AOR DELINEATION

CTV VI

Computational Modeling Results

1. Predictions of System Behavior

Figure 1 and **Figures 2a through 2g** show the computational modeling results and development of the CO_2 plume at different time steps. The plume boundary is defined by a 0.01 CO_2 global mole fraction cutoff at 100 years post-injection, which results in a boundary that contains 99.99 percent of the total injected CO_2 mass for injection. This cutoff provides confidence that the corrective action well review and potential impact to USDWs is conservative and has been appropriately evaluated. **Figures 2a through 2g** display cross sections of the plume evolution for the base case scenario at each injection well location. The average reservoir pressure in the approximate CO_2 plume area vs. time for [redacted] are shown in **Figure 3**.

[redacted] **Figure 4** shows the cumulative storage for each of the mechanisms.

2. Model Calibration and Validation

In addition to the plume modeling, CTV performed a volumetric estimate of the storage capacity of our plume footprint using U.S. Department of Energy (DOE) methodology (Goodman et al., 2011), using distributions from our geomodel for the storage reservoir and CO2 properties, and storage efficiency coefficients for a deltaic sandstone reservoir using the widely applicable storage efficiency coefficients from Gorecki et al. (2009). The P50 estimate from this volumetric approach was [redacted], which is well over the estimate from our dynamic modeling, which gives us further confidence that our storage capacity estimate from the dynamic modeling is appropriate.

CO_2 Injectate Effect on Plume and AoR Modeling Results

The compositional simulation model developed in CMG GEM software was run for the two simplified injectate compositions discussed in Section 7.2 of **Attachment A**, and their results were also compared against a 100 percent CO_2 injectate case. The cumulative volume, rate, and injection duration for all three cases were kept the same.

The Injection Zones CO_2 plume for Injectate 1 and Injectate 2 is consistent with the plume outline for 100 percent CO_2 injectate (**Figure 5**), with negligible difference among the three cases. The CO_2 plume outline was defined by a 0.01 global CO_2 mole fraction cutoff at 100 years post-injection for all three cases. The 100-year post end of injection plumes for the three cases are shown in **Figure 5.** The wells that fall within the CO_2 plume are the same for all three cases.

Additionally, the average pore volume weighted reservoir pressure within the approximate plume boundary for three Injection Zones was plotted for the three cases and was found to be very close, with a maximum difference of 4 pounds per square inch (psi) seen between the cases, as shown in **Figure 6**. Multiple scenarios were also run to test the effect of mixing Injectate 1 and Injectate 2 in different ratios on the plume shapes. As expected, because the resulting mixed injectates were still high-purity CO_2 streams with impurity concentrations in between those of Injectates 1 and 2, the plume shapes for these scenarios were within the envelope represented by the end-point compositions.

In summary, there is minimal effect of the minor components on the CO_2 plume boundary for the proposed injectate compositions. As such, CTV's plume and AoR modeling for corrective action assessment is adequate for the expected injectate composition ranges. CTV will confirm that the properties of the injectate are consistent with the model inputs during pre-operational injectate sampling, and will do so for any additional sources. In addition, the AoR will be reviewed per **Section 6 Reevaluation Schedule and Criteria**.

Sensitivity Cases

The base model simulation case (base case) contains a realistic representation of the hydrogeologic structure with conservative assumptions about site conditions, making the base case suitable for delineating the AoR. A sensitivity analysis was performed to examine the effects of varying inputs that represent site conditions with the potential to significantly impact the simulation results. The sensitivity analysis scenarios are listed in **Table 1** and include permeability, porosity, phase trapping, relative permeability end points and shape, and capillary pressure. The sensitivity analysis is performed using 100 percent CO_2 injectate in all scenarios. Results from the sensitivity analysis are displayed graphically in **Figure 7 and 8**.

To quantify the results of the sensitivity analysis, the size of the CO_2 plume was measured as an area (using the 0.01 CO_2 global mole fraction cutoff at 100 years post-injection) and the changes are quantified as percentage changes compared with the base case. There are only two cases with a plume size change greater than 10 percent compared to the base case. Case C results in a +34.7 percent plume size change, corresponding to increasing the permeability transform by a multiplier of 3, which is a high-end increase in the system permeability. Case A showed a -12.1 percent plume size change, corresponding to a porosity multiplier of 1.24. In all the sensitivity cases, the resulting CO_2 plume boundaries are similar and do not overlie additional corrective action wells except for Case C. Case C would have the potential to add three corrective action wells within the plume.

Overall, based on these sensitivity analyses, the proposed base case is considered conservative. The sensitivity analysis provides confidence that the corrective action well review and assessment of the potential endangerment of the USDW based on the base case are conservative and have been appropriately evaluated. During pre-operational testing, the model will be updated and the AoR and corrective action wells list will be re-evaluated based on the additional site-specific data gathered.

3. AoR Delineation

AoR delineation consists of determining the outermost extent of the separate-phase CO_2 plume and area of elevated pressure (pressure front) that pose risk to USDWs during the lifetime of the project. Elevated pressure may pose a risk to USDWs due to the potential for brine leakage from the injection zone into a USDW through an existing conduit, such as an improperly abandoned well. In most cases the AoR will at a minimum be defined by the CO_2

plume footprint and may be larger if the pressure front extends beyond the CO_2 plume. CTV VI used the risk-based AOR approach as documented in **Appendix 9: Risk Based AoR Delineation** (**Appendix 9**).

Various methods are available to determine the pressure threshold value that defines the outermost extent of the pressure front. In general, these methods are used to define a pressure at which brine will leak upwards through an abandoned well, leak into a USDW, and endanger the USDW due to water quality impairment. Risk-based AoR delineation accounts for processes that inhibit brine leakage through abandoned wells (e.g., presence of the mud column) and processes that minimize potential USDW impacts from hypothetical brine leakage (e.g., dilution and attenuation in the USDW). Risk-based AoR delineation strategies are supported by the U.S. Environmental Protection Agency (EPA) *Class VI AoR and Corrective Action Guidance* (p. 42).

Appendix 9 risk-based AoR delineation consisted of modeling brine leakage under conservative assumptions and resulting salinity impacts to the lowermost USDW. Brine leakage and USDW salinity transport modeling used conservative assumptions and accepted methods to simulate (1) brine leakage through an abandoned well and (2) subsequent contaminant fate and transport within the lowermost USDW. Modeling indicated that the vast majority of brine leakage through a hypothetical abandoned well in the vicinity of the project would discharge to the Zilch dissipation zone (below the lowermost UDSW); therefore, brine leakage to the USDW would be negligible. Concomitantly, elevated salinity levels in the lowermost USDW are calculated to be negligible. These results were based on an assumed injection-zone pressure increase of 500 psi. CMG-GEM modeling results indicate that a pressure increase of this magnitude will not occur outside the boundary of the CO_2 plume.

Based on these results, pressures great enough to endanger USDWs are not anticipated outside the CO_2 plume footprint, and the final AoR boundary was based on the extent of the CO_2 plume. **Figure 9** shows the AoR extent, injector locations, and proposed monitoring well locations. Details on the monitoring wells are discussed further in **Attachment C**.

Table 1. Simulation sensitivity scenarios

Claimed as PBI

[redacted]

Claimed as PBI

[redacted]

Figure 1. Injection Zone plume development through time: 1-year, 5-year, 10-year, 30-year (end of injection), 50-year, and 100-year post-injection.

Claimed as PBI

Figure 2a. Base case CO_2 well Claimed as PBI CO_2 global mole fraction distribution at 1 year, 5 years, 10 years, 30 years (projected end of injection), 50 years (since start of injection), and 100 years post-injection.

Claimed as PBI

[redacted]

Figure 2b. Base case CO_2 well [redacted] Claimed as PBI CO_2 global mole fraction distribution at 1 year, 5 years, 10 years, 30 years (projected end of injection), 50 years (since start of injection), and 100 years post-injection.

Claimed as PBI

[redacted]

Figure 2c. Base case CO_2 well Claimed as PBI [redacted] CO_2 global mole fraction distribution at 1 year, 5 years, 10 years, 30 years (projected end of injection), 50 years (since start of injection), and 100 years post-injection.

Claimed as PBI [redacted]

Figure 2d. Base case CO_2 well Claimed as PBI [redacted] CO_2 global mole fraction distribution at 1 year, 5 years, 10 years, 30 years (projected end of injection), 50 years (since start of injection), and 100 years post-injection.

Claimed as PBI

Figure 2e. Base case CO_2 well Claimed as PBI CO_2 global mole fraction distribution at 1 year, 5 years, 10 years, 30 years (projected end of injection), 50 years (since start of injection), and 100 years post-injection.

Claimed as PBI

Figure 2f. Base case CO_2 well Claimed as PBI CO_2 global mole fraction distribution at 1 year, 5 years, 10 years, 30 years (projected end of injection), 50 years (since start of injection), and 100 years post-injection.

Claimed as PBI

[redacted]

Figure 2g. Base case CO_2 well Claimed as PBI CO_2 global mole fraction distribution at 1 year, 5 years, 10 years, 30 years (projected end of injection), 50 years (since start of injection), and 100 years post-injection.

Average Reservoir Pressure in Approximate CO2 Plume Area vs. Time

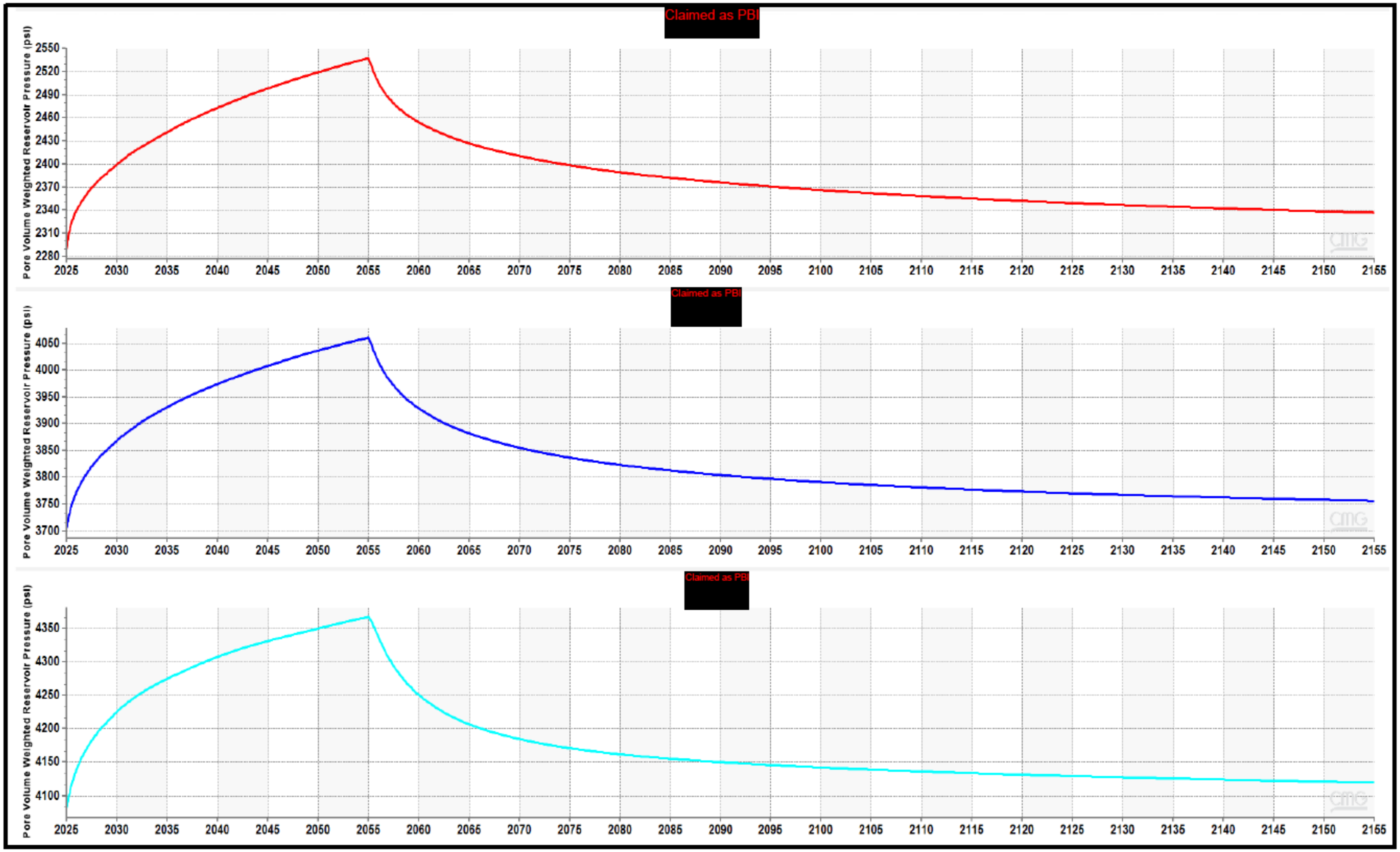

Figure 3. Base case CO_2 Average reservoir pressure within approximate plume area.

Claimed as PBI

[redacted]

Figure 4 CO_2 storage mechanisms in the reservoir

Claimed as PBI

[redacted]

Figure 5. CO_2 plume boundary for Injectate 1 case (light blue dash line), Injectate 2 case (light green dashed line), and Base case CO_2 (red). Larger pink outline is the model boundary. Minimal differences in plume boundaries are observed among the three cases, with boundaries generally overlying each other.

Average Reservoir Pressure in Approximate CO2 Plume Area vs. Time

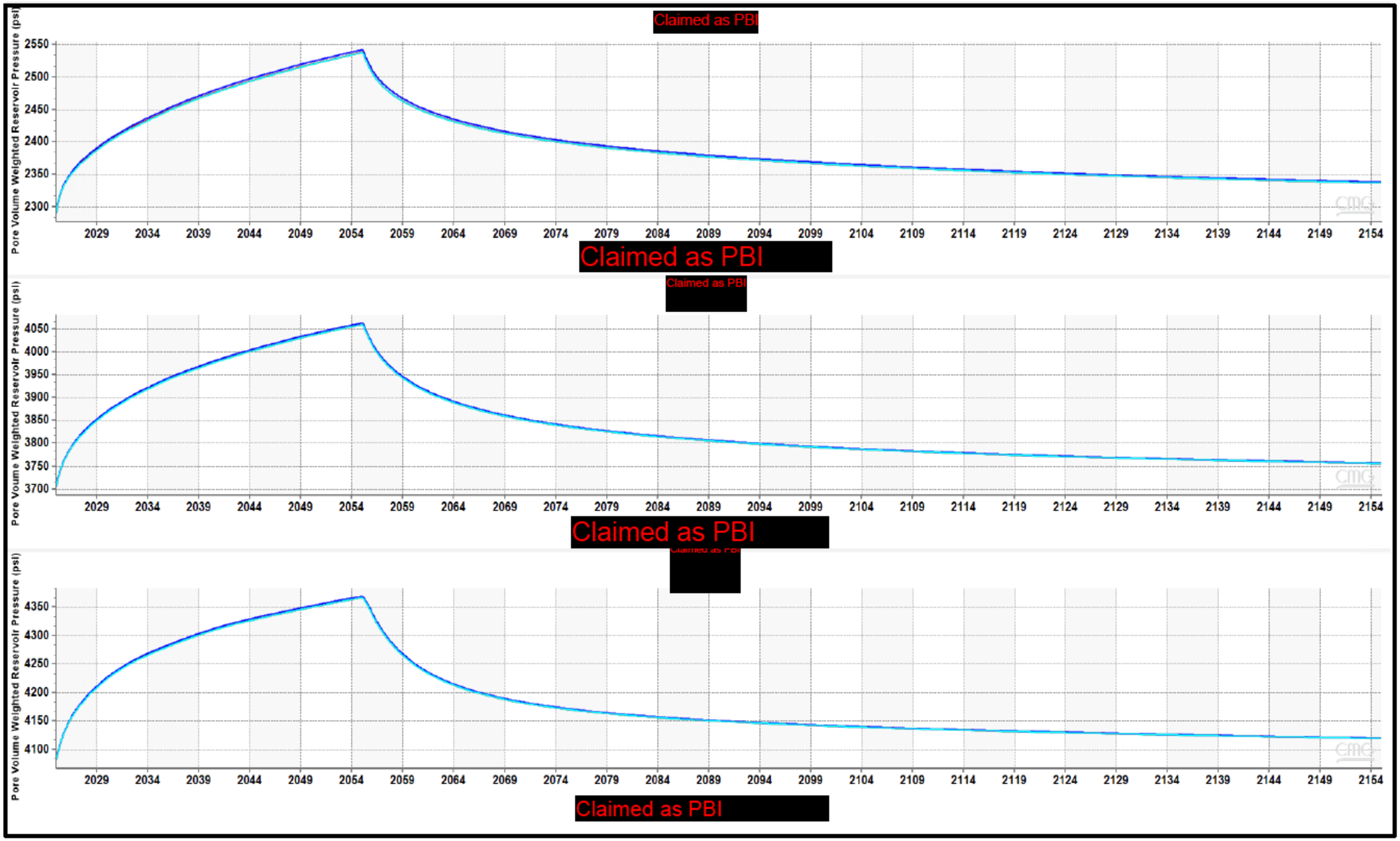

Figure 6. Average reservoir pressure within approximate plume area for Injectate 1, Injectate 2, and Base case (100% CO_2). Pressure trends for all cases plot almost on top of each other.

Claimed as PBI

[redacted]

Figure 7. Submitted plume boundary and CO_2 plume outlines for CASE A to CASE J vs. reference case (Case 0) with 100% CO_2. Larger red outline is model boundary. Minimal difference in plume boundaries for most scenarios except for Case C with extreme parameters. CO_2 plume is defined by 0.01 CO_2 global mole fraction cutoff 100 years post-injection. See **Table 1** for scenario descriptions.

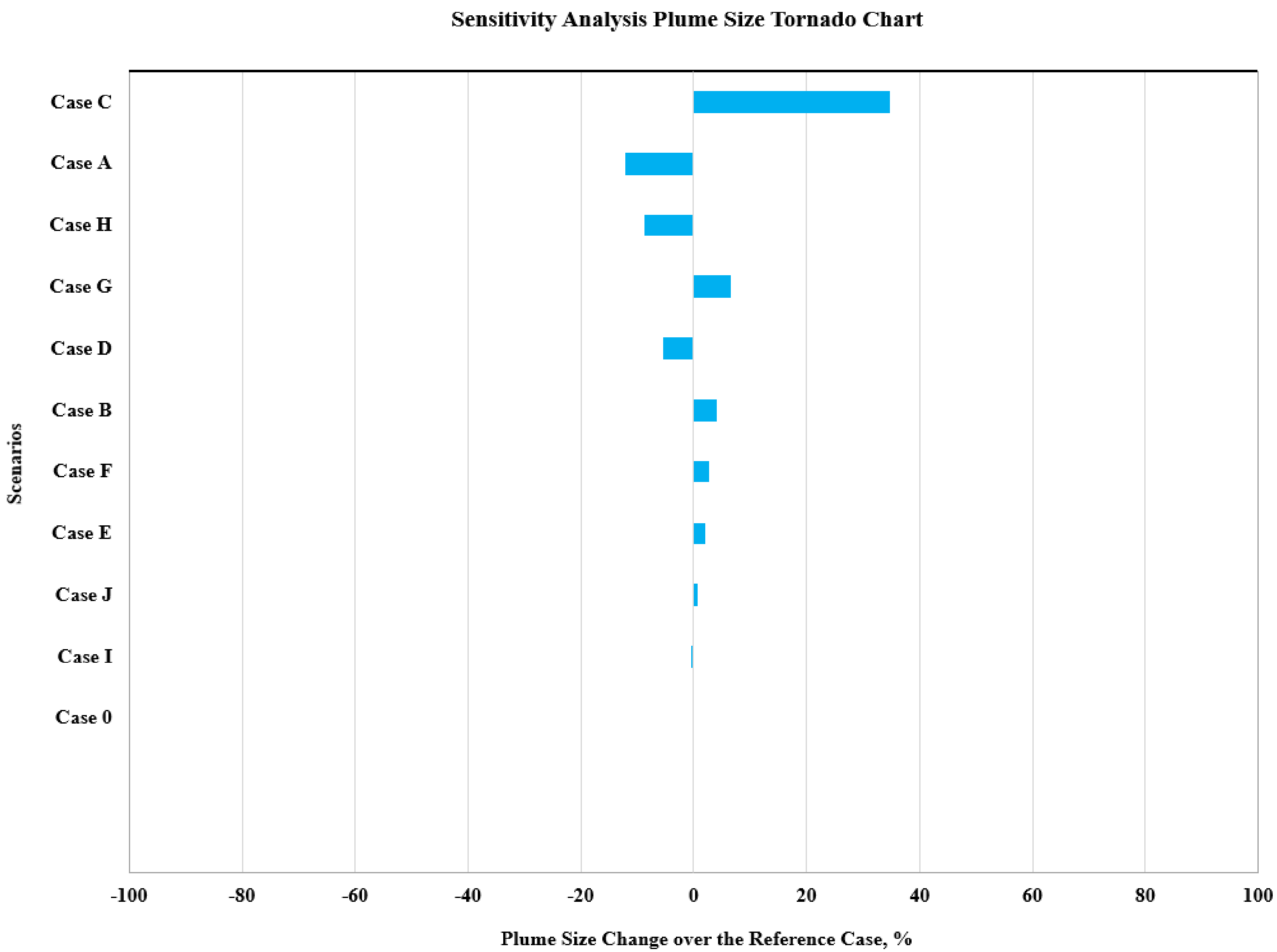

Figure 8. Injection Zone, Sensitivity analysis Tornado chart for plume size. See **Table 1** for scenario descriptions.

Claimed as PBI

[redacted]

Figure 9. Location of injection and monitoring wells.