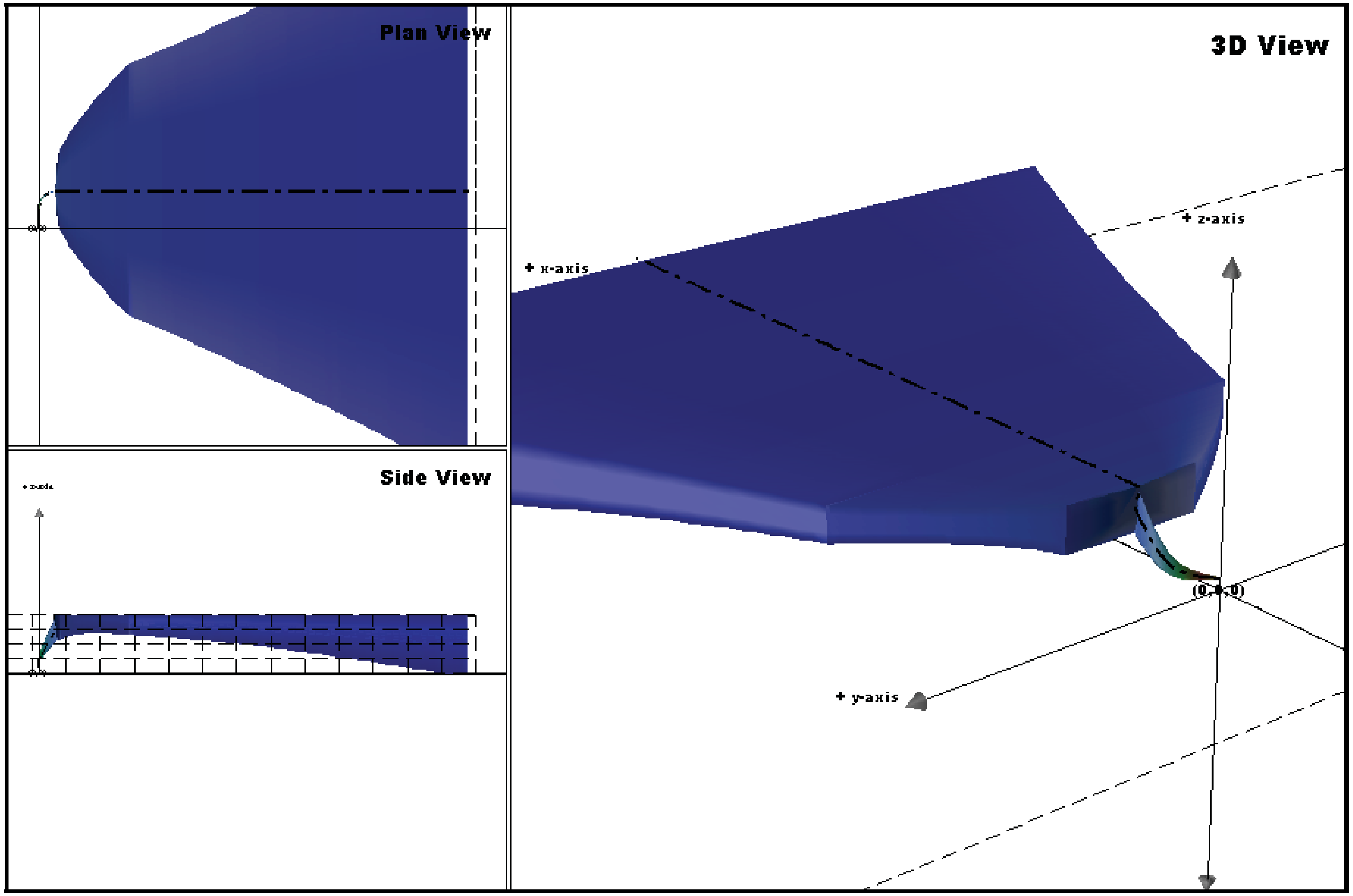

Figure 6-10 Scenario 12 Views of Plume Development (Note the plume is predicted to make contact with the bottom at a distance greater than 800 m from the outlet)

Comments and Recommendations

7.1 Comments

The results of the cooling water discharge assessment suggest:

- Water quality objectives associated with trigger values for temperature can be achieved within 3.5 m from the outlet of the diffuser.
- Modifications to the diffuser design could improve environmental outcomes.
- An accumulation of temperature in the vicinity of the diffuser outlet of 0.3ºC is considered to be a conservative estimate of the potential for the localised elevation of background temperatures.

It should be noted that:

- Limited data was available with which to characterise the temporal variations of temperature, salinity, currents within the water column.
- The far-field modelling assumed constant heat loading of the environment but did not incorporate variations in ambient water temperature due to the late availability of this information.
- Results of the far field modelling are considered to be conservative however and are believed to be representative of worst-case conditions.
- It has been assumed that the chemical nature of the chemicals associated with anti-fouling that may be required are adequately represented by the dilutions that have been presented and that full water-quality modelling is not required. This assumption is adequate for chemical species that are not reactive (or limited in their chemical activity) once discharged from the diffuser.

7.2 Recommendations

Based on the findings of the cooling discharge assessment, consideration should be given to the following:

- Additional near-field modelling of the diffuser design may be warranted during the detailed design stage.
- Although we have adopted a conservative approach for this assessment consideration should be given to validating the near-field model predictions of the dilution with distance from the diffuser after the diffuser has become operational. Such a model validation exercise could involve (for example) a controlled release dye study. Sufficient data should be collected at the time of the field study (such as water column temperature, salinity and current velocities) in order to ensure that the model inputs accurately represent the conditions during the sampling period.

References

ANZECC, 2000 Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000

DECC, 2000 Environmental Planning and Assessment Regulation 2000

DECC, 2005 Marine Water Quality Objectives (MWQO) for NSW ocean waters (2005)

DECC, 2005 Protection of Environment Operations Amendment Act 2005

DOM, 2009 Coastal Sea Surface Temperatures and Coastal Sea Surface Temperatures, (http://www.metoc.gov.au/products/data/aussst.php)

IMCRA, 2008 Interim Marine and Coastal Regionalisation for Australia: An ecosystem-based classification for marine and coastal environments

NSW Government (1979) Environmental Planning and Assessment Act 1979

URS, 2009 Design of Seawater Intake and Outlet System - Preliminary Work

9 Limitations

URS Australia Pty Ltd (URS) has prepared this report in accordance with the usual care and thoroughness of the consulting profession for the use of South East Fibre Exports Pty Ltd. and only those third parties who have been authorised in writing by URS to rely on the report. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in the Proposal dated April 2009.

The methodology adopted and sources of information used by URS are outlined in this report. URS has made no independent verification of this information beyond the agreed scope of works and URS assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to URS was false.

This report was prepared between 01/09/09 and 04/12/09 and is based on the information available at the time of preparation. URS disclaims responsibility for any changes that may have occurred after this time.

This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

Appendix A Incorporation of the Diffuser Design into CORMIX

Appendix A Incorporation of the Diffuser Design into CORMIX

As noted in Section 6.4 the proposed vertical diffuser design with two outlets on either side (**Figure A-1**) is not a typical CORMIX diffuser design configuration. The non-typical design issues include:

- The outlets aligned one above the other in the vertical plane (CORMIX is limited to single-port vertical diffuser configurations or multi-port, horizontal diffuser configurations).
- Two opposing outlets (CORMIX accepts either a single point discharge or greater than three discharge points).

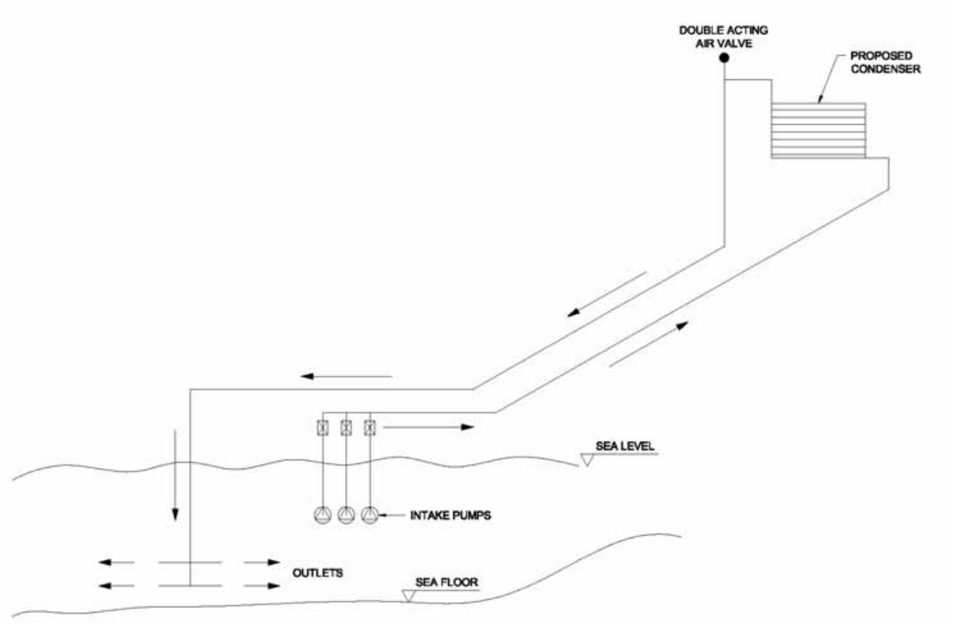

Figure A-1 Diffuser Configuration

Therefore, in order to assess the near-field mixing zone, the following methodology was implemented:

- Each pair of outlets (shoreward pointing and offshore pointing) was represented as a single discharge point or 'effective outlet'.
- The combined flow of each pair of outlets was assumed to emanate from each of the two effective outlets.
- The diameter of the effective outlet was 212 mm compared with a single outlet diameter of 150 mm. This ensures that the exit velocity of the combined outlet is equivalent to each of the single outlets.
- Each effective outlet was assessed individually. The potential impact of each of the two discharge plumes on the other was considered and accounted for assuming worst-case overlapping of plumes as discussed in the following.

Presented in **Figure A-2** is the centreline and boundary of the discharge plume from the effective outlet that is directed away from the shoreline that was presented for Scenario 12 (worst-case conditions) in Section 6.6.2 (compare with **Figure 6-10**).

Appendix A

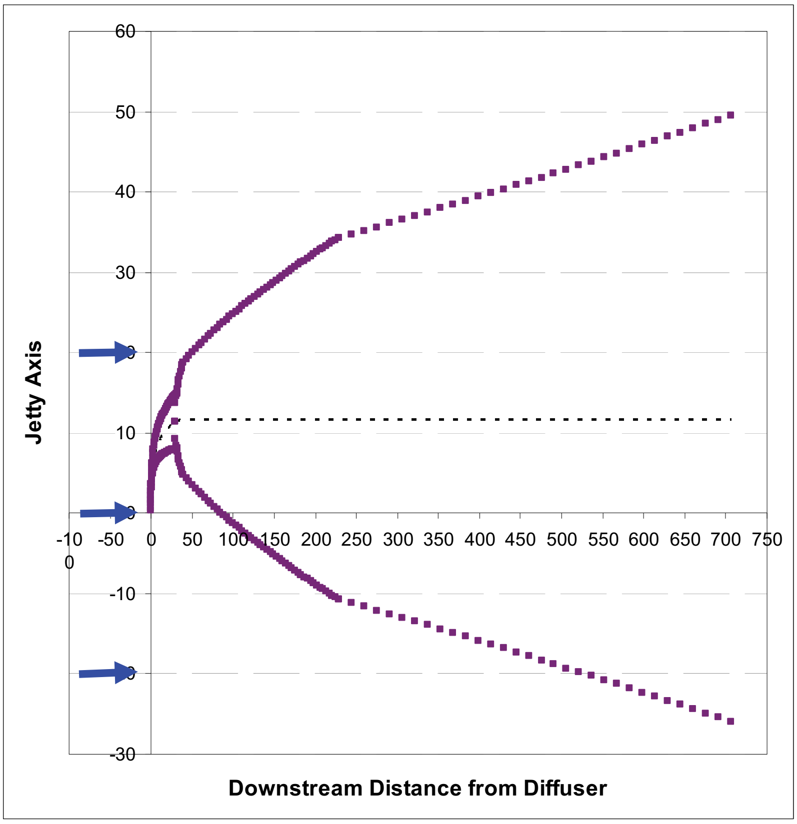

Figure A-2 Scenario 12: Boundaries and Centreline of the Discharge Plume from the Effective Outlet Directed Offshore

Consideration of the effective outlet directed towards the coastline leads to a mirror image, multi-plume profile as depicted in **Figure A-3**.

For conditions depicted in **Figure A-3** the plumes are predicted to intersect at a downstream distance of approximately 85 m. The second plume is not predicted to contribute to the centreline concentration of the other until a distance of approximately 260 metres downstream of the diffuser.

In order to account for the potential impact of plume merging on centreline concentrations, a conservative approach has been adopted. For each of the Scenarios modelled, the two plumes are overlayed with a separation distance of one meter. This would correspond to impacts associated with a current directed along the axis of the diffuser (which is a non-typical occurrence as the flow will be primarily directed parallel to the shoreline)

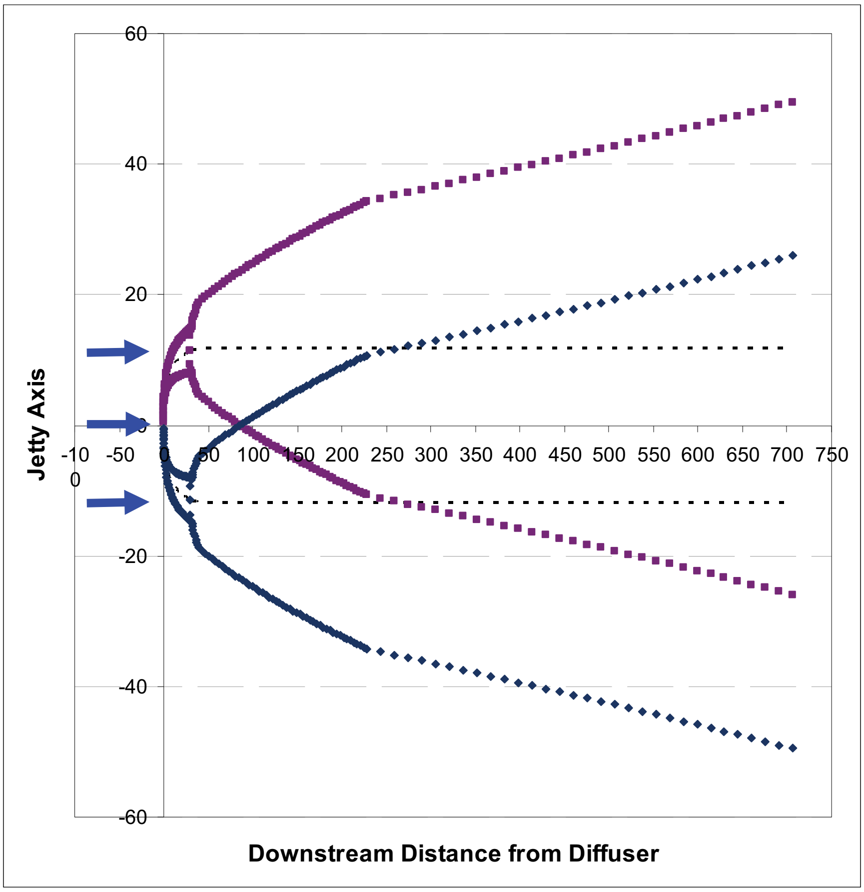

Figure A-3 Scenario 12: Boundaries and Centre Lines of the Discharge Plumes from Both Effective Outlets

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