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5 February 2021

AGL WHOLESALE GAS LIMITED

WORKS APPROVAL APPLICATION 1003907

RESPONSE TO SECTION 22(1) NOTICE TO SUPPLY FURTHER INFORMATION: QUESTIONS 1 - 4

STATE ENVIRONMENT PROTECTION POLICY (WATERS) (SEPP (WATERS))

1. **With respect to clause 25, provide detailed information as to whether wastewater discharges from the FSRU "provide water for the environment", in the sense that the wastewater will be reused in some way to help protect, or provide a benefit to, the environment.**

Summary Response

This question raises issues concerning the proper construction of SEPP (Waters). For the reasons that follow, AGL contends that:

- *First, whether discharges from the FSRU "provide water for the environment" is not directly relevant to the EPA's assessment of the WAA; and*
- *Second, even if this matter is directly relevant, the discharge of wastewater from the FSRU will in fact be consistent with the provision of water for the environment.*

Detailed Response

Clause 25 only has direct application to "applications to discharge wastewater to surface waters *to provide water for the environment or other uses*" (emphasis added). The Crib Point FSRU operations are not purposively directed toward the provision of water for the environment or other uses (although, for the reasons discussed further below, discharges from the FSRU will in fact make provision for, and will be consistent with, both outcomes). Instead, the proposed discharge of wastewater from the FSRU will arise as a consequence of the operation of the FSRU, such that the WAA is not properly characterised as one to which clause 25 directly applies.

The application should be assessed under clause 21 as "an application for approval of a discharge of wastewater to surface waters". Clause 22(3)(b) relevantly provides, in respect of applications of this type concerning waters of high conservation value, that the EPA must not approve an application unless it is satisfied that the wastewater discharge "*will be consistent with the requirements of* clause 25" (emphasis added). Clause 25 is accordingly relevant to the assessment of this application only by operation of clause 22(3)(b).

Two points are noted in this respect:

- First, clause 22(3) does not require that the application be consistent with clause 25 in its entirety. It instead requires consistency with the 'requirements' of that clause, which are readily identifiable as subclauses (a) and (b), and which specifically provide that:

- the Authority must be satisfied that the wastewater can be treated and managed to a level to protect beneficial uses; and
- the waterway manager (if applicable) must be satisfied that the discharge is consistent with environmental flow requirements.

- Secondly, the requirement for "consistency" in clause 22(3) requires harmony between the application and the requirements of clause 25, as opposed to strict conformity between the application and the requirements of the clause.

AGL contends, in light of these matters, that the reference to the provision of "water for the environment or other uses" in clause 25 is not a "requirement" of that clause. It is instead a qualifying factor that informs whether clause 25 and the requirements specified in subclauses (a) and (b) apply directly to an application for the discharge of wastewater to surface water (that is, independently of the operation of clause 22(3)).[1] This being the case, AGL contends that whether wastewater discharged from the FSRU will "provide water for the environment or other uses", is ultimately not relevant to the EPA's assessment of whether the application is consistent with the *requirements* of clause 25. Indeed, because there is no applicable waterway manager for the purposes of clause 25(b), the key consideration for the EPA in this respect should be whether it is satisfied that the wastewater can be treated and managed to a level to protect beneficial uses (as specified in clause 25(a)). This matter is addressed in further detail in AGL's response to question three.

These matters notwithstanding, AGL contends that the discharge of wastewater from the FSRU will in fact be consistent with the provision of water for the environment within the meaning of clause 25 (even if this was considered a requirement of that clause). It is important to recognise in this respect that that the "wastewater" in question will be seawater that has been entrained within and discharged from the FSRU during operation. Importantly, when operating in open, combined, or closed loop modes, the seawater would be within the regasification system onboard the vessel for a period of only approximately 5 minutes prior to discharge.

The seawater discharged from the FSRU will not contain any additional nutrients, nor will there be any change in levels of dissolved oxygen, pH, or turbidity. Instead, the seawater discharged from the FSRU will be of a different temperature (which will either be above or below ambient levels depending on the mode of operation), and contain residual concentrations of chlorine-produced oxidants (as a consequence of the proposed biofouling process). As the extensive hydrodynamic modelling undertaken as part of the EES process demonstrates, the seawater discharged from the FSRU will rapidly mix with waters in relatively close vicinity to the FSRU, so as to achieve parity with background conditions. In this way, the seawater discharged from the FSRU will continue to contribute to the ecological processes of Western Port, and to broader environmental values.

Accordingly, to the extent that it considers it relevant, the EPA should be satisfied that the operation of the FSRU will in fact provide water to the environment, notwithstanding that it does not do this with the purpose, aim or intention of providing water "for" the environment. The question that then arises is not what use the discharge water will have (in terms of how it protects or provides a benefit to the environment as question 1 suggests), but rather whether it meets the requirement that the water can be treated and managed to a level to protect beneficial uses.

2. **With respect to clause 25, provide detailed information as to whether wastewater discharges from the FSRU "provide water … for uses", other than for the**

[1] That is to say, the requirements of clause 25 would apply to any application to discharge wastewater to surface waters to provide water for the environment or other uses, regardless of whether clause 22(3) is enlivened.

environment, in the sense that the wastewater will be reused in some way rather than simply being disposed of.

Summary Response

This question raises similar issues concerning the proper construction of SEPP (Waters). For the reasons that follow, AGL contends that:

- *First, whether discharges from the FSRU "provide water for … other uses", is not directly relevant to the EPA's assessment of the WAA; and*

- *Second, even if this matter is relevant, the discharge of water from the FSRU will in fact be consistent with the provision of water for other uses.*

Detailed Response

As explained in response to question 1, AGL contends that whether wastewater discharged from the FSRU will "provide water for the environment or other uses" is ultimately not directly relevant to the EPA's assessment under clause 22(3) of whether the application is consistent with the *requirements* of clause 25.

Again, this matter notwithstanding, AGL contends that the discharge of wastewater from the FSRU will in fact be consistent with the provision of water for "other uses" (which AGL understands to be a reference to the range of beneficial uses identified in Table 4 of Schedule 2 of the SEPP). Indeed, as the EPA recognised in submissions before the IAC, "clause 25 is not confined to discharges that provide an environmental benefit".[2] It necessarily extends to other specified beneficial uses, such as shipping and navigation, and industrial and commercial uses.[3]

It is useful, in assessing the consistency of the project with the provision of water for "other uses", to consider its consistency with the wastes hierarchy in s 1I of the *Environment Protection Act 1970* (the **1970 Act**), which relevantly provides that "waste"[4] (including wastewater[5]) should be re-used or re-cycled.

The words "re-use" and "re-cycle" are not defined in either the 1970 Act or the SEPP. Accordingly, one must look to the ordinary meaning of those words.[6] The Macquarie Dictionary provides the following definitions:

(a) "re-use" is to "use again"; and

(b) "re-cycle" is (for present purposes) "to prepare something for a second use, often with some adaptation or reconstruction".

In the context of the current proposal, the wastewater in question will be relevantly "re-used" or "re-cycled" because it is being returned to its source (the surface waters of Western Port) where it can be utilised for any one or more of the scheduled beneficial uses in a sustainable

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[4] See s 4 of the 1970 Act

[5] See s 6 of the SEPP.

[6] *Grey v Pearson* (1857) 6 HLC 61, 106; 10 ER 1216, 1234; *Australian Boot Trade Employees' Federation v Whybrow & Co* (1910) 11 CLR 311, 341-2; and *Broken Hill South Ltd v Commissioner of Taxation (NSW)* (1937) 56 CLR 337, 371.

way after being discharged. That is because, once it has been re-introduced into the environment, the discharged wastewater will (through naturally occurring phenomena) be successfully reintegrated into the marine environment where it will be available to be utilised for any one or more of the scheduled beneficial uses.

3. **With respect to clause 25, provide detailed information as to whether the wastewater can be treated and managed to a level to protect beneficial uses? In particular, can the wastewater be treated and managed to a level to protect beneficial uses of water from the point of discharge (without a mixing zone)?**

Summary Response

AGL contends that the material before the EPA demonstrates that, when operating in open, combined, or closed loop modes, wastewater from the FSRU can be treated and managed to a level to protect beneficial uses of water, including at the point of discharge. This is demonstrated by:

- *the degree of conformance with the environmental quality objectives specified in respect of the North Arm of Western Port; and*
- *the comprehensive site-specific risk assessment undertaken in respect of the Project, which demonstrates that the discharge of wastewater from the FSRU will result in negligible risk of any material adverse impact on the waters of Western Port.*

Detailed Response

The words "treated" and "managed" are not defined terms in the 1970 Act or the SEPP and therefore assume their natural and ordinary meanings, thus:[7]

(a) "treated" relevantly means "to subject to some agent or action in order to bring about a particular result"; and

(b) "managed" relevantly means "to bring about" or "to handle, direct, govern, or control in action or use".

AGL contends that the "wastewater" (in the form of the entrained seawater) can be "treated" and/or "managed" through a range of design and operational management processes, including adjustments to the electrolysis process for the discharge water, prior to being re-used or re-cycled for one or more of the relevant scheduled beneficial uses. Those processes are described in detail in the EES and in the WAA. As documented in technical notes 15, 35, and 53 (which are attached to this response for ease of reference), these processes have been refined throughout the course of the EES hearing, and should be considered best practice having regard to the particular tidal conditions of the North Arm of Western Port. Further details concerning the proposed treatment and management processes are provided in response to question four below.

Whether the EPA is satisfied that these processes are sufficient to protect beneficial uses must properly be informed by an assessment of the anticipated environmental impact of the wastewater that will be discharged from the FSRU, as opposed to whether there remains a technical requirement for a mixing zone at the point of discharge,[8] or whether there may

[7] Drawing on the definitions of those terms from the Macquarie Dictionary.

[8] As clause 17(2) makes clear, the non-attainment of an environmental quality objective does not indicate that one or more beneficial uses *is* at risk. It instead indicates that there "may" be a risk, and that "an investigation is required to assess the level of risk to those beneficial uses and determine the actions needed to address those risks".

theoretically be scope to further minimise risks to beneficial uses.[9] In this respect, the Minister for Planning's assessment of potential environmental impacts (as informed by the IAC's report), will be relevant to this aspect of the EPA's determination.

AGL's closing submissions to the IAC address why, having regard to the evidence before the IAC, it contends that the discharge of wastewater from the FSRU would result in a negligible risk of any material adverse impact on the waters of Western Port (and, consequently, why the proposed wastewater treatment and management regime will necessarily be sufficient to protect all beneficial uses undertaken within those waters). The relevant part of those closing submissions is also attached to this response for ease of reference.[10]

The following matters are noted for present purposes:

- First, the detailed hydrodynamic modelling and risk assessment undertaken for the purposes of the EES, demonstrate that regardless of whether the FSRU operates in open, combined, or closed loop modes, the extent of any potential impact will be confined to a *small* area in the *immediate vicinity of* the FSRU. That area is wholly contained within the port zone (and within the dredged area in and around the Crib Point Jetty) and will be well-removed from any sensitive ecological features that are of particular significance to Western Port.

- Secondly, subject to the implementation of the refined management and treatment measures specified by AGL, a very high level of environmental protection will be achieved *within the immediate vicinity of the FSRU*:

    - Discharge from the FSRU will demonstrate a high degree of conformance with the applicable environmental quality objectives specified in Schedule 3 of the SEPP.

    - In respect of CPOs, the modelling demonstrates that when operating in open loop mode without an adjacent LNG carrier, tidally averaged chlorine concentrations at the seabed would be *below* the default guideline value of 2.2 ug/L *at all locations* (including immediately below and adjacent to the FSRU).[11] Furthermore, given the limited prospect of marine organisms encountering the plume of seawater discharged from the FSRU for anything other than very limited periods of time, the modelled CPO concentrations at and around the immediate point of discharge would not pose any material risk of harm to any beneficial use or to any component of the environment or the local ecosystem.

    - In respect of temperature differential, which AGL notes is not a specified environmental quality indicator for the purposes of the North Arm of Western Port, the physical extent of any difference would be limited in close vicinity to the FSRU, and even then, would remain within the range of natural temperature variation experienced within the Northern Arm of Western Port.

AGL intends to elaborate on these matters in providing its response to other aspects of the Notice. For present purposes, however, it contends that the material before the EPA demonstrates that, subject to the implementation of the proposed design and operational measures, the FSRU would not have any material adverse effects on the waters of Western Port when operating in open, combined or closed loop mode. This being the case, it follows

[9] AGL contends, in this respect, that the protection of beneficial uses does not necessarily require that any risk posed by a particular discharge of wastewater be minimised to the maximum extent possible. It instead requires that the wastewater be managed and treated so as to ensure that it does not prejudice the realisation of the beneficial uses of the relevant surface waters.

[10] See, in particular, paragraphs 159 - 187.

[11] That is the default guideline value achieving 99% species protection.

that the EPA should necessarily be satisfied that wastewater from the FSRU can and will be treated and managed to a level to protect beneficial uses.

While not central to the response provided here, it is appropriate to acknowledge that AGL's position continues to be that, in the circumstances set out above, the relative implications of operations in closed loop for emissions and feasibility are such that open and combined loop operations are preferable and supportable.

4. **With respect to clause 21(2)(b), provide detailed information to demonstrate how all reasonably practicable measures have been and will be taken in design, operation and management to minimise risks to beneficial uses of the receiving waters from the point of discharge, having regard to temperature variations and chlorine (or chlorine compounds) that are likely to result from such discharges.**

<u>Summary Response</u>

AGL contends that, subject to the implementation of the proposed design and operational controls, the EPA should be satisfied that all reasonably practicable measures (within the meaning of clause 12 of the SEPP) have been taken in the design, operation and management of the FSRU, to minimise risks to the beneficial uses of Western Port.

<u>Detailed Response</u>

As noted above, and as is contemplated in approvals under the SEPP, AGL has continued to consider and explore operational and technical measures to reduce, or eliminate, risks to beneficial uses and would continue to do so in operation with the benefit of performance monitoring. These matters are described in technical notes 15, 35, and 53 and in AGL's closing submissions to the IAC (as attached). Relevant refinements to the design and operational measures proposed to address residual risks to beneficial uses include:

(a) Designing the discharge port locations on the FSRU and discharge velocity to maximise mixing of the discharged wastewater and increase dispersion into the waters of Western Port.

(b) Committing to operating the FSRU in a manner that is consistent with a minimised area of impact, being the modelled extent of the discharge plume as if the FSRU was operating *without* an adjacent LNG carrier. If the FSRU is operated while an adjacent LNG Carrier is moored, it will be necessary to innovate the operations or FSRU design to achieve the same minimised impact area.

(c) Reducing the chlorine level at the point of discharge, including elimination for periods of the day, in accordance with the levels proposed in two options for EPR-ME01A, being:

(i) **Option 1 – Varying chlorination rate at point of discharge**

Except as approved or required by the EPA, the OEMP must include requirements that seawater discharges from the regasification system must:

a. have a chlorine residual concentration of up to 0.1mg/L other than at Slack Tide;

b. have a chlorine residual concentration of 0mg/L during Slack Tide;

c. not exceed a tidally averaged chlorine residual concentration of 0.0022mg/L beyond a distance of 100 metres from the FSRU; and

d. not exceed a temperature variation of 7°C from ambient

Note: The time of Slack Tide is half an hour either side of high tide or low tide at Crib Point. High tide and low tide at Crib Point are to be calculated by reference to the BOM Victorian Tide Tables or other source to the satisfaction of the EPA.

(ii) **Option 2 – Constant chlorination rate at point of discharge**

Except as approved or required by the EPA, the OEMP must include requirements that seawater discharges from the regasification system must:

a. have a chlorine residual concentration of 0.02mg/L ;

b. not exceed a tidally averaged chlorine residual concentration of 0.0022 mg/L beyond a distance of 100 metres from the FSRU; and

c. not exceed a temperature variation of 7°C from ambient.

AGL contends in this latter respect, that given the particular tidal characteristics of the North Arm of Western Port, the option whereby the chlorine level is controlled by local hydrodynamic conditions including elimination at and around slack tide is superior to the constant chlorination option (given the extent to which tidal currents influence dispersion). This notwithstanding, the implementation of either of the two options, would result in considerably lesser concentrations of CPO at all locations (and under all scenarios) than were modelled in the EES.[12] The Minister for Planning's assessment of the acceptability of these alternate chlorine discharge levels (as informed by the IAC's report) will again be relevant to the EPA's assessment in this respect.

Ultimately, subject to the implementation of the suite of proposed measures, AGL contends that there is no reasonable basis to conclude that the discharge of wastewater from the FSRU would present any material risk to Western Port (or to any of the beneficial uses of those waters). This being the case, the EPA should be satisfied that all reasonably practicable measures have and will be taken in the design, operation and management of the FSRU, to minimise risks to beneficial uses of the receiving waters from the point of discharge. Indeed, having regard to the matters specified in clause 12 of SEPP (Waters), AGL contends that:

(a) the implementation of the proposed measures would result in a low to negligible likelihood of any risk of adverse impact eventuating to any of the beneficial uses of Western Port;

(b) the residual risk of any impact would realistically be limited to areas in the immediate vicinity of the FSRU and would be limited in nature and extent;

(c) The proposed measures have been informed by detailed assessments undertaken by expert consultants and represent best practice having regard to the tidal conditions of the North Arm of Western Port;

(d) There are not presently any other practicable means to further reduce risks associated with the discharge of wastewater from the Project; and

(e) Given that the residual risk of any environmental impacts associated with wastewater discharge is low to negligible, the costs of further eliminating or reducing risk is not warranted.

These matters notwithstanding, in response to approved limits, AGL will continue to examine and implement operational measures and technological advances to further reduce the chlorine levels at the point of discharge. This may include, for example, a dedicated and tailored mechanical cleaning regime. Furthermore, any approval of the FSRU may require,

[12] This is because the modelling recorded within the EES assumed a residual chlorine concentration at point of discharge of 100ug/L.

once operational, monitoring of the biofouling requirements to assess whether further reductions of CPO concentration in the wastewater at the discharge points can be achieved.

ATTACHMENT A

TECHNICAL NOTES 15, 35, AND 53

GAS IMPORT JETTY AND PIPELINE PROJECT
ENVIRONMENT EFFECTS STATEMENT
INQUIRY AND ADVISORY COMMITTEE

TECHNICAL NOTE

TECHNICAL NOTE NUMBER:	TN 015
DATE:	07 October 2020
LOCATION:	Crib Point Jetty Works
EES/MAP BOOK REFERENCE:	Technical Report A
SUBJECT:	Response to RFI 007 – Section 2.3 Regasification when LNG tanker is present
SUMMARY	The information in this technical note explains the regasification process when a LNG Carrier is present.
REQUEST:	Explain the discharge and water quality implications of re-gasification operations (and the discharge ports) when an LNG tanker is moored beside the FSRU.

NOTE:

Introduction

1. This question is similar to a more pointed question asked on behalf of MPSC and addressed in TN 015, namely, whether the FSRU will operate while there is an adjacent LNG Carrier.

2. The basis of the question presumably arises from the conclusions of the hydrodynamic modelling summarised at Table 6-11 in EES Technical report A, Part 1, reproduced below.

Table 6-11. Summary of Results for Chlorine and Temperature Predictions

Production rate	Operating Mode	Vessels at Crib Point Jetty (Berth 2)	Chlorine above Guideline Value (6 µg/L)	Temperature above/below Guideline Value (0.5 °C)
Peak	Open loop	No LNG Carrier	Complies	0.7 ha
Average	Open loop	No LNG Carrier	Complies	0.5 ha
Peak	Open loop	With LNG Carrier	5 ha	20 ha
Average	Open loop	With LNG Carrier	2 ha	12 ha
One-third Peak	Open loop	With LNG Carrier	1 ha	6 ha
Peak	Closed loop	No LNG Carrier	0.2 ha	0.2 ha
Peak	Closed loop	With LNG Carrier	0.2 ha	0.3 ha

3. The table provides the results for chlorine and temperature predictions when the FSRU is operating while an adjacent LNG Carrier is moored. The critical point is the operation of the FSRU, rather than the presence of the adjacent LNG Carrier. While the FSRU is operating, the hydrodynamic model provides for seawater discharge from 6 ports facing east. The discharge flow is interrupted by the presence of an adjacent LNG Carrier. Where the FSRU is not in operation, there is no discharge from the east facing ports, so the presence of an adjacent LNG Carrier is immaterial.

4. Table 6-11 includes the results for open loop operation, which is the primary proposed mode of operation for the FSRU. The intake and discharge of seawater is similar for the operation of combined loop. For the purposes of this TN, operation in closed loop can be set aside.

5. Table 6-11 also assumes that the FSRU is operating at its peak rate (750 mmscf/d -3 trains operating including in closed loop), average rate (500 mmscf/d – 2 trains operating) or low rate (250 mmscf/d -1 train operating).

6. In the scenarios summarised in Table 6-11 the worst case is shown while there is an adjacent LNG Carrier and peak rate of operation in open loop. This scenario results in an area of impact of 5 ha where chlorine levels are above the guideline value of 6µg/L (0.006mg/L) and an area of 20 ha where the temperature differential is above/below the guideline value 0.5°C.

7. The best case in Table 6-11 is shown when there is no adjacent LNG Carrier while the FSRU is operating. As explained in the summary, the area of chlorine exceedance in this scenario is limited to the 40 metre discharge flow (albeit not at any point on the sea bed), and the area of temperature differential above/below the guideline value of 0.5°C is limited to an area around the vessel of 0.7 ha in peak operation (note this is predicted to be 0.5 ha in average operation).

Minimising the area of impact – Operations Environment Management Plan

8. As part of the EMP, the operation of the FSRU is proposed to be regulated by an approved Operations Environment Management Plan (**OEMP**) prepared in consultation with the EPA and approved by the Minister for Planning under Clause 4.3.4 of the Incorporated Document.

9. The EMP is also required to be generally consistent with any works approval granted by the EPA.

10. AGL has proceeded on the basis that:

    (a) The EES models scenarios to inform the assessment of environmental impacts.

    (b) The actual operation of the FSRU will be consistent with a minimised area of impact, regardless of the assessment of acceptability of impacts of a larger area of impact.

    (c) The OEMP would be prepared on the basis that the impacts of the FSRU must be contained within the minimised area of impact identified for the purpose of the OEMP or any Works Approval.

    (d) If the FSRU is operated while an adjacent LNG Carrier is moored it would be necessary to innovate the operations, or to design, to achieve this . For example, as shown in the witness statement of Dr Ian Wallis, the discharge ports could be reconfigured so as to allow the FSRU to continue to operate at the low rate while there is an adjacent LNG Carrier.

11. The effect is that the area of impact will be confined to the minimised area.

12. In his expert witness statement, Dr Wallis was instructed to assist to formulate a minimised area of impact which could be used as the basis for an appropriate Mitigation Measure (**MM**) / Environmental Performance Requirement (**EPR**) to be given effect in the OEMP.

13. A draft OEMP has not yet been prepared as it would follow the recommendations of the IAC, a final set of MMs/EPRs and consultation with the EPA. By way of background, an internal memorandum prepared by AGL's project director for the purposes of preparing a consultation draft of the OEMP is attached to this TN.

A Performance Based Approach

14. For the purposes of the assessment by the IAC, the response to item 7 is summarised as follows:

    (a) The area of impact for chlorine and temperature variation is demonstrated to be minimised when the FSRU is operated without an adjacent LNG Carrier;

    (b) The area of impact for chlorine and temperature variation should not exceed the minimised areas of impact that would result from the operation of the FSRU when no LNG Carrier is adjacent to the satisfaction of the EPA ;

    (c) This can be given effect by means of an appropriate MM /EPR and/or within the OEMP or any Works Approval;

    (d) Any requirement should be performance based to enable engineering, design, and operational innovation and to support continued operation of the FSRU if practical and to the satisfaction of the EPA.

15. The revised MM/EPR in the Day One EPRs includes the following:

    Except as approved or required by the EPA, the OEMP must include requirements that discharges from the FSRU must not exceed:

    a. a chlorine residual concentration of 0.1mg/L;
    b. a temperature variation of 7°C from ambient;
    c. a chlorine residual concentration of 0.006mg/L beyond a distance of 40 metres from the FSRU.

CORRESPONDENCE: N/A

ATTACHMENTS: 1 Attachment.

1. Memorandum, Gas Import Jetty Project – Marine Operational Parameters (21 September 2020).

Attachment 1

Memorandum

To:	Markus Brokhof – Chief Operating Officer, Integrated Energy
From	Lucy Martin – General Manager, Major Projects
Endorsed:	Doug Jackson - Executive General Manager, Group Operations, David Moretto - General Manager Integrated Portfolio Planning, Paul Meech, Program Director – Project Spirit, Major Projects, Ricky McNally - Project Director, Major Projects, Brian Kitney - Head of LNG Origination, Origination,
Subject:	**Gas Import Jetty Project – Marine Operational Parameters**

Dear Markus

This memorandum reflects the outcomes of the various review meetings held in recent months and informs the preparation of the Operations Environment Management Plan (OEMP) as it would affect core operational parameters which may impact on the intake and discharge of seawater at Crib Point. While it is too early to prepare a draft OEMP, it is appropriate to commit to some operational parameters to guide internal decision making, and to help to inform the assessment process by the project team, consideration by the IAC, and consultation with the EPA and other relevant stakeholders. It is assumed that the OEMP will need to be consistent with any operating licence issued by the EPA and that operational limits would be applied.

1. Incorporated Document

Under the Incorporated Document (Clause 4.3.2), prior to commencement of use and development, an Environmental Management Plan (EMP) must be prepared to the satisfaction of the Minister for Planning and in consultation with the Mornington Peninsula Shire Council.

Clause 4.3 requires that the EMP must set out the process and timing for development of an OEMP and other plans and procedures required by the mitigation measures including the process and timing for consultation with relevant stakeholders including DEWLP, Worksafe, the EPA and POHDA.

There will be an overlap between aspects of the OEMP and any relevant licence or requirement on operations imposed by the EPA. Further, aspects of the operations inform the potential for environmental impacts to occur, and may properly be reflected in mitigation or environment performance measures together with any refinements or improvements that may emerge from the assessment by the Inquiry and Advisory Committee.

2. Parameters EES

For the purpose of modelling potential environmental effects in the EES, various worst case scenarios were adopted, as well as some variations to these scenarios. For example, the hydrodynamic modelling includes scenarios depending on rate of flow and tidal conditions.

This is appropriate as the FSRU is designed to have an engineering capacity to meet future demand if required albeit it is anticipated that the intensity of operation will vary throughout the operating life of the facility and will not operate continuously at full engineering capacity in the initial phase. For example, while not proposed as a limit, the EES records that the FSRU would initially receive approximately 45 petajoules (PJ) of LNG per annum (approximately 12 LNG carriers) and that the amount of LNG could be increased to 160 PJ per annum (approximately 40 LNG carriers) depending on demand. Beyond the initial phase it is difficult to predict when demand in Victoria would require additional supplementary supply from Crib Point, either on an annual basis or short term for system security, as this may be influenced by a range of factors. Accordingly, to ensure flexibility, the operational limits should be set on the basis that the marine impacts must not exceed the best case scenarios that can be achieved by design and operational decisions.

For the OEMP, and in consultation with the EPA, it will be necessary to state with sufficient clarity the proposed operations, including any operational limits, and the timing and processes for any change to those limits over time.

The OEMP is intended to be a document that can be reviewed from time to time in consultation with the EPA and with the approval of the Minister. This provides an opportunity for revisions or changes to operation over the 20 year life of the Project to be considered in consultation with the EPA and with the benefit of the results of monitoring programs.

3. Operational Parameters - Consultation Draft

This memorandum provides a framework for core operational parameters informing the Project premised on possible project limits. The core operational parameters are set out in Annexure A.

4. **Monitoring**

The consultation process should finalise monitoring programs to be undertaken throughout the life of the Project. It is envisaged that the OEMP would include a regular review procedure, eg, every 3 years, providing updates based on monitoring. This would include water quality and verification monitoring. There are precedents available to support this discussion.

5. Process and timing considerations

The preparation of an OEMP is required prior to the commencement of the development and use. The OEMP must cover a range of issues apart from marine issues of direct interest to the consultation phase with the EPA. The Project Team will observe the EES process and hearings and the IAC recommendations with a view to preparing a consultation draft for the OEMP as soon as possible.

It is noted that any OEMP will also have to consider the potential to deal with any unforeseen demand issues arising from any deficiencies of supply in the market or as a consequence of any energy crisis.

Kind regards,

Lucy Martin
General Manager, Major Projects

Annexure A – Core Operational Parameters

The core operational parameters are set out as follows:

Gas Import and Jetty Project - Marine Parameter	Initial Phase (Years 1 and 2)	Operational Phase (From year 3)
Permissible operating modes	‘Open Loop’ mode other than in circumstances where seawater temperature is close to or below 10° celsius ‘Combined Loop’ mode in circumstances where ambient seawater temperature is close to or below 10° celsius	‘Open Loop’ mode other than in circumstances where seawater temperature is close to or below 10° celsius ‘Combined Loop’ mode in circumstances where ambient seawater temperature is close to or below 10° celsius
Maximum daily gas production rate (mmscf/day*) without LNG carrier moored adjacent to the FSRU	Up to 500 mmscf/day	1 March – 31 August: Up to 750 mmscf/day 1 Sep – 28 Feb: Up to 500 mmscf/day
Maximum 14 day average (mean) daily seawater flow rates in open and combined loop regasification mode (m^3/day) without LNG carrier moored adjacent to the FSRU**	Up to 312,000 m^3/day	1 March – 31 August: –Up to 468,000 m^3/day 1 Sep – 28 Feb: Up to 312,000 m^3/day
Maximum daily gas production rate (mmscf/day*) with LNG carrier moored adjacent to the FSRU	Minimise the area of impact by establishing an area informed by the ‘no adjacent vessel scenario’ as a guide in the first instance and then design and operate to remain within this area of impact. To operate within the area of impact include	Minimise the area of impact by establishing an area informed by the ‘no adjacent vessel scenario’ as a guide in the first instance and then design and operate to remain within this area of impact. To operate within the area of impact include

	measures such as the following:
	• Zero transmission while adjacent vessel is present; or
	• Transmission rates as follows if the EPA is satisfied that the area of impact is not unreasonably changed or increased:
	  ○ Rate equal to the regasification rate that can occur without any of the regasification trains operating; or
	  ○ Up to 250,000 mmscf/d subject to discharge ports being situated to the west or to the south of the FSRU; or
	  ○ Rate based on further or different design, operation or innovation that can be shown not to exceed or to reduce the area of impact.
		measures such as the following:
		• Zero transmission while adjacent vessel is present; or
		• Transmission rates as follows if the EPA is satisfied that the area of impact is not unreasonably changed or increased:
		  ○ Rate equal to the regasification rate that can occur without any of the regasification trains operating; or
		  ○ Up to 250,000 mmscf/d subject to discharge ports being situated to the west or to the south of the FSRU; or
		  ○ Rate based on further or different design, operation or innovation that can be shown not to exceed or to reduce the area of impact.

Maximum 14 day average (mean) daily seawater flow rates in open and combined loop regasification mode (m^3/day) with LNG carrier moored adjacent to the FSRU**	[To be determined to accord with regasification rate specified above].	[To be determined to accord with regasification rate specified above].

* Million standard cubic feet per day.

** Excluding cooling of freshwater generator and intermittent flows relating to ballast water, water curtain and fire testing.

GAS IMPORT JETTY AND PIPELINE PROJECT
ENVIRONMENT EFFECTS STATEMENT
INQUIRY AND ADVISORY COMMITTEE

TECHNICAL NOTE

TECHNICAL NOTE NUMBER:	TN 035
DATE:	19 October 2020
LOCATION:	Gas Import Jetty Works
EES/MAP BOOK REFERENCE:	Technical Report A and Attachment VIII - Appendix C and Annexure A-A
SUBJECT:	Response to RFIs 16, 17, 18, and 19 - Section 2.5 Chlorine and temperature discharge conditions
SUMMARY	Responses relate to subsection: Chlorine and temperature discharge conditions
REQUEST:	This technical note has been prepared in response to the Request for Further Information 16, 17, 18, and 19 provided to the proponents by the Crib Point Inquiry and Advisory Committee dated 16 September 2020.

NOTE:

[RFI 16] Provide information on the feasibility of alternative discharge options during the discharge of wastewater to manage chlorine and temperature such as:

- **discharging wastewater on an ebb tide**
- **moderating discharge based on tide and currents**
- **holding water to allow for adequate de-chlorination and temperature stabilisation prior to discharge**
- **alternative biocides to chlorine**

1. Limiting discharge to the ebb tide may be technically feasible but is not practical for the operation of the FSRU and has the potential to disrupt supply according to tidal conditions. This would effectively limit the times of day or duration for which the FSRU could be operated.

2. If the storage of waste water for regasification was to occur during periods of flood tide, or for the purposes of holding water to allow for de-chlorination and temperature stabilisation, large onshore holding tanks would be required, as the FSRU would not have sufficient storage capacity onboard. This solution would not be feasible due to the high storage tank capacity requirements as well as the complex connections that would be required between the FSRU and jetty. A storage tank or multiple storage tanks with a storage capacity of approximately 234,000 tonnes would be required for 12-hours of

regasification. This is over 78 times the storage capacity of the proposed 3,000 tonne nitrogen storage tank at the Crib Point Receiving Facility.

3. The preferred approach, supported by the proposed EPRs is to minimise the impact area for chlorine impacts and demonstrate that even this minimised area assumes the slack tide. The strength of tidal currents is such that any residual chlorine is effectively dispersed with tidal movement.

4. See also TN15. The marine growth prevention system proposed for the FSRU is an electro-chlorination growth protection system, which produces hypochlorite from the naturally occurring salt (NaCl) already existing in the sea water, through electrolysis. This system, which is also commonly used by most ships for the treatment of their engine cooling water systems, is the globally preferred method to prevent marine fouling as it introduces no chemicals from outside sources and decays rapidly. Alternate systems used for marine growth protection systems, such as a copper-based systems, require external biocides to be added to the local seawater and may accumulate in the local environment.

[RFI 17] Explain how the concentration of 100 parts per billion (ppb) discharged from the FSRU has been qualified and provide evidence of 100 ppb being the maximum discharge concentration.

5. After chlorination at the seawater intake, the chlorine rapidly dissipates and is absorbed by the seawater back to its natural state during the exposure time in the internal piping and heat exchangers. It is recommended an initial chlorine dosing of 500 parts per billion (ppb) by mass to prevent marine fouling in the system. It is understood that this would result in an upper limit of 100ppb (0.1mg/l) at the point of discharge, and would continue to rapidly decay away.

6. The FSRU proposed for the Crib Point LNG import facility is similar to other FSRUs and LNG carriers around the world, being equipped with an electro-chlorination system for protection of the onboard seawater systems against excessive marine growth. For this system, a free chlorine discharge concentration of no more than 100 ppb is presented as the project specific requirement for the FSRU operations at Crib Point. This concentration has been used in the assessment of an area of impact and this has in turn been minimised by operational and or design requirements under EPR MM01A.

7. While it may be possible to impose a lesser limit for residual free chlorine discharge concentration, this would be a matter for ultimate consideration in final detailed approval. However, a lesser residual concentration would be expected to require design modifications or more frequent shutdowns for maintenance. At Crib Point the tidal conditions provide for a minimised area of impact without a requirement for a lower residual concentration.

8. International examples involving discharges of chlorine from industrial premises vary. More recently, the Port Kembla approval appears to require a lower residual discharge for chlorine of 0.02 mg/l (20 ppb) but that FSRU is not operational, is yet to receive any wastewater discharge approval, has a single discharge port and is located within a harbour with significantly less tidal influence.

[RFI 18] Explain why 500 ppb is the suggested chlorine dosing concentration when efficacy as an antifoulant is implied as low as 200 ppb. Explain the dosing scenarios that would result in 0 ppb at the discharge point.

9. The initial dosing rate allows for the natural degradation of the chlorine concentration as the water is transported throughout the various sea water systems onboard the vessel.

As much of the hypochlorite decays whilst still in the internal piping, the initial dosing rate is selected to ensure chlorine levels are sufficient at the most distant part of the ship that require antifouling protection.

10. When referring to chlorine concentrations it is therefore important to distinguish between the following main locations of the onboard seawater system:

(a) The initial dosing point (typically in relation to the seawater intake points)

(b) The most distant part of the process where a certain concentration must be maintained in order to maintain sufficient antifouling efficacy

(c) The discharge point(s) where the treated water is returned to sea (which is normally the reference point in environmental permitting)

11. The chlorine concentration starts to decay once generated, and decays rapidly within the time the sea water passes through the piping onboard the vessel. The sea water intake on the vessel, where the growth prevention system is installed, is in the engine room. The pipe run length, from the sea water intake to the regas system is above 100 meters, and due to the rapid decay rate the dosing concentration at the inlet point needs to be higher to allow for the degeneration as the water flows through the piping.

12. It is also important to note that the initial dosing will be flow dependent. If a low flow is transferred through the same piping system as a higher flow, the lower flow will have a longer retention time in the system than the larger flow. Consequently, the initial dosing level needs to be higher concentration for a low flow compared to a high flow, if the same residual chlorine level is targeted at the given discharge point(s).

13. The 500 ppb dosing concentration is the marine growth protection system maker's typical recommendation for the initial dosing point to ensure proper protection of the onboard sea water piping and equipment.

14. The 200 ppb is commonly used as a reference level for the concentration that provides adequate biofouling protection at the local process component (i.e. equipment or piping element).

15. Dosing rates that resulted in a guaranteed 0 ppb concentration at the discharge points of the ship would not provide adequate levels biofouling protection within the equipment.

16. Subject to the results of post commissioning monitoring and operational experience, it may be possible to further reduce dosing rates.

[RFI 19] Provide details of the optional chlorine reduction system referenced in Appendix C (Technical Specifications and Drawings) and explain why this has not been factored into the Project.

17. The project is still working with the FSRU supplier on design options to reduce chlorine levels while asking that the EES assesses the project on the assumption of 0.1mg/l (100ppb).

18. The options that AGL are reviewing to reduce the residual chlorine levels below 0.1mg/l (100ppb), include;

(a) Modification of the location(s) of the marine growth protection systems to enable better control of chlorine levels

(b) Increased maintenance frequency to allow for increased levels of fouling

(c) Utilising new alternative technologies (UV and/or ultrasonic)

19. An increase in manual cleaning may result in frequent gas export disruptions impacting market supply security, intensive manual labour and the risk of damage to the ships system.

<u>Guideline Values for Chlorine in Marine Waters</u>

20. A copy of the following journal article is provided at Attachment 1 of this technical note:

(a) Batley, G E and Simpson, S L (2020). Short-Term Guideline Values for Chlorine in Marine Waters. *Environmental Toxicology and Chemistry*, 39(4), 754–764.

CORRESPONDENCE: N/A

ATTACHMENTS: 1 Attachment:

1. Batley, G E and Simpson, S L (2020). Short-Term Guideline Values for Chlorine in Marine Waters. *Environmental Toxicology and Chemistry*, 39(4), 754–764.

Attachment 1

Batley, G E and Simpson, S L (2020). Short-Term Guideline Values for Chlorine in Marine Waters. *Environmental Toxicology and Chemistry*, 39(4), 754–764.

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Environmental Chemistry

Short-Term Guideline Values for Chlorine in Marine Waters

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Abstract: Chlorination is commonly used to control biofouling organisms, but chlorine rapidly hydrolyzes in seawater to hypochlorite, which undergoes further reaction with bromide, and then with organic matter. These reaction products, collectively termed chlorine-produced oxidants (CPOs), can be toxic to marine biota. Because the lifetime of the most toxic forms is limited to several days, appropriate guideline values need to be based on short-term (acute) toxicity tests, rather than chronic tests. Flow-through toxicity tests that provide continuous CPO exposure are the most appropriate, whereas static-renewal tests generate variable exposure and effects depending on the renewal rate. There are literature data for acute CPO toxicity from flow-through tests, together with values from 2 sensitive 15-min static tests on 30 species from 9 taxonomic groups. These values were used in a species sensitivity distribution (SSD) to derive guideline values that were protective of 99, 95, and 90% of species at 2.2, 7.2, and 13 μg CPO/L respectively. These are the first marine guideline values for chlorine to be derived using SSDs, with all other international guideline values based on the use of assessment factors applied to data for the most sensitive species. In applying these conservative guideline values in field situations, it would need to be demonstrated that concentrations of CPOs would be reduced to below the guideline value within an acceptable mixing zone through both dilution and dissociation. *Environ Toxicol Chem* 2020;39:754–764. © 2020 SETAC

Keywords: Environmental chemistry; Ecotoxicology; Water quality guidelines; Chlorine; Chlorine-produced oxidants

INTRODUCTION

Chlorination, either by the addition of sodium hypochlorite (NaOCl) or electrolysis of seawater, remains one of the most effective approaches for the control of biofouling organisms in seawater (Nguyen et al. 2012; Rajagopal 2012). When chlorine-treated waters are discharged, there are concerns for the impacts of chlorine and its decomposition products on the health of nontarget aquatic biota.

The derivation of a water quality guideline value for chlorine is complicated by the fact that chlorine is highly reactive in seawater, first hydrolyzing and then rapidly oxidizing bromide. Because these reactions are rapid, chlorine or hypochlorite are not expected to pose a direct toxicity threat; however, a potential toxicity remains from their reaction products that can be assessed in the laboratory. On that basis, it is possible to generate a guideline value that relates to the original chlorine or hypochlorite concentration.

The derivation of guideline values for chlorine and its reaction products has already been dealt with by a number of jurisdictions (US Environmental Protection Agency 1985; Canadian Council of Ministers of the Environment 1999; Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand 2000; Sorokin et al. 2007), however, with improvements in methods for guideline value derivation (e.g., Batley et al. 2018), and the availability of newer toxicity data, there is an opportunity to potentially derive a more robust guideline value. In evaluating the toxicity data from experiments with reactive chemicals, there is the option to use the results of static tests (to simulate one-off discharges), of static-renewal tests where the test solution is typically renewed every 24 h, or of flow-through tests that model continuous discharges and avoid decay of toxic reaction products where tests continue for several days. The latter are more appropriate for the derivation of guideline values for ecosystem protection. Furthermore, given that toxicity will be time dependent, it becomes appropriate to derive a short-term guideline value rather than one based on longer term chronic effects.

A key application of the guideline value would be the use of chlorine in the biocidal treatment of heat-exchanger pipes or other systems. This treatment is often continuous, but where the discharge is into the marine environment, the impacts of the discharge are also influenced by varying rates of dilution of

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chlorine-produced oxidants (CPOs) due to tidal currents and wave action. The guideline value we have derived is conservative because it is based on toxicity testing where the toxicant is continuously renewed, and not on static-renewal or static tests. The guideline value can thus be applied to all discharges, both continuous and intermittent. The risk assessment of intermittent scenarios would further consider the influence of exposure dynamics (duration and frequency; Angel et al. 2015).

Reactivity of chlorine in seawater

The rapid hydrolysis of chlorine leads to the formation of hypochlorous acid (HOCl) and its dissociation product, the hypochlorite ion (OCl^-). At the pH of seawater, HOCl is 80% dissociated to hypochlorite (dissociation constant [$pK_a = 7.54$). The term "free chlorine" is used to refer to the mixture of Cl_2, HOCl, and the hypochlorite ion, OCl^-, in equilibrium.

Both chlorine and the hypochlorite ion are powerful oxidants. In particular, the bromide ion, present in seawater at a high concentration near 65 mg/L, is rapidly oxidized by hypochlorite to form hypobromous acid ($pK_a = 8.6$), which is only some 20% dissociated to the hypobromite ion at the pH of seawater (8.1). This reaction is 99% complete in 10 s (Jenner et al. 1997).

Hypobromous acid is still a good oxidant, although a weaker oxidant than hypochlorite. The antifouling and oxidative capacity of electrolysed seawater is therefore largely due to hypobromite rather than hypochlorite. The term "residual chlorine" is given to the concentration of chlorine and its reaction product (hypochlorite ion) that remain in solution. The term "total residual chlorine" in seawater is commonly taken as comprising all CPOs in seawater and is expressed as mg Cl/L (Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand 2000). This would include hypobromous acid and would in fact be mostly bromine based. The use of total residual chlorine is commonly a reference to freshwaters, whereas in marine waters, the equivalent term is CPOs.

In addition, in waters where ammonia is present at elevated concentrations, the formation of chloramines (NH_2Cl; and bromamines) is also a possibility. It was estimated that for these to be significant, ammonia concentrations would need to exceed 10 μg/L for chlorination at 1 mg/L (Sugam and Helz 1977), but values of this order are uncommon in seawater. Because the majority of hypochlorous and hypobromous acids are consumed by reaction with organic compounds, the main products are a diverse range of halogenated organics, in particular trihalomethanes. Jenner et al. (1997) found that bromoform was the major product in a power station seawater cooling water discharge at 16 μg/L for a mean chlorine dosage of 0.5 to 1.5 mg/L as Cl_2. The high volatility of such compounds means that they are reasonably rapidly lost. The half-life of bromoform varies from 16.9 h at 1 m depth to 85 h at 5 m (Abarnou and Miossec 1992), considerably longer than the half-life for chloroform of near 30 min. Measured total residual chlorine (and CPO) includes free chlorine and combined chlorine (as chloramines).

In assessing the ecological impacts of residual chlorine discharges, the rates at which chlorine and hypochlorite species react initially to form hypobromite species and further with other receiving water constituents such as ammonia or natural dissolved organic matter (DOM), will be critical. Very few studies have examined this factor in any detail. Zeng et al. (2009) showed that at 15 °C, an initial residual chlorine concentration of 2.35 mg/L reduced to approximately 0.8 mg/L in less than 1 min. This reduction resulted from the oxidation of bromide to hypobromous acid, which is literally too fast to measure. This was followed by a slower first order decomposition over 15 min to 0.5 mg/L and almost to completion in 30 to 40 min. The higher the water temperature, the faster the reactions and the reduction in chlorine concentration. Zeng et al. (2009) also noted that in summer, the CPO had fully decayed before discharge, whereas in winter, the CPO decomposition was slower and might be incomplete.

Using CPO decomposition data and models from the literature (Wang et al. 2008; Saeed et al. 2015), a CPO concentration of 100 μg/L is predicted to decay to 50 μg/L within 2 h (~50%), and to 25 μg/L within 24 h (~75%) in a 5 to 15 °C receiving seawater environment. The CPO decomposition is slower at salinities lower than 35‰. The rate of reaction with DOM is slower than the reaction with bromide and increases with increasing DOM concentrations (Wang et al. 2008). Similar findings were obtained by Saeed et al. (2015).

The above findings are relevant to how the toxicity testing data might be interpreted and applied to derive guideline values to protect aquatic organisms in the receiving environment. In tests using continuous flow hypochlorite addition, reaction with bromide would be presumed to have occurred (available bromide reacts rapidly), and in seawater there is a large excess of bromide over the typical CPO concentration, whereas in static tests, depending on the duration, further oxidative reactions might have progressed (slower reactions with DOM). Application of toxicity data derived in this way will need to take into account the time of exposure required to elicit either acute or chronic toxicity to determine the nature of the impact, if any.

Existing water quality guideline values for chlorine in marine waters

The oldest guideline value is that of the US Environmental Protection Agency (1985), which recommended that "except possibly where a locally important species is very sensitive, saltwater aquatic organisms and their uses should not be affected unacceptably if the 4-day average concentration of CPOs does not exceed 7.5 μg/L more than once every 3 years on the average and if the one-hour average concentration does not exceed 13 μg/L more than once every 3 years on the average."

The Canadian Council of Ministers of the Environment (1999) noted that the 4 most sensitive species endpoints in their database were reduced egg fertilization successes for sand dollars and green sea urchins at 2 and 5 μg Cl/L, respectively (Dinnel et al. 1981), the 48-h median lethal concentration (LC50) for the eastern oyster larvae of 5 μg/L, and the 48-h median effect concentration (EC50) for hard clam larvae of 6 μg/L (Roberts et al. 1975). These were not considered acceptable due to reservations with respect to the analytical methodologies and testing protocols. Their default acute guideline value, termed a short-term guideline value, was derived by applying an "application factor" of 0.05 to the 10-μg/L LC50 for the next most sensitive species, blue crabs (Patrick and McLean 1971), American oysters (Capuzzo 1979), the rotifer *Brachionus plicatilis* (Capuzzo et al. 1976), and phytoplankton (Eppley et al. 1976), giving a guideline value of 0.5 μg/L.

A risk assessment report for the UK Environment Agency (Sorokin et al. 2007) identified the lowest reliable short-term toxicity data point as a 24-h LC50 of 5 μg Cl/L as free available chlorine for a freshwater species, the crustacean *Ceriodaphnia dubia*. A standard assessment factor of 100 was applied, resulting in a predicted no-effect concentration (PNEC) in saltwater of 0.05 μg Cl/L. This was recommended as a replacement for the existing environmental quality standard (EQS) as part of the European Water Framework Directive. The existing EQS for total residual oxidants (TROs; Lewis et al. 1994) was based on an assessment factor of approximately 2 applied to an acute LC50 value of 28 μg/L for both plaice and sole for TROs. This resulted in an EQS of 10 μg/L, substantially higher than the proposed PNEC in saltwater.

In Australia and New Zealand, the absence of sufficient toxicity data for marine species led to the adoption in 2000 of a moderate reliability freshwater chronic guideline value of 3 μg Cl/L as a low-reliability environmental concern value for marine waters (Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand 2000). It was noted that although the chlorine figure for 95% species protection was relatively close to the acute toxicity value for the most sensitive species, this was considered sufficiently protective, due to its decomposition rate in seawater, the narrow difference between acute and chronic toxicity, and the lesser sensitivity of other data for this species (Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand 2000).

A revision of the marine chlorine default guideline value for Australia and New Zealand was identified as a priority as part of the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (Australian and New Zealand Governments 2018).

MATERIALS AND METHODS

A thorough review of the literature was undertaken for all toxicity data, both acute and chronic, pertaining to CPOs in seawater. Data were quality assessed following the procedure outlined by Warne et al. (2018). Only data for salinities of 25‰ or higher were included. The results for both flow-though and static tests were recorded. The full dataset is shown in Table 1.

A species sensitivity distribution (SSD) of the toxicity dataset was plotted with the Burrlioz 2.0 software (Commonwealth Scientific and Industrial Research Organisation 2019) and used to derive guideline values that were protective of 99, 95, 90, and 80% of species with 50% confidence.

RESULTS AND DISCUSSION

Toxicity testing

Because the half-lives of chlorine and its toxic reaction products are short in marine waters, it is usual for toxicity tests to be flow-through, resulting in continuous renewal of the test water and maintenance of a near-constant chlorine (hypochlorite) exposure to the test organisms. Concentrations of CPOs must be measured frequently to demonstrate that substantial reduction in concentration is not occurring. Static-renewal tests in which the test hypochlorite-containing seawater was replaced regularly (usually daily) were used in some instances. In static laboratory tests, the exposure is to rapidly decaying hypochlorite concentrations, and not surprisingly the LC50 values from such tests were generally higher (i.e., toxicity was lower) than those for flow-through tests.

Table 1 is a composite of the available toxicity data from Chariton and Stauber (2008), Canadian Council of Ministers of the Environment (1999), US Environmental Protection Agency (1985), and additional recent literature data, all of which have been quality assessed in the present study to meet the latest Australian and New Zealand Governments (2018) criteria (score of more than 50%) as documented by Warne et al. (2018). As already noted, the revised guideline value derivation approach in Australia and New Zealand recommends not using data for estuarine waters in which the salinity is below 25‰. There were a number of tests conducted at salinities just outside this range (15–25‰), and these are shown in Table 2.

Nearly all the reported bioassays were classified as acute tests, in which a lethal or adverse sublethal effect occurred after exposure to a chemical for a short period relative to the organism's life span (acute test durations are organism specific as defined by Warne et al. 2018). Chronic tests by comparison are ones in which a lethal or adverse sublethal effect occurs after exposure to a chemical for a period of time that is a substantial portion of the organism's life span or an adverse effect is seen on a sensitive early life stage. The only chronic data reported were for 72-h algal bioassays (Lopez-Galindo et al. 2010), which, by definition, are considered chronic tests (Warne et al. 2018), and for one 8-d fish test (Alderson 1972).

Data from short-term tests are most appropriate for the development of guideline values when contaminants are short-lived and nonpersistent due to dispersion, volatilization, or degradation, as is the case with chlorine in marine waters. The minimum exposure period is generally 96 h, but there might be circumstances in which a lesser exposure time is relevant (Batley et al. 2018). For acute effects, usually only LC50 data are recorded, but given that this represents a 50% effect on

TABLE 1: Toxicity data for chlorine-produced oxidants (CPOs) in seawater with salinity ≥25‰

Species	Life stage	Exposure duration (h)	Acute/chronic	Test type	Toxicity measure	Test medium	Temp (°C)	Concentration (μg/L)[a]	Reference	Comments
Algae (chronic)										
Alga (*Isochrysis galbana*)		96	Chronic	Static	Growth (EC15)	Synthetic seawater	20	172	Lopez-Galindo et al. 2010	CPO measured every 30 min, IC50 1390 μg/L
Alga (*Dunaliella salina*)		96	Chronic	Static	Growth (EC15)	Synthetic seawater	20	481	Lopez-Galindo et al. 2010	Daily biomass (optical density) measurements, IC50 824 μg/L
Invertebrates (acute)										
American oyster (*Crassostrea virginica*)	Larvae	0.5	Acute	Flow-through	Mortality (LC50)	Seawater (28‰)	25	**80**	Capuzzo 1979	Acceptable quality
Copepod (*Acartia tonsa*)		0.5	Acute	Flow-through	Mortality (LC50)	Seawater (28‰)	20	**820**	Capuzzo 1979	Acceptable quality
Rotifer (*Brachionus plicatilis*)		0.5	Acute	Flow-through	Mortality (LC50)	Seawater (28‰)	25	**90**	Capuzzo 1979	Acceptable quality
Rotifer (*Brachionus plicatilis*)	0.5 h old	24	Acute	Static	Mortality (LC50)	Synthetic seawater	20	586 (LC50), 438 (LC10)	Lopez-Galindo et al. 2010	Measured concentrations in 0.3-mL well plates
Amphipod (*Hyale barbicornis*)	Juveniles	96	Acute	24-h renewal	Mortality (LC50)	Seawater (34‰)	20	1050	Anasco et al. 2008	Measured concentration decayed rapidly. Nominal concentration used for 24-h exposure, measured concentrations for other exposure times.
Amphipod (*Hyale barbicornis*)	Juveniles	96	Acute	24-h renewal	Body length (EC50)	Seawater (34‰)	20	524	Anasco et al. 2008	Measured concentrations decayed rapidly. Nominal concentration used for 24-h exposure, measured concentrations for other exposure times.
Amphipod (*Pontogeneia* sp.)	Adult	96	Acute	Flow-through	Mortality (LC50)	Seawater (28‰)	15	**687**	Thatcher 1978	Acceptable quality
Amphipod (*Anonyx* sp.)	Adult	96	Acute	Flow-through	Mortality (LC50)	Seawater (28‰)	15	**145**	Thatcher 1978	Acceptable quality
Coon stripe shrimp (*Pandalus danae*)	Juvenile and adult	96	Acute	Flow-through	Mortality (LC50)	Seawater (28‰)	15	**178**	Gibson et al. 1975 and Thatcher 1978	Acceptable quality
Sea urchin (*Strongylocentrotus droebachiensis*)	Sperm	15 min	Acute	Static	Fertilization (EC50)	Seawater (28‰)	14	<5, <6	Dinnel et al. 1981	Sperm exposed for 15 min, eggs exposed pre-test for 24 or 48 h.
								5	Value selected	
Sand dollar (*Dendrastur excentricus*)	Sperm	15 min	Acute	Static	Fertilization (EC50)	Seawater (28‰)	14	**6.4** (geomean of 3 shortest pre-exposure times)	Dinnel et al. 1981	Sperm exposed 15 min before adding to eggs; pre-exposure of eggs for 1–60 min did not affect toxicity.

(*Continued*)

TABLE 1: (*Continued*)

Species	Life stage	Exposure duration (h)	Acute/ chronic	Test type	Toxicity measure	Test medium	Temp (°C)	Concentration (µg/L)[a]	Reference	Comments
Lobster (*Homarus americanus*)	Larvae	1	Acute	Flow-through	Mortality (LC50)	Seawater (28‰)	nr	**2890**	Capuzzo et al. 1976	Seawater and toxicant mixed for 14 h before larvae addition. Flow-through system. After 60 min exposure LC50 was 16 300 based on applied conc. and 2890 µg Cl/L (calculated from a decay equation) based on the residual; used ACR of 4.5 for crustaceans.
Mysid (*Neomysis* sp.)	Adult	96	Acute	Flow-through	Mortality (LC50)	Seawater (28‰)	15	**162**	Thatcher 1978	Acceptable quality
Shrimp (*Pandalus goniurus*)	Adult	96	Acute	Flow-through	Mortality (LC50)	Seawater (28‰)	15	**90**	Thatcher 1978	Acceptable quality
Shrimp (*Crangon nigricauda*)	Adult	96	Acute	Flow-through	Mortality (LC50)	Seawater (28‰)	15	**134**	Thatcher 1978	Acceptable quality
Shore crab (*Hemigrapsus nudus* and *H. oregonensis*	Juvenile and adult	96	Acute	Flow-through	Mortality (LC50)	Seawater (28‰)	15	**1420**	Thatcher 1978	Acceptable quality
Fish (acute)										
Tidewater silverside juvenile (*Menidia peninsulae*)	Fry	96	Acute	Flow-through	Mortality (LC50)	Seawater (22–27‰)	25	**54**	Goodman et al. 1983	Acceptable quality
Fish (*Oryzias javanicus*)	Larvae	96	Acute	24-h renewal	Mortality (LC50)	Seawater (34‰)	26	91	Anasco et al. 2008	Conc. decayed rapidly; nominal for 24-h, measured for others.
Fish (*Oryzias javanicus*)	Larvae	24	Acute	24-h renewal	Mortality (LC50)	Seawater (34‰)	26	152	Anasco et al. 2008	
Plaice (*Pleuronectes platessa*)	Larvae	96	Acute	Flow-through	Mortality (LC50)	Seawater (35‰)	8	**24**	Alderson 1972, 1974	Low temperature
Coho salmon (*Oncorhynchus kisutch*)	Juvenile	96	Acute	Flow-through	Mortality (LC50)	Seawater (28‰)	15	**32**	Thatcher 1978	Acceptable quality
Pacific herring (*Clupea harengus pailasi*)	Juvenile	96	Acute	Flow-through	Mortality (LC50)	Seawater (28‰)	15	**65**	Thatcher 1978	Acceptable quality
Threespine stickleback (*Gasterosteus aculeatus*)	Juvenile and adult	96	Acute	Flow-through	Mortality (LC50)	Seawater (28‰)	15	**167**	Thatcher 1978	Acceptable quality
Shiner perch (*Cymatogaster aggregata*)	Juvenile and adult	96	Acute	Flow-through	Mortality (LC50)	Seawater (28‰)	15	**71**	Thatcher 1978	Acceptable quality

(*Continued*)

TABLE 1: (*Continued*)

Species	Life stage	Exposure duration (h)	Acute/chronic	Test type	Toxicity measure	Test medium	Temp (°C)	Concentration (μg/L)[a]	Reference	Comments
Pacific sand lance (*Ammodytes hexapterus*)	Juvenile and adult	96	Acute	Flow-through	Mortality (LC50)	Seawater (28‰)	15	**82**	Thatcher 1978	Acceptable quality
English sole (*Parophrys vetulus*)	Juvenile	96	Acute	Flow-through	Mortality (LC50)	Seawater (28‰)	15	**73**	Thatcher 1978	Acceptable quality
Fish (chronic)										
Plaice (*Pleuronectes platessa*)	Eggs	8 d	Chronic	Flow-through	Mortality (LC50)	Seawater (35‰)	8	120	Alderson 1972, 1974	Low temperature

[a]Values in bold type used in the species sensitivity distribution (SSD).
nr = not reported; EC10 = effect concentration, 10%; IC50 = median inhibitory concentration; LC50 = median lethal concentration; LC10 = 10% lethal concentration; ACR = acute-to-chronic ratio.

species survival, it is more reasonable to use acute LC or EC10 values in deriving a default guideline value, because this represents a point of incipient toxicity, not 50% mortality.

The most sensitive species were sea urchins, with impacts on fertilization being seen at near 5 μg Cl/L as CPO (Dinnel et al. 1981). Although these were static tests, the exposure duration was sufficiently short to warrant their inclusion. In these tests, sperm were pre-exposed to hypochlorite in seawater for 15 min with no effect on viability, whereas a time from 1 to 60 min of pre-exposure of eggs before adding sperm did not affect the result, for the sand dollar *Dendraster excentricus*. The LC50 values for 15-min sperm plus egg exposures following a 1-, 1-, 1-, 5-, 6-, and 60-min pre-exposure, were 2, 10, 13, 7, 6, and 8 μg/L respectively, so the geometric mean of the 3 1-min pre-exposures, 6.4 μg CPO/L, was used. For the sea urchin *Strongylocentrotus droebachiensis*, an experiment in which the hypochlorite and seawater were premixed for 24 or 48 h before exposure did not affect the toxicity to sperm fertilization, suggesting that reaction products other than CPOs were causing toxicity (Dinnel et al. 1981). Because the exposure time of sperm and eggs was only 15 min in these fertilization experiments, the tests are considered to be acute (Warne et al. 2018); chronic tests with this species require 1 h or more of exposure. The next most sensitive species were fish, with plaice (*Pleuronectes platessa*) having a 96-h LC50 of 24 μg CPO/L (Alderson 1972).

There were results for only 2 algal species, *Isochrysis galbana* and *Dunaliella salina* (Lopez-Galindo et al. 2010), and these were not particularly sensitive, with chronic EC15 values for 2 species of 172 and 481 μg Cl/L respectively. These values were, however, based on 96-h static exposures, which might explain the lower sensitivity. Their respective EC50 values of 1390 and 824 μg Cl/L were the highest of any tests reported (Table 1). Flow-through tests with algae are difficult to undertake and are therefore rarely reported.

A few studies have examined the toxicity of reaction products. The oxidation products from bromine were found to be less toxic than those from chlorine (Dinnel et al. 1981), whereas the toxicity of chloroform and bromoform produced by reactions with organics has been described as "moderate to high," although a recent review showed that, at least for chloroform, effects on algae and fish are typically seen at mg/L concentrations, orders of magnitude above those for hypochlorite toxicity (UK Marine Special Areas of Conservation 2019). The LC50 values for larval survival for the oyster *Crassostrea virginica* estimated from the published dose–response curves (Stewart et al. 1979) were 2, 1, and 0.1 mg/L, respectively, for chloroform, bromoform, and bromate. These authors noted that chloroform and bromoform were both lost from solution by volatilization. Not considered was the toxicity of chloramine and bromamine products only formed when ammonia concentrations are elevated in the seawater.

There are several general observations that can be made with respect to the toxicity data. First, static tests with regular renewal (24 h) show lower toxicity (higher LC50 values) than continuous flow-through tests because of the reactivity of chlorine (hypochlorite). For example, a 0.5-h flow-through test with the rotifer *Brachionus plicatilis* had an LC50 of 90 μg CPO/L

TABLE 2: Toxicity data for chlorine-produced oxidants (CPOs) in seawater with salinity ≥15 and <25‰

Species	Life stage	Exposure duration (h)	Acute/ chronic	Test type	Toxicity measure	Test medium	Temp (°C)	Concentration (µg/L)	Reference	Comments
Invertebrates										
American oyster (*Crassostrea virginica*)	Larvae	48	Acute	Flow-through	Mortality (LC50)	Seawater (20‰)	19–28	26	Roberts and Gleeson 1978	Acceptable quality
American oyster (*Crassostrea virginica*)	Larvae	96	Acute	Flow-through	Mortality (LC50)	Seawater (20‰)	19–28	23	Roberts et al. 1975	Acceptable quality
								25	**Geometric mean**	
Copepod (*Acartia tonsa)*		96	Acute	Flow-through	Mortality (LC50)	Seawater (20‰)	20	**29**	Roberts and Gleeson 1978	Acceptable quality
Glass shrimp (*Palaemonetes pugio*)	Adult	96	Acute	Flow-through	Mortality (LC50)	Seawater (20‰)	19–28	**220**	Roberts and Gleeson 1978	Acceptable quality
Mysid (*Mysidopsis bahia*)	Juvenile	96	Acute	Flow-through	Mortality (LC50)	Seawater (20.5‰)	20	73	Fisher et al. 1994	Acceptable quality
Mysid (*Mysidopsis bahia*)	Juvenile	96	Acute	Flow-through	Mortality (LC50)	Seawater (20‰)	20	62	Fisher et al. 1999	Acceptable quality
								68	**Geometric mean**	
Atlantic marine amphipod (*Amphiporeia virginiana*)	Juvenile	48	Acute	Static	Mortality (LC50)	Seawater (21‰)	10	626	Wan et al. 2000	Acceptable quality
Pacific marine amphipod (*Eohaustorius washingtonianus*)	Juvenile	48	Acute	Static	Mortality (LC50)	Seawater (21‰)	15	567	Wan et al. 2000	Acceptable quality
Fish										
Atlantic silverside (*Menidia menidia*)	Juvenile	96	Acute	Flow-through	Mortality (LC50)	Seawater (20‰)	19–28	**37**	Roberts and Gleeson 1978	Used lower value (most sensitive life stage)
Atlantic silverside (*Menidia menidia*)	Eggs	48	Acute	Flow-through	Mortality (LC50)	Seawater (15‰)	8–12	300	Morgan and Prince 1977	Acceptable quality
Inland silverside (*Menidia beryllina*)	Juvenile	96	Acute	Flow-through	Mortality (LC50)	Seawater (20.5‰)	20	128	Fisher et al. 1994	Acceptable quality
Inland silverside (*Menidia beryllina*)	Juvenile	96	Acute	Flow-through	Mortality (LC50)	Seawater (20‰)	20	143	Fisher et al. 1999	Acceptable quality
								135	**Geometric mean**	Used lower 2 values
Inland silverside (*Menidia beryllina*)	Eggs	48	Acute	Flow-through	Mortality (LC50)	Seawater (15‰)	8–12	210	Morgan and Prince 1977	Acceptable quality
Northern pipefish (*Synnathus focus*)	Juvenile	96	Acute	Flow-through	Mortality (LC50)	Seawater (20‰)	17–28	**270**	Roberts et al. 1975	Acceptable quality
Naked gobi (*Gobiosoma bosci*)	Juvenile	96	Acute	Flow-through	Mortality (LC50)	Seawater (20‰)	17–28	**80**	Roberts et al. 1975	Acceptable quality
White perch (*Morone americana)*	Eggs	76	Acute	Flow-through	Mortality (LC50)	Seawater (15‰)	8–12	**270**	Morgan and Prince 1977	Acceptable quality
Striped bass (*Morone saxatilis)*	Eggs	48	Acute	Flow-through	Mortality (LC50)	Seawater (15‰)	8–12	**200**	Morgan and Prince 1977	Acceptable quality
Blueback herring (*Alosa aestivalis)*	Eggs	48	Acute	Flow-through	Mortality (LC50)	Seawater (15‰)	8–12	**240**	Morgan and Prince 1977	Acceptable quality

LC50 = median lethal concentration.

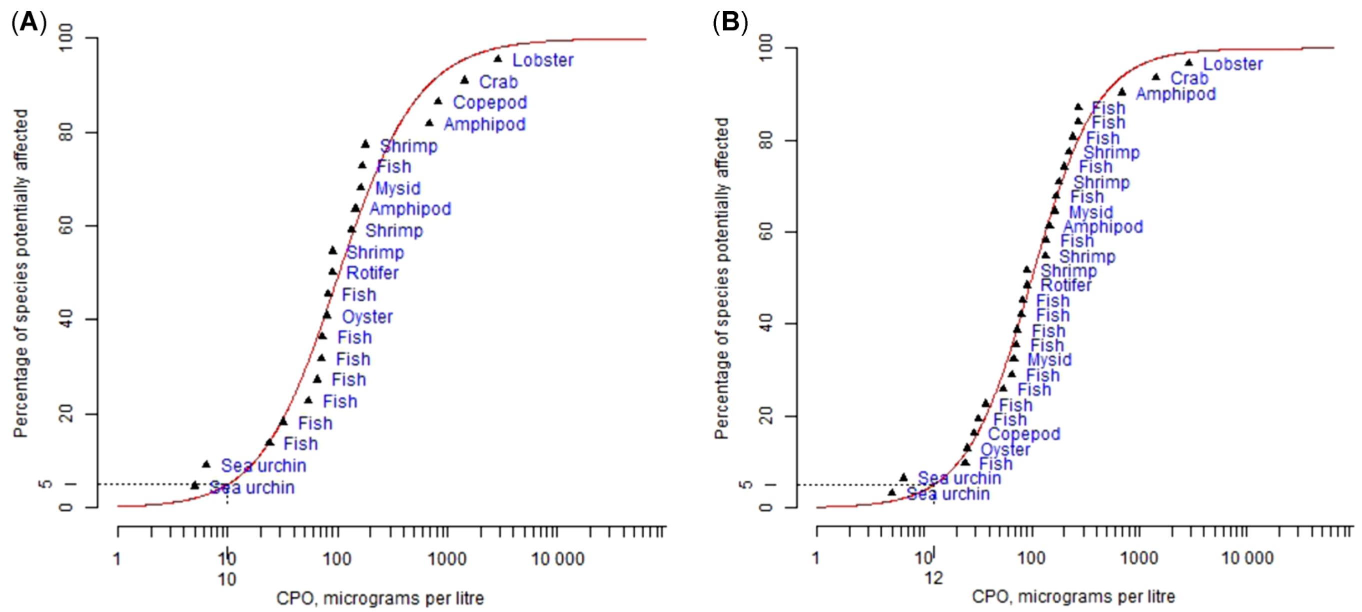

FIGURE 1: Species sensitivity distribution of selected (in bold) acute toxicity test data (flow-through plus static [15 min]). (**A**) ≥25‰ salinity data from Table 1, and (**B**) (**A**) plus <25‰ data from Table 2, showing the 95% species protection (PC95) value as an *x*-axis intercept. CPO = chlorine-produced oxidants.

(Capuzzo et al. 1976) compared with a 24-h static test LC50 of 586 µg CPO/L (Lopez-Galindo et al. 2010; Table 1).

Second, in flow-through systems, short-term exposures (0.5 h) generally show lower toxicity than 96-h exposures for the same species. The former may better reflect discharge conditions and the high reactivity of chlorine and its reaction products in seawater. For some species in flow-through tests, LC50 values decreased significantly as exposure duration increased from 24 to 96 h, as shown by Wan et al. (2000) for 2 marine amphipods, although for studies on *M. beryllina* fish embryos, Fisher et al. (1994) found little difference between 24- and 48-h LC50 values (i.e., a steep toxicity curve).

Guideline value derivation

The derivation of guideline values for CPOs in marine waters followed the procedures outlined by Warne et al. (2018) as used in Australia and New Zealand. Because of the high reactivity of chlorine, and with the lifetime of the reaction products being on the order of several hours at most, it was appropriate for management purposes to develop and apply guideline values that are protective against short-term effects. Any toxicity tests that use flow-through systems in an attempt to prolong the exposure period will result in greater effects than tests undertaken with exposure conditions that mimic the field situation, where the discharged CPOs are decreasing in concentration due both to reactions (e.g., with bromide) and to dilution caused by dispersion through wave and tidal action, and so the guideline values derived using such data will be quite conservative. For static tests, it is the renewal frequency in the context of reaction rate that is important, and hence 1- 15-min static exposures cannot be treated as analogous to 24+-h static tests.

Using only the highlighted more than 25‰ acute toxicity data from flow-through or very short-term static tests (i.e., less than 15 min) from Table 1, an SSD was plotted (Figure 1A) and used to derive guideline values. Values of 2.9, 10, and 18 µg CPO/L, respectively, were obtained for 99, 95, and 90% species protection (Table 3, column 2). If all data from non-flow-through tests were omitted, the values for 99 and 95% species protection increased

TABLE 3: Summary of short-term toxicity values derived from different data combinations (µg CPO/L, with 95% confidence limits in parentheses)

Level of protection (% of species)	All flow-through LC50 data plus 15-min static LC50 data salinity ≥25‰ ($n = 21$)	All flow-through LC50 data, plus 15-min static LC50 data, plus low salinity data ($n = 30$)	Column 3 acute LC50 data converted to LC10 values by multiplying by 0.6[a] Recommended default guideline value
99	2.9 (0.6–26)	3.7 (0.8–21)	2.2 (0.5–13)
95	10 (3.8–38)	12 (5.1–32)	7.2 (3.1–19)
90	18 (7.5–48)	21 (11–41)	13 (6.6–25)
80	33 (16–66)	37 (22–62)	22 (13–37)
Reliability	Very high	Very high	Very high

[a]See text for justification.
LC50 = median lethal concentration; LC10 = 10% lethal concentration; CPO = chlorine-produced oxidant.

to 19 and 31 µg CPO/L, respectively, largely due to the removal of the most sensitive endpoints, which were static tests using sea urchin species, although the minimum reaction time was only 15 min before each test plus 1 to 10 min during fertilization, which is a lot shorter than the other static tests.

Note that there were no data for toxicity to algae in this derivation. The European Chemicals Bureau (2002) recommend using the 72-h (or longer) algal EC50 values as equivalent to a short-term result, with the EC10 being the long-term result. The values were, however, from static tests lasting longer than 15 min, which we had decided against including because of the decay in concentration that would occur, even with 24-h renewal.

Given the small difference in salinity between the 25‰ or higher and the less than 25‰ datasets (Tables 1 and 2), the possibility of combining the datasets was considered, assuming that the lowered salinity did not result in greater toxicity. Data for 2 species were common to both sets, namely, for the oyster *Crassostrea virginica* and the copepod *Acartia tonsa*. For the oyster, Capuzzo (1979) found an LC50 of 80 µg/L after only a 30-min exposure in seawater, but in estuarine water of 20‰ salinity, Roberts and Gleeson (1978) obtained a 48-h LC50 of 26 µg/L, both in flow-through systems. Although the shorter exposure was possibly more appropriate for a chlorine discharge, for consistency with other data, the 48-h value was used in the combined data SSD.

For the copepod, the difference was more dramatic, with an LC50 of 820 µg/L after 30 min compared with 29 µg/L after 96 h in 20‰ water. The reasons for this difference were unclear. Again, in a combined dataset, the lower value was used in the combined data SSD.

A second SSD plot (Figure 1B) was obtained using the more than 25‰ data just mentioned supplemented by all the acute flow-through less than 25‰ salinity data from Table 2 (values highlighted in bold). The results are shown in column 3 of Table 3. As already noted, in this combined dataset, for the oyster *C. virginica* and the copepod *A. tonsa*, only the lower (less than 25‰) results were used. The results for the 2 datasets were effectively the same within the error of the determination.

Within a regulatory context, the application of a short-term guideline value makes sense, not necessarily one based on effects to 50% of the test population (i.e., LC50 values), but rather one based on a no or low effect (e.g., LC10), as we apply to chronic tests that use no or low effect values (Warne et al. 2018). In some instances, however, regulations have stipulated an acute LC50/EC50-based guideline value not to be exceeded in mixing zones, and in such cases the raw LC50 values would be applicable. Determining an appropriate LC10 value from the literature requires a published dose–response curve, and in almost all cases these were absent. In some instances, however, there were published LC10 or LC5 values.

Morgan and Prince (1977) reported LC values for flow-through tests on eggs and larvae of 5 estuarine fish species. Ratios of LC10/LC50 were 0.55, 0.50, 0.66, 0.53, and 0.76 (mean = 0.6). In static tests on the rotifer *B. plicatilis,* Lopez-Galindo et al. (2010) found an LC10/LC50 ratio of 0.75. Given the uncertainties in measurement of LC5 and LC10 values, as well as uncertainties in the effects of salinity and temperature, and in flow-through versus static tests, this difference is probably not that significant. Adopting an alternative and more conservative default ratio of 0.2, which is used to convert chronic EC50 values to EC10s (Warne et al. 2018), cannot be justified. Thus, for chlorine, the recommended guideline value used an LC10/LC50 factor of 0.6 applied to the combined dataset SSD (Figure 1B), as shown in Table 3. This dataset comprised results from 30 toxicity tests including 9 different taxonomic groups. There was an excellent fit of the data in the SSD such that the derived guideline values were classified as of very high reliability (Warne et al. 2018).

These guideline values for chlorine in marine waters are the first to be derived using SSDs, with all other international guideline values being based on smaller datasets and using assessment factors applied to data for the most sensitive species. Note that, owing to the large variation in bioassay durations, but limited overall toxicity data, it is not feasible to develop guideline values for specific durations that are protective of percentages of species.

It was notable that the majority of the data were derived from studies in the 1970s, 1980s, and 1990s, and although their quality was acceptable, newer data that looked more closely at the effects of exposure time, salinity, and temperature, as well as reporting both LC10 and LC50 values and showing the dose–response curves, would allow refinement of some of the existing data and construction of laboratory studies that more closely represent the field situation. Consideration should be given to deriving median time to lethality (LT50) and LT10, in which effects after a fixed time such as the lifetime of the CPOs in the field could underpin a guideline value derivation.

In applying these conservative guideline values in field situations, it would need to be demonstrated that concentrations would be reduced to below these values within an acceptable mixing zone both through dilution and dissociation.

Having decided that a short-term guideline value is the most appropriate way to manage the impacts of chlorine in marine waters, it is worth considering what the longer term impacts on biota might be. In terms of defining a chronic exposure guideline value, one option is to apply an acute-to-chronic ratio (ACR) to the guideline value based on LC50 values (column 3 in Table 3). Fisher et al. (1994) reported ACRs for continuous flow tests of 3.7 for the mysid *Mysidopsis bahia* and 1.5 for the silverside *M. beryllina*. Using the geometric mean of these values, 2.4 (multiplying an LC50-based guideline value by 0.42), yielded chronic guideline values of 1.5 and 5.0 µg CPO/L. However, these are also highly conservative, because we know that the most toxic CPOs are gone within 1 to 2 d, leaving products that are less toxic by at least 1 order of magnitude. The implication then is that compliance with the conservative short-term guideline values is likely to also be protective against chronic effects on biota downstream of any discharge.

CONCLUSIONS

A dataset of 30 species from 9 taxonomic groups was obtained by combining literature data for acute CPO toxicity in flow-through tests in ≥25‰ salinity seawater with those from more than 15 to less than 25‰ salinity flow-through tests. Included were the values from 2 very sensitive 15-min static tests with sea urchin species for tests in waters of less than 25‰ salinity. Using these values in an SSD resulted in guideline values of 2.2, 7.2, 13, and 24 µg CPO/L that were protective of 99, 95, 90, and 80% of species, respectively. Adding the less than 25‰ salinity data did not significantly affect the derived guideline values. These are the first marine guideline values for chlorine to be derived using SSDs, with all other international guideline values being based on the use of assessment factors applied to data for the most sensitive species. In applying these conservative guideline values in field situations, it would need to be demonstrated that concentrations of CPOs would be reduced to below the guideline value within an acceptable mixing zone through both dilution and dissociation.

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Data Availability Statement—All data are in the main text. Data, associated metadata, and calculation tools are available from the corresponding author (graeme.batley@csiro.au).

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GAS IMPORT JETTY AND PIPELINE PROJECT
ENVIRONMENT EFFECTS STATEMENT
INQUIRY AND ADVISORY COMMITTEE

TECHNICAL NOTE

TECHNICAL NOTE NUMBER:	TN 053
DATE:	7 December 2020
LOCATION:	Crib Point Jetty Works - FSRU
EES/MAP BOOK REFERENCE:	N/A
SUBJECT:	Response to IAC further RFI in relation to chlorine discharge from the FSRU
REQUEST:	On 1 December 2020, the IAC asked the Proponent to advise if it is technically feasible to operate the proposed FSRU, or any other FSRU, in such a way to achieve a zero chlorine discharge rate, or an absolute maximum of 0.02mg/L (20µg/L), at the point of discharge.

NOTE:

1. On 1 December 2020 the IAC posed the following question seeking a response on behalf of the Proponents:

   > *advise if it is technically feasible to operate the proposed FSRU, or any other FSRU, in such a way to achieve a zero chlorine discharge rate, or an absolute maximum of 0.02mg/L (20µg/L), at the point of discharge*.

2. This question concerns the discharge of seawater from the regasification system which is proposed to be the subject of EPR ME01A.

Is it technically feasible to operate the proposed FSRU regasification in such a way as to achieve a chlorine discharge rate of 0 mg/L, or an absolute maximum of 0.02 mg/L, at the point of discharge?

3. While it is possible to operate the FSRU to achieve a chlorine discharge of zero by avoiding electrolysis altogether, this is not practicable at all times when the FSRU is operating.

4. A reduction in chlorine discharge to 0.02mg/L is technically feasible, and has consequences for maintenance and operation including:

   a. no biofouling prevention, or very limited biofouling prevention, will require an increased maintenance and cleaning regime;

   b. inefficiency including cost, shut down and onshore waste disposal; and

   c. potential for shut down of one train co-inciding with periods of high gas demand.

Is it technically feasible to operate a different FSRU regasification system in such a way as to achieve a chlorine discharge rate of 0mg/L, or an absolute maximum of 0.02mg/L, at the point of discharge?

5. Possibly. AGL understand this question to be whether there are alternative technologies for biofouling prevention other than electrolysis. As explained in Technical Note 035[1], AGL has been working with the FSRU supplier on possible design options to reduce chlorine levels, including utilising alternative technologies. Through Hoegh LNG, the Proponents are not aware of any operating FSRU or comparable land based facility using seawater that is operated to achieve a chlorine discharge of 0mg/L.

6. Some potential alternative technologies include (limited to the question of chlorination):

   a. Ultrasonic growth prevention system: This system would require ultrasonic transmitters to be fitted to the seawater piping. The ultrasound prevents biofilm and micro-organisms from adhering to the equipment surfaces. This technology has not been tested for use in a regasification system or with large seawater volumes. As such, use of this system would require verification that installing ultrasonic transmitters on the regasification sea water heat exchanger will not impact the equipment or the performance or safety of the regasification system.

   b. Ultraviolet growth prevention system: This system uses ultraviolet (**UV**) radiation to prevent fouling of the regas systems. UV systems are large and have limited capacity to handle large volumes of water. For an FSRU using large seawater volumes, multiple UV systems would be required. Retrofitting multiple UV systems into an FSRU is complex due to space constraints.

   c. Dedicated electro-chlorination injection for the regasification system: This proposes the installation of a dedicated electro-chlorination Marine Growth Prevention System (**MGPS**) for the regasification system or relocation of the MGPS, to enable more tailored control of chlorine levels for different equipment. This would only reduce the chlorine discharge rate, not result in zero chlorine discharge.

7. The proponents understand that:

   a. The Port Kembla approval includes a residual limit of 0.02 mg/L having applied for a limit of 0.2 mg/L within one discharge point. The Port Kembla approval has not proceeded to date and is not yet subject to detailed operational requirements or approval.

   b. The Croatian FSRU approval requires no chlorine discharge. The Croatian FSRU is not operational and the available information indicates that it will rely on mechanical cleaning.

Revised EPR ME01A

8. AGL has proposed the revised EPR-ME01A in the version 3 EPRs (Document 531). EPR-ME01A contains two options, and is set out below:

   Option 1 – Varying chlorination rate at point of discharge

   Except as approved or required by the EPA, the OEMP must include requirements that seawater discharges from the regasification system must not :

[1] Document 273

a. have a chlorine residual concentration range of between 0.05mg/L and 0.1mg/L other than at Slack Tide;

b. have a chlorine residual concentration of 0mg/L during Slack Tide;

c. not exceed a tidally averaged chlorine residual concentration of 0.0022mg/L beyond a distance of 100 metres from the FSRU; and

d. not exceed a temperature variation of 7°C from ambient

Note: The time of Slack Tide is half an hour either side of high tide or low tide at Crib Point. High tide and low tide at Crib Point are to be calculated by reference to the BOM Victorian Tide Tables or other source to the satisfaction of the EPA.

Option 2 – Constant chlorination rate at point of discharge

Except as approved or required by the EPA, the OEMP must include requirements that seawater discharges from the regasification system must:

a. have a chlorine residual concentration of 0.02mg/L ;

b. not exceed a tidally averaged chlorine residual concentration of 0.0022 mg/L beyond a distance of 100 metres from the FSRU; and

c. *not exceed a temperature variation of 7°C from ambient.*

9. AGL contends for Option 1 of EPR-ME01A, on the basis that this is supported by the evidence, and has acceptable impacts for beneficial uses and the ecological character of the area. Option 1 of EPR-ME01A is a bespoke response to the particular characteristics of Crib Point and the tidal influences in Western Port Bay

10. Option 2 of the EPR-ME01A is also technically feasible. However, it will result in greater inefficiencies listed in paragraph 4 above.

11. Both Options 1 and 2 would be supported by a dedicated maintenance and management plan. A memo from the FSRU supplier, Hoegh LNG, is provided at Attachment 1 to the Technical Note, and details the additional requirements for mechanical cleaning that is required in order to ensure compliance with revised ME01A, and Option 2 in particular.

CORRESPONDENCE: N/A

ATTACHMENTS: 1 Attachment:

1. Hoegh LNG, Mechanical Cleaning of Sea Water Systems dated 4 December 2020.

ATTACHMENT 1

Hoegh LNG, Mechanical Cleaning of Sea Water Systems dated 4 December 2020.

HÖEGH LNG

Memo

Project	
AGL Gas Import Jetty Project	
Subject Mechanical Cleaning of Sea Water Systems	**Doc. No** HLNG-AGL-09093-04 Rev 02
Author HLNG / VIA, BJH	**Date** 04 Dec 2020
To [Name]	
cc [Name]	

Mechanical Cleaning of Sea Water Systems

The memo elaborates on mechanical cleaning of the sea water systems onboard the Crib Point FSRU and is prepared in a response to the proposed ERP ME01A, as requested by AGL.

This results from the ongoing Environmental Effects Statement (EES) process, which may see a changed acceptance level for residual chlorine concentrations of the Marine Growth Prevention System (MGPS) for the sea water discharges from the FSRU, either in terms of a lower accepted residual chlorine concentration than the 0.1ppm initially envisaged, or alternatively a regime where the 0.1ppm concentration level is maintained and the MGPS is switched off at slack tides. Please also see the proposed ERP ME01A.

A changed acceptance level of residual chlorine concentration in the discharged sea water may impact how well the MGPS is able to protect key elements of the onboard sea water systems on the FSRU. To mitigate this, cleaning operations of the vital parts, such as for instance the regas sea water heat exchangers will be initiated if it is observed in operation that the fouling cannot be sufficiently controlled with the changed chlorine residuals acceptance level, affecting the regas performance of the FSRU.

The Cleaning Operation

The majority of heat exchangers in seawater service are gasketed plate type units, which are designed for easy dismantling and cleaning when required. The units in the regas module are also plate type heat exchangers, although these units in contrast to the conventional plate heat exchangers in the engine room are of the semi-welded type where two and two plates are welded together to cassettes in order to minimize the risk for leaks but also to improve the robustness of the heat exchangers for managing the higher design pressures on the propane side. The cassettes can be cleaned on the outside like for a normal plate heat exchanger, but this will leave the propane loop open, meaning that if one heat exchanger in a train shall be cleaned, the entire train’s propane loop will need to be emptied and gas free. It will therefore be natural to clean all heat exchangers in one train whenever one of the units in a train shows symptoms of increasing pressure drops or deviating temperatures that could be

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Org.no: NO 989 837 877 MVA

resulting from excessive marine growth. Once the cassettes/plates have been dismantled, the plates will be subject to cleaning by pressure wash and physical scraping/removal of any remaining elements fixed to the surfaces. In relation to such cleaning the accessible associated seawater piping and valves would also be inspected and cleaned to the extent possible.

The main seawater headers are common for the regas train, and designed for the maximum installed capacity of 750 MMSCFD in open service, based on a differential seawater temperature not exceeding 7°C. The main sea water headers will be inspected on regular intervals, and cleaned if required. The headers will typically be cleaned by means of physical scraping after having drained and opened the concerned segments.

The sea water cooling systems for the engine room consumers are protected against marine growth by the MGPS as well, and will also be inspected and cleaned as required if a change in acceptance level for residual chlorine concentrations will leave these systems more exposed to fouling. The cleaning of the engine room sea water systems is further discussed in the following section.

Impact and Duration of the Cleaning Operations

The most cumbersome and time-consuming components to clean are the sea water heat exchangers in the regas module. This does not relate solely to the cleaning part, but involves the whole operation of isolating, emptying and gas freeing the individual regas train subject for cleaning, the cleaning of the three sea water heat exchangers on the train, and then the process of drying the heat exchangers, refilling propane from the onboard storage tank, and bringing the train online again. This operation is expected to take in excess of one week for each train at first, and then be reduced to a (short) week when the crew onboard the FSRU have performed the cleaning operation a few times and have familiarised themselves with the process. HLNG may also assess whether there are modifications that can be implemented on the regas trains to ease the cleaning operation and potentially shorten the duration.

While one train is being mechanically cleaned, the other two trains will be available for regas operations.

The condition of the sea water header to the regas module, and the sea water crossover between the sea chests in the engine room will be inspected, and cleaned as required. Regas sendout will be unavailable during this cleaning operation, which may be expected to take a couple of days.

The sea water cooling systems for the engine room consumers, including the engine cooling water system and the auxiliary machinery cooling water system will also be monitored and cleaned if required. The engine room cooling water systems have redundant sea water to fresh water heat exchangers in a 2 x 100% configuration, which implies that the time it takes to isolate and clean one set of heat exchangers should not impact the performance of the vessel.

Inspection and potential cleaning (to the extent possible) of the piping for the sea water cooling systems in the engine room is expected to be carried out at the same time as for the sea water header to the regas module and the engine room crossover, i.e. for the same number of days.

Waste Management and Propane Emissions

The solid marine waste from the cleaning operation, such as e.g. mud or seaweed will be collected and sent to shore for disposal at an appropriate facility.

Pressure washers are typically used for cleaning of the sea water heat exchangers, and a dialogue should be held with the Environmental Protection Authority (EPA) and other relevant regulators in Victoria to establish whether this wash water can be drained to sea, or if it will have to be collected and sent to shore for disposal. If the latter will be required from the regulators, trays will be put in place for collecting the wash water, and the scuppers in the area will be closed as well to ensure that the wash water does not drain overboard. The collected wash water can then be pumped to portable tanks and sent to shore for disposal, or pumped to the FSRU bilge holding tank if this should have sufficient spare capacity to contain the wash water. Due to the relatively large water volumes it should however be discussed with the regulators whether the “clean” wash water may be drained to sea

In this context it should also be mentioned that if any cleaning agent or detergent is being applied in the washing process, then the wash water will be collected and disposed of through a shore facility (unless the agent would be considered “green” and allowed to be flushed to sea). The same applies if CIP cleaning of the regas sea water heat exchangers is applied as a marine growth mitigating measure.

Mechanical Cleaning Risk Management

Dedicated procedures for the cleaning operations will be developed and implemented as activities in the AMOS maintenance management database. This in particular relates to the cleaning of the regas sea water heat exchangers which involves isolation of a regas train, draining, gas freeing, drying of cleaned heat exchangers and refill of propane, in addition to the cleaning itself.

Before a cleaning operation commence a Safe Job Analysis (SJA) will be carried out by the involved crew and others potentially participating in the process, such as e.g. service engineers, to ensure that the operation will be carried out in accordance with the established procedures and the governing HSE requirements on the vessel. Trays, buckets and required equipment for collecting the waste from the washing operation, such as for instance shovels and brooms will be put in place before the cleaning is started, to limit the risk of waste spills to the environment. Spill prevention will also be a dedicated item in the cleaning operations procedure.

The SJA will also cover the human risks, and for more exposed operations, such as for instance entering the sea water headers for cleaning, a more comprehensive risk assessment may be performed prior to the operation. It could also be mentioned that the components subject to the cleaning operation are of a size that allows the crew to handle them without the aid of a lifting device

Performance risks related to the cleaning operations will be addressed in the specific cleaning operation procedures, and maintenance management plans.

Frequency of Cleaning

The cleaning of the regas SW heat exchangers and the associated sea water piping and valves is condition / performance based, and will be carried out if the regas performance is degraded from fouling in the system, caused by insufficient protection by the MGPS.

The common sea water headers are (initially) expected to be inspected, and cleaned if required on an annual basis. Regas sendout will be unavailable during this operation.

When the FSRU is in operation at Crib Point, experience will be gained on the local marine climate and how the regas performance might be affected over time due to fouling. This will further aid to tailor a cleaning regime specific to the given location.

ATTACHMENT B

RELEVANT PART OF AGL'S CLOSING SUBMISSIONS

PART 2: RESPONSE TO SCOPING REQUIREMENTS BY TOPIC

115. Specific issues raised in evidence and submissions are addressed in detail below, in the same order in which the Proponents called evidence.

Marine ecology

Overview

116. The Evaluation Objectives relevant to marine biodiversity, as set out in the Scoping Requirements, are reproduced below:

> *Section 4.2: Biodiversity – To avoid, minimise or offset potential adverse effects on native flora and fauna and their habitats, especially listed threatened or migratory species and listed threatened communities.*
>
> *Section 4.3: Water and catchment values – To minimise adverse effects on water (including groundwater, waterway, wetland, estuarine, intertidal and marine) quality and movement particularly as they might affect the ecological character of the Western Port Ramsar site.*
>
> *Section 4.6: Waste management – To minimise generation of wastes by or resulting from the project during construction and operation, including accounting for direct and indirect greenhouse gas emissions.*

117. The Proponents' opening remarks in relation to marine ecology are set out in Document 269. Since making those opening remarks, the Proponents have filed various technical notes and other materials relevant to marine ecology, which are listed in Appendix A to these submissions.

118. The main potential for impacts to marine ecology arise as a consequence of the operation of the FSRU. Relevantly, the process would involve the intake into and discharge from the FSRU. When operating in either closed or open loop modes the seawater would be within the regasification system on the vessel for a period of approximately 5 minutes prior to discharge.

119. The seawater discharged from the FSRU will not contain any additional nutrients, nor will there be any change in levels of dissolved oxygen, pH, or turbidity. Instead, the seawater discharged from the FSRU will be of a lower temperature and contain residual concentrations of chlorine-produced oxidants (as a consequence of the proposed biofouling process), and will rapidly mix with waters in relatively close

vicinity of the FSRU so as to achieve parity with background conditions. In this way, it is readily apparent that the seawater discharged from the FSRU will continue to contribute to the ecological processes of Western Port, and to broader environmental values.

120. The assessment of marine ecological impacts documented in Technical Report A has been informed by a combination of detailed field monitoring and assessment coupled with sophisticated hydrodynamic modelling. This process has allowed the Proponents to accurately identify the nature and scope of potential impacts and to tailor the ecological assessment accordingly.

121. Notably, whilst the adequacy of aspects of the assessment has been called into question before the IAC, there appears to be universal acceptance amongst the expert witnesses that the hydrodynamic modelling was undertaken to a high standard. Indeed, Professor Baldock was of the view that the IAC should proceed with "a reasonably high degree of confidence concerning the outputs of the model", and that it provides a "sound basis" on which to assess the potential impacts of the Project as it may impact upon areas of particular environmental sensitivity.

122. This is important because it is not in contention that the modelling clearly demonstrates that the discharge from the FSRU will be well-removed from areas of particular environmental sensitivity, including intertidal areas and seagrass. Any potential impacts will be limited to the immediate vicinity of the FSRU within that part of Crib Point that is designated for the purposes of the Port (and that has been dredged). Furthermore, as will be addressed in further detail below, the assessment demonstrates that even within this area very high levels of environmental protection will be achieved.

123. The IAC has heard evidence from a number of witnesses concerning the potential for ecological impacts to arise. None have identified any particular impacts that should be considered unacceptable (let alone on threatened or migratory species, or on the ecological character of Western Port, as is the focus of the relevant evaluation objectives). The highest that the case has been put in opposition to the Project is that certain marine impacts remain uncertain. For the reasons that follow, the Proponents contend that the IAC has sufficient information to assess the potential environmental

effects of the Proposal, and that it should conclude that those potential environmental effects are acceptable subject to the implementation of the proposed EPRs.

124. These submissions will continue by first addressing the adequacy of the EES assessment before specifically addressing the potential impacts of the operation of the FSRU as it concerns the intake of seawater (entrainment and impingement) and the discharge of seawater (chlorine and temperature).

The Adequacy of the Assessment

125. The marine ecology impact assessment is documented in Technical Report A to the EES. It was undertaken by Mr Chidgey and Dr Wallis who are highly experienced marine ecological consultants and who possess considerable first-hand knowledge in assessing environmental processes within Western Port. It was informed by input from the CSIRO and from a large number of sub-consultants (including experts in particular plankton species and consultants with particular expertise in hydrodynamic modelling).

126. Peer reviews were undertaken in respect of the hydrodynamic modelling and in respect of the report as a whole.[78] The latter peer review was undertaken by a team of consultants at GHD with particular expertise in marine environmental assessment, hydrodynamic modelling, and underwater noise assessment.[79] The conclusions of that peer-review were that:[80]

- *The marine ecology assessment methodology is appropriate for the assessment required and the conclusions presented can be reasonably drawn from the methods used.*
- *The underwater noise assessment methodology is appropriate for the assessment required and the conclusions presented can be reasonably drawn from the methods used.*
- *The hydrodynamic modelling methodology adequately assesses the cool (from heat exchangers) and warm (from FW cooler) water discharges on the seabed habitat over a number of scenarios. In particular, the assessment sensibly identified the optimal solution for the discharge of open loop (cool water) from the FSRU as reconfiguring the design for port (west) side discharge. The*

[78] Annexures K and L to Technical Report A.

[79] Annexure I to Technical Report A at Part 1.6.

[80] *Ibid.* at Part 3.3.

methodology provides reasonable estimates of the areal extent in which the seabed criterion of ±0.5°C is exceeded (i.e. Table 6-6).

- *The modelling methodology adequately assesses the chlorine discharges on the seabed habitat over a number of scenarios. The methodology provides reasonable estimates of the areal extent in which the seabed criterion of 6 μg/L is exceeded (i.e. Table 6-7).*
- *The modelling methodology adequately assesses the entrainment predictions of planktonic organisms in the water column into the FSRU sea chest over a number of scenarios with the caveat of further clarification of withdrawal envelope volumes provided in Table 6-8 (see below). The methodology appears to provide reasonable estimates of the expected percentage of entrainment of planktonic organisms within North Arm (i.e. Table 6-10).*

127. Dr Blount and Dr Lincoln Smith, who had participated in the TRG process[81] but who do not possess any particular expertise in environmental assessment within Western Port, nevertheless contend that further assessment was required. They were critical of the scope of the assessment and the definition of existing ecological values within Western Port. Detailed responses to the various assertions are contained within the reply statement prepared by Mr Chidgey.[82]

128. It is relevant to note, for present purposes, that the assessment completed by Dr Blount and Dr Lincoln Smith focused on the adequacy of information within the EES rather than on the acceptability of the modelled impacts. To this end, both confirmed in cross-examination that they had not identified any particular significant or unacceptable impact at Crib Point, or within the Ramsar area more broadly.

129. Both experts also confirmed that they considered the hydrodynamic modelling to be comprehensive, that it identified the areas of potential effects from FSRU discharges, and that beyond this area, assuming the modelling was correct, it was appropriate to proceed on the basis that impact had been avoided.[83]

[81] The prior participation of Dr Blount and Dr Lincoln Smith in the TRG process is relevant because their criticisms, by admission, were focused on information and process gaps (as opposed to conclusions about unacceptability of impacts or disagreement with modelled impacts). Given the room for professional judgement in these respects, it is relevant that throughout the TRG process and in the various subsequent peer-review, the adequacy of information was assessed independently of the project team.

[82] Document 164.

[83] Hearing recording, 11 November 2020 at 1:19:20 (as part of series of questions on modelling 1:11 and 1:23): https://youtu.be/j5874RdyhyY?t=4760.

130. Professor Baldock specifically commented on the adequacy of the modelling, concurring in cross-examination that:[84]

(a) the near-field and far-field modelling was appropriate and robust;

(b) the modelling had been "well-used and verified" for the applicable tidal environments";

(c) the IAC can proceed with "a reasonably high degree of confidence concerning the outputs of the model";

(d) in the context of the modelling undertaken in respect of discharge from the FSRU, the modelling provides a "sound basis" upon which to:

(i) assess potential impacts concerning proximity of discharge to areas of particular environmental sensitivity; and

(ii) calculate the extent of discharge at seabed relative to the applicable guideline values.

131. Professor Baldock's views in this respect are consistent with those expressed by the independent peer reviewer.[85]

132. This evidence is significant given the specific terms of the Scoping Directions (addressed in Part 1 above). It supports the approach that was taken, wherein the impact assessment was focused on identified impacts *within* the area of impact, as opposed to more generalized studies of ecological values outside of that area (and in respect of which the hydrodynamic and environmental analysis satisfactorily demonstrates there is little realistic potential for impact).

133. For Dr Edmunds, this Project was seemingly another opportunity to pursue his opinion that environmental impact assessment is not undertaken correctly within Victoria. It is not the first time he has articulated these views. He did so, for instance, in the critique he authored for the VNPA of the draft Scoping Requirements. The

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[84] Oral evidence of Professor Baldock, 25 November 2020 at 42:20 – 45.32: https://youtu.be/Qux3tZfCDDw?t=5845.

[85] Annexure K.

Scoping Requirements were nonetheless issued by the Planning Minister and serve to define the nature of the environmental assessment that is to be undertaken within the EES. Dr Edmunds also expressed his views in his submissions to the Parliamentary Enquiry into the EES process.

134. Dr Edmunds continued his attack on the process in his written and oral evidence to the IAC. The following extract is from Dr Edmunds' oral evidence, in which he was asked to respond to the nature of his attack on the EES despite the Scoping Requirements, the approval of the EES by the TRG, and the approval by the Department:[86]

> *There are these systemic issues with how we manage the environment, marine environment in Victoria. It is not surprising that it has gone through such a phase, and still has these major issues. There are drivers that prevent people, there is no scope for people to speak out, it is detrimental for people to speak out. There are all these drivers for people to follow the line – don't tell the emperor, they are not, he isn't wearing any clothes.*
>
> *There is a lot of issues that should be addressed systemically, and I suggest that, how did we get to this point is a major issue and that should be addressed as well.*
>
> *I addressed some of these points in my submission to the parliamentary inquiry into the EES many years ago. This is not new.*

135. While Dr Edmunds may have significant expertise as an ecologist, his approach to the practice of environmental impact assessment is not based on significant experience in preparing EES assessments, does not accord with Victorian practice, and is inconsistent with the terms of the governing Scoping Requirements for this EES. His views also discount the very substantial amount of work that was undertaken in the preparation of EES and its testing and refinement throughout the TRG process and subsequent departmental approval.

136. A central component of Dr Edmunds' evidence was his contention that a more comprehensive ecological model was required in order to properly assess the impacts of the Project. Mr Lane, responding to this assertion in the context of terrestrial

[86] 24 November 2020, recording at 1:37.24 – 1:38:13.

ecology, succinctly explained why a model of this type was not feasible (or required) in this instance:

> *Modelling a complex ecological system inevitably involves assumptions where knowledge is incomplete (as it inevitably always is) and variance around estimates of known parameters that compound one another. Predictive ecological modelling is therefore not usually feasible in the context of an individual project EES. Regional studies by government can attempt such exercises to provide a context for environmental decision-makers. In the absence of a validated model, impact assessment based on spatial and temporal duration of impacts and studies of the responses of individual ecological components (e.g. benthic communities, waterbirds) is still very informative.* [87]

137. Similarly, by reference to the Scoping Requirements, Mr Lane correctly identified that:

> *At no point does it require ecological modelling or a highly reductionist approach to impact assessment. It requires a focus on the highest ecological values and many specific impact pathways. This is consistent with practice for Victorian EESs.*[88]

138. The distinction between broad scale ecological modelling as advocated for by Dr Edmunds, and the more targeted spatial and temporal modelling undertaken within the EES, lies at the heart of the difference in opinion between the witnesses. The matter is readily resolved in this case by reference to the terms of the Scoping Requirements.

139. For the reasons stated earlier, and consistent with the peer review conducted by GHD, the IAC should be satisfied that Technical Report A responds positively to the Scoping Requirements and provides a proper basis upon which to assess the potential effects of the Project on the marine environment.

<u>The Intake of Seawater</u>

Entrainment

140. The EES assessed the risk of entrainment of plankton and other small marine organisms by reference to numerous groups of Western Port habitats and species groups. This included the assessment of risks of entrainment from mangroves and

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[87] Document 210, p 7.

[88] Document 210, p 8.

saltmarsh, intertidal mudflat and invertebrate communities, intertidal and subtidal seagrasses, benthic subtidal invertebrate fauna, pelagic and demersal fish, plankton, Ramsar areas and protected species.[89]

141. The characteristics of the planktonic community in Western Port were sampled to inform the impact assessment. Those sampling programs, which specifically concerned phytoplankton, zooplankton (planktonic invertebrates) and ichthyoplankton (fish larvae) within North Arm, were led by Mr Chidgey over the course of 13 months and are documented within Annexures B – D of Technical Report A. They are by *far* the most detailed studies of planktonic communities ever undertaken within North Arm and constitute the best available evidence as to species population and distribution. Descriptions of the plankton survey results were provided by independent specialist phytoplankton ecologists, zooplankton ecologists and fish biologists/ecologists, who contributed to the design of the studies and provided specialist reports that explain the variations based on the results of the surveys reported in the EES.

142. Whilst the Proponents recognize that the composition and dynamics of the relevant planktonic communities may vary over time and between different seasons and different years, the IAC should be satisfied that the sampling programs undertaken provide an adequate record of existing conditions to describe and inform the potential environmental impacts. Those programs respond directly to the Scoping Requirements (which direct the Proponents to identify "potential impacts associated with … effects on plankton and larvae production") and do so in a manner that is far more sophisticated than the approach historically adopted by the EPA within Western Port (wherein chlorophyll-a measurements are adopted as a proxy for phytoplankton biomass within Western Port).[90]

143. It would be unreasonable to require the Proponents to have undertaken more lengthy sampling programs prior to completing the EES or for those sampling programs to have been undertaken on a regional scale (as was seemingly proposed by Dr Lincoln Smith). The sampling programs were instead properly focused on planktonic

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[89] See, in particular, Technical Report A at Part 7.6.

[90] See, for instance, Annexure B at page 37.

communities within North Arm and were undertaken over the course of 13 month so that an understanding of seasonal variation could be obtained.

144. In his witness presentation, Dr Lincoln Smith expressed the view that there was insufficient replication to support the conclusions expressed within the EES concerning seasonal variation. To this end, Dr Lincoln Smith presented a slide showing *aggregate* monthly zooplankton counts, as a means of demonstrating a high variability in monthly abundance.[91] In doing so, no mention was made of the 26 plots of individual species' spatial, monthly and seasonal raw and statistical summary abundances in the EES. This information, as documented in Section 5.8.4 of Technical Report A, shows that the abundance of certain species have "boom and bust" characteristics. These characteristics are well-understood and are consistent with the analysis recorded within the EES. Dr Lincoln Smith's approach is too coarse, such that it overstates the apparent variability in the zooplankton community.

145. The utilization of the comprehensive hydrodynamic model predictions to inform the assessment of entrainment should be considered best practice. This is because, unlike less sophisticated methods of calculating entrainment rates, the hydrodynamic model allows an accurate assessment to be undertaken in respect of the impacts of entrainment on *different* areas within Western Port. This is important given the different ecological values within Western Port and their varying sensitivity.

146. The report prepared by Dr Wallis in response to the evidence of Professor Baldock contains a useful summary of the methodology and results of the entrainment modelling undertaken in respect of the Project.[92] Critically, the particle analysis tracked the dispersion of particles released within the *entirety* of Western Port, in 20 second increments over 28 days (being a full lunar cycle of two neap and two spring tides). By dividing Western Port into different zones, the model allows for a prediction of the rate of entrainment of plankton communities originating in different parts of Western Port, as well as an understanding of how the rates of entrainment on plankton communities originating in particular locations compares to natural dispersion rates throughout the Bay. The method has been utilized in other studies of

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[91] Document 403, slide 8.

[92] Document 540.

entrainment[93] and was identified as being necessary to understand the spatial distribution of entrainment impacts in the literature cited by Professor Baldock.[94]

147. Professor Baldock identified his "main concern" about the modelling undertaken to inform the EES as being "the reduction in the number of particles in zone 2 over time".[95] However, Professor Baldock's comments in this respect, mischaracterize the modelling exercise that was undertaken. This is because, whilst it is the case that the model does predict that particles *originating* in zone 2 (which is in close proximity to the FSRU) would over time be further dispersed within Western Port and Bass Strait, it also predicts that those particles *would in each case be replaced by other particles* entering from other zones.

148. The initial reduction in the rate of entrainment identified by Professor Baldock arises as a consequence of the initial distribution of particles in close proximity to the FSRU. As the modelling shows, as those particles are mixed with other particles entering the area (so that a constant concentration is established within the relevant zone), the rates of entrainment approach equilibrium.

149. It is important, in assessing the actual impact of the Project on particular subsets of the plankton communities, to have regard to the life cycles of different types of plankton. Whereas phytoplankton have a lifecycle of 7 days (or less), zooplankton and ichthyoplankton generally have lifecycles of 21 days (of less). This being the case, the modelling relevantly demonstrates that:

(a) Over the course of the lifespan of phytoplankton (7 days):[96]

(i) 0.11% of phytoplankton originating in North Arm would be entrained, as opposed to 18% being flushed to Bass Strait;

(ii) 0.07% of phytoplankton originating in Western Port would be entrained, as opposed to 14% being flushed to Bass Strait;

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[93] Document 450 at [31].

[94] *Ibid.* at [98] – [99].

[95] Document 521 at [4].

[96] Document 540 at p 5.

(b) Over the course of the lifespan of zooplankton and ichthyoplankton (21 days):[97]

(i) 0.28% of zooplankton and ichthyoplankton originating in North Arm would be entrained, as opposed to 25% being flushed to Bass Strait;

(ii) 0.20% of zooplankton and ichthyoplankton originating in Western Port would be entrained, as opposed to 28% flushed to Bass Strait.

150. These entrainment rates can be considered insignificant, particularly given the rates of daily predation, and the extent to which the various planktonic communities will be replenished over these 7 and 21 day periods.

151. Three further matters should be noted in respect of the modelled rates of entrainment:

(a) First, much of the assessment assumes that the FSRU will operate at *maximum capacity* throughout the relevant period. When the FSRU is operated with one train, the rate of entrainment would be in the order of 1/3 of those modelled (that is, when regasification occurs at rates of below 250 mmscf/day). When the FSRU is operated with two trains, the rate would be in the order of 2/3 of those modelled (that is, when regasification occurs at rates of between 251 – 500 mmscf/day). As Technical Note 33 demonstrates, the FSRU will predominantly operate at these lower rates of intensity, such that the actual levels of entrainment will likely be markedly below than those modelled in the EES.[98] EPR ME02 operates to limit rates of seawater intake (and consequently regasification) between August and February when the prevalence of ichthyoplankton and other biota is greatest.

(b) Second, the assessment assumes that all organisms that are entrained with the FSRU are killed. However, as recognised by GHD in its peer review, this assumption should be considered "conservative" given that "some [of those organisms] will survive entrainment".[99] Dr Wallis estimated that in the order of 40-50% of entrained organisms will survive (such that the rates of impact

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[97] Document 540 at p 6.

[98] Document 270.

[99] Annexure L at Part 2.2.2.

will again be markedly below those modelled). This level would likely increase in the event that the measures specified in EPR ME01A were to be implemented.

(c) Third, even having regard to those plankton that would be lost, there would be no reduction in organic carbon or nutrients due to entrainment (given that the organic carbon and nutrients would remain in North Arm and be cycled by bacteria and infauna). That is to say, the ecological character of the cycle would remain unchanged.

152. Professor Baldock identified two alternate methods to check entrainment rates attributable to the FSRU.[100] The Proponents rely on Dr Wallis' response to these methods, and note that when allowances are made for the replacement of water within North Arm over the relevant periods of time, the alternate methods are corroborative of the more sophisticated methodology adopted in the EES.

153. Dr Blount and Dr Lincoln Smith criticized the modelling undertaken within the EES on the basis that it assumed that particles (and by proxy organisms) were evenly distributed within the water column. The field data summarized in Technical Report A support this as being a reasonable assumption.[101] Further, as Dr Wallis explained, the organisms were assumed to be neutrally buoyant on account of the small particle size and the strength of the currents in this part of Western Port. Professor Baldock agreed that this was an appropriate assumption to adopt for the purposes of the modelling given the prevailing conditions within this part of North Arm.

154. Accordingly, for the reasons set out above, the Proponents contend that the IAC should conclude that the impact assessment documented within the EES is sound, and that the modelled impacts are properly characterized as low.

Impingement

155. Impingement occurs when an aquatic organism is killed upon being pressed against an intake screen. Technical Report A deals comprehensively with impingement at

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[100] Document 540.

[101] See, for example, Figure 5-69 in Technical Report A (p 140) for phytoplankton.

section 7.5.1. EPR-ME01 sets out mitigation measures based directly on this analysis and requires that the intake of the FSRU be designed in consultation with EPA. The prescribed mitigation measures involve the installation of a screen, that the intake of seawater be horizontal, and that a limit be placed on intake velocity.

156. This latter measure, which has been prescribed at 0.15 m/s, will allow larger fish and other biota to swim away from the intake and therefore avoid impingement or entrainment. As set out in the Technical Report, this measure has been the subject of significant study, and has been endorsed in comprehensive guidance published by the USA EPA.[102]

157. The impingement controls proposed are well-understood and the IAC can confidently proceed on the basis that they will be effective and that impacts from impingement will be minimal and within the range of acceptability.

158. The prospect of impingement in this case is less than that associated with the Victorian desalination plant (given the relative volumes of water and rates of intake associated with the two facilities). The practical experience of that facility, which is regularly inspected for marine impingement, supports the analysis recorded within the EES.

<u>The Discharge of Seawater</u>

Chlorine – Potential Acute Impacts

159. Detailed Project-specific investigations have been undertaken in respect of the potential impacts of chlorine produced oxidants (CPOs) that would be contained within the seawater discharged from the FSRU.

160. Dr Batley of the CSIRO was engaged to formulate guideline values in respect of the Project as a means of measuring the nature and extent of potential impacts. Dr Batley, whose report is Annexure A to Technical Report A, determined that:

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[102] See discussion in Technical Report A and eg US EPA, 2014, National Pollutant Discharge Elimination System-Final Regulations To Establish Requirements for Cooling Water Intake Structures at Existing Facilities and Amend Requirements at Phase I Facilities.

(a) time-averaged short-term guideline values should apply in respect of CPO concentrations within marine environments (given the chemical properties of CPOs);

(b) different time-averaged short-term guideline values should apply in circumstances where CPO concentrations are consistent over time as opposed to circumstances where they are "intermittent or variable over time such as North Arm of Western Port";[103] and

(c) in the latter context, time-averaged short-term guideline values of 6.0 ug/L should be applied at the edge of the mixing zone to achieve 99% species protection.[104]

161. These values were derived by reference to various toxicology studies and were characterized by Dr Batley as being of "very high reliability".[105] Dr Batley subsequently advised Dr Wallis that the guideline value should be time averaged over a 24 hour period.[106]

162. Dr Batley's subsequent paper titled "Short-Term Guideline Values for Chlorine in Marine Waters"[107] identifies a *default* time-averaged short-term guideline value of 2.2 ug/L for adoption within the ANZEC Guidelines. That paper was not specifically directed to this Project and makes no allowance for the impact of tidal conditions within North Arm.

163. Notwithstanding that CSIRO elected not to participate directly in the hearing process, correspondence between Dr Batley and Professor Cook concerning the derivation of guideline values for the Project, was introduced without notice during the cross-

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[103] CSIRO Report at 4.1.

[104] *Ibid.*

[105] *Ibid* at iv.

[106] Document 395 at p 5.

[107] Document 273 (paper is attached to Technical Note 035).

examination of Dr Wallis and Mr Chidgey.[108] Dr Batley's position in this respect was clarified in further correspondence to Dr Wallis.[109]

164. The IAC subsequently heard evidence from Professor Cook concerning the application of an appropriate guideline value to the Project. Professor Cook's evidence in this respect was that the more stringent guideline value of 2.2ug/L should be applied at the edge of any mixing zone. He agreed that this guideline value should be tidally-averaged (that is, over the course of one tidal cycle), and that compliance with this guideline value would result in 99% species protection.[110] He also agreed that, using this guideline, it would not be necessary to include additional monitoring for acute effects for seabed biota.

165. As described above, detailed hydrodynamic modelling was undertaken in respect of seawater discharge from the FSRU, as a means of assessing the potential impact of CPOs on the marine environment. That modelling is described in Technical Report A and in the Hydrodynamic Modelling Report.[111] It was undertaken in respect of a variety of operational scenarios (including in respect of open and closed loop modes of operation, different rates of regasification, and scenarios with and without an adjacent LNG carrier).

166. The modelling was undertaken on the basis that the concentration of chlorine within the seawater at the point of discharge would be 100 ug/L. It was conservative in that it did not assume *any* decay in chlorine over time (notwithstanding that studies have shown decay at a rate of 66% over a 1-minute period in seawater at 15 degrees celsius).[112] The modelled reduction in chlorine concentrations as documented in Technical Report A was instead a function of discharge velocity from the designated discharge ports and the effect of tidal currents.

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[108] Document 280.

[109] Document 395, final page.

[110] Professor Cook's evidence, Day 23 of the Hearing (23 November 2020) at 3:03:40 and from 3:25:20 – 3:29:18.

[111] Annexure H to Technical Report A.

[112] Technical Report A at p 263.

167. The modelling shows that, when operating in open loop mode without an adjacent LNG carrier, tidally averaged chlorine concentrations at the seabed would be *below* the default guideline value of 2.2 ug/L *at all locations*.[113] That is to say, whilst the chlorine concentration at the seabed would vary throughout the tidal cycle, the tidally-averaged concentration at all locations on the seabed would be *below* that identified as achieving 99th percentile species protection.

168. This outcome is significant in the context of the impact assessment. The potential impacts of the Project on benthic biota in the immediate vicinity of the FSRU was the focus of much of the evidence on this topic. It is apparent, however, that the proper conclusion to be reached in this respect, is that the operation of the FSRU (even when operating at peak capacity and with chlorinated discharge at 100 ug/L) would have *no material impact* on this element of the environment.

169. Furthermore, given the limited prospect of marine organisms encountering the plume of seawater discharged from the FSRU for anything other than very limited periods of time, it is seemingly common ground that the modelled CPO concentrations in this respect would pose little risk to the environment.

170. More generally, but equally significantly, the modelling demonstrates that discharge from the FSRU will be well-removed from more sensitive and ecologically significant environmental features (such as areas of seagrass or intertidal zones), such that there is a sound basis to conclude that it would not have any material adverse impact on these components of the environment.

171. These matters notwithstanding, the Proponents have consistently recognized their obligation to minimize any area of impact to the extent practicable, and to implement measures to this effect pursuant to the OEMP.

172. To this end, as documented within Technical Note 15,[114] the Proponents have proceeded on the basis that:

(a) the EES models scenarios to inform the assessment of environmental impacts;

[113] Document 395 at p 9.

[114] Document 143.

(b) the actual operation of the FSRU will be consistent with a minimised area of impact, regardless of the assessment of acceptability of impacts of any larger area;

(c) the OEMP would be prepared on the basis that the impacts of the FSRU must be contained within the minimised area of impact identified for the purpose of the OEMP or any Works Approval; and

(d) if the FSRU is operated while an adjacent LNG Carrier is moored, it would be necessary to innovate the operations, or the design, to achieve this.

173. Dr Wallis gave evidence concerning different means by which this outcome could be achieved (including by the reconfiguration of discharge ports to allow one train of the FSRU to operate whilst a LNG carrier is adjacent to it).[115] Other proposed operational parameters are specified in the memorandum attached to Technical Note 15.[116]

174. At the request of the IAC, further investigations have been undertaken in respect of the capacity to reduce the concentration of CPO within seawater discharged from the FSRU. The Proponents detailed response to those queries is set out in Technical Note 53.[117]

175. In short, it is the Proponents' position that:

(a) Whilst it may be theoretically possible to operate the FSRU to achieve a chlorine discharge of zero (or equally a very low concentration of 0.002 mg/L) by avoiding electrolysis altogether, this approach is not proven and is not practicable at all times when the FSRU is operating;

(b) A reduction in chlorine discharge to 0.02mg/L (as specified, subject to conditions, in respect of the approved Port Kembla facility) is technically feasible, [118] but has consequences for maintenance and operation including:

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[115] See, for instance, Document 70 at Part 10.

[116] Attachment 1 to Document 143.

[117] Document 535.

[118] As that term is described in paragraph 177.

(i) inadequate control of biofouling prevention, requiring an increased maintenance and cleaning regime;

(ii) inefficiency including cost, shut down and onshore waste disposal; and

(iii) potential for one train to be shut down at periods of high gas demand; and

(c) An alternative (and in the Proponents' submission both environmentally and operationally superior) regime could be implemented whereby chlorine discharge would be eliminated at and around slack tide (at which time there is greatest scope for the pancake to form at the seabed), and where varying rates (not exceeding 0.1 mg/L) could be implemented at other points in the tidal cycle.

176. It should be noted that the implementation of either of the regimes identified in paragraphs (b) and (c) above, and as proposed pursuant to EPR ME01A, would result in considerably lesser concentrations of CPO at all locations (and under all scenarios) than were modelled in the EES. The option whereby chlorine discharge is eliminated at and around slack tide is considered superior to the constant chlorination option given the extent to which tidal currents influence dispersion. This notwithstanding, either option demonstrates the Proponents' willingness to implement measures to minimise potential impacts beyond objective tests of acceptability.

177. Appendix B to these submissions contains a table summarizing the Proponents position in respect of the potential to reduce chlorination at the point of discharge. In describing potential outcomes as "technically feasible" the Proponents adopt the language of the IAC. The Proponents understand that term to refer to whether it is technically possible to operate the FSRU at a particular discharge rate, as opposed to whether doing so would:

(a) be practicable (in the sense that it would be capable of being implemented or put into practice in the context of the operation of the FSRU within Crib Point);

(b) constitute best practice (in the sense of those outcomes having been achieved in practice in respect of seawater discharge from operating FSRUs); or

(c) result in proportionate or materially better environmental outcomes

178. Bearing these matters in mind, the Proponents' position as it concerns CPO concentrations at point of discharge, are as specified in EPR ME01A. That said, the Proponents recognize that lower levels of chlorination than those specified in that EPR may properly constitute aspirational targets that may be capable of being implemented in the event of technological advances or upon the particular requirements of biofouling being better understood upon the commencement of operation within North Arm.

Chlorine – Potential Chronic Impacts

179. Professor Cook, in giving evidence before the IAC, accepted that the majority of CPOs were short-lived and that they posed no risk of chronic exposure. He did, however, identify a "possible chronic exposure pathway" associated with the accumulation of Tribromophenol (or other related molecules) within sediment. He made clear that this constituted a possibility only and that he did not consider it to be a likely outcome of the Project.

180. Professor Cook's views in this respect were not supported by literature. Instead, contrary to the views expressed by Professor Cook, the CSIRO Report dismissed the application of chronic guideline values to the Project having regard to the chemical properties of CPOs and their reactivity (favoring instead the formulation of short-term values as described above).[119]

181. It is important to recognize, also, that Professor Cook's opinions in this respect were premised upon calculations set out within his presentation to the IAC.[120] As part of those calculations, Professor Cook assumed an organic matter content of 5%, which substantially overstates the organic content measured within sediments at Crib Point. This assumption was material to Professor Cook's analysis.

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[119] See, for instance, executive summary at p iv and commentary within Part 3.3 at p 10.

[120] Document 462, slides 10 and 11.

182. In fact, sediments at Berth 1 and 2 at Crib Point Jetty were analysed for particle size, organic carbon content and potential contaminants as part of the EES studies. Results provided in Technical Report E, Appendix A-B, Table B13 “Marine Sediment Analytical Results”, show that sediments are “sands” with a relatively low organic content.

183. The EES study results show, more particularly, that the median total organic carbon content of the 21 sediment samples collected at Berths 1 and 2 was 2,280 mg/kg, or 2,280 parts per million. The latter converts to 0.228 parts per hundred organic carbon (0.23 %), which is approximately *22 times lower* than the 5% estimated by Prof Cook.

184. Adopting the formula utilized by Professor Cook, the amount of TBP in the sediments under constant long-term exposure to the plume at an average of 6 µg/L (which would itself substantially exceed the time averaged levels modelled) would be 0.0016 µg/kg (or 0.0016 parts per billion). This level is *substantially* below the lowest level at which observable effects have been detected in respect of exposure to TBP[121] such that the risk posed by the ‘possible chronic exposure pathway’ identified by Professor Cook can be considered negligible.

Temperature Variation

185. Consistent with the relatively limited potential for adverse impacts to arise, the temperature differential of seawater discharged from the FSRU has received considerably lesser attention during the course of this hearing, than have the issues associated with chlorine.

186. The scope for any impacts to arise is substantially ameliorated by those operational and design measures proposed in respect of the modelled impacts associated with the presence of an adjacent LNG carrier. Indeed, in the absence of an LNG carrier, the modelled temperature differential is limited to the area of the pancake of cooler water that would form at and around slack tide (and that would be in the order of 0.5 – 1.0 degrees below ambient levels). These levels are not tidally-averaged and constitute short-term worst-case outcomes.

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[121] Professor Cook’s evidence, Day 23 of the Hearing (23 November 2020), at 3:05:25 – 3:18:26; with reference to Table 3 in Document 164 (Mr Chidgey Evidence in Reply).

187. That order of change, which would be present for less than an hour during the course of any given tidal cycle, is well within the range of natural variation (which can be in the order of 2 degrees for waters within this location over the course of any given day) and would not be expected to result in any material environmental impact. This appears to be a matter of common ground between the expert witnesses that have appeared before the IAC.

Other Potential Impacts

188. The Proponents rely on the evidence of Dr Wallis and Mr Chidgey in respect of the range of other matters raised in respect of potential impacts on marine ecology. Detailed written responses to many of these issues are contained within the reply statements prepared by Dr Wallis and Mr Chidgey[122] and further relevant information is contained within the Proponents' responses to the IAC's RFI.

189. These relevantly include responses prepared in respect of:

(a) the potential for tug movements associated with the berthing of LNG carriers to result in scouring of the seabed;

(b) the potential for cetacean strikes to occur as a consequence of increased shipping numbers; and

(c) the potential for impacts to arise in respect of local penguin populations;

(d) the potential impacts on jetty biota;

(e) the adequacy of the proposed monitoring program.

190. The first of these matters attracted a disproportionate amount of attention during the course of the hearing. Impacts arising from the use of tugs are in many respects impacts of shipping and of the port, not of the Project. This issue has nevertheless been addressed in the EES and subsequently by Dr Wallis.

[122] Documents 163 and 164 respectively.

191. Dr Wallis calculated the amount of sediment resuspended by tugs at 0.01% of the amount of sediment naturally resuspended within Western Port by tidal currents and waves.[123]

192. In oral evidence, Dr Wallis confirmed that while he had not modelled where the sediment would settle, he had considered it and was confident that it would all settle within the Port. Dr Wallis' evidence was that the fact that 25 years of operations at berth 1 had not resulted in movement of contaminated sediments from berth 1 to berth 2 suggested that sediments resuspended by tugs settle locally.

193. While queries were raised about specific tug movements for berth 1 and berth 2, and the need for more or larger tugs for LNG carriers, no cogent basis was identified that would suggest that there was any reasonable likelihood of problematic levels of sediment resuspension or redistribution of contaminated sediments.

194. To the contrary, Dr Wallis' evidence supports the conclusion that these impacts will be negligible; their quantum will be small and their extent will limited to the Port area.

195. The potential impacts of the Project on penguin colonies was also raised in a number of submissions. It is common ground that the penguin colony at Barralier Island, which is not generally publicized, was not discussed in the EES. Mr Chidgey provided a comprehensive discussion of the Barralier Island colony in his reply statement in response to an IAC question.[124] Technical Report A and Mr Chidgey's reply evidence and oral evidence were consistent in saying that few penguins had been seen or heard swimming or feeding in the North Arm channel. Mr Chidgey also confirmed in oral evidence that penguins are noisy, that he had spent 30-40 days in the Crib Point area preparing the EES, and that he would have expected to detect their presence were they to have been in the vicinity.

196. Even if there are occasions where penguins are present in or around Crib Point, there is no basis to conclude that they would suffer adverse impacts. The risk of

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[123] Expert witness statement of Dr Wallis, Document 70, p 16. See also reply statement of Dr Wallis, Document 163, p 4.

[124] Document 164, p 26.

impingement is addressed by the measures to be implemented pursuant to the EPRs, the levels of chlorine are low and below relevant thresholds, and the underwater noise generated by the FSRU is not anticipated to materially impact upon the colony.[125]

197. Finally, Drs Blount and Lincoln Smith (along with the MPSC) expressed concern about impacts on jetty biota. Technical Report A and Mr Chidgey's reply statement address this matter. The starting point, as Mr Chidgey observed, is that "Crib Point Jetty may act as an artificial reef, but its primary role is as a functional port facility".[126] As the IAC witnessed on the site inspection, cleaning of biota from jetties within ports is a normal part of operations. MPSC queried the legal basis for such activities, but it is self-evident that these activities comprise maintenance, and that jetties require maintenance as part of the operations of a port.[127] Furthermore, notwithstanding that biota may be present at and around the jetty, there is no proper basis to conclude that the operation of the FSRU would give rise to any material impact.

Findings and recommendations

198. In light of the above, the IAC should conclude that:

(a) The marine ecology assessment methodology was appropriate for the assessment required and the conclusions presented can be reasonably drawn from the methodology adopted;

(b) The predicted rate of entrainment is small relative to natural mortality and dispersion loss to Bass Straight and would be unlikely to have any material effect on ecosystem values;

(c) Subject to the implementation of the design and operating measures proposed by the Proponents, the extent of potential chlorine and temperature effects would be minimised, such that they would:

[125] See, in particular, the attachment to Document 318 at Part 3.3.

[126] Reply statement of Mr Chidgey, Document 164, p 13.

[127] These activities are accordingly protected as elements of an existing use and are protected under both the Planning Scheme (cl 63) and the EPBC Act (ss 43A or 43B).

(i) exceed objective tests of acceptability;

(ii) not result in any material impacts on significant ecological values or in adverse impacts on beneficial uses.

(d) The modelled impacts fall comfortably within the limits of acceptable change formulated in respect of Western Port (by virtue of its Ramsar status) and would not adversely affect any matters of national environmental significance;

(e) Other risks associated with increased shipping movements, or with related port-activities, are relatively minor in scope and effect and would not materially alter existing risk profiles.

Terrestrial and freshwater ecology

<u>Overview</u>

199. The Evaluation Objective relevant to terrestrial and freshwater ecology, as set out at sections 4.2 and 4.3 of the Scoping Requirements, is reproduced below:

> *Biodiversity - To avoid, minimise or offset potential adverse effects on native flora and fauna and their habitats, especially listed threatened or migratory species and listed threatened communities.*
>
> *Water and catchment values – To minimise adverse effects on water (including groundwater, waterway, wetland, estuarine, intertidal and marine) quality and movement particularly as they might affect the ecological character of the Western Port Ramsar site.*

200. The Proponents rely on their opening remarks as a record of their position in respect of the issues raised concerning terrestrial and freshwater impacts associated with the Project, and as a record of documents filed before the IAC relevant to this topic at that date.[128]

201. Since the opening remarks were tabled:

(a) the following document referred to in the opening remarks, was given a document number: Technical Note 046: Response to IAC RFI 41-43:[129]

[128] Document 326.

[129] Document 328.

APPENDIX B: SUMMARY TABLE – CHLORINE REDUCTION

CRIB POINT IAC
GAS IMPORT JETTY AND PIPELINE PROJECT

SUMMARY OF CHLORINE DISCHARGE SCENARIOS FOR REGASIFICATION PROCESS

No.	Residual chlorine at discharge points	Technically feasible?	CSIRO 99% species protection at seabed	CSIRO 99% species protection at boundary of plume	Scoping requirement - minimised impact area	EPBC Act - Protects MNES	Terms of reference - Acceptable outcomes	Other comments
	Note: Scenarios 1 – 6 apply at all times including when the FSRU is operating while an LNG carrier is adjacent.	Whether it is technically possible (as opposed to practicable, best practice or necessary to achieve acceptable environmental outcomes) to operate the FSRU. See paragraph 178 in Proponent's closing submissions.	Tidally averaged residual chlorine concentration of 2.2µg/L at seabed all areas.	Tidally averaged residual chlorine concentration of 2.2µg/L at boundary of minimised plume.	Area of impact minimised.		• Achieves risk assessment indicators of very low or low • Separation of plume from intertidal zones, seagrass and shoreline ecology	
1.	Zero mg/L	Technically feasible, but not practicable	Yes	N/A no chlorine in plume	Yes No or negligible area of impact	Yes	Yes No chlorine impact.	Aspirational but not practicable.

No.	Residual chlorine at discharge points	Technically feasible?	CSIRO 99% species protection at seabed	CSIRO 99% species protection at boundary of plume	Scoping requirement - minimised impact area	EPBC Act - Protects MNES	Terms of reference - Acceptable outcomes	Other comments
								Well exceeds the requirement for acceptability. Beyond best practice.
2.	0.002 mg/L (2 µg/L)	Technically feasible, but not practicable.	Yes	N/A – 99% species protection achieved within the plume.	Yes No or negligible area of impact	Yes	Yes No or negligible chlorine impact.	Aspirational but not practicable. Well exceeds the requirement for acceptability. Beyond best practice.
3.	0.002 mg/L (2 µg/L) tidally averaged over 12 hours.	Pulse chlorination technically feasible but practicability and limits under investigation.	Yes	N/A – 99% species protection achieved within the plume.	Yes No or negligible area of impact.	Yes	Yes No or negligible chlorine impact.	Aspirational but under investigation, not expected to be practicable. Well exceeds the requirement for acceptability. Beyond best practice.
4.	Up to 0.1 mg/L (100 µg/L), other than at Slack Tide. 0 mg/L at Slack Tide. EPR-ME01A, Option 1	Yes, technically feasible and practicable Note: no chlorination for 2 hours during each tide cycle.	Yes • See Section 10.2 and Figure 6-38 of Dr Wallis witness statement	Yes • Tidally averaged chlorine level of 0.0022 mg/L within a distance of 100 metres from the FSRU.	Yes Negligible area of impact. • Compliance with GV at seabed;	Yes • The reduced area will be well away from the areas of seagrass, intertidal mudflats,	Yes Negligible chlorine impact. • Responds to the site specific tidal context of North Arm to eliminate impact at Slack Tide.	Acceptable and appropriate for site specific context. Well exceeds the requirement for acceptability. Beyond best practice.

No.	Residual chlorine at discharge points	Technically feasible?	CSIRO 99% species protection at seabed	CSIRO 99% species protection at boundary of plume	Scoping requirement - minimised impact area	EPBC Act - Protects MNES	Terms of reference - Acceptable outcomes	Other comments
		(See further TN 053, Document 535).	(document 70).	Note: potential for distance to be reduced.	• Elimination of chlorine at Slack Tide; • No impact to species within the plume; • Plume wholly within port basin around FSRU.	mangroves and saltmarsh, and there will be no impact on these habitats. • Area of impact wholly within port basin around FSRU.		Discharge can be monitored to support ongoing reductions to reduce or eliminate discharge. (Optimal and preferred, see paragraph 177 in the Proponents closing submissions).
5.	0.02 mg/L (20 µg/L) EPR-ME01A, Option 2	Technically feasible but practicability is subject to maintenance and operations, including frequency of shut down of regasification trains. (See further TN 053, Document 535)	Yes	Yes • Tidally averaged chlorine level of 0.0022 mg/L within a distance of 100 metres from the FSRU Note: potential to reduce to 50m.	Yes Negligible area of impact. • Compliance with GV at seabed; • No impact to species within the plume; • Plume wholly within port basin around FSRU.	Yes • The reduced area will be well away from the areas of seagrass, intertidal mudflats, mangroves and saltmarsh, and there will be no impact on these habitats. • Area of impact wholly within port basin around FSRU.	Yes Negligible chlorine impact. • Acknowledges numerical limit in Port Kembla approval (other aspects of approval not investigated).	Acceptable with general applicability. Well exceeds the requirement for acceptability. Beyond best practice. Despite other approvals, no evidence of operating FSRU complying with this scenario. (Less preferred than site specific option 4.)

No.	Residual chlorine at discharge points	Technically feasible?	CSIRO 99% species protection at seabed	CSIRO 99% species protection at boundary of plume	Scoping requirement - minimised impact area	EPBC Act - Protects MNES	Terms of reference - Acceptable outcomes	Other comments
6.	0.1 mg/L (100 µg/L) (Day 2 version of EPR-ME01A)	Yes, technically feasible and practicable	Yes • See Section 10.2 and Figure 6-38 of Dr Wallis witness statement (document 70).	Yes • Tidally averaged chlorine concentration of 0.006 mg/L within a distance of 40 metres from the FSRU. • Tidally averaged chlorine concentration of 0.0022 mg/L within a distance of 100 metres from the FSRU.	Yes Negligible area of impact. • Compliance with GV at seabed under normal operating conditions; • No impact to species within the plume; • Discharge ports designed and located to achieve a minimised area of impact. • Plume wholly within port basin around FSRU.	Yes • The reduced area will be well away from the areas of seagrass, intertidal mudflats, mangroves and saltmarsh, and there will be no impact on these habitats. • Area of impact wholly within port basin around FSRU.	Yes Negligible chlorine impact. • Discharge ports designed and located to achieve a minimised area of impact.	Acceptable. Discharge can be monitored to ensure future elimination or reduction. Superseded by Day 3 EPRs.
7.	0.1mg/L, with LNG carrier adjacent and 6 discharge ports oriented to the east. EES scenario (pre Dr Wallis minimisation of	Yes, technically feasible and practicable	No. An area of 5ha on the seabed will experience residual chlorine level exceeding 6ug/L.	Yes • Tidally averaged chlorine concentration of 0.006 mg/L within a distance of 100 metres from the FSRU.	Area of impact not minimised for this purpose on account of impact of adjacent LNG carrier. Based on primary mitigations and risk assessment the	Yes • The area will be separate from the areas of seagrass, intertidal mudflats, mangroves and	Options set out above, and supported by draft EPR-ME01A, deliver a more acceptable outcome.	Modelled on worst case, rather than minimised impact area. Superseded by proposed EPR-ME01A and options set out above.

No.	Residual chlorine at discharge points	Technically feasible?	CSIRO 99% species protection at seabed	CSIRO 99% species protection at boundary of plume	Scoping requirement - minimised impact area	EPBC Act - Protects MNES	Terms of reference - Acceptable outcomes	Other comments
	impact area set out in Document 70).			• Tidally averaged chlorine concentration of 0.0022 mg/L within a distance of approximately 130 metres from the FSRU.	beneficial uses of Western Port will not be adversely affected, with the area of impact being wholly contained within the port zone in dredged area in around jetty.	saltmarsh, and there will be no impact on these habitats. • Area of impact wholly within port basin around FSRU.		