CHEVRON AUSTRALIA PTY LTD

REPORT

DISPERSION MODELLING FOR BRINE DISCHARGE FROM SWRO ON PROJECT SUPPORT VESSELS

For The

GORGON PROJECT
BARROW ISLAND LNG PLANT

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Kellogg Joint Venture Gorgon

KBR JGC HATCH CLOUGH

Chevron

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1. ABBREVIATIONS

Table 1 Abbreviations and Definitions

Term	Definition
CVX	Chevron Australia
KJVG	Kellogg Joint Venture Gorgon
LAT	Lowest Astronomical Tide
LNG	Liquefied Natural Gas
mCD	metres, with respect to Chart Datum
MOF	Materials Offloading Facility
NWS	North-West Shelf
PSV	Project Support Vessel
RO	Reverse Osmosis (Desalination)
SWRO	Sea Water Reverse Osmosis (Desalination)

2. EXECUTIVE SUMMARY

This technical note has been prepared to demonstrate to Chevron Australia (CVX) the likely impact associated with the discharge of reject brine associated with the operation of the Sea Water Reverse Osmosis (SWRO) located on the Project Support Vessels (PSV).

It was demonstrated that the sufficiently high dilution of the brine, equal or higher than the required 40 fold dilution, can be achieved in the proximity of the point of discharge, if the brine is discharged within a well flushed area.

3. INTRODUCTION

The Greater Gorgon Area Gas Field, situated approximately 130 km off the north-west coast of Western Australia, contain two of the largest individual gas fields, the Gorgon and Jansz Gas Fields, ever discovered in Australia. Chevron Australia Pty Ltd (Company) is the proponent and the person taking action for the Gorgon Gas Field development on behalf of the Gorgon Joint Venturers (GJV);

- Chevron (TAPL) Pty Ltd
- Shell Development (Australia) Pty Ltd
- Mobil Australia Resources Company Pty Ltd
- Osaka Gas Gorgon Pty Ltd
- Tokyo Gas Gorgon Pty Ltd
- Chubu Electric Power Gorgon Pty Ltd

Central to the commercial viability of the proposed development is the establishment of the gas processing facility and supporting infrastructure on Barrow Island (BWI), which lies between the gas fields and the Australian mainland. The marine waters surrounding BWI are part of the Montebello–Barrow Island marine conservation reserves. Most of the conservation area is zoned as a Marine Management Area but also includes the Barrow Island Marine Park and Bandicoot Bay Conservation Area, located in waters adjoining the west and south coasts of Barrow Island, respectively. These waters provide habitat for significant benthic communities and various species listed under the Commonwealth Environment Protection and Biodiversity Conservation (EPBC) Act.

Project Support Vessels (PSV) will be used for water production where they will be fitted with SWRO plants to provide potable water to the Project. Brine resulting from operation of the SWRO plants will be discharged via a dedicated discharge line and outfall system.

The Marine Facilities on the eastern side of Barrow Island, including the PSV SWRO intake and outfall structures, will be contained within the Barrow Island Port Area, which is excluded from the Marine Management Area.

This technical note has been prepared to demonstrate to CVX the likely temporal and spatial extent of the brine that is to be discharged from these SWROs.

4. DISPERSION MODELLING

The key objective of dispersion modelling is to illustrate and quantify the dilution of the reject brine once it has been released into the marine environment. Two major steps were undertaken during modelling in order to establish the key processes affecting this behaviour:

- Review of ambient conditions
- Establishment of criteria to select a dispersion model.

The above applies to the two steps considered in the dilution of the reject brine:

- Near-field dilution, dilution immediately of the diffusers
- Far-field dilution, further dilution and interaction with the ocean water

Both the near field and the far field may be important for the ultimate dilution of reject brine. Initial dilution, upon exiting the diffuser ports and reaching the ocean floor, is governed by the outfall's hydraulic design, particularly by the jet exiting velocity. As the diluted brine travels further away from the outfall, along the ocean floor, it further entrains sea water which may further dilute the brine. Ambient currents assist this process by providing "fresh" sea water for continuous dilution and further dispersing the brine. Accordingly, both the contribution of near and far field need to be considered.

Often the design of the discharge system aims to ensure that the near field dilution alone reaches the required dilution targets. If this is achieved and the discharge point is located in a well flushed area where the exchange of sea water is unrestricted and results in effective mass transport (dilution) away from the area, there is no need to undertake detailed oceanographic modelling of the far field dilution. The analysis presented within this report will focus on the near field dilution estimates only, considering that the discharge from these SWROs is into open water with flushing ocean currents, assumed to be on the open water side of any structure or vessel.

In what follows, the brine discharge details will be presented first, followed by the near-field dispersion modelling.

4.1 Brine discharge details

The PSV's and associated SWRO plants are proposed to be discharged within a well flushed area.. For the purpose of modelling, the discharge of brine from the SWRO plants has been assumed to be to the north of the Roll-On, Roll-Off berth at the marine offloading facility (MOF). The discharge line will be oriented perpendicular to the Roll-On, Roll-Off berth and the outfall will discharge horizontally.

Basic system information for the SWROs is presented in Table 2. The brine is discharged in batch mode, i.e. the discharge is either on or off.

It would be reasonable to expect the outfall modelling outcomes presented may represent brine discharge at other potential brine discharge locations where conditions and input data (i.e. discharge flowrate, brine concentration (salinity)) are the same as those used in the modelling (see Section 4.2 and Section 4.3). In particular, the minimum water depth below the discharge point (at LAT) should be no less than the modelled depth of 6m and the well flushed conditions present at the modelled discharge location should be maintained.

Table 2 SWRO brine ocean outfall: Design parameters (ref: e-mail from CVX 13 Oct 2014)

Component	Values
Discharge flow rate (total)	0.0087 (m^3/sec)
Discharge salinity	62.169 psu
Diffuser details	To be designed to achieve 100 fold dilution in the near field

4.2 Near-field Dilution Modeling

Near-field dilution modelling evaluates dilution in the proximity of the brine discharge.

As stated above, most of the brine dilution takes place in this area, under the assumption that local and regional oceanographic conditions generate sufficient flushing by ocean currents (i.e. no obstructions exist to the supply of fresh ocean water into the zone of discharge).

4.2.1 Modeling Approach

Key steps followed in establishing the near-field dilution model can be summarised as follows:

- Set up well established and verified plume model for the discharge area.
- Establish appropriate ambient or background oceanographic conditions in the model to simulate likely and conservative scenarios for mixing and plume dispersion.
- Present key modelling results graphically to illustrate key features and to facilitate its review by other parties.

The Visual Plumes™ model has been selected because of its track record in similar studies. The model has been successfully used at the same location in previous studies [G1-NT-REPX0001104].

4.2.2 Visual Plumes Model Description

Visual Plumes™ simulates single and merging submerged plumes in arbitrarily stratified ambient flow and buoyant surface discharges [Frick, 2004]. Visual Plumes™ is one of the outcomes of the US Environmental Protection Agency's efforts since 1979 to develop and disseminate models that predict the physical properties and dilution of plumes. It is widely used by the USEPA in particular to simulate waste water outfalls.

From the suites of five models recommended in Visual Plumes™ (DKHW, NRFIELD/FRFIELD, UM3, PDSW, DOS PLUMES), the most commonly used, UM3, was selected to predict near-field dilution. UM3 is an acronym for the three dimensional Updated Merge (UM) model for simulating single and multi-port submerged discharges. UM3 is a Lagrangian model that features an established hypothesis, which quantifies forced entrainment, the rate at which mass is incorporated into the plume in the presence of current [Frick, 2004].

Visual Plumes™ can also inform, using a simplified approach, an initial assessment of the effluent dilution as the plume travels away from the near field, carried along by the ambient ocean currents. This approach evaluates only a potential dilution away from the outfall diffuser, as it doesn't account for the actual bathymetric of infrastructure generated constraints.

Importantly, Visual Plumes™ model, as any other integral plume model, evaluates the steady state solution for the effluent plume propagation dilution under particular discharge conditions.

As discussed earlier brine dispersion takes place in the near field (i.e. proximity of the point of discharge) first, followed by the further dispersion away from the point of discharge (far field).

4.3 Brine dilution analysis

Key input data used to establish the model included: current speed and direction, seawater quality [G1-TE-T-4500-RFI0500], discharge geometry, and the effluent discharge parameters. Table 3 summarises inputs used for plumes modelling. The analysis was undertaken assuming that the water level is at the Lowest Astronomical Tide (LAT), i.e. at a minimum water depth at the discharge location. Importantly, the discharge pipe, 35 mm in diameter, will be submerged by a minimum of 0.5m below the water surface during the discharge episodes.

To illustrate the impact of the ocean currents on the brine dilution the analysis was undertaken for two values of the ocean currents:

- Case 1 with zero ocean currents
- Case 2 with a magnitude of ocean currents of 0.1 m/s

Table 3 Input data to model near-field dilution for SWRO outfall using Visual Plumes model

Parameters	Unit	
Diffuser		
Port diameter	m	0.035
Port elevation above sea bed @ LAT	m	6
Vertical angle	º	-5
Horizontal angle	º	90
Number of ports		1
Port spacing	m	1
Port depth	m	0.5
Effluent flow	m^3/s	0.0087
Effluent salinity	psu	62.169
Effluent temperature	ºC	25
Effluent density	kg/m^3	1044.1
Ambient		
Current speed	m/s	0.0 (Case 1) 0.1 (Case 2)
Ambient salinity	psu	35.6
Ambient temperature	º	25
Ambient density	kg/m^3	1023.8
Far-field diffusion coefficient	$m^{2/3}/s$	0.0001

The results of the simulations are shown in Figure 3 and Figure 4. The simulations indicate that at the estimated discharge location high near field dilutions can be achieved, under both conditions (i.e. zero ocean currents and ocean currents of 0.1 m/s magnitude)

Figure 1 Profile view of the plume trajectory and dilution of brine, from source (discharge point) to the ocean floor, for a zero ocean current.

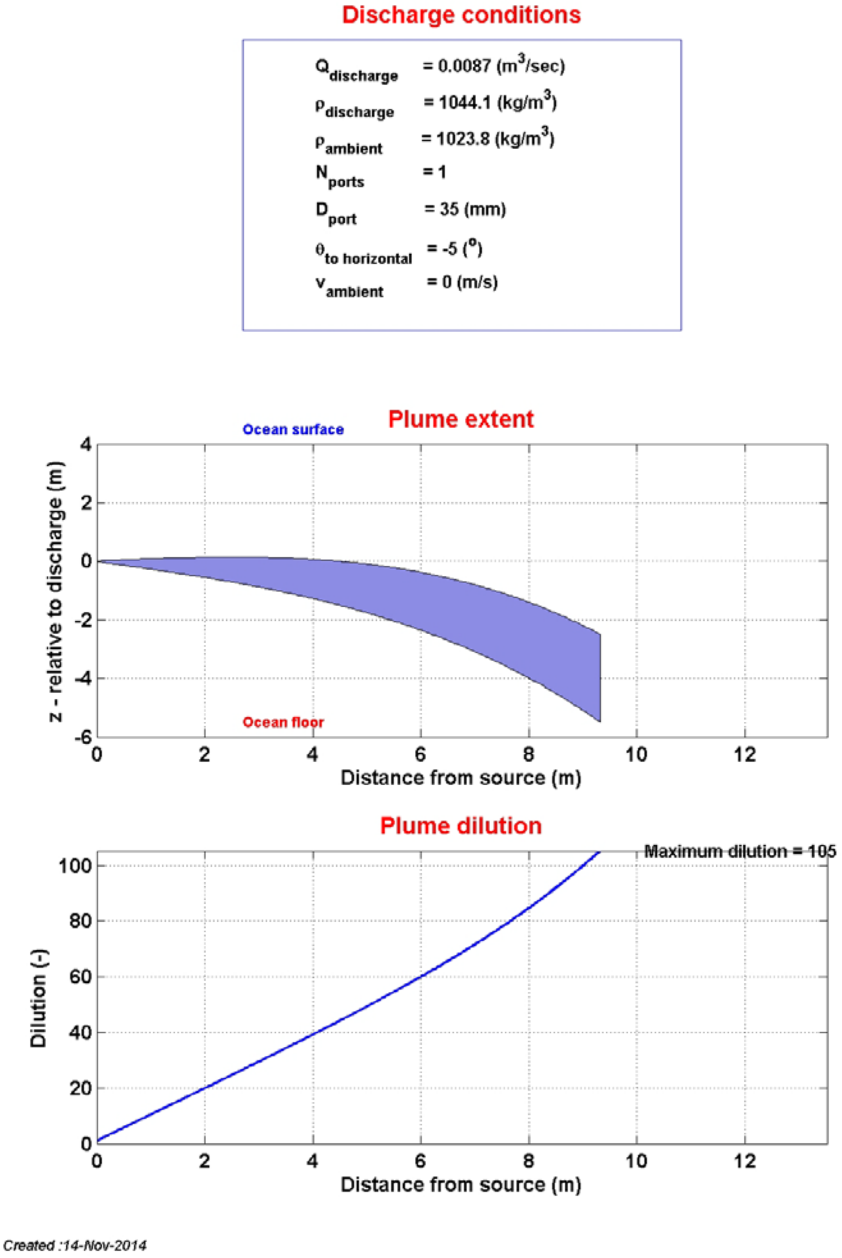
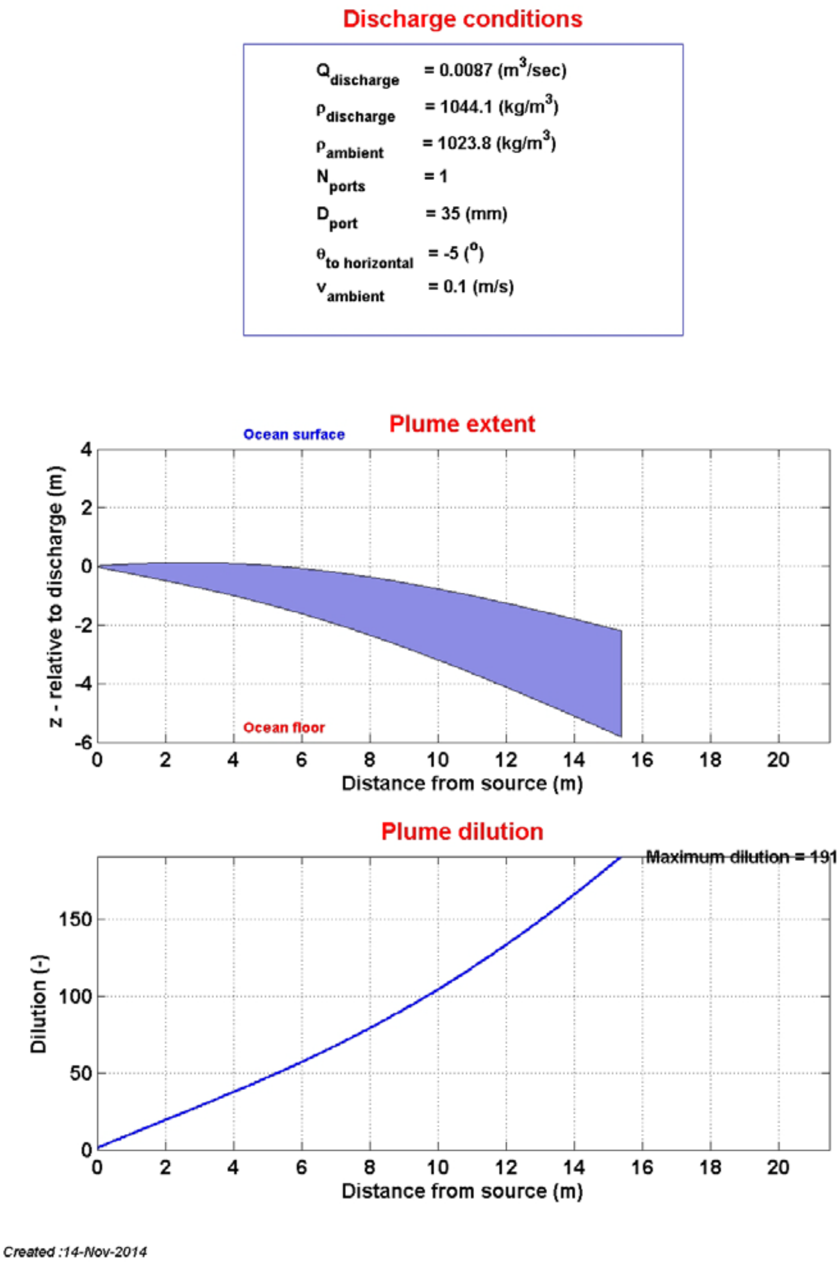


Figure 2 Profile view of the plume trajectory and dilution of brine, from source (discharge point) to the ocean floor, for ocean current at 0.1 m/s.



5. CONCLUSIONS

This technical note has been prepared to provide the likely extent of the impact zone following the release of reject brine associated with the SWRO located on the PSVs.

The brine dilution was analysed using the near-field model that has been previously used for several dilution studies for the Gorgon LNG project.

The simulations indicate that, if the brine is discharged within a well flushed area, high near field dilutions can be achieved within the vicinity of the discharge point, even under the conditions of no contribution from the local ocean currents. Under both conditions (zero ocean currents and 0.1m/s ocean currents) 40 fold dilution was reached within an approximate 4m vicinity of the discharge point; however a plume will travel further with 0.1m/s ocean currents prior to reaching the ocean floor and ultimately reach higher.

It would be reasonable to expect the outfall modelling outcomes presented may represent brine discharge at other potential brine discharge locations where conditions and input data (i.e. discharge flowrate, brine concentration (salinity)) are the same as those used in the modelling (see Section 4.2 and Section 4.3). In particular, the minimum water depth below the discharge point (at LAT) should be no less than the modelled depth of 6m and the well flushed conditions present at the modelled discharge location should be maintained.

6. REFERENCES

Table 4 Project Documents and Drawings

Ref.	Document Number	Rev. (Date)	Title
1.	G1-NT-REPX0001104	-	DISPERSION MODELLING STUDY SEAWATER INTAKE & REJECT BRINE OUTFALL (20 Dec 07)
2.	G1-TE-T-4500-RFI0500	(12 May 08)	METOCEAN DATA FOR SEAWATER INTAKE AND OCEAN OUTFALL MODELLING (CVX response to RFI, transmittal ICR-1549)

Table 5 Published References

Ref.	Details
3.	Frick, WE, Visual plumes mixing zone modelling software, Environmental Modelling & Software, Vol 19, Issue 7-8, pages 645-654, 2004.