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Queensland Government

Department of
Regional Development, Manufacturing and Water

15 March 2023

[redacted]
Director, Technical and Assessment Services
Environmental Services and Regulation
Department of Environment and Science

Email: [redacted]

Dear [redacted]

Request for advice on proposed CTSCo Surat Basin Carbon Capture and Storage Project Environmental Impact Statement

Thank you for your request for advice dated 9 February 2023 in relation to the Proposed CTSCo Surat Basin Carbon Capture and Storage (CCS) Project (the Project) Environmental Impact Statement (EIS).

You requested the Office of Groundwater Impact Assessment's (OGIA) advice in terms of eight specific questions relating to groundwater impact assessment in the Environmental Impact Statement (EIS). For ease, the advice and response to those questions (the advice) is grouped in three categories: assessment and modelling; monitoring and risk assessment; and remediation plan.

This advice is provided in the context of assessing risk associated with injecting liquid CO_2 at about 2,300 m deep into the Precipice Sandstone. Particular attention is given to the potential implications for the long-term viability of the aquifers in the area for water supply. The Precipice Sandstone and the overlying Hutton Sandstone are two of the most important regional aquifers of the Great Artesian Basin (GAB) which support existing and future water supplies. It is understood that many elements of the proponent's assessment are still progressing as a continuum in the post-EIS period. Some of these elements were made available to OGIA as work in progress.

Details of the advice are provided in **Attachment 1**. In general, the proponent's assessment is comprehensive and broadly commensurate with the potential risks. However, some additional bolt-on assessment is necessary to firm up on the core conclusion that the extent of the plume is likely to be limited to within a few hundred metres of the injection. This will result in a more complete assessment beyond a reasonable doubt and assist in the management of associated risks. Broadly, the proposed monitoring and remedial approach is also appropriate but some strengthening of the approach is necessary to provide more certainty.

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Key additional assessments suggested by OGIA in the attached advice include:

- an uncertainty analysis to improve confidence in the extent and migration of the plume
- scenario testing to assess potential remobilisation of the plume in response to changes in groundwater pressure around the injection site from the exercise of existing entitlements, release of unallocated water and future closure of the Moonie oil field
- additional monitoring in the Hutton Sandstone and the Precipice Sandstone
- further details on the effectiveness of the seismic monitoring
- a firmer commitment to remediation actions beyond monitoring, such as the pump out of injected CO_2 and the consequences of any accidental leakage into a water supply bore.

I trust this meets your requirement. Please do not hesitate to contact me if you require further clarification on any aspect of the advice.

Yours sincerely

[redacted]
Executive Director
Office of Groundwater Impact Assessment

Attachment 1: Detailed Advice

Basis for the advice

Data and information

Advice is formulated on the basis of:

- information provided by the Department of Environment and Science (DES) dated 9 February 2023
- a meeting between the OGIA team and the proponent on 24 February 2023 to seek further clarification and information
- following the above meeting, additional information requested by OGIA from the proponent on 28 February 2023, which was provided to OGIA on 3 March 2023 (**Attachment 2**).

Contextual understanding

Based on the information provided by the proponent and OGIA's understanding of the geology and hydrogeology of the area, key contextual understandings relevant to the advice are as below.

- The Precipice Sandstone and the overlying Hutton Sandstone are two of the most important regional aquifers of the GAB supporting existing and future water supply.
- The project proposes to inject about 0.5 ML/day of liquid CO_2 into the Precipice Sandstone at about 2,300 m below ground (**Attachment 3**) for three years.
- The Precipice Sandstone is deep in the proposed project area and becomes progressively shallower to the north and east. In these other areas, groundwater quality is fresh and supports water supplies and springs.
- In the project area, the Precipice Sandstone is more brackish, with the salinity of the groundwater being about 1,800 mg/L total dissolved solids.
- The project is for testing purposes only, with injection proposed to commence in 2025 and last for three years until 2028.
- The proposed injection site is 35 km west of the existing Moonie oil field and in the same formation from which oil is extracted.
- The proponent's assessment suggests that the CO_2 plume will remain within between 500 and 600 m of the injection site at any time in the future.
- The proponent states that the nearest water supply bore is 17 km away from the injection site. However, information from DRDMW suggests that there are existing entitlements in the area which could result in potential water supply bores being located closer than this in future.
- The proponent's assessment of plume migration primarily includes:
    - building static geological models both regional (Southern Surat Basin) and local (EPQ10 and West Moonie) based on geological, geophysical and petrophysical data
    - using the geological models to build regional and local groundwater flow models to assess pressure propagation in response to injection
    - building geochemical models, supported by laboratory generated data, with simplified assumptions to assess the extent of the CO_2 plume and associated changes to groundwater chemistry.
- The proposed monitoring strategy includes:
    - a monitoring bore in the Precipice Sandstone within 200 m of the injection well
    - neutron pulsed monitoring in the overlying Hutton Sandstone
    - a once-off 3D seismic survey scheduled for 2023, followed by a 2D seismic monitoring program to commence three months prior to operations, then six-

monthly to track the extent and migration of the plume in the Precipice Sandstone
    - two monitoring bores in the shallower aquifers.
- The remediation plan hinges primarily on monitoring and investigation, and suspension of injection in the event of departure from predicted behaviour.

Assessment and modelling

Summary of proponent's assessment

- Multiple geological models were constructed for the Southern Surat Basin, EPQ10 and West Moonie – these form the structural framework for hydrodynamic aquifer modelling, dynamic flow simulations, and geochemical reactive transport models. Details on the development and construction of the static geological models are reported in Chapter 8 of the EIS and in supplementary documents provided: *201126_Southern Surat Static Modelling Report Final* and *210217 WM2 Plume Modelling Inputs*.
- The objective of the local West Moonie static and dynamic models was to identify the optimum location for the placement of the Precipice Sandstone monitoring well. Model design is detailed in the supplementary documents provided: *201126_Southern Surat Static Modelling Report Final* and *210217 WM2 Plume Modelling Inputs*.
- A regional groundwater flow model was prepared to assess impacts on groundwater pressure resulting from CO_2 injection. Sensitivity analysis was also conducted for a number of cases, all of which show small head increases of less than 1 m.
- A reservoir model was subsequently prepared to assess the likely distance of CO_2 migration following injection. Properties were populated based on data from the West Moonie-1 injection well and some limited sensitivity analysis was undertaken to explore the impact of variogram range and relative permeability curves. Based on this, the maximum modelled plume travel distance was between 500 and 600 m.
- Geochemical models were prepared that simulate the extent of CO_2 migration and likely changes to groundwater chemistry, particularly the potential for mobilisation of trace metals, such as lead and arsenic. Geochemical modelling reported in the *ANLEC* document (*7-0320-C323*) is substantially more sophisticated than the modelling presented in the EIS submission. On the understanding that this model supersedes previous modelling presented in the EIS, comments related to geochemical modelling refer only to the models in *7-0320-C323*.
- 2D and 3D geochemical reactive transport models have been prepared with parameters based on laboratory measurements of core from the West Moonie-1 well. A summary of OGIA's understanding of the workflow and input datasets used in geochemical modelling is provided in **Attachment 4**. Both 2D and 3D reactive transport models indicated that, within the extent of CO_2 migration, dissolution of CO_2 will result in reduction of pH to between 4 and 6, and dissolution of carbonate minerals in the aquifer introducing trace elements to solution. Trace element concentrations are variable through time but, within the extent of CO_2 migration, may remain at levels which constrain potential water uses after 100 years.

Comments and advice on the assessment

- Conclusions based on the regional flow model – that head increases from the proposed activity are likely to be small – are considered reasonable and are supported by the modelling work. However, the particle tracking results are at odds with both the reservoir modelling and reactive transport modelling, which are considered more suitable to explore plume travel distance.
- The regional deterministic static model and the West Moonie plume movement model have very limited assessments of the influence of variograms on the CO_2 plume

dimensions. The tested variogram ranges are likely to lead to an underestimation of the lateral plume migration distance.
- The above limitation has, however, been largely addressed in the reactive transport modelling, which assumes laterally continuous permeability.
- The 3D geochemical model was terminated after 10 years of simulation, limiting the conclusions that can be drawn from the model results. Additionally, the injected CO_2 reached the edge of the model domain after 5 years, meaning the maximum distance of CO_2 plume migration could be greater than 800 m.
- The radial 2D geochemical model ran for 100 years of simulation time, indicating CO_2 would migrate 500–600 m from the injection site. However, this model did not account for the regional dip of the Precipice Sandstone, which could lead to underestimation of the modelled travel distance. This is considered a material assumption and its implications are unclear.
- No parametric sensitivity analysis was undertaken and so it has not been demonstrated whether the parameter values used are conservative, nor has any uncertainty analysis been undertaken to explore the range of possible/likely outcomes.
- Geochemical models simulate changes in porosity of the Precipice Sandstone due to mineral dissolution and precipitation, but any potential affects this may have on rock properties/geomechanics are not discussed.
- Work to constrain parameterisation and design of the reactive transport model is considered more rigorous than commonly applied methods and exceeds the standard of many EIS submissions.

Suggestions for additional work

- The current assessment does not sufficiently explore the implications of parametric and conceptual uncertainty on plume migration and extent. Therefore, the latest model should be subjected to a rigorous analysis of sensitivity – and, ideally, uncertainty – to support conclusions about the maximum potential extent of the plume.
- Additional scenario testing should also be undertaken to assess potential remobilisation of the plume, or groundwater affected by the plume, in response to changes in pressure (hydrostatic head) around the injection site resulting from the exercise of existing entitlements, release of unallocated water and future closure of the Moonie oil field.

Monitoring

Summary of the proponent's proposal

- Six-monthly groundwater pressure and chemistry monitoring of the shallow Griman Creek Formation and the Gubberamunda Sandstone.
- Continuous groundwater pressure and six-monthly groundwater chemistry monitoring in the deeper Precipice Sandstone (West Moonie-2).
- Six-monthly pulsed neutron logging of the injection well (West Moonie-1) and the deeper monitoring well (West Moonie-2) to monitor plume migration in the vicinity of the injection well.
- A 2D seismic survey (32 km) three months prior to operation, and every six months thereafter to evaluate plume migration and extent within the Precipice Sandstone. Supplementary material on case studies in the application of these methods was provided by the proponent: *210600_Aquistore, 110000_Weyburn, 130000_Ketzin and 170919_Glenhaven Seismic M&V Modelling Results.*
- A once-off 3D seismic survey (40 km^2) to provide structural information and to refine geological understanding in the vicinity of the injection site.

Comments and advice on the assessment

- The monitoring program is primarily designed to assess the migration of the plume within the Precipice Sandstone and vertically around the injection well. An additional monitoring point in the Precipice Sandstone beyond the maximum predicted extent of the plume will provide additional data for calibration and will act as a safeguard to assess potential migration.
- The overlying Hutton Sandstone is a regionally important aquifer, separated from the Precipice Sandstone by the Evergreen Formation. Continuous monitoring of groundwater pressure, and six-monthly groundwater chemistry in the Hutton Sandstone at West Moonie-2, should provide an additional safeguard to assess the potential migration of the plume into this aquifer.
- Site-specific feasibility studies are not available for the seismic monitoring program. 3D and 2D time-lapse seismic surveys are commonly applied internationally to evaluate plume migration within the reservoir but supporting information is limited due to commercial-in-confidence arrangements.

Suggestions for additional work

- Following the initial 2D surveys, it is recommended that the effectiveness of this monitoring tool for this specific hydrogeological setting and purpose be evaluated.
- Additional monitoring in the Hutton Sandstone should be considered.
- Additional monitoring in the Precipice Sandstone around the injection site should also be considered.

Mitigation of risks and remedial actions

Inferred summary of the proponent's proposal

- The approach to mitigation and remedial actions is included in the proponent's Monitoring and Verification Plan (MVP).
- The purpose of the MVP is to manage departures from the predicted behaviour of the plume, i.e. in the event that the plume spreads further than predicted in the Precipice Sandstone and/or leaks into the overlying Hutton Sandstone.
- The plan hinges primarily on monitoring and investigation, and suspension of injection in the event of departure from predicted behaviour.
- A Trigger Action Response Plan (TARP) is proposed that may include a pump-and-treat program to remove the plume.

Comments and advice on the assessment

- The management plan is primarily focused on monitoring and investigation when the plume extends beyond what is predicted, instead of firm actions for removal of the plume in such an event.
- The proposed pump-and-treat approach is based on (1) plume spreading beyond 2 km from the injection well rather than the currently predicted 500 m extent of the plume; and (2) the TARP being developed in consultation with the administrative authorities.

Suggestions for additional work

- Although a remedial action does not need to be linked to the extent of the predicted plume, a clear upfront plan and basis is still required to ensure that the actions are effective and timely.
- Effectiveness of the remedial plan needs to be demonstrated through supporting modelling or conceptual assessment.

- To develop an appropriately comprehensive risk profile, two further assessments are necessary:
    - Characterisation of consequences in the event of an accidental leak of CO_2 into another aquifer or a groundwater asset, such as a water supply bore, even though the likelihood of such an event may be low.
    - Additional scenario testing to assess potential remobilisation of the plume in response to changes in pressure (hydrostatic head) around the injection site resulting from the exercise of existing entitlements, release of unallocated water and future shut-down of the Moonie oil field.