AdelaideAqua
D&C Consortium

Adelaide Desalination Project (ADP) – DBOM

Report – Intake and Outfall Systems Environmental Performance Summary

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GLOSSARY

Term	Description
ADP	Adelaide Desalination Plant
Ambient	Natural regional salinity levels
ANZECC	Australian and New Zealand Environment and Conservation Council
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
Benthic Community	A community of organisms living in or on the seabed.
Biofouling	The overgrowth or algae, marine invertebrates, and other organisms on nets, intake pipes, and structures in the water.
Clean In Place (CIP)	The general term for the in situ cleaning of the reverse osmosis and ultrafiltration membranes and process based equipment.
DAC	South Australian Development Assessment Commission
Diffuser	An engineered structure designed to release the flow of saline concentrate into the receiving seawater with sufficient velocity and momentum to mix and disperse the brine rapidly and effectively.
Dodge	Local South Australian term for a neap tide with minimal rise and fall generally over the course of 24-48 hours.
Ecotoxicity	A study of the harmful effects of chemical compounds on species, population and the natural environment.
EDTA / SDS	Ethylenediaminetetraacetic acid / sodium dodecyl sulfate
EIS	Environmental Impact Statement
Far Field	Whole of Gulf St Vincent
GSV	Gulf St Vincent
Hydrodynamic modelling	A computer model that simulates the water movements, speeds, densities, temperatures and the effects of tidal and wind influences, used to predict salinity movement and dispersion through the receiving seawater.

Term	Description
IC_{10}	The concentration that inhibits an endpoint by 10 %. It represents a point estimate of a concentration of test material that causes a designated percent inhibition (p) compared to the control. The IC_{10} is usually expressed as a time-dependent value, e.g. 24-hour IC10 is the concentration estimated to cause an effect on 10% of the test organisms after 24 hours of exposure.
Initial Dilution	Impact point dilution at the seabed as defined by the Roberts equation, without consideration of salinity dispersion effects over time.
Intake System	Means the infrastructure which conveys fresh seawater to the process plant. Comprises the Intake Structure, Intake Conduit, Intake Pumping Station and Intake Pipeline.
Intertidal Reef Zone	The area between the high and low water mark of a spring tide. It is defined as the rocky platform, approximately 100m in width running along the section of coastline adjacent to the Port Stanvac oil refinery.
Mid Benthic Zone	The marine area between the depths of 12 and 18 metres that is broadly defined by large areas of bare sand
Mid Field	Greater than 100 m but less than 10km from the outfall diffuser
Minister's Conditions of Approval	In approving a major project, the Minister for Planning sets conditions that must be complied with in the design, construction and operational phases of a project. These conditions are set out in the South Australian Government Gazette. The final authorisation for the Adelaide Desalination Plant and conditions of approval was set out in the *Gazette* on 12 March 2009.
MSL	Mean Sea Level
Near Field	Within 100m from the outfall diffuser.
NOEC	The highest observed concentration of a toxicant used in a toxicity test that does not exert a statistically significant adverse effect ($P > 0.05$) on the exposed population of test organisms compared to the controls. This is estimated by hypothesis based statistical methods and is therefore not a point estimate.
Outfall System	Means the infrastructure which conveys Saline Concentrate from the Process Plant through the Outfall Conduit to the Sea. Comprises the outfall shaft, outfall tunnel, riser shafts and diffuser system.
PLC	Program Logic Controller
Protective concentrations (PC)	The concentration predicted by species sensitivity distribution methods that will protect a chosen percentage of species from experiencing toxic effects. For example, the PC99 should protect 99% of species in the ecosystem being considered.

Term	Description
ppt	Parts per thousand, expressed as a mass unit as grams of solute (e.g. salt) in kilograms of solution
Roberts' Equations	A set of experimentally derived design formulae that represent best practise design formulae for predictions of impact point dilution of inclined dense jets into stationary environments.
RO Permeate	Desalinated water from RO membranes that has not been dosed with any post-treatment chemicals.
Safe dilution factors	The concentration that a chemical or discharge must be diluted by in order to meet a selected PC value. The lower the PC value the higher the dilution factor must be to protect the selected percentage of species.
Saline Concentrate	A liquid by-product of the desalination process that has a higher concentration of suspended and dissolved materials (particularly salt) than intake seawater due to the salt concentrating effect of the reverse osmosis system.
Subtidal Reef Zone	The area defined as the medium to low profile reef that extends from the low water mark to a depth of approximately 12 metres.
Slack Tides	Period of minimal tidal movement, occurring at the turn of the tide.

1 Introduction

The primary purpose of the Adelaide Desalination Plant is to deliver a climate independent supply of 100 billion litres of potable water per year, to secure and diversify metropolitan Adelaide's water supply system and offset reduced reservoir inflows from the Mt Lofty Ranges and Murray-Darling Basin.

The Adelaide Desalination Project was granted Major Development status by the South Australian Government on 17 April 2008, which triggered a comprehensive and coordinated assessment process culminating in the publication of an Environmental Impact Statement (EIS) for community comment. The project proponent, SA Water, produced a Response document to address all community concerns and Development Approval was granted in March 2009 by the Minister for Urban Development and Planning. The Minister's Conditions of Approval (gazetted Development Authorisation Conditions) and the EIS define specific environmental conditions to be achieved in the design, construction and operation of the plant.

The Adelaide Desalination Project design and construct contract was awarded to AdelaideAqua D&C consortium in February 2009. Construction commenced in April 2009 and delivery of first water will be in December 2010. It is expected that the plant will be fully operational in late 2012.

The plant is required to have a production capacity of 300ML/day. Due to variations in seawater salinity and temperature, and depending on plant operating conditions, the plant can produce up to 326ML/day.

The plant will include the following key elements:

- A seawater intake structure and connecting tunnel/s and pipelines;
- Intake pumping station and screening system;
- Pre-treatment system and associated buildings;
- Reverse osmosis treatment system and associated buildings;
- Post-treatment system and associated buildings;
- An outfall structure with diffusers and connecting tunnel/s and pipelines;
- Waste treatment area, including solids thickening and dewatering.

In addition, the Desalination Project will include:

- Transfer pump station for pumping desalinated water to the Happy Valley Water Treatment Plant. This pump station is not part of the Major Development assessment process and has been subject to a separate assessment under Section 49 (Crown Development) of the Development Act 1993;
- Dedicated areas for unloading and storage of chemicals associated with the Plant;
- Electrical substation, power cabling and switchgear for distributing power within the site;
- Energy recovery facility for the saline concentrate prior to its discharge to the Gulf St Vincent;
- Site access roads, internal access roads and parking areas;
- Stormwater management infrastructure and other buried services across the site;
- Site offices and administration buildings, control rooms, laboratory, research and development test facility, and a visitor education/interpretive centre; and

- Site landscaping, lighting and security fencing across the site.

One key aspect of the ADP is the requirement for the Intake and Outfall Systems to meet specified performance criteria for design, construction and operation to ensure that environmental protection objectives are achieved.

The Environmental Impact Statement and subsequent Response document (EIS – SA Water 2008) presented during the Major Development Approval process for the Adelaide Desalination Plant (ADP) was based on a concept design with specific environmental and engineering performance criteria. The environmental and engineering performance objectives established by SA Water (EIS – SA Water 2008 – Table 3.1) and the Minister's Conditions of Approval (Development Authorisation Conditions Gazetted June 2009) provide the functional requirements for AdelaideAqua D&C Consortium (AA) detailed design.

This report summarises the technical investigations and detailed design carried out to confirm that the performance criteria of the Intake and Outfall Systems are in compliance with the ADP EIS (SA Water 2009) and Development Authorisation Conditions (June 2009, pg 2707-2708).

The purpose of this report is to:

- Identify the legislative and contractual requirements for the intake and outfall systems of the ADP
- Demonstrate that the specified requirements for design and performance are met
- Recognise the over-arching requirement to not "pollute the environment in a way that causes or may cause environmental harm (DA Conditions, June 2009, pg 2708)
- Discuss the potential operational licence conditions
- Summarise and present key information contained within the various appendices

This report must be read in conjunction with the following documents included in the appendices.

- Adelaide Desalination Plant Outfall Dilution Modelling Assessment November 2009
- Adelaide Desalination Plant Duckbill Valve Hydraulic and Dilution Performance Investigations October 2009
- Ecotoxicity Evaluation of Adelaide Desalination Plant Effluent and Process Chemicals November 2009
- Clean-In-Place (CIP) Ecotoxicity Assessment Report Document Reference E015-020-2974 2009
- Outfall Infrastructure Diffuser Extension – Concept Paper. November 2009
- Diffuser Selection Report – December 2009

2 Environmental Objectives and Performance Criteria

2.1 Conditions of Development Authorisation Gazetted 11th June 2009 (DA Conditions)

Table 1: Intake and Outfall Conditions of Development Authorisation

Criteria	Criteria Achieved	Statement of Compliance	Report Reference
Intake Structure – Condition 9 The proponent shall design, construct and operate the intake infrastructure in accordance with design parameters provided in the Environmental Objectives and Performance Criteria (or as modified by the EPA through licensing requirements) including the following parameters:			
a) location of the intake structure must be within the mid to deep benthic zone (Figure 2);	Yes	Location of intake structure is within the mid benthic zone	3.2 Intake Location
b) Intake structure to be located at a sufficient distance from the subtidal reef area to minimise the risk of entrainment or entrapment of reef species;	Yes	intake structure is approximately 700m from the subtidal reef zone	3.3 Subtidal Reef and Figure 2
c) seawater intake velocity at the entry to the intake structure should not exceed 0.15 m/s under any operating condition;	Yes	Maximum Intake velocity does not exceed 0.15m/s.	3.4 Intake Velocity
d) seawater intake to incorporate screen/grill to restrict ingress of marine biota with a maximum clear grill spacing of 75 millimetres (as installed); and	Yes	The intake screen's clear grill spacing is 75mm.	3.5 Intake Grill
e) Any chlorination (or approved biocide) dosing system from the intake structure must ensure that there is no backflow of chemical dosing into the marine environment.	Yes	The chemical dosing system is located to prevent backflow into the marine environment.	3.6 Chemical Dosing System

Criteria	Criteria Achieved	Statement of Compliance	Report Reference
In addition to the above performance criteria, the proponent shall design the intake infrastructure as follows (or as modified by the EPA through licensing requirements): f) Installation of the full tunnel option (and not the hybrid tunnel option) for the intake and outfall infrastructure.	Yes	Both intake and outfall systems are full tunnels.	3.7 Full Tunnel Option
Outfall Structure – Condition 10 The proponent shall design, construct and operate the outfall infrastructure in accordance with design parameters provided in the Environmental Objectives and Performance Criteria (or as modified by the EPA through licensing requirements) including the following parameters:			
a) location of the outfall structure must be positioned within the envelope zone shown in Figure 2 and far enough from the intake to avoid any short circuiting;	Yes	Outfall structure located within designated envelope, and distance from intake sufficient to avoid short circuiting.	4.2 Outfall Location
b) the outfall system must terminate with diffusers designed to promote rapid dispersion of the saline concentrate into the surrounding seawater;	Yes	Duckbill valves have been utilised to promote rapid dispersion of saline concentrate.	4.3 Outfall – Diffuser Design
c) the outfall must achieve the required initial dilution of 50:1 at the seabed, under all current scenarios for the full range of operating conditions/flows;	Yes	Design achieves initial dilution of at least 58:1 under all current and plant flow scenarios to account for the higher process recovery rate.	4.4 Outfall – Initial Dilution
d) the design of the outfall system should include consideration of the use of bypass flows or other measures to ensure the achievement of the target dilution requirements, particularly under low discharge flows;	Yes	Bypass system is provided to ensure initial dilution achieved during low discharge flows.	4.5 Outfall – Bypass System

Criteria	Criteria Achieved	Statement of Compliance	Report Reference
e) the outfall diffuser shall be capable of: o being extended; and o being modified to reduce the number of diffuser outlets and/or to adjust dispersion rates from each diffuser outlet; and	Yes	Outfall diffuser system has been designed to be capable of being extended and modified to adjust dispersion rates from each diffuser outlet.	4.6 Outfall – Diffuser Modifications
f) The saline concentrate discharge must not contain Cleaning in Place (CIP) chemicals or any other preservation chemicals, unless permitted by the EPA through licensing requirements.	Yes	Discharge of CIP via the outfall will only be incorporated if permitted by the EPA	4.7 Outfall – Clean In Place (CIP)

2.2 ADP Environmental Impact Statement (EIS)

The Intake and Outfall Systems Environmental Objectives and Performance Criteria prescribed in Table 3.1 ADP EIS and Response document (SA Water 2008) (Appendix 5) is summarised below:

Table 2: Intake and Outfall Conditions of the ADP Environmental Impact Statement 2008

Criteria	Criteria Achieved	Statement of Compliance	Report Reference
Intake Structure Design and operation to ensure:			
a) Location of the intake structure must be within the mid benthic zone (Figure 2).	Yes	Location of intake structure is within the mid benthic zone	3.1 Intake Design Overview 3.2 Intake Location
b) Intake structure to be located at a sufficient distance from the subtidal reef area to minimise the risk of entrainment or entrapment of reef species.	Yes	Intake structure is approximately 700m from the subtidal reef zone	3.2 Intake Location 3.3 Subtidal Reef
c) Location of the seawater intake structure at a height above the seabed to minimise the risk of entrainment of sediment or floating debris.	Yes	Intake structure located 8m above the seabed, and 12m below mean sea level.	3.2 Intake Location Figure 1

Criteria	Criteria Achieved	Statement of Compliance	Report Reference
d) Seawater intake velocity at the entry to the intake structure should not exceed 0.15m/s under any operating condition	Yes	Maximum Intake velocity does not exceed 0.15m/s	3.4 Intake Velocity
e) Seawater intake to incorporate screen/grill to restrict ingress of marine biota with a maximum clear grill spacing of 75 millimetres (as installed).	Yes	The intake screen's clear grill spacing is 75mm.	3.5 Intake Grill
f) Any chlorination (or approved biocide) dosing system from the intake structure must ensure that there is no backflow of chemical dosing into the marine environment.	Yes	The chemical dosing system is located to prevent backflow into the marine environment.	3.6 Chemical Dosing System
g) Develop and implement a monitoring program (as part of the Operational Environment Management and Monitoring Plan) in accordance with Major Development approval and EPA licence, including: o Monitoring and reporting on entrainment on marine biota.	Yes. Under development	Operational Management and Monitoring Program will be developed in accordance with license conditions for plant operation and maintenance phase	5.1 Proposed Operational Monitoring
Outfall Structure The saline concentrate discharge must comply with EPA licence conditions and any other regulatory requirements. Design and operation to ensure:			
a) The outfall structure must be positioned within the envelope zone shown in Figure 2 and far enough from the intake to avoid any short circuiting.	Yes	Outfall structure located within designated envelope, and distance from intake sufficient to avoid short circuiting	4.1 Outfall Design Overview 4.2 Outfall Location

Criteria	Criteria Achieved	Statement of Compliance	Report Reference
b) The outfall system must terminate with diffusers designed to promote rapid dispersion of the saline concentrate into the surrounding seawater.	Yes	Duckbill valves have been utilised to promote rapid dispersion of saline concentrate	4.3 Outfall – Diffuser Design
c) The outfall must achieve the required initial dilution of 50:1 at the seabed, or as otherwise agreed with the EPA, under all current scenarios for the full range of operating conditions / flows.	Yes	Design achieves initial dilution of at least 58:1 under all current and plant flow scenarios to account for the higher process recovery rate.	4.4 Outfall – Initial Dilution
d) The design of the outfall system should include consideration of the use of bypass flows or other measures to ensure the achievement of the target dilution requirements, particularly under low discharge flows.	Yes	Bypass system is provided to ensure initial dilution achieved during low discharge flows.	4.5 Outfall – Bypass System
e) The outfall diffuser shall be capable of: o being extended; and o being modified to reduce the number of diffuser outlets and/or to adjust dispersion rates from each diffuser outlet.	Yes	Outfall diffuser system has been designed to be capable of being extended and modified to adjust dispersion rates from each diffuser outlet	4.6 Outfall – Diffuser Modifications
f) The saline concentrate discharge must not contain Cleaning in Place (CIP) chemicals or any other preservation chemicals, unless permitted by the regulatory authorities.	Yes	Discharge of CIP via the outfall will only be incorporated if permitted by the EPA	4.7 Outfall – Clean In Place (CIP)

Criteria	Criteria Achieved	Statement of Compliance	Report Reference
• Ecotoxicity testing (Direct Toxicity Assessment) of the saline concentrate, with representative process chemicals, should be undertaken to confirm species sensitivity and the dilution requirements to protect 95% of species (in accordance with ANZECC guidelines slight to modified ecosystems).	Yes	Ecotoxicity assessment of saline concentrate and representative chemicals has been undertaken to confirm species tolerance and dilution requirements	4.9 Outfall – Ecotoxicity
• Develop and implement an Operational Environmental Management and Monitoring Plan that incorporates a monitoring program in accordance with the Major Development approval and EPA licensing requirements. The monitoring program shall include: o process monitoring to confirm that performance is within acceptable range (as supported by environmental assessments); o discharge water quality monitoring; o diffuser performance validation; and o Habitat / receiving environment monitoring and water quality.	Yes. Under Development	Operational Management and Monitoring Program will be developed in accordance with license conditions for plant operation and maintenance phase	5.1 Proposed Operational Monitoring
• Demonstrate through modelling and field measurements that the outfall design system achieves the required mixing and dispersion requirements.	Yes	Near-field, mid-field and far-field modelling have been undertaken to demonstrate mixing and dispersion of the outfall structure	4.8 Outfall – Modelling

Each of the above conditions for the Intake and Outfall Systems are addressed in the following sections.

3 Intake Structure

3.1 Intake Design Overview

The intake riser will be connected into the intake tunnel which extends 1.4km from the tunnel shaft onshore, to bring seawater into the desalination plant. The riser shaft extends vertically 20m from the tunnel, and is connected to the intake structure head at the seabed. The intake structure head extends approximately 8m above the seabed and is 12m below mean seawater level (MSL). The design of the Marine Intake Head structure incorporates (refer to Figure 1):

- A base stem or shaft of 5.4m internal diameter that encompasses the Intake Riser. This section of the intake structure is located below the seabed;
- A 9.5m internal diameter seawater intake head sits on the base stem. The cylindrical head structure has eight equal openings through which seawater is drawn in;
- The eight equal openings are covered with a cupronickel grill structure having 75mm clear spacing between the grills. The presence of these grills on the intake head are intended to minimise the ingress of marine fauna; and
- The intake structure is surrounded by rock armour to prevent erosion of the seabed around the intake head and to provide additional support and protection to the base stem.

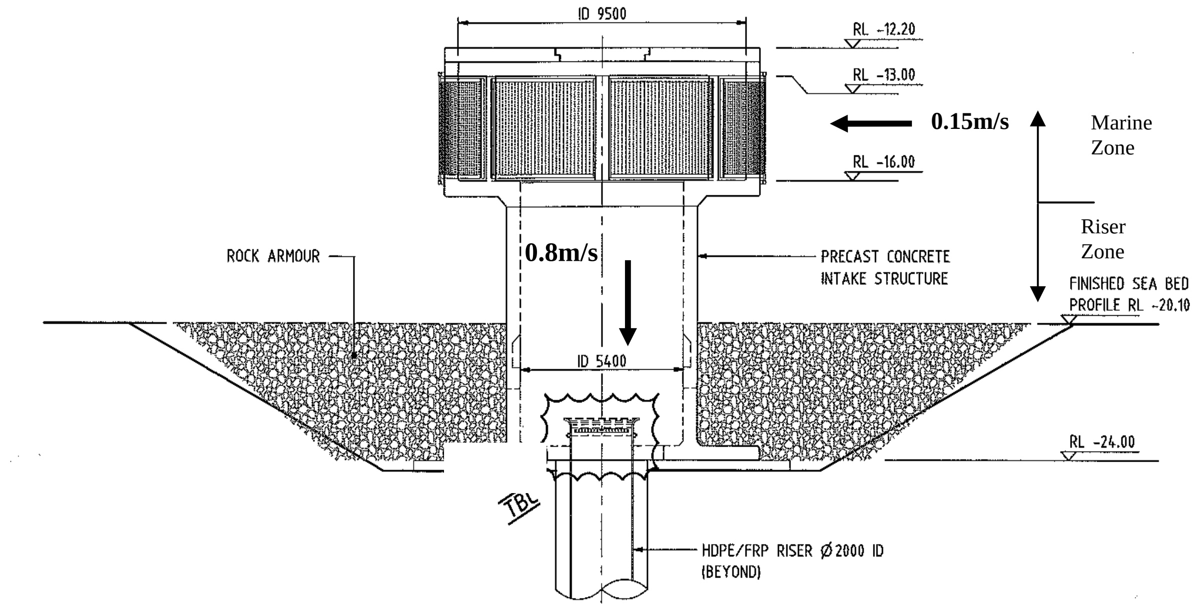

Figure 1: Intake Structure Diagram

3.2 Intake Location

The intake structure is located 1.2km offshore, within the mid benthic zone (Figure 2) and the marine exclusion zone defined in the Notice to Mariners No. 43 of 2009.

The distance between the intake structure and the offshore outfall diffuser is approximately 300m, and thus minimises the potential for direct recirculation of diluted saline concentrate from the outfall diffusers. The intake location also provides sufficient clear water depth under all operating conditions to prevent ingress of surface contaminants, approximately 12m below mean sea level. The intake location is 8m above the seabed to minimise the risk of entrainment of sediment.

Figure 2: Location of Intake and Outfall Structures Within the Mid Benthic Zone, and Designated Envelope Zone.

3.3 Subtidal Reef

The intake structure is located approximately 700 metres from the nearest subtidal reef (Figure 2). The benthic community in the immediate vicinity of the intake is characterised as bare sand interspersed with red macroalgae and a mixed invertebrate community (DEH 2008).

3.4 Intake Velocity

The intake structure is designed to have a maximum operating seawater inflow of 7.77m^3/s.

The net area of the intake structure, based on 8 screens comprising 36 slots 75mm wide and 3m high is 64.8m^2. To take into consideration the potential for marine growth to reduce the net area of the intake structure, the intake velocity calculation considered a reduced area of 80% of the actual area. Maximum velocity is calculated by maximum flow / area, which equals 0.15m/s. Therefore the intake velocity will not exceed 0.15m/s.

The intake velocity is illustrated in Figure 1.

3.5 Intake Grill

The intake head has been designed to comprise eight equal openings covered by a cupronickel grill as illustrated in Figure 3. The geometry of the grill mitigates the risk of ingress of marine fauna into the system.

The cupronickel inhibits marine growth on the grill. Cupronickel is commonly used in marine applications on pipes, offshore platforms and inside condensors to reduce biofouling. Latest research into the mechanism by which the cupronickel prevents marine growth is that a protective surface oxide film forms naturally in seawater to discourage biofouling (Powell 2004).

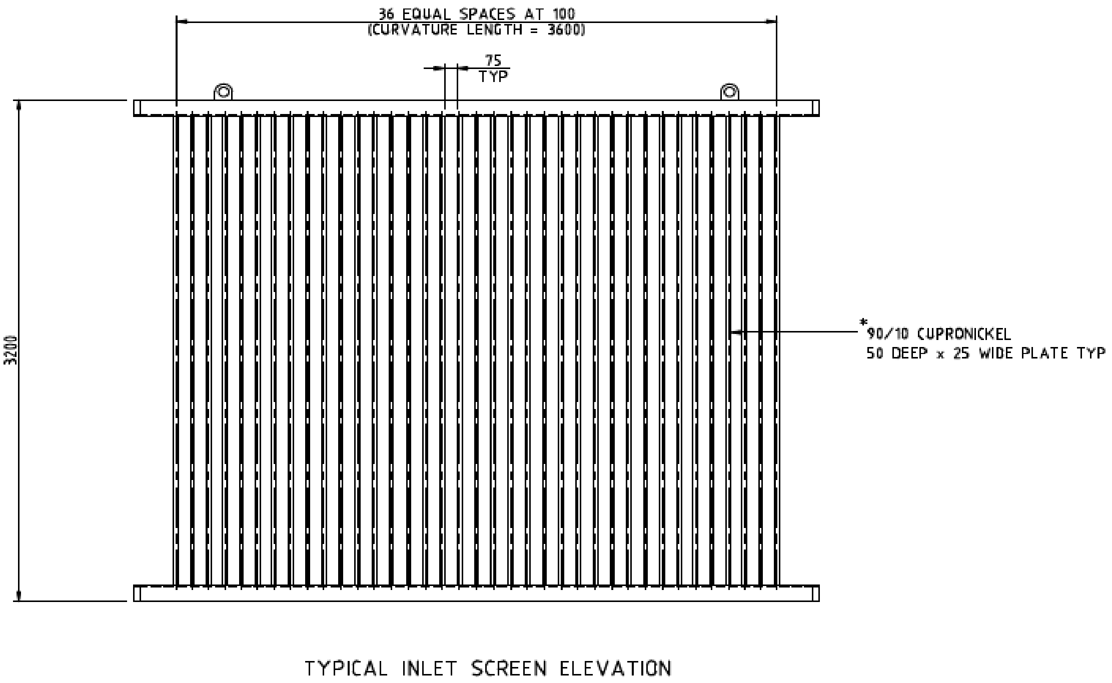

Figure 3: Intake Grill Diagram

3.6 Chemical Dosing System

A chemical dosing system is used to treat incoming seawater to prevent fouling of the intake tunnel as a result of marine growth. Chlorine dosing generally occurs daily for 20 minutes to 1 hour duration. Seawater chlorinated as a result of the tunnel cleaning process is de-chlorinated within the plant. The design of the intake structure and dosing system ensures that no chemicals are released to the marine environment at the intake through incorporation of the following:

- Control interlocks preventing dosing of the chemicals to the intake tunnel if the intake pump station is not operational
- Control interlocks to immediately stop chemical dosing if the intake pumping station stops
- Flushing of the chemical dosing lines after each use to prevent any residual chemicals remaining within the dosing system
- Locating the chemical dosing system sparge ring, approximately 8m below the underside of the intake bar screens
- Provision of a surge chamber within the intake pumping station to store any upsurge of water from the intake tunnel in the event of an emergency pump station stop.

- Approximately 180m3 of storage within the intake structure, below the inlet screen, is available to contain any surge event, thereby preventing the release of chemicals during an emergency pump station stop. A surge analysis of the worst case scenario (emergency stop of fully operating pumping system) has been conducted to demonstrate that there is sufficient capacity within the confines of the tunnel and intake system to contain the chemically treated intake water during this transient event.

3.7 Full Tunnel Option

The intake and outfall systems consist of full length tunnels terminating in the mid to deep benthic zones.

4 Outfall Structure

4.1 Outfall Design Overview

The outfall system is gravity operated and designed to facilitate the effective dispersion of the saline concentrate produced during the desalination process. A tunnel beneath the seabed conveys the saline concentrate offshore to six separate risers located along the last section of the outfall tunnel with the outermost riser being located approximately 850m offshore. Each riser is approximately 20m long and connects the outfall tunnel to the diffuser heads on the seabed. The diffuser heads incorporate duckbill valves designed to disperse the saline concentrate into the seawater. The duckbill valves themselves are raised off the seabed, at a water depth of approximately 16.5 m at MSL.

The general arrangement of the outfall structure is illustrated in Figure 4.

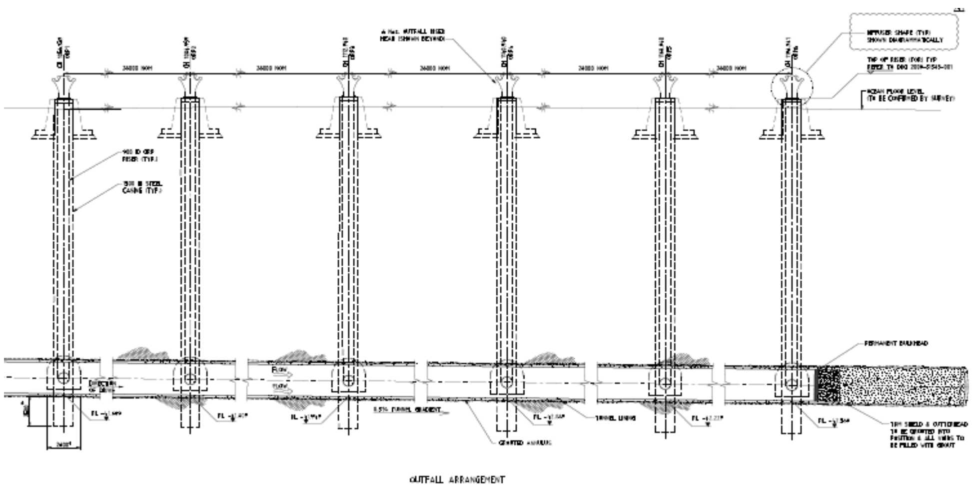

Figure 4: General Design Arrangement for Outfall System

4.2 Outfall Location

The outfall diffuser is located to the east of the intake to assist with the dispersal of the diluted saline concentrate away from the diffuser through the gravity action of the seabed slope acting in conjunction with tidal and local wind-driven coastal currents. Positioning the outfall diffuser in this location takes advantage of the hydrodynamics in the area and assists in the midfield advection and diffusion of the diluted saline concentrate stream.

The outfall design:

- Achieves rapid dispersion of the saline concentrate with the surrounding sea water

- Ensures the diffuser is located well away from and does not have any effect upon sensitive habitats such as reefs
- Locates the diffuser appropriately to avoid short circuiting of the outfall saline concentrate into the intake structure
- Minimises interference of adjacent discharge plumes
- Provides improved dispersion of the diluted saline concentrate under low current conditions when the main flushing mechanism is gravity driven, as the plume flows down the natural slope of the sea bed.

The location of the Outfall structure is shown in Figure 2 above.

4.3 Outfall – Diffuser Design

The outfall diffuser arrangement consists of 24 x 250mm duckbill diffuser ports, arranged in groups of four duckbill valves on each of the six diffuser heads mounted on a line of six risers which will be connected directly to the outfall tunnel, under the seabed. The distance from inshore to offshore diffuser head will be 140m.

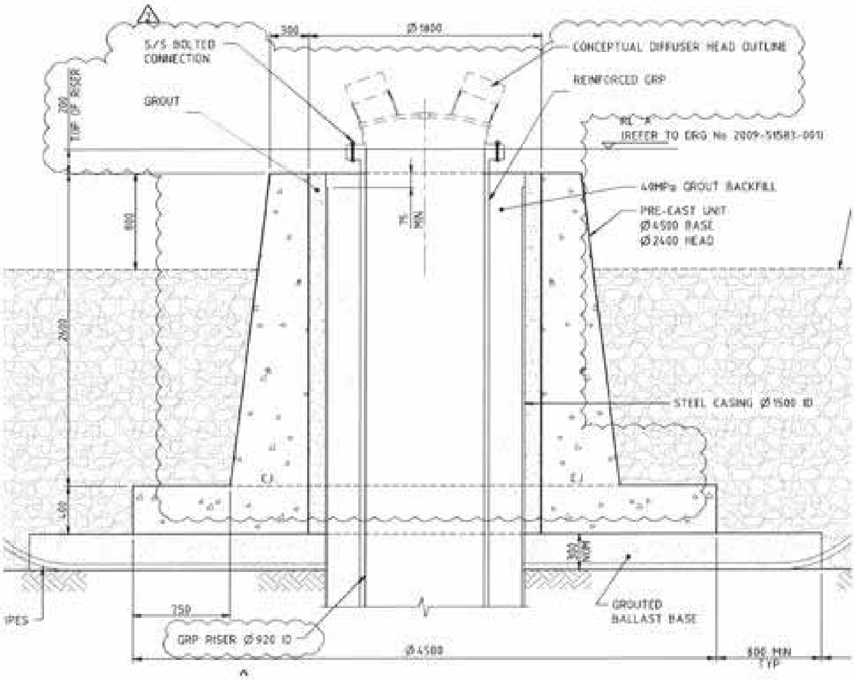

Figure 5: General Design Arrangement for Diffuser Head

This configuration was one of several considered, and was selected due to its optimal dilution performance whilst still satisfying outfall tunnel pressure constraints. Further information on the process for selection of the diffuser system is provided in the Diffuser Selection Report (Appendix 6).

4.3.1 Duckbill Performance

Duckbill valves are commonly used on marine discharge systems and have been assessed for their suitability and durability in this application.

Long term performance of the diffuser system is reliant upon the elasticity and stiffness of the duckbill valves. This will be examined through a regular monitoring program in order to fully document the behaviour of the valves over time in this particular environment. However, experience to date indicates that significant stiffness or elasticity degradation should not occur over the short or medium term and therefore should not affect performance. The potential for total failure of a duckbill valve, while considered unlikely, has been considered in the design of the outfall system by providing a flange connection to allow easy replacement of the valve if required.

A sensitivity analysis was undertaken on performance of the outfall system with the loss of two duckbill valves, which indicates that the performance of the outfall as a whole is not significantly impacted. Loss of valves will be detectable through trend analysis of the water levels in the outfall shaft, or through inspections. Subtle losses in stiffness of valves, and corresponding impact to diffuser performance, will be detected through the regular inspection program.

4.4 Outfall – Initial Dilution

The EIS calls for an initial dilution of 50:1 which was based on a nominal recovery rate of 45%. As the ADP will be designed for a recovery rate of up to 48.5%, the equivalent initial dilution has been taken as 58:1 to reflect the higher recovery. This is in accordance with discussions with the EPA.

4.4.1 Initial Dilution

Initial dilution is defined as impact point dilution at the seabed as calculated by the Roberts equation (Roberts *et al* 1997).

The empirical relations as developed by Roberts et al (1997) have been widely applied to diffuser design and near field mixing analysis and dispersion of dense plumes, and are considered current best practice to determine initial dilution ratios.

It should be noted that the Roberts equation does not consider the effects of salinity dispersion over time. This has been considered through mid field hydrodynamic modelling, and assessed against the results of the ecotoxicity analysis. This ensures maximum salinity levels as predicted by the hydrodynamic model are considered when assessing potential environmental impact.

Extensive physical modelling and prototype testing of the duckbill valves was undertaken as part of the detailed design of the outfall diffuser (Appendix 2). These investigations were undertaken to evaluate the capability of duckbill valves to develop appropriate hydraulic conditions at the diffuser ports and thereby maintain adequate initial dilutions over the full range of outfall flow rates. The physical model successfully demonstrated that the Duckbill dilution performance maintains high velocities under low flows, as well as enhanced mixing due to the elliptical shape of the duckbill jets.

The predicted initial dilution at various plant productions is presented in Figure 6 below. Note that during periods of less than 39% plant production the required initial dilution is maintained by augmenting the flow by pumping seawater through the bypass system (refer to Section 4.5).

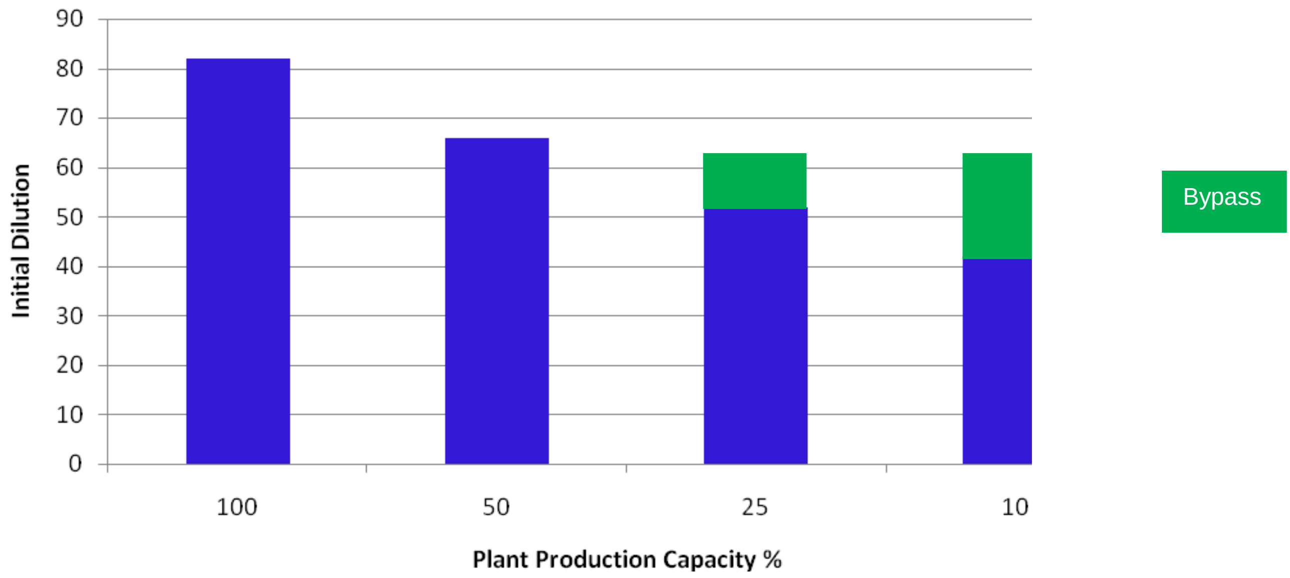

Figure 6: Plant Production Capacity Illustrating Achievement of Initial Dilution and Augmentation with Bypass Flow.

These dilution calculations were based on the Roberts model (Water Technology 2009b), and were validated in a laboratory using scaled diffuser ports in large water tanks (Appendix 1).

4.4.2 Initial Dilution under all Current Scenarios

Dilution is significantly enhanced by the actions of winds, tidal movements and cross currents. Even during slack or dodge tides, some cross current effects and / or wind will be evident.

Despite these likely contributions, initial dilution rates have been calculated assuming zero contribution from the effects of wind and / or cross currents. That is, the design calculates initial dilution ratios on the basis that the receiving waters are stationary.

The existence of cross currents at the outfall will increase dilution of the diffuser plumes such that the net impact of any cross currents will be to increase dilution above that calculated under quiescent conditions.

4.5 Outfall – Bypass System

For plant production rates below 39% of full capacity, a bypass flow will be incorporated to ensure that the minimum criterion of 58:1 is achieved.

The current proposal for the bypass system is to dilute the saline concentrate by piping seawater from within the RO plant into the saline concentrate discharge system. As the RO plant can only operate and discharge saline concentrate when there is seawater coming into the plant through this line, there will always be seawater available to dilute the saline concentrate when it is discharged. The PLC will be programmed to open the valves and introduce dilution water based on actual plant flow.

An opportunity exists to take advantage of natural tidal and current movements and utilises the bypass system during dodge tide events only. This approach results in reduced power consumption and is the preferred option.

4.6 Outfall – Diffuser Modifications

The Outfall Infrastructure Diffuser Extension – Concept Paper, Nov 2009 (Appendix 4) details the proposed design for extending the diffuser. The concept design allows for a number of diffuser options (Appendix 4). All options utilise the existing infrastructure with a bolted connection to the top of the risers. The concept design indicates the outfall hydraulics is feasible, and flow rates through the 900mm diameter outfall pipe would not significantly change the hydraulic losses through the extended system.

4.7 Outfall – Clean In Place (CIP)

Clean in Place (CIP) is the general term for in situ cleaning of the Reverse Osmosis (RO) and Ultrafiltration (UF) membranes. Cleaning of the membranes is required to remove any scaling, or fouling observed during the long term operation of the plant.

4.7.1 Process Flow

Seawater is pre-treated using a submerged type UF membrane system. Pre-treatment ensures the seawater is of suitable quality to prevent RO membrane damage. Backwashing and cleaning of the UF system is required to remove any solids collected and maintain system performance accordingly.

UF filtrate is pumped into the first pass RO racks at high pressure (approximately 70 bar). The first pass RO system produces permeate (low salinity product water) at a 50% recovery ratio with the remaining 50% (saline concentrate) passing through energy recovery devices to minimise power consumption. Product water is re-treated through second pass RO racks to ensure the quality of the permeate meets Australian Drinking Water Quality guidelines. Permeate water from the RO plant is then re-mineralised disinfected and fluoridated before distribution.

The CIP system proposed is summarised in the outline process flow diagram in Figure 7.

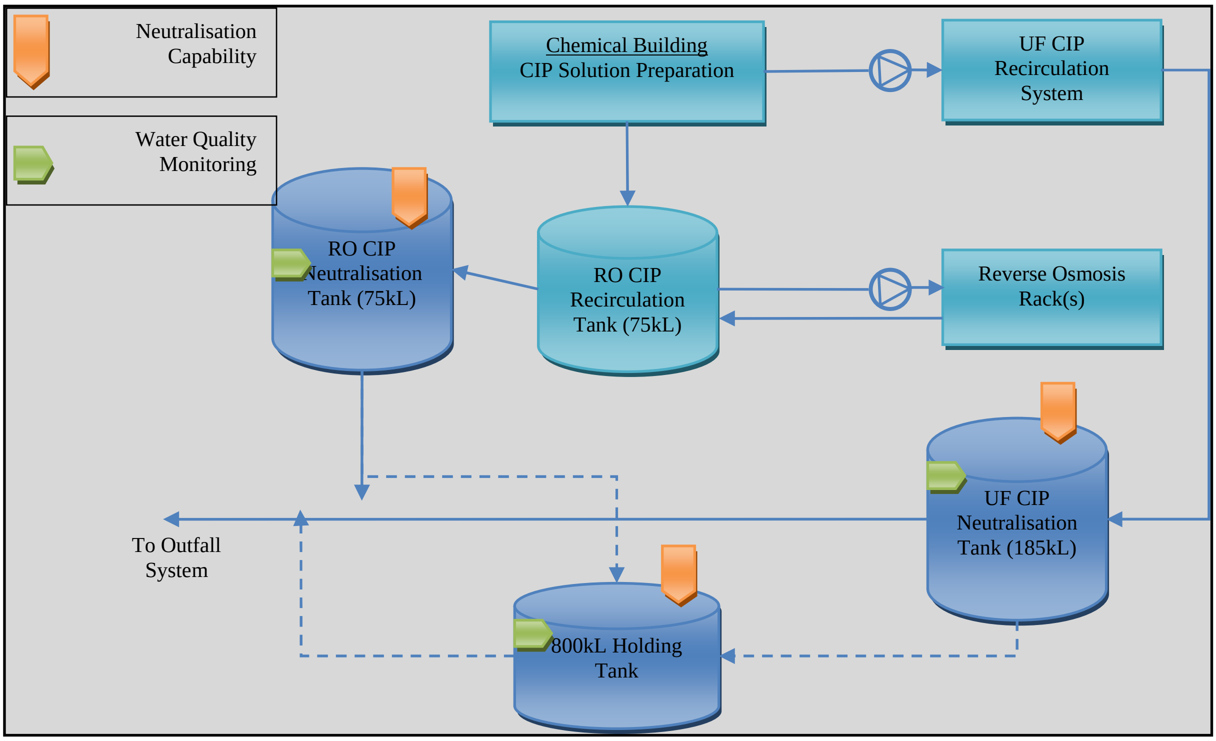

Figure 7: Simplified Process Flow Diagram for Clean in Place Systems

The UF system will gradually foul due to solids build-up during operation. Regular backwashing and air scrubbing will be used to dislodge solids. Backwash water is then transferred to the Wash Water Treatment Facility for further treatment and is not the subject of this report. After a period of time backwashing operations alone will not clean the membranes satisfactorily and chemical cleaning will be required to maintain performance.

Membranes racks / tanks are taken offline and are cleaned based on plant configuration, to maintain production with the remaining operational membranes. Each CIP cycle may involve multiple batches of chemicals to achieve the required clean. Once complete, each batch is directed to a neutralisation tank to neutralise the chemical.

Most chemicals used during CIP are either acids or alkalines, and when neutralised generate a salt based solution (> 4,000mg/L on average). Neutralised CIP solutions have been assessed to determine a safe dilution factor to determine suitability for potential discharge, subject to EPA approval.

Operational ultra filtration cells will be cleaned on a time basis using a dedicated clean in place system as follows.

- Maintenance Cleaning – Every 2 days using 42 kL of a solution of sodium hypochlorite (0.3 g Cl_2/L) and every 4 days using 42 kL of a solution of sulphuric acid (1g/L)
- Recovery Cleaning – Every 30 days using 42 kL of a solution of sulphuric acid (1g/L) and citric acid (2.5g/L) followed (in a different batch process to avoid contact) by 42 kL of a solution of sodium hypochlorite (1.0 g Cl_2/L). The order of these chemicals may be reversed.

Table 3 summarises the approximate volume of UF CIP solution generated per day. Should the desalination plant be operating at less than full capacity the volume of CIP solution discharged will decrease in proportion to the reduction in product water capacity, i.e. 50% production capacity = 50% UF CIP volume.

Table 3: Approximate volume of UF CIP solution generated per day

Cycle	Number of UF Cells	Frequency	Volume per Clean (kL) (including flushing)	Average No. of Cells Cleaned per Day	Average Volume per Day (kL)
Maintenance Cleaning NaClO	28	Every 2 days	185	14	2,590
Maintenance Cleaning H_2SO_4	28	Every 4 days	185	7	1,295
Recovery Cleaning NaClO / H_2SO_4 + citric acid	28	Every 30 days	370	1	370

Periodic cleaning of the RO membranes is also necessary to maintain the plant performance by removing scaling and potential foulants. The cleaning frequency depends on the raw water conditions, efficiency of the pre-treatment system and operational conditions of the system. The membranes are cleaned in place by recirculating cleaning solutions through the pressure vessels in each RO rack. Different cleaning protocols can be used to specifically address each type of fouling by varying the type of chemical, concentration, pH, temperature and cleaning duration.

Table 4 summarises the approximate average volume of RO CIP solution generated per day. RO CIP is conducted on a performance basis and not strictly a time basis as summarised below. Therefore, the average cleaning frequency in Table 4 is considered the worst case scenario resulting in the largest volume of cleaning solution. Operators at the desalination plant will aim to minimise the frequency of cleaning in line with plant performance.

Table 4: Approximate volume of RO CIP solution generated per day

Cycle	Number of RO trains	Frequency	Volume per Clean (kL) (including flushing)	Average No. of Racks Cleaned per Day	Average Volume per Day (kL)
1st Pass	20	Every 14 days	300	1.4	420
2nd Pass	10	Every 2 months	300	0.2	60

4.7.1.1 Pre-Dilution Rates Prior to the Outfall

The following pre-dilution rates are achieved during the discharge of neutralised CIP solution under high and low desalination plant production scenarios. Pre-dilution is deemed to be the dilution achieved in the gravity outfall pipes, shaft and tunnel prior to release via the outfall diffusers.

Effective pre-dilution rates between 3:1 and 16:1 are achieved in the outfall system prior to release when neutralised CIP solutions are discharged at the maximum design flow rate.

Table 5: Pre dilution rates achieved during discharged of neutralised CIP solutions

Area	Plant Production 30ML/d			Plant Production 300ML/day		
	Maximum CIP Flow (L/s)	Outfall Flow (L/s)	Pre-dilution prior to diffusers (outfall: CIP)	Maximum CIP Flow (L/s)	Outfall Flow (L/s)	Pre-dilution prior to diffusers outfall: CIP)
UF CIP	175	525	3:1	700	4200	6:1
RO CIP	60	410	7:1	240	3740	16:1

4.7.1.2 Dilution Achieved via Outfall

Dilution rates achieved for neutralised CIP solutions need to consider the initial dilution achieved via the outfall diffusers, combined with the predilution which occurs when neutralised CIP is mixed into the saline concentrate prior to discharge.

Table 6: Effective dilution rates of neutralised CIP solutions

Area	Plant Production 30ML/d			Plant Production 300ML/day		
	Pre-dilution prior to diffusers (outfall:CIP)	Initial Dilution via Outfall (seawater: outfall)	Effective CIP Dilution (seawater:CIP)	Pre-dilution prior to diffusers (outfall:CIP)	Initial Dilution via Outfall (seawater: outfall)	Effective CIP Dilution (seawater:CIP)
UF CIP	3:1	58:1	174:1	6:1	81:1	486:1
RO CIP	7:1	58:1	406:1	16:1	81:1	1296:1

4.7.2 CIP – Chemicals

An ecotoxicity assessment was undertaken of the neutralised CIP chemicals in order to determine those chemicals likely to pose an environmental impact if discharged. The chemical compositions of these solutions were subjected to further lab based testing, and are defined in Table 7.

Table 7: Chemical Compositions of Neutralised CIP Samples Assessed for Ecotoxicity.

Sample No.	Description	Solute	Chemical	Concentration	Neutralization
1.	Saline Concentrate - Control	Saline concentrate	No chemicals	Nil	Nil
2.	Saline Concentrate following chlorination / dechlorination	Saline Concentrate	Sodium hypochlorite	15 mg/l (as Cl_2) free chlorine	Neutralised with sodium metabisulphite until free chlorine disappear
3.	Neutralised UF CIP Solution	RO Permeate	Sulphuric acid	1,000 mg/l	Neutralised with caustic soda
			Citric acid	2,500 mg/l	
4.	Neutralised RO CIP Solution	RO Permeate	DBNPA solution	30 mg/l	Neutralised with sodium metabisulphite
5.	Neutralised RO CIP Solution B	RO Permeate	Sodium hydroxide	0.13% w/w until pH 12.5	Neutralised with sulphuric acid
			Sodium dodecyl sulphate	0.05% w/w	
			Na_4-EDTA	0.35% w/w	
6.	Polyelectrolyte Flocculant	Seawater	Polymer LT25	0.1% w/w	Nil

The ADP will also apply antiscalants to prevent RO membrane scaling. The ecotoxicity studies for various antiscalants have been previously presented to EPA by SA Water as part of the EIS submission. The safe dilution factors for antiscalants are provided in Appendix 4.

4.7.3 CIP Discharge Options

The discharge options for neutralised CIP chemicals are:

Trade Waste

This was considered but was eliminated for the majority of chemicals as the receiving treatment system (i.e. municipal wastewater treatment plants) is unable to accept the high flowrates, volumes and salinity levels. Average salinity of neutralised CIP solutions exceeds trade waste discharge limit of 1,400mg/L and would restrict future reuse opportunities from Christies Beach WWTW. Note that it is proposed to discharge the EDTA / sodium dodecyl sulphate (SDS) solution to trade waste, as this is considered potentially harmful to the marine environment without further treatment.

Onsite Treatment

Onsite treatment through further concentration is possible, but is energy and chemically intensive, and generates large volumes of waste solutions that would require road transport to prescribed waste landfill sites.

Outfall Discharge

Discharge of neutralised CIP saline streams into the marine environment through the outfall diffuser system is considered standard industry practice nationally and worldwide. Ecotoxicity assessment has been performed to determine safe dilution levels and ensure that the design of the outfall system will achieve the required dilution required to prevent environmental harm.

This has been undertaken, and the resultant safe dilution levels are summarised below.

4.7.4 CIP - Safe Dilution Factors

Safe dilution factors of the neutralised CIP samples were determined through the ecotoxicity testing (Appendix 3) to evaluate risk of environmental harm. The observed toxicity and safe dilution factors for the neutralised CIP samples are described in Table 8.

Table 8: Observed toxicity and safe dilution factors for the neutralised CIP samples

Sample No.	Description	Safe Dilution Factor (protect 95% of species)	Minimum Dilution achieved	Maximum Dilution Achieved	Proposed Discharge
1.	Saline Concentrate - Control	20:1	58:1	81:1	Outfall
2.	Saline Concentrate following chlorination / dechlorination	21:1	58:1	81:1	Outfall
3.	Neutralised UF CIP Solution	21:1	174:11	486:1	Outfall
4.	Neutralised RO CIP Solution	11:1	406:1	1296:1	Outfall
5.	Neutralised RO CIP Solution (EDTA / SDS)	2500:1	406:1	1296:1	Trade Waste
6.	Polyelectrolyte Flocculent	10:1	58:1	81:1	Outfall

The results of the ecotoxicity testing conclude:

- A toxicity response was observed in all saline concentrate, permeate and feedwater samples;
- The majority of the observed toxicity in the saline concentrate is believed to have been caused by the salinity of the samples; and
- The diffusion that is achieved by the diffuser dilution (Refer to Section 4.7.1.1) adequately achieves the safe dilution for five of the samples tested.

- Sample 5 - Neutralised RO CIP Solution (EDTA/SDS) is unable to be discharged safely into the Marine environment, therefore this waste stream will be disposed of via trade waste.

4.8 Outfall – Modelling

The hydrodynamic assessment (Appendix 1) of the outfall diffuser has been undertaken at the following three different spatial scales:

- Near-field modelling of the individual saline concentrate diffuser plumes
- Three-dimensional, mid-field numerical modelling of the outfall diffuser and coastal waters at Port Stanvac
- Two-dimensional, far-field numerical modelling for the hydrodynamics of the Whole of Gulf St. Vincent

It should be noted that reference to 120% plant flow shown within the Outfall Dilution Modelling assessment is included for purposes of clarity of the relevant graphs only. This is not intended to reflect a likely operating condition.

4.8.1 Near Field

Near field modelling was conducted to determine initial dilution ratios achieved by the outfall diffusers, and has been addressed in Appendix 1 and summarised in Section 4.4.

4.8.2 Mid Field - Three-Dimensional

The mid field model examines a number of different scenarios to determine the influence of currents, wind patterns and tidal conditions on the behaviour of the saline concentrate discharged from the diffuser. The model is a three dimensional mathematical representation of the receiving environment around the diffusers and is used to predict the variation of salinity over space and time. The model considers an area of 20km by 11.5km.around at the diffusers at Port Stanvac. The model has been reviewed to ensure accuracy particularly at points 100m and further from the diffusers. The model considers potential build-up of a dense saline layer at the seabed in the vicinity of the diffusers, and the impact of this layer being re-entrained into the diffuser jets.

Three representative tidal and meteorological scenarios have been assessed and are considered to capture the envelope of conditions that would influence the dilution performance of the outfall diffuser. The scenarios are:

- Scenario 1 - Six week scenario from 1 May to 15 June 2006
- Scenario 2 – A worst case dodge tide scenario
- Scenario 3 – A scenario containing an upwelling (onshore advection) of bottom waters

A detailed analysis of each of the scenarios is provided in Appendix 1.

The data generated by the midfield model assumes continuous plant operation at 100% capacity and 48.5 % recovery.

Ambient salinity concentrations were measured over a 12 month period and vary from 36 ppt during spring to 38 ppt around early autumn. This broad salinity range is characteristic of the upper and mid regions of Gulf of St Vincent. Further south the Gulf waters are influenced more by oceanic conditions and as a result ambient salinity concentrations tend to be lower and more constant. Figure 8 illustrates average monthly salinity concentrations off the coast of Port Stanvac for 2008-2009.

Note; This dataset covers a twelve month period, however the salinity of the seawater in the Gulf of St Vincent may fluctuate more than this due to natural variability. As a result, the plant itself has been designed to treat intake seawater up to a maximum of 42g/L salinity.

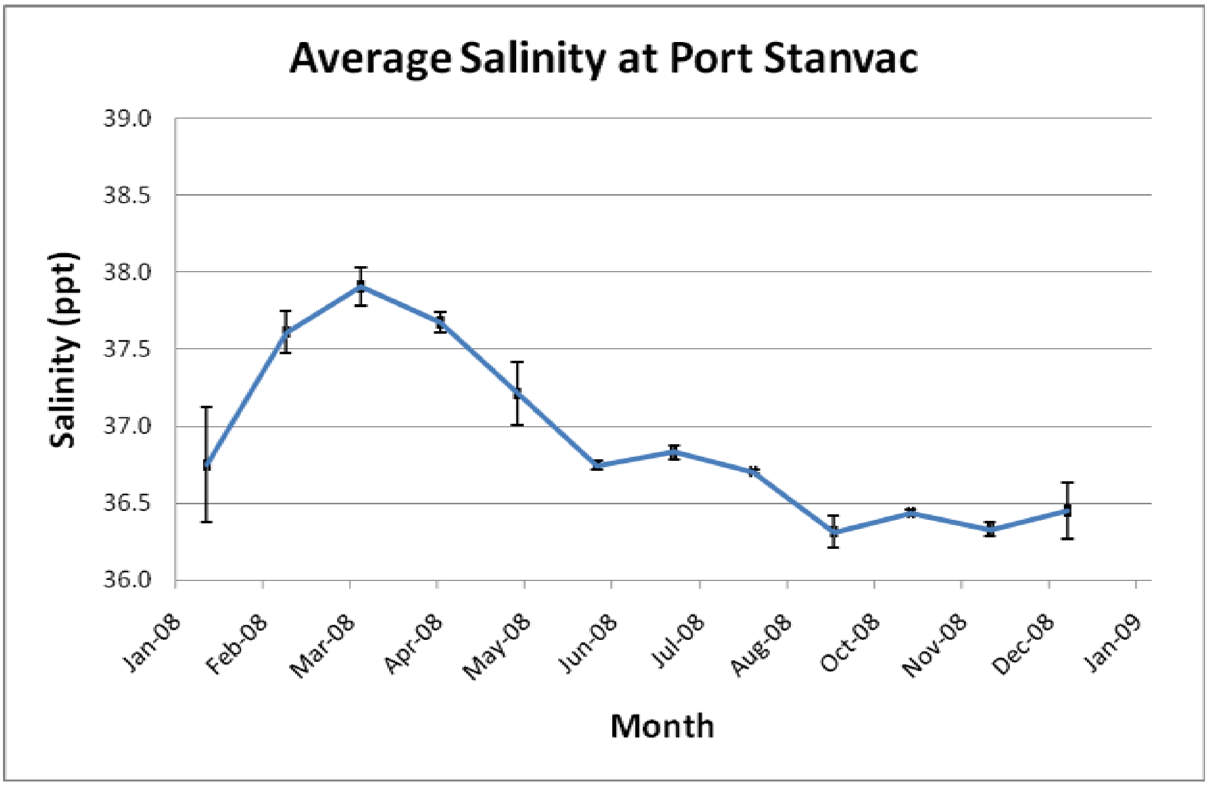

Figure 8: Average Monthly Salinity Concentrations off the Coast of Port Stanvac. Error Bars Represent Standard Deviation (Kildea et al)

The results of the model can be used to predict salinity levels over time at any point within the model area, relative to regional ambient salinity concentrations. These results show that the maximum salinity that will occur at 100m and 400m from the diffuser averaged over 1, 6 and 24 hour periods is as follows:

Table 9: Maximum Salinity Levels Above Ambient at 100m and 400m from the Diffuser, Time Averaged Over 1, 6 and 24 Hour Periods

	Max Salinity at 100m (ppt)		Max Salinity at 400m (ppt)	
Time average (hr)	Onshore	Offshore	Onshore	Offshore
1 hr	0.8	1.0	0.2	0.7
6 hr	0.6	0.9	0.2	0.6
24 hr	0.4	0.8	0.2	0.5

This information can be further expressed as maximum predicted variation to annual ambient salinity and is demonstrated in Figure 9 below:

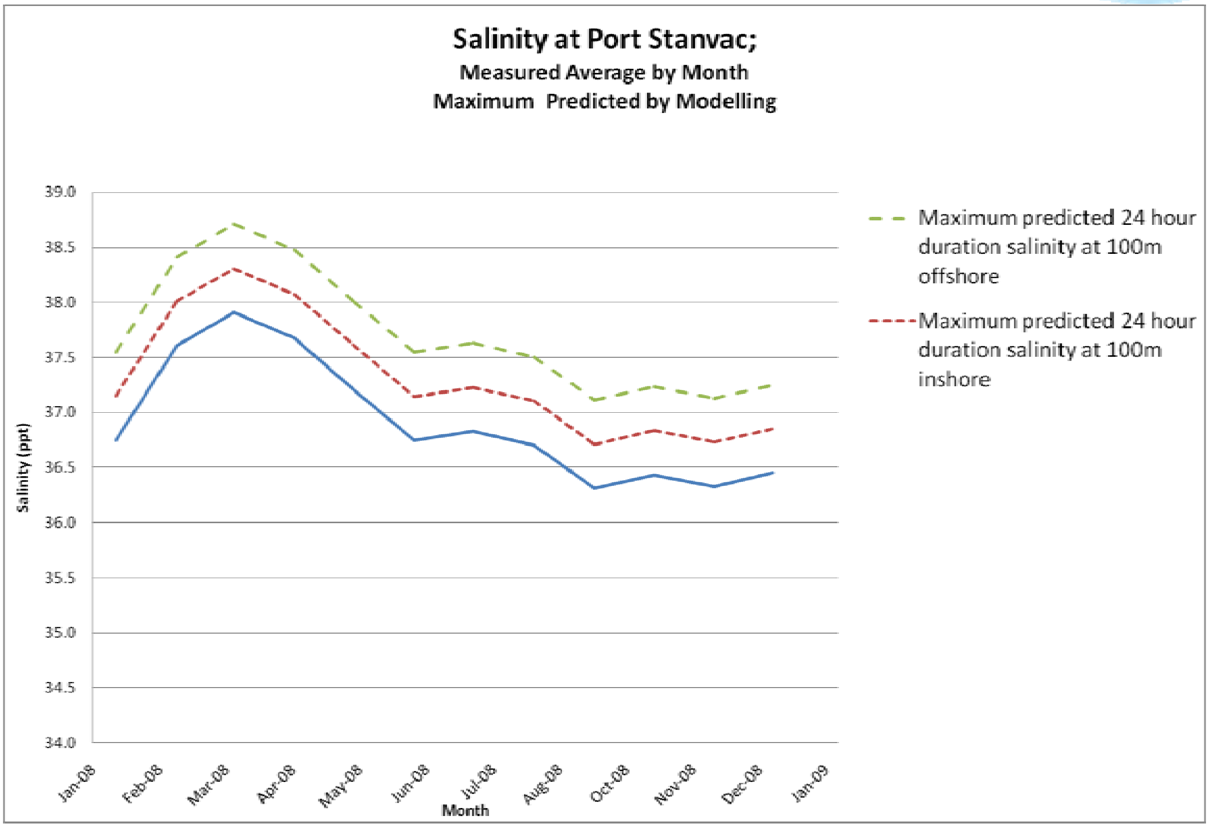

Figure 9: Maximum Salinity Variation with Change in Ambient Salinity Levels Over a Calendar Year

Significant variations to ambient salinity generally occur for short periods of time only, and the model is able to predict the amount of time that these salinity variations occur. Model results for the 6 week period, which includes the worst case dodge tide, have been used to determine these periods of variance, and are represented below as percentages of times that the salinity, at 100m and 400m from the diffuser, will exceed the regional ambient levels by 0.3, 0.6, 0.9 and 1.0 ppt (Table 10):

Table 10: Exceedance Levels at 100m and 400m for a Series of Salinity Level Increases above Ambient.

ppt above Regional Ambient	100m	400m
	% of Time	% of Time
>0.3	37%	19%
>0.6	19%	0.5%
>0.9	1%	0
>1.0	0%	0

The 6 week period used to obtain these results can be considered representative of the exceedance times over a complete calendar year

Spatial distribution of particular exceedance levels.

The model can also show spatial distribution of salinity levels over time, and are shown here for the 0.3, 0.6 and 0.9ppt exceedance cases:

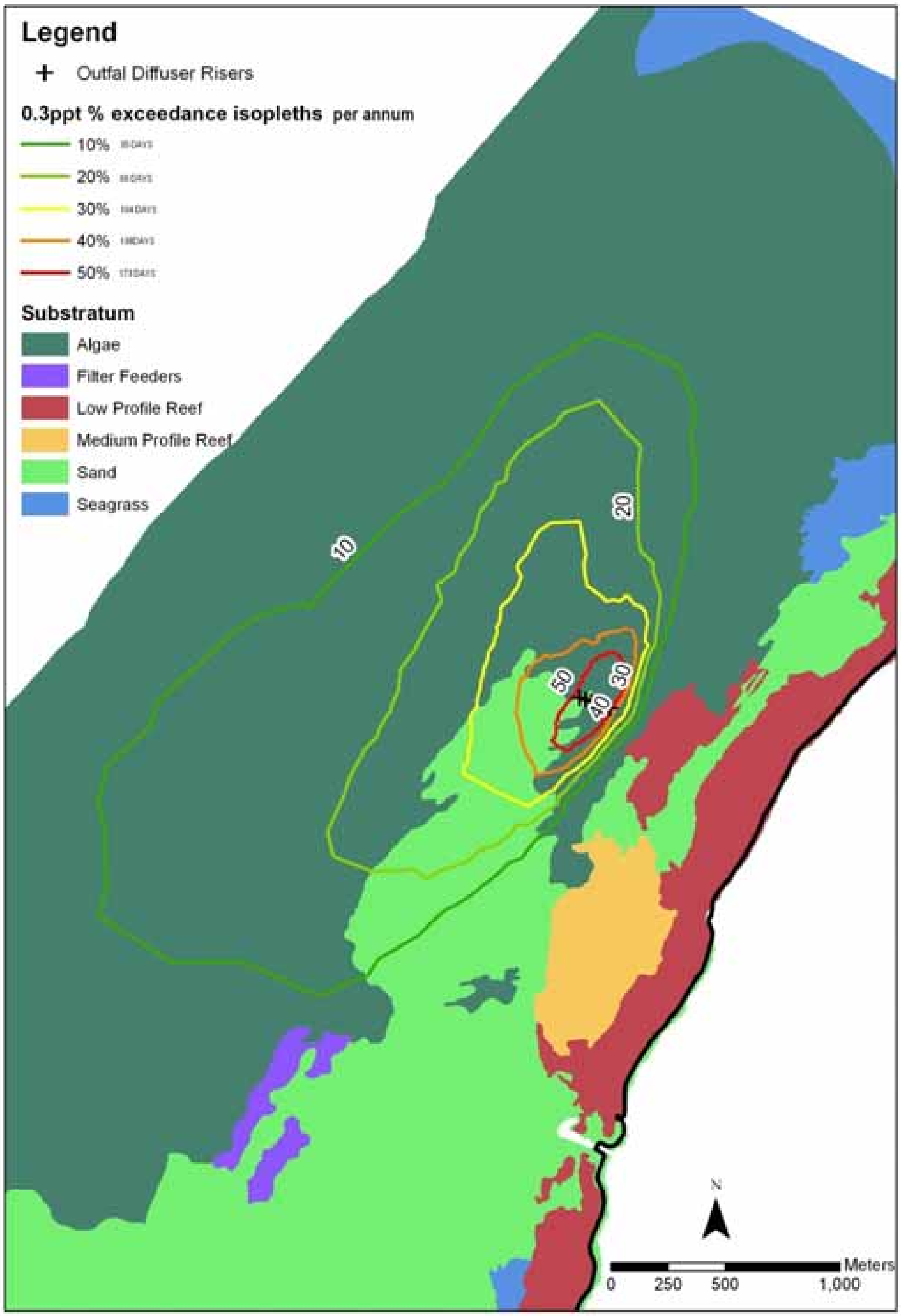

Figure 10: Percentage Exceedance of 0.3ppt Salinity Isopleths at the Bed Relative to Substratum Type.

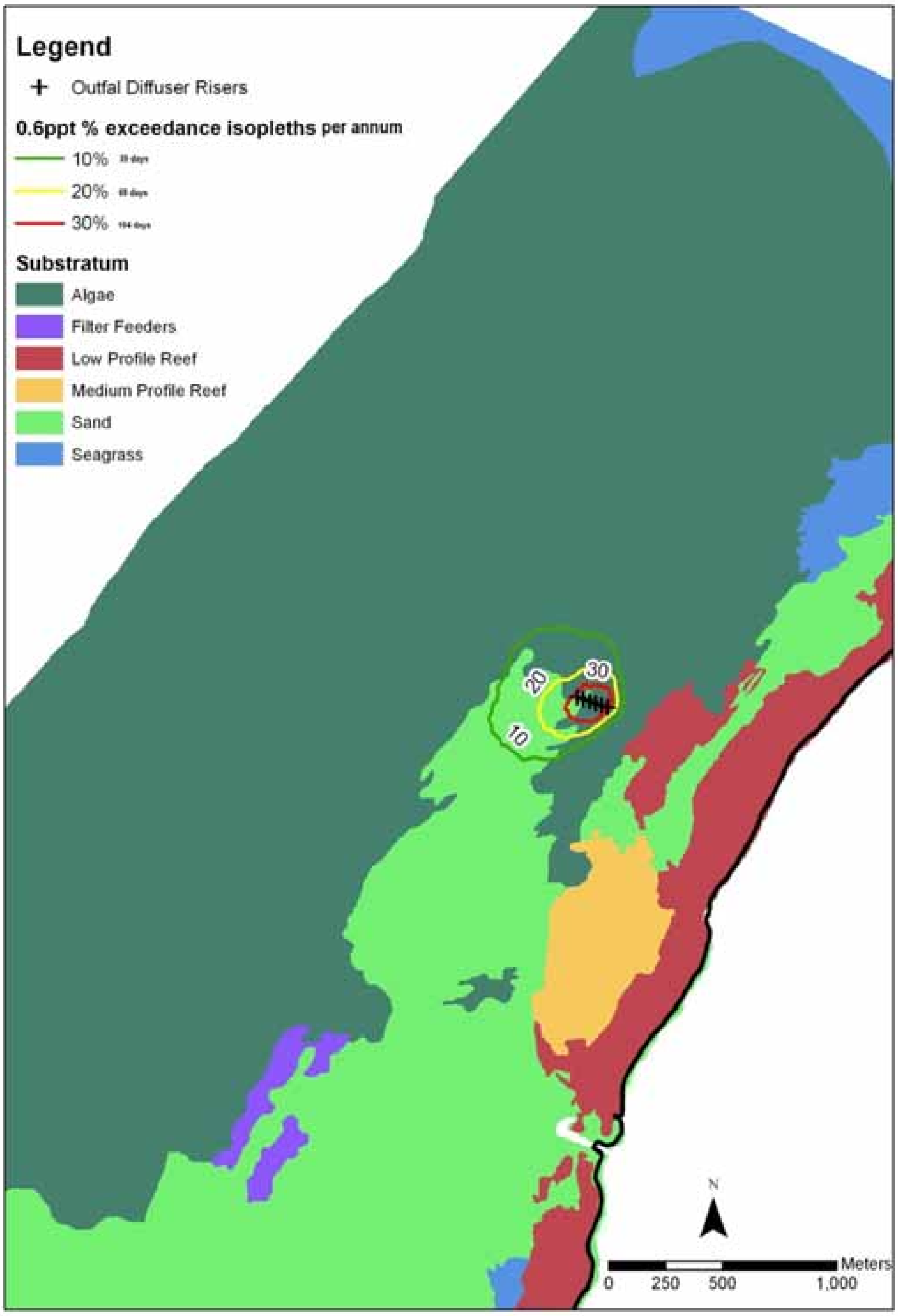

Figure 11: Percentage Exceedance of 0.6ppt Salinity Isopleths at the Bed Relative to Substratum Type.

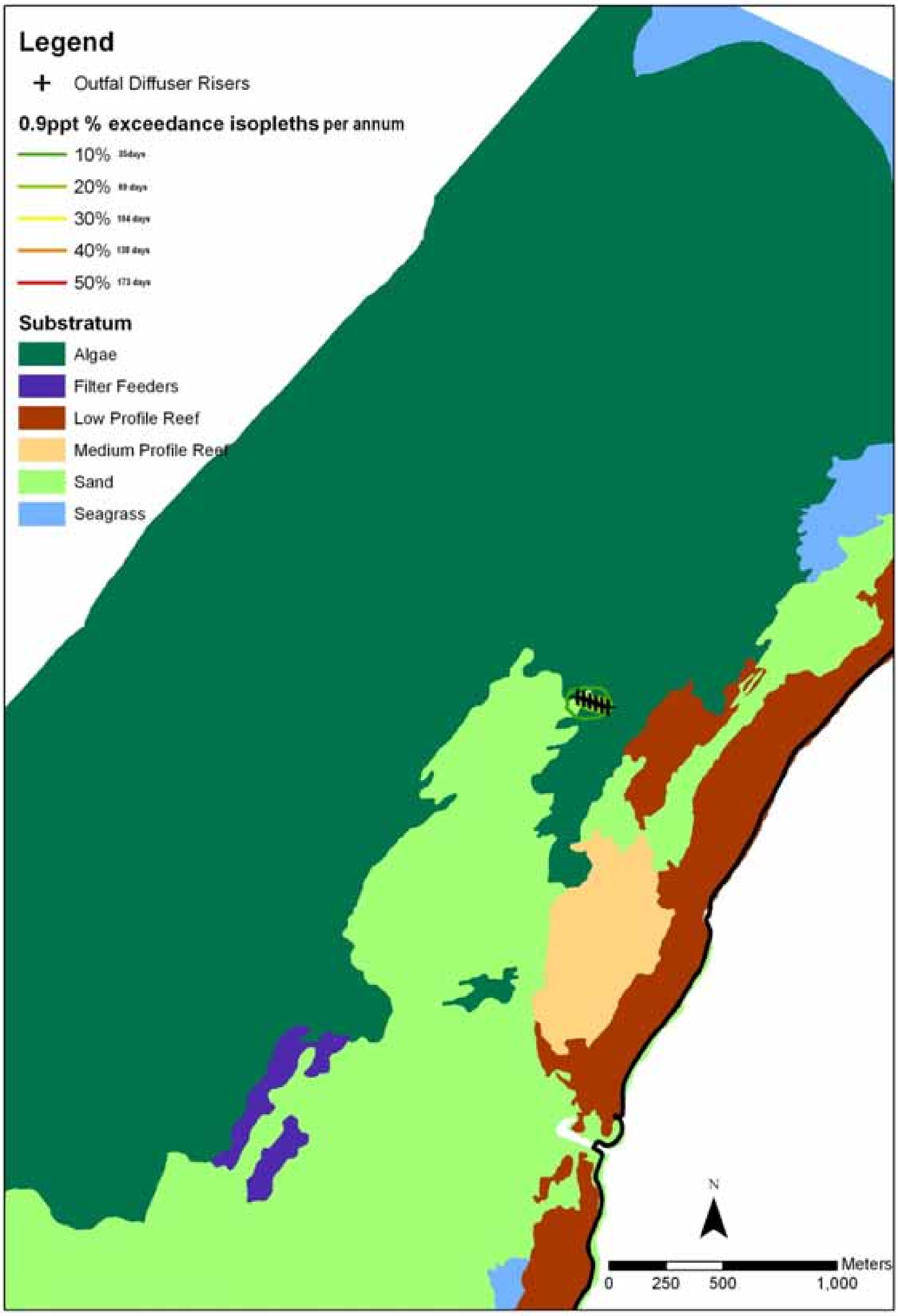

Figure 12: Percentage Exceedance of 0.9ppt Salinity Isopleths at the Bed Relative to Substratum Type.

4.8.3 Far Field - Two-Dimensional

From the findings of the ADP EIS (SAW 2008) Response document, it was concluded that the flushing and exchange of water between Gulf St Vincent and the Southern Ocean is sufficient to ensure negligible accumulation of salt within the Gulf as a result of the ADP. The relatively small increase in salt load from the saline concentrate discharge (compared to natural processes) and a whole of Gulf flushing rate of 3 to 4 months will allow for the sustainable operation of ADP within Gulf St Vincent.

4.9 Outfall – Ecotoxicity

Tolerance of marine fauna to salinity variations has been assessed by ecotoxicity testing (Appendix 3). The ecotoxicity assessment was undertaken using larvae acclimatised to stable laboratory conditions, and is therefore considered a conservative evaluation of marine biota tolerance to salinity variations, compared to the natural environment where flora and fauna are acclimatised to seasonal variations in temperature and salinity. In addition, a desktop review of published research has been conducted to verify the potential ecological impact of elevated salinity. These assessments are described below.

4.9.1 Ecotoxicity Assessment

An ecotoxicity assessment was undertaken to establish the minimum dilution rate required to avoid adverse affects of saline concentrate and CIP chemicals on marine flora / fauna. This assessment includes an evaluation of the potential impact of any residual chlorine in the saline discharge following the chlorination and subsequent de-chlorination of the intake water (refer section 3.6). The calculated safe dilution factors for the saline concentrate and the chlorinated / dechlorinated saline concentrate indicated that the chlorination process did not significantly impact ecotoxicity of the saline concentrate. The saline concentrate was calculated to require a dilution of 20:1 to protect 95% of species while the chlorinated / dechlorinated saline concentrate was calculated to need a dilution of 21:1 (Appendix 3).

The safe dilution factor of 20:1 equates to a salinity tolerance of 2.2ppt above ambient. This concentration can be compared to predicted maximum salinities from the model in order to determine the risk of harm to the environment. This is discussed further in section 4.9.3.

It should be noted that the ecotoxicity study involved exposing marine organisms to elevated salinities for periods ranging from three to seven days, compared to predicted maximum salinity levels averaged over 1, 6 and 24 hours

4.9.2 Ecological Assessment

The desktop review of ecological field data considers the marine habitat in the region of the outfall diffusers, ambient salinity concentrations and the salinity tolerance of marine mammals. An extract from WHO (2002) summarises how marine organisms acclimatise to natural variations in salinity.

Aquatic life salinity tolerance threshold

Many marine organisms are naturally adapted to changes in seawater salinity. These changes occur seasonally and are mostly driven by the evaporation rate from the ocean surface, by rain/snow deposition and runoff events and by surface water discharges. Typically, the range of natural salinity fluctuation is at least ± 10% of the average annual ambient seawater salinity concentration. The "10% increment above ambient ocean salinity" threshold is a conservative measure of aquatic life tolerance to elevated salinity. The actual salinity tolerance of most marine organisms is usually significantly higher than this level.

Salinity in excess of 10% above ambient salinity levels have been demonstrated to be a ‘crux point’ at which development of many species starts to respond adversely. This ‘crux point’ corresponds with the WHO (2007) prediction that most species can tolerate a 10% increase in salinity. In the case of the Port Stanvac marine environment, with ambient salinity in the range of approx 36-38ppt during the period 2008-2009, the WHO estimation gives a predicted upper limit tolerance of 40.6ppt, which is significantly higher than the maximum salinity levels predicted for the ADP discharge.

4.9.2.1 Marine Habitat in the Region of the Diffuser

The benthic habitat in the region of the diffuser is characterised by a predominance of bare sand, sparsely interspersed with red macroalgae and sea squirts (ascidians) (SARDI 2009). The biota that are most likely to be influenced by the saline concentrate discharged into this region are the organisms that live in the sand. These benthic infauna communities are composed of a range of different organisms including polychaetes and crustaceans (amphipods, tanaids and isopods; Loo *et al*. 2008). The infauna communities in the region of the diffuser are highly variable and are dependent on the type of sediment in the area (coarse or fine sand). The fine sand around the diffuser area generally supports fewer infauna animals than the coarser sand found in the deeper water (Loo *et al*. 2008).

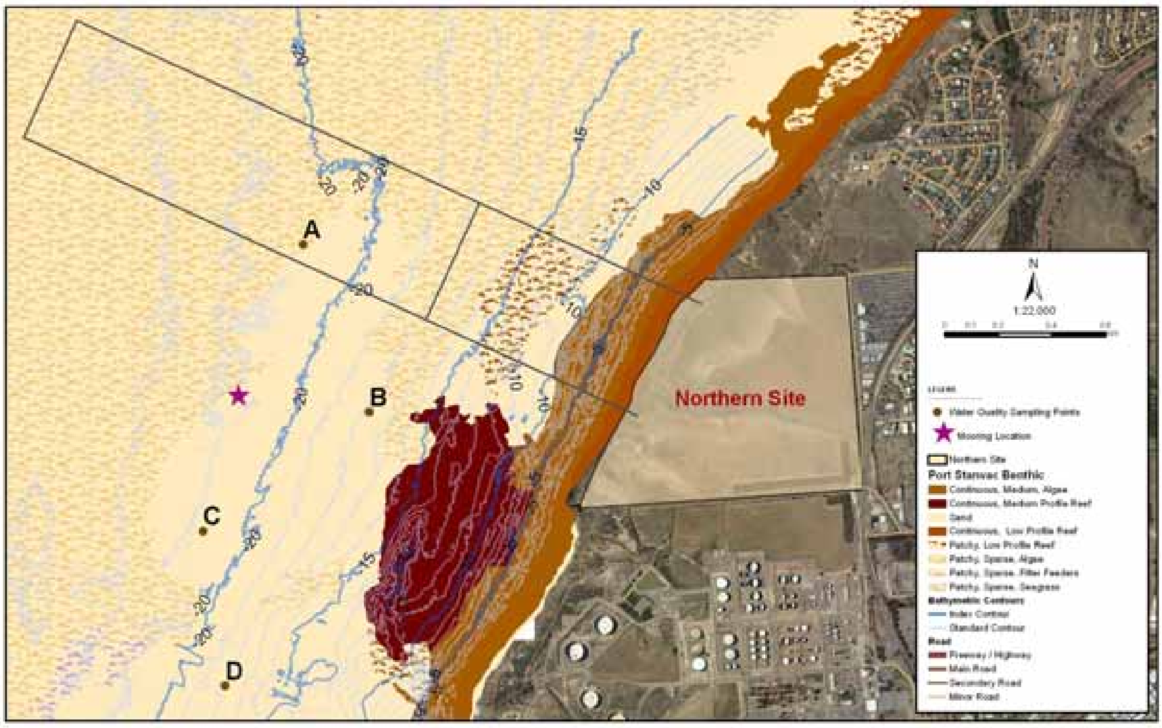

Figure 13: Marine Habitats Off the Coast of Port Stanvac as Identified by DEH (2008). Water quality sampling points (A-D) and Acoustic Doppler Current Profiler (ADCP, represented as a star) locations are included with bathymetry

4.9.2.2 Salinity Tolerance of Marine Organisms

Larvae and young individuals are particularly susceptible to elevated ambient salinity concentrations (Einav *et al*., 2002). Numerous studies examining the ecotoxicological effects of increased salinity levels upon larval development of marine organisms have concluded that there is a salinity threshold, which when exceeded significantly influences growth and survival (Blaszkoski and Moreira, 1986; Reynolds *et al*, 1976; Pillard *et al*, 1999).

Certain species such as echinoderms, squid and cuttlefish are osmo-conformers that are unable to regulate internal salinity concentrations and are therefore susceptible to changes in ambient conditions. Sea urchins, for example, possess a permeable body wall where the gonads in the coelomic cavity are not protected from osmotic change. As such salinity effects are likely to impact these species more than osmo-regulating species (such as fish). Fernández-Torquemada *et al*. (2005) demonstrated that echinoderms were one of the first species to disappear from a brine discharge point when salinity was greater than 39.4 ppt. Squid (*Sepioteuthis australis*) and cuttlefish (*Sepia apama*) eggs have also been shown to be sensitive to changes in ambient salinity concentrations with a salinity threshold of around 44 ppt (Flinders and Adelaide University), after which there is a significant increase in mortality.

Infauna such as polychaetes are known for the ability to adapt to environmental variation and are well suited as indicator organisms of environmental change, as the group contains both sensitive and tolerant species and can be utilised to show a gradient of sensitivity from pristine to heavily disturbed areas (Del Pilar Ruso *et al.* 2008). Del Pilar Ruso *et al*. (2007) examined the spatial and temporal effects of a brine discharge and concluded that the brine causes reduction in abundance and diversity of infauna species (including salinity sensitive polychaetes) within the discharge zone, with the immediate area of the diffuser characterised by a community of nematode worms where the salinity exceeded 39ppt (background salinity in this case was usually 37.1-38.7ppt).

Other infauna species such as bivalves are better able to tolerate increases in salinity as they have mechanisms by which to limit the saline effects. Cockles and mussels for example will stop feeding and close their shells if conditions are unfavourable and Goolwa cockles are thought to be able to tolerate salinities ranging from 20-45 ppt (Nell and Gibbes 1986). Tanner (in prep) showed that juvenile metamorphosis and D-larval development of the Goolwa cockle was affected at salinities greater than 40 ppt, with all development ceasing when salinity concentrations reached 50 ppt. Adult ascidians (*Pyura praeputialis*) and brittle stars (*Ophiuroidea sp*.) have shown some tolerance to increased salinity concentrations, with a salinity threshold of 44 ppt after which mortality rapidly increases (Beatie 2009).

There are very few studies that have examined the effects of salinity on marine plants. Most studies have focused on species such as seagrasses as these species are considered to be more sensitive to water quality changes. Ralph (1998); Kahn & Durako (2006) and Kerr & Strother (1985) demonstrated that some seagrass species such as *Halophila ovalis* are able to tolerate elevated salinities of 25-150% higher than background levels without significant changes to their photosynthetic response to light. The species tended to tolerate elevated salinity concentrations better than a reduction in ambient salinity. This has also been observed in other studies on both tropical (Lirman & Manzello 2009) and temperate (Westphalen *et al*. 2006) seagrass species.

A number of studies (Del Pilar Ruso, 2007,2009; Lirman & Manzello, 2009; Raventos *et al*. 2006; Ralph 1998; Kahn & Durako 2006) have examined the potential effects on marine species from both a reduction and an increase in ambient salinity concentrations, due to freshwater (e.g. waste water treatment plants and storm water) and saline concentrate discharges (desalination plants). Generally organisms tend to be more sensitive to a reduction in salinity rather than an increase.

Work carried out for the ADP EIS (SA Water 2008) and subsequently for AA has utilised ecotoxicology testing in order to assess the potential biological impacts that saline concentrate may have upon marine organisms. The studies utilised where possible South Australian species and the ADP selection of species satisfied the requirements of the ANZECC and ARMCANZ 2000 guidelines for the assessment of toxicants in receiving waters, by having at least 5 species from four taxonomic levels as part of the testing suite.

4.9.3 Potential Impact of Outfall Discharge

Ecotoxicity testing has calculated a safe salinity tolerance of 2.2ppt above ambient salinity in order to protect 95% of marine species. This tolerance was determined by assessing the observable toxicity of the saline concentrate solution on a variety of flora and fauna species, noting that the result is likely to be very conservative given that the tested species are acclimatised to stable laboratory conditions.

ANZECC and WHO guidelines have considered normal variations in salinity that occur naturally in marine environment, indicating that safe salinities levels of 10% above average annual ambient to be an appropriate guide to environmental protection. The salinity of the receiving waters in the Port Stanvac marine environment in 2008 - 2009 averaged 36.9ppt implying a safe guideline level of 40.6ppt.

Modelling conducted for the proposed diffuser indicates a maximum salinity level for 24 hour duration of 0.8ppt above regional ambient salinity at 100m from the diffusers. This corresponds to a "worst case" peak salinity of 38.6ppt (2008-2009 measured ambient salinities), and would occur only during plant production under dodge tide and no wind conditions. This information is summarised in Figure 14.

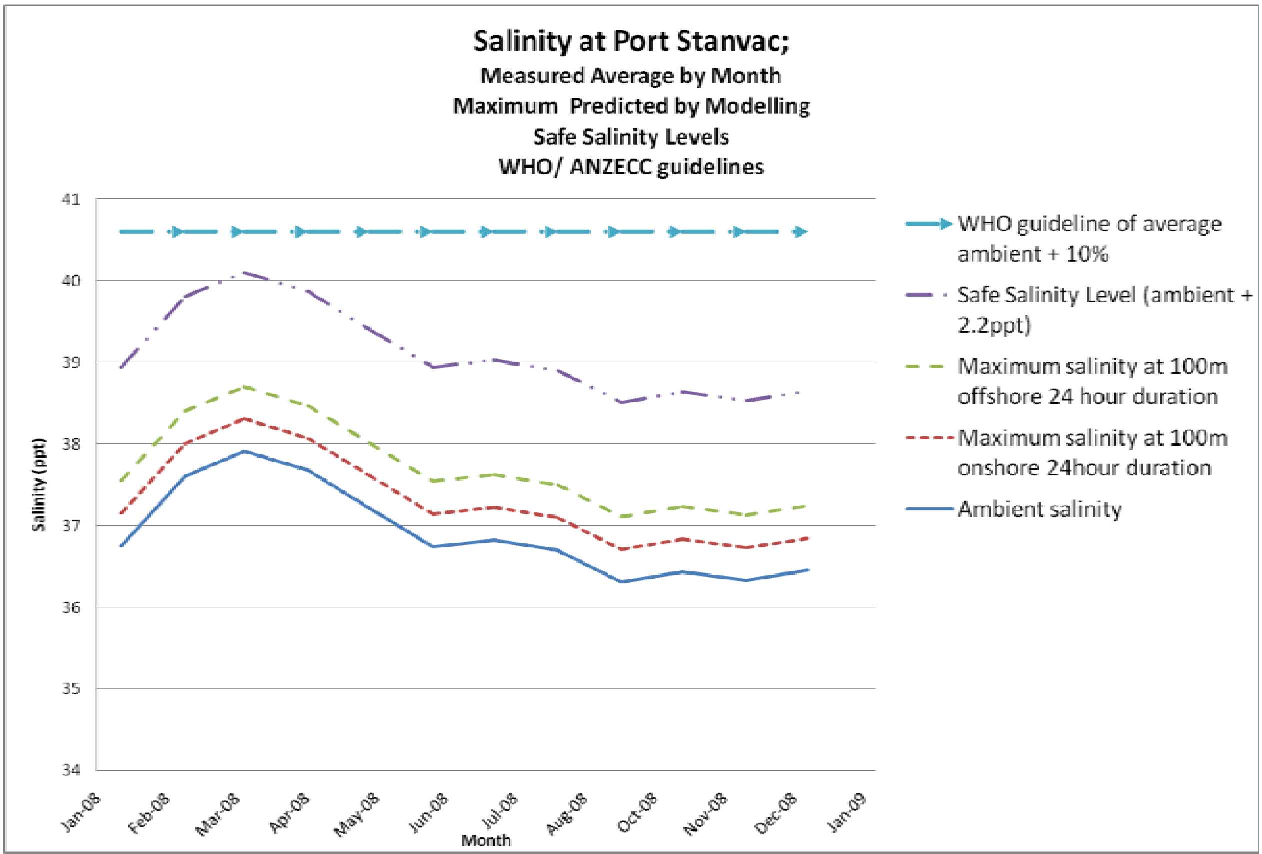

Figure 14: Comparison of Average Salinity at Port Stanvac with Predicted Salinity Levels from Mid Field Model and Ecotoxicity Protective Salinity Concentration

The graph presented in Figure 14 illustrates the average predicted salinity per month, based on average ambient salinity measurements for 2008/2009, and compares these with regulatory guidelines and results from ecotoxicity testing.

Note that;

1. The average salinities are taken from figure 10 of section 4.9.2.2

2. The maximum predicted salinities are based on the extensive modelling discussed in Appendix 1. These demonstrate that at 100m from the diffuser array, the maximum predicted salinity increase averaged over 24 hours will not exceed 0.8ppt above ambient under any of the scenarios considered.
3. The maximum predicted salinity line plotted is equal to the sum of the average measured ambient and the predicted maximum salinity variation of 0.8ppt to illustrate the extreme upper limit salinity levels predicted from the modelling.
4. The maximum predicted salinity of 38.6ppt remains significantly below the safe salinity level of 40.0ppt and WHO guideline of 40.6ppt.
5. The maximum salinity line plotted is an upper limit value that could occur by a coincidence of dodge tides, no wind driven cross currents and maximum plant production.

5 Conclusions

The EIS and Development Approval conditions define specific environmental and engineering performance criteria to which AdelaideAqua D&C are required to comply. It has been demonstrated in this report and appendices that the legal and contractual requirements for the intake and outfall systems of the Adelaide Desalination Plant have been met.

The Intake Structure, is located within the mid benthic zone, a legal and contractual parameter, and the grill and height arrangement minimises the risk of entrainment or entrapment of reef species, sediment or floating debris. The seawater inflow velocity will not exceed 0.15m/s under any operating condition. Marine biota ingress to the plant is restricted by the 75mm free spaced cupronickel grill. Further the chemical dosing system that treats incoming seawater to remove marine microbial growth prior to pre-treatment and the desalination process is designed as a controlled system preventing the backflow of chemical dosing into the marine environment.

The outfall structures positioned within the prescribed envelope zone will utilise the localised hydrodynamics assisting in midfield advection and diffusion of the diluted saline concentrate stream without short circuiting. The physical modelling of the duckbill diffusers and the nearfield modelling of the outfall has been discussed to demonstrate compliance with the gazetted requirement for initial dilution. The design achieves the required initial dilution target of at least 50:1 with an equivalent 58:1 due to higher recovery rates into the local ambient water column under all current scenarios for the full range of operating conditions and/or flows. A bypass system has been incorporated into the ADP design as an assurance that the 58:1 criterion is met during lower plant production rates.

The outfall system design is shown to not cause environmental harm, by demonstrating that the salinity elevations will be well within the safe dilution factors as determined by the ecotoxicity assessments and achieve protection of species in accordance with ANZECC guidelines. Ecotoxicity assessed the potential ecological impacts of saline concentrate discharge into Port Stanvac and confirmed that the saline concentrate is sufficiently diluted through the outfall system. Although the subject of further licensing approval, ecotoxicity assessments were also undertaken on CIP chemicals to demonstrate that the discharge of neutralised CIP saline streams could be undertaken without risk of environmental harm. Finally a monitoring program to address all EPA Discharge Licence requirements will be incorporated within the Operational Environmental Management & Monitoring Plan.

The process of detailed design of the intake and outfall systems and the technical investigations undertaken to verify the EIS and DA conditions have been presented to consolidate overall compliance of the design. In order to reduce the potential risks of the intake and outfall structures on the marine environment, and meet the overarching requirement to "not pollute the environment in a way which causes or may cause environmental harm"; the following areas have been addressed:

- The Intake structure is discussed in section 3, and the detailed design demonstrates compliance with the DA condition 9.
- The outfall structure is discussed in section 4, and addresses the following:
    - The physical modelling of the duckbill diffusers and the nearfield modelling of the outfall has been discussed to demonstrate compliance with the gazetted requirement for initial dilution.
    - The mid field modelling of the outfall system has been presented to illustrate the hydrodynamics of the outfall system
    - far field modelling was undertaken to delineate boundary conditions of the Gulf St Vincent
    - Ecotoxicity testing was undertaken to assess the potential ecological impacts of saline concentrate discharge into Port Stanvac and confirms that the saline concentrate is sufficiently diluted through the diffusers to minimise the potential to cause environmental harm.
- The outfall system design is shown to minimise risk of environmental harm, by demonstrating that the salinity elevations will be well within the safe dilution factors as determined by the ecotoxicity assessments and achieve protection of 95% of species (in accordance with ANZECC guidelines - slight to modified ecosystems).
- The process design and neutralised CIP waste discharged via the outfall is shown to minimise the risk of environmental harm, by demonstrating that the concentrations will be well within the safe dilution factors as determined by the ecotoxicity assessments and achieve protection of 95% of species (in accordance with ANZECC guidelines - slight to modified ecosystems).
- Ecotoxicity assessment of the saline concentrate determined a salinity tolerance of 2.2ppt above ambient to achieve protection of 95% of species. Applied to the maximum average ambient salinity of 37.8ppt recorded for 2008/2009, this equates to a safe salinity level of 40.0ppt.
- The ANZECC / WHO guidelines applied to the annual average ambient salinity is calculated to be 40.6ppt
- Midfield modelling predicts a maximum salinity increase, averaged over 24hours of 0.8ppt (with an instantaneous maximum salinity increase not exceeding 1.0ppt) This result compares favourably to both the ecotoxicity testing results and the ANZECC / WHO guidelines, providing a significant buffer for protection of the marine environment.

5.1 Proposed Operational Monitoring

The DA conditions (Notes to the Proponent, page 2709) note the following with regard to the operational license:

It is likely that as a condition of such licences the EPA will require the licensee to carry out specified environmental monitoring of water quality and to make reports of the results of such monitoring to it. For the purposes of the Discharge Licence the EPA may require, at a minimum, for the operator to monitor and report on:

- Discharge water quality of the different streams discharged via the outfall shaft.

- diffuser performance
- desalination process
- ecological impacts on the marine environment

The monitoring program to address the above parameters will be incorporated within the Operational Environmental Management & Monitoring Plan and will be developed in consultation with the EPA.

6 References

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Appendix A

Water Technology 2009 “Adelaide Desalination Plant - Outfall Dilution Modeling Assessment” November 2009

Appendix B

Water Technology 2009 “Adelaide Desalination Plant - Duckbill Valve Hydraulic and Dilution Performance Investigations” October 2009

Appendix C

Clean-In-Place (CIP) Ecotoxicity Assessment Report

(Document Reference E015-020-2974, 2009)

Appendix D

AdelaideAqua 2009 "Outfall Infrastructure Diffuser Extension – Concept Paper" November 2009

Appendix E

Table 3.1 ADP EIS (SA Water 2008)

E.1.1 Table 3.1- Environmental Objectives and Performance Criteria

Issue	Objective	Performance Criteria/ Requirements and Environmental Management Measures
Marine flora and fauna	Protect marine flora and fauna and associated habitats.	<u>Intake Structure</u> <u>Design and operation to ensure:</u> • Location of the intake structure must be within the mid benthic zone (envelope/zone shown on Figures 3.4 and 3.5). • Intake structure to be located at a sufficient distance from the subtidal reef area to minimise the risk of entrainment or entrapment of reef species. • Location of the seawater intake structure at a height above the seabed to minimise the risk of entrainment of sediment or floating debris. • Seawater intake velocity at the entry to the intake structure should not exceed 0.15 m/s under any operating condition • Seawater intake to incorporate screen/grill to restrict ingress of marine biota with a maximum clear grille spacing of 75 millimetres (as installed). • Any chlorination (or approved biocide) dosing system from the intake structure must ensure that there is no backflow of chemical dosing into the marine environment. • Develop and implement a monitoring program (as part of the Operational Environment Management and Monitoring Plan) in accordance with Major Development approval and EPA licence, including: o Monitoring and reporting on entrainment on marine biota.
Marine flora and fauna	Protect marine flora and fauna and associated habitats.	<u>Outfall</u> The saline concentrate discharge must comply with EPA licence conditions and any other regulatory requirements. <u>Design and operation to ensure</u>: • The outfall structure must be positioned within the envelope zone shown on Figures 3.4 and 3.5 and far enough from the intake to avoid any short circuiting. • The outfall system must terminate with diffusers designed to promote rapid dispersion of the saline concentrate into the surrounding seawater. • The outfall must achieve the required initial dilution of 50:1 at the seabed, or as otherwise agreed with the EPA, under all current scenarios for the full range of operating conditions / flows. • The design of the outfall system should include consideration of the use of bypass flows or other measures to ensure the achievement of the target dilution requirements, particularly under low discharge flows. • The outfall diffuser shall be capable of:

Issue	Objective	Performance Criteria/ Requirements and Environmental Management Measures
		o being extended; and o being modified to reduce the number of diffuser outlets and/or to adjust dispersion rates from each diffuser outlet. • The saline concentrate discharge must not contain Cleaning in Place (CIP) chemicals or any other preservation chemicals, unless permitted by the regulatory authorities. • Ecotoxicity testing (Direct Toxicity Assessment) of the saline concentrate, with representative process chemicals, should be undertaken to confirm species sensitivity and the dilution requirements to protect 95% of species (in accordance with ANZECC guidelines slight to modified ecosystems). • Develop and implement an Operational Environmental Management and Monitoring Plan that incorporates a monitoring Program in accordance with the Major Development approval and EPA licensing requirements. The monitoring program shall include: o process monitoring to confirm that performance is within acceptable range (as supported by environmental assessments); o discharge water quality monitoring; o diffuser performance validation; and o habitat / receiving environment monitoring and water quality. • Demonstrate through modelling and field measurements that the outfall design system achieves the required mixing and dispersion requirements.

Appendix F

Diffuser Development Report