Environmental Impact Assessment: Proposed Reverse Osmosis Plant, Iron–ore Handling Facility, Port of Saldanha

Addendum to the Specialist Marine Impact Assessment: Sensitivity Analysis of Model Results to Elevations in Seawater Temperature after Intake and prior to Discharge into the Bay

Prepared for:

PD Naidoo and Associates Pty (Ltd) & SRK Consulting Engineers and Scientists
Joint Venture (PDNA/SRK JV)

Jointly prepared by:

CSIR, Natural Resources and the Environment,
PISCES Environmental Services (Pty) Ltd and
Nina Steffani, Marine Environmental Consultant

May 2008

This page intentionally left blank

CSIR/NRE/ECO/ER/2008/0050/C

Prepared for:

PD Naidoo and Associates Pty (Ltd) and SRK Consulting Engineers and Scientists Joint Venture (PDNA/SRK JV)

On behalf of:

Transnet Capital Projects

This report was compiled by:

Roy van Ballegooyen
CSIR, Natural Resources and the Environment
PO Box 320, Stellenbosch 7599, South Africa
Tel: + 27 21 888 2572
Fax: + 27 21 888 2693
Email: rvballeg@csir.co.za

Dr Andrea Pulfrich
PISCES Environmental Services (Pty) Ltd
PO Box 31228, Tokai 7966, South Africa
Tel: + 27 21 782 9553
Fax: + 27 21 782 9552
Email: apulfrich@pisces.co.za

Nina Steffani
Marine Environmental Consultant
21 Skippers End, Zeekoevlei 7941, South Africa
Tel: + 27 21 705 9915
Fax: + 27 21 705 9915
Email: ninasteffani@telkomsa.net

Published by:

CSIR
P O Box 395
0001 PRETORIA
Republic of South Africa

Issued and printed by, also obtainable from:

CSIR
P O Box 320
STELLENBOSCH 7599
South Africa

Tel: + 27 21 888-2400
Fax: +27 21 888-2693
Email: rvballeg@csir.co.za

The report to be cited as:

Van Ballegooyen, N. Steffani and A. Pulfrich 2008. Environmental Impact Assessment: Proposed Reverse Osmosis Plant, Iron-ore Handling Facility, Port of Saldanha - Addendum to the Specialist Marine Impact Assessment: Sensitivity Analysis of Model Results to Elevations in Seawater Temperature between the Intake and Discharge Locations. Joint CSIR/Pisces Report, CSIR/NRE/ECO/ER/2008/0050/C, 44pp.

This page intentionally left blank

SCOPE OF WORK

The Iron-Ore Handling Facility at the Port of Saldanha (including the proposed upgrades to the facility), will require increased water supplies for dust suppression measures. It is proposed that a Reverse Osmosis (RO) seawater desalination plant be constructed to meet this water demand. In terms of existing legislation, this proposed activity (*i.e.* the construction and operation of an RO Plant) requires that a Basic Assessment of potential environmental impacts be undertaken.

PD Naidoo & Associates (Pty) Ltd and SRK Consulting Scientists and Engineers Joint Venture (PDNA/SRK Joint Venture) have been appointed by Transnet to undertake a Basic Assessment for a proposed RO plant at the Port of Saldanha. The PDNA/SRK JV, in turn, have contracted the CSIR to undertake the Specialist Marine Impact Assessment for the Basic Assessment. CSIR has sub-contracted PISCES Environmental Services (Pty) Ltd and Nina Steffani (Independent Consultant) to provide the ecological assessment component of this specialist study, while the Coastal Systems Research Group of the CSIR Natural Resources and the Environment Unit, has undertaken the water quality modelling to characterise the predicted changes in water quality associated with the proposed discharges from the RO Plant.

Under this agreement the CSIR and its sub-consultants are to:

- Advise on the design of the RO Plant early in the process;
- Undertake an assessment of potential environmental impacts in the marine environment associated with the construction and operation of an RO Plant;
- Identify the environmentally preferred site and intake and discharge positions from the alternatives identified through the Basic Assessment process.

The purpose of this addendum to the Specialist Marine Impact Assessment study informing the Basic Assessment of potential environmental impacts associated with the proposed Reverse Osmosis Plant, Iron-ore Handling Facility, Port of Saldanha (van Ballegooyen *et al.,* 2007), is to undertake a sensitivity analysis of model results to elevations in seawater temperature that occur between the point of intake and the point of discharge. The detailed terms of reference for this study are contained in Section 1 of this report.

Roy van Ballegooyen
Coastal Systems Research Group — Stellenbosch, South Africa
Natural Resources and the Environment CSIR — May 2008

This page intentionally left blank

EXECUTIVE SUMMARY

Introduction

The Iron-ore Handling Facility at the Port of Saldanha (including the proposed upgrades to the facility), will require increased water supplies for dust suppression measures. It is anticipated that ultimately a total of 3600 kℓ of water per day will be required for this purpose. The municipality currently supplies water to the Iron-ore Handling Facility, but Transnet propose to supplement this supply with additional sources of freshwater. Of all potential sources of such water, seemingly the most feasible is that of a Reverse Osmosis (RO) plant, for the desalination of seawater.

A Specialist Marine Impact Assessment study informing the Basic Assessment of potential environmental impacts associated with the proposed Reverse Osmosis Plant, Iron–ore Handling Facility, Port of Saldanha (van Ballegooyen *et al.,* 2007) has been undertaken using the engineering design specification available at that time. Subsequent to the study being completed additional design information on the possible temperature elevations in the brine discharge has become available that potentially could change the results of the modelling studies undertaken to predict the transport and fate of the brine discharge plume and its constituents in the marine environment.

While the specification of the elevation in salinity in the brine discharge and the concentrations of potential co-discharges remained unchanged, clarifications in the engineering design specifications in terms of the elevation in temperature[1] of the seawater that is likely to occur between the point of intake and the point of discharge, indicate that the temperature characteristics of the brine discharge assumed in the Specialist Marine Impact Assessment study (van Ballegooyen *et al.,* 2007) are not necessarily conservative.

Purpose of the Study

The purpose of this addendum to the Specialist Marine Impact Assessment study informing the Basic Assessment of potential environmental impacts associated with the proposed Reverse Osmosis Plant, Iron-ore Handling Facility, Port of Saldanha (van Ballegooyen *et al.,* 2007), is to undertake a sensitivity analysis of model results to elevations in seawater temperature between the intake and

---

[1] The elevation in seawater temperature referred to here is that occurring between the point of intake and the point of discharge due to:

- any warming of the intake seawater whilst being pumped via pipeline to the RO Plant;
- any warming of the intake seawater that may occur in any storage facility prior to being processed through the RO Plant;
- any warming of the intake seawater and/or brine that may occur during the RO process;
- any warming of the discharge brine ithat may occur in any storage facility prior to discharge; and
- any warming of the discharge brine whilst being pumped via pipeline to the discharge location.

The temperature elevation referred to here is not related to the expected temperature differences between the ambient water temperature at the point of intake and that at the point of discharge.

discharge locations. The rationale of the sensitivity study is to determine whether or not the original modelling and associated assessments remain valid given potential changes in the temperature of the brine discharge.

The reason for the concern is that temperature is a fundamental property of seawater that determines its density. The influence of changes in temperature on the density of the brine effluent upon discharge into the marine environment, if significant, could change the near-field and far-field behaviour of the brine discharge plume and consequently the dilution characteristics of the brine and any co-discharges. The purpose of this sensitivity study is to assess the potential changes in behaviour and mixing of the brine discharge plume upon entering the marine environment for a range of temperature elevations in the brine discharge.

Approach to the Study

Given the uncertainties in the magnitude of these potential elevations in temperature, it is deemed prudent to assess the sensitivity of the original model results and impact assessments undertaken for a range in temperature elevations in the discharge brine that encompass the minimum to maximum temperature elevations expected. The original marine impact assessment study was undertaken for a zero temperature elevation between the intake and discharge locations.

Given the uncertainty in the exact temperature elevation likely to occur in the seawater intake waters and brine discharge between the intake and discharge locations, it has been decided that the sensitivity analysis should assess temperature elevations ranging between 1ºC and 5ºC. It is anticipated that the temperature elevation in the seawater intake waters and brine discharge between the intake and discharge locations will lie in the lower end of this range and not exceed the upper limit of 5ºC.

To adequately characterise the sensitivity of the model results to these temperature changes it is necessary only to consider i) the least optimal or perceived “worst-case” discharge location (Site 2) and, ii) the preferred discharge location (Site 3 – Caisson 3) that is also the most optimal discharge location in terms of the minimisation of potential marine impacts. Furthermore, in keeping with the philosophy of a conservative approach, simulations to test the sensitivity of the model to such rises in temperature have been undertaken only for the “season” indicating the worst impacts. Typically this is the “autumn” season, however, for Site 3 the “summer” season on occasion seems to indicate larger plume footprints than the “autumn” (i.e. or “worst-case”) season. Consequently, in addition to “autumn” simulations, “summer” simulations have been undertaken for Site 3. For completeness of the sensitivity analysis, the “winter” scenario has also been run for Site 3 as it is the preferred site.

The range of simulations undertaken is tabulated below.

Location	Temperature rise	Autumn Scenario	Summer	Winter
Site 2 (discharge into Small Bay)	1ºC	Temperature, salinity and biocide analyses	n/a	n/a
	3ºC	Temperature, salinity and biocide analyses	n/a	n/a
	5ºC	Temperature, salinity and biocide analyses	n/a	n/a
Site 3 (discharge at Caisson 3)	1ºC	Temperature, salinity and biocide analyses	Temperature, salinity and biocide analyses	Temperature, salinity and biocide analyses
	3ºC	Temperature, salinity and biocide analyses	Temperature, salinity and biocide analyses	Temperature, salinity and biocide analyses
	5ºC	Temperature, salinity and biocide analyses	Temperature, salinity and biocide analyses	Temperature, salinity and biocide analyses

Results

The brine discharge plume becomes progressively less dense as the temperature of the discharged brine increases. The less dense the plume, the less is the tendency for the plume to sink to the seabed and the greater is the expected initial mixing of the plume in the near-field. The greater the initial mixing in the near-field, the greater will be the dispersion of the plume in the far-field. The consequences of such changes in behaviour are an increased dispersion of the salinity and co-discharges as the temperature of the brine increases. Thus, as the temperature of the brine discharge increases, it is expected that the potential impacts of salinity and co-discharges will decrease. The extent to which the temperature elevation in the brine precipitates increases the dispersion and mixing of the plume will depend on how significant are the changes in density due to temperature in comparison the effects of the high salinity in the brine (In terms of changes in seawater density there is a rough equivalence between a 5ºC temperature elevation and a 2 psu salinity decrease. This suggests that the effects of a 5ºC increase on plume dispersion and mixing should remain limited).

In contrast to the potential impacts of salinity and co-discharges that are expected to decrease as the temperature of the brine discharge increases, the situation is less clear in terms of temperature impacts. The reason for this is that there will be an increased thermal load in the brine discharge that needs to be effectively dispersed. Thus, in terms of potential thermal impacts, temperature elevations in the brine lead to competing effects. As the temperature of the brine discharge increases there is an expectation of increased dispersion and mixing of the brine discharge (albeit small), however, the increases in temperature leads to potentially increased thermal impacts. Whether the thermal impacts increase or not will be determined by the extent to which the increased thermal load is dispersed by the expected changes in plume behaviour leading to more effective dispersion and mixing of the brine discharge plume. This balance will change depending on the dispersion characteristics of the particular site. The more dispersive a discharge location the less is the likelihood of increased thermal impacts due to temperature elevation in the brine discharge.

The modelling undertaken here assesses the extent that elevations in temperature between the point of intake and the point of discharge affect the near-field plume behaviour and dispersion of the discharge plume consituents.

The model results (maximum plume footprints) indicate that the predicted changes in the thermal impacts and impacts of elevated salinity, biocides (and other co-discharges) are negligible outside an initial "mixing zone". Temperature elevations of up to 5ºC result in negligible changes in plume "footprints" when compared to the initial results of the Specialist Marine Impact Assessment study that were based on a zero temperature increase.

There will be changes in the thermal impacts and impacts of elevated salinity, biocides (and other co-discharges) within a mixing zone of approximately 50 m extent surrounding the discharge locations, however, due to (near field) limitations in the model resolution the changes within these mixing zones are less well resolved.

The model results indicate that there is likely to be a minimum effective 10-times dilution of effluent within these mixing zones. While detailed near-field modelling has not been undertaken (or deemed necessary for the purposes of this assessment), such near-field dilutions seem reasonable and should be achievable by appropriate engineering design of discharge diffuser systems. This means that any changes within these mixing zones is expected to be limited, *i.e*. a 1ºC temperature elevation of the brine discharge is likely to result in an approximate 0.1ºC elevation in temperatures integrated over the area of the mixing zone.

Conclusion

Temperature elevations of up to 5ºC in the seawater and discharge brine between the intake and discharge locations will not significantly change the predicted thermal impacts and impacts of elevated salinity, biocides (and other co-discharges) beyond an initial "mixing zone".

There will be changes within this initial "mixing zone" (approximately 50 m in extent) surrounding the discharge locations. However, appropriate engineering design of discharge diffuser systems should ensure that even these changes are of limited significance.

As the plume behaviours and impact "footprints" of the plume are not significantly different to those indicated in the main report, the ecosystems impacts will also not differ significantly from those reported in the main marine impact assessment report (van Ballegooyen *et al*., 2007). Consequently, no further updating of the impact table presented in the main marine impact assessment report is deemed necessary and the conclusions of the main report remain valid.

TABLE OF CONTENTS

This page intentionally left blank

LIST OF FIGURES

LIST OF TABLES

This page intentionally left blank

ABBREVIATIONS, UNITS AND GLOSSARY

Abbreviations

CSIR	Council for Scientific and Industrial Research
TNPA	Transnet National Ports Authority
PDNA	PD Naidoo & Associates (Pty) Ltd
RO	Reverse Osmosis
RSA	Republic of South Africa
RSA DWAF	Republic of South Africa, Department of Water Affairs and Forestry
SWRO	Seawater Reverse Osmosis
TRC	Total Residual Chlorine

Units used in the report

h	hours
kg	kilogram
km	kilometres
$\mu g.\ell^{-1}$	micrograms per litre
m	metres
$m.s^{-1}$	metres per second
$mg.\ell^{-1}$	milligrams per litre
ppt	parts per thousand
psu	practical salinity units which in the normal oceanic salinity ranges are the same as parts per thousand (ppt)
%	percentage
~	approximately
<	less than
≤	less than or equal to
>	greater than
≥	greater than or equal to
℃	degrees centigrade

Glossary

Anoxia	The absence or near absence of oxygen, i.e. < 0.1 ml O2/ℓ.
Benthic	Referring to organisms living in or on the sediments of aquatic habitats (lakes, rivers, ponds, *etc*.).
Benthos	The sum total of organisms living in, or on, the sediments of aquatic habitats.
Benthic organisms	Organisms living in or on sediments of aquatic habitats
Biocide	A substance, such as a chlorine, that is capable of destroying living organisms if applied in sufficient doses.
Biota	The sum total of the living organisms of any designated area.
Contaminant	Biological (*e.g*. bacterial and viral pathogens) and chemical introductions capable of producing an adverse response (effect) in a biological system, seriously injuring structure or function or producing death.
Dilution	The reduction in concentration of a substance due to mixing with water
Dissolved oxygen (DO)	Oxygen dissolved in a liquid, the solubility depending upon temperature, partial pressure and salinity, expressed in milligrams/litre or millilitres/litre
Ecosystem	A community of plants, animals and organisms interacting with each other and with the non-living (physical and chemical) components of their environment
Effluent	A complex waste material (e.g. liquid industrial discharge or sewage) that may be discharged into the environment.
Environmental impact	A positive or negative environmental change (biophysical, social and/or economic) caused by human action
Far-field	The region beyond the near-field where secondary dilution effects such as dispersion by environmental flows, etc predominate rather than initial dilution effects due to buoyancy forcing and entrainment.
Guideline trigger values	These are the concentrations (or loads) of the key performance indicators measured for the ecosystem, below which there exists a low risk that adverse biological (ecological) effects will occur. They indicate a risk of impact if exceeded and should 'trigger' some action, either further ecosystem specific

	investigations or implementation of management/remedial actions.
Habitat	The place where a population (*e.g*. animal, plant, micro-organism) lives and its surroundings, both living and non-living.
Hypoxia	Low oxygen levels in the water column and/or sediments, *i.e.* < 2ml O_2/l
Initial dilution	Dilution that occurs in the near-field whilst the effluent plume is still under the influence of strong buoyancy forcing and entrainment effects.
Marine discharge	Discharging wastewater to the marine environment either to an estuary or the surf zone or through a marine outfall (*i.e*. to the offshore marine environment).
Marine environment	Marine environment includes estuaries, coastal marine and near-shore zones, and open-ocean-deep-sea regions.
Near-field	A region in close proximity to the discharge where buoyancy forcing and entrainment effects primarily determine plume dynamics
Oligotrophic	Refers to a body of water with very low nutrient levels. Usually these waters are poor in dissolved nutrients, have low photosynthetic productivity, and are rich in dissolved oxygen.
Pollution	The introduction of unwanted components into waters, air or soil, usually as a result of human activity; *e.g*. hot water in rivers, sewage in the sea, oil on land.
Population	Population is defined as the total number of individuals of the species or taxon.
Pycnocline	A transition layer of water in the ocean, with a steeper vertical density gradient than that found in the layers of ocean above and below, *i.e*. a narrow range of depths at which density changes abruptly between warm surface waters and deeper, colder waters.
Reverse Osmosis	A filtration process that removes dissolved salts and metallic ions from water by forcing it through a semi-permeable membrane that removes molecules larger than the pores of the membrane.
Remineralisation	Remineralisation refers to the transformation of organic molecules to inorganic forms, typically mediated by biological respiration. Usually remineralisation relates to organic and

	inorganic molecules involving biologically important elements such as carbon, nitrogen and phosphorus. For example, the following simplified equation shows the complete remineralisation of organic material to oxidised inorganic minerals such as carbon dioxide, nitrate and phosphate. Biological Organic Matter (phytoplankton detritus) + oxygen --> CO_2 + Nutrients (NH_4, NO_3, PO_4) + energy. It can be understood to be the opposite reaction to photosynthesis which uses solar energy to convert CO_2 and nutrients into biological organic matter.
Sediment	Unconsolidated mineral and organic particulate material that settles to the bottom of aquatic environment.
Species	A group of organisms that resemble each other to a greater degree than members of other groups and that form a reproductively isolated group that will not produce viable offspring if bred with members of another group.
Surf zone	Also referred to as the ‘breaker zone’ where water depths are less than half the wavelength of the incoming waves with the result that the orbital pattern of the waves collapses and breakers are formed.
Suspended material	Total mass of material suspended in a given volume of water, measured in $mg.\ell^{-1}$l.
Suspended matter	Suspended material in the water column.
Suspended sediment	Unconsolidated mineral and organic particulate material that is suspended in a given volume of water, measured in $mg.\ell^{-1}$.
Thermal stratification	The existence of an often sharp change in temperature (and often mixing) between warmer surface and cooler bottom waters.
Thermocline	A transition layer of water in the ocean, with a steeper vertical temperature gradient than that found in the layers of ocean above and below, *i.e*. a narrow range of depths at which temperature changes abruptly between warm surface waters and deeper, colder waters.
Toxicity	The inherent potential or capacity of a material to cause adverse effects in a living organism.

Turbidity	Measure of the light-scattering properties of a volume of water, usually measured in nephelometric turbidity units.
Vulnerable	A taxon is vulnerable when it is not Critically Endangered or Endangered but is facing a high risk of extinction in the wild in the medium-term future.

This page intentionally left blank

1 INTRODUCTION

The Iron-ore Handling Facility at the Port of Saldanha (including the proposed upgrades to the facility), will require increased water supplies for dust suppression measures. It is anticipated that ultimately a total of 3600 kℓ of water per day will be required for this purpose. The municipality currently supplies water to the Iron-ore Handling Facility, but Transnet propose to supplement this supply with additional sources of freshwater. Of all potential sources of such water, seemingly the most feasible is that of a Reverse Osmosis (RO) seawater desalination plant.

1.1 Background

A Specialist Marine Impact Assessment study informing the Basic Assessment of potential environmental impacts associated with the proposed Reverse Osmosis Plant, Iron–ore Handling Facility, Port of Saldanha (van Ballegooyen *et al.,* 2007) has been undertaken using the engineering design specification available at that time. Subsequent to the study being completed additional design information on the possible temperature elevations in the brine discharge has become available that potentially could change the results of the modelling studies undertaken to predict the transport and fate of the brine discharge plume and its constituents in the marine environment.

While the specification of the elevation in salinity in the brine discharge and the concentrations of potential co-discharges remained unchanged, clarifications in the engineering design specifications in terms of the elevation in temperature[2] of the seawater that is likely to occur between the point of intake and the point of discharge, indicate that the temperature characteristics of the brine discharge assumed in the Specialist Marine Impact Assessment study (van Ballegooyen *et al.,* 2007) are not necessarily conservative.

1.2 Purpose of the Study

The purpose of this addendum to the Specialist Marine Impact Assessment study (van Ballegooyen *et al.,* 2007), is to undertake a sensitivity analysis of model results to elevations in seawater temperature between the intake and discharge locations. The purpose of the sensitivity study is to

---

[2] The elevation in seawater temperature referred to here is that occurring between the point of intake and the point of discharge due to:

- any warming of the intake seawater whilst being pumped via pipeline to the RO Plant;
- any warming of the intake seawater that may occur in any storage facility prior to being processed through the RO Plant;
- any warming of the intake seawater and/or brine that may occur during the RO process;
- any warming of the discharge brine ithat may occur in any storage facility prior to discharge; and
- any warming of the discharge brine whilst being pumped via pipeline to the discharge location.

The temperature elevation referred to here is not related to the expected temperature differences between the ambient water temperature at the point of intake and that at the point of discharge.

determine whether or not the original modelling and associated assessments remain valid given potential changes in the temperature of the brine discharge.

The reason for the concern is that temperature is a fundamental property of seawater that determines its density. The influence of changes in temperature on the density of the brine discharge upon release into the marine environment, if significant, could change the near-field and far-field behaviour of the brine discharge plume and consequently the dilution characteristics of the brine and any co-discharges. The purpose of this sensitivity study is to assess the potential changes in behaviour and mixing of the brine discharge plume upon entering the marine environment for a range of temperature elevations in the brine discharge.

1.3 Scope of Work

The detailed Terms of Reference specific for this Addendum to the Specialist Marine Impact Assessment are to:

- Undertake a sensitivity analysis of the modelling results to potential changes in temperature elevation in the intake seawater and brine discharge between the intake and discharge points (see footnote 2 above);
- Based on these sensitivity studies, re-assess (to the extent required) potential impacts of the proposed development on the marine environment;
- To the extent required, recommend further mitigation measures to minimise impacts associated with the proposed RO Plant.

The sensitivity analysis requires only that the brine discharge from the perceived “worst-case” location (Site 2) and preferred discharge location (Site 3 with an brine discharge at Caisson 3) be simulated for the “worst-case” environmental conditions that typically comprise the “autumn” period. However, for the sake of completeness all seasons were assessed for the preferred site (Site 3 with a brine discharge at Caisson 3).

2 APPROACH AND METHODS

The approach taken in this study is to assess the validity of the modelling and impact assessment contained in the Specialist Marine Impact Assessment study of potential environmental impacts associated with the proposed Reverse Osmosis Plant in Saldanha Bay (van Ballegooyen *et al.,* 2007), by undertaking a sensitivity analysis of RO Plant discharge model results to a range of specified elevations in seawater temperature between the intake and discharge locations.

2.1 Motivation for the Study

Given that temperature is a fundamental property of seawater that determines its density, any changes in temperature of the brine discharge will influence its density. Should the influence of changes in temperature on the density of the brine discharge upon release into the marine environment be significant, there could be a substantial change in both the near- and far-field behaviour of the brine discharge plume (and consequently the dilution characteristics of the brine and any co-discharges).as well as potential increased impacts on the environment due to the elevated temperature of the discharge brine. Given the uncertainties in:

- the magnitude of these potential elevations in temperature, and;
- the complexity of the processes determining the magnitude of potential thermal impacts in the marine environment (*i.e*. the competing effects of potentially increased dispersion of the brine discharge plume and increased thermal loading of the brine discharge),

it is deemed prudent to assess the sensitivity of the original model results and impact assessments undertaken to a range in temperature elevations in the discharge brine that encompass the minimum to maximum temperature elevations expected. The original marine impact assessment study was undertaken for a zero temperature elevation between the intake and discharge locations.

2.2 Approach

Originally it was specified that there would be a zero temperature elevation of the seawater and brine between the intake and discharge locations. Subsequent design updates suggest that this may not be a conservative assumption. There remains a degree of uncertainty in the exact extent of this temperature rise occurring between the point of intake and the point of discharge due to:

- warming of the intake seawater whilst being pumped via pipeline to the RO Plant;
- any warming of the intake seawater that may occur in any storage facility prior to being processed through the RO Plant;
- any warming of the intake seawater and/or brine that may occur during the RO process;
- any warming of the discharge brine ithat may occur in any storage facility prior to discharge; and
- warming of the discharge brine whilst being pumped via pipeline to the discharge location.

Given this uncertainty, it has been decided that the sensitivity analysis should assess temperature elevations ranging between 1ºC and 5ºC. It is anticipated that the temperature elevation in the seawater intake waters and brine discharge between the intake and discharge locations will lie in the lower end of this range and not exceed an upper limit of 5ºC.

To adequately characterise the sensitivity of the model results (contained in the main report of van Ballegooyen *et al*., 2007) to these temperature changes it is necessary only to consider:

i) the least optimal or perceived "worst case" discharge location (Site 2) and,

ii) the preferred discharge location (Site 3 – Caisson 3) that is also the most optimal discharge location in terms of the minimisation of potential marine impacts.

Furthermore, in keeping with the philosophy of a conservative approach, simulations to test the sensitivity of the model to such rises in temperature have been undertaken only for the "season" indicating the worst impacts. Typically this is the "autumn" season, however for Site 3 the "summer" season on occasion seems to indicate larger plume footprints than the "autumn" (i.e. or "worst case") season. Consequently, in addition to "autumn" simulations, "summer" simulations have been undertaken for Site 3. For completeness of the sensitivity analysis, the "winter" scenario also has been run for Site 3 as it is the preferred site. The parameters simulated, post-processed and analysed are tabulated below (Table 2.1).

Table 2.1: Scenarios simulated as part of the sensitivity analysis of the modelling results to elevations in temperature of the seawater and discharge brine between the intake and discharge locations.

Location	Temperature Elevation (between Intake and Discharge Locations)	Environmental Scenarios		
		Autumn	Summer	Winter
Site 2 (discharge into Small Bay)	1ºC	Temperature, salinity and biocide analyses	n/a	n/a
	3ºC	Temperature, salinity and biocide analyses	n/a	n/a
	5ºC	Temperature, salinity and biocide analyses	n/a	n/a
Site 3 (discharge at Caisson 3)	1ºC	Temperature, salinity and biocide analyses	Temperature, salinity and biocide analyses	Temperature, salinity and biocide analyses
	3ºC	Temperature, salinity and biocide analyses	Temperature, salinity and biocide analyses	Temperature, salinity and biocide analyses
	5ºC	Temperature, salinity and biocide analyses	Temperature, salinity and biocide analyses	Temperature, salinity and biocide analyses

Consistent with the main report (van Ballegooyen *et al*., 2007), the near field plume behaviour is not explicitly simulated. A conservative near-field behaviour has been assumed and consequently the reported results will be conservative in that, if anything, the dispersion of the brine discharge plume in the near-field (and consequently the far-field) has been underestimated.

3 RESULTS

In this section the following are discussed:

- The brine discharge plume behaviour and how it leads to impacts in the marine environment;
- Possible changes in the brine discharge plume behaviour due to temperature elevations in the discharge brine;
- The changes in predicted impacts beyond an initial mixing zone due to temperature elevations in the discharge brine;
- The changes in predicted impacts within the initial mixing zone due to temperature elevations in the discharge brine.

3.1 Brine Discharge Plume Behaviours and Associated Impacts in the Marine Environment

The major potential impacts affected by elevations in the temperature of the discharge brine may be categorised as follows:

- Changes in the magnitude and spatial extent of thermal impacts;
- Changes in the magnitude and spatial extent of the impacts associated with the elevated salinity, residual biocide and co-discharge concentrations in the brine discharge; and,
- Changes in the magnitude and spatial extent of impacts associated with changing dissolved oxygen (DO) concentration in the brine discharge plume.

Thermal Impacts

The nature of the thermal impacts induced by the brine discharge are somewhat counter-intuitive in that they arise more from a (relatively modest) degree of suppression of the natural temperature variability in the bottom waters of the bay (particularly in the deeper shipping channels, *etc*) rather than the imposition of increased temperature variability by the discharge. These effects are, however, not large.

The brine discharge, being very saline, remains significantly denser than the surrounding waters for even moderately higher increases in temperature of the discharge brine. The plume behaviour after discharge is such that is remains close to the seabed unless subject to a significant wind- or wave-forcing event. In shallower waters wave-mixing and strong winds may distribute the brine plume throughout the water column, whereas this is extremely unlikely in deeper waters (> 15 m).

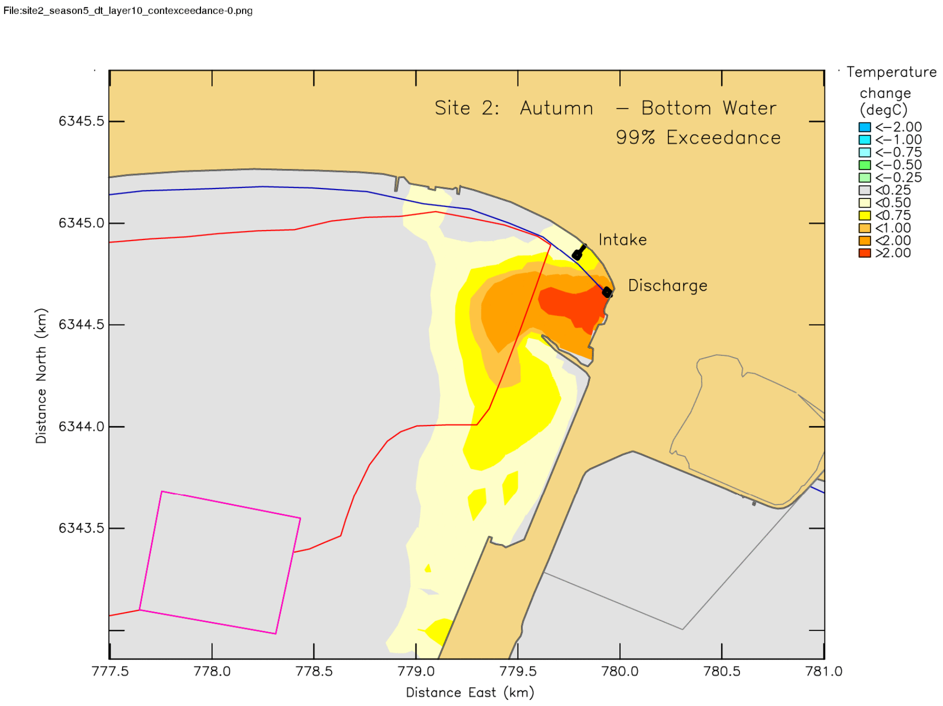

Figure 3.1a: **Site 2: 99% exceedance contours of elevation in seawater temperature (ºC) near the seabed during autumn (Figure C2.4f in Appendix C of van Ballegooyen *et al*., 2007).**

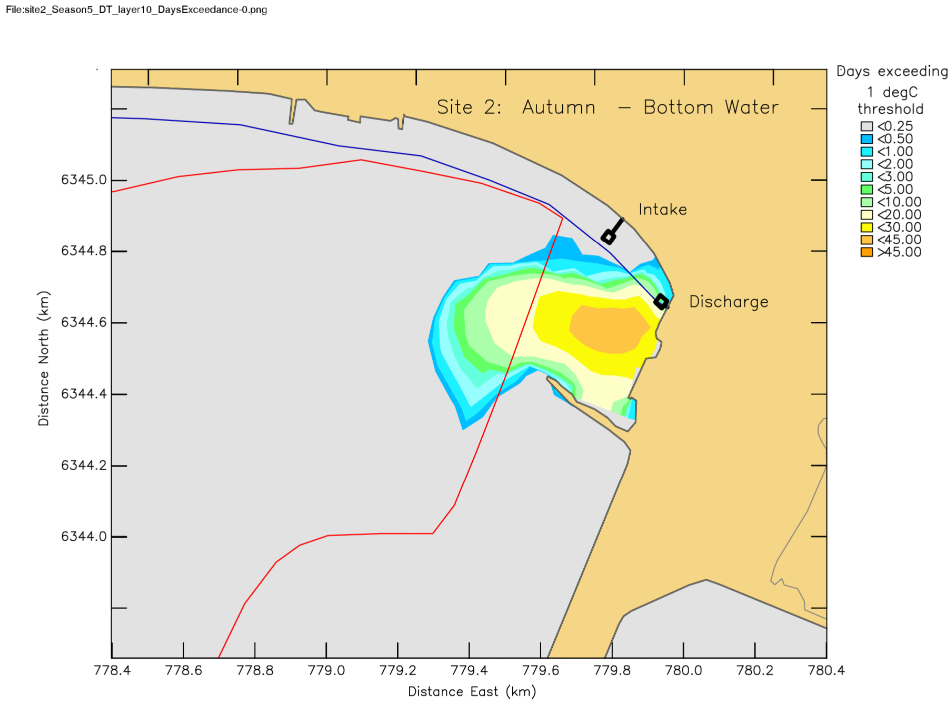

Figure 3.1b: **Site 2: Contours of days of exceedance of a seawater temperature elevation of approximately 1 ºC above ambient seawater temperature near the seabed during autumn (Figure 2.5f in Appendix C of van Ballegooyen *et al*., 2007).**

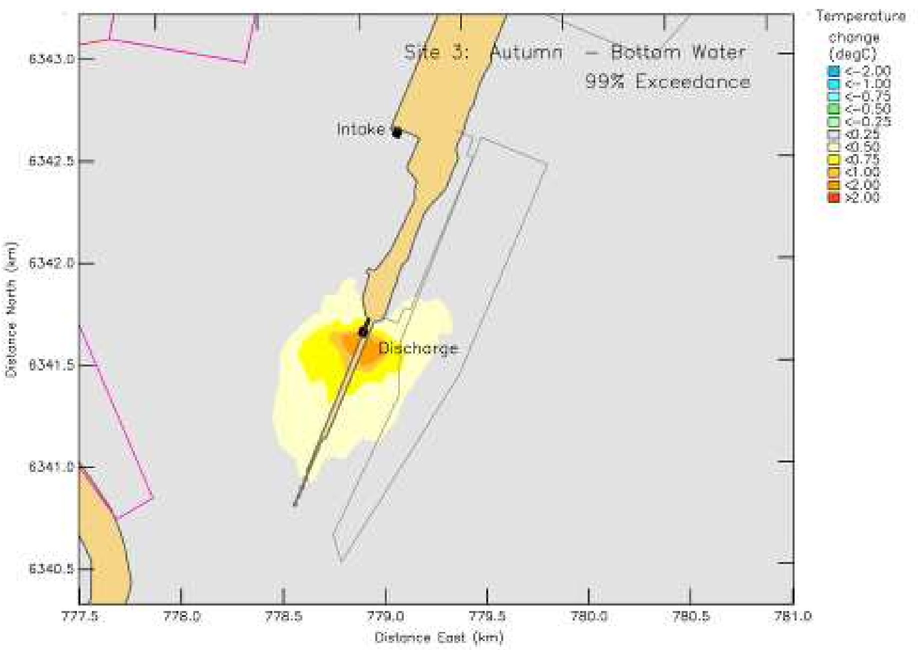

Figure 3.2a: **Site 3 – discharge at caisson 3: 99% exceedance contours of elevation in seawater temperature (°C) near the seabed during autumn (Figure C5.4f in Appendix C of van Ballegooyen *et al*., 2007).**

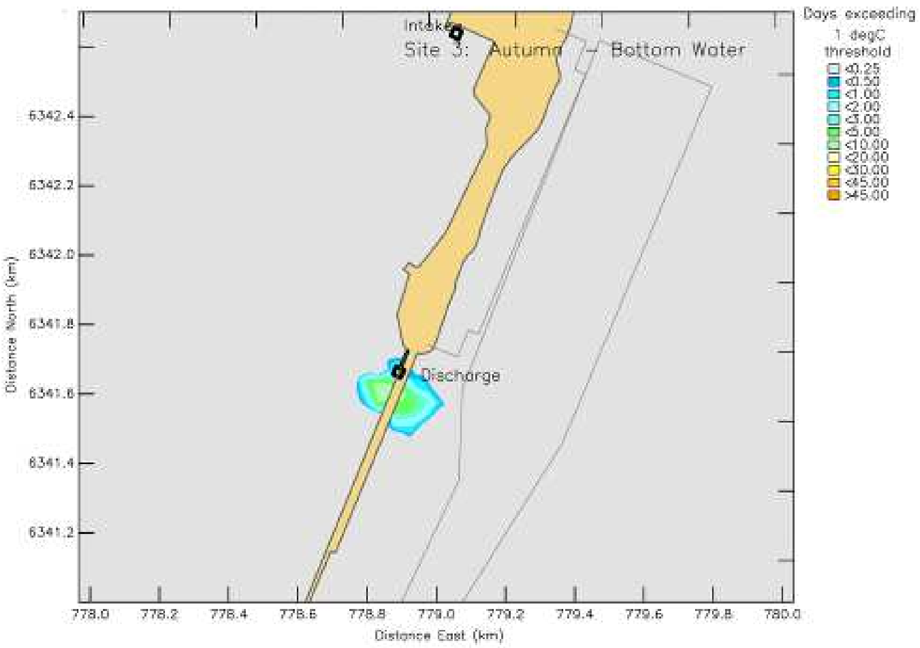

Figure 3.2b: **Site 3 – discharge at caisson 3: Contours of days of exceedance of a seawater temperature elevation of approximately 1 °C above ambient seawater temperature near the seabed during autumn (Figure C5.5f in Appendix C of van Ballegooyen *et al*., 2007).**

The 99% exceedance contours (*i.e*. maximum plume footprints) and days of exceedance of accepted water quality guidelines[3] (see van Ballegooyen *et al*., 2007 for a more detailed explanation of the quantities being plotted) reported in Figures 3.1 and 3.2, provide a clear indication of expected plume behaviours.

In shallow discharge sites such as Site 1 the primary mechanisms for dispersion of the plume are vertical mixing, horizontal mixing and advective transports. At deeper discharge sites such as Caisson 3, the flushing of the brine discharged is primarily due to upwelled waters entering the bay at depth. When the brine enters these deeper waters and/or shipping channels it initially causes the upwelled waters to "ride up" over the dense brine, however, the upwelled waters do flush the brine during the period that upwelling occurs. When the upwelling waters retreat, the dense brine again enters these deeper waters, replacing the colder upwelled waters. The net effect of the brine discharge is to slightly delay (by a couple of hours) the penetration of upwelling waters into the regions affected by the discharge plume. Similar behaviour is observed at Site 2 where the dense brine enters the deeper shipping channels just south of the discharge.

These effects lead to the thermal impacts at times being greatest at some distance from the discharge location as can be seen in Figures 3.1 (Site 2) and 3.2 (Site 3-Caisson 3). The complexity of these potential behaviours and potential thermal effects is the reason why due diligence required that the present sensitivity analysis be undertaken.

Impacts of elevated salinity and co-discharges of backwash waters containing pre-treatment chemicals

The nature of the impacts of elevated salinity and co-discharges of biocides, *etc* is one where the greatest impacts occur in the immediate vicinity of the discharge and decrease along a concentration gradient extending outwards from the discharge. The salinity in the receiving environment is steady at approximately 34.9 psu while the background concentrations in the receiving environment of co-discharges or constituents similar or the same as the break-down products of these co-discharges are negligible or non-existent. Consequently, no matter what the behaviour of the plume, there is a gradient of decreasing salinity or co-discharge concentration on moving away from the point of discharge (Figure 3.3, 3.4 and 3.5). The predictability of salinity or co-discharge footprints is thus less complex.

Given that the impacts of all co-discharges are assessed using the concept of achievable dilution of the constituent concentration that have been calculated using the dilution of the elevated salinities in the brine discharge plume (see van Ballegooyen *et al*., 2007), all conclusions reached in terms of the sensitivity of the salinity footprints to elevated temperatures in the discharge brine will hold equally well for all co-discharges. For example, if the salinity distributions are insensitive to temperature elevations in the brine discharge, so will be the distributions of all co-discharges.

---

[3] See van Ballegooyen *et al*., (2007 for a more detailed explanation of the quantities being plotted),

File:site2_Season5_DS_layer10_ContExceedance-0.png

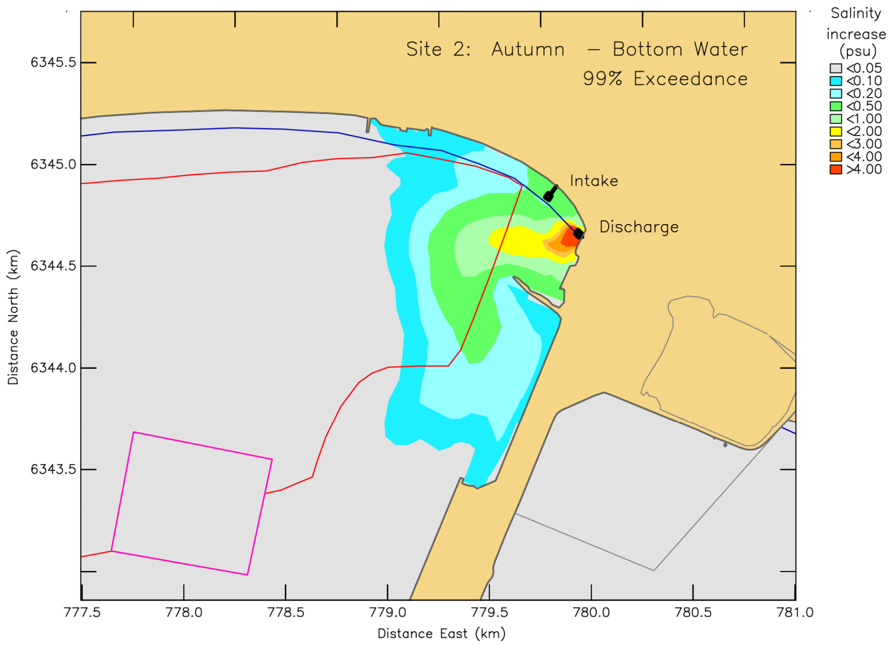

Figure 3.3a: **Site 2: 99% exceedance contours of elevation in salinity (psu) near the seabed during autumn (Figure C2.1f in Appendix C of van Ballegooyen *et al*., 2007).**

File:site2_Season5_DS_layer10_DaysExceedance-0.png

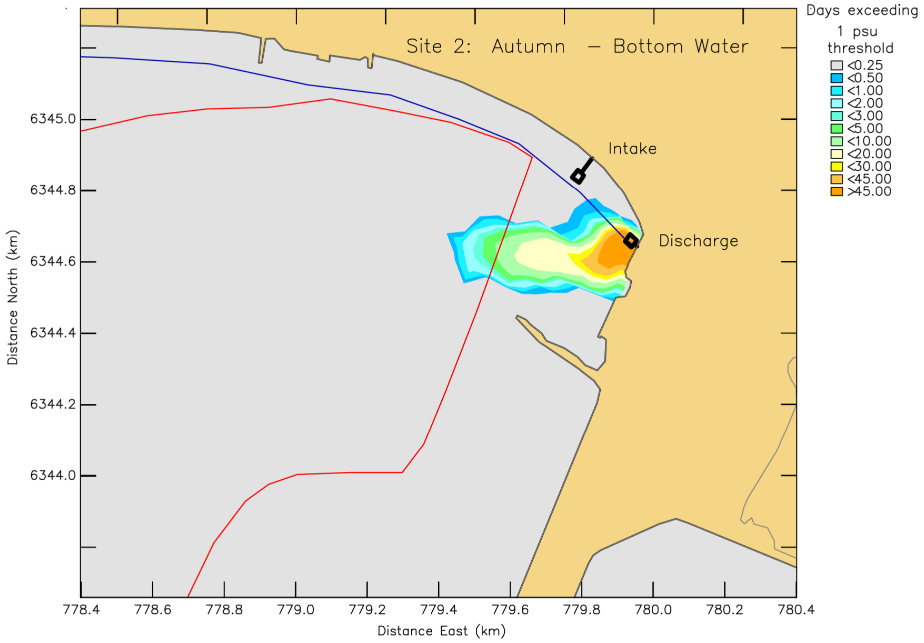

Figure 3.3b: **Site 2: Contours of days of exceedance of a salinity of approximately 36 psu (ΔS = 1 psu above ambient salinity) near the seabed during autumn (Figure C2.2f in Appendix C of van Ballegooyen *et al*., 2007).**

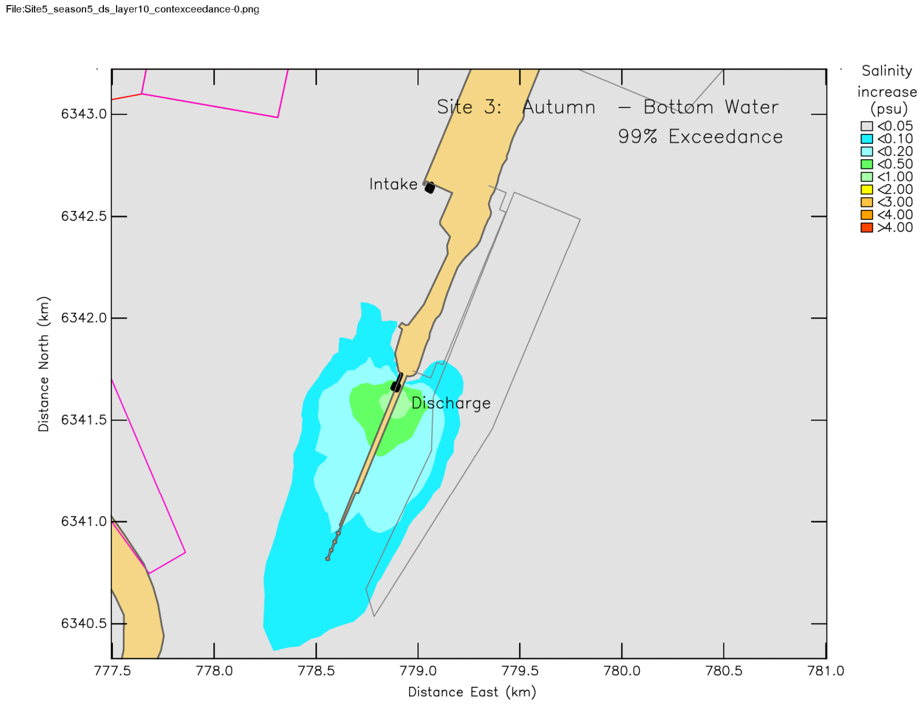

Figure 3.4: **Site 3 – discharge at caisson 3: 99% exceedance contours of elevation in salinity (psu) near the seabed during autumn (Figure C5.1f in Appendix C of van Ballegooyen *et al*., 2007).**

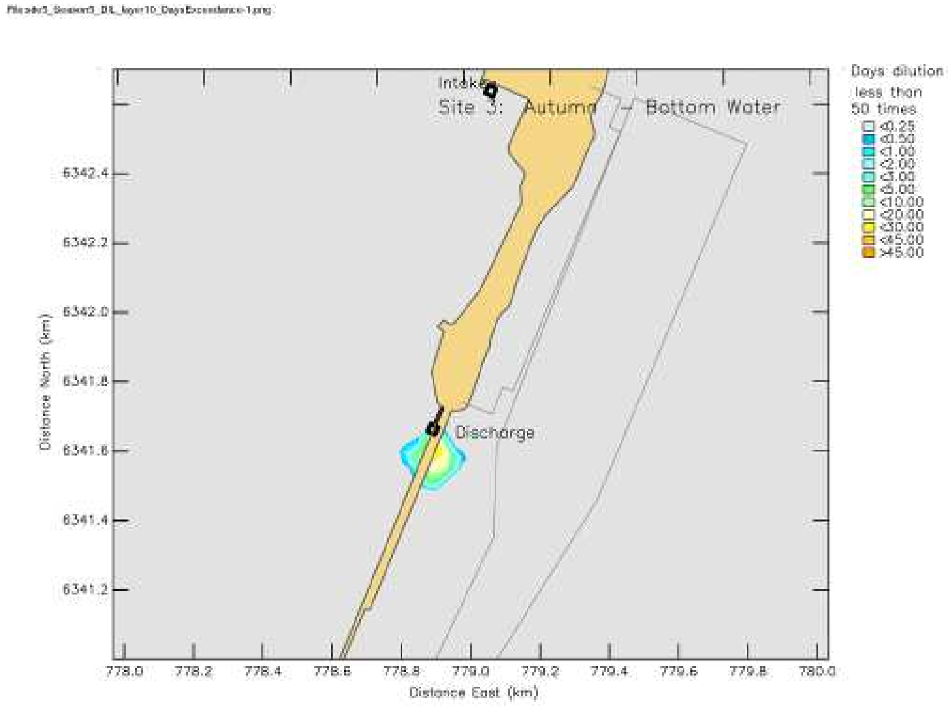

Figure 3.5: **Site 3 – discharge at caisson 3: Contours of days of exceedance of an achievable dilution of 50 near the seabed during autumn (Figure C5.10f in Appendix C of van Ballegooyen *et al*., 2007).**

Impacts associated with dissolved oxygen concentration in the brine discharge plume

The bottom waters of the West Coast are often characterised by hypoxic conditions as a result of decomposition of organic matter and low-oxygen water generation processes. In particular, the bottom waters of Small Bay often experience oxygen deficits (Atkinson *et al.,* 2006), particularly during thermal stratification. It is thus unlikely that the receiving bottom water will have notably higher oxygen concentrations than the surface waters. Descending brine plumes, comprising mainly more highly oxygenated surface waters that have passed through the RO process, may therefore act as localised suppliers of oxygenated water to the seabed, rather than contributing to oxygen depletion. A decrease in DO levels in the discharged brine is thus not of critical concern, and is assessed as being of *low significance*.

Elevated seawater temperatures have a *direct effect* on dissolved oxygen concentrations surrounding the discharge in that the solubility of oxygen in seawater decreases with increased temperature. *Indirect changes* in DO content of the water column and sediments due to changes in hydrodynamic and ecosystem functioning in the bay are also possible. For example, oxygen concentrations may change (particularly in the bottom waters and in the sediments) due to:

i) changes in phytoplankton production as a result of changes in nutrient dynamics (both in terms of changes in nutrient inflows and vertical mixing of nutrients) and subsequent deposition of organic matter, and

ii) changes in remineralisation rates (with related changes in nutrient concentrations in near bottom waters) associated with near bottom changes in seawater temperature associated with the brine discharge plume.

Temperature elevations will increase remineralisation rates (with related changes in nutrient concentrations in near bottom waters) resulting in an reduction in oxygen concentrations,

As impacts associated with changes in DO were not explicitly modelled, it is expedient to discuss the expected changes in DO in the marine environment where there has been an elevation in the temperature of the intake seawater and/or the discharge brine between the point of intake and discharge.

Increases in the salinity of the brine discharge from approximately 35 ppt to 63.5 ppt at a water temperature of 10°C will reduce oxygen saturation values from approximately 9.0 mg O_2/ℓ to 7.5 mg O_2/ℓ. An increase of the temperature of the brine by +5°C to 15°C will further reduce oxygen saturation values to 6.85 mg O_2/ℓ. Similarly, increases in the salinity of the brine discharge from approximately 35 ppt to 63.5 ppt at a water temperature of 20°C will reduce oxygen saturation values from approximately 7.4 mg O_2/ℓ to 6.3 mg O_2/ℓ. An increase in the temperature of the brine by +5°C to 25°C will further reduce oxygen saturation values to 5.8 mg O_2/ℓ. Measurements of dissolved oxygen (DO) concentrations in the bottom waters of Small Bay range between 3.3 mg O_2/ℓ and

9.0 mg O_2/ℓ. The increased temperature effect results in a ireduction in the oxygen saturation concentrations from approximately 16% to 25%. A potential difference in DO concentration in the range of 15% to 25% is thus within the natural variability range of the waters in Saldanha Bay (Atkinson *et al.,* 2006). Furthermore, the brine discharge is likely to be diluted by a factor of 10 or more within the mixing zone, thus the potential for a reduction in dissolved oxygen levels will also drastically reduce within the mixing zone and possibly even within a few meters of the outlet as the effluent mixes with the receiving waters.

Although temperature elevations will increase remineralisation rates (with related changes in nutrient concentrations in near bottom waters) resulting in an reduction in oxygen concentration, the temperature elevation after initial dilution of the brine discharge plume in the near-field is unlikely to result in significant changes in oxygen concentrations at depth due to this effect.

Given that temperature elevations are unlikely to result in significant changes in oxygen concentrations beyond the immediate vicinity of the discharge location, it can be stated that the potential impacts associated with changes in oxygen concentration are not sensitive to the temperature elevations considered in this sensitivity study. For this reason, and the fact that oxygen effects were not explicitly modelled, there is no further discussion of these impacts in Section 3.3 and 3.4 below.

3.2 Potential changes in the brine discharge plume behaviour due to temperature elevations in the discharge

The brine discharge plume will become progressively less dense as the temperature of the discharge brine increases. The less dense the plume, the less the tendency for the plume to sink to the seabed and the greater the expected initial mixing of the plume in the near-field. The greater the initial mixing in the near-field, the greater will be the dispersion of the plume in the far-field.

The consequences of such changes in behaviour will be increased dispersion of the salinity and co-discharges as the temperature of the brine increases. Thus, as the temperature of the brine discharge increases, it is expected that the potential impacts of salinity and co-discharges will decrease. The extent to which the temperature elevation in the brine precipitates increased dispersion and mixing will depend on how significant are the changes in density due to temperature in comparison to the effects of the high salinity in the brine.

Table 3.1: Seawater density for a range of combinations of ambient conditions and brine discharge temperature and salinity.

Location	Temperature Elevation (between Intake and Discharge Locations)	Density	
		Ambient Salinity (34.9 psu)	Brine Discharge Salinity (63.5 psu)
Warm surface waters (20ºC)	0ºC	1 024.7 kg.m^{-3}	1 046.7 kg.m^{-3}
	1ºC	1 024.4 kg.m^{-3}	1 046.6 kg.m^{-3}
	3ºC	1 023.9 kg.m^{-3}	1 045.7 kg.m^{-3}
	5ºC	1 023.3 kg.m^{-3}	1 045.1 kg.m^{-3}
Cold bottom waters (10ºC)	0ºC	1 026.9 kg.m^{-3}	1 049.4 kg.m^{-3}
	1ºC	1 026.7 kg.m^{-3}	1 049.1 kg.m^{-3}
	3ºC	1 026.3 kg.m^{-3}	1 048.7 kg.m^{-3}
	5ºC	1 025.9 kg.m^{-3}	1 048.1 kg.m^{-3}

In terms of changes in seawater density there is a rough equivalence between a 5ºC temperature elevation and a 2 psu salinity decrease (Table 3.1). This suggests that the effects of a 5ºC elevation in brine discharge temperature on plume dispersion and mixing should remain limited.

In contrast to the potential impacts of salinity and co-discharges that are expected to decrease as the temperature of the brine discharge increases, the situation is less clear in terms of temperature impacts. The reason for this is that there will be an increased thermal load in the brine discharge that needs to be effectively dispersed. Thus, in terms of potential thermal impacts, temperature elevations in the brine lead to competing effects. As the temperature of the brine discharge increases there is an expectation of increased dispersion and mixing of the brine discharge (albeit small), however, the increases in temperature leads to potentially increased thermal impacts. Whether the thermal impacts increase or not will be determined by the extent to which the increased thermal load is dispersed by the expected changes in plume behaviour leading to more effective dispersion and mixing of the brine discharge plume. This balance will change depending on the dispersion characteristics of the particular site. The more dispersive a discharge location the less the likelihood of increased thermal impacts due to temperature elevation in the brine discharge.

3.3 Changes in predicted impacts beyond an initial mixing zone due to temperature elevations in the discharge brine

The scenario simulations comprising the sensitivity analysis are listed in Table 2.1. The Site 2 simulations have been undertaken for temperature elevations of 1ºC, 3ºC and 5ºC as indicated in Table 2.1, however, the contours of exceedance and days that selected water quality guidelines have been exceeded (within a season) have only been presented for a 0ºC temperature rise (from the initial assessment) and for a +5ºC temperature rise (from this sensitivity analysis). The reason for this approach is that there is little difference between the simulated footprints for the initial 0ºC temperature rise simulations contained in the Specialist Marine Impact Assessment study (van Ballegooyen *et al.,* 2007) and the present simulations assuming a +5ºC temperature rise between the intake and discharge locations. Consequently, it is superfluous to also present the results for the simulations assuming a +1ºC and a +3ºC temperature rise between the intake and discharge locations.

The results are presented for temperature, salinity and biocides, however, as the impacts are only indicated to occur near the bottom, only the results for the near-bottom waters are presented. An index to the plotted results are contained in Table 3.2. The respective results for a 0ºC and a +5ºC temperature rise in the seawater and brine discharge temperature between intake and discharge are plotted on the same page to ease the comparison of the results.

It should be noted that the plots for the biocide, while referring to an oxidising biocide (NaOCl) and its water quality guideline of < 3µg/ℓ apply equally well for the non-oxidising biocide (DBNPA) proposed for use in the RO Plant. The water quality guideline of < 3µg/ℓ for NaOCl is equivalent to a guideline of < 0.035 mg/ℓ for DBNPA (see van Ballegooyen *et al.*, 2007).

In summary, both the exceedance contour plots (maximum plume footprints) and those indicating contours of days of exceedance of the relevant water quality guidelines, indicate that the predicted changes in the thermal impacts and impacts of elevated salinity, biocides (and other co-discharges) for temperature elevations of up to 5ºC in the discharge are negligible outside an initial "mixing zone".

Table 3.2: Reference to figure numbers containing the analyses of the various scenarios simulated in the sensitivity analysis.

Location	Parameter	Type of Plot	Temperature Elevation (between Intake and Discharge)	Environmental Scenarios		
				Autumn	Summer	Winter
Site 2 (discharge into Small Bay)	Temperature	Exceedance contours	+0ºC	Figure 3.6a	n/a	n/a
			+5ºC	Figure 3.6b	n/a	n/a
		Days of exceedance	+0ºC	Figure 3.7a	n/a	n/a
			+5ºC	Figure 3.7b	n/a	n/a
	Salinity	Exceedance contours	+0ºC	Figure 3.8a	n/a	n/a
			+5ºC	Figure 3.8b	n/a	n/a
		Days of exceedance	+0ºC	Figure 3.9a	n/a	n/a
			+5ºC	Figure 3.9b	n/a	n/a
	Biocide	Exceedance contours	+0ºC	Figure 3.10a	n/a	n/a
			+5ºC	Figure 3.10b	n/a	n/a
		Days of exceedance	+0ºC	Figure 3.11a	n/a	n/a
			+5ºC	Figure 3.11b	n/a	n/a
Site 3 (discharge at Caisson 3)	Temperature	Exceedance contours	+0ºC	-	Figure 3.12a	-
			+5ºC	-	Figure 3.12b	-
		Days of exceedance	+0ºC	-	Figure 3.13a	-
			+5ºC	-	Figure 3.13b	-
	Salinity	Exceedance contours	+0ºC	Figure 3.14a	-	-
			+5ºC	Figure 3.14b	-	-
		Days of exceedance	+0ºC	*	-	-
			+5ºC	*	-	-
	Biocide	Exceedance contours	+0ºC	Figure 3.15a	-	-
			+5ºC	Figure 3.15b	-	-
		Days of exceedance	+0ºC	*	-	-
			+5ºC	*	-	-

* Within the resolution of the modelling, there is no exceedance of water quality guidelines indicated and thus no discernable differences with or without a temperature elevation

This page intentionally left blank

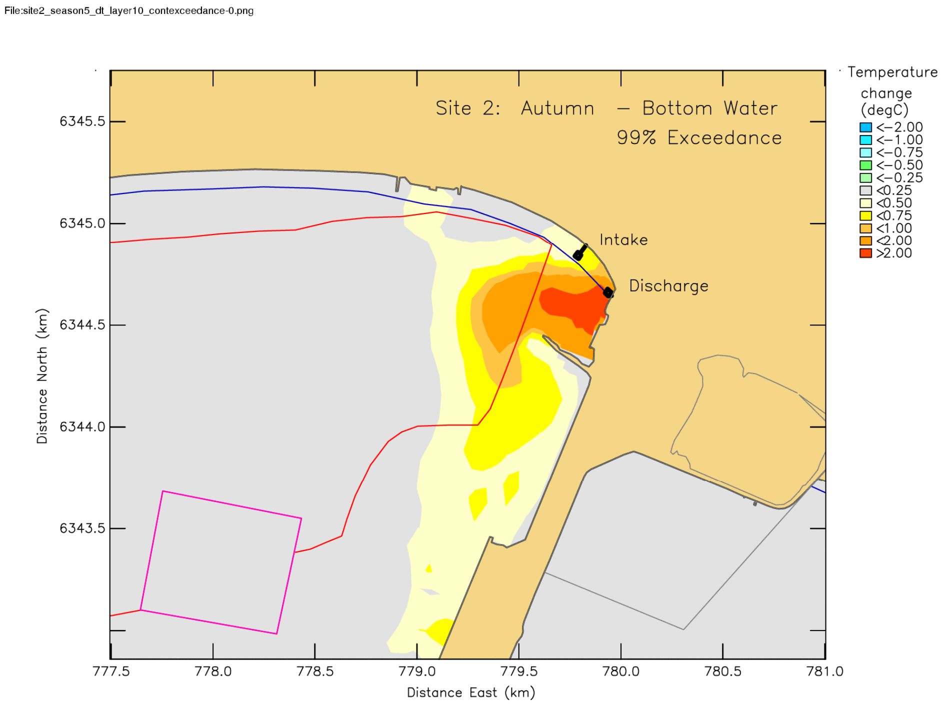

Figure 3.6a: Site 2: 99% exceedance contours of elevation in seawater temperature (°C) near the seabed during autumn for a zero temperature elevation in the brine discharge.

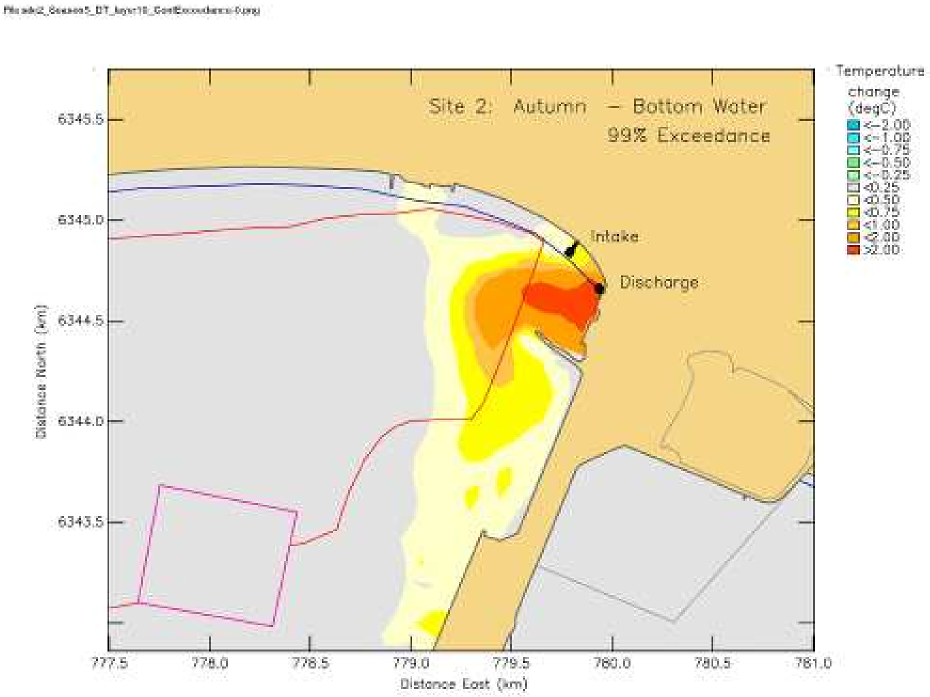

Figure 3.6b: Site 2: 99% exceedance contours of elevation in seawater temperature (°C) near the seabed during autumn for a +5ºC temperature elevation in the brine discharge.

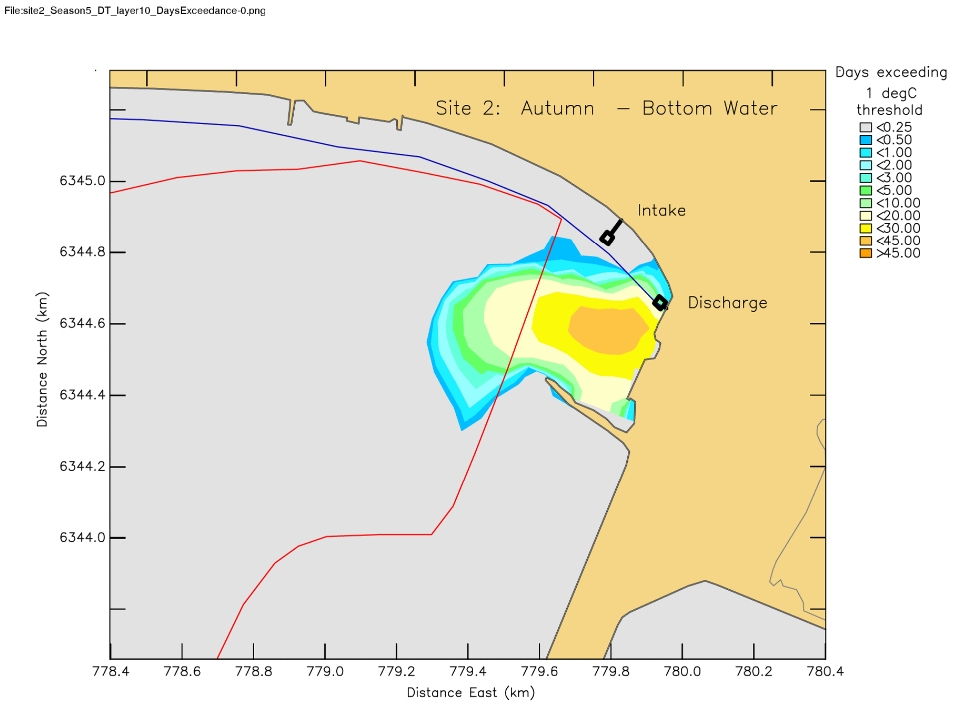

Figure 3.7a: **Site 2: Contours of days of exceedance of a seawater temperature near the seabed during autumn for a zero temperature elevation in the brine discharge.**

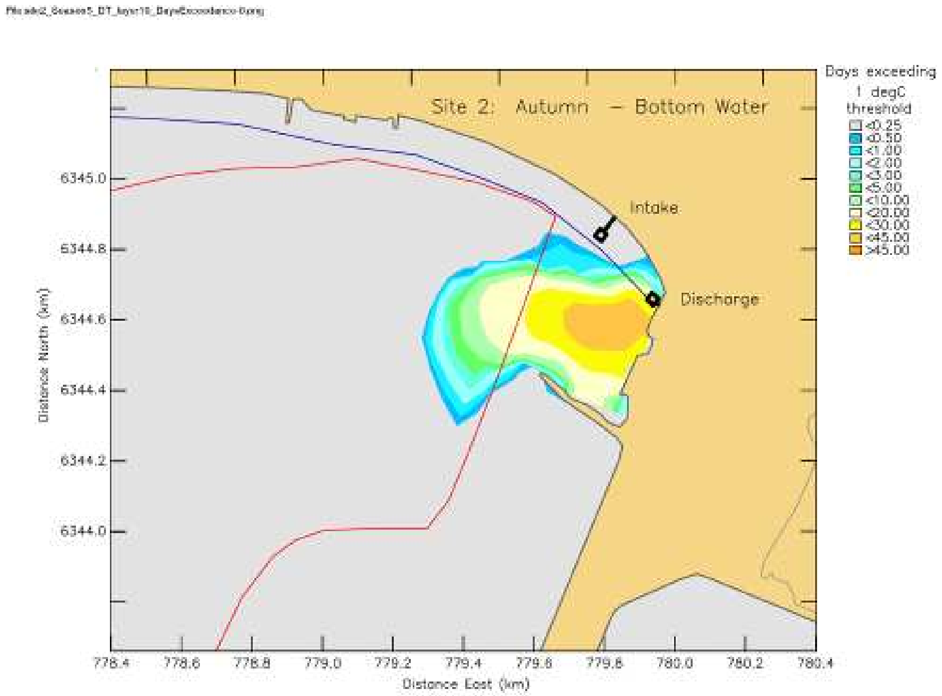

Figure 3.7b: **Site 2: Contours of days of exceedance of a seawater temperature near the seabed during autumn for a +5ºC temperature elevation in the brine discharge.**

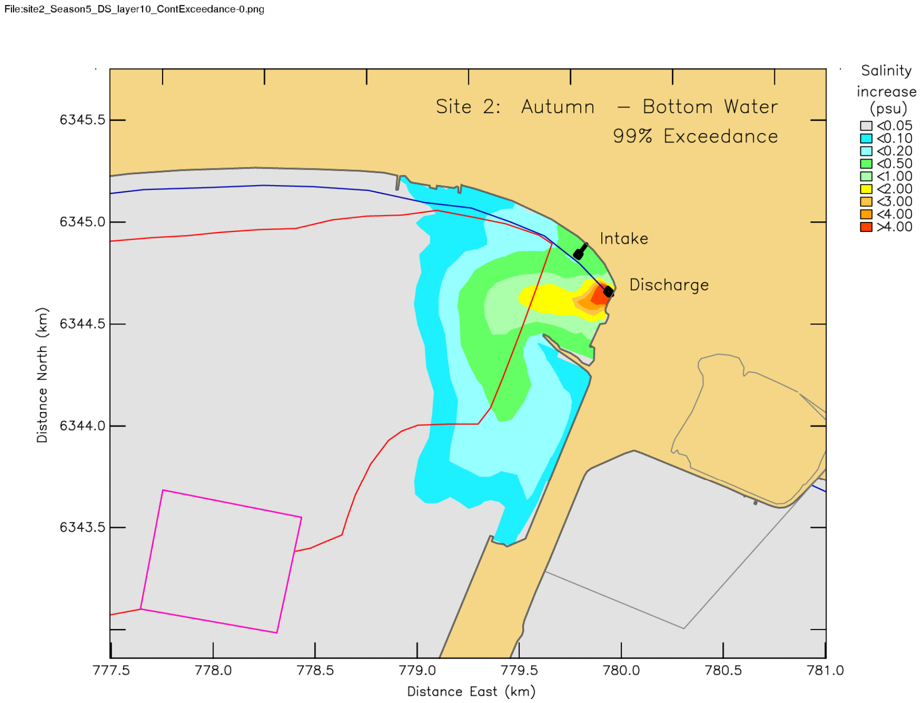

Figure 3.8a: Site 2: 99% exceedance contours of elevation in Salinity (psu) near the seabed during autumn for a zero temperature elevation in the brine discharge.

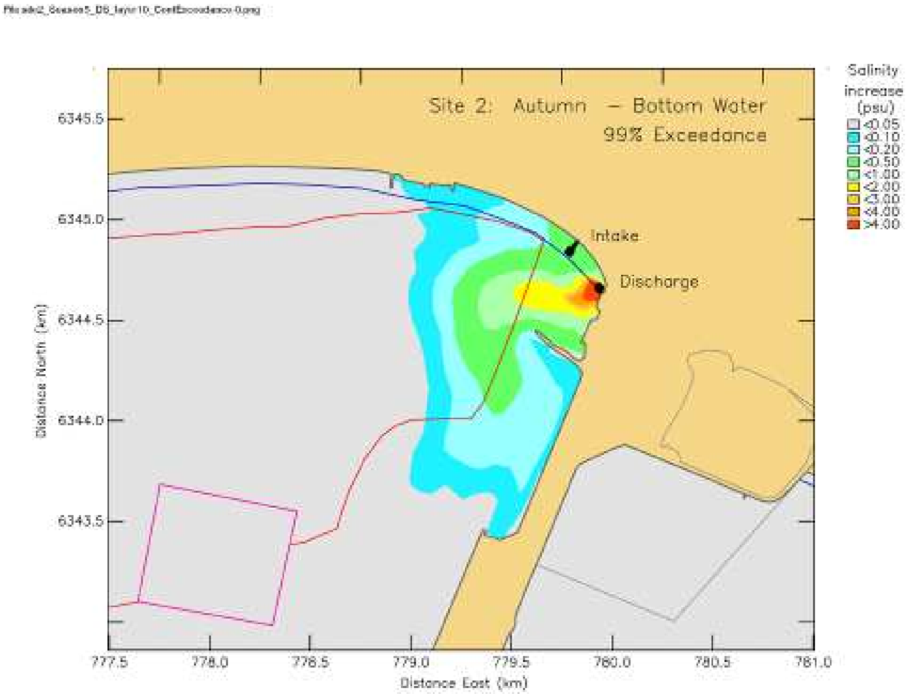

Figure 3.8b: Site 2: 99% exceedance contours of elevation in salinity (psu) near the seabed during autumn for a +5ºC temperature elevation in the brine discharge.

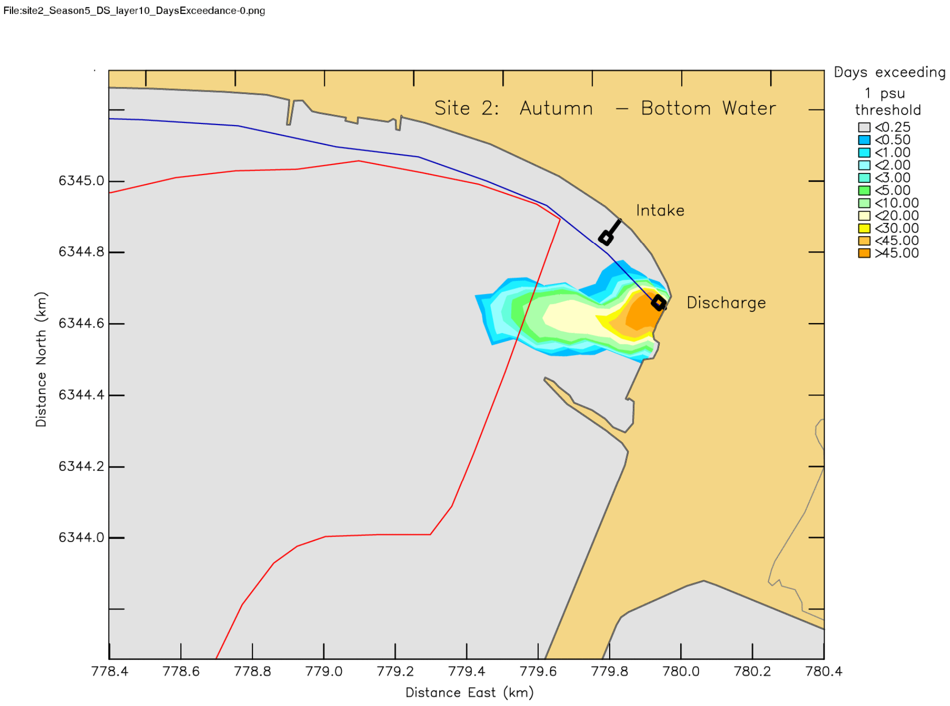

Figure 3.9a: **Site 2: Contours of days of exceedance of salinity near the seabed during autumn for a zero temperature elevation in the brine discharge.**

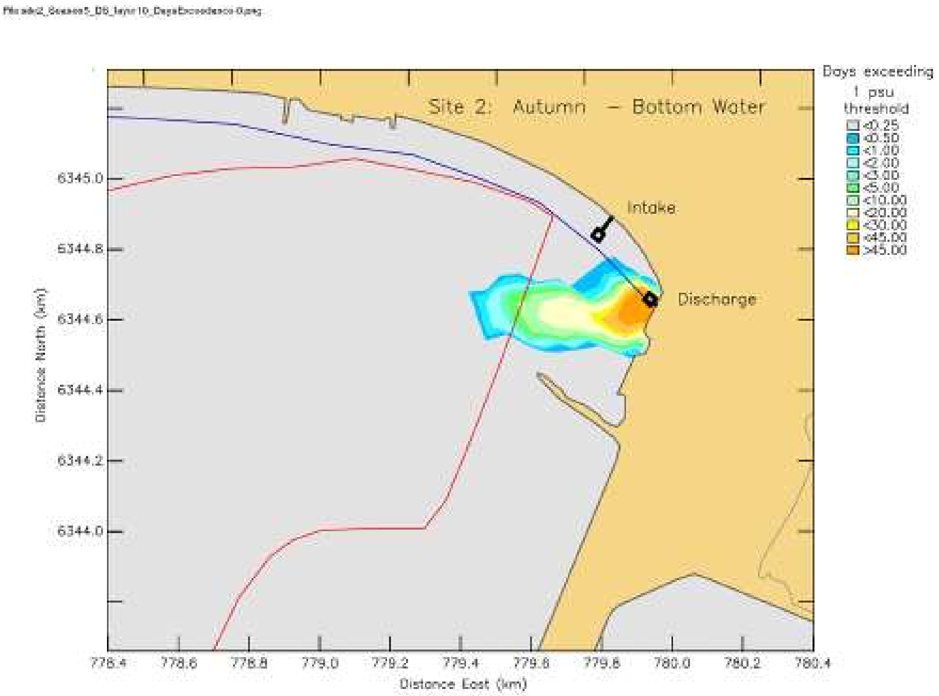

Figure 3.9b: **Site 2: Contours of days of exceedance of a salinitynear the seabed during autumn for a +5ºC temperature elevation in the brine discharge.**

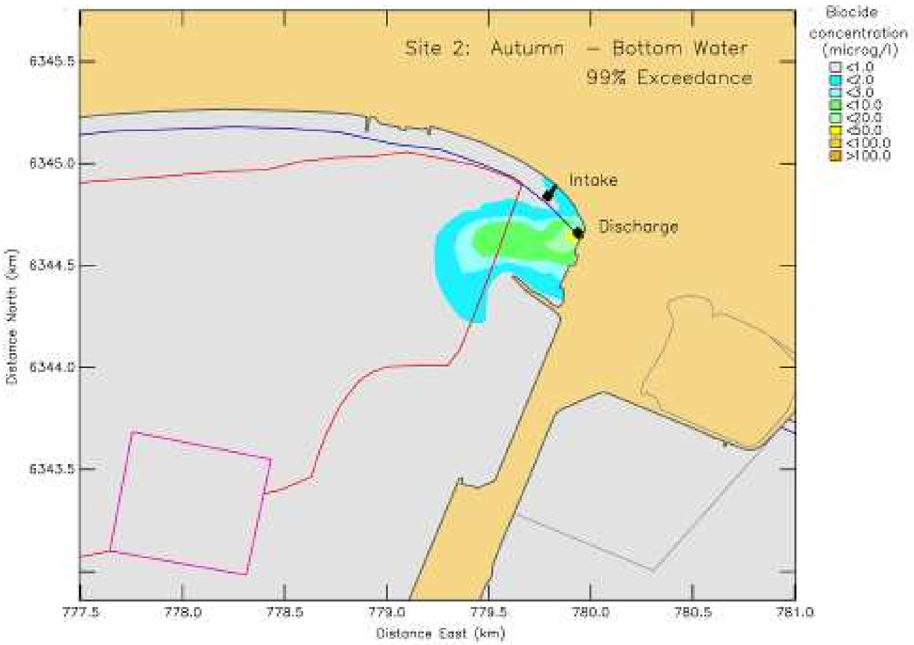

Figure 3.10a: **Site 2: 99% exceedance contours of biocide concentration (µg/ℓ) near the seabed during autumn for a zero temperature elevation in the brine discharge.**

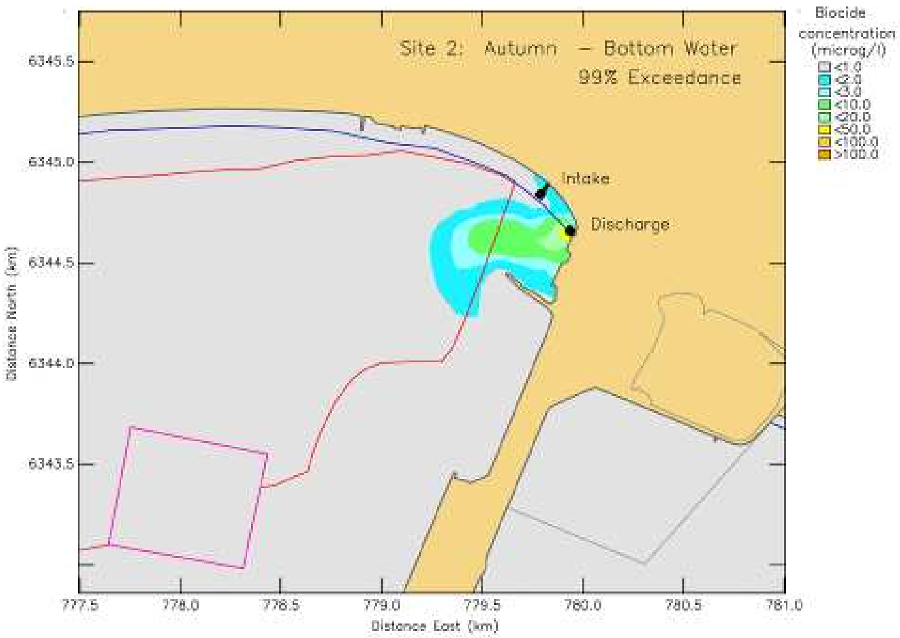

Figure 3.10b: **Site 2: 99% exceedance contours of biocide concentration (µg/ℓ) near the seabed during autumn for a +5ºC temperature elevation in the brine discharge.**

File:adc2_Season3_BIO_layer10_DaysExceedance-0.png

.

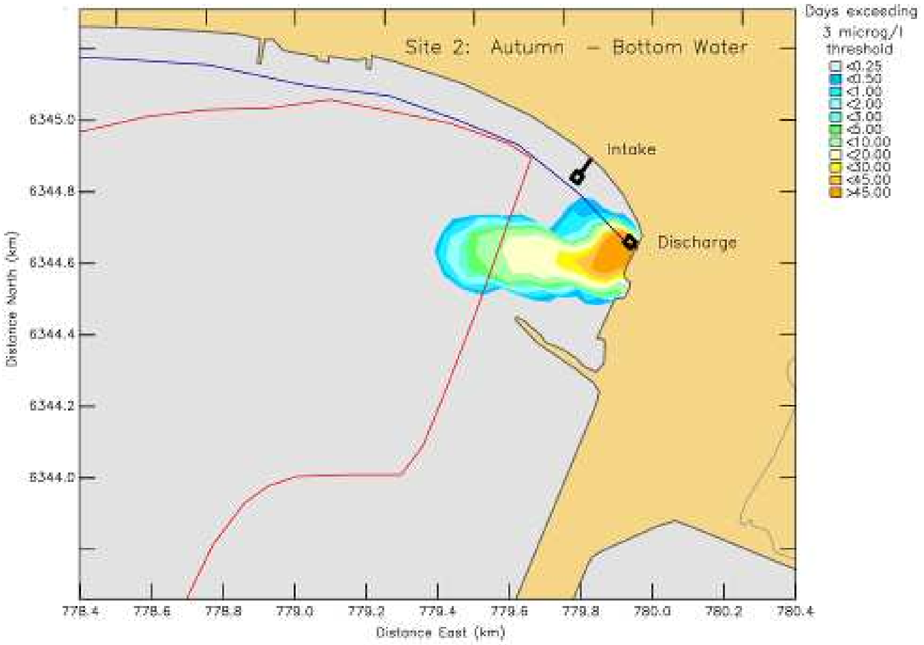

Figure 3.11a: **Site 2: Contours of days of exceedance of an oxidising biocide (NaOCl) concentration of 3µg/ℓ near the seabed during autumn for a zero temperature elevation in the brine discharge.**

File:adc2_Season5_BIO_layer10_DaysExceedance-5.png

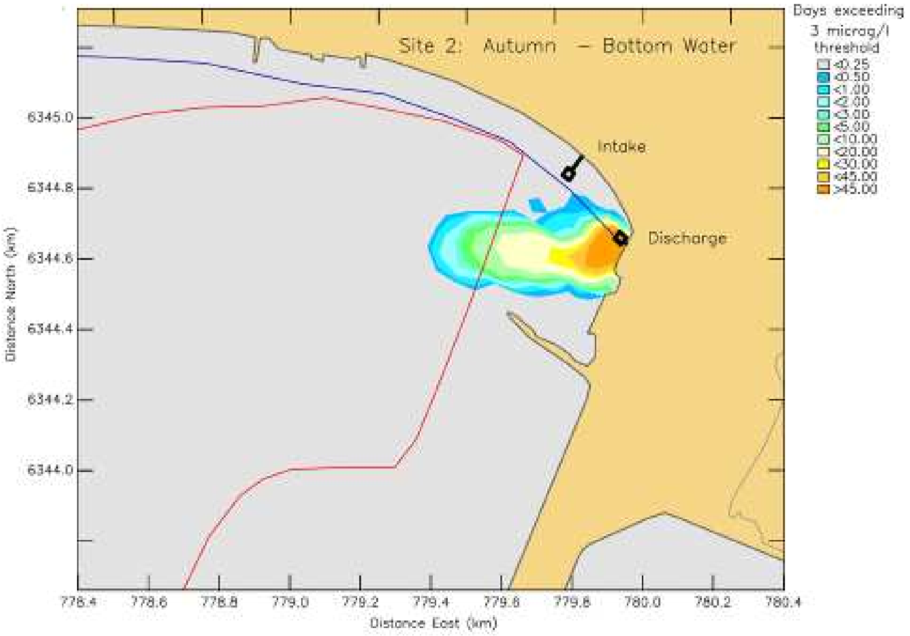

Figure 3.11b: **Site 2: Contours of days of exceedance of an oxidising biocide (NaOCl) concentration of 3µg/ℓ near the seabed during autumn for a +5ºC temperature elevation in the brine discharge.**

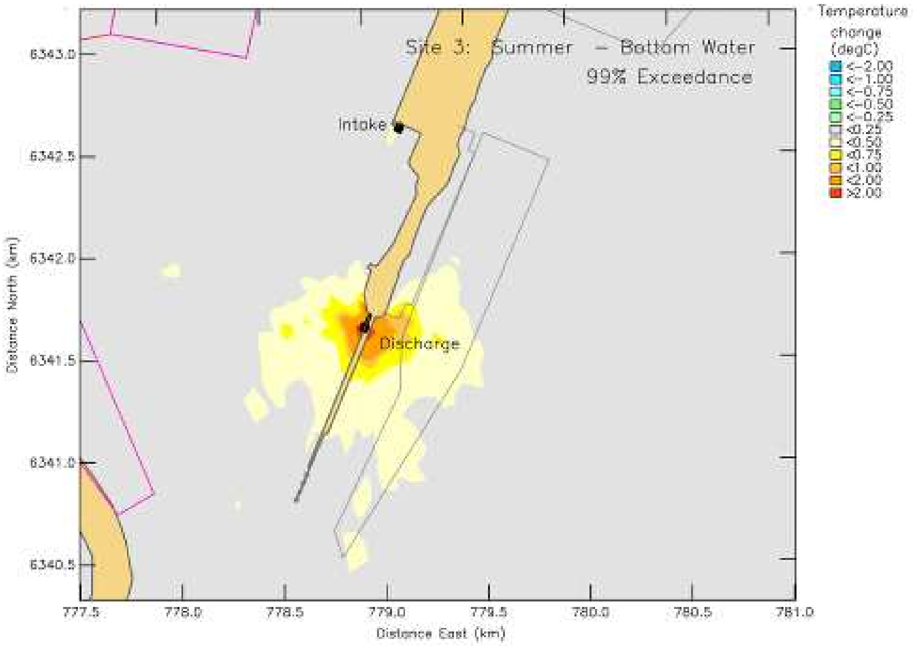

Figure 3.12a: **Site 3 - Caisson 3: 99% exceedance contours of elevation in seawater temperature (°C) near the seabed during summer for a zero temperature elevation in the brine discharge.**

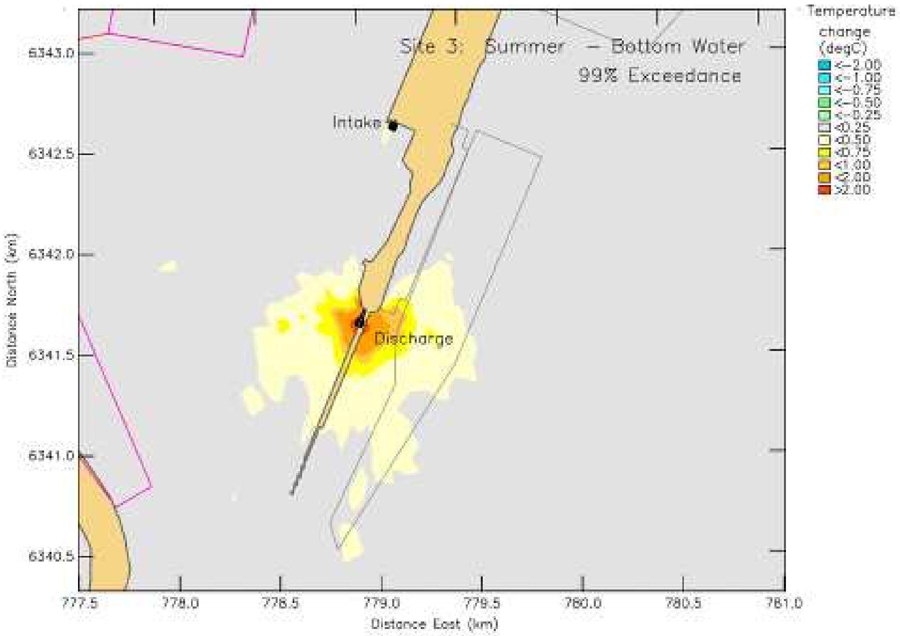

Figure 3.12b: **Site 3 - Caisson 3: 99% exceedance contours of elevation in seawater temperature (°C) near the seabed during summer for a +5ºC temperature elevation in the brine discharge.**

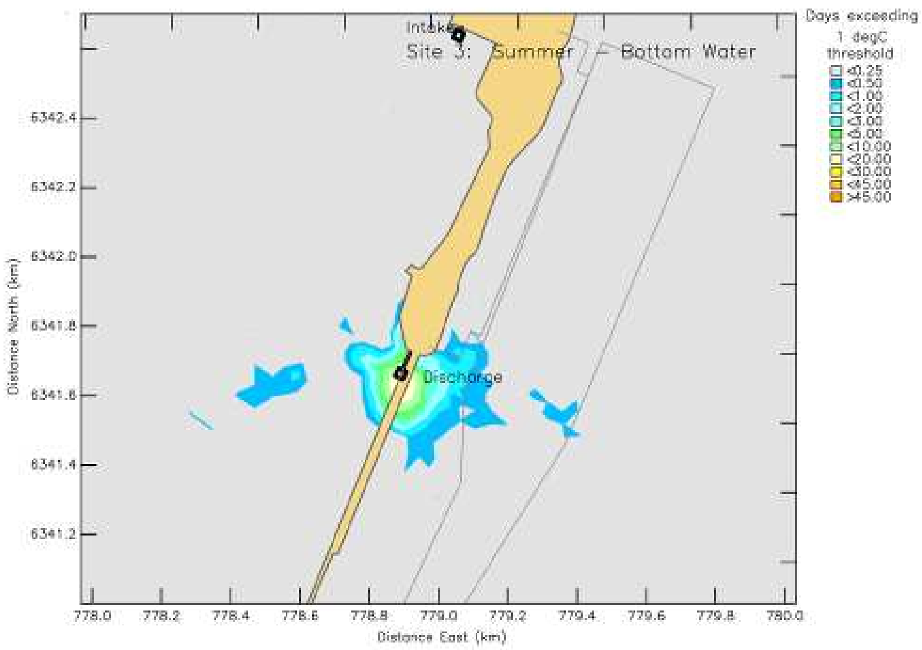

Figure 3.13a: Site 3 - Caisson 3: Contours of days of exceedance of a seawater temperature near the seabed during summer for a zero temperature elevation in the brine discharge.

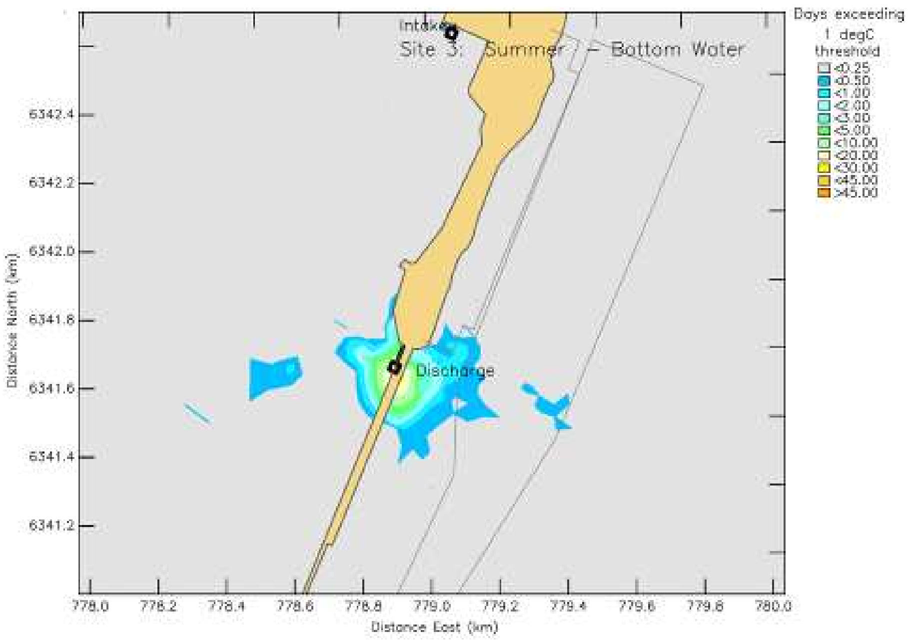

Figure 3.13b: Site 3 - Caisson 3: Contours of days of exceedance of a seawater temperature near the seabed during summer for a +5ºC temperature elevation in the brine discharge.

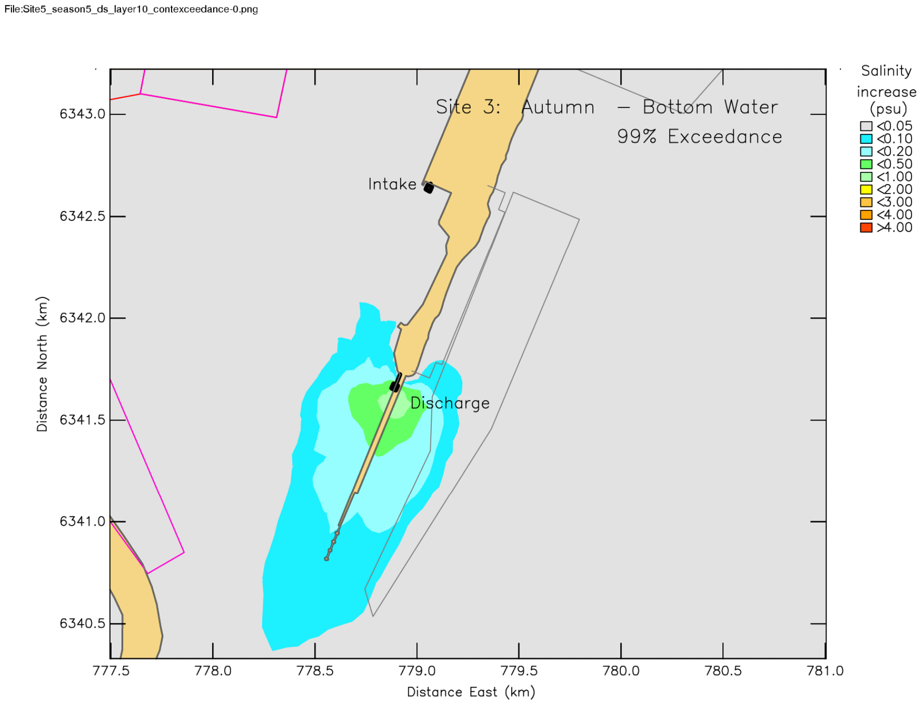

Figure 3.14a: **Site 3 - Caisson 3: 99% exceedance contours of elevation in Salinity (psu) near the seabed during autumn for a zero temperature elevation in the brine discharge.**

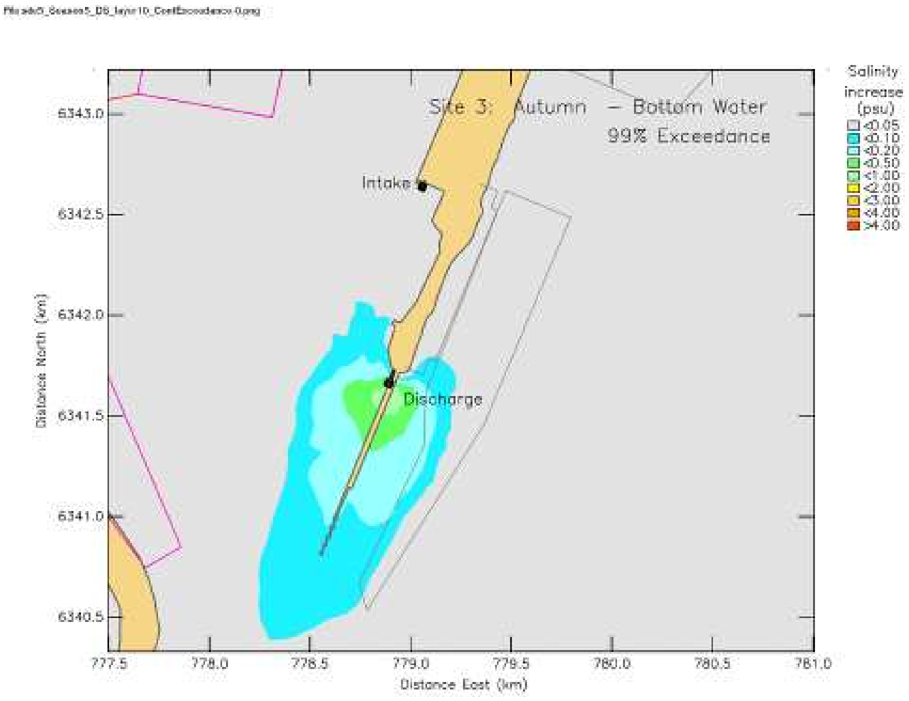

Figure 3.14b: **Site 3 - Caisson 3: 99% exceedance contours of elevation in salinity (psu) near the seabed during autumn for a +5ºC temperature elevation in the brine discharge.**

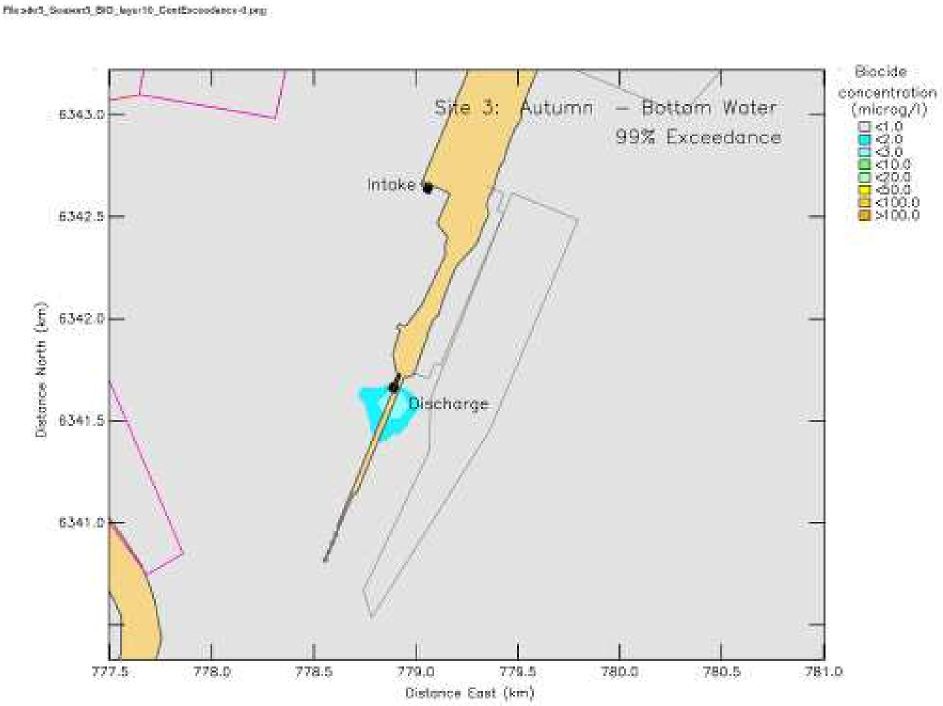

Figure 3.15a: **Site 3 - Caisson 3: 99% exceedance contours of biocide concentration (µg/ℓ) near the seabed during autumn for a zero temperature elevation in the brine discharge.**

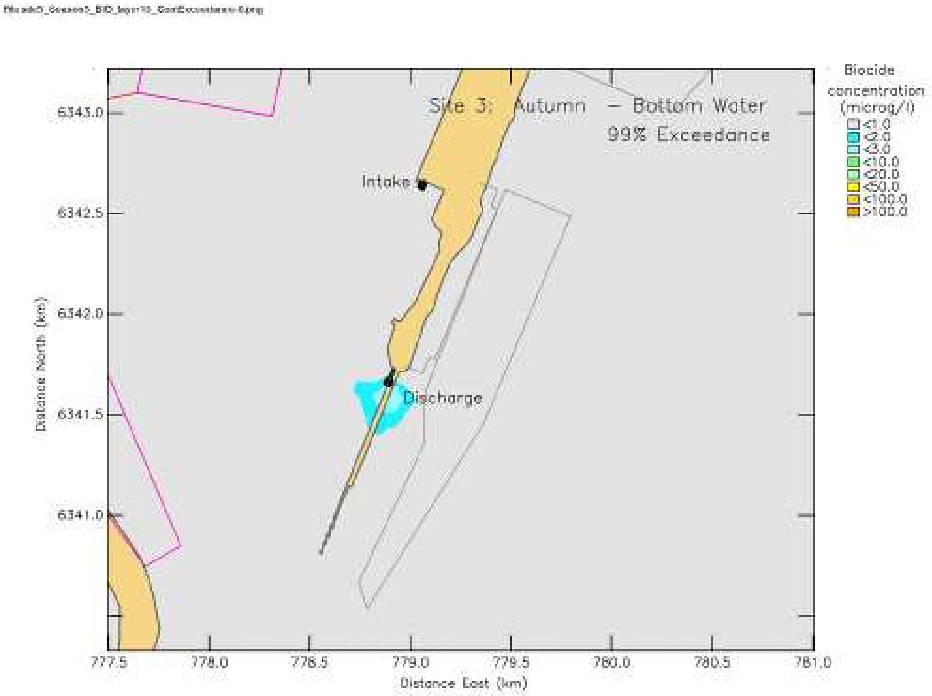

Figure 3.15b: **Site 3 - Caisson 3: 99% exceedance contours of biocide concentration (µg/ℓ) near the seabed during autumn for a +5ºC temperature elevation in the brine discharge.**

3.4 Changes in predicted impacts within an initial mixing zone due to temperature elevations in the discharge brine

There will be changes within a mixing zone of approximately 50 m extent surrounding the discharge locations, however due to limitations in the model resolution, the changes within these mixing zones are less well resolved.

Temperature and salinity differences have been plotted in the immediate vicinity of the discharge and at sites at distances of 50 m and 100 m along the main axis of predicted footprints of the discharge plume as indicated in Figures 3.16 (Site 2) and 3.17 (Site 3 – Caisson 3). The time series parameters reported as being in the immediate vicinity of the discharge location (Figures 3.18 to 3.21) represent spatially averaged values within an approximate 20 to 30 m radius around the discharge.

The model results for both temperature (Figure 3.18) and salinity (Figures 3.19) indicate that there is likely to be a minimum effective 5 times dilution of effluent within the mixing zone at Site 2. At Site 3 (with a discharge at Caisson 3) a minimum effective 10 times dilution of effluent within the mixing zone is indicated (Figure 3.20 and 3.21).

While detailed near field modelling has not been undertaken (or deemed necessary for the purposes of this assessment), such near field dilutions seem reasonable and should be achievable by appropriate engineering design of discharge diffuser systems. This means that any changes within these mixing zones is expected to be limited, *i.e*. a 1ºC temperature elevation of the brine discharge is likely to result in an approximate 0.2ºC and a 0.1ºC elevation in temperatures integrated over the area of the mixing zone of Site 2 and Site 5, respectively.

Temperature elevations of up to 5ºC in the seawater and discharge brine between the intake and discharge locations will not significantly change the predicted thermal impacts and impacts of elevated salinity, biocides (and other co-discharges) beyond an initial “mixing zone”. However there may be significant changes within this zone. This is particularly the case for Site 2 where the dispersion of the plume is more limited (*e.g.* Figure 3.18a). The difference in thermal impacts due to elevations in the temperature of the brine generally are negligible beyond 50 to 100m of the discharge location.

The results also indicate that the elevation in temperature of the brine discharge considered in this study (*i.e*. a maximum increase of 5ºC) is insufficient to change the dispersion behaviour of the plume in the model. The difference between no temperature elevation and a 5ºC temperature elevation in the discharge brine are so small that they cannot be discerned in the plots of salinity and biocides (*e.g*. Figures 3.19a,b,c and 3.21a,b,c where the times series plots for the no temperature elevation and a 5ºC temperature elevation in the discharge brine are so similar that the red lines representing the quantities associated with the zero temperature elevation in the brine are overplotted by the blue lines representing the quantities associated with a 5ºC temperature elevation in the brine discharge and are thus not visible in the plots.

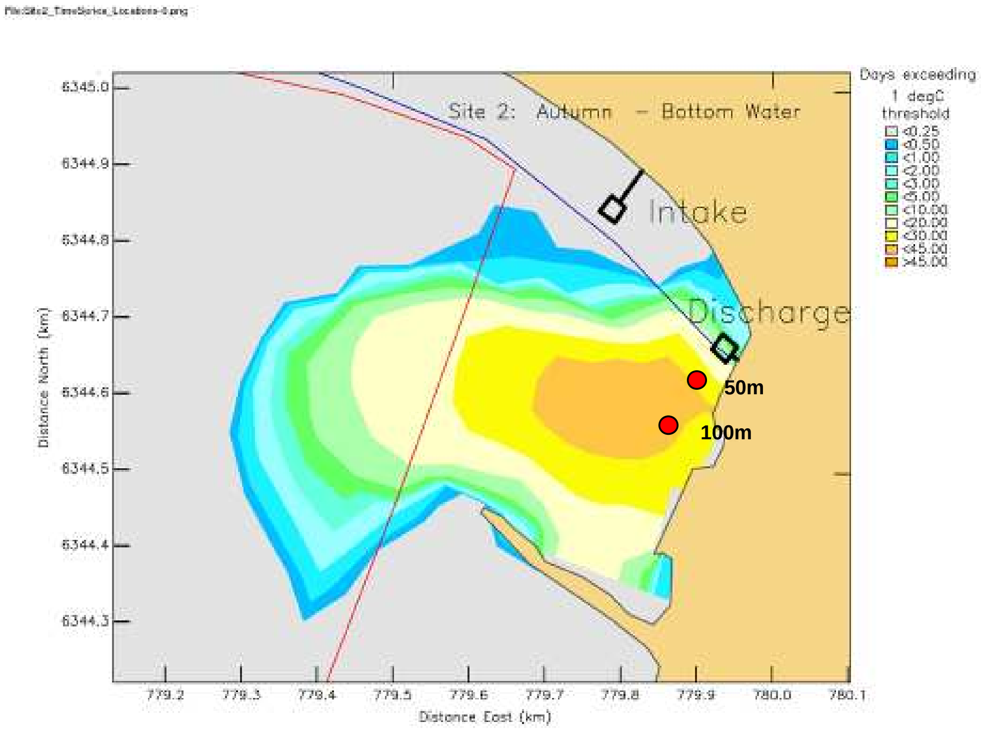

Figure 3.16: **Figure indicating the location of the time series presented in Figures 3.19 and 3.20.**

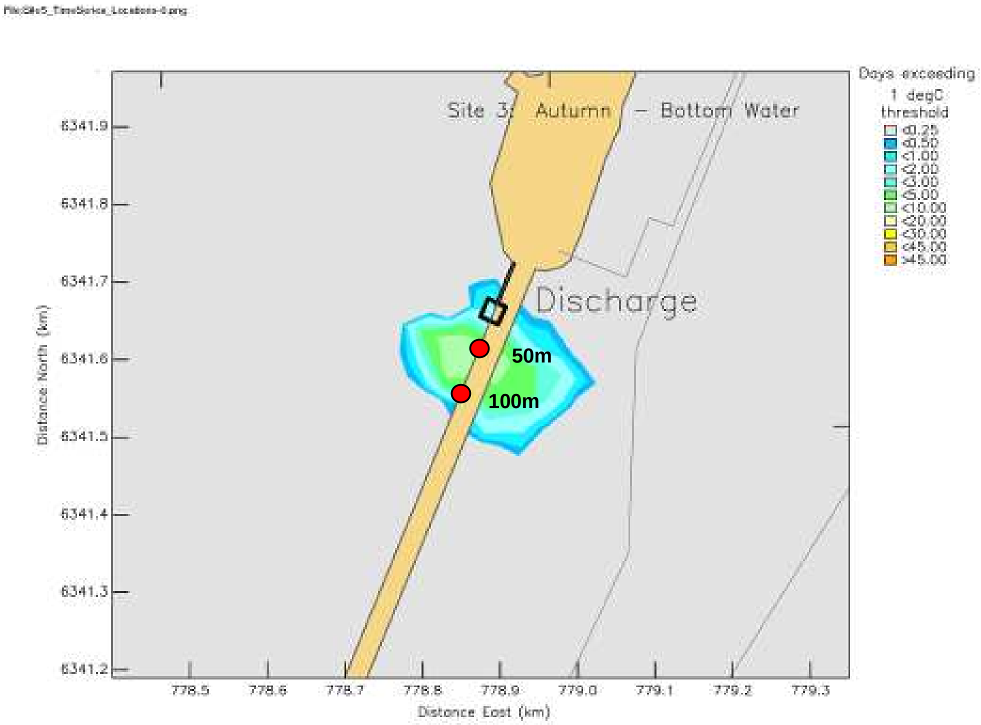

Figure 3.17: **Figure indicating the location of the time series presented in Figures 3.21 and 3.22.**

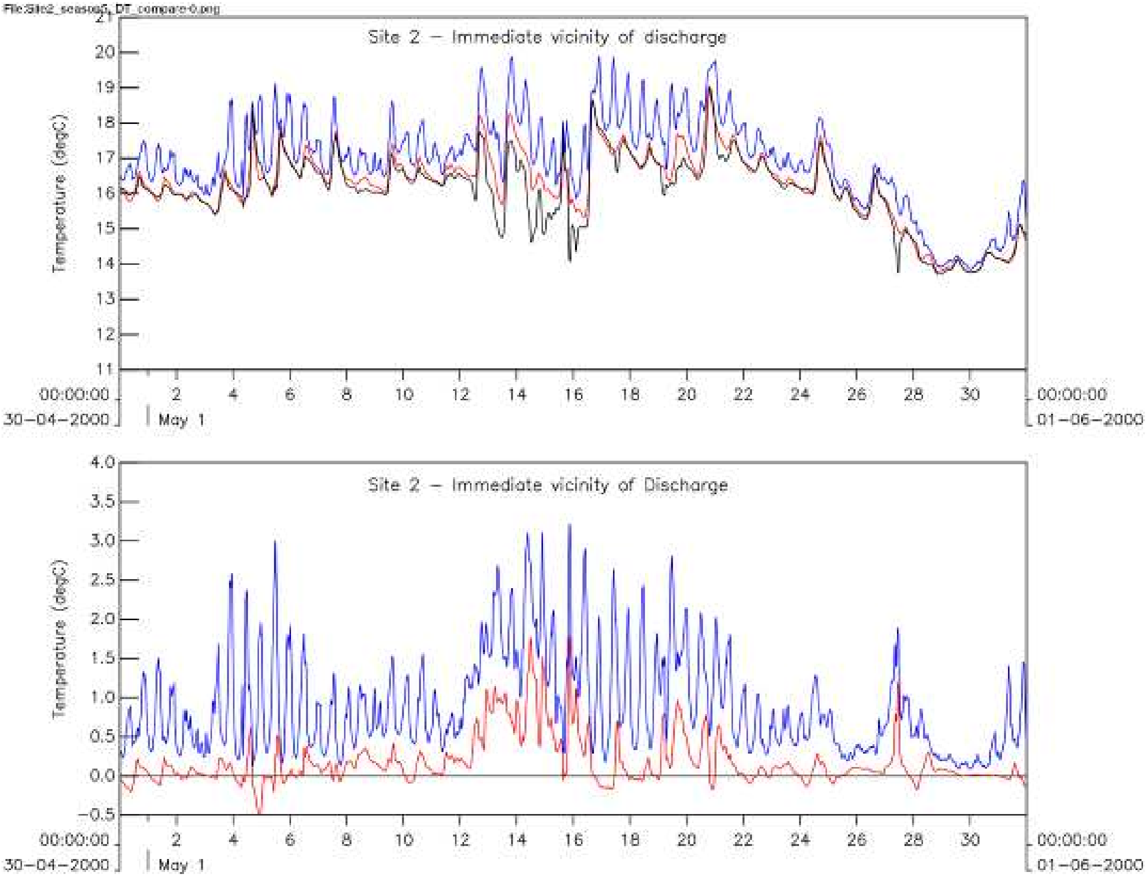

Figure 3.18a: Time series of seawater temperature near the seabed in the immediate vicinity of the discharge at Site 2 during Autumn.

Upper panel: Simulated seawater temperature with:

- **i. with no discharge (black);**
- **ii. a +0ºC temperature rise in the discharge (red), and;**
- **iii. a +5ºC temperature rise in the brine discharge (blue).**

Lower Panel: Simulated seawater temperature differences in the immediate vicinity of the discharge between:

- **i. simulations with a 0ºC temperature rise in the discharge brine and the no discharge simulation (red) and**
- **ii. simulations with a +5ºC temperature rise in the discharge brine and the no discharge simulation (blue).**

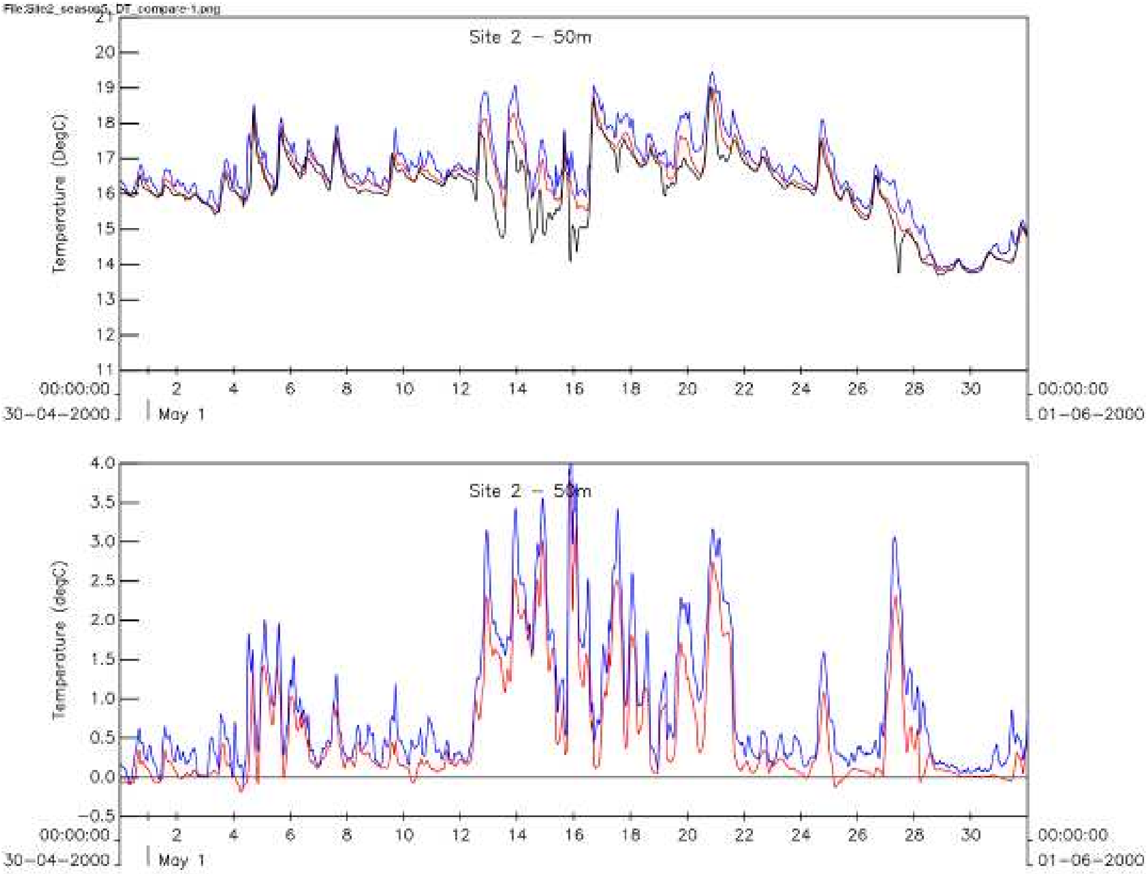

Figure 3.18b: **Time series of seawater temperature near the seabed at a distance of 50 m from the discharge location at Site 2 during Autumn.**

Upper panel: Simulated seawater temperature with:

i. **with no discharge (black);**
ii. **a +0ºC temperature rise in the discharge (red), and;**
iii. **a +5ºC temperature rise in the brine discharge (blue).**

Lower Panel: Simulated seawater temperature differences in the immediate vicinity of the discharge between:

i. **simulations with a 0ºC temperature rise in the discharge brine and the no discharge simulation (red) and**
iii. **simulations with a +5ºC temperature rise in the discharge brine and the no discharge simulation (blue).**

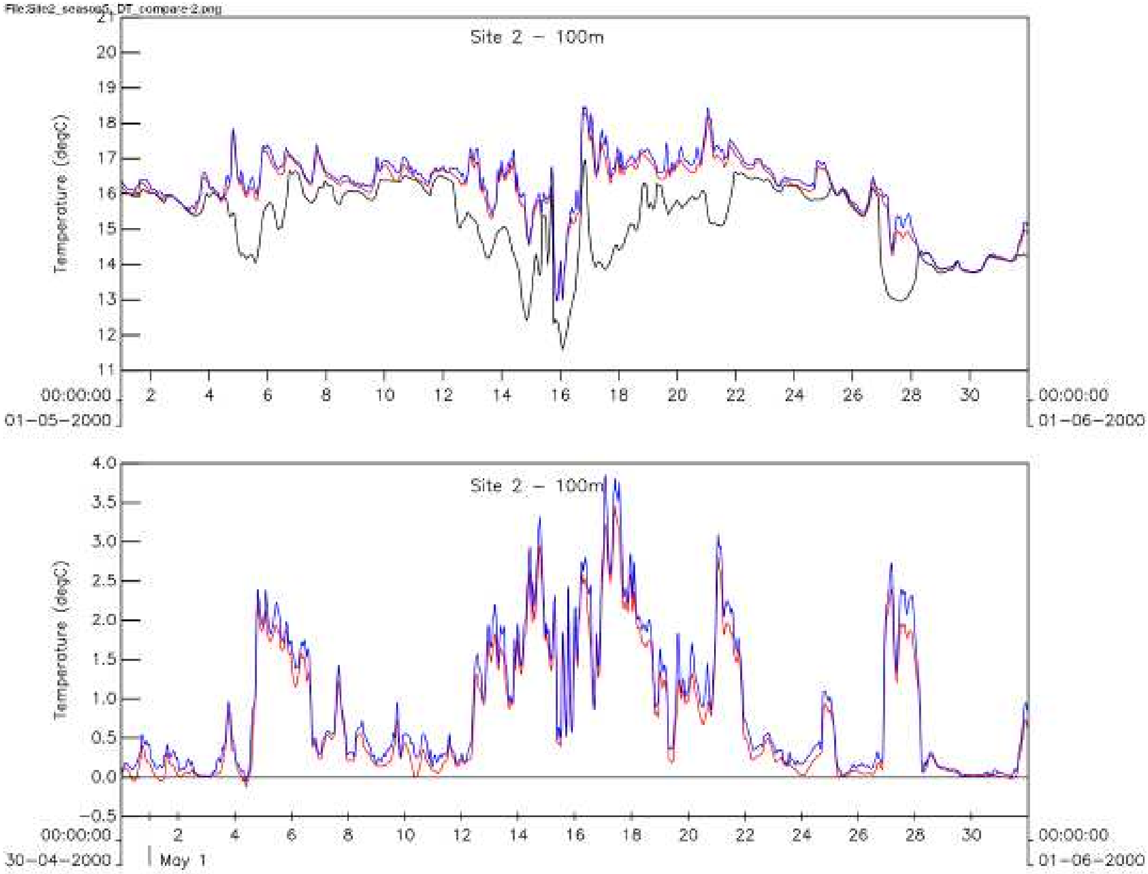

Figure 3.18c: Time series of seawater temperature near the seabed at a distance of 100 m from the discharge location at Site 2 during Autumn.

Upper panel: Simulated seawater temperature with:

- **i. with no discharge (black);**
- **ii. a +0ºC temperature rise in the discharge (red), and;**
- **iii. a +5ºC temperature rise in the brine discharge (blue).**

Lower Panel: Simulated seawater temperature differences in the immediate vicinity of the discharge between:

- **i. simulations with a 0ºC temperature rise in the discharge brine and the no discharge simulation (red) and**
- **ii. simulations with a +5ºC temperature rise in the discharge brine and the no discharge simulation (blue).**

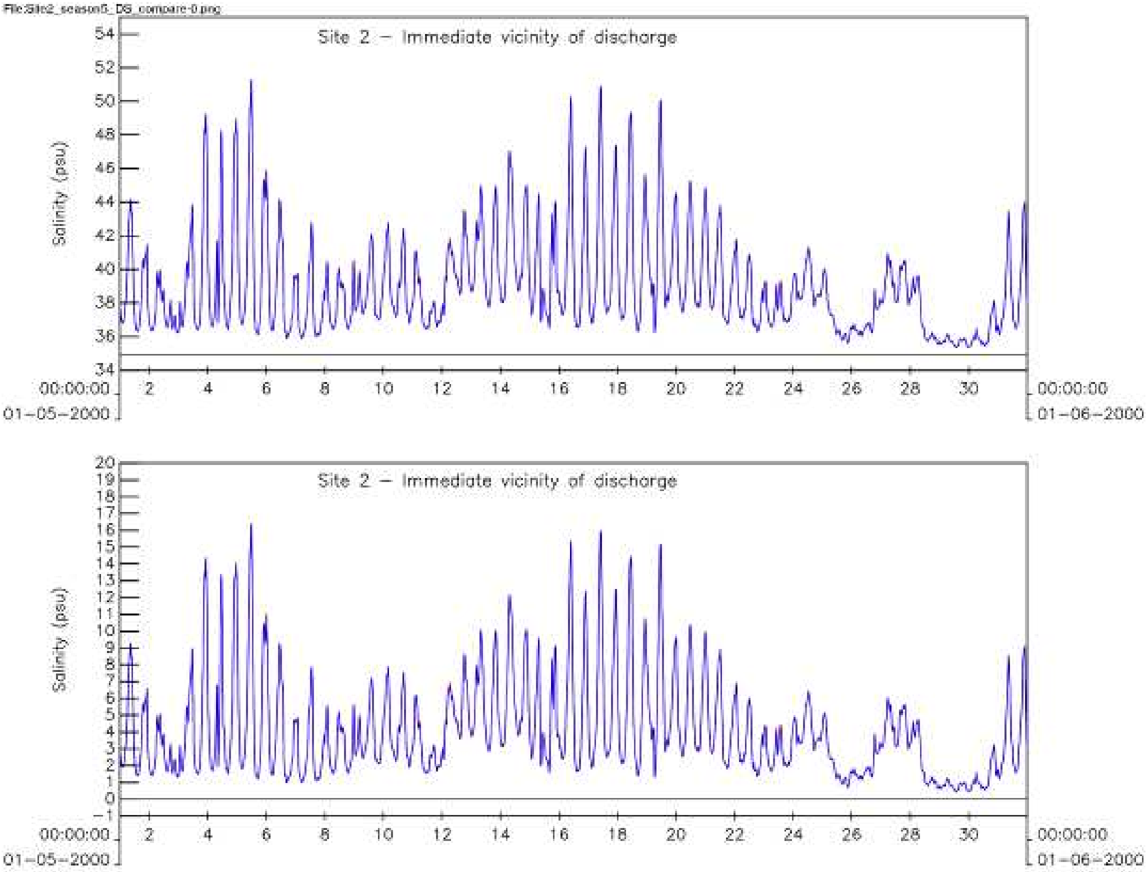

Figure 3.19a: Time series of seawater salinity near the seabed in the immediate vicinity of the discharge at Site 2 during Autumn.

Upper panel: Simulated seawater salinity with:

i. **with no discharge (black);**
ii. **a +0ºC temperature rise in the discharge (red), and;**
iii. **a +5ºC temperature rise in the brine discharge (blue).**

Lower Panel: Simulated seawater salinity differences in the immediate vicinity of the discharge between:

i. **simulations with a 0ºC temperature rise in the discharge brine and the no discharge simulation (red) and**
ii. **simulations with a +5ºC temperature rise in the discharge brine and the no discharge simulation (blue).**

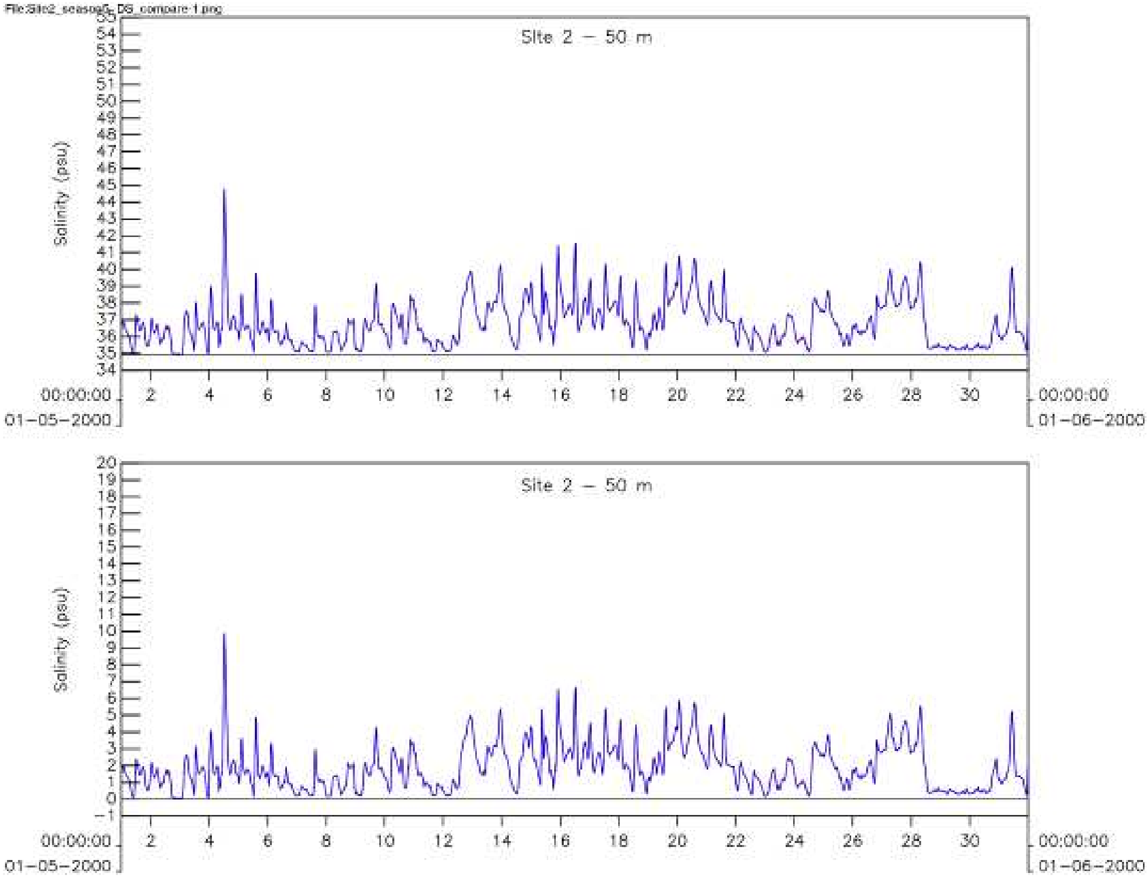

Figure 3.19b: **Time series of seawater salinity near the seabed at a distance of 50 m from the discharge location at Site 2 during Autumn.**

Upper panel: Simulated seawater salinity with:

- i. **with no discharge (black);**
- ii. **a +0ºC temperature rise in the discharge (red), and;**
- iii. **a +5ºC temperature rise in the brine discharge (blue).**

Lower Panel: Simulated seawater salinity differences in the immediate vicinity of the discharge between:

- i. **simulations with a 0ºC temperature rise in the discharge brine and the no discharge simulation (red) and**
- ii. **simulations with a +5ºC temperature rise in the discharge brine and the no discharge simulation (blue).**

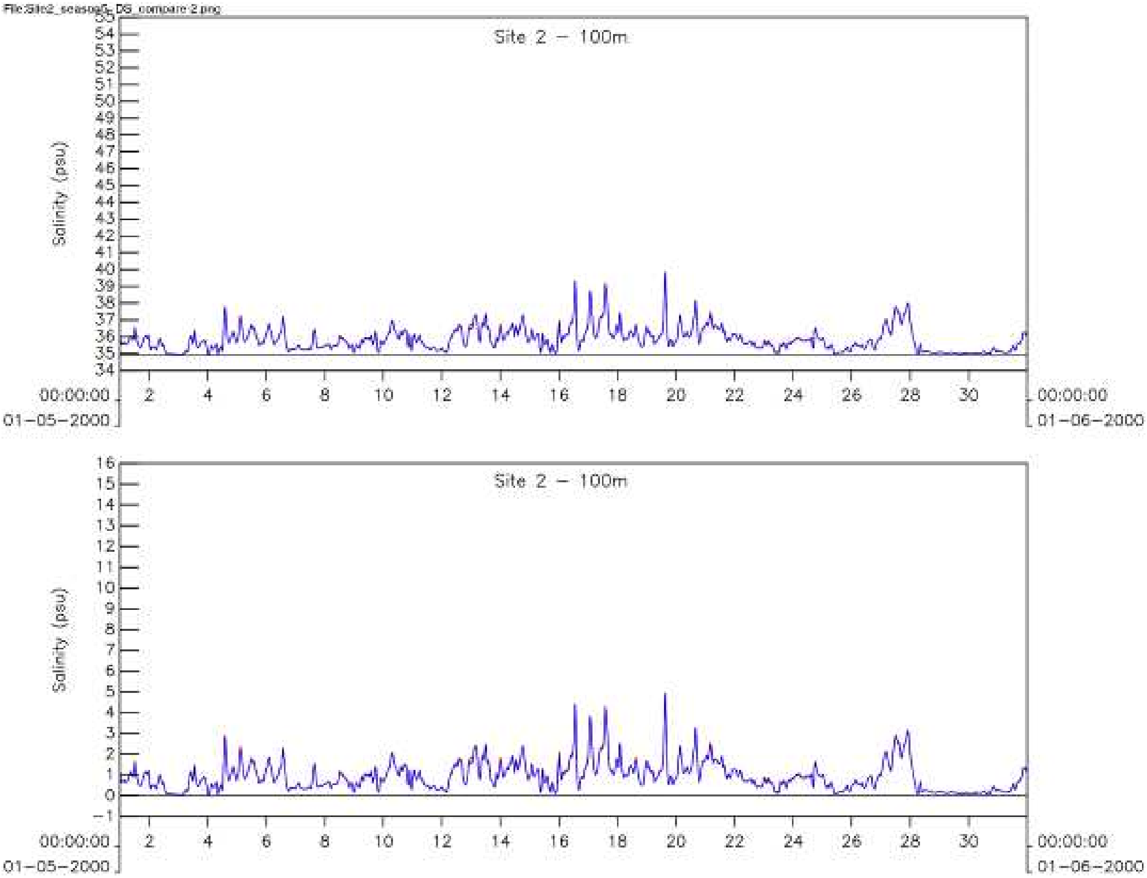

Figure 3.19c: **Time series of seawater salinity near the seabed at a distance of 100 m from the discharge location at Site 2 during Autumn.**

Upper panel: Simulated seawater salinity with:

- **i. with no discharge (black);**
- **ii. a +0ºC temperature rise in the discharge (red), and;**
- **iii. a +5ºC temperature rise in the brine discharge (blue).**

Lower Panel: Simulated seawater salinity differences in the immediate vicinity of the discharge between:

- **i. simulations with a 0ºC temperature rise in the discharge brine and the no discharge simulation (red) and**
- **ii. simulations with a +5ºC temperature rise in the discharge brine and the no discharge simulation (blue)**

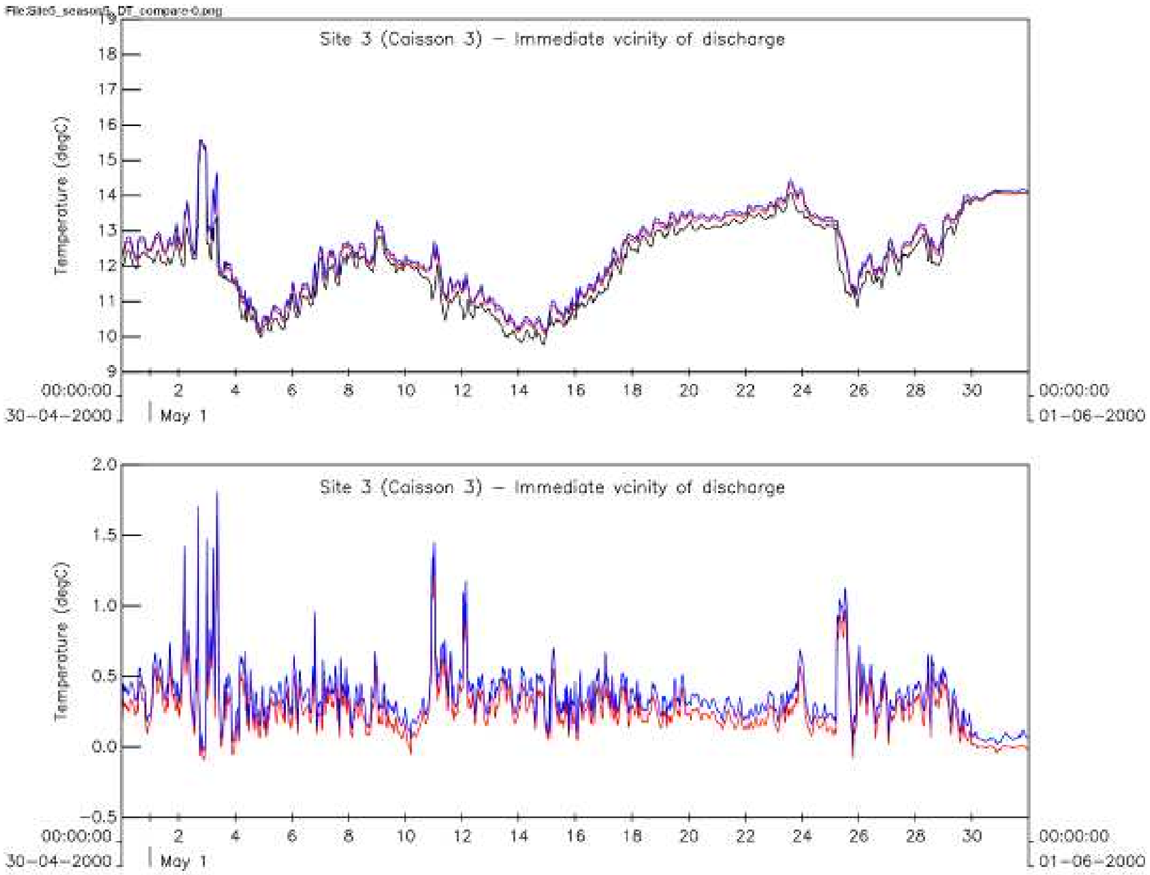

Figure 3.20a: **Time series of seawater temperature near the seabed in the immediate vicinity of the discharge at Site 3 – Caisson 3 during Autumn.**

Upper panel: Simulated seawater temperature with:

i. **with no discharge (black);**
ii. **a +0ºC temperature rise in the discharge (red), and;**
iii. **a +5ºC temperature rise in the brine discharge (blue).**

Lower Panel: Simulated seawater temperature differences in the immediate vicinity of the discharge between:

i. **simulations with a 0ºC temperature rise in the discharge brine and the no discharge simulation (red) and**
ii. **simulations with a +5ºC temperature rise in the discharge brine and the no discharge simulation (blue).**

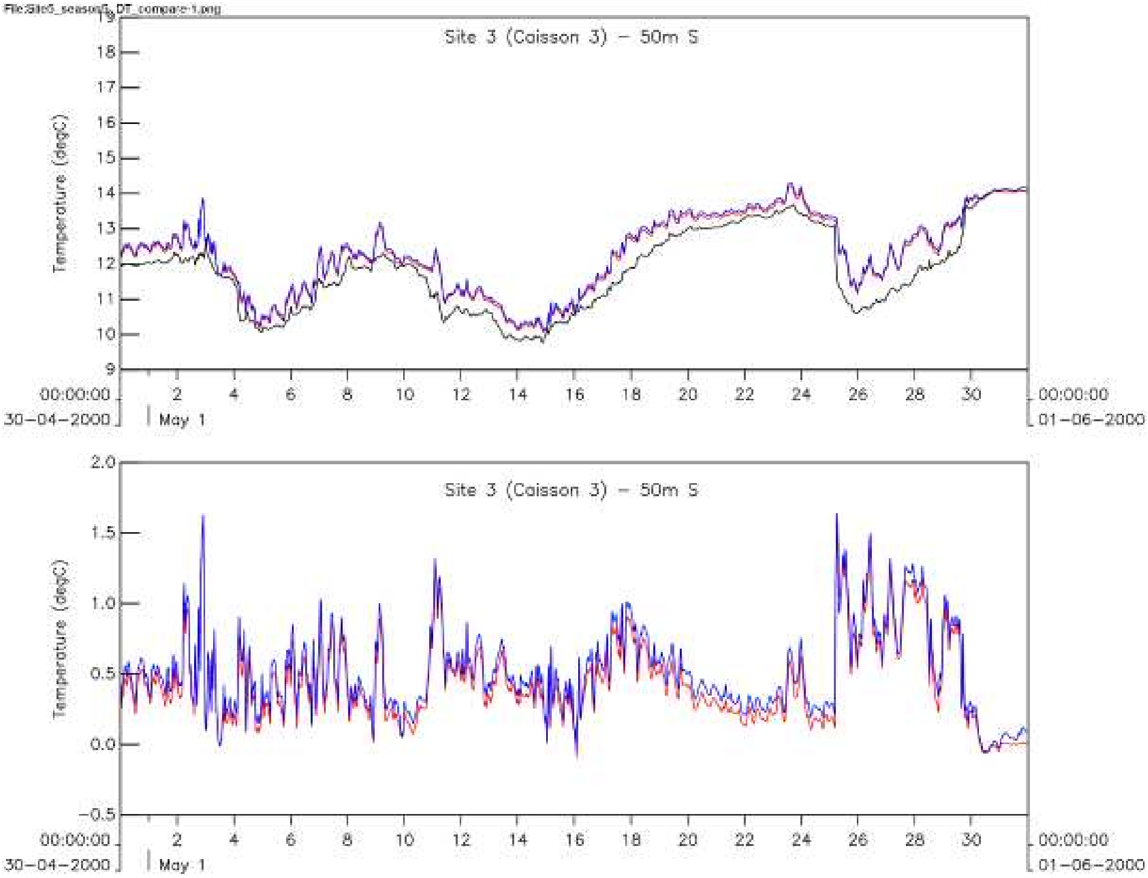

Figure 3.20b: **Time series of seawater temperature near the seabed at a distance of 50 m from the discharge location at Site 3 – Caisson 3 during Autumn.**

Upper panel: Simulated seawater temperature with:

- i. **with no discharge (black);**
- ii. **a +0ºC temperature rise in the discharge (red), and;**
- iii. **a +5ºC temperature rise in the brine discharge (blue).**

Lower Panel: Simulated seawater temperature differences in the immediate vicinity of the discharge between:

- i. **simulations with a 0ºC temperature rise in the discharge brine and the no discharge simulation (red) and**
- ii. **simulations with a +5ºC temperature rise in the discharge brine and the no discharge simulation (blue).**

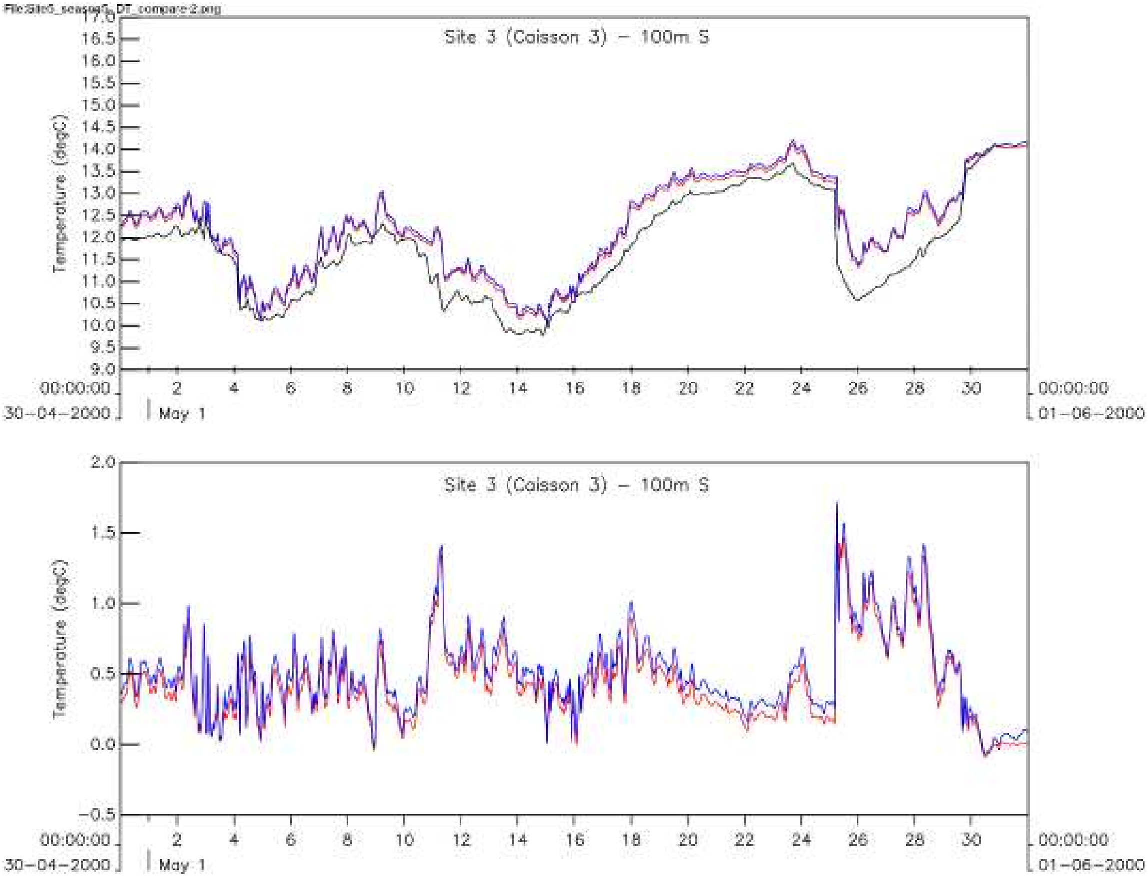

Figure 3.20c: Time series of seawater temperature near the seabed at a distance of 100 m from the discharge location at Site 3 – Caisson 3 during Autumn.

Upper panel: Simulated seawater temperature with:

i. **with no discharge (black);**
ii. **a +0ºC temperature rise in the discharge (red), and;**
iii. **a +5ºC temperature rise in the brine discharge (blue).**

Lower Panel: Simulated seawater temperature differences in the immediate vicinity of the discharge between:

i. **simulations with a 0ºC temperature rise in the discharge brine and the no discharge simulation (red) and**
ii. **simulations with a +5ºC temperature rise in the discharge brine and the no discharge simulation (blue).**

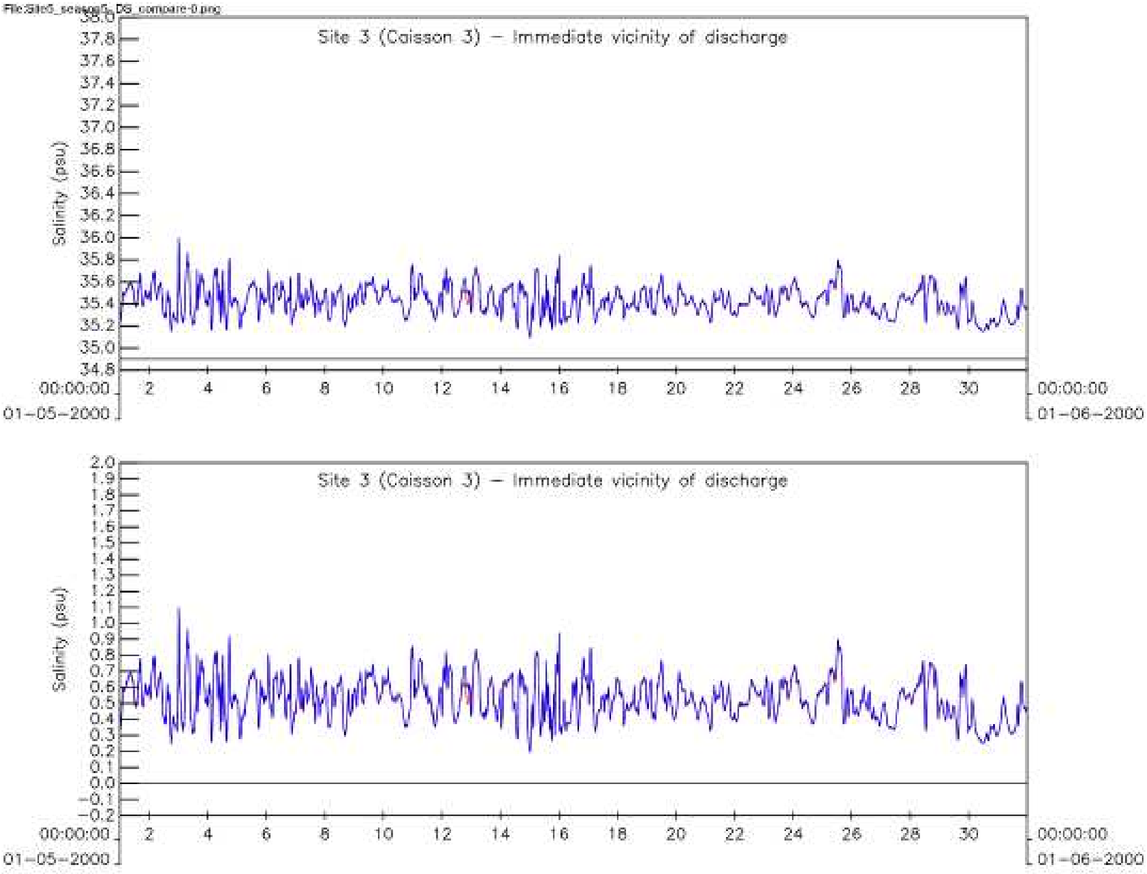

Figure 3.21a: Time series of seawater salinity near the seabed in the immediate vicinity of the discharge at Site 3 – Caisson 3 during Autumn.

Upper panel: Simulated seawater salinity with:

- **i. with no discharge (black);**
- **ii. a +0ºC temperature rise in the discharge (red), and;**
- **iii. a +5ºC temperature rise in the brine discharge (blue).**

Lower Panel: Simulated seawater salinity differences in the immediate vicinity of the discharge between:

- **i. simulations with a 0ºC temperature rise in the discharge brine and the no discharge simulation (red) and**
- **ii. simulations with a +5ºC temperature rise in the discharge brine and the no discharge simulation (blue).**

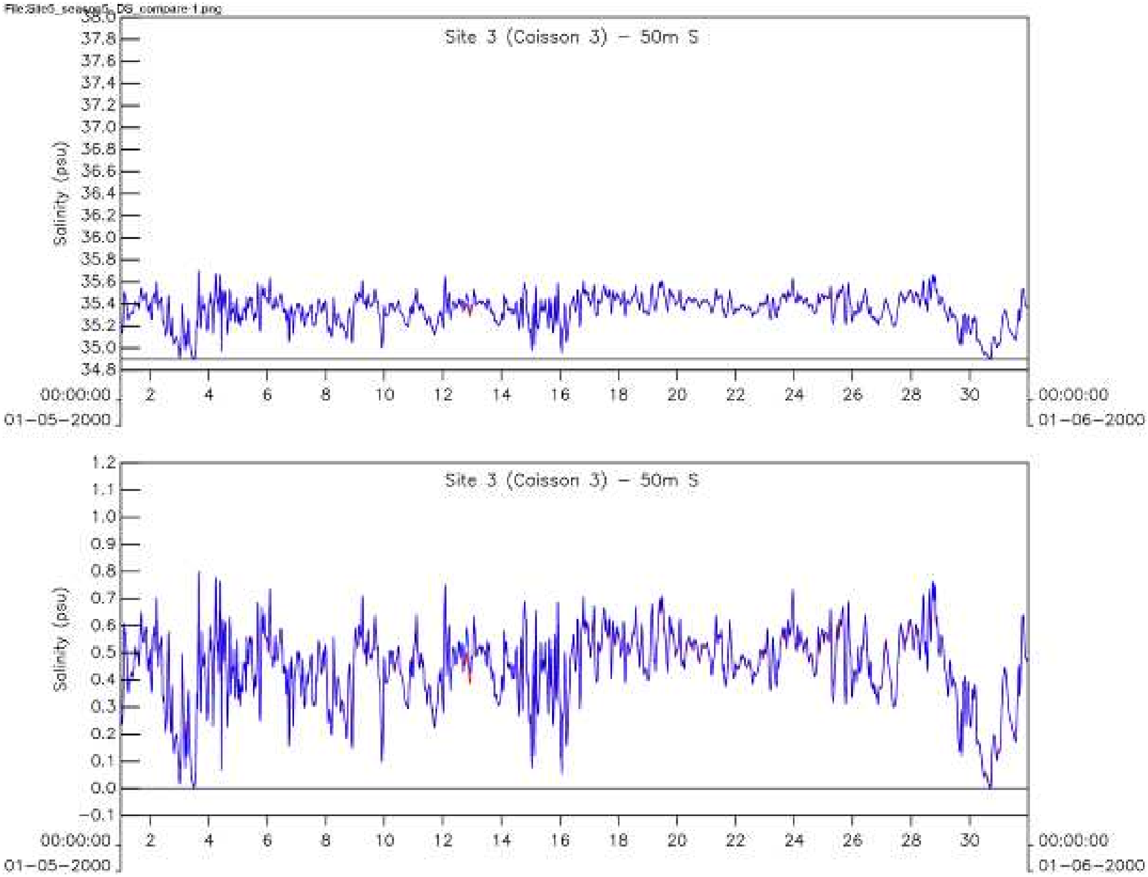

Figure 3.21b: **Time series of seawater salinity near the seabed at a distance of 50 m from the discharge location at Site 3 – Caisson 3 during Autumn.**

Upper panel: Simulated seawater salinity with:

i. **with no discharge (black);**
ii. **a +0ºC temperature rise in the discharge (red), and;**
iii. **a +5ºC temperature rise in the brine discharge (blue).**

Lower Panel: Simulated seawater salinity differences in the immediate vicinity of the discharge between:

i. **simulations with a 0ºC temperature rise in the discharge brine and the no discharge simulation (red) and**
ii. **simulations with a +5ºC temperature rise in the discharge brine and the no discharge simulation (blue)**

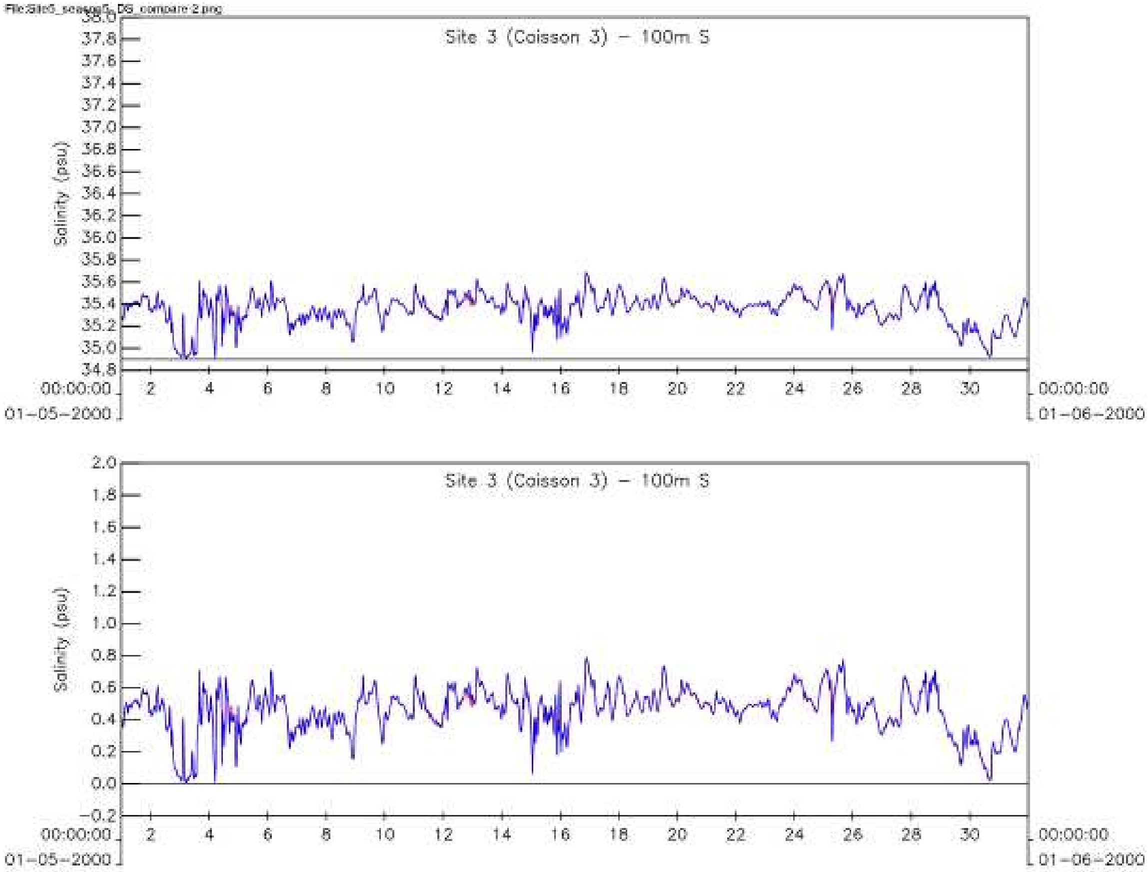

Figure 3.21c: Time series of seawater salinity near the seabed at a distance of 100 m from the discharge location at Site 3 – Caisson 3 during Autumn.

Upper panel: Simulated seawater salinity with:

i. with no discharge (black);
ii. a +0ºC temperature rise in the discharge (red), and;
iii. a +5ºC temperature rise in the brine discharge (blue).

Lower Panel: Simulated seawater salinity differences in the immediate vicinity of the discharge between:

i. simulations with a 0ºC temperature rise in the discharge brine and the no discharge simulation (red) and
ii. simulations with a +5ºC temperature rise in the discharge brine and the no discharge simulation (blue).

4 CONCLUSION

Temperature elevations of up to 5ºC in the seawater and discharge brine between the intake and discharge locations will not significantly change the predicted thermal impacts and impacts of elevated salinity, biocides (and other co-discharges) beyond an initial “mixing zone”. This has been explicitly confirmed (using model simulations) for all seasons for the preferred site (Site 3 with a brine discharge at Caisson 3)

There will be changes within this initial “mixing zone” of approximately 50 m extent surrounding the discharge locations. However, appropriate engineering design of discharge diffuser systems should ensure that even these changes are of limited significance. This is an indicated requirement in the main marine impact assessment specialist study (van Ballegooyen *et al*., 2007). No further specific mitigation measures are required. However, in keeping with the precautionary approach, efforts should be made in the design process to avoid excessive warming of the intake seawaters and/or discharge brine. Certainly the temperature elevation should be limited to the maximum temperature elevation of +5 ºC considered in this assessment.

As the plume behaviours and impact “footprints” of the plume are not significantly different to those indicated in the main report, the ecosystems impacts will also not differ significantly from those reported in the main marine impact assessment report (van Ballegooyen *et al*., 2007). Consequently, no further updating of the impact table presented in the main marine impact assessment report is deemed necessary and the conclusions of the main report remain valid.

This page intentionally left blank

5 REFERENCES

Atkinson, L., Hutchings, K., Clark, B., Turpie, J., Steffani, N., Robinson, T. and A. Duffell-Canham (2006). State of the Bay 2006: Saldanha Bay and Langebaan Lagoon. Technical Report. *Prepared for Saldanha Bay Water Quality Trust*, 93 pp. + Appendices.

Van Ballegooyen, N. Steffani and A. Pulfrich 2007. Environmental Impact Assessment: Proposed Reverse Osmosis Plant, Iron –ore Handling Facility, Port of Saldanha - Marine Impact Assessment Specialist Study, Joint CSIR/Pisces Report, CSIR/NRE/ECO/ER/2007/0149/C, 184pp + 198pp App (Draft).

This page intentionally left blank