# ATTACHMENT B: AREA OF REVIEW AND CORRECTIVE ACTION PLAN

## Facility Information

Facility name: Marquis Biocarbon Project
MCI CCS 3

Facility address: 10000 Marquis Dr.
Hennepin, IL 61327

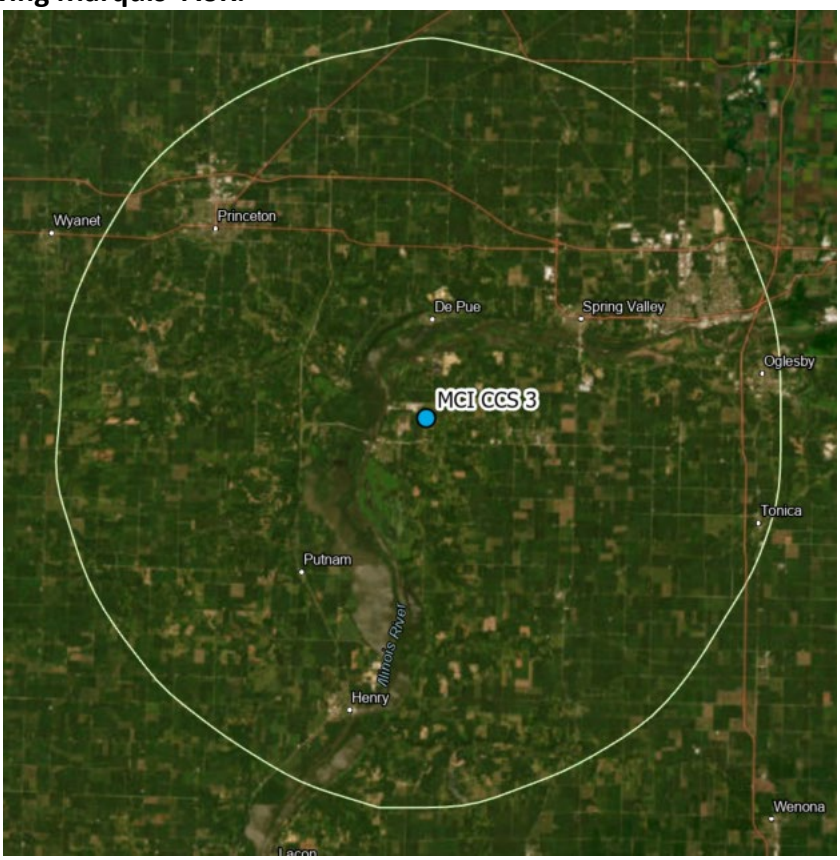
Well location: S2 T32N R2W
41.27026520°N, 89.30939322°W

## Introduction

As a condition of the permit and as required by EPA's regulations set forth at 40 C.F.R. § 146.84, Marquis Carbon Injection LLC (Marquis) must maintain and implement an approved plan to delineate the Area of Review (AoR) for a proposed geologic sequestration project, periodically reevaluate the delineation, and a perform corrective action on all wells in the AoR needing corrective action as determined by the Director.

This attachment to the Permit delineates the AoR, which is the region surrounding the geologic sequestration project where Underground Sources of Drinking Water (USDWs) may be endangered by the injection activity. This attachment also details Marquis' approved plan for how wells within this area will be assessed and addressed by Marquis to ensure containment and corrective action. The map in Figure 1 below presents the AoR based on the approved modeling performed by Marquis.

**Figure 1: Map showing Marquis' AoR.**




## Computational Modeling Approach

The AoR for a Class VI injection project must be delineated using a model that accounts for the physical and chemical properties of all phases of the injected carbon dioxide. 40 C.F.R. § 146.84(a).

Marquis used two models in its Class VI application: a 7x7 mile (mi) model for the $CO_2$ plume and a 100x100 mi model to assess the AoR. The 100x100 mi AoR model is an expansion of the 7x7 mi plume model. That is, it utilized similar parameters. The models were static earth models (SEM) run by Battelle on the Schlumberger Petrel® modeling software. The SEM serves as the framework for Dynamic Reservoir Modeling (DRM) of $CO_2$ injection. The injection of carbon dioxide into a saline aquifer was modeled using the flow simulator CMG-GEM, 2016. Marquis used site-specific data for the modeling. The model simulation used a closed boundary, resulting in a 29-mile diameter AoR 35 miles from the model's edges on each side. A second simulation was run under multiplier boundary conditions (constant pressure boundary) to further confirm the observations that the dynamic reservoir modeling boundary conditions do not significantly impact the AoR size. Model resolution

increased near the injection well. Within 500 feet (ft) of MCI CCS 3, cell size was 62.25 ft x 62.25 ft. This increased to 100 ft x 100 ft within 3,960 ft, and beyond this, 500 ft x 500 ft.

**Figure 2: Map showing the modeled CO2 plume footprint, and existing and proposed project.**


Legend

- Proposed Injection Well (MCI CCS 3)
- Proposed Monitoring Well – Above Confining Zone (ACZ 1)
- Proposed Monitoring Well – Deep (MW 1, MW 2)
- Proposed Monitoring Well – Shallow Groundwater – (GW 1, GW 2, GW 3, GW 4)
- Existing J&L Well
- Plume Extent
- Approx. Location of New or Existing GW 5 Shallow Monitoring Well
  - Box denotes Plume Extent, 50 years post-injection

**Figure 3: Stratigraphic column with lithology and hydrostratigraphy for the Marquis site based on data from the characterization well, MCI MW 1.**

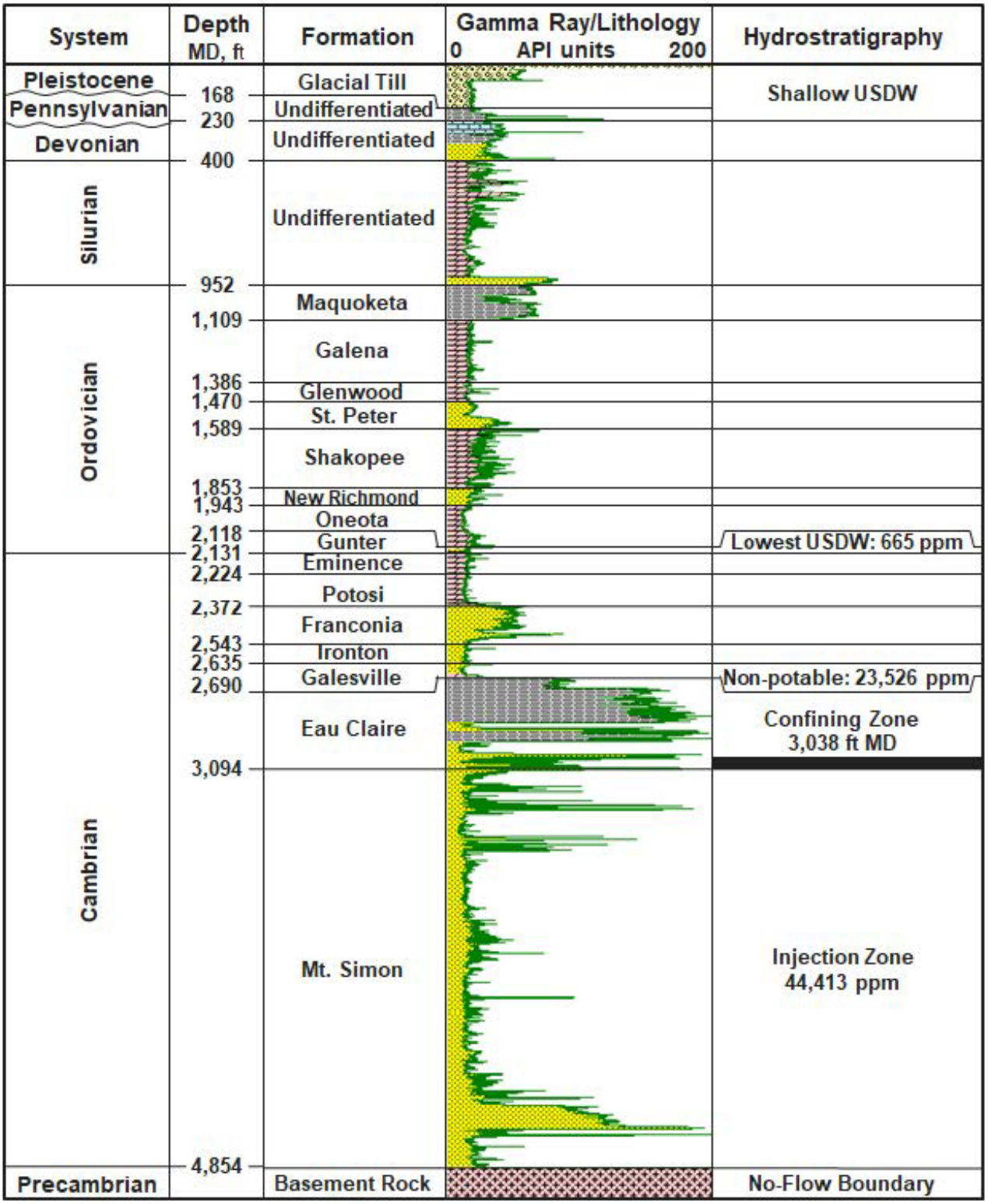


**Table 1: Proposed zone for injection reservoir at the Marquis project area, as identified in the MCI MW 1.**

| Injection zone | Formation Thickness (ft) | Depth (ft) | Avg. Porosity (%) | Avg. Permeability (mD) |
|---|---|---|---|---|
| Mt. Simon Sandstone | 1,760 | 3,094 | 7.9 | 79.9 |

**Table 2: Model domain information.**

| | | | |
|---|---|---|---|
| **Coordinate System** | NAD 1983 BLM Zone 16N ft US | | |
| **Horizontal Datum** | NAD83 | | |
| **Coordinate System Units** | Field = feet | | |
| **Zone** | UTC -06:00 Central Time (US & Canada) | | |
| **FIPSZONE** | 1202 | **ADSZONE** | 3801 |
| **Coordinate of X min** | 735761.96 | **Coordinate of X max** | 14729359.72 |
| **Coordinate of Y min** | 1274438.25 | **Coordinate of Y max** | 15267988.58 |
| **Elevation of top of domain** | -4851.12 | **Elevation of bottom of domain** | -1903.17 |

**Table 2: Initial Modeled Conditions.**

| Parameter | Value or Range | Units | Corresponding Elevation (ft MSL) | Data Source |
|---|---|---|---|---|
| Temperature | 81.5<br>83.34<br>92.6 | F | Top Eau Claire: 2,699<br>Top Mt. Simon: 3,068<br>Base Mt. Simon: 4,912 | Temperature Log |
| Formation pressure | 0.44 | psi/ft | 2,699 – 4,912 | Drill Stem Testing |
| Fluid density | 0.029 | $lb/ft^3$ | 2,699 – 4,912 | CMG Reservoir Simulator Calculation |
| Salinity | 45000 | ppm | 2,699 – 4,912 | Drill Stem Testing |

Table 3: Modeled Operating Parameters.

| Operating Information | | MCI CCS 3 |
|---|---|---|
| Location (global coordinates) | X<br>Y | 41.27026520°<br>-89.30939322° |
| Model coordinates (ft) | X<br>Y | 987293.52°<br>14979542.23° |
| No. of perforated intervals | | 5 |
| Perforated interval (ft MSL) | Z Top<br>Z Bottom | 3225 – 3383<br>3445 – 3488<br>3519 – 4137<br>4268 – 4290<br>4411 – 4791 |
| Wellbore diameter (in) | | 9 5/8 |
| Planned injection period | Start<br>End | |
| Injection duration (years) | | 6 |
| Maximum injection rate (million tonnes (MT)/year) | | 1.5 |

**Table 5: Parameters and values used as input in the critical pressure calculation.**

| Parameter | Value | Units | Source |
|---|---|---|---|
| Pressure at the base of the lowermost USDW | 895.99 | psi | MCI MW 1 |
| Depth to base of lowermost USDW | 2,140 | ft | MCI MW 1 |
| Depth to top of injection zone | 3,054 | ft | MCI MW 1 |
| Hydrostatic injection zone pressure | 1,343.15 | psi | MCI MW 1 |
| Fluid density within the injection zone | 1,051.48 | $kg/m^3$ | MCI MW 1 |

**Corrective Action Plan and Area of Review Re-evaluation**

This Corrective Action Plan and Area of Review Re-evaluation describes how Marquis will comply with the plan requirements at the Permit CCS Project site pursuant to 40 C.F.R. § 146.84 and per Section G of this permit. Data from MCI MW 1 indicates that the top of the confining zone at the project site is 2,690 ft MD (Figure 1). There are 6 wells within the AoR not associated with the Marquis project that partially penetrate the local confining zone depth (i.e., 2,690 ft MD), and a seventh non-project well approximately 1.25 mi from the injection well that penetrates the entire confining zone: the J&L well. The J&L well was properly plugged and abandoned in 2013 using cement suitable for contact with brine and acid. Data collected as part of the Testing and Monitoring Plan (See attachment C of this permit) will be evaluated to assess the prohibition of fluid movement and protection of USDWs. The Corrective Action Plan will be re-evaluated in accordance with this permit and all applicable regulations.

Monitoring well MCI MW-2 is predicted to come into contact with the injected $CO_2$ per this permit's computational modeling. Should the subsurface $CO_2$ plume interact with any additional well(s) or be predicted to interact with any additional well(s) per a revision to the project's computational modeling, such wells interacting or predicted to interact with the subsurface $CO_2$ plume will be evaluated for proper construction materials for the environment to which the wells will be exposed. The results of the well construction materials evaluation must be submitted to the Director within 14 days of the permittee learning of the interaction or predicted interaction. Within 45 days of the permittee learning of the interaction or predicted interaction, the permittee must submit a corrective action plan to address any construction deficiencies and must complete any corrective actions within a timeframe acceptable to the Director.

**Reevaluation of CAP: Schedule and Criteria**

Marquis will take the following steps to evaluate project data and, if necessary, reevaluate the AoR. AoR reevaluations will be performed during the injection and post-injection phases at least every 5 years. Marquis will:

1) Review available monitoring data and compare it to the model predictions. Marquis will analyze monitoring and operational data from the injection well, the formation monitoring wells and confinement monitor wells, and other sources to assess whether the predicted carbon dioxide plume migration is consistent with actual data. Monitoring activities to be conducted are described in the Testing and Monitoring Plan and the Post Injection Site Care (PISC) and Closure Plan. Specific steps of this review include:

    a) Reviewing available data on the position of the carbon dioxide plume and pressure front.
        i) Both direct and indirect methods will be used to monitor the carbon dioxide plume and pressure front. See Attachments C, E, and K for more information.

    b) Reviewing groundwater chemistry monitoring data taken in the Gunter Sandstone, Galesville Sandstone, and Mt. Simon Sandstone to verify that there is no evidence of excursion of carbon

dioxide or brines that represent an endangerment to any USDWs.

c) Reviewing operating data, e.g., on injection rates and pressures, and verifying that it is consistent with the inputs used in the most recent modeling effort.

d) Reviewing any geologic data acquired since the last modeling effort, e.g., additional site characterization performed, updates of petrophysical properties from core analysis, etc. Identifying whether any new data materially differ from modeling inputs/assumptions.

2) Compare the results of computational modeling used for AoR delineation to monitoring data collected. Monitoring data will be used to show that the computational model accurately represents the storage site and can be used as a proxy to determine the plume's properties and size. Marquis will demonstrate this degree of accuracy by comparing monitoring data against the model's predicted properties (i.e., plume location, rate of movement, and pressure decay). Statistical methods will be employed to correlate the data and confirm the model's ability to accurately represent the storage site.

3) If the information reviewed is consistent with, or is unchanged from, the most recent modeling assumptions or confirms modeled predictions about the maximum extent of the plume and pressure front movement, Marquis will prepare a report demonstrating that, based on the monitoring and operating data, no reevaluation of the AoR is needed. The report will be submitted to the Director within 30-days of its review of the data and will include the data and results demonstrating that no changes are necessary. Marquis will review all data within 90-days of the commencement of Marquis 5-year review process.

4) If changes have occurred (e.g., in the behavior of the plume and pressure front, operations, or site conditions) such that the actual plume or pressure front may extend beyond the modeled plume and pressure front, Marquis will re-delineate the AoR. The following steps will be taken:

a) Revise the site conceptual model based on new site characterization, operational, or monitoring data.
    i. Reevaluation of the AoR and CAP must meet the requirements of 40 C.F.R. § 146.84(e) and must include a new survey of wells within the existing or modified AoR.

b) Calibrate the model in order to minimize the differences between monitoring data and model simulations.

c) Perform the AoR delineation as described in the Computational Modeling section of the AoR and Corrective Action Plan.

5) Review wells in any newly identified areas of the AoR and apply corrective action to deficient wells. Specific steps include:

a) Identifying any new wells within the AoR that penetrate the confining zone and provide a description of each well type, location, depth, and date of plugging/completion.

b) Performing corrective action on all deficient wells that penetrate the primary confining zone using methods designed to prevent the movement of fluid into USDWs.

6) Prepare an annual report documenting the AoR reevaluation process, data evaluated, any corrective actions determined to be necessary, and the status of corrective action or a schedule for any corrective actions to be performed. The report will be submitted to EPA per the schedule for submitting annual reports in this permit. The report will include maps that highlight the similarities and differences in comparison with previous AoR delineations.

**AoR Reevaluation Cycle**

Upon commencement of injection, Marquis will reevaluate the above described AoR at least once every 5 years during the injection and post-injection phases. More frequent reviews may occur if any of the events described in the next section occur or at the discretion of the Director. Marquis will also review this AoR and corrective action plan following any AoR reevaluation and submit an amended plan or demonstrate to the Director that no amendment to the AoR and corrective action plan is needed. Marquis must retain all modeling inputs and data used to support AoR reevaluations for 10 years.

**Triggers for AoR Reevaluations Prior to the Next Scheduled Reevaluation**

Unscheduled reevaluation of the AoR will be based on quantitative changes of the monitoring parameters in the deep monitoring wells, including unexpected changes in pressure, temperature, neutron saturation, and deep groundwater constituent concentrations indicating that the actual plume or pressure front may extend beyond the modeled plume and pressure front. These changes may include but are not limited to:

1) **Pressure:** Changes in pressure that are unexpected and outside three standard deviations from the average will trigger a new evaluation of the AoR.

2) **Pressure front arrival**: If the arrival time of the pressure front at the deep monitoring well differs significantly from the model projections (2 standard variations) or if the pressure and plume data recorded at the well differs materially from expectations, an AoR reevaluation will be performed.

3) **Change in pressure front not seen in monitoring well**: A reevaluation of the AoR will be triggered in the event that a secondary means of pressure front and/or plume distribution is detected (such as through seismic observation).

4) **AoR interaction:** Potential interaction of AoRs from different wells: Future modeling could indicate possible interactions of AoRs from different injection wells in the same injection zone. This has the

potential to change the evaluation schedule (i.e., cause an unscheduled AoR reevaluation) to assess the possible impact of such an occurrence.

5) **Temperature:** Changes in temperature that are unexpected and outside three standard deviations from the average will trigger a new evaluation of the AoR.

6) **RST saturation:** Increases in carbon dioxide saturation that indicate the movement of the carbon dioxide into or above the confining zone will trigger a new evaluation of the AoR unless the changes are found to be related to the well integrity. Marquis must investigate and address any well integrity issues pursuant to 40 C.F.R. § 146.88(d) and (f).

7) **Deep groundwater constituent concentrations:** Unexpected changes in fluid constituent concentrations that indicate movement of the carbon dioxide or brines into or above the confining zone will trigger a new evaluation of the AoR unless the changes are found to be related to the well integrity. Marquis must investigate and address any well integrity issues pursuant to 40 C.F.R. § 146.88(d) and (f).

8) **Exceeding fracture pressure conditions:** Pressure in any of the injection or monitoring wells exceeding 90 percent of the geologic formation fracture pressure at the point of the measurement. This would be a violation of the permit conditions. The Testing and Monitoring Plan and the operating procedures in the Narrative provides a discussion of pressure monitoring and specific procedures that will be completed during the injection start-up period and continuing operations.

9) **Exceeding established baseline hydrochemical/physical parameter patterns:** A statistically significant difference between observed and baseline hydrochemical/physical parameter patterns (e.g., fluid conductivity, pressure, temperature) immediately above the confining zone. The Testing and Monitoring Plan provides extended information regarding how pressure, temperature, and fluid conductivity will be monitored.

10) **Compromise in injection well mechanical integrity:** A significant change in pressure within the protective annular pressurization system surrounding each injection well that indicates a loss of mechanical integrity at an injection well.

An unscheduled AoR reevaluation will also be needed if it is likely that the actual plume or pressure front may extend beyond the modeled plume and pressure front because any of the following has occurred:

1) Seismic event greater than $M_w$ 3.5 within 100 km the injection well.

2) If there is an exceedance of any Class VI operating permit condition (e.g., exceeding the permitted volumes of carbon dioxide injected); or

3) If new site characterization data changes the computational model to such an extent that the predicted plume or pressure front exceeds, or is expected to exceed, vertically or horizontally beyond the predicted AoR.

Marquis will discuss any such events with the Director to determine if an AoR reevaluation is required. If an unscheduled reevaluation is triggered, Marquis will reevaluate the AoR in accordance with the regulations.

**Table 6: Observed changes in monitoring data that may trigger an AoR re-evaluation.**

| Observed Change | Monitoring Technology |
|---|---|
| Significantly larger pressure increases in the Mt. Simon Sandstone in the monitor well than were predicted by the model | Pressure sensors |
| Early breakthrough of $CO_2$ at the monitoring well | Fluid sampling<br>Pulsed neutron logging |
| $CO_2$ plume expands at a rate inconsistent with what the model predicted | Time-lapse surface seismic data |
| Sustained pressure increases observed in above confining zone in the MCI ACZ 1 monitoring well intervals | Pressure sensors |
| Geochemical changes in the MCI ACZ 1 monitoring intervals indicate potential $CO_2$ or brine migrations above the confining layer | Fluid sampling |
| $CO_2$ accumulations identified in the MCI ACZ 1 intervals | Pulsed neutron logging<br>Time-lapse surface seismic data |