CHEVRON AUSTRALIA PTY LTD

TECHNICAL NOTE FOR

TEMPORARY OCEAN OUTFALLS DILUTION MODELLING

For The

GORGON PROJECT

BARROW ISLAND LNG PLANT

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Kellogg Joint Venture Gorgon

KBR JGC HATCH CLOUGH

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1. ABBREVIATIONS

Table 1.1 Abbreviations and Definitions

Term	Definition
BOD	Basis of Design
BWI	Barrow Island
EMP	Environment Management Plan
KJVG	Kellogg Joint Venture Gorgon
MOF	Materials Offloading Facility
RO	Reverse Osmosis

2. EXECUTIVE SUMMARY

The Gorgon Project on Barrow Island (BWI) will use Reverse Osmosis (RO) to desalinate seawater and provide fresh water to Project users. In order to meet increasing water demand during construction, temporary RO facilities will be installed in a staged manner.

Gorgon proposes to use ocean outfall as a means for disposing of RO reject streams, which requires authorization by the Western Australian Minister, under both State and Commonwealth Environmental Approval conditions. In order to support an application requesting authorization to discharge RO reject streams by ocean outfall, Chevron Australia will submit an Environmental Management and Monitoring Plan (EMMP), which includes environmental impact assessments and monitoring programs for the proposed temporary ocean outfalls.

This technical note has been prepared to provide detailed information on the dilution levels the temporary floating outfalls (utilized by phase 1, 2/3 and bridging RO facilities), demonstrating how these outfalls can achieve required dilutions over a range of possible discharge conditions.

The information presented here is based on detailed oceanographic modeling, using the same methodology and the oceanographic model (Delft3D), deployed to evaluate the proposed permanent outfall and verified with measured ocean currents.

The temporary outfalls are presented with the following characteristics:

- Phase 1 outfall will be located on a floating pipelines discharging through diffusers just beneath the water surface;
- Phase 2/3 and bridging phase outfalls will be fixed at the height of 1 m above the ocean seabed. Both outfalls will be installed at one location.
- At the outfalls are located within the Zone of High Impact between 250 m and 500 m offshore;
- A minimum separation distance between the intake point and outfall will be 100 m for Phase 1 and 200 m for Phase2/3 and bridging;
- Dilution will vary depending on water depth (i.e. tide).

Analysis of the potential dilution and spatial dispersion of the proposed outfall demonstrates:

- In all cases a safe dilution of 40 will be achieved in the Zone of High Impact;
- Near field dilution will vary in conjunction with the tidal water level, deeper water results in greater dilution;
- All cases show that the brine disperses quicker in the offshore direction (additional water depth/volume assists the mixing process).

3. INTRODUCTION

3.1 General

The Gorgon Project on Barrow Island (BWI) will use Reverse Osmosis (RO) to desalinate seawater and provide fresh water to Project users. In order to meet the water demand during construction, temporary RO facilities will be installed in a staged manner.

The first installation consists of a RO facility (Phase 1) located on Town Point. The second and third installations consist of two RO facilities (bridging and phase 2/3) located within the Gas Treatment Plant site site.

Gorgon proposes to use ocean outfall as a means for disposing of RO reject streams, which requires authorisation by the Western Australian Minister, under both State and Commonwealth Environmental Approval Conditions. In order to support an application requesting authorisation to discharge RO reject streams by ocean outfall, Chevron Australia will submit an Environmental Management Monitoring Plan (EMMP), which includes environmental impact assessments and monitoring programs for the proposed ocean outfalls.

This technical note has been prepared to provide detailed information on the dilution levels the temporary outfalls (utliised by Phase 1, 2/3 and bridging RO facilities), demonstrating how these outfalls can achieve required dilutions over a range of operating conditions.

The information presented here is based on detailed oceanographic modeling, using the same methodology and the oceanographic model (Delft3D), deployed to evaluate the proposed permanent outfall and verified with measured ocean currents [3].

3.2 Background and Design Basis

A permanent seawater intakes and ocean outfalls will be installed to support the temporary RO facilities. The permanent facility to be installed later will be a robust marine installation with a 30-year design life, capable of full exposure to the marine environment throughout all weather conditions, including cyclones. A temporary seawater intake and ocean outfalls are required to support Gorgon Project activities from the first day of mobilisation to BWI and throughout the construction period.

Based on Whole Effluent Toxicity testing undertaken [1], a 40 fold dilution has been adopted as an acceptable dilution target for the edge of the Zone of High Impact in order to minimise the potential impact to the marine environment.

The primary performance criterion for the temporary ocean outfall is to achieve a 40 fold dilution of the RO reject brine within the Zone of High Impact for all potential operating flow rates.

4. TEMPORARY WATER SUPPLY SUMMARY

4.1 Temporary RO facilities

Temporary RO facilities will be installed in a staged manner. The first installation consists of a RO facility (phase 1) located on Town Point. The second and third installations consist of two RO facilities (bridging and phase 2/3) located within the Gas Treatment Plant site site.

The capacity of the temporary RO facility (phase 1) located on Town Point is sized to produce an equivalent of 1000 m^3/day fresh water, and are equipped with a pre-filtration system to removed suspended material from the water prior to RO treatment. The water produced from the RO facility is dosed with chlorine for disinfection and passed through calcite media vessels to add calcium and adjust pH prior to distribution for construction and/or potable uses. It is anticipated that the Town Point RO facility (and associated temporary intake and outfall) will be operated for approximately six months until the temporary RO facilities within the Gas Treatment Plant site (along with associated temporary intakes and outfalls), can be relied upon to supply the Project's water requirements throughout construction.

The capacity of the temporary RO facilities (bridging and phase 2/3) located within the Gas Treatment Plant site will be sized to produce an equivalent of 3800 m^3/day, and will be equipped with a more complex pre-filtration system in the form of hydrocyclones, disc filters and microfiltration units. The RO product water is treated with chlorine and carbon dioxide prior to distribution for construction and potable uses. It is anticipated that the temporary RO facilities located within the Gas Treatment Plant site (and associated temporary intake and outfall) will be operated for approximately three years.

4.2 Temporary Seawater Intake

The temporary RO facility located on Town Point will be supplied with seawater from a set of pumps mounted on a floating structure located up to 500 m from shore, within the Zone of High Impact. The pumping system will be equipped with intake screens limiting the intake velocity to 0.1 m/s to reduce the potential for marine fauna entrainment. Power supply shall be from onshore generators.

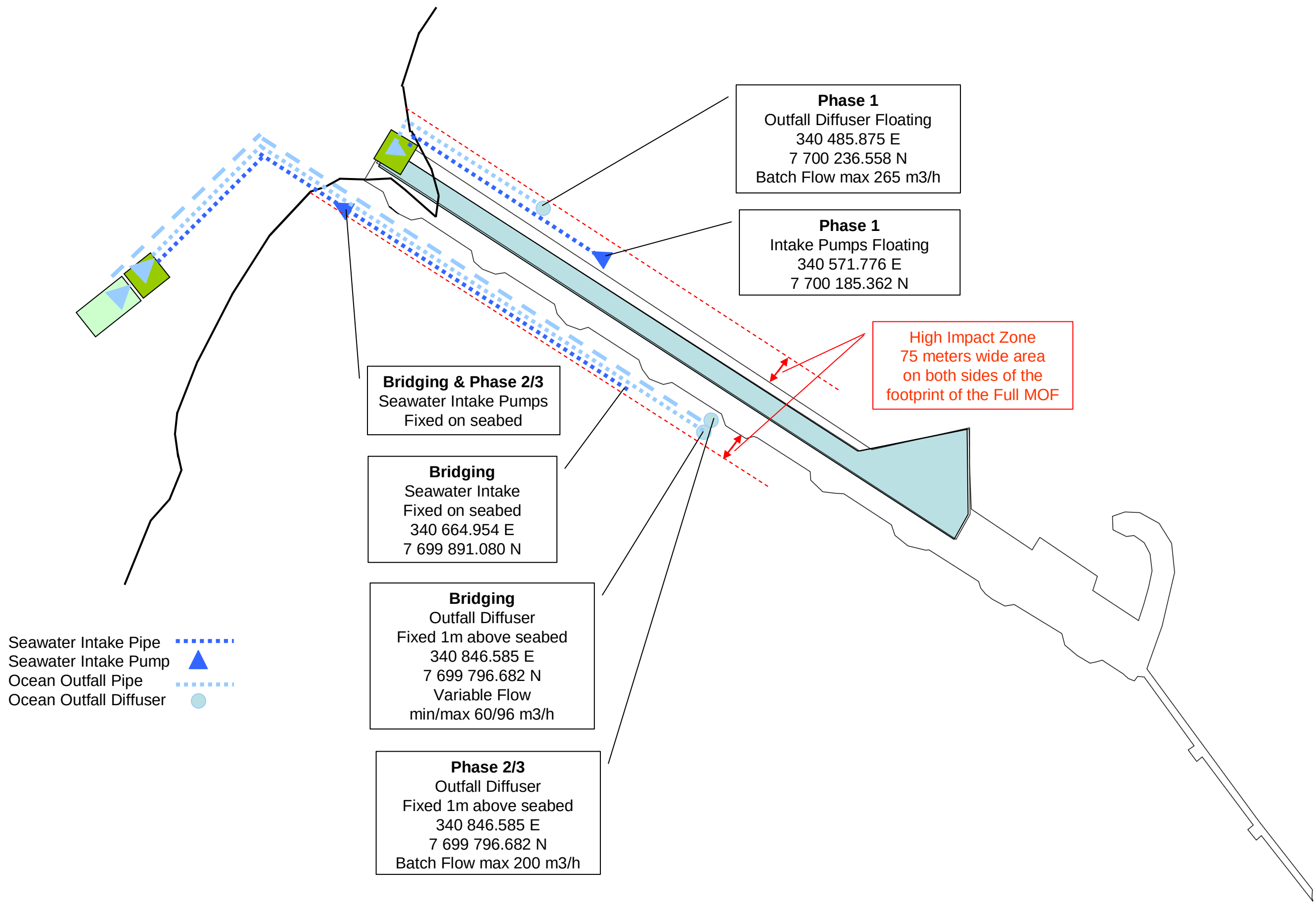
Given the temporary RO facilities located within the Gas Treatment Plant site will be in service for approximately three years, the associated intake and outfall design is more suited to that duration of service. The temporary seawater intake system will consist of a series of pumps mounted on a structure located close to the shoreline within the Zone of High Impact. The intake pipes will extend approximately 700 m off shore and will be secured to the sea bed with concrete clump weights. The pumping system will be equipped with intake screens limiting the intake velocity to 0.1 m/s to reduce the potential for marine fauna entrainment. The location of the pump structure will be defined during detailed design and may be re-located during construction. An area within the Gas Treatment Plant site has been set aside to accommodate the power generation equipment, control and instrumentation container and bulk fuel storage.

4.3 Temporary Ocean Outfalls

The temporary RO facility, phase 1, located at Town Point will discharge brine and backwash water via a floating outfall located within 500 m from shore, within the Zone of High Impact. The outfall diffuser has been designed to achieve a minimum of 40 dilutions within the Zone of High Impact.

The temporary RO facility, bridging and phase 2/3, located at Gas Treatment Plant site will each discharge brine and backwash water via an outfall located up to 900 m from the shore, within the Zone of High Impact. The outfall pipes will be anchored to the sea floor using concrete clump weights as per the intake lines. The outfall diffuser will be designed to achieve a minimum of 40 dilutions within the Zone of High Impact, and will be held above the ocean floor at a set depth to maintain the required dilution performance. A minimum separation distance between the intake point and outfall will be 200 m. Dilution will vary depending on water depth (i.e. tide).

Figure 4-1 Schematic of the simulated scenarios Phase 1, 2/3 and bridging system operating together (worst case scenario)



5. OCEANOGRAPHIC MODELLING

5.1 Model Definitions and Methodology

The key objective of oceanographic modelling is to illustrate and quantify the likely temporal and spatial evolution of the brine once it has been released into the marine environment.

The modelling presented here builds on the detailed oceanographic modelling undertaken to evaluate dispersion of the brine as released from the permanent outfall. The same, well established and verified 3D oceanographic model Delft3D, has been reapplied [3].

Key components of the methodology undertaken in the oceanographic modelling scope of work can be summarised as follows:

- determine the initial mixing in the vicinity of the outlet diffuser. The most rapid dilution takes place over a distance of only a few tens of metres from the diffuser. This dilution results from the entrainment of sea water in the outlet diffuser jets. This zone in the immediate vicinity of the ocean outlet diffuser is usually referred to as the 'near-field' region. The near-field model results are used to define the initial conditions for the farfield model
- define the initial conditions at the 'diffuser' grid cell (i.e. the computational cell or cells where the outlet diffuser was located)
- establish oceanographic and meteorological forcing conditions to simulate likely and worst-case scenarios for mixing and brine dispersion (i.e. minimal contribution from wind and high heat input)
- present the modelling results in a range of graphs, including computer animations, to illustrate key features and to facilitate its review by other parties.

The oceanographic modelling uses identical set-up (model grid, model parameters, boundary and forcing conditions, etc) as in the modelling of the permanent outfall. Importantly, the model (in its current set-up) has been found to compare very well with the observed ocean currents in the considered area [3].

5.2 Relevant Forcing

KJVG conducted a review of the available Metocean reports and other available data to gain an understanding of the environmental conditions that are relevant to dilution and dispersion [2]. The report identified the oceanographic and meteorological forces in the area that could potentially affect the evolution of brine and determined their relevance and importance. Conditions considered included: Water levels, Waves, Currents, Wind, Steric Gradients and Heat fluxes.

The study concluded the following assumptions are relevant for hydrodynamic modelling:

- In general, waves are small and can be discounted in a worst case scenario affecting mixing
- Stratification acts to inhibit mixing, however in this case it can be neglected due to lack of an observable thermocline or pycnocline in nearshore waters
- In the context of mixing processes the periods with low winds represent the most adverse conditions as they lead to the reduced mixing in the water column

- Generally from available current data and modelling undertaken to date by others the currents within the region are tidally dominated.

As a result of these findings, the primary force used in the hydrodynamic model will be tide (which generates currents).

Based on modelling results for the permanent outfall [3], there are no significant differences between summer or winter heat conditions. The modelling will therefore only be undertaken for forcing conditions for one season (3-months duration). Summer conditions will be used as this is theoretically the most detrimental to mixing (i.e. higher heat input may lead to stratification that may lead to reduced mixing and accordingly it represents a more conservative case).

6. SIMULATION CASES

Given that final design of all the phases of the temporary water supply system has not been completed at the time of undertaking hydrodynamic modelling, extreme simulation conditions have been selected to provide a wide envelope of likely cases, to ensure that the simulation results encompass likely impacts of any likely final configuration, in terms of outfall locations and flow rates.

Accordingly, the following extreme simulations cases have been considered, with all the temporary outfalls operations at the same time and assuming that the MOF will be present:

Table 6.1 and Table 6.2 provide more information on simulation conditions, and on proposed outfall configuration as well as the dilution target in the near field.

Table 6.1 Simulation Scenarios

Diffuser	Water depths range at diffuser location during operation (min - max) [m]	Flow (Q) [m³/s]
1	0.6 – 4.7	0.074
2/3	1.8 – 5.9	0.06
Bridging	1.8 – 5.9	0.03

Table 6.2 Proposed Ocean Outfall Design

Item	Design Component	Current Design	Development Considerations
1.	Discharge salinity	59 ppt	Salinity approximated from the current RO recovery. Detailed design may dictate a change to the recovery rate, and consequently a change in salinity.
2.	Minimum Near-field dilution	40:1	-
3.	Diffuser: 1	Number of ports: 10 Port diameter: 40.4mm	Diffuser design may change depending on discharge flow rate.
4.	Diffuser: 2/3	Number of ports: 10 Port diameter: 32.3mm	Diffuser design may change depending on discharge flow rate.

Item	Design Component	Current Design	Development Considerations
5.	Diffuser: Bridging	Number of ports: 8 Port diameter: 26mm	Diffuser design may change depending on discharge flow rate.

7. NEARFIELD DILUTION

The near field dilution was estimated by the outfall diffuser design team using PLUMES model developed by US EPA [7], as given in [4,5 & 6]

Table 7.1 shows diffuser dilutions over the range of operating water depths.

Diffuser	Dilution [-]	
	Minimum operating depth	Maximum operating depth
1	40	>50
2/3	44	>50
Bridging	40	>50

8. MODELLING RESULTS AND ANALYSIS

Oceanographic modelling was undertaken by incorporating the results from the near field analysis into the 3D oceanographic model by providing the brine concentration (resulting from the near field dilution) and the discharge flow rate in the "diffuser cell". The near field analysis shown in Section 7 indicates that due to the significant variation in the water depth the brine dilution can vary significantly, from some 40 to more than 50 in the near field. However, in 3D oceanographic analysis only the lowest dilution, i.e. 40 fold dilution, has been applied as the near field dilution for all the analysed cases. This (greatly simplified) approach, leading to the lowest dilutions, was applied to provide conservative estimates of dilutions for the proposed outfall.

8.1 Output Data and Interpretation of Results

Output data from the modelling software package was stored as follows (for each simulated case):

- A complete (three dimensional) record of the simulated parameters over the entire computational domain, stored at a frequency of 1-hour;
- A record of the simulated parameters at a series of selected monitoring locations, stored at a frequency of -minutes

The stored data was then processed and statistically analysed using a numerical software package, MATLAB®, to facilitate interpretation and presentation of the results. Analysed results include:

- Dilution Animations – Animations of brine dilution on the ocean floor during the course of each simulation case;
- Dilution Contours – Plots showing the 50th, 80th and 95th percentile dilution contours on the ocean floor for each simulation case;

To assist interpretation of the results, it is worth noting that brine dilution D is proportional to salinity reduction according to the following relationship:

$$D_{(x,y,z)} = \frac{S_{Discharge} - S_{Background}}{S_{(x,y,z)} - S_{Background}}$$

Where D is the dilution;

S is the salinity;

(x, y, z) is the point of interest;

$S_{discharge}$ is the salinity value at the point of discharge from the diffuser; and

SBackground is the salinity value of the background reading

8.2 Percentile Dilution Contours

Dilution contours, expressed as percentile, are shown in Figure 8-1 below. The percentiles are based on the actual expected dilutions in the far field as the near field dilution varies over time. In order to produce the plots, the following post processing of the modelling data was undertaken:

1. The time series change in water depth at the outfall discharge location was correlated with actual expected dilutions in near field to produce a time series change of near field dilution (based on the relationship actual depth and dilution that can be achieved for that depth (see Table 7.1)
2. The time series change of near field dilution was translated to actual expected dilutions in far field (based on correlating the model output data with the varying near field dilution)
3. Statistical analysis of the actual expected dilutions was completed to produce dilution contours.

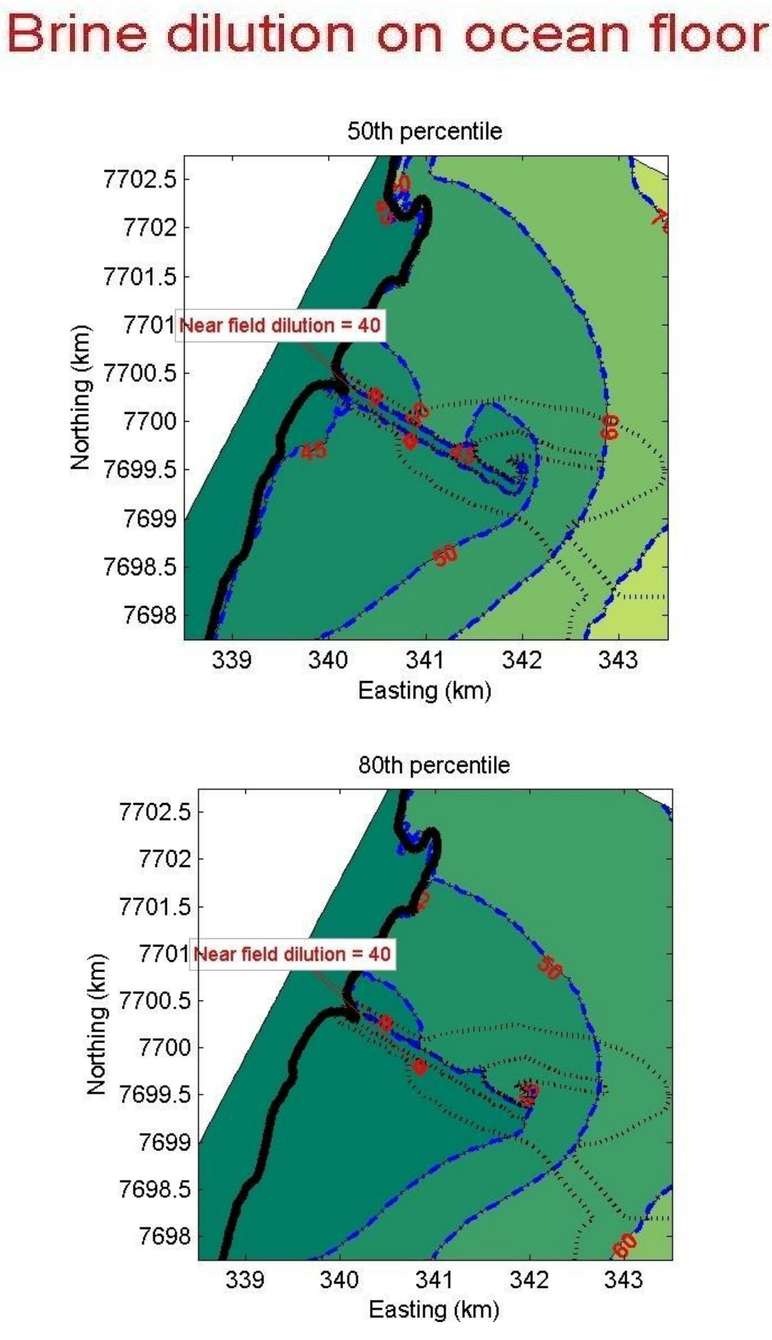
Percentile is defined as per Bhattacharyya and Johnson [8]: The sample p^{th} percentile is a value that after the data are ordered from smallest to largest, at least p% of the data are at or to the left of (below) this value and at least 100(1-p)% are at or to the right of (above) this value.

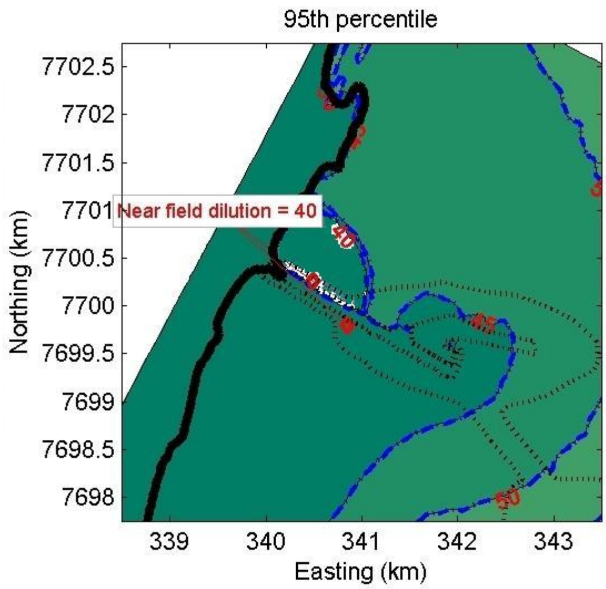
The inspection of results indicates that:

- A safe dilution of 40 fold has been achieved within the Zone of High Impact. This is seen in the dilution contours as a minimum of 40 dilutions is always achieved in the diffuser cell
- The dilution increases as the diffuser is placed in greater depth (i.e. at higher chainages)
- All cases show that the brine disperses quicker in the offshore direction. (additional water depth/volume assists the mixing process)

While MOF does have an impact, by reducing the ocean currents that could be present locally without its presence, the required dilutions have been achieved within the Zone of High Impact

Figure 8-1 Outfall located at CH 300 with shallowest intake (high flow)





9. CONCLUSIONS

Temporary outfalls have been proposed to support the early water requirements of the Gorgon Project.

In summary:

- A series of pipelines is proposed discharging through diffusers just beneath the water surface;
- Outfalls are to be located within the Zone of High Impact between 250 m and 900 m offshore;
- A minimum separation distance between the intake point and outfall will be 100 m for phase 1 and 200 m for phase 2/3 and Bridging;
- 40:1 dilution required within the Zone of High Impact;
- Dilution will vary depending on water depth (i.e. tide).

Analysis of the potential dilution and spatial dispersion of the proposed outfall demonstrates:

- A safe dilution of 40 will be achieved in the Zone of High Impact;
- Near field dilution will vary in conjunction with the tidal water level, deeper water results in greater dilution;
- The brine disperses quicker in the offshore direction (additional water depth/volume assists the mixing process).

10. REFERENCES

Table 10.1 Project Documents and Drawings

Ref.	Document Number	Rev.	Title
1	G1-NT-REPX0001646	-	WHOLE EFFLUENT TOXICITY TESTING OF BRINE EFFLUENTS, GORGON DEVELOPMENT, BARROW ISLAND
2	G1-TE-T-4500-TCN0500	C	REVIEW OF REGIONAL AND LOCAL OCEANOGRAPHIC, METEOROLOGICAL AND HYDROLOGICAL FEATURES FOR OCEANOGRAPHIC MODELLING
3	G1-TE-Z-4500-TCN1502	C	TECHNICAL NOTE FOR MINISTERIAL APPROVAL SUPPORTING DATA – OCEAN OUTFALL DILUTION MODELLING
4	G1-VE-C-8500-F04001060004	-	PHASE 1 RO PLANT OUTFALL DIFFUSER DESIGN REPORT
5	G1-VE-C-8500-F04001064022	-	BRIDGING RO PLANT OUTFALL DIFFUSER DESIGN REPORT
6	G1-VE-C-8500-F04001064021	-	PHASE 2&3 RO PLANT OUTFALL DIFFUSER DESIGN REPORT

Table 10.2 Published References

Ref.	Details
Ref.	**Details**
7	Frick, W. E., Roberts, P. J. W., Davis, L. R., Keyes, J., Baumgartner, D. J., and George, K. P. (2001). "Dilution Models for Effluent Discharges, 4th Edition (Visual Plumes) Draft." U.S. Environmental Protection Agency, Environmental Research Division, NERL, Standards and Applied Science Division, Office of Science and Technology, Athens, Georgia, 18 July 2001.
Ref.	Details
7	Frick, W. E., Roberts, P. J. W., Davis, L. R., Keyes, J., Baumgartner, D. J., and George, K. P. (2001). "Dilution Models for Effluent Discharges, 4th Edition (Visual Plumes) Draft." U.S. Environmental Protection Agency, Environmental Research Division, NERL, Standards and Applied Science Division, Office of Science and Technology, Athens, Georgia, 18 July 2001.
8	Bhattacharyya G.K. and R.K. Johnson, 1977, Statistical Concepts and Methods, Wiley