Advice on the Desalination Project Environment Effects Statement

Independent Expert Group, October 2008

to the Secretary
Department
of Planning and
Community Development

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Victoria
The Place To Be

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1. Executive Summary

An Independent Expert Group (IEG) was established in April 2008 at the request of the Minister for Planning to provide advice to the Secretary of the Department of Planning and Community Development (DPCD) on key aspects of the coastal and marine studies to be undertaken for the desalination plant component of the proposed Victorian Desalination Project ("the project"). The IEG was also to review the Environment Effects Statement (EES) prepared by the Department of Sustainability and Environment (DSE) as the interim proponent.

The IEG includes four expert members:

- Professor Mick Keough, University of Melbourne – specialist in marine ecology.
- Adjunct Professor Des Lord, University of Western Australia – specialist in oceanography and hydrodynamics
- Mr Tom Pankratz, Water Consultants International - specialist in water treatment
- Dr Jenny Stauber, CSIRO Land and Water, Centre for Environmental Contaminants Research - specialist in water and sediment quality, including ecotoxicology.

DPCD has sought the IEG's advice on the final EES Main Document - Volumes 1, 2 and 3, and relevant EES Technical Appendices as well as the associated Works Approval Application (WAA) No. WA64404, under the *Environment Protection Act 1970*. The IEG has been asked to advise on the desalination plant concept design (Reference Project), the hydrodynamic characterisation of its operation and the marine ecological impacts arising from its construction and operation. In particular, the IEG has been asked by DPCD to provide collective advice on five questions in relation to the exhibited EES and WAA:

- Question 1 - Consistency of the Reference Project with industry best practice;

  DPCD has sought comment on the consistency of the Reference Project concept design for the desalination plant and associated marine structures with relevant industry best practice.

- Question 2 - Adequacy of hydrodynamic investigations;

  DPCD has sought comment on the adequacy of the hydrodynamic investigations for characterising likely impacts on both larval entrainment from the seawater intake and ecological impacts of plant discharge, in the context of reasonable risk scenarios.

- Question 3 - Assessment of marine ecological impacts;

  DPCD has sought comment on the adequacy of the assessment of likely marine ecological impacts arising from the construction and operation of the desalination plant and marine structures based on the Reference Project concept design and variations.

- Question 4 - Further information for project design and monitoring;

  DPCD has sought comment on further information that may be required in order to verify the risk assessment and optimise the final design and process configuration for plant performance. Advice is sought, in this context, on the principles that should guide the on-going environmental monitoring and management of the plant's operations.

- Question 5 - Suitability of key Performance Requirements.

  DPCD has sought comment on the suitability of key performance requirements that relate to the environmental performance of the desalination plant and marine structures, with respect to discharges to the environment, energy efficiency and waste management. This advice should consider whether the draft performance requirements are sufficiently comprehensive and protective of the environment, as well as offering sufficient flexibility for best practice solutions, and also being both achievable and measurable.

IT IS THE COLLECTIVE VIEW OF THE IEG THAT:

Overall, the desalination plant component of the EES is comprehensive, well planned, mostly well integrated, and sufficiently broad in scope for the assessment of the potential effects of the plant and its marine structures. It seems unlikely, given the scope of the EES, and the approach adopted, that a major impact of the desalination plant has been overlooked or underestimated to the point where significant and unexpected marine impacts will result. At the same time, there are some weaknesses in the EES that should be addressed when the final design is confirmed through verification of the risk assessment and a robustly designed Environmental Management Plan (EMP). In the IEG's opinion, these precautions are essential to fully optimise the plant's design and to subsequently monitor its performance.

The IEG notes that the EES is not always presented in an easily accessible fashion. The main EES documents are sometimes superficial, verbose and contain large amounts of duplication and unnecessary material. The links between summary statements in the main body of the EES and the supporting evidence in the Technical Appendices are often obscure. These structural and editorial weaknesses, however, are not substantial matters that would affect the EES's main findings and conclusions.

The IEG also considers that insufficient attention has been paid to clearly distinguishing between statements that are based on considerable data, and those reflecting best professional judgment of the project team. This is considered a weakness that warrants further attention during verification of the risk assessment and optimisation of the final design.

Question 1 - Consistency of the Reference Project with industry best practice

The Reference Project concept design for the desalination plant and associated structures is consistent with industry best practice. No significant or proven technology options appear to have been overlooked.

When properly applied, the proposed variations to the Reference Design are equally acceptable from both a technical feasibility and environmental performance point of view.

Question 2 - Adequacy of hydrodynamic investigations

The collation of existing information from the area, supplemented with field measurements, has been undertaken in sufficient detail to characterise the major oceanographic features of the area.

The suite of hydrodynamic models of varying complexity that were selected for this study is appropriate. They cover the full range of spatial scales and resolutions that are needed to interpret the effects of the construction and operation of the proposed desalination plant.

The 2-dimensional South Eastern Australia (SEA) and the upper Bass Strait and Port Phillip and Western Port Bays areas (BAS) models are suitable for representing the main oceanographic processes occurring at a regional scale. The models are appropriately structured and calibration and validation of these models was good.

The detailed models used to depict the initial dilution of the saline concentrate discharge and its subsequent advection and dispersion within receiving marine waters are appropriate. The proponents still need to combine the results of these two models into a consistent form to resolve the assessment of the plume impacts.

The results of these models should provide the basis for designating an acceptable "mixing zone" around the diffuser.

Question 3 - Assessment of marine ecological impacts

Marine ecological impacts have been assessed using a combination of habitat mapping to identify appropriate sites for intake and outlet structures and possible construction impacts, sophisticated hydrodynamic modelling to develop an understanding of impacts associated with operation of intakes, and modelling and toxicity testing to predict the operational effects of the outlets.

Overall, the IEG considers that no major potential marine ecological impacts have been overlooked or underestimated.

In the marine ecological assessment, it is not always clear when a statement is supported strongly by evidence, and when it reflects the professional judgement of the members of the EES Project team. The IEG acknowledges that professional judgments will always be required and has no issue with them being presented. However, consideration of the material would benefit from the nature of the judgement being made explicit.

Ecological impacts can occur both during construction and operation of the plant. During construction, the primary impacts are related to disturbance of the seabed, noise and increased risk of introduction of marine pests. The seabed disturbance will occur over a relatively small spatial scale and the footprint will probably be within, or of comparable size to, the anticipated boundaries of the mixing zone. The IEG accepts this view.

The main operational risks of the plant are the issues of entrainment and impingement, associated with the intake of seawater and its filtration, and the ecological effects of the saline concentrate discharge, with or without pre-treatment supernatant.

Operations effects - Intake. The IEG considers that the risks from impingement, which is considered a relatively minor issue, have been assessed appropriately as part of the EES.

The EES has also provided a valuable assessment of the effects of entrainment. The modelling approach is appropriate for widely-dispersing species with known or widespread spawning areas. The effects predicted for these species do not depend on small-scale features of the Project area. However, the models may not be accurate for species with short larval periods.

Operations effects – Discharge. The IEG agrees that there is unlikely to be lethal effects to water column marine biota within the anticipated boundaries of the mixing zone. The ecotoxicological studies also suggest that there is unlikely to be acute or chronic toxic effects on marine biota if the saline concentrate discharge is diluted at least 20 times. This result is indicative that an initial dilution of 50 fold to be required by the Reference Design is conservative and would therefore provide suitable protection to the receiving environment. Further toxicity testing when an actual effluent is available will be essential to confirm these estimates.

The main effects from the discharge are likely to be those associated with elevated salinity. As long as the discharge structures perform as expected, the plume should be diluted rapidly to levels at which elevated salinity would not pose a major risk to marine biota.

Although the Reference Project provides for separating and dewatering pre-treatment solids, the discharge of pre-treatment solids is offered as an option. If this option is employed indirect effects due to iron precipitation and possible smothering of benthic biota in the immediate vicinity of the outfall are likely to be minimal due to the high energy marine environment.

Inclusion of pre-treatment waste supernatant in the saline concentrate discharge (an option to the reference design) is unlikely to increase the toxicity of the discharge. However, a desk-top screening assessment of the potential effects on marine biota of several pre-treatment chemicals including chlorine, acid, polyDADMAC, sodium bisulfite and polyphosphate, showed that the potential impacts of these chemicals may warrant further investigation.

Question 4 - Further information for project design and monitoring

As part of the Reference Project, the seawater intake head and tunnel would be intermittently dosed with high levels of chlorine to reduce marine fouling. The concentrations of brominated organics, formed by the reaction of chlorine with bromide in seawater, are likely to be low. However the toxicity of these compounds to marine biota is largely unknown and may warrant further investigation if these compounds are detectable in seawater in the future monitoring programme.

The proponent still needs to combine the results of the models of initial plume dilution and plume advection and dispersion into a consistent form to resolve the assessment of the plume impacts.

Although safe dilutions should be achieved within 100m of the discharge under most conditions, it is expected that there may be periodic elevations of salinity over a more extended area. There is considerable scientific uncertainty about the effects of varying salinity on marine organisms.

Once the chemical constituents of the final discharge stream are known and the discharge is available for testing, then the concentrations of various additives and chemicals in it should be compared to the trigger values derived for individual contaminants in the EES.

Further samples will be required to get good baseline pre-operational data of background concentrations of contaminants in sediments in the vicinity of the marine structures.

There will need to be a clear indication of how the remaining uncertainties will be resolved. Development of the final design will reduce some of these uncertainties, and will determine the eventual scope for appropriate monitoring. Some monitoring will be required (e.g. toxicity testing), to determine whether the project is meeting performance criteria, and to allow for operational feedback. Some of this monitoring will benefit from early initiation of sampling programmes, which will depend on the final design being developed quickly. In other cases, it is not clear whether rigorous, cost-effective monitoring will be possible, given the nature of the project area, and consideration should be given to whether resources should be used for monitoring, or for more strategic research that is designed to reduce uncertainty in future project assessments (e.g., developing a better scientific understanding of entrainment).

Question 5 - Suitability of key performance requirements

The Performance Requirements proposed for this project are generic in nature and will need to be made more detailed and specific to better inform development of the final design once it has been confirmed.

A comprehensive Environmental Management Plan which includes an appropriate programme of measurement and monitoring is needed to ensure these broad criteria can be properly addressed.

Among the most critical of the Performance Requirements are those related to the operation of the diffuser system and the ability to always meet the requirements for initial dilution. Once the plant is operating, a comprehensive programme of hydrodynamic modelling and *in situ* measurements including physical parameters (such as currents, structure of water column and sea surface elevation) will be needed to ensure that the required levels of initial dilution and subsequent dispersion are being achieved.

2. Preamble to IEG Advice

The IEG was established in April 2008 at the direction of the Minister for Planning to provide advice to the Secretary DPCD on the environmental assessment and management of the desalination plant component of the proposed Victorian Desalination Project. The IEG advice is related to both the plant's marine effects and its environmental performance.

The IEG comprises four technical experts. The IEG members and their expertise are (alphabetically):

- Professor Mick Keough, University of Melbourne – specialist in marine ecology.
- Adjunct Professor Des Lord, University of Western Australia – specialist in oceanography and hydrodynamics
- Mr Tom Pankratz, Water Consultants International - specialist in water treatment
- Dr Jenny Stauber, CSIRO Land and Water, Centre for Environmental Contaminants Research - specialist in water and sediment quality, including ecotoxicology.

DPCD has sought the IEG's advice on the final EES Main Document - Volumes 1, 2 and 3, and relevant EES Technical Appendices as well as the associated Works Approval Application (WAA) No. WA64404. In particular, the IEG's advice was sought on five aspects of the exhibited EES:

- Consistency of the Reference Project with the industry best practice;
- Adequacy of hydrodynamic investigations;
- Assessment of marine ecological impacts;
- Further information for project design and monitoring; and
- Suitability of key Performance Requirements.

These aspects reflect relevant parts of the EES Scoping Requirements, which were issued by the Minister for Planning in May 2008, setting out the matters to be investigated for the EES. The primary focus for the IEG's advice is whether the marine environmental assessment of the desalination plant is essentially sound, such that core technical design aspects can be supported. While the IEG has previously provided advice to DPCD on preliminary outputs of the EES's development, this advice provides the IEG's conclusions on the relevant final EES documentation.

While it is understood that the IEG's advice will inform the Inquiry's consideration of the project, the IEG is aware that the Inquiry will draw its own conclusions, having regard to the exhibited EES and public submissions, as well as the IEG's advice.

This advice does not duplicate the detailed peer reviews commissioned by the Department of Sustainability and Environment as part of its internal quality assurance process for the EES.

3. IEG Mode of Operation

The IEG was briefed by the Department of Sustainability and Environment (DSE) during development of the EES (see Table below). These briefings, together with the IEG's consideration of draft technical documentation, have informed the IEG's advice to DPCD during development of the EES.

Date	Subject matter	IEG participation	IEG attendance
2 April 2008 (am)	Draft Scoping Requirements	working session	D Lord, J Stauber, T Pankratz
2 April 2008 (pm)	DSE briefing – EES Evaluation Framework, Reference Project, Marine Studies Programme, Marine Hydrodynamics, Waste Management	briefed	D Lord, J Stauber, T Pankratz
20 May 2008	DSE briefing - Marine Study progress, Toxicity Assessment, Waste, Energy Efficiency, Environment Management Framework	briefed	All members
21 May 2008 (am)	EES Studies' Scope and Progress	working session	All members
21 May 2008 (pm)	Site Visit to Wonthaggi	briefed	D Lord, J Stauber, T Pankratz
10 July	DSE briefing – Marine Studies' outcomes, Reference Project Refinement, Performance Requirements, Preliminary Marine Monitoring	briefed	All members
11 July	IEG preliminary advice	working session	All members
16 September	IEG Teleconference – review of the exhibited EES	discussion	All members

The IEG recognises that there will inevitably be uncertainties and gaps in the scientific component of any environmental assessment. In forming its view, it used the following series of questions to form an opinion on the seriousness of any gaps and uncertainties.

1. *What is the nature of the scientific uncertainty?*

2. *Does the uncertainty have a strong influence on the assessment of impact?*

   An uncertainty that is associated with a key impact pathway, and where the conclusion is sensitive to the particular uncertainty, would be of concern. In contrast, uncertainty associated with a minor pathway, or situations where the conclusion is robust with respect to values of the parameters in question, are areas that do not affect the robustness of the assessment.

3. *If the uncertainty is important, could the level of uncertainty be removed by additional work in the near future?*

   In some cases, uncertainties might be resolved by further studies, which could be completed without greatly altering project timelines. In other cases however, resolution of uncertainties may not be possible at all, or might require large investments or long time periods.

4. *If it is not feasible to resolve the uncertainty in the short term, is it desirable to reduce that uncertainty in future?*

   For residual uncertainties, it may be desirable to initiate further studies. These studies might include a requirement for monitoring, which would be conducted with the expectation of the data being fed back to manage the operation of the project, or possibly to characterise the impacts of the project better, as a basis for other regulatory action (e.g. mitigation). If there is no clear link between data collection and project management, such as to inform improved project outcomes, the option also exists of initiating more strategic studies, with the aim of developing sufficient scientific understanding to remove the particular source of uncertainty from future coastal decision-making.

Answers to these questions provided a framework for the detailed responses below and provide a rationale for not providing extensive details of uncertainties that are not viewed as critical ones. The sequence used by the IEG is summarized in Figure 1 below.

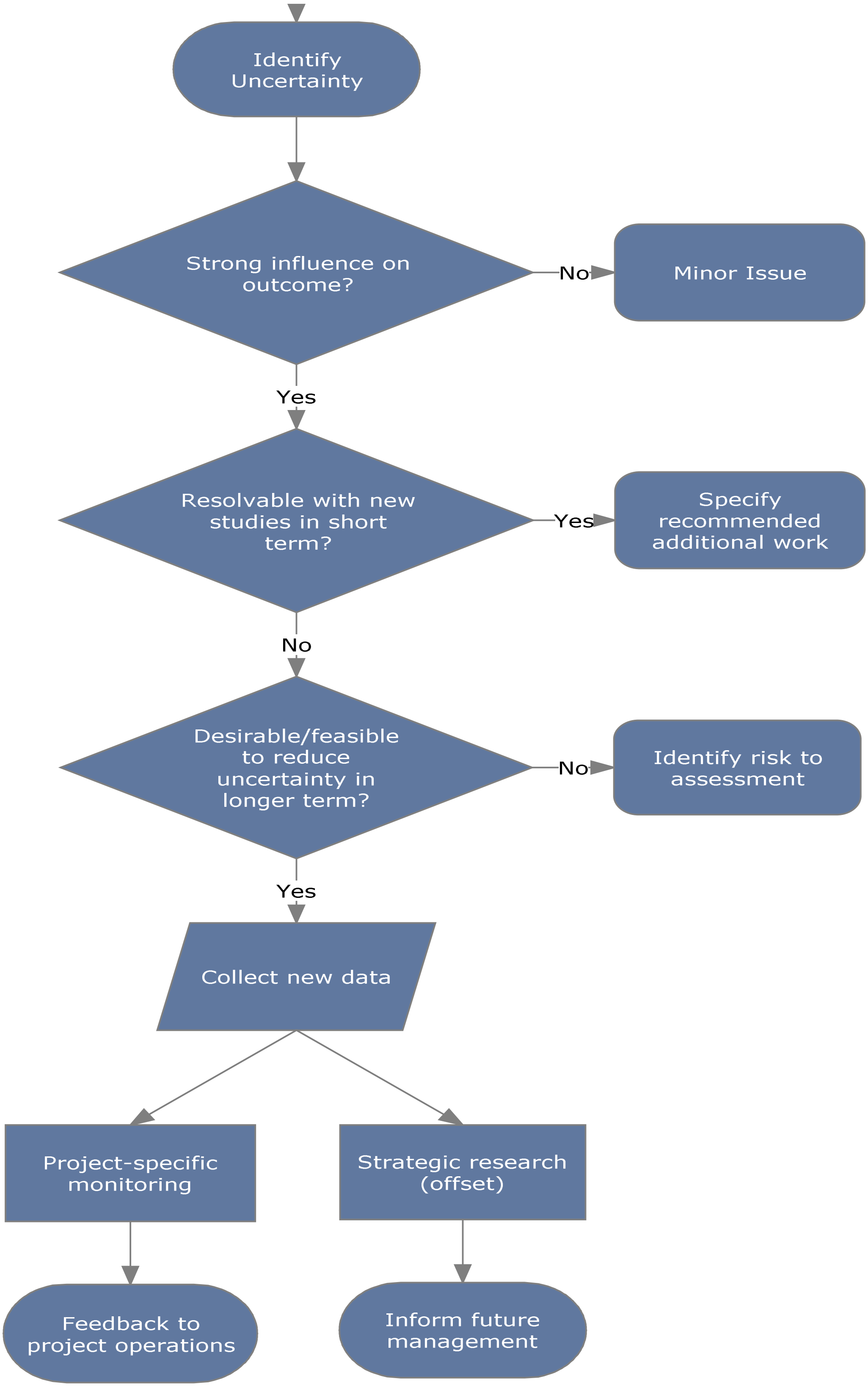

Figure 1 Framework for the IEG's response to uncertainties

4. Collective IEG Advice in Response to Thematic Questions on EES

4.1 Question 1 – Consistency of the Reference Project with industry best practice

DPCD has sought comment on the consistency of the Reference Project concept design for the desalination plant and associated marine structures with relevant industry best practice.

IEG RESPONSE:

Large-scale seawater desalination plants employing the reverse osmosis process have emerged as an effective freshwater supply solution since 1998. Since then, an increasing number of facilities—including Perth's Kwinana plant—have proven that such projects can be developed and operated reliably and with minimum environmental impacts, even in environmentally sensitive areas.

Process for Determining Reference Project

The range of concepts considered when establishing the Reference Design embodied virtually all of the currently proven techniques for minimizing environmental impacts, reducing energy consumption, ensuring reliability and addressing regulatory requirements.

There are no consistent international regulatory requirements for seawater desalination plant design with the exception of those that apply to the drinking water product quality produced. Most environmental regulatory requirements are site specific based on the sensitivity of the local seawater environment from which the water is withdrawn and into which the concentrate will be discharged. The Reference Project embodies the environmental impact mitigation measures that meet or exceed those in practice at virtually every large-scale plant in the world.

No significant or proven technologies or technology options appear to have been overlooked.

Seawater desalination can be accomplished using evaporative or membrane processes. The methodology used to select the most appropriate process for the Reference Project considered the technical feasibility and the social and environmental objectives of the project. Selection of the reverse osmosis process is clearly the most appropriate choice and the best international industry practice for the Reference Project in terms of its energy efficiency, minimum environmental impact and ability to meet the project Performance Requirements.

Not only can reverse osmosis be considered the best industry practice for this project, the subsystems employed within the Reference Project are of a high technical standard and represent the desalination industry's best practice. For example, the isobaric energy recovery device selected for the Reference Project has proven to be the most energy efficient method of recovering pressure energy in the concentrate stream, on virtually every large-scale seawater reverse osmosis plant in the world since 2001.

Another example of the Reference Project's employment of best industry practice extends to the location of the seawater intake to reduce pre-treatment solids loading to minimize chemical consumption and waste generation. Adequate precautions have been taken in selecting the Reference Project to handle and deal with chemical constituents that could have a toxic impact on marine life.

Marine Intake and Outlet Design

A desalination plant's primary interface with the local environment is that associated with the intake system it employs to withdraw seawater and the outlet system used to return saline concentrate back to the sea.

The Reference Design of the intake system includes:

- Intake subsurface tunnel - 4m diameter, approx. 1.25 km long, and
- 4 intake heads - 4m in diameter positioned about 20m below sea surface.

Numerous tests were undertaken in the EES to demonstrate the effectiveness of the intake design to mitigate marine life impingement and entrainment, and extensive hydrodynamic modelling investigations were conducted to ensure concentrate could be successfully dispersed and rapidly assimilated with seawater. The IEG comments on the effects of the plant's intake and discharge on the receiving marine environment are provided in Section 4.3.

The Reference Design of the outlet system includes:

- Outlet subsurface tunnel - 3.2m diameter, approx. 1.5 km long, and
- 6 rosette-style diffusers with 4 nozzles per rosette - positioned 2m above seafloor in deep water more then 10m below sea surface.

Intake/outlet design considerations extended to the site selection itself to ensure both were located in areas identified to be the least sensitive in terms of marine flora and fauna populations.

The EES also outlines variations and options for marine structures (Fig. 3-5 Vol. 1 pg. 3-12). Variations to the Reference Project that were considered included:

- Multiple subsurface tunnels or series of pipes on the seabed instead of one each large subsurface tunnel for intake and outlet;
- Passive fine screens at the intake head instead of a grill screen on the intake head and active screens offshore;
- Pipeline diffusers instead of rosette-style diffusers connected to the outlet tunnel.

The considered options included:

- Seabed filtration instead of direct intake in deep water
- Intake and outlet tunnels or pipes trenched into the seabed.

While the "variations and options" for marine structures provide the latitude for alternative intake/outlet tunnel construction methods, the seabed filtration option mentioned would seem to be highly impractical without further and extensive investigations, in the context of the geology understood to exist in the discharge area.

The Reference Design performance requirements for the marine structures are intended to ensure that any of the proposed variations, if properly executed, would also meet the project requirements.

Pre-treatment Design

The performance and reliability of a seawater reverse osmosis plant is usually determined by its pre-treatment system. While it may in-principle be desirable to conduct a long-term pilot study of an intended pre-treatment system to capture the full range of seasonal and diurnal water quality variations, it is not often practical on the basis of project time constraints. It is therefore necessary, as has been done for the Reference Project, to take a conservative approach based on the information available. Prior to the reverse osmosis process, the intake seawater must be treated to remove marine biota, particulates and organic matter that would otherwise adversely affect the reverse osmosis membranes.

The Reference Project and the variations and options identified represent technologies and systems currently in service in some of the most successful desalination plants in the world. The Reference Project pre-treatment system employs:

- coagulation using ferric chloride coagulant, polymer-assisted flocculation; and
- granular media (i.e. anthracite/sand) filtration.

Pre-treatment wastewater produced by intermittent filter backwashing is proposed to be thickened and dewatered prior to landfill disposal, with clarified supernatant returned to the head of the plant. In fact, most plants with backwash water treatment systems discharge the supernatant directly to the ocean. This is done on the basis that the very low levels of iron present are likely to be rapidly assimilated by primary producer organisms living in the nutrient-deficient seawater environment.

Disposal of the pre-treatment waste to the ocean, along with the saline concentrate, is identified as an option to the Reference Project. The IEG provides comments on the potential effects of this disposal option in Section 4.3.

Use of the membrane filtration (micro filtration (MF) or ultra filtration (UF) technology), as a variation to conventional pre-treatment proposed in the Reference Project, could result in adoption of the ocean disposal option for virtually all pre-treatment waste. In most cases, the use of the membrane filtration pre-treatment can reduce or eliminate the need for a primary coagulant and the flush/backwash water can be blended directly with the reverse osmosis concentrate and discharged to the sea with no deleterious effects.

The membrane filtration variation would also provide a higher level of reverse osmosis feedwater quality, which should be reflected in a reduced level of reverse osmosis membrane particulate fouling. This will result in lower transmembrane pressure and energy consumption and less frequent reverse osmosis membrane cleaning, which will reduce cleaning chemical consumption.

Reverse Osmosis Design

The Reference Project has been designed to employ standard, commercially-available reverse osmosis membrane elements that have been proven effective at removing 99.75 percent of the dissolved salts in hundreds of applications around the world. When arranged in the two-pass configuration defined in the Reference Project, the membranes would produce the required product water quality.

Further, this configuration ensures that plants are able to operate with reduced chemical and energy consumption while minimizing saline concentrate volumes.

Reverse osmosis technology represents the best international practice for seawater desalination by reducing both energy consumption and environmental impacts on the receiving waters. By comparison, a thermal desalination plant would greatly increase energy consumption and water intake requirements, while producing a saline concentrate discharge with a significantly higher temperature and flow rate, hence greater environmental impacts.

The IEG concludes that:

- The Reference Project concept design for the desalination plant and associated structures is consistent with industry best practice. No significant or proven technology options appear to have been overlooked.
- When properly applied, the proposed variations to the Reference Project are equally acceptable from both a technical feasibility and environmental performance point of view.

4.2 Question 2 – Adequacy of hydrodynamic investigations

DPCD has sought comment on the adequacy of the hydrodynamic investigations for characterising likely impacts on both larval entrainment from the seawater intake and ecological impacts of plant discharge, in the context of reasonable risk scenarios.

IEG RESPONSE:

A critical component of this EES Marine Studies is the use of numerical models to:

- characterise the major oceanographic features of the area;
- simulate the effects of the discharge of a higher salinity flow back into the receiving seawater ; and
- simulate the effects of the intake of large volumes of seawater at ambient conditions.

The selection of the models to be used was strongly influenced by the fundamental understanding of the regional and local oceanographic features of the area.

The combined information that was assembled and interpreted was then used to support:

- the engineering design of the inlet and outlet structures;
- the determination of the levels of dilution needed at the diffuser; and
- the interpretation of the ecological consequences of the construction and operation of the desalination plant.

Description and Characterisation of Regional and Local Oceanographic Conditions

Available existing information, supplemented by a series of field measurements at the proposed project site, was used to describe and characterise the regional and local oceanographic features and conditions of the area. This analysis provided the following important broad description of the site.

Wonthaggi is situated along the north shore of Bass Strait, which is a large body of semi enclosed water of average depth 60-80 m. The area is characterised by frequent strong winds and large waves. Currents are a combination of tides and wind driven flows, supplemented by less dominant features such as coastal trapped waves (CTWs). Currents are strongest at the eastern and western ends of Bass Strait and are lowest along the northern shore (such as just offshore Wonthaggi). In addition, the processes of up- and down-welling, frequent thermal stratification (more frequently in summer), and interactions with local freshwater flows such as from the Powlett River, occur in the area at various times during the year.

The description and characterisation of these important features of the area has been well documented and explained in the EES.

The IEG concludes that:

- The collation of existing information from the area, supplemented with field measurements, has been undertaken in sufficient detail to explain the major oceanographic features of the area. This knowledge has been appropriately used in the selection of the suite of hydrodynamic models that have been used in the study to represent these features in greater detail and also to interpret important ecological effects of the desalination plant construction and operation.
- There is still only a limited set of field measurements close to (i.e. up to 5 km distance alongshore) the proposed inlet and outlet structures. Continued measurements close to the proposed inlet and outlet positions are needed to progressively improve the ability to measure and forecast potential influences of construction and operation of the desalination plant and thereby manage these in the most appropriate manner.

Suitability of Hydrodynamic Models

A suite of six main hydrodynamic models and modelling systems were used to generate information for the EES. The results of model simulations were then applied to address various ecological issues.

The hydrodynamic model covering the largest area is the SEA (South Eastern Australia) model, while the next model (called BAS model) focuses on the upper Bass Strait and Port Phillip and Western Port Bays areas. These are considered "large scale" models and are designed to represent regional but not local features. The third model used is a fine scale and high resolution model, covering an area of 8.5 by 3.5 km around the proposed plant which simulates local conditions. Two further separate models were used to depict the mixing, dilution and subsequent advection of the discharge. The first, VISJET, depicts the immediate discharge of the dense high saline effluent and allows for the prediction of levels of initial dilution and also allows for the design of the diffuser system to be optimised. A second high resolution model then depicts the subsequent advection and dilution of the saline plume.

A sixth model presents the effects of the freshwater plume from the Powlett River.

The IEG concludes that:

- The suite of models of varying complexity that were selected for this study is appropriate. They cover the full range of scales and resolutions that are needed to interpret the effects of the construction and operation of the desalination plant.

Farfield Models

South Eastern Australia (SEA) Model

This model includes the whole of Bass Strait. It is a 2-dimensional model and was run at a grid cell size of 1 minute (approximately 1.8 x 1.8 km). The model was able to separately account for currents generated from tides, wind and other major forces such as CTWs. The model outputs calibrated extremely well with sea-surface-elevation measurements made along the coast, in particular at Lorne. The model clearly represented the strong gradient in currents at the Wonthaggi site, with weaker currents inshore and stronger currents offshore.

The SEA model is limited by being only 2-D and cannot be used for addressing issues where vertical motion is significant or important.

Bass Strait and Bays (BAS) Model

The BAS model (as with the SEA model) is also 2-D and similarly has limitations for modelling of processes where vertical features and processes are important. In principle the BAS model uses the results of the SEA model to commence its finer scale operation. An important technical matter addressed in the EES was the development of protocols to limit transfer of 'errors' during the nesting process, in other words, to better define the boundary conditions for the BAS model based on external forcing, i.e. the BAS model can now be run independently of the SEA model. This could have an important implication for subsequent EMPs for the project, where further validation of hydrodynamic modelling predictions will probably be required.

A good set of validation results show the BAS model is able to properly simulate sea surface elevations and currents in the area.

The IEG concludes that:

- The SEA model is an appropriate model to represent regional features. The model is widely used and has been calibrated for this region. It includes all of the relevant forces and was able to represent well the features of the complex Bass Straight area.
- The good validation obtained for the BAS model provides a significant level of confidence in the use of this model for addressing ecological issues.
- The SEA and BAS models are suitable for representing the main 2-dimensional oceanographic processes occurring at a regional scale. The models are appropriately structured, and calibration and validation of these models was good.

Local Fine Scale Model

A local fine scale model covering an area of 8.5 x 3.5 km was run in 3-D using a cell size of 100 x 100 m and 10 layers, to depict local features in the study area. The model performed with a high degree of agreement with field measurements and depicted flows parallel to shore (which are stronger and therefore more significant) with more accuracy than those at right angles to shore. The model uses the method known as ‘Body Force’ to establish boundary conditions. This approach has been supported by separate peer reviews.

The IEG concludes that:

- The local fine scale model run in 3-D includes all appropriate forcing mechanisms and provides suitable resolution. Model results compared well with measurements, providing confidence in the model’s ability.
- The use of the Body Force method to represent the sum of unmeasured forcing features is appropriate, particularly due to the limited set of field measurements in the area.

Nearfield Modelling of Desalination Plant Discharge (with VISJET)

This component of the modelling programme is one of the most crucial to the EES. It is assumed that the principal purpose of the diffuser system is to allow the brine plume to be very rapidly mixed with and diluted by surrounding seawater to close to ambient salinity levels that will have no toxic effects due to elevated levels of salinity.

Relevant to the interpretation of the results of this modelling are two additional factors:

- A companion study in this programme (See Appendix 24: Toxicity Assessment for the Victorian Desalination Project) states that a ‘safe’ dilution of the brine discharge is 20:1. This means that the ABSOLUTE MINIMUM DILUTION TO BE ACHIEVED AT ALL TIMES must be 20. A safe dilution of 29:1 is required if the Reference Design with the option of discharge of pre-treatment supernatant together with the brine is to be used.(see Question 3).
- The Reference Design requires a minimum dilution of 50 to be achieved.

The model VISJET was used to develop options for the diffuser designs and determine rates of initial dilution. It is noted that VISJET has not previously been used for discharges as dense as the proposed brine; consequently a series of laboratory studies were undertaken to calibrate the model. The IEG commends this action by the study team. Recognising the normal difficulties in transferring laboratory information directly to field conditions, the satisfactory calibration of the model provides further confidence in its predictions.

Of importance, is that the VISJET clearly showed that the diffuser configuration contained in the Reference Design (6 rosettes of 4 nozzles each in 20 m of water) would allow the 50-fold dilution requirement to be met under notional operating conditions. 'Tuning' of the diffuser design may allow increased levels of dilution to be achieved.

All VISJET simulations were undertaken using notional (or design) flow conditions. Experience from desalination plants indicate these flows are not normally achieved all of the time, and there may be extended periods when flows are lower. Under such conditions, a number of operational steps can be taken to maintain the high speeds of discharge that are needed to ensure a sufficient level of initial dilution. These include: seawater bypass (i.e. add seawater to the discharge line to maintain flow rates through the diffuser) or cap some of the diffuser ports.

The successful proponent will use the VISJET model results as a guide, but will need to (and will probably choose to) conduct its own modelling of diffuser configuration and initial dilution. When undertaken, this further modelling should include all realistic operating conditions, such as low or variable flows and should also test all of the options available to the operators to retain high speeds of discharge from the diffuser ports which is essential to maintain the required levels of initial dilution.

The IEG concludes that:

- The model VISJET is an appropriate model for assessing minimum dilutions to be obtained from diffuser systems.
- The laboratory calibration of the VISJET model is commended. This provides additional confidence in the model.
- The results of modelling with VISJET show that both ecotoxicological requirements (minimum dilution of 20 times with brine and 29 times with brine plus pre-treatment supernatant), as well as Reference Design requirements (minimum dilution of 50 times) can be met during normal operation.
- The successful proponent for the contract to construct and operate the plant should model all possible and realistic operating conditions (not only notional high flows) to demonstrate that required levels of initial dilution will always be attained, especially under conditions of low levels of brine flows to sea.

Midfield Modelling of Desalination Plant Discharge
A fine resolution 3-D model has been used to represent the mid-field advection, dispersion and dilution of the saline plume. This is an appropriate model to address this matter.

The mid-field model should be influenced by output from the initial dilution model (VISJET) and hence their results should be comparable.

The IEG has noted:

- The diffuser modelling (VISJET) used an ambient salinity of 35.0‰. The mid-field model used an ambient salinity of 35.5‰. This is inconsistent. They should be using the same ambient conditions to allow for transfer of information between models.
- The diffuser modelling (VISJET) of the reference design clearly shows an initial dilution of 50 or more ALWAYS occurring, and achieving this within 25-50 m of the diffuser (see fig 6.4 of Appendix 30). A 50 fold dilution elevates the ambient salinity by 0.58‰. However, the Mid Field Modelling report states that, "…zones of salinity elevated to 36‰ (i.e. 0.5‰ above ambient) and 36.5‰ (1.0‰ above ambient) are typically observed in asymmetric regions of approximately 1.5 km by 1.5 km and 1 km by 1 km respectively".
- Clearly the spatial extent of the elevated levels of salinity is not consistent between the model results provided in these two reports.

A critical performance requirement for the desalination plant is to achieve a dilution of the saline concentrate discharge of at least 50:1 within 100 m of the diffuser. The results of the Mid Field modelling show isopleths of a salinity change (ΔS) of 1‰ (which corresponds to only a 30:1 dilution) will reach out to 1 km from the outlet system.

This is an important matter that requires resolution.

The IEG concludes that:

- Numerical modelling has shown that rapid dilution will occur close to the diffuser. However the results of the numerical modelling of the diffuser system and the near field advection are not providing similar advice.
- The proponent must resolve this matter. The proponent should consider all options for combining the results of the diffuser modelling and near field modelling and presenting these appropriately. Both models should use the same background conditions.

Numerical Modelling of the Powlett River Freshwater Plume
Freshwater from the Powlett River enters the sea to the north west of the proposed desalination plant at Wonthaggi.

A fine scale and high resolution 3-D model was employed to simulate the movement and dilution of this plume.

Model results clearly showed that under even the most conservative conditions the plume would not reach the intake head. Consequently under current and expected climatic conditions there is a very low risk of freshwater from the Powlett River being entrained at the intake for the desalination plant.

The IEG concludes that:

- The high resolution numerical model employed to simulate the advection of freshwater from the Powlett River is appropriate for the purpose. Model results clearly show a very low risk of entrainment of Powlett River water at the desalination plant.

4.3 Question 3 - Assessment of marine ecological impacts

DPCD has sought comment on the adequacy of the assessment of likely marine ecological impacts arising from the construction and operation of the desalination plant and marine structures based on the Reference Project concept design and variations.

IEG RESPONSE:

Adequacy of Marine Ecological Assessment

Marine ecological impacts have been assessed using a combination of habitat mapping to identify appropriate sites for intake and outlet structures and possible construction impacts, sophisticated hydrodynamic modelling to develop an understanding of impacts associated with operation of intakes, and modelling and toxicity testing to predict the operational effects of the outlets.

In general, the IEG considers that no major potential marine ecological impacts have been overlooked, and the main risks have been investigated thoroughly.

We do note, however, that in the marine ecological assessment, it is not always clear when a statement is supported strongly by evidence, and when it reflects the best professional judgement of the members of the Project team. The IEG acknowledges that professional judgments will always be required, and has no issue with them being presented. However, consideration of the material would benefit from the nature of the judgement being made explicit When judgements are evidence-based, the conclusion can be assessed easily, but when professional judgements are involved, it is reasonable to ask whether other professionals would make the same judgement. This leads to the level of uncertainty not always being clear in the EES.

The recommendations behind site selection provide a good illustration of this issue. It is asserted, in the main body of the EES and in the relevant Technical Appendix (No. 31), that biodiversity is higher on high relief reefs. This assertion is not based on any quantitative data, and particularly not data from the local area, where biodiversity was not assessed in any detail. The strong recommendation that intakes and outlets should avoid high-relief reefs should be identified as a conclusion that is not evidence-based, but reflects professional judgment by the consultant team. Scientifically, the precise relationship between biodiversity and reef topography should be regarded as a gap or uncertainty. In this case, the IEG agrees with the judgment of the project team and the marine ecological consultant in particular. While data could be collected to make a formal quantitative assessment, the conclusion would not be likely to change.

These statements are relatively common in the EES (e.g., high relief reefs and biodiversity; reef fish are sparse through the area; Blue-throated wrasse are likely to play an important ecological role, spring is the period of highest biological activity, commercial fish are likely to have been depleted).

A related issue to this is the attribution of information. In the EES, other pieces of evidence are presented in a way that leaves the reader with the impression that the material is the result of work done for this EES, rather than simply obtained from other sources (e.g. Table 5-1). Where information comes from other sources, it may have been taken some time ago, or from other places. Again, the errors are not likely to alter major conclusions, but they reduce a reader's ability to determine the level of confidence attached to the conclusions

The IEG concludes that:

- In general, the IEG considers that no major potential marine ecological impacts have been overlooked.
- In the marine ecological assessment, it is not always clear when a statement is supported strongly by evidence, and when it reflects the professional judgement of the members of the Project team. The IEG acknowledges that professional judgments will always be required and has no issue with them being presented. However, consideration of the material would benefit from the nature of the judgement being made explicit.

Effects of Construction of the Desalination Plant

There will inevitably be some impacts associated with construction. These are predicted to come from activities associated with the installation of the intake and outlet structures in the case of the Reference Project, and from these activities, plus the trenching and laying of pipes in the case of variations.

Reference Project - construction

In the case of the Reference Project, effects will not come from the structures themselves, but from the equipment that is required to install them. In particular, it will be necessary to position a large barge over the intake and outlet locations and to secure it against movement. There will also be the need to store some construction materials on site for short periods and there will be increased vessel traffic to provide support for the drilling and construction barge. The primary impacts are related to disturbance of the seabed, noise, and increased risk of introduction of marine pests

The seabed disturbance will occur over a relatively small spatial scale and the footprint will probably be within, or of comparable size to, the eventual mixing zone.

This small footprint should result in the consequence of this disturbance being minor. The consequences will depend on details of the actual vessel that is used and the structures needed to stabilize it, and the location of the actual intakes and outlets. Within the EES, it is stated that the disturbed area will recover rapidly to its previous state (Sec. 7.2). There is no evidence provided to support this statement and we note that uncertainty about recovery of marine ecological communities was a feature of the recent Channel Deepening Inquiry. Recovery rate is likely to depend on the final siting of intakes and outlets, so this decision will determine the actual construction impact. In general, ecological communities in soft-sediments recover quickly from small to medium-sized disturbances, while those on rocky reefs take longer. This difference is acknowledged in the Technical Appendix, but there is inconsistency in the risk matrix (Table 7-1), where the same event, *'removal or damage of seabed habitat'* is assessed as certain in one case and likely in another.

The IEG is of the opinion that this source of uncertainty is minor, given the consequences of even very slow recovery, or recovery to a different ecological state. We consider that little would be gained from any immediate gathering of additional information. This uncertainty does, however, highlight a broader knowledge gap concerning the resilience of marine ecological communities in Victoria, a gap that would best be remedied by strategic research.

We also note that in assessing the existing conditions of the project area there has been little attempt to describe biodiversity in detail. This reflects the speed with which the EES was prepared, the extreme difficulty associated with field work in this region and limitations of the survey methods used. The latter two limitations are acknowledged in Technical Appendix 31, but it does reflect another uncertainty associated with construction impacts. It is the judgment of the project team that the biodiversity of these reefs will not be markedly different from those along neighbouring areas of the Victorian coast. This should be acknowledged in the main sections of the EES and viewed as an uncertainty, albeit one with a relatively minor risk. It might be instructive in dealing with this uncertainty if there were to be a comparison between the reef biota from the Bunurong area and Phillip Island, as reflected in data held by DSE and Parks Victoria, despite some of the limitations of those data sets.

Noise will be an inevitable part of construction and the EES highlights the available information on this matter in Victoria. Concerns about noise are most often raised with respect to whales and dolphins, but the Project Area is not considered critical habitat, or even used frequently, by these species.

The residual risk from marine pests is considered minor. Risks are proposed to be reduced by vessel management consistent with national and state guidelines. The risk from pests has been assessed in a relatively cursory fashion, using large-scale distributional records from state and national databases. These databases provide detail at the scale of IMCRA regions, so the project area is part of a much larger region that includes areas near Port Phillip Bay and encompasses a range of habitats. At this scale, it is not easy to determine which species pose high risks. For example, broad distributional records do not reflect the recording of the invasive sea star *Asterias amurensis* near to the project area, but in a habitat completely different from that of the project area. The IEG agrees with the overall assessment of residual risk, but considers that a better case could have been made, taking greater consideration of the extent to which the project would raise risks, given the existing levels of vessel traffic in the area and making use of what is known about the extent to which invasive species have been recorded in open coast areas near to Port Phillip Bay (e.g. in Marine National Parks close to the entrance of the Bay).

Variations - construction

Variations to the Reference Project would have a larger ecological footprint, because of trenching and/or laying of pipe. The total area that would be affected is still relatively small and the consequence would depend on the spatial extent of the habitat affected. For both soft sediments and reef habitats, the habitat is widespread (subject to earlier *caveats* about actual measures of biodiversity), and many of the organisms dispersive over scales of kilometres, so the proportion of habitat affected would be small.

The IEG concludes that:

- The EES concludes that the primary construction impacts are related to disturbance of the seabed, noise and increased risk of introduction of marine pests. The IEG agrees with this assessment.
- The seabed disturbance will occur over a relatively small spatial scale and the footprint will probably be within, or of comparable size to, the anticipated mixing zone boundaries. The EES states that the disturbed area will recover rapidly to its previous state. However, recovery rate is uncertain, and is likely to depend on the final siting of intakes and outlets. The IEG is of the opinion that this source of uncertainty is minor, given the consequences of even very slow recovery, or recovery to a different ecological state.
- The IEG agrees with the overall assessment of residual risk of the introduction of marine pests, but considers that a better case could have been made, taking greater consideration of the extent to which the project would raise risks, given the existing levels of vessel traffic in the area, and making use of what is known about the extent to which invasive species have been recorded in open coast areas near to Port Phillip Bay.
- Uncertainties associated with the resilience of marine ecological communities in Victoria could be reduced through further strategic research.

Effects of Operation of the Desalination Plant

The main operational risks of the plant are the issues of entrainment and impingement, associated with the intake of seawater and its filtration, and the effects of the discharge. The residual risks associated with the intake are primarily those of entrainment, which is the entry of marine organisms into the intake structure, where they are very likely to be killed, either by chlorine treatment or by the action of fine screens. The effects of the discharge, which is hypersaline water, plus some process chemicals, have been assessed by two separate study streams, one focusing on the nature of its discharge and assessment of its toxicity using laboratory bioassays, and a broader ecological consideration of impacts, incorporating the toxicity studies and hydrodynamic models. Toxicity studies and broader ecological impacts of discharge are treated separately below.

The IEG considers that these components pose the main marine ecological risks associated with operation of the desalination plant.

The intake system has been designed with a low velocity at the inlet riser screen to reduce entrapment of marine life. Despite the fact that intermittent chlorination would be employed to minimise accumulations of biological growth, it would be impossible to stop all growth on the intake structure, particularly the protective grill on the intake head.

As growth accumulates over time, it will eventually begin to occlude grill openings and result in higher entrance velocities. The Reference Project has identified that manual cleaning would occasionally be required and the IEG recommends diligence in monitoring such growth to ensure that design velocities are not exceeded beyond acceptable levels.

All seawater intakes that abstract water above the seabed will experience some impingement and entrainment, the magnitude of which may be exacerbated by seasonal or climatic conditions. During the operation of the plant, it will be necessary to monitor the level of the impingement by means of inspecting the screenings collected in the travelling band screen wash water. If unacceptably high levels of marine life are found to be present, the intake operation and/or travelling band screens may require some modification to improve survival of impinged organisms.

Intake Effects - entrainment and impingement

The potential ecological impacts of most interest are entrainment and impingement. Impingement refers to the trapping of larger marine organisms against the initial screens. Entrainment is the entry of organisms into the intake system and their eventual removal via the fine filters or the rivers osmosis membranes. This term is generally applied to small organisms, particularly the tiny larval stages of fish and invertebrates. These organisms are unable to swim fast enough to escape even the relatively weak intake currents[1], and are presumed to be killed. The Reference Project also includes chlorination of water within the intake pipes (with consideration also given to the use of copper), and the Project team use the term entrapment to describe organisms that move into the intake pipes, where they encounter the chlorine. This group of organisms might include some fish that take up residence in the intake structures.

Impingement is considered to be a relatively minor issue. The intakes will be engineered to keep intake water velocities low and it is intended that coarse mesh screens will keep larger organisms from entering the intake system. The low velocities will mean that only very weakly swimming animals, such as jellyfish, would be unable to escape the intake stream. The IEG considers that the risks from impingement have been assessed appropriately as part of the EES.

Entrainment is a much more difficult issue to assess. It is an issue not only with desalination plants, but also with coastal power plants that use seawater for cooling. Consequently, it has received considerable attention, particularly in areas such as California[2]. Assessing the consequence of entrainment requires first, an

[1] Swimming speeds of marine invertebrate larvae are typically < 1 mm/s, compared to intake currents of the order of 15 mm/s. Larval fish are capable of swimming at much faster speeds than most invertebrate larvae, depending on their age and size.

[2] A good recent review of this issue is provided by Steinbeck et al. (2007), California Energy Commission, Report CEC-700-2007-010.

understanding of how many organisms are entrained. This will depend on the local environment, in particular how many larvae[3] are present per cubic metre of water and where that water comes from. When the organisms being entrained are larval stages, those dead larvae may represent lost recruitment into the adult population of the species in question. Deciding the importance of these lost larvae is the difficult step. Ideally, we would know what proportion of the total larval production is lost, and whether that level of reduction would result in reductions in the population of adults. Proportional losses may vary between species, particularly depending on how widely larvae disperse. For example, if a species is widespread and its larvae disperse widely, then local entrainment may result in a tiny fraction of the total larval pool being lost, and wide dispersal of larvae may spread those losses over a very large area. At the other extreme, for a species that does not have an extensive distribution, with larvae that do not disperse widely, entrainment could account for a substantial proportion of the larval pool.

The consequences of larval loss will vary between species. The fundamental question concerns the processes that regulate population size. Some species are limited by the actions of their predators, or by resources such as feeding territories. For these species, fluctuations in the number of larvae arriving may be irrelevant, with many more larvae arriving than can possibly survive. In contrast, other species may be limited by the number of larvae arriving. For these species, fewer larvae means fewer adults. The question of whether marine populations are regulated by larval supply or by adult resources and/or predation has been a source of considerable debate amongst marine ecologists. The current view is that species vary and that, in a given area, some species may be limited by supply, while others may not. Along the Victorian coast, the status of most species with respect to larval supply is unknown. This is an important source of scientific uncertainty.

The Project team has made a promising start to predicting the effects of entrainment. Their focus has been to predict the proportion of larvae that are expected to be lost. In doing this, they have recognised the diversity of marine species, with larval periods varying from minutes to months for common species. They have constructed a family of hydrodynamic models and used them with a combination of patterns of larval release, including spawning in particular locations (e.g. Port Phillip Bay), or spawning over the whole area. The models have treated larvae as passive particles, transported by currents.

The IEG has previously endorsed this approach as an appropriate starting point. There are, however, some uncertainties, some of which are acknowledged in the Technical Appendices.

1. The modelling approach is appropriate for widely-dispersing species with known or widespread spawning areas. The results for these species do not depend on small-scale features of the Project area.
2. The models may not be accurate for species with short larval periods. These species will not disperse far and larvae that are entrained will be locally derived. Their dispersal may reflect small-scale features of the area, such as habitat that is patchily distributed (e.g. high-relief reef). Understanding the

[3] Organisms entrained include those spending their lives in the plankton ("holoplankton"), and juvenile stages of marine animals (larvae), and dispersive stages of marine plants (spores, seeds, etc.). For convenience, we refer to these latter groups as larvae, while recognising that the term applies to algae and seaweeds.

level of entrainment would require fine-scale hydrodynamic models, comparable to those used for modelling the behaviour of the discharge plume. In the most extreme case, it is likely that entrainment would be underestimated for larvae that are released from a few points in the Project area and have a very brief period in the planktonic phase of their life cycle. The magnitude of the underestimation is hard to assess, as is the proportion of species that might fit into this category.

3. It is possible that the proportions of species might vary between habitats, with potentially a higher proportion of non-dispersing species on reefs than on sandy habitats. This possibility is included as part of the risk assessment in Technical Appendix 31. The IEG considers that this question would not be answered by collection of additional data, but a desktop study could be conducted to better inform eventual site selection for the intakes.
4. A substantial number of reef-associated species, particularly benthic invertebrates, such as sponges, colonial ascidians, and bryozoans, have larval durations considerably shorter than the 1-day duration. These species may also be those most at risk from the discharge. It would be helpful to consider the extent to which larval depletion could occur in such species.
5. The models were run for relatively short times and there is no capacity to consider the longer term consequences if small entrainment losses caused reduced adult populations, which in turn resulted in fewer larvae being produced. This uncertainty is acknowledged, but its consequences are not clear at this stage. There is the suggestion that entrainment may result in moderate effects on ecological communities at scales up to 2 km (page 8-16 in EES, vol. 2). Evidence for this is unclear.
6. The most important uncertainty is whether particular species are limited by larval supply or not. The approach taken in the EES is that most species produce very large numbers of larvae, the vast majority of which die, and therefore species can tolerate small reductions in larval supply. This is not an accurate reflection of current ecological views. There is, however, a lack of data for Victorian species to determine which species are sensitive to reductions in larval supply and which are not. The IEG considers that the generation of data to answer this question is a strategic research need, and little would be gained by additional data collection at this stage. The uncertainty needs to be included in the assessment, however.

There are other minor clarifications that would be helpful.

In discussion of species of concern, it would be of interest to know if there are species with limited dispersal, for which local depletion may be an issue. Syngnathid fish (pipefish and sea horses) would appear to be a strong candidate, with live-borne juveniles that have weak swimming abilities.

The presentation of the entrainment results could be improved. The main illustrations are plots of percentage reduction in larval abundance across the Project area, with different degrees of reductions represented by different colours. The ranges associated with each colour are puzzling, and it is hard to see why 0 was not used as a cut-off, rather than values such as -0.1341.

The IEG concludes that:

- The IEG agrees with the EES assessment that the issues of entrainment and impingement, associated with the intake of seawater and its filtration, and the effects of the discharge pose the main marine ecological risks associated with operation of the desalination plant.
- Impingement is considered a relatively minor issue in the EES. The IEG considers that the risks from impingement have been assessed appropriately as part of the EES.
- The EES has provided a valuable assessment of the effects of entrainment. They have constructed a family of hydrodynamic models, which have treated larvae as passive particles, transported by currents. The IEG considers that this approach provides an appropriate starting point.
- There are some uncertainties associated with entrainment modeling: the models may not be accurate for species with short larval periods; the models were run for relatively short times and there is no capacity to consider the longer term consequences if small entrainment losses caused reduced adult populations, which in turn resulted in fewer larvae being produced. The most important uncertainty is whether particular species are limited by larval supply or not.

Effects of Discharge - composition of the discharge and its toxicity

The IEG is supportive of the general approach being used in the ecotoxicity component of the EES to assess the composition and toxicity of the proposed discharges. In particular, the IEG is pleased that the proponent has responded to previous IEG suggestions and revised aspects of the testing programme accordingly.

The EES examined composition and potential toxicity of the desalination plant's main liquid waste streams, including:

- pre-treatment waste's clarified supernatant produced by thickening and dewatering of filter back-wash;
- reverse osmosis membrane cleaning wastes; and
- saline concentrate.

In the Reference Project ocean disposal is considered for all these waste streams, with exception of the clarified supernatant.

Pre-treatment Waste Composition and Potential Toxicity

Methodology Used

The potential risk associated with the use of pre-treatment chemicals was investigated in the EES in:

1. a desk top study using the Hazard Quotient (HQ) method to compare likely exposure concentrations with effects on marine biota, as previously suggested by the IEG; and
2. direct toxicity assessment (DTA) of various individual waste streams from the Perth desalination plant, including intake seawater after chlorine dosing, ferric-dosed seawater, polymer-dosed seawater and various blends of pre-treatment waste with saline concentrate (Appendix 24).

The desk-top HQ hazard assessment of the possible chemicals to be used in the pre-treatment was limited by lack of exposure data (which had to be estimated from expected dosing rates) and lack of effects data (the known toxicity of these chemicals to marine biota). The approach was therefore not always consistent with established methods. The effects concentration (the denominator in the HQ) is usually a NOEC[4] or EC10[5] value for chronic effects. However, presumably due to lack of available chronic data, acute LC50[6] data were often used, leading to possible incorrect conclusions about risk. For example, HQs could be ten-fold higher if acute LC50 data are used after the application of an acute:chronic ratio (ACR) of 10, e.g. for post-treatment chemicals such as sodium bisulfite, the HQ increases from 0.3 (given in Appendix 24) to 3, indicating a potential risk. This screening assessment should be conservative and the potential effects on marine biota of several chemicals including chlorine, acid, polyDADMAC, sodium bisulfite and polyphosphate may warrant further investigation.

The IEG comments on the methodology used in the DTA of pre-treatment chemicals are given in the saline concentrate section.

Methodology 1: Desk-top assessment

While the desk-top risk assessment found that some chemicals would not present a risk to marine biota, there were several gaps.

As part of the Reference Project, the seawater intake head and tunnel would be intermittently dosed with high levels of chlorine to reduce marine fouling. Although chlorine is rapidly lost, in seawater it reacts with bromide to form bromine and hypobromous acid, and in the presence of organic matter, forms brominated organics such as bromoform, dibromoacetonitrile and dibromochloromethane, some of which are more stable than similar chlorinated compounds. The likely concentrations of these brominated compounds is low, however the toxicity of these compounds to marine biota is largely unknown. For example, the toxicity of dibromoacetonitrile to marine biota is unknown, but effects on freshwater fish have been reported at around 0.5 mg/L (LC50). Further consideration of the potential impacts of these compounds should be undertaken, as they are only briefly discussed in Appendix 23 (water and sediment quality report). This is particularly important if a seawater bypass from the screen/pumping station, as indicated on the process flow diagram 6-17 in the WAA, is built, as this could mean that chlorinated seawater (before neutralisation with sodium bisulfite) may be discharged in times of reduced plant operation.

In the WAA, possible seawater intake dosing with copper/chlorine in place of sodium hypochlorite is also mentioned, but this is not considered further in the EES Reference Design. If this were to be a variation or option, then consideration should be given to the concentration of copper, which is highly toxic to marine biota at ppb[7] concentrations, in the discharge.

Although the direct toxic effect of iron, used as a coagulant in pre-treatment, on marine biota is unlikely, there may be indirect effects due to iron precipitation and

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[4] No observable effect concentration – i.e. the highest concentration of a test sample to cause no significant effect compared to a control.
[5] The concentration of a test sample to cause a 10% effect or affect 10% of the test organisms.
[6] The median lethal concentration – i.e. the concentration of test sample to kill 50% of the test organisms.
[7] parts per billion e.g. micrograms per litre

possible smothering of benthic biota in the immediate vicinity of the outfall. This is briefly discussed in the water quality report (Appendix 23) and marine biology report (Appendix 31) but was not included in the main EES document. It was concluded that because iron is proposed to be removed by sedimentation before discharge of the supernatant, that iron concentrations will only be a few ppm[8] and that this will not lead to a visible precipitate. If a visible precipitate does occur, it will be a light floc that is unlikely to settle out in the highly turbulent environment offshore from Wonthaggi. However, this will need to be assessed and visual monitoring of the discharge zone will be required in the design of the final monitoring programme. In addition, the possible stimulation of algal growth due to addition of iron (normally a limiting nutrient) was only briefly considered in the Marine Biology report.

Aluminium is also mentioned as a possible alternative coagulant for pre-treatment waste, due to its ability to potentially mitigate waste generation. However accepted practice is to use iron salts rather than aluminium salts for seawater desalination reverse osmosis processes due to their lower tendency to form scaling deposits on the reverse osmosis membranes and their wider range of effective PH. Another important reason not to use aluminium salts is their greater toxicity to marine biota than iron. This aspect is not discussed in the EES or in the specialist reports.

Methodology 2: DTA approach

Direct toxicity testing of the ferric-dosed seawater and polymer-dosed seawater showed that the toxicities of these waste streams to a range of sensitive marine biota were low (Appendix 24). Discussion of the toxicity of the pre-treatment waste blended with the saline concentrate is given in the saline concentrate section below.

Reverse Osmosis Membrane Cleaning Wastes Composition and Potential Toxicity

The Reference Project also included ocean disposal of the reverse osmosis membrane cleaning wastes, which may contain dilute acids (citric acid and hydrochloric acid), alkalis, surfactants, disinfectants and ammonia. It is proposed that these wastes (approximately 8000 cubic metres per year) would be neutralised and blended with the saline concentrate and discharged via the outlet. If this waste was blended over the course of a day with saline concentrate discharge, it was estimated that dilutions of 1000:1 would be achieved at the point of discharge. Thus, although it is unlikely that there would be any toxicity to marine biota, no toxicity assessment of this waste stream was undertaken in the EES, so it may require monitoring during discharge once the plant is operating.

Saline Concentrate Composition and Potential Toxicity

The major discharge from the desalination plant is the saline concentrate (up to 210 GL[9] per year). The discharged concentrate will consist primarily of constituents removed from the raw seawater, including salts (salinity about 60‰, nearly double that of seawater) and process chemical additives such as antiscalants, sodium bisulfite and sodium hydroxide. In the Reference Project, only the saline concentrate is discharged through the outlet, without the pre-treatment waste. However, one option is to blend all of the pre-treatment waste (solids and liquid) with the saline concentrate prior to discharge, or alternatively to blend the clarified supernatant pre-treatment

[8] parts per million e.g. milligrams per litre
[9] Gigalitres

waste (liquid only, no solids) with the saline concentrate, as is discharged currently at the Perth desalination plant. The potential toxicity of all these options was assessed in the EES.

Methodology Used

It was not possible to characterise the composition and likely toxicity of the discharged saline concentrate of the Reference Project, because no pilot plant concentrate was available for testing. Instead, samples from the Perth desalination plant, the only large operating desalination plant in Australia, were used as a surrogate. This was justified in the EES on the basis that: 1) there were no major differences in seawater composition between Perth and Wonthaggi; 2) desk-top mass balance predictions for the composition of the Reference Project discharge were similar to the waste stream composition from the Perth discharge; and 3) differences in the process design between the Perth desalination plant and the proposed Reference Project were minimal. In fact, the major difference between the Perth plant and the Reference Project in the EES is that the Perth saline concentrate contains pre-treatment waste supernatant, whereas the proposed Reference Project is saline concentrate only. This caused some confusion in the reporting of toxicity results in the EES, discussed below. Two rounds of toxicity testing of the Perth discharge (saline concentrate + pre-treatment supernatant) were conducted, whereas the Reference Project discharge of saline concentrate only was subsequently tested only once in Round 2 (Appendix 24).

The toxicity tests included acute, sub-chronic and chronic tests (not just acute and sub-chronic tests as stated in the EES) with appropriate local species. All species except the sea urchin and fish (sand whiting in Round 1 and bass in Round 2 testing) are found in coastal waters of Southern Victoria. Bass larvae were used in Round 2 as whiting were not seasonally available. The choice of this species may be questionable given that it is stated that it is tolerant to hypersaline conditions (Appendix 24) and therefore may not be particularly sensitive to salts compared to some other fish species. It should be noted that the microalgal growth test was wrongly described in the executive summary of Appendix 24 as a growth rate test (actually a cell yield endpoint was used) and that the macroalgal test was a 72-h germination test, not a 2 h fertilization test, wrongly described in the methods section of Appendix 24.

All the toxicity testing was carried out with appropriate quality assurance (QA) and in accordance with standard protocols. QA[10] included acceptability criteria for controls, water quality monitoring throughout the tests and use of reference toxicants. All the toxicity testing was best practice and the methods were entirely appropriate.

The species sensitivity distribution (SSD) methodology used to estimate safe dilutions was a modification of the ANZECC[11]/ARMCANZ [12](2000) approach. EC10 values, rather than NOECs, were used as the input data and this is a valid approach. When acute and chronic data from toxicity tests are to be combined in SSDs, it is usual to apply an acute:chronic ratio (ACR) to the acute LC/EC50[13] data, which are then used together with chronic NOEC or EC10 data, to estimate a safe dilution. A default ACR

[10] Quality Assurance

[11] Australian and New Zealand Environment and Conservation Council

[12] Agriculture and Resource Management Council of Australia and New Zealand

[13] The concentration of a test sample to cause a 50% effect or affect 50% of test organisms.

of 10 is usually used in the absence of experimentally derived ACRs. The approach used in the EES differs from this in that:

1. ACRs were applied to acute LC/EC10 data rather than LC/EC50 data. This is in fact a more conservative approach than that used in ANZECC/ARMCANZ and potentially gives higher safe dilutions (2-5 fold higher). The IEG has no problem with the extra conservatism of this modified approach.
2. An ACR of 2.5 was used rather than the default value of 10, although safe dilutions were calculated for ACRs of 1, 2.5, 5 and 10. All the justification for the ACR of 1 or 2.5 is based on freshwater data and the fact that, for an osmotic stressor such as salinity, there is very little difference in the magnitude of acute and chronic effects to freshwater species. However, freshwater biota tolerance to salt may be very different to marine biota tolerance to hypersalinity. Further justification is needed for use of the default ACR of 2.5. This is important because it greatly affects the required safe dilutions. When taken in context with 1) above, this overall approach is probably sufficiently conservative. A similar ACR has been proposed for use at the Sydney desalination plant. An alternative approach would have been to apply a standard ACR of 10 (in the absence of data) to the acute LC/EC50 data. One suspects the outcome would have been similar and possibly easier to justify on the basis of standard methods.

No mention in the EES or the specialist reports is made as to the level of confidence around the estimated safe dilutions. It is assumed that the EES reported the estimated safe dilution from the ecotoxicity testing for 99% species protection **with 50% confidence**, as per ANZECC/ARMCANZ (2000). This is important because 1 in 2 times the safe dilution could be under or overprotective.

Saline Concentrate Potential Toxicity
There was little difference in the acute or chronic toxicity of the intake seawater (salinity adjusted to match the saline concentrate salinity) or the saline concentrate discharge, with/without pre-treatment wastes, to the test species. The majority of the toxicity was due to the high salinity of the discharge, rather than the chemical additives.

Neither the EES nor the specialist report (Appendix 24) discusses the relative sensitivity of the different test species/endpoints to the saline concentrate. It is clear that the invertebrate larval development tests and the microalgal growth tests are the most sensitive tests to the discharge samples. This data should be used to inform the selection of appropriate species for future long-term toxicity monitoring when real desalination plant effluent becomes available.

In Appendix 24, it is repeatedly stated that sea urchin fertilisation data are used in the SSDs rather than sea urchin larval development data, because this was a more sensitive endpoint than larval development. However, larval development was usually more sensitive, and the numbers actually used in the SSD were the larval development numbers. Tables 6.3, 6.7, 6.8, 6.9, 6.10 all need correcting.

Apart from in the WAA document, there is no discussion of the acute toxicity found for fish for all saline concentrate/pretreatment discharge samples. Given that the State Environment Protection Policy (Waters of Victoria) (SEPP (WoV)) Clause 27(4) states that there should be no acute lethality, even in the mixing zone, an explanation is needed as to why this is not perceived to be a problem. An immediate dilution of

1:5-1:10 at the diffuser would possibly be required to prevent acute lethality to fish in the mixing zone, although this doesn't take into account the very short exposure times near the outlet compared to the longer term (96 hour) exposure durations in the toxicity tests. Near-field hydrodynamic modelling showed that initial dilution at the diffuser is likely to be rapid (5 seconds to achieve a 1:10 dilution at a distance of less than 10 m), therefore acute toxicity to fish in the mixing zone is highly unlikely. This of course could be checked experimentally by exposing fish to saline concentrate (or artificial sea salts matched to the same salinity) for several minutes and then replacing the test solution with clean seawater, and following effects over several hours. It may also be argued that salinity is not a toxicant, but rather a physico-chemical stressor, and it will be rapidly dispersed (but not degraded). While this is not discussed in the EES, the IEG agrees that there is unlikely to be lethal effects to water column marine biota in the mixing zone.

Safe dilutions were determined for several discharge scenarios. In Round 1, in which only one scenario was tested (pre-treatment supernatant + concentrate), the derived safe dilution was 29:1, rounded up to 30:1 in the EES. This was within the range of dilutions required for a salinity-matched seawater intake water sample (17:1 to 40:1), suggesting that most of the toxicity was due to high salinity as the stressor. However, there is some confusion in the main EES document, as on Page 8-26 it clearly states that only the Reference Project toxicity test is discussed, whereas the reported 30:1 dilution applies to Reference Project **option** for discharge of saline concentrate + pre-treatment supernatant, not the Reference Project itself. The actual safe dilution for the Reference Project is 18:1, compared to 17:1 for the intake seawater salinity adjusted to match the discharge (determined in Round 2 testing).

The toxicity of wastewater from the Perth desalination plant, for all three discharge scenarios, was tested in Round 2 (Appendix 24). Although the report concluded that the combined wastewater (pre-treatment solids +supernatant + concentrate) required slightly less dilution than discharge of concentrate only and discharge of pre-treatment supernatant + concentrate only, the derived "safe" dilutions were in fact very similar – 18:1, 18:1 and 23:1. These small differences would certainly be within the error of the SSD method used to estimate safe dilutions, so it should have been concluded that, based on the assumptions used in the report, there is no difference in the toxicity of the discharge nor its required safe dilution between the various discharge options. Note that the Reference Project discharge scenario (saline concentrate only), was only tested once in the second round of testing, presumably due to lack of initial understanding of what the operating Perth desalination plant was actually discharging.

The actual toxicity of the real discharge will need to be assessed on a regular basis when the desalination plant is operating to confirm these findings.

Effects of the discharge on the receiving environment

The effects of discharge are determined by dilution of the discharge, and the effects of elevated salinity from the outlet discharge on marine biota may include 1) short term acute toxic effects on survival and physiological/biochemical functions due to osmotic effects (e.g. dehydration of cells, decreasing cell turgidity and ultimately death in larvae and juveniles) and 2) chronic or long-term effects on the structure of marine communities close to the outlet.

These effects were predicted using a combination of published literature on effects of salinity, laboratory testing of comparable effluent from the Perth plant and modelling of the plume. The acute and chronic toxic effects were addressed through the DTA[14], described above.

The international literature on long-term effects is sparse and summarised in Technical Appendix 31. The existing field studies are detailed, but the summary would benefit from providing details of the actual monitoring done in overseas studies; within the summary table, some studies are described in appropriate detail, but there is considerable uncertainty in reporting. The conclusion from overseas work is that elevated salinities of 1‰ or so provide little threat to marine biota. This conclusion is reasonable, although it should be recognised that uncertainty comes from the relatively sparse data set.

Due to the short exposure times and rapid dilutions predicted under a range of modelling scenarios, adverse effects on marine biota in the water column due to hypersalinity are unlikely. Near-field hydrodynamic modelling showed that under average conditions, the saline concentrate would be rapidly diluted (5 seconds to achieve a 10:1 dilution at a distance of <10 m). A dilution of 20:1 (the safe dilution for saline concentrate discharge alone from the DTA) would be achieved rapidly within 100 m of the outlet for the majority of the time. A 30:1 dilution (equivalent to 1‰ salinity above background, and corresponding to the safe dilution for discharge of saline concentrate + pre-treatment supernatant) would also occur within 100 m of the outfall. Overall, hydrodynamic modelling suggests that a dilution of 50:1 will be achievable within 100m of the diffuser under all discharge scenarios and oceanographic conditions, and therefore performance requirements require an engineering design dilution target of at least 50:1 in the water column within 100 m of the diffusers under all design flow conditions. This also suggests that there should be minimal direct toxicity on marine biota in the water column outside the mixing zone, assuming that all the assumptions used in the DTA are appropriately conservative.

It is well known that dissolved oxygen saturation reduces as water salinity and temperatures increase, however, given the high energy nature of the discharge environment and the rapid dilution, such impacts are unlikely. This was briefly discussed in Appendix 3, but not in the EES main document.

Any adverse impacts are most likely to be on benthic sessile species on the seabed near the diffuser outfall. Accumulation of contaminants in sediments and impacts on sediment biota beyond the immediate vicinity of the outlet are unlikely, particularly given the lack of sediment present in the area. Due to the high density of the saline concentrate compared to seawater, there is potential for elevated salinity on the sea bed beyond the 100 m distance. The 36.5‰ salinity contours (equivalent to 1‰ salinity above background and a 30:1 dilution) from the mid field modelling showed that the area of >36.5‰ salinity is quite variable in extent and location – usually patches of 500 m radius, but sometimes covering 1 x 1 km, or under worst case conditions, 2 km x 2 km from the outlet.

The hydrodynamic modelling assumed that the salinity of the discharge concentrate will be 65‰ (see page 8-30) however the actual salinity of the Perth discharge measured in the ecotoxicity tests was 59.4‰ in Round 1 and 61.4‰ in Round 2. It is

[14] Direct toxicity assessment

not known how this difference in salinity will affect the dispersion of the dense salty plume or the achievable dilutions of the diffusers. It also wasn't clear if the modelling scenarios included various diffuser/outlet pipeline design variations and options which could potentially alter the modelled safe dilutions. The EES merely says that these could be designed to comply with these safe dilutions.

It is also possible that ambient currents could transport the plume back towards the diffuser reducing the achieved dilution under certain current conditions. This was briefly mentioned in the EES and would require further modelling prior to the plant operational phase.

One particular knowledge gap surrounds the effects of varying salinity. While average background elevations of, for example 1‰, might overall pose little risk, it is possible that this average would be attained despite excursions of salinity beyond this value. It is not generally known, for example, whether the risks from 1‰ for 100% of the time would differ from exposure of 1‰ all of the time compared to, say, 0.5‰ for 95% of the time and 10‰ for 5% of the time. If salinity were 10‰ above background for a small proportion of time, would effects vary if that 5% of the time occurred as single widely spaced events, or as occasionally brief periods. The information about the effects of varying salinity is very limited, as acknowledged in Technical Appendix 31, and this information gap could not be filled in the near future.

This issue may be important if the plume behaviour results in salinities elevated more than 1‰ over larger distances for extended periods.

Despite this uncertainty, it has been suggested that there may be effects on, for example, competitive ability of benthic species and consequent long-term changes in ecological communities. This seems speculative and hence quite uncertain.

It is likely that effects on ecological communities will not be able to be predicted with great certainty. The risk of ecological changes occurring more than 100 m from the outlets will depend on the final engineering design of the outlets and the degree of compliance with conditions of any eventual Works Approval. Ecological monitoring may be required, but the extent of such monitoring should be considered as part of a general programme that takes into account the monitoring required to verify plume dilution and the likelihood of operational changes following a demonstration of ecological impact beyond the Mixing Zone. This issue is discussed in more detail below.

Effects of the discharge might also come from other chemicals present, in addition to effects of elevated salinity. In terms of background concentrations of contaminants in sediments in the vicinity of the marine structures, ambient monitoring showed that sediment quality guidelines (ISQG[15]-low) were not exceeded for any of the measured contaminants. Exceptions were several individual low molecular weight PAHs[16], which, when normalised to 1% organic carbon, exceeded ISQG-low values. This may be due to natural occurrence of these PAHs and this is briefly discussed in Appendix 23, but not mentioned in the main EES. It should also be noted that only 5 sites were sampled once only for sediments, due to lack of sediment close to the proposed site. Due to the heterogeneous nature of sediments, it is difficult to draw conclusions from this limited sediment sampling and analysis, and further samples will be required to

[15] Interim Sediment Quality Guidelines
[16] Poly-aromatic hydrocarbons

get good baseline data prior to operation of the desalination plant. Methods used to digest the sediments for metals analysis were also not reported.

The background (ambient) water quality monitoring (given in Appendix 23) was useful to characterise the local receiving environment quality prior to desalination plant operation. However, the attempt to derive trigger values for toxicants is questionable. The trigger value for non-toxicants is usually the 80th percentile of the background data (reference site or pre-discharge), or the default south-eastern Australian guideline (ANZECC/ARMCANZ, 2000). SEPP (WoV) uses a more conservative 75th percentile. However for toxicants, the ANZECC/ARMCANZ guideline (derived from ecotoxicity data) should be used. If a guideline doesn't exist, a standard is not usually determined from background data as has been done in this EES. Exceeding the background for a toxicant is not the issue; rather it is exceeding the toxic concentration that is important. The ecotoxicity data, rather than exceedances for individual physico-chemical or chemical parameters, should drive the safe dilution requirement. When the plant is operational, the effluent concentration of each individual chemical can be compared to appropriate trigger values, but the ecotoxicity of the discharge and on-going monitoring of the ecology of the receiving environment, will be the critical components ensuring ecosystem protection.

The IEG concludes that:

- Safe dilutions of 18:1 (rounded up to 20:1) for the saline concentrate and 30:1 for the saline concentrate plus pre-treatment supernatant, derived from the laboratory toxicity tests of Perth desalination discharge, are reasonable estimates for the proposed discharge at Wonthaggi. Further toxicity testing when an actual effluent is available is essential to confirm these estimates.
- There are unlikely to be lethal effects from the saline concentrate to water column marine biota in the immediate mixing zone.
- The main effects from the discharge are likely to be those associated with elevated salinity. As long as the discharge structures perform as expected, the plume should be diluted rapidly to levels at which elevated salinity should not pose a major risk to marine biota.
- Inclusion of pre-treatment waste supernatant in the saline concentrate discharge (an option to the reference design) is unlikely to increase the toxicity of the discharge. However, a desk-top screening assessment of the potential effects on marine biota of several pre-treatment chemicals including chlorine, acid, polyDADMAC, sodium bisulfite and polyphosphate, showed that the potential impacts of these chemicals may warrant further investigation.
- Indirect effects due to iron precipitation and possible smothering of benthic biota in the immediate vicinity of the outfall are likely to be minimal due to the highly turbulent marine environment.

4.4 Question 4 – Further information for project design and monitoring

DPCD has sought comment on further information that may be required in order to verify the risk assessment and optimise the final design and process configuration for *plant performance. Advice is sought, in this context, on the principles that should guide the on-going environmental monitoring and management of the plant's operations.*

IEG RESPONSE:

While the introductory sections of technical reports make reference to consideration of uncertainty as is required by the EES Scoping Requirements, this is not carried through individual reports. There is some consideration of knowledge gaps and particularly, whether some of the uncertainties have the potential to change the assessment of impacts. In some cases the uncertainty is dealt with by using conservative assumptions for the risk assessment, but elsewhere it is not clear how large uncertainties are taken into account. This is perhaps best illustrated by the important issue of entrainment. Uncertainties exist about the real spatial patterns of larval release, the actual larval durations of most species and potentially important uncertainty associated with broader ecological consequences of larval depletion. Even if the predictions of larval depletion are robust, there remains the question of whether a reduction in larval abundance would affect local population sizes. Not all of these sources of uncertainty are obviously taken into account and a clearer statement of uncertainty is needed to guide appropriate responses.

These sources of uncertainty may also be accommodated by the collection of further information, most often in the form of project-specific monitoring or strategic responses. These are discussed separately below.

Reference Project

The Reference Project provides a firm framework to develop a seawater desalination plant that reflects the international best practice in terms of expected plant performance and reliability while minimizing subsequent environmental impacts. However, the final design should be validated to ensure that these objectives are fully incorporated and risks are minimized.

Hydrodynamics

The programme of field measurements and hydrodynamic modelling that has been used to support this EES has been comprehensive and has not produced any indication that the project cannot be managed without incurring any significant or measurable environmental effects.

The successful operation of desalination plants (i.e. from an environmental perspective) elsewhere in the world indicates the same response is anticipated for the proposed Wonthaggi plant. However the scale of the proposed Wonthaggi plant is larger than comparable operations. Consequently the risk associated with assessing a low probability of environmental effects relates to the limited comparable information for similar size operations, and the fact that the bulk of ecological interpretations are based mainly on model outputs, and on only limited field measurements.

It is considered important to address this matter and progressively improve and make more robust the base for understanding the issues involved.

A comprehensive monitoring and modelling programme should be commenced and maintained before construction, lasting during construction and continued once operation has commenced. A programme of detailed field measurements of water column structure, current fields and sea surface level determinations at the project site and in its immediate surroundings is needed to provide information over the full range of oceanographic conditions that could be experienced at this site. Modelling of particularly near-field and mid-field processes should continue. Model validation should be expanded to address all of these different conditions.

Effects of Intake and Discharge on Receiving Environment

Effects of entrainment

As discussed in the previous section, consideration should be given to the likely results of entrainment for species with very short larval durations. This might take the form of additional modelling, with larval release targeted at reefs in the Project Area.

Nature and effects of the discharge

Some of the data gaps in the EES and further work required on the nature of the discharge to verify the risk assessment and optimise final design were identified previously under Question 3. These are briefly summarised below.

As all the toxicity testing has been carried out on the Perth saline concentrate, it is essential to validate the results and safe dilution predictions using pilot plant or actual discharge when the plant is operational. The full suite of toxicity tests used here should be carried out and the data used to re-calculate the actual safe dilutions for the Wonthaggi plant.

It is also essential to include ecotoxicity monitoring in the proposed longer-term monitoring programme. Toxicity testing of the final discharge is essential to ensure that no toxicity will be observed after dilution and that “safe” dilutions are being achieved. After initial testing, it may be possible to reduce the number of tests used in on-going routine monitoring. Both the invertebrate larval development tests and the microalgal growth tests were the most sensitive tests to the discharge samples. It is recommended that these tests form the basis of a longer-term toxicity monitoring programme throughout the operational life of the desalination plant.

Additional toxicity testing to further reduce the uncertainties associated with the safe dilution estimates could include:

1. Experimental derivation of an ACR using acute and chronic tests with several species. Given that the toxicity is mostly attributable to the high salinity, it is appropriate to use artificial sea salt solutions rather than Perth desalination wastewater for this purpose.

2. Expose fish larvae to saline concentrate (or artificial sea salts matched to the same salinity) for very short durations (minutes) and then replace the test solutions with clean seawater, and follow effects over several hours.

This will help determine whether acute lethality to fish is likely within the mixing zone (short exposure durations), which will provide further confidence that the SEPP (WoV) Clause 27(4) will be met.

Once the chemical constituents of the final waste stream are known and the waste stream is available for testing, then the concentrations of various additives and chemicals in it can be compared to the trigger values derived for individual contaminants in the EES. Particular attention needs to be paid to the use and concentrations of pre-treatment additives which were identified as of possible risk in the hazard assessment (Appendix 24). Further consideration to the potential impacts of brominated compounds, formed by the reaction of chlorine with bromide in seawater needs to be assessed. This is particularly important if a seawater bypass from the screen/pumping station is built, as this could mean that chlorinated seawater (before neutralisation with sodium bisulfite) may be discharged in times of reduced plant operation. Alternative disinfection agents (e.g. copper/chlorine) and coagulants (e.g. alum) would also need to be assessed for potential impacts on marine biota, if they were to be proposed for use in the pre-treatment plant.

Careful monitoring of reverse osmosis membrane cleaning wastes, if discharged along with saline concentrate, would also be required as their toxicity was not considered as part of the EES.

It is possible that ambient currents could transport the plume back towards the diffuser reducing the achieved dilution under certain current conditions. This was briefly mentioned in the EES and would require further modelling prior to the plant operational phase.

In terms of background concentrations of contaminants in sediments in the vicinity of the marine structures, further samples will be required to get good baseline pre-operational data.

Principles to Inform Ongoing Monitoring

The main response to unavoidable scientific uncertainty regarding specific outcomes is to develop deeper understanding of the relevant processes.

Deeper understanding can be used to adjust performance of a particular project (i.e., mitigation), or to provide a basis for more certain decision-making in future projects. It can also be used to provide an accurate estimate of the actual impact of a project, which might form a basis for action to offset impacts.

It is tempting to require monitoring as a matter of course, but monitoring is valuable only when the purpose is explicit.

The EES and WAA list some possible monitoring scenarios. Some of these are plausible, and with unlimited resources, should be supported. Against this however, is the understanding that resources for monitoring will not be unlimited, and, for marine ecological effects, the Project area is a technically demanding location. Monitoring will be difficult, with many days lost through bad weather.

Monitoring might include construction impacts, but given the small footprint of construction, most attention is likely to focus on operational aspects, particularly entrainment, water quality (particularly with respect to nature and toxicity of the discharge and compliance with the Mixing Zone) and effects of the discharge.

For entrainment, it is unlikely that a cost-effective monitoring programme could be developed to accurately measure densities of larvae in the immediate area of the intake. Abundances of larvae are highly variable and obtaining accurate estimates of their numbers usually requires extensive field sampling. The environment of the project area is likely to restrict this sampling. An alternative might be to sample the intake stream just before the final filtration, to provide such estimates.

In the short term, there is little chance of being able to assess the consequences to local populations of entrainment losses. Consideration should be given to developing alternative estimates of loss, such as Adult Equivalent Loss. These alternative approaches would still require some local data collection, but not to the same extent as developing full models of entrainment.

The nature of the discharge would be expected to be monitored regularly, and there are well established techniques, both analytical and statistical, for conducting such monitoring programmes.

The effects of the discharge on the receiving environment will be more difficult to assess. There are two plausible approaches. The first is to rely on measurements of the plume as a guide to ecological effects. This approach would rely on the threshold of 1‰ increase in salinity above background levels being a reasonable and moderately conservative criterion that would, if met, prevent ecological impacts beyond the edge of the mixing zone. In this case, monitoring of salinity and characterising the nature of any salinity exceedances would be the decision-making tool. The second approach would be to take ecological samples around the project area. This could be done using some of the approaches outlined in, for example, Technical Appendix 31. There is an extensive literature on the design of such monitoring programmes.

The nature of any ecological monitoring programme(s) will be limited by the patchy distribution of habitats in the Project Area and influence by the final decision on locations of the outlets. For example, should it be desirable to sample reef habitats at increasing distances from the outlets, the distribution of similar reef habitats will determine exactly where sampling can occur. These limitations may reduce the eventual level of confidence in any monitoring programme. In the worst case, the conclusions might be so uncertain that a decision might be made to shift from a project-specific monitoring to the development of strategic understanding (e.g. a research programme to better understand the effects of varying salinity). It will be important in the design of the eventual monitoring programmes to consider the limitations of each component, and be prepared to make difficult decisions about project-specific versus strategic data acquisition.

The IEG concludes that:

- As part of the Reference Project, the seawater intake head and tunnel would be intermittently dosed with high levels of chlorine to reduce marine fouling. The concentrations of brominated organics, formed by the reaction of chlorine with bromide in seawater, are likely to be low, however the toxicity of these compounds to marine biota is largely unknown and may warrant further investigation if these compounds are detectable in seawater in the future monitoring programme.
- The proponents still need to combine the results of the models of initial plume dilution and plume advection and dispersion into a consistent form

to resolve the assessment of the plume impacts.

- Although safe dilutions should be achieved within 100m of the discharge under most conditions, it is expected that there may be periodic elevations of salinity over a more extended area. There is considerable scientific uncertainty about the effects of varying salinity on marine organisms.
- Once the chemical constituents of the final discharge stream are known and the discharge is available for testing, then the concentrations of various additives and chemicals in it can be compared to the trigger values derived for individual contaminants in the EES.
- Further samples will be required to get good baseline pre-operational data of background concentrations of contaminants in sediments in the vicinity of the marine structures.
- There will need to be a clear indication of how the remaining uncertainties will be resolved. Development of the final design will reduce some of these uncertainties, and will determine the eventual need for monitoring. Some monitoring will be required (eg. toxicity monitoring), to determine whether the project is meeting Performance Requirements, and to allow for operational feedback. Some of this monitoring will benefit from early initiation of sampling programmes, which will depend on the final design being developed quickly. In other cases, it is not clear whether rigorous, cost-effective monitoring will be possible, given the nature of the project area, and consideration should be given to whether resources should be used for monitoring, or for more strategic research that is designed to reduce uncertainty in future project assessments (e.g., developing a better scientific understanding of entrainment).
- The final design should be validated against the Reference Project to ensure that these objectives are fully incorporated and risks are minimized.

4.5 Question 5 – Suitability of key performance requirements

DPCD has sought comment on the suitability of key performance requirements that relate to the environmental performance of the desalination plant and marine structures, with respect to discharges to the environment, energy efficiency and waste management. This advice should consider whether the draft performance requirements are sufficiently comprehensive and protective of the environment, as well as offering sufficient flexibility for best practice solutions, and also being both achievable and measurable.

IEG RESPONSE:

The nature of the manner in which the Victorian Government chose to procure this project (i.e. through the public private Partnership delivery model) means that the final design is not being assessed, but rather, a range of concepts defined by the Reference Project, variations and options. The Reference Project describes these concepts that have met the project's objectives (i.e. technical feasibility, as well as environmental, economic and social requirements). Possible variations that meet the project's objectives have also been assessed in the EES, as well as options that may be considered in the final design.

The Performance Requirements developed for this project as a result, clearly have more of a generic nature than those that would be applied to the final design. The IEG has recognised this uncertainty and has reviewed the Performance Requirements with the objective to ensure that clarity and specificity of these are sufficient to ensure an acceptable environmental outcome.

Proposed Performance Requirements are shown in Vol 1, Table 10-2 of the EES and Table 17-3 of the WAA.

Specific IEG Comments

Marine Flora and Fauna – General

General performance requirements and Performance Requirements have been developed to provide an environmental framework for management of potential impacts associated with the Project during the construction and operational phases.

The Performance Requirements are suitable and are a reasonable list, although some are not very specific (e.g. "no significant effects on Bunurong Marine National Park"). Performance Requirements are generally consistent with Performance Requirements. The habitat map showing sensitive areas where no construction should occur is an important guide.

The monitoring programme to address the Performance Requirements needs to be incorporated into a comprehensive EMP, but the requirements need to be assessed against feasibility and usefulness of the information. For example the proposed monitoring programme to detect marine pest incursions would be extremely difficult to design and implement, with a substantial risk of failure. It is also not clear whether any incursion could be treated. The same questions might be asked of the Performance Requirement to design and implement a monitoring programme to evaluate effects of entrainment. Such a programme would need to be assessed against the logistics of sampling, the likelihood of detecting subtle effects, and the use to which the result of such a monitoring programme would be put.

Marine Flora and Fauna – Intake

The Performance Requirements are suitable and are sufficiently specific.

The monitoring and modelling programme needed to address these criteria needs to be incorporated into a comprehensive EMP.

Marine Flora and Fauna – Outlet

The Performance Requirements are suitable and provide specific requirements for the 2 most important issues associated with the diffuser operation, namely:

- achieving an initial dilution at the diffuser of at least 50 times, and
- limiting the increase in salinity to a suggested 1‰ within a relatively small mixing area which is proposed to be a zone described by a boundary 100 m in radius from the diffuser system.

The Performance Requirements for the discharge management and disposal, however, are quite general. An additional Performance Requirement could be to avoid/minimise the formation of an iron precipitate in the immediate vicinity of the outlet that could otherwise smother benthic biota. This would be required if the option to discharge pre-treatment waste with the saline concentrate is being considered.

A comprehensive programme of both hydrodynamic modelling and *in situ* measurement, including physical parameters (such as currents, structure of water column and sea surface elevation) and measures of environmental condition will need to be developed to address these criteria.

The IEG concludes that:

- The Performance Requirements proposed for this project are generic in nature, are appropriate for a project being developed in the current manner but will need to be made more specific once a final design has been confirmed.
- A comprehensive EMP, which includes an appropriate programme of measurement and monitoring, is needed to ensure these broad requirements can be properly addressed.
- Among the most critical of the Performance Requirements are those related to the operation of the diffuser system and the ability to always meet the requirements for initial dilution. A comprehensive programme of hydrodynamic modelling and in situ measurements including physical parameters (such as currents, structure of water column and sea surface elevation) will be needed.