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Working with water

Islandmagee Gas Storage Project

Brine dispersion study review - FEED stage

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Executive summary

Islandmagee Energy Ltd (IMEL) is working on the Islandmagee underground gas storage project on the east coast of County Antrim, Northern Ireland. Gas will be stored in underground caverns, constructed by leaching with seawater. During the construction of the caverns, hypersaline brine will be released into the sea via a submerged outfall.

To support the project's discharge licence application, the potential dispersion of the brine and associated impurities was assessed using computational models by IMEL's subcontractors, RPS Consulting Engineers (RPS), Belfast. An independent review of the assessment is required, to establish whether appropriate methods and data have been used.

HR Wallingford previously reviewed similar studies used to inform the project's Environmental Statement. Since then, a confirmation borehole has been completed at the discharge site, and Front End Engineering Design (FEED) has been completed. The FEED studies included an updated dispersion assessment by RPS, based on new brine and production characteristics.

HR Wallingford assessed the updated study in terms of the following:

- The suitability of the computational models used;
- The validity and appropriateness of the model settings and input parameters to the models;
- Whether the models have been applied in an appropriate manner, given their limitations and the study objectives;
- The validity of the study's conclusions.

This report presents the findings of HR Wallingford's review.

Refinements were made to the hydrodynamic model on our recommendation. We consider that:

- The updated model is now suitable for the purpose of assessment;
- Appropriate parameters appear to have been used for the assessment;
- The models have now been applied appropriately, given their limitations and the study objectives;
- The study's conclusions appear to be valid.

Modelling was carried out using the highest possible concentrations of leached brine at the highest discharge flow rate. In reality higher leaching rates will result in lower brine saturation levels, and therefore salinities at the edge of the 100 m mixing zone are likely to be lower than presented in the report. We note that, for certain cases, the refined model shows salinities at the edge of the mixing zone that are above the environmental threshold. If, as expected, operational brine saturation levels are lower than those simulated, mixing and dispersion is likely to be improved, and concentrations at the edge of the mixing zone are likely to be lower.

It is also likely that a final stage of refinement to the discharge configuration would lead to a design that generates higher rates of dilution, and therefore lower salinities at the edge of the mixing zone. IMEL has also indicated that any minor breach of the salinity requirements would trigger an alarm and stop discharge.

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1. Introduction

Islandmagee Energy Ltd (IMEL) is working on the Islandmagee underground gas storage project on the east coast of County Antrim, Northern Ireland. Gas will be stored in underground caverns, constructed by leaching with seawater. During the construction of the caverns, hypersaline brine will be released into the sea via a submerged outfall, where it will form a dense plume at the seabed.

To support the project's discharge licence application, the potential dispersion of the brine and associated constituents was assessed using computational models by IMEL's subcontractors, RPS Consulting Engineers, Belfast (RPS). IMEL commissioned HR Wallingford to carry out an independent review of RPS's assessment, to establish whether appropriate methods and data have been used.

HR Wallingford previously reviewed similar studies used to inform the project's Environmental Statement (Reference 1). Since then, a confirmation borehole has been completed at the discharge site, and Front End Engineering Design (FEED) has been completed. The FEED studies included an updated dispersion assessment by RPS, based on new brine and production characteristics.

This document presents HR Wallingford's review of the updated dispersion assessment, and has been updated following discussions with IMEL and RPS through April and May 2019, and to reflect modelling updates made in response to our recommendations.

2. Review approach

The review was originally based on RPS report IBE1547 D01 (Reference 2), received by email on 20 March 2019. This document was reviewed by HR Wallingford's experts in effluent dispersion to assess the following:

- The suitability of the computational models used;
- The validity and appropriateness of the model settings and input parameters to the models;
- Whether the models have been applied in an appropriate manner, given their limitations and the study objectives;
- The validity of the study's conclusions.

The review was updated following receipt of:

- The Department of the Environment's Consent to Discharge of Effluent (941/14/1, TC 147/12_1), received 17 April 2019;
- Diffuser layout drawings, received 17 April 2019;
- RPS's amended reports, received on 9 May 2019 and 23 May 2019;
- Additional model analysis plots received 23 and 29 May 2019; and,
- Further modelling plots received 5 June 2019.

3. HR Wallingford – capability and experience

HR Wallingford is ideally qualified to carry out this independent review. The company has several decades' experience of the assessment of discharge dispersion and dilution for all types of marine discharge, including hypersaline brines from salt cavern leaching activities, and reject brines from desalination plants worldwide. Successfully completed studies include salt cavern leaching assessments for Project Gateway in the Irish Sea, and King Street Energy in the Mersey Estuary. Key experts at HR Wallingford have also developed and validated assessment procedures for saline discharges[1], and presented the research at international conferences (References 3-6).

4. Review

4.1. Environmental requirements and discharge behaviour

The Department of the Environment's discharge consent requires that the dilution of the discharge must be sufficient to reduce the salinity to 36 PSU within a 100 m mixing zone around the outfall. The wording of the consent document indicates that this mixing zone threshold should apply at all times (i.e. 36 PSU is the Maximum Allowable Concentration, or MAC).

As the assumed background salinity is 34.2 PSU and the maximum discharge salinity is 260 PSU, this means the target dilution is more than 100:1.

The brine discharge will be denser than the receiving seawater, which means it will tend to sink following release, forming a dense layer or gravity current at the seabed. Rates of dilution in gravity currents can be relatively slow, and so outfalls for reject brines must be designed to ensure high levels of dilution and mixing with the ambient seawater before the plume reaches the edge of the near-field region (usually a few tens of metres from the outfall).

4.2. Overview of dispersion study methodologies

Accurate and appropriate assessment of the dispersion and dilution of effluent is important when planning marine discharges. Both environmental impact and engineering constraints must be considered. Studies used to support the design and planning process usually employ computational models, and model studies typically involve the following stages:

- Flow modelling (with verification against field data) to establish the typical hydrodynamic conditions (currents and water levels) near the discharge site;
- Near-field dilution assessment, based on mixing zone software or empirical formulae to assess the initial behaviour of the discharge in the vicinity of the outfall;
- Mid- to far-field dilution/dispersion modelling to check longer-term build-up of background concentrations and wider dispersion patterns, using three-dimensional hydrodynamic models.

The modelling study conducted by RPS included each of these stages. Flow and dispersion modelling were carried out using the Danish Hydraulics Institute's MIKE 3D software, and initial dilution was modelled using the United States Environmental Protection Agency's Visual Plumes software. These can be considered

[1] http://www.hrwallingford.com/projects/hypersaline-discharges

appropriate tools for such an assessment, provided they are applied using suitable parameters and the results are interpreted carefully.

In the following sections each of the stages of the model study is assessed in terms of:

- The validity and appropriateness of the model settings and input parameters to the models; and,
- Whether the models have been applied in an appropriate manner, given their limitations and the study objectives.

4.3. Modelling stages

4.3.1. Hydrodynamic modelling and calibration

The same hydrodynamic model area and mesh used for the ES studies was used for the FEED update far-field modelling. The MIKE software version has been updated since the previous modelling. RPS provided HR Wallingford with plots, independent from the main report, demonstrating the hydrodynamic agreement between the two far-field models. Our previous review comments, which can be summarised as follows, still apply:

- Appropriate parameters appear to have been used for the hydrodynamic (flow) assessment.
- Comparisons of the hydrodynamic model predictions with observed tides and currents are generally acceptable, and suggest the underlying flow fields represent the tidal environment sufficiently well for use in the far-field dispersion assessment.

4.3.2. Initial dilution modelling

The stated diffuser configuration consists of two 6” ports, fitted with TideFlex (duckbill) valves, and located 20 m apart. Three operating flow rates are considered in the study (250, 500, and 1000 m^3/h). A single port will be used for discharge flow rates up to 500 m^3/h and two ports will be used when the discharge flow rate exceeds 500 m^3/h.

Initial dilution modelling was carried out by RPS using the UM3 module of Visual Plumes. Drawings provided by IMEL confirm that the ports are spaced at 20 m, along a line perpendicular to the main current direction.

The UM3 module of Visual Plumes was used to simulate both ports discharging together, rather than independently. Independent checks carried out by HR Wallingford show that there will be limited overlap between the neighbouring plumes in the near-field and so it would be more appropriate to simulate the jets separately. However, this would not significantly affect the near-field results.

Jet dilution rates are dependent on the characteristics of the TideFlex valves used. From discussions with RPS, it is understood that the effects of the TideFlex valves have not been included in the near-field calculations. We recommend that these are included in any refinement stages. However, their inclusion is likely to improve rates of dilution and therefore the present approach is likely to be conservative.

Predicted dilutions and excess salinities are presented for several stages of the tide, at the point of impact with the seabed. Minimum predicted dilutions range between 13:1 and 52:1, depending on the speed of the ambient currents and the configuration tested.

The Visual Plumes UM3 module does not explicitly include the turbulent collapse and restricted mixing that occurs in the density current after contact with the seabed (before the end of the near-field region). Therefore, as noted by RPS beneath each figure, the near-field predictions should only strictly be used up to point of impact with the bed. Dispersion over the wider area is then correctly simulated in the MIKE mid-field model.

During a conference call (21 May 2019), IMEL confirmed that the final discharge port design would be optimised during subsequent project stages. The reduced rates of dilution around the slackwaters could be partially mitigated through such refinements to the diffuser design, in-line with modern brine diffuser design practice.

4.3.3. Brine dispersion modelling

RPS modelled the wider dispersion of the brine using MIKE 3, which is the 3D finite element module of the MIKE modelling system. A 3D approach is necessary to represent the dense discharge, which will form a layer near the seabed. A range of spring tide and neap tide conditions has been assessed.

Predicted dispersion patterns for brines (and particularly hypersaline brines from solution mining activities) are affected by the resolution of the vertical mesh of the 3D model (References 3-6). The selection of the vertical layering is therefore important for this type of study. Based on our recommendation, RPS set up a mid-field model using the MIKE software, to supplement the far-field model, with appropriately fine resolution.

In any study of pollutant dispersion, it is also important to carefully choose the resolution of the horizontal mesh. Insufficient resolution can lead to artificially high dilution, and inadequate representation of key features of the far-field plume. A mesh of less than 5 m was used around the outfall in the revised mid-field model. This is appropriate for this type of discharge.

Modelling was carried out using the highest possible concentrations of leached brine at the highest discharge flow rate. In reality higher leaching rates will result in lower brine saturation levels, and therefore salinities at the edge of the 100 m mixing zone are likely to be lower than presented in the report. We note that, for certain cases, the refined model shows salinities at the edge of the mixing zone that are above the environmental threshold. If, as expected, operational brine saturation levels are lower than those simulated, mixing and dispersion is likely to be improved, and concentrations at the edge of the mixing zone are likely to be lower.

It is also likely that a final stage of refinement to the discharge configuration would lead to a design that generates higher rates of dilution, and therefore lower salinities at the edge of the mixing zone. IMEL has also indicated that any minor breach of the salinity requirements would trigger an alarm and stop discharge.

5. Conclusions

HR Wallingford has reviewed the FEED-stage modelling study. Following updates to reflect our recommendations, the modelling study includes the following appropriate stages:

- Flow modelling (with verification against field data) to establish the typical hydrodynamic conditions (currents and water levels) near the discharge site;
- Near-field dilution assessment, based on mixing zone software to assess the initial behaviour of the discharge in the vicinity of the outfall;

- Mid- to far-field dilution/dispersion modelling to check longer-term build-up of background concentrations and wider dispersion patterns, using three-dimensional hydrodynamic models.

We consider that:

- The updated hydrodynamic model is now suitable for the purpose of assessment;
- Appropriate parameters appear to have been used for the assessment;
- The models have now been applied appropriately, given their limitations and the study objectives;
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6. References

1. Islandmagee Gas Storage Project – Brine dispersion study review, HR Wallingford Report EBR5104-RT001-R02-00, 10 April 2013.
2. IGSF Brine Dispersion Modelling – FEED Update, RPS Report IBE1547 D01, 21 February 2019.
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4. Wood, M, Mead, C, and Wild, R, "Buoyancy Implications for Integrated Discharges". Proc. 6th International Symposium on Environmental Hydraulics, Athens, Greece, 23-25 June 2010.
5. Mead, C T, Bourban, S E, Cawthorn, C J, and Turnbull, M S, "The Importance of Model Plane Location and Movement in Dense Discharge Assessment" in Proceedings of the International Symposium on Outfall Systems, Mar del Plata, Argentina, 15-18 May 2011.
6. Wood, M., Henno, F., and Mead, C., "Validation of computational models for hypersaline and other dense marine discharges". Proc. 7th Int. Symp. on Environmental Hydraulics, Singapore, 5-7 January 2014.

Appendices

A. Construction Design and Management Regulations (CDM 2015)

The Construction (Design and Management) Regulations 2015 (CDM 2015) require a designer to avoid foreseeable risks to those involved in construction and future use of the structure, and in doing so, they should eliminate hazards (so far as is reasonably practicable, taking into account other design considerations) and reduce and control risks associated with those hazards which remain. It is essential that, where required to do so, a principal designer and principal contractor are appointed to fulfil their respective duties under the CDM 2015. It is also essential to highlight and record the impacts of the works on health, safety and welfare which should feed into the Health and Safety File (if required). Further details of the requirements of CDM 2015 can be found on: http://www.hse.gov.uk/construction/cdm/2015/index.htm.

This project consists of a peer review of modelling work which may be used by others in the design process. No design work, as defined in the CDM 2015, has been undertaken by HR Wallingford and we have not identified any particular issues that should be drawn to the attention of the principal designer and principal contractor in any ultimate construction work which may be undertaken. It is assumed that the appointed principal designer will review the information produced in this study when discharging his duties under the CDM 2015.

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HR Wallingford is an independent engineering and environmental hydraulics organisation. We deliver practical solutions to the complex water-related challenges faced by our international clients. A dynamic research programme underpins all that we do and keeps us at the leading edge. Our unique mix of know-how, assets and facilities includes state of the art physical modelling laboratories, a full range of numerical modelling tools and, above all, enthusiastic people with world-renowned skills and expertise.

FS 516431
EMS 558310
OHS 595357

HR Wallingford, Howbery Park, Wallingford, Oxfordshire OX10 8BA, United Kingdom
tel +44 (0)1491 835381 fax +44 (0)1491 832233 email info@hrwallingford.com
www.hrwallingford.com