

Advice to decision maker on carbon capture and storage project

IESC 2022-139: Surat Basin Carbon Capture and Storage Project (EPPG00646913) – New Development

Requesting agency	The Queensland Department of Environment and Science
Date of request	06 December 2022
Date request accepted	21 December 2022
Advice stage	Assessment

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The IESC was requested by the Queensland Minister for the Environment and Queensland Department of Environment and Science to provide advice on the Carbon Transport and Storage Company Pty Ltd's Surat Basin Carbon Capture and Storage Project in Queensland. The request has been approved in writing by the Australian Government Environment Minister. This document provides the IESC's advice in response to the requesting agency's questions. These questions are directed at matters specific to the project to be considered during the requesting agency's assessment process. This advice draws upon the available assessment documentation, data and methodologies, together with the expert deliberations of the IESC, and consideration of the IESC Information Guidelines (IESC, 2018).

Summary

The Surat Basin Carbon Capture and Storage Project (the project) is a proposed greenhouse gas (GHG) stream injection and storage testing site located in the Darling Downs of Queensland. The project will inject GHG as a supercritical fluid into the Precipice Sandstone aquifer within the southern Surat Basin at a rate of up to 110,000 tonnes annually for three years (CTSCo 2022a, p. 6). Within the project's

operational lands, the Precipice Sandstone aquifer is approximately 2,300 m below ground level. The injected GHG is expected to remain trapped and stored as a mixture of dense fluid and mineral solids within the aquifer and within the bounds of the operational lands (CTSCo 2022a, p. 47) with increasing storage containment over time.

Substantial project infrastructure was constructed by the proponent in 2021 as permitted under Queensland Environmental Authority (EA) EPPG00646913, including West Moonie-1 Injection Well and West Moonie-2 Monitoring Well, both targeting the Precipice Sandstone aquifer, and a water quality monitoring bore targeting the shallow Griman Creek formation (CTSCo 2022a, Table 7-2, p. 21). Construction of a final monitoring bore targeting the Gubberamunda Sandstone aquifer is planned for 2024. In addition to the existing infrastructure, the project will require the construction of a 7.35-ha Transportation Facility and a 9.5-km buried flowline to carry the GHG stream from the Transportation Facility to West Moonie-1 Injection Well (CTSCo 2022a, p. 16).

Limited site-specific data have been used to develop the models relied on by the proponent to predict plume behaviour and potential impacts from the project. Despite this, given the small scope of the project and geological stability of the storage complex at the project location, impacts from the project are expected to be minimal and manageable in both the immediate and long term.

Potential impacts from this project that require further consideration are:

- changes to groundwater quality in the Precipice Sandstone aquifer, within the GHG plume extent, which may have implications for future usability; and
- leakage of GHG into aquifers overlying the Precipice Sandstone due to corrosive-mechanical failure of bore casings and seals, resulting in groundwater quality and pressure changes.

The IESC has identified additional work to address the potential impacts, as detailed in this advice. These are summarised below.

- Improved baseline groundwater quality data for the Precipice Sandstone aquifer near the injection site are required to enable the proponent to establish a robust baseline and set appropriate trigger values for water quality.
- Improved estimates should be made of the maximum likely extent of plume migration. Once the local-scale groundwater model has been updated with information from the planned 3D-seismic survey, a scenario analysis should be conducted, considering combinations of possible factors that could maximise plume migration. These results should also be used to inform adaptive management.
- A more comprehensive spatial monitoring network and sampling program should be established to reflect the project's status as a feasibility study which aims to provide 'proof-of-concept' for geological storage of GHG in the Surat Basin. This should include:
 - Collection of data to measure groundwater quality within the Precipice Sandstone aquifer beyond the predicted GHG plume extent. Monitoring should continue throughout the project, and for at least 3 years after injection ceases, to enable the proponent to confirm the prediction that groundwater quality will not be impacted outside of the GHG plume extent.
 - Additional bores targeting shallower aquifers should be added to the groundwater monitoring program to ensure that groundwater resources are not being impacted by the project. Sampling of these bores should be undertaken prior to GHG injection to establish a baseline which will facilitate detection of any impacts.

- The integrity of the caprock seal and containment of injected GHG without impacts to the environment could also be verified by suitable environmental tracers (e.g., carbon-13), and monitoring of soil gas at several key sites (e.g., near the injection bore) above the expected plume and at unimpacted reference sites.

Context

The Surat Basin Carbon Capture and Storage Project (the project) is located in the southern Surat Basin approximately 44 km west of Moonie in the Darling Downs of Queensland. The operational lands of the project are located in the Moonie River catchment, which forms part of the Murray-Darling Basin (CTSCo 2022b, p. 8). The project will target the Precipice Sandstone aquifer, which is within the Basal Great Artesian Basin (CTSOCo 2022a, p. 50).

Exploration and appraisal activities for the project commenced in 2019 under Queensland Greenhouse Gas (GHG) Exploration Permit EPQ10 and Environmental Authority (EA) EPPG00646913 (CTSCo 2022a, p. 20). These activities included the construction of West Moonie-1 Injection Well and West Moonie-2 Monitoring Well, both targeting the Precipice Sandstone aquifer (CTSCo 2022a, p. 21).

The project was assessed by the then Department of Agriculture, Water and the Environment under the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act), and determined to be not a controlled action (DAWE 2022). The proponent is now seeking amendments to the existing Queensland EA to allow GHG stream injection testing, which is currently expressly prohibited under Condition 1 (CTSCo 2022c, p. 4). The proponent has developed an Environmental Impact Statement (EIS) to support the requested amendments.

During the three-year injection phase of the project, up to 330,000 tonnes of GHG will be injected into the Precipice Sandstone aquifer as supercritical fluid (CTSCo 2022a, p. 6). Once the injection is complete, the GHG is expected to remain trapped within the Precipice Sandstone aquifer and the project's operational lands (CTSCo 2022a, p. 47) with increasing storage containment over time, as a mixture of dense fluid and mineral solids.

The project will require the construction of a 7.35-ha Transportation Facility for the receipt and conversion of GHG to a supercritical fluid (CTSCo 2022a, p. 28), and installation of a 9.5-km buried flowline to convey the supercritical GHG stream to the West Moonie-1 Injection Well for injection into the aquifer (CTSCo 2022a, p. 30). Construction of the flowline will require clearing of 0.06 ha of vegetation (CTSCo 2022d, p. 31). The proponent will use conventional trenching to install the flowline across Stephens Creek, but utilise horizontal directional drilling to install it under South Branch Stephens Creek and a stand of brigalow (*Acacia harpophylla*) to avoid impacts on these assets (CTSCo 2022a, p. 30).

The project's operational lands are located adjacent to the Currajong State Forest and Southwood National Park (CTSCo 2022a, p. 16) in an area otherwise dominated by grazing (CTSCo 2022a, p. 39). It is unlikely that the project will significantly impact any surface water or shallow groundwater-dependent ecosystems (GDEs) as no extractive activities or water releases are planned or permitted under the EA, and the project's disturbance area is small (CTSCo 2022a, p. 17). The project is expected to significantly alter groundwater quality within the Precipice Sandstone aquifer; however, it is expected that these impacts will remain contained within the project's operational lands with increasing storage containment over time.

Response to questions

The IESC's advice in response to the requesting agency's specific questions is provided below.

Question 1: The IESC is requested to provide comment on the groundwater and surface water assessments presented in the EIS, especially in relation to the adequacy of the:

- identification and assessment of potential impacts and risks including their predicted duration, extent and magnitude
- hydrogeological characterisation and conceptualisation
- assumptions and calibration of models used to predict potential impacts.

1. The groundwater assessment is constrained by limited site-specific data and requires further information to characterise the duration, extent and magnitude of predicted impacts and improve the hydrogeological characterisation and conceptualisation (Paragraphs 2 and 3). There is particular uncertainty about groundwater quality, and a more robust spatial baseline data set is needed (Paragraph 4). The groundwater modelling is not fully documented and could explore a wider range of possibilities, particularly when more data (e.g., from the 3D seismic survey) are available (Paragraph 3). The surface water assessment is constrained by limited site-specific data but impacts are predicted to be minimal because of the small spatial scale of surficial disturbance (Paragraphs 6 and 7).

Groundwater

2. The groundwater impact assessment provided includes a detailed review of available literature and data from a range of studies and projects within the Surat Basin and beyond to inform modelling, assessment and monitoring. Site-specific data are limited. Further site-specific data will be collected during the project. The IESC suggests that once these data are obtained:
 - a. a detailed review of impact predictions and risks should be undertaken (e.g., caprock integrity, well integrity, faulting, palaeochannels) to confirm the current risk assessment and update monitoring and management requirements (see CTSCo 2022e, Table 9-29, p. 81), and
 - b. the plume-migration modelling should be updated as planned (CTSCo 2022e, p. 88) and the scenario analysis expanded to include a broader range of possible combinations of parameters that could maximise plume migration (see Paragraph 3).
3. The assessment of potential impacts to groundwater included modelling of the GHG plume migration, groundwater movements and pressure changes, and geochemical modelling of potential reaction pathways. The IESC notes that the following further information would be useful for fully characterising the duration, extent and magnitude of these potential impacts:
 - a. additional work to understand groundwater movement and to explore alternative conceptualisations of the southern Surat Basin (see WSP Golder 2022, Section 4.6.7, pp. 120-121). This work is needed given the uncertainty that exists regarding groundwater flow paths to build an understanding of whether any future developments may need to be avoided, and where, to prevent potential migration of the plume.
 - b. extended analysis to more fully explore site characterisations to support ranges of parameters which will influence groundwater impacts; at a minimum, simulating (i) a parameter combination likely to increase maximum pressure changes, and (ii) a parameter combination likely to increase the spatial extent of the plume. This should also consider the possibility of geological features which may enhance permeability through the injection area.
 - c. improved reporting (as per the Australian Groundwater Modelling Guidelines (Barnett *et al.* 2012)) with a particular focus on calibration and the scenario outcomes to increase the understanding of the parameter ranges and potential extents, magnitudes and durations of impacts. This may also require some modelling to be extended for multi-decadal time periods.
4. The hydrogeological conceptualisation provided is consistent with other available information. The site-specific characterisation remains limited but the planned seismic studies should improve this. Groundwater quality data are also limited to one or two sampling events (CTSCo 2022e, Table 9-6,

p. 19) from bores which have been installed. The IESC recommends that the Gubberamunda Monitoring Bore be installed as soon as possible. Additional sampling (e.g., at least four sampling campaigns from the Gubberamunda aquifer) is needed for a robust baseline which will enable the proponent to set appropriate trigger values and achieve a more credible 'proof-of-concept'.

5. Assumptions and calibration of models are discussed in the response to Question 2.

Surface water

6. The surface water assessment presented in the EIS is limited. Site-specific water quality data are restricted to measurements taken at four sites within the project's operational lands as part of an aquatic ecological survey undertaken over only two days in June 2021 (CTSCo 2022b, p. 22). This is contextualised with regional water quality data for the Moonie River at Nindigully gauging station (CTSCo 2022b, pp. 21-22), over 150 km downstream of the project's operational lands.
7. Despite the limited data presented, the IESC considers that the potential risks to surface water from the project (e.g., increased sedimentation during the project's construction and rehabilitation phases, accidental spills, introduced weeds) are likely to be minimal. These risks have been adequately identified by the proponent, along with appropriate management and mitigation measures to reduce potential impacts (CTSCo 2022b, pp. 26-28).

Question 2: The IESC is requested to provide comment on the adequacy of the EIS models (including plume migration and geochemical models), assumptions, input data and interpretation of outputs and conclusions on potential impacts from the proposal including the modelling predictions of near-field plume extents and water quality changes as well as far-field pressure changes to EVs associated with the Precipice Sandstone Aquifer.

8. It is not possible to be certain of the adequacy of the regional groundwater and plume migration models because of the lack of documentation provided. The approach appears to be broadly suitable given the limited site-specific data. However, the information provided did not include comprehensive descriptions of model design and parameterisation. Model calibration was not clearly discussed for any model. The approach will require significant data collection and model updating during the project to verify impact predictions. The proponent will need to justify management activities to be implemented to ensure that impacts are quickly detected and operations ceased if needed.
9. The IESC suggests that additional scenario-testing be undertaken using the regional groundwater and plume migration models to enable full consideration of a range of potential impact scenarios. This would inform monitoring, mitigation and management plans to be developed to enable rapid detection of changes that may signal deviations from the base-case predictions (see response to Question 5).
10. Geochemical modelling of potential CO₂-water-rock interactions has adequately described changes in pH, major ions and trace metal concentrations (CTSCo 2022f, pp.28-29, 68-69). Geochemical models were based on geochemical data and rock core observations and at likely pressure and temperature conditions within the Precipice Sandstone aquifer. Geochemical models predicted that there would be no change to groundwater chemistry outside the plume. The IESC recommends that the geochemical modelling be validated with additional experimental (cf. Pearce et al. 2022) or project-site data on actual changes in groundwater chemistry and hydraulics around the injection point.
11. The IESC notes that far-field pressure changes are not predicted to extend to the outcrop areas of the Precipice Sandstone (CTSCo 2022e, Figure 9-19, p. 66) where GDEs supported by the Precipice Sandstone aquifer have been identified by the proponent. The IESC agrees with this conclusion and considers that pressure changes during this feasibility project are likely to be limited in magnitude and positive, thus are unlikely to have material impacts on GDEs and other environmental values that occur at the outcrop some 250 km north (CTSCo 2022a, p. 52).

12. Given the depth of the Precipice Sandstone aquifer at the project location and the limited predicted extent of impacts to groundwater quality, it appears unlikely that environmental values (EVs) will be affected should the project operate as predicted. As it is possible that a loss of well integrity could create a pathway to EVs supported by overlying aquifers, the IESC suggests that any relevant wells and EVs be identified, and appropriate monitoring implemented (see Paragraphs 2, 13 and 15-18).

Question 3: The IESC is requested to provide comment on the adequacy of the exposure pathway assessment to examine the potential for fracturing to open new pathways to potential receptors such as other aquifers, groundwater dependent ecosystems, and surface EVs from the injection of supercritical CO₂.

13. The provided exposure pathway assessment (CTSCo 2022e, pp. 70-76; WSP Golder 2022, pp. 166-175) was focussed on groundwater impact pathways. It considered four potential scenarios including a loss of caprock integrity (damage to the Evergreen Formation), loss of well integrity (existing, legacy or future bores), impacts to the plume from mining and other underground activities, and impacts to the plume from water management actions (extraction or managed aquifer recharge). Potential improvements to the assessment would include:
- Clarification of the time-scales over which these scenarios were considered.
 - Assessment of potential future changes (e.g., increased water scarcity, improved drilling technologies, reduced drilling costs, improved water treatment) which may make currently unattractive or uneconomic water sources more viable.
 - Analysis of the type and location (through scenario analysis in the relevant model/s) of future activities that could allow impact pathways to develop. This analysis is needed to understand whether, and where, exclusion zones may need to be enacted to prevent future impacts.
 - Discussion of the potential future risks (including long-term well integrity) of drilling into, or through, the Precipice Sandstone.
 - Documentation of the geomechanical testing and modelling should be provided, in addition to the high-level review provided (WSP Golder 2022, pp. 167-169). Direct test evidence and the 1D geomechanical model indicated that the proposed injection pressures would not compromise the integrity of the caprock seal. However, information on the model code (1D MEM) and its limitations and uncertainty with the available data at this site were not discussed, and the testing and modelling reports were not presented.
 - Given the limitations of 1D geomechanical models based on well logs, additional geomechanical models were run to evaluate the risk of fault reactivation that could be associated with induced seismicity and potential hydraulic connectivity through the caprock. However, information on the fault-shear model code (assumed to be 2D) and its limitations were not presented, and the modelling reports were not presented. The IESC supports the recommendation that the 3D seismic survey be completed to identify faults within the project area (WSP Golder 2022, p. 100, 184).

Question 4: The IESC is requested to provide comment on the adequacy of the assessment of all water-dependent ecological assets, including but not limited to stygofauna, GDE assessment areas 1 and 2, riparian and floodplain ecosystems and associated threatened species habitats and connectivity areas, and whether sufficient information is provided to support conclusions regarding these assets and the level of proposed impact made in the EIS.

14. The proponent has done a cursory assessment of water-dependent ecological assets including stygofauna, GDEs, riparian and floodplain ecosystems and associated threatened species habitats

and connectivity areas. Given that the proposed project's impacts on these assets are likely to be minimal, this assessment is probably sufficient for this small-scale feasibility study. However, if the project is scaled up in future, a more extensive assessment of these assets will be required.

Question 5: The IESC is requested to provide comment on the adequacy of the proposed mitigation, management and monitoring to be implemented by the project. Does the IESC consider that any additional measures are needed to reduce risks and projected levels of impact?

15. The proposed mitigation, management and monitoring program has been developed through a review of several carbon capture and storage (CCS) projects globally to inform the selection of appropriate measures. The IESC commends this approach. However, given the proof-of-concept nature of the project and the potential for 'scaling up' sometime in the future, the following measures would provide additional valuable information for verifying impact predictions and managing potential risks.
- a. Monitoring of groundwater quality and pressure is limited both spatially and temporally, with the locations strongly influenced by the modelling outcomes of the base case. Additional monitoring sites with multi-level piezometers surrounding the injection bore and targeting several aquifers at different depths are needed to sample and track changes in water quality and pressure and verify the predicted impacts.
 - b. A selection of existing landholder bores within several kilometres of the site should be added to the groundwater monitoring program to verify that important groundwater resources are not being adversely impacted by the project (either through water quality or pressure changes). Two sampling campaigns may be sufficient as impacts from the project are considered unlikely.
 - c. The post-injection monitoring period should be at least equal to the duration of the injection period (i.e., three years), in line with the project's status as a feasibility study intended to provide proof-of-concept.
 - d. Should monitoring show that impact predictions are being exceeded, additional monitoring, modelling and investigation are recommended to determine the magnitude and spatial extent of the actual impacts.
 - e. The predicted changes to groundwater quality (e.g., the reduction of pH to approximately 4, potentially leading to mobilisation of metals) could limit the future usability of the groundwater. Although the changes to groundwater quality are only predicted to occur within the plume (CTSCo 2022a, p.53), additional monitoring (e.g., polycyclic aromatic hydrocarbons, and other organics) and measures may be required to manage this potential risk to future uses.
 - f. If the project outcomes indicate that there is potential for 'scaling up' of CCS in the area, then monitoring should be continued over a wider area and for a longer period.
16. The integrity of the caprock seal and containment of injected GHG without impacts to the environment could also be verified by using suitable environmental tracers (e.g., carbon-13 in water) and monitoring soil gas at several sites above the expected plume and reference sites. Suitable environmental tracers are required that can distinguish sources of CO₂ from the injected GHG stream and natural subsurface processes and that can identify mixing and leakage at this site. Monitoring sites above the expected plume such as fault zones identified by the planned 3D seismic survey and near well casings (e.g., using soil gas monitoring) could verify containment and provide evidence that induced fracturing of the caprock seal has not occurred during injection operations.
17. The proponent has proposed groundwater investigation trigger values for the Precipice Sandstone aquifer (CTSCo 2022e, Table 9-30, p. 84). These trigger values are inadequate.

- a. The trigger values are based on insufficient baseline data (i.e., one data point/parameter from one bore (West Moonie-1) in July 2021) with no justification provided for the selected trigger values, parameters or how they were derived.
 - b. As a broad range of parameters is being monitored by the proponent, trigger values should be included for relevant additional parameters (e.g., other metals).
 - c. The monitoring locations to which the trigger values will apply need to be clearly specified and justified.
 - d. How the proposed investigation trigger values will be used to identify exceedances and prompt remedial actions requires further detail to ensure that actions are timely.
18. The IESC suggests that the proponent develop a trigger action response plan (TARP) that includes trigger values for a range of parameters and processes that enable the early identification of potential deviation of impacts from predicted levels. The TARP should incorporate early-warning triggers to initiate investigations, trigger values to initiate timely mitigation and management actions to limit impacts, and triggers for ceasing injection.

Date of advice	05 February 2023
Source documentation provided to the IESC for the formulation of this advice	CTSCo 2022. <i>Surat Basin Carbon Capture and Storage Project Environmental Impact Statement</i> . Carbon Transport and Storage Corporation (CTSCo) Pty Ltd. November 2022. (Surat Basin CCS Project EIS).
References cited within the IESC's advice	<p>Barnett, B, Townley, LR, Post, V, Evans, RE, Hunt, RJ, Peeters, L, Richardson, S, Werner, AD, Knapton, A, and Boronkay, A 2012. <i>Australian groundwater modelling guidelines</i>, Waterlines report, National Water Commission, Canberra. Available [online]: Groundwater Modelling Guideline accessed 2 February 2023.</p> <p>CTSCo 2022a. <i>Surat Basin Carbon Capture and Storage Project Executive Summary</i>. Carbon Transport and Storage Corporation (CTSCo) Pty Ltd. November 2022. (Executive Summary of the Surat Basin CCS Project EIS).</p> <p>CTSCo 2022b. <i>Surat Basin Carbon Capture and Storage Project Chapter 10: Surface Water</i>. Carbon Transport and Storage Corporation (CTSCo) Pty Ltd. November 2022. (Chapter 10 of the Surat Basin CCS Project EIS).</p> <p>CTSCo 2022c. <i>Surat Basin Carbon Capture and Storage Project Chapter 22: Proposed Environmental Authority EPPG00640913 Condition Amendments</i>. Carbon Transport and Storage Corporation (CTSCo) Pty Ltd. November 2022. (Chapter 22 of the Surat Basin CCS Project EIS).</p> <p>CTSCo 2022d. <i>Surat Basin Carbon Capture and Storage Project Chapter 14A: Terrestrial Flora and Fauna</i>. Carbon Transport and Storage Corporation (CTSCo) Pty Ltd. November 2022. (Chapter 14A of the Surat Basin CCS Project EIS).</p> <p>CTSCo 2022e. <i>Surat Basin Carbon Capture and Storage Project Chapter 09: Groundwater</i>. Carbon Transport and Storage Corporation (CTSCo) Pty Ltd. November 2022. (Chapter 9 of the Surat Basin CCS Project EIS).</p> <p>CTSCo 2022f. <i>Surat Basin Carbon Capture and Storage Project Chapter 08 Geology</i>. Carbon Transport and Storage Corporation (CTSCo) Pty Ltd. November 2022. (Chapter 8 of the Surat Basin CCS Project EIS).</p>

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- IESC, 2018. *Information Guidelines for proponents preparing coal seam gas and large coal mining development proposals*. Available [online]: [Information guidelines for proponents preparing coal seam gas and large coal mining development proposals | iesc](#) accessed 2 February 2023.
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<https://doi.org/10.1016/j.coal.2022.103966>
- WSP Golder 2022. *Surat Basin Carbon Capture and Storage (CCS) Project Groundwater Assessment Technical Report*. Prepared for Carbon Transport and Storage Corporation (CTSCo) Pty Ltd. 28 September 2022. (Appendix A to Chapter 9 of the Surat Basin CCS Project EIS).
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