

ENCLOSURE

Request for Additional Information

AoR Delineation Modeling Approach

Carbon TerraVault (CTV) IV Carbon Capture and Storage (CCS) Project
Underground Injection Control (UIC) Permit Application
Class VI Pre-Construction Permit Application Nos. R9UIC-CA6-FY23-3.1 to 3.8

This Enclosure for the proposed CTV IV Class VI geologic sequestration project summarizes EPA's review of the computational modeling performed by CTV as described in their permit application, specifically the Area of Review (AoR) and Corrective Action Plan (CAP) document dated April 12, 2023 (also known as Attachment B). Clarifying questions or requests that require further work are provided below in ***bold, italic*** text. Text that is not ***bold, italic*** is provided to give context or is recommended for further work.

Design of the model

1. In Table 3.4, [REDACTED] need to be double-checked for accuracy.
For example: [REDACTED] ***Please double check the calculations in Table 3.4.***
2. The units for the injection rates provided in Attachment B and Appendix 4 are not consistent. ***Please make the units consistent, or otherwise provide an in-situ CO₂ density for the unit conversion.***
3. ***Please clarify how the wellbore was incorporated into the model setup.***
4. Attachment B states that the lateral and vertical extents of the model of the CO₂ plume have been defined with a 0.01 CO₂ global mole fraction cutoff. ***Please explain why a 0.01 CO₂ global mole fraction was selected.***
5. The simulator can accommodate preferential pathways; however, since no preferential pathways have been identified at the site, it is assumed that the model does not include any preferential pathways.
6. Time step values are not discussed explicitly in the application. ***Please explain how time steps for the simulation were selected, including the maximum timestep of the model, and discuss why they are appropriate.***

Model Inputs

7. The initial model conditions for temperature, formation pressure, and salinity are provided in Table 3.3 of Attachment B, but the data sources are not discussed adequately. ***Please provide additional detail of the data sources to demonstrate that the model was run from the initial conditions listed in Table 3.3.***

8. [REDACTED] as shown in Figure 3.9 of Attachment B; however, maps of the permeability and porosity at additional cross-sections are needed. ***Please provide additional cross-sections showing the distribution of the permeability and porosity in other directions to show any variations / heterogeneities within the formation.***
9. Beyond Figure 3.10 and Figure 3.11, there is no discussion of the relative permeability and capillary pressure parameters. ***Please provide a detailed discussion of the relative permeability and capillary pressure parameters, including a discussion as to whether a single set of parameters are used for the full model, or if they are based on facies or absolute permeability.***
10. ***In addition to Figure 3.11, please provide a plot that shows the capillary pressure saturation curves using a log scale for the Y (capillary pressure) axis, to better illustrate the differences (if any) in the entry pressures. Additionally, please provide either tabular data for the k-S-p relations, or the functional forms and parameters used for these relations.***
11. No fracture gradient information was found for the upper confining zone. It is stated that a step rate test for the upper confining zone would be part of the preoperational testing. While there is no fracture gradient for the upper confining zone, the fracture gradient of 0.76 psi/ft is assumed for the injection zone (per Table 3.5 in Appendix B).
12. ***To prove that the proposed injection operation includes an acceptable safety margin, please include plots that show time vs. bottom hole pressure (BHP) for each well.***
13. There are no major structural features (faults, fractures, folds) noted within the geology that can affect fluid flow and thus no such features were represented within the model and AoR. The overlying sealing layer and barrier between upper injection zone and lower injection zone were considered impermeable. No information was given for those impermeable zones.
14. While operational details are presented in tabular format, the application does not include a detailed description of the operational parameters. ***Please provide modeled operation profiles of each well (i.e., time vs. injection mass rate, accumulated injection mass, and BHP) to demonstrate that the dynamic model was modeled as described, and to analyze potential risk of pressure build up around bottom holes.***

Modeling Outcomes

15. The maximum lateral extent of CO₂ plume and pressure front are described in Section 4.0 of Attachment B. Although plots of vertical cross-sections through simulated plumes are shown (Figure 4.2), the vertical extent of the CO₂ plumes are not discussed, and detailed information on the pressure front is lacking. ***Please incorporate pressure maps and BHP of all injection wells over time and show the vertical extent of the CO₂ plume, to better assess potential risks of the local pressure build up around injectors. Also, please discuss the critical pressure calculation and pressure front determination in***

more detail. The information provided at present is not sufficient to verify the calculation.

16. Although the application indicates that the critical pressure is calculated for each grid of the Petrel model, these datasets were not submitted. ***Please submit the relevant datasets (e.g., pressure distribution in the USDW and injection zones, bottom elevation distribution, calculated critical pressure, temperature distribution in all formations, etc.). Additionally, please provide the ranges (min, max, average), in a tabulated fashion, of values used for each of the parameters in the AoR Delineation equations [1] and [2], along with any assumptions and/or sources used in the equations.***
17. Appendix 6 includes many penetrating wells (either abandoned or injectors) within the AoR, but no leakage risk assessment was made. ***Please include an assessment of the risk of leakage for the penetrating wells.***
18. Although the plume development through time is provided in Figure 4.1 and the application describes that “the final AoR boundary was determined by combining the outermost extent of the threshold pressure for the Upper Injection zone (seen at ■ years of injection) and the Lower Injection zone (seen at ■ years of injection),” the application is missing detailed discussion of the extent of the pressure front. ***Please include the lateral extent of the pressure front at additional points over the model timeframe including at 1 year, 5 years, and 30 years.***
19. ***Please add time vs. cumulative CO₂ injection for each well to demonstrate if the operation modeling is performed as described.***
20. ***Please specifically mark CO₂ saturations in maps containing the CO₂ plume.***

Modeling Calibration and Sensitivity Analysis

21. The sensitivity analysis provided is insufficient, making it difficult to determine which modeling parameters are the most impactful. Only the porosity, permeability, and grid size parameters were varied, and the results were not sensitive to these varied parameters, as shown in Table 4.1 of Attachment B. The sensitivity analysis was only discussed qualitatively and consists of variations of the porosities and permeabilities by +/- 10%, which is likely too low. ***Please revisit the sensitivity analysis to add a greater range of uncertainty for permeability, relative permeability, and capillary pressure. A larger range of absolute permeabilities should be considered. The analysis should be quantitative, so consider including an order of magnitude in each direction, instead of 10%.*** The sensitivity analysis should clearly show which parameters have the greatest impact on the modeling results, so it can be determined what parameters may cause the AoR to significantly extend beyond what is presented.
22. ***Please include additional uncertainty simulations with a larger range of absolute permeability and uncertainty simulations that show the impact of capillary pressure and relative permeability.***

23. ***Please confirm that local mesh refinement is used for all the sensitivity / uncertainty analyses.***

Other

24. ***Please revise the model to include the additional simulations:***

- a. Plots and discussion of pressure at the wells as a function of time and pressure distribution throughout the reservoir at various snapshots in time. Consider using the same times as the plume snapshots – 1 year, 5 years, and 30 years.***
- b. An assessment of brine leakage through injection wells into the underground source of drinking water (USDW).***

25. Table 3.4 shows the average [REDACTED], but Appendix 4 indicates the [REDACTED] is variable. ***Please clarify the discrepancy.***