ATTACHMENT C: TESTING AND MONITORING 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

This Testing and Monitoring Plan describes how Marquis will monitor the Marquis Biocarbon Project site pursuant to 40 C.F.R. § 146.90 and per Section N of this permit. The Marquis Biocarbon Project will utilize one injection well to achieve the required annual injection rate. The Testing and Monitoring plan includes activities related to the injection well and the associated carbon dioxide plume. Marquis will use the monitoring data to demonstrate that the well is operating as planned, the carbon dioxide plume and pressure front are moving as predicted, and there is no endangerment to underground sources of drinking water (USDWs). Marquis will also use the monitoring data to validate and adjust the geological models used to predict the distribution of the carbon dioxide within the storage zone to support Area of Review (AoR) reevaluations and a non-endangerment demonstration.

Results of the testing and monitoring activities described below may require Marquis to take action as described in the Emergency and Remedial Response Plan in Attachment F of this permit.

Testing and Monitoring Schedule of Sampling

All testing and monitoring will be conducted in accordance with the requirements of this permit, and the procedures will meet the requirements of the Quality Assurance and Surveillance Plan (QASP) in Attachment K of this permit.

The schedule of sampling is as follows:

1) Continuous: Data is continuously sampled and recorded per the frequencies presented in Table 2 of this attachment.
2) Quarterly: Sampling will take place within 5 days before the following dates each year: March 31st, June 30th, September 30th, December 31st.
3) Semi-annual: Sampling will take place within 5 days before June 30th and December 31st.
4) Annual: Sampling will take place within 45 days before January 1st of each year.
5) 5 Year: Sampling will take place every 5 years within 45 days before January 1st during injection and PISC periods (i.e., 5, 10, 15, etc. years after commencement of injection until site closure).

Measurement, Monitoring and Verification (MMV) Technologies

Two key objectives of any risk assessment evaluation and the development of a viable MMV plan are to:

1) Ensure Conformance by demonstrating that storage performance aligns with expectations regarding injectivity, capacity, and carbon dioxide behavior inside the geologic storage reservoir; and
2) Ensure Containment, which demonstrates security of carbon dioxide storage to protect human health, groundwater resources, hydrocarbon resources (if present), and the environment, and meets regulatory requirements.

Reporting procedures

Marquis will report the results of all testing and monitoring activities to the EPA in compliance with this attachment, the requirements under 40 C.F.R. § 146.91, and Section O of this permit.

Carbon Dioxide Stream Analysis

Marquis will analyze the carbon dioxide stream during the operation period with sufficient frequency to yield data representative of its chemical and physical characteristics and to meet the requirements of 40 C.F.R. § 146.90(a). Sampling will take place continuously via permanently installed field analysis equipment. Marquis will sample and analyze the carbon dioxide stream as presented below.

Analytical Parameters

Marquis will employ continuous monitoring of the carbon dioxide stream with in-situ analysis at the Permit facility. Samples of the injection stream will be collected for chemical analysis. The CO_2 compression system that will be used to inject the off gases into the MCI CCS 3 well has been selected. The compressor design includes the use of a triethylene glycol (TEG) gas dehydration system to remove moisture from the gas stream. The carbon dioxide will be sampled for the following parameters:

Table 1: CO_2 Stream Analytical Parameters.

Parameter	Analytical Method(s)
Oxygen	Mass Spectrometer
Nitrogen	Mass Spectrometer
Carbon Monoxide	Mass Spectrometer
Oxides of Nitrogen	Mass Spectrometer
Total Hydrocarbons	Mass Spectrometer
Methane	Mass Spectrometer
Hydrogen Sulfide	Mass Spectrometer
Carbon Dioxide Purity	Mass Spectrometer
Moisture	Hygrometer

If at any time this continuous monitoring reveals a substantive change from expected for the carbon dioxide stream, process troubleshooting will begin to determine the root cause of the carbon dioxide quality deviation. If carbon dioxide purity falls below 99.86% causes will be investigated and AoR re-modeling will be initiated, if appropriate.

Continuous Recording of Operational Parameters

As required by 40 C.F.R. § 146.90(b), Marquis will install and use continuous recording devices to monitor injection pressure, rate, and mass; the pressure on the annulus between the tubing and the long string casing; the fluid volume added to or produced from the annulus; and the temperature of the carbon dioxide stream.

System Operation Monitoring

Marquis will perform the activities identified here and in the QASP in Attachment K to continuously monitor operational parameters listed in Appendix A and verify internal mechanical integrity of the injection well. All monitoring will take place at the locations and frequencies shown in the table below.

Table 2: Sampling devices, locations, and frequencies for continuous monitoring.

Parameter	Device(s)	Location	Min. Sampling Frequency	Min. Recording Frequency
Injection Pressure at Wellhead	Pressure Transducer	Wellhead	Every 1 min.	Every 1 min.
Injection Pressure at Formation (downhole)	Pressure Transducer	Tubing string above injection packer	Every 1 min.	Every 1 min.
Mass Injection Rate	Coriolis Flow Meter	After Compressor before wellhead (Pre- Wellhead)	Every 10 sec.	Every 10 sec.
Annular Surface Pressure	Pressure Transducer	Wellhead Annulus Monitoring System (WAMS) Surface Skid	Every 1 min.	Every 1 min.
Annular Downhole Pressure	Pressure Transducer	Above Injection Packer	Every 1 min.	Every 1 min.
Annulus Fluid Volume Added	Volume Level Instrument	WAMS Surface Skid	Every 1 min.	Every 1 min.
CO_2 Stream Temperature (surface injection)	Thermocouple	Wellhead	Every 1 min.	Every 1 min.
CO_2 Stream Temperature (downhole)	Thermocouple	Tubing string above packer	Every 1 min.	Every 1 min.
Wellbore Temperature Profile	Distributed Temperature Sensing (DTS) Fiber Optic	Distributed Temperature Sensing (DTS) Fiber Optic	Annual	Annual

Notes:

- Sampling frequency refers to how often the monitoring device obtains data from the well for a particular parameter. For example, a recording device might sample a pressure transducer monitoring injection pressure once every two seconds and save this value in memory.
- Recording frequency refers to how often the sampled information gets recorded to digital format (such as a computer hard drive). For example, the data from the injection pressure transducer might be recorded to a hard drive once every minute.

System Monitoring details

The monitoring of the injection operations will be conducted through a distributed control system (DCS), and the computerized system will collect data from the sensors and record that data. The DCS system will also use alarms that will notify if the injection system is out of a specified range of operational parameters detailed in Attachment A, and if the operational parameters are exceeded, the DCS will shut down the system. The managers, supervisors, and operators will have the capability to monitor the injection system from Marquis' control centers.

Any pressure anomalies outside of the normal operating specifications may indicate that an issue has occurred with the well, such as a loss of mechanical integrity or blockage in the tubing or a change in injection flowrate. Anomalous pressure measurements would trigger the need for further investigation of the cause of the change (40 C.F.R. § 146.89(b)).

The temperature of the CO_2 injection stream will be continuously measured using an electronic thermocouple. The thermocouple will be mounted in a temperature thermowell in the CO_2 injection stream at a location close to the pressure transmitter near the wellhead. The transmitter will be electronically connected to the DCS system. The transmitter will be calibrated prior to the start of injection operations and calibrated annually per manufacturer's instructions.

The wellhead pressure of the injected CO_2 will be continuously measured by an electronic pressure transducer located after the compression system and before the wellhead with the MCI CCS 3 well. The transmitter will be electronically connected to the DCS system located in the Control Building, which can shut down the system or change the flowrate depending on the pressures measured at the wellhead. The transducer will be calibrated prior to the start of injection operations, and as recommended by the manufacturer thereafter.

The pressure on the annulus between the injection tubing and the long-string casing will be measured by an electronic pressure transducer with output, such as a Foxboro I/A Series® IAP20 or similar, that is mounted on the wing valve/annular fluid line connected to the wellhead of the MCI CCS 3 well. The transmitter will be connected to the well control system and the DCS system to regulate the annular pressure.

The volume of the annulus fluid between the injection tubing and the long-string casing will be measured using the brine reservoir level on the well annular control system. The brine reservoir level will be measured using a level transmitter (Rosemont 3051CD2A22A1AE5M5 or equivalent). The transmitters will be connected to the DCS system to regulate the annular pressure.

Annular pressure in MCI CCS 3 is expected to vary up to 20% during normal operations due to atmospheric and CO_2 stream temperature fluctuations. The annular pressure gauge will be calibrated annually, and the transducer will be recalibrated according to the manufacturer's recommendations. Annular pressure between the casing and tubing string in the MCI MW 1, MCI MW 2, and MCI ACZ 1 wells will be monitored using a simple pressure gauge at the wellhead checked weekly.

Pressure and temperature data will be recorded from MCI CCS3 continuously on surface and in down hole before and after injection. The pressure and temperature will be measured using a pressure transducer and thermocouple, respectively. The surface and down hole pressure and temperature equipment will be calibrated over the full operational range according to manufacturers' specifications or recognized industry standards.

In accordance with the AoR recalculation schedule, the data collected during the monitoring program will be analyzed and interpreted annually. The data will then be integrated into the static and dynamic models every 5 years or 4 million tons whichever is earlier, incorporating the data collected in the storage formation. The pressure, temperature, and CO_2 plume data will be crucial to the AoR update. If there is confirmed anomalous data that could affect the AoR or CO_2 plume development, the static and dynamic models will be updated to show the effect of the data on the modeling results. AoR will then be re-established, and any necessary corrective actions will be taken.

Injection Rate and Pressure Monitoring

The Surface Facility Equipment and Control System will limit the bottomhole pressure to the maximum injection pressure (MIP) listed in Attachment A of this permit. NOTE: The injection pressure limit may be changed if the Fracture Gradient is significantly different during subsequent well testing during the drilling of the injection well(s). All injection operations will be continuously monitored and controlled by Marquis operations staff using the DCS system. This system will continuously monitor, control, record, and will alarm and shutdown if specified control parameters, identified in Attachment A, exceed their normal operating range.

These set points may need to be adjusted after the injection well is constructed and the startup testing has been conducted. The final alarm set points will be included in the startup report submitted to EPA.

More specifically, all critical system parameters, e.g., pressure, temperature, and flow rate will have continuous electronic monitoring with signals transmitted back to a master control system. Operators will monitor the status of the entire system from the main operations control room.

Calculation of Injection Volumes

The mass flowrate of CO_2 injected into the well will be measured by a Coriolis mass flow meter. This flow meter will be placed in the CO_2 delivery line between the final compressor and the well. The Coriolis mass flow meter flow transmitter will have an output for instantaneous flow rates and density values along with a pulse output for totalization values (Micro Motion Elite Coriolis mass flow and density meter or similar). The Coriolis meter flow transmitter and P/T compensation transmitters will all be connected to the Measurement RTU flow computer system (Fisher FB 3000) for continuous monitoring and control of the CO_2 injection rate into the well. A hardwired signal will be connected from the Measurement RTU flow computer to the main DCS control panel via PROFINET. Two Coriolis mass flow meters will be supplied; this will provide one spare flow meter to allow for flow meter servicing and calibration. The mass flow meters will be calibrated annually.

Continuous Monitoring of Annular Pressure

Marquis will use the procedures below to monitor annular pressure. The following procedures will be used to limit the potential for any unpermitted fluid movement into or out of the annulus:

1) The annulus between the tubing and the long string of casing will be filled with brine. The brine will have a specific gravity and a density that meets the requirements of the downhole conditions. The final values will be determined after the construction of the injection well.
2) The surface annulus pressure will be kept at a minimum of 100 pounds per square inch (psi) during injection (This is subject to changes based upon actual conditions encountered at the injection site).
3) During periods of well shut down, the surface annulus pressure will be kept at a minimum pressure to maintain a pressure differential of at least 100 psi between the annular fluid directly above (higher pressure) and below (lower pressure) the injection tubing packer set at 3,000’ MD depth.
4) The pressure within the annular space, over the interval above the packer to the confining layer, will be greater than the pressure of the injection zone formation at all times.
5) The pressure in the annular space directly above the packer will be maintained at least 100 psi higher than the adjacent tubing pressure during injection.

Casing-Tubing Pressure Monitoring

Marquis will monitor the casing-tubing pressure on a continuous basis. During the injection timeframe of the project, the casing-tubing pressure will be monitored and recorded in real time. Surface pressure of the casing-tubing annulus is anticipated to be 956 psi. As detailed in the Emergency and Remedial Response Plan in Attachment F, significant changes in the casing-tubing annular pressure will be investigated.

Corrosion Monitoring

To meet the requirements of 40 C.F.R. § 146.90(c) and Section N(6) of this permit, Marquis must monitor well materials during the operational period for loss of mass, thickness, cracking, pitting, and other signs of corrosion to ensure that the well components meet the minimum standards for material strength and performance set forth in 40 C.F.R. § 146.86(b).

Monitoring Location and Frequency

This monitoring will occur quarterly, in accordance with Section N and Attachment A of this permit. Marquis will monitor corrosion using Corrosion Coupon Method and collect samples according to the description below.

Sample Description

Samples of material used in the construction of the compression equipment, pipeline and injection well which come into contact with the carbon dioxide stream will be included in the corrosion monitoring program either by using actual material and/or conventional corrosion coupons. The samples consist of those items listed in Table 3 below. Each coupon will be weighed, measured, and photographed prior to initial exposure (see "Sample Handling" below).

Table 3: List of equipment coupon with material of construction.

Equipment Coupon	Material of Construction
Pipeline	Carbon Steel Alloy
Long String Casing	25Cr Steel Alloy/ 13Cr Steel Alloy
Injection Tubing	25Cr Steel Alloy
Wellhead	Carbon Steel Alloy
Packers	25Cr Steel Alloy Corrosion resistant material

Monitoring details

Marquis will include the following elements in the monitoring program: continuous recording of injection pressure; continuous recording of injection mass flowrate; dynamic modeling; continuous recording of annular pressure; continuous recording of annulus fluid volume; continuous recording of CO_2 stream temperature; and down hole pressure and temperature. See "System Monitoring details" above for further discussion.

A bailer system will be used to collect the fluid samples to evaluate geochemical changes in groundwater fluids. Samples will be analyzed for field constituents using a calibrated water quality meter (Horiba U-53, or similar). The geochemical analyses will be performed by a qualified laboratory. The isotopic analyses will be performed by a qualified laboratory.

Sample Handling

A nationally accredited environmental laboratory will analyze the CO_2 stream samples. The third-party laboratory will follow standard sample handling and chain-of-custody guidance (EPA 540-R-09-03, or equivalent).

Sample holding times will be consistent with standard methods, identified in Attachment K. After collection and any necessary preservation, samples will be placed in ice chests in the field and maintained thereafter at approximately 4 degrees Celsius (°C) until analysis. The samples will be maintained at their preservation temperature and sent to the designated laboratory within 24 hours.

Above Confining Zone Groundwater Monitoring

Marquis will monitor groundwater quality and geochemical changes above the confining zone during the operation period to meet the requirements of 40 C.F.R. § 146.90(d) and Section N(4) of this permit.

Monitoring Location and Frequency

Table 4: Monitoring of groundwater quality and geochemical changes above the confining zone.

<table>
<tr><th>Target Formation</th><th>Monitoring Activity</th><th>Monitoring Location(s)</th><th>Spatial Coverage</th><th>Frequency</th></tr>
<tr><td>Gunter Sandstone</td><td>Pressure/ Temperature</td><td>MCI ACZ 1</td><td>1 sample point @2,118 ft</td><td>Continuous (Every minute)</td></tr>
<tr><td rowspan="2">Gunter Sandstone</td><td>Groundwater Geochemistry</td><td rowspan="2">MCI ACZ 1</td><td rowspan="2">1 sample point @2,118 ft</td><td>Twice / year (Note 1)</td></tr>
<tr><td>Stable Isotopes</td><td>Twice / year</td></tr>
<tr><td>Galesville Sandstone</td><td>Pressure/ Temperature</td><td>MCI ACZ 1</td><td>1 sample point @2,635 ft</td><td>Continuous (Every minute)</td></tr>
<tr><td rowspan="2">Galesville Sandstone</td><td>Groundwater Geochemistry</td><td rowspan="2">MCI ACZ 1</td><td rowspan="2">1 sample point @2,635 ft</td><td>Twice / year (Note 1)</td></tr>
<tr><td>Stable Isotopes</td><td>Twice / year</td></tr>
</table>

Target Formation	Monitoring Activity	Monitoring Location(s)	Spatial Coverage	Frequency
Formations shallower than 300 ft below ground surface (bgs)	Shallow groundwater monitoring	MCI GW 1-5	Above 300 ft bgs	Twice/year
Formations shallower than 300 ft bgs	Isotope Analysis	MCI GW 1-5	Above 300 ft bgs	Twice/year
Note: (1) For establishing baseline, sampling of the deep wells will occur during well drilling and prior to start of injection.				

Analytical Parameters

Table 5: Summary of analytical and field parameters for groundwater samples.

Parameters	Analytical Methods
Formation: Galesville Sandstone and Gunter Sandstone	
Cations (Sodium (Na), Calcium (Ca), Magnesium (Mg), Barium (Ba), Iron (Fe), Potassium (K), Strontium (Sr))	ASTM D1976 EPA Method 6020
Anions (Chloride (Cl), Bromide (Br), Sulfate (SO_4))	ASTM D4327 EPA Method 300
Dissolved Inorganic Carbon	ASTM D513-11 SM 5310C EPA Method 9060
Density	ASTM D4052 SM 2710F
Total Dissolved Solids	ASTM D5907 SM 2540C
Alkalinity	ASTM D3875 SM 2320B
pH	ASTM D1293 Standard Method (SM) 4500H
Conductivity/Resistivity	ASTM D1125 SM 2510B
Stable Isotopes of Carbon (C), Oxygen (O), and Hydrogen (H)	CRDS Laser H Isotopes Ratio Mass Spectrometry (IRMS) for C (Note 1)

Carbon-14	Accelerator Mass Spectrometer (AMS) (Note 1)
Temperature (field)	Distributed Temperature Sensing (DTS) Fiber Optic
Specific Conductance (field)	APHA 2510
pH (field)	EPA Method 150.1
(Note 1): If an alternative analytical method(s) is considered, Marquis must obtain prior approval from the UIC Director.	

Sampling methods

Sampling will be performed as described in Section B.2 of the QASP (Attachment K), which describes the groundwater sampling methods to be employed, including sampling SOPs (Section B.2.1) and sample preservation (Section B.2.6).

Sample handling and custody will be performed as described in Section B.3 of the QASP.

Quality control will be ensured using the methods described in Section B.5 of the QASP.

Laboratory to be Used/Chain of Custody Procedures

The laboratory selected will meet all requirements set forth here and in the QASP (Attachment K). The Chain-of-Custody procedures will follow the requirements of Section B.3.5 of the QASP.

Section A.4. of the QASP, Quality Objectives and Criteria, provides the detection limits and analytical methods to be employed during the Testing and Monitoring of all critical parameters of the project.

External Mechanical Integrity Testing

Marquis will conduct at least one of the external mechanical integrity tests (Temperature Measurements or Oxygen Activation Log) presented in Table 6 during the injection and post-injection phase to verify external mechanical integrity (MI) as required by 40 C.F.R. §§ 146.89(c) and 146.90(e) and Sections L and N(7) of this permit.

Table 6: Mechanical Integrity Tests.

Test Description	Location/ Depth Range (ft, MD)	Frequency
Annular Pressure MIT	MCI CCS 3, MCI MW 2, and MCI MW1/ Upper Mt. Simon (3,000)	After Completion of Workover
Annular Pressure Monitoring	MCI CCS 3, MCI MW 2, and MCI MW1/ Upper Mt. Simon (3,000)	Continuous
Temperature Measurements	MCI CCS 3, MCI MW 2, and MCI MW1/ Upper Mt. Simon (0-3,100)	Continuous
Oxygen Activation Log	MCI CCS 3, MCI MW 2, and MCI MW1/ Upper Mt. Simon (0-3,100)	Annually

Test Procedures

The following procedures are approved by use by the Director per Section L of this permit. Any deviation from the methods and procedures below will require approval by the Director at least 30 days prior to conducting the test and must comply with the witnessing requirements of Section L(5) of this permit.

Temperature Logging Using Wireline

To ensure the mechanical integrity of the casing of the injection well, temperature data will be recorded across the wellbore from surface down to primary caprock. Bottom hole pressure data near the packer will also be provided. The following procedures will be employed for temperature logging.

1) To conduct a static temperature log, the well must be shut in for at least 36 hours, or longer if temperature stabilization based on previous logs requires more time.
2) If the well cannot be shut in for 36 hours, shut in for as long as possible and run two logs at least six hours apart.
3) Calibrate the temperature tool in a bucket of ambient temperature water and a bucket of ice water immediately prior to conducting the test.
4) Log from the top of the well to the bottom, recording both temperature and natural gamma ray activity.
5) Record log data at least once per foot.
6) Logging speed shall not exceed 30 feet per minute. Reduce speed to 20 feet per minute in air-filled well bores.
7) The test shall include a written report by a knowledgeable log analyst. Such report must explain any anomalies shown in the results.
8) The test report shall include an up-to-date well schematic, digital logging data in a spreadsheet format, and a plot of the logging activity.
9) The test report shall include a tabulation of values for the following background parameters: EPA permit number, long string casing length (ft), tubing and/or tail pipe

lowermost depth (ft), top of open hole or uppermost perforation (ft), well total depth (ft), plugged back total depth or top of fill depth (ft), Kelly bushing elevation (ft), depth to top of confining zone (ft), and depth to top of permitted injection zone (ft). The test report shall also include a tabulation of values for the following test specific parameters: test date, depth reference (Kelly bushing or ground level), date of last injection, temperature of last injected fluid (F), elapsed time since last injection (hr), volume injected into the well in the past year (gal), names and depths of any other injection formations used at the site, temperatures logged by the tool and thermometer during calibration (F), depth to fluid level in the tubing (ft), depth to top of receptive strata (ft), and depth to bottom of receptive strata (ft).

10) The test must conclusively demonstrate its objectives and satisfy the Director to be considered a completed test.

Temperature Logging Using DTS Fiber Optic Line

The injection well will be equipped with a DTS fiber optic temperature monitoring system that is capable of monitoring the injection well's annular temperature along the length of the tubing string. The DTS line is used for real-time temperature monitoring and, like a conventional temperature log, can be used for early detection of temperature changes that may indicate a loss of well mechanical integrity. The procedure for using the DTS for well mechanical integrity is as follows:

1) After the well is completed and prior to injection, a baseline temperature profile will be established. This profile represents the natural temperature gradient for each stratigraphic zone.
2) During injection operation, record the temperature profile for 6 hours prior to shutting in well.
3) Stop injection and record temperature profile for 6 hours.
4) Evaluate data to determine if additional cooling time is needed for interpretation.
5) Start injection and record temperature profile for 6 hours.
6) Data interpretation involves comparing the time lapse well temperature profiles and looking for temperature anomalies that may indicate a failure of well integrity, i.e., tubing leak or movement of fluid behind the casing. The DTS system monitors and records the well's temperature profiles at a pre-set frequency in real time. As the well cools down the temperature profile along the length of the tubing string is compared to the baseline. Any unplanned fluid movement into the annulus or outside the casing creates a temperature anomaly when compared to the baseline cooling profile. Because this data can be continuously monitored to provide real-time mechanical integrity testing (MIT) surveillance, DTS fiber optic temperature logging is preferred to wireline temperature logging.

Oxygen Activation (OA) Logging

To ensure the mechanical integrity of the casing of the injection well, logging data will be recorded across the wellbore from surface down to the base of the casing. Bottom hole pressure data near the packer will also be provided. OA logging will be carried out while injection is occurring. The following procedures will be employed:

1) Move in and rig up an electrical logging unit with lubricator.
2) Conduct a baseline Gamma Ray Log and casing collar locator log from the top of the injection zone to the surface prior to taking the stationary readings with the OA tool.
3) The OA log shall be used only for casing diameters of greater than 1-11/16 inches and less than 13-3/8 inches.
4) All stationary readings should be taken with the well injecting fluid at the normal rate with minimal rate and pressure fluctuations.
5) Prior to taking the stationary readings, the OA tool must be properly calibrated in a “no vertical flow behind the casing” section of the well to ensure accurate, repeatable tool response and for measuring background counts.
6) Take, at a minimum, a 15-minute stationary reading adjacent to the confining interval located immediately above the injection interval. This must be at least 10 feet above the injection interval so that turbulence does not affect the readings.
7) Take, at a minimum, a 15-minute stationary reading at a location approximately midway between the base of the lowermost USDW and the confining interval located immediately above the injection interval.
8) Take, at a minimum, a 15-minute stationary reading adjacent to the top of the confining zone.
9) Take, at a minimum, a 15-minute stationary reading at the base of the lowermost USDW.
10) If flow is indicated by the OA log at a location, move uphole or downhole as necessary at no more than 50-foot intervals and take stationary readings to determine the area of fluid migration.
11) Interpret the data: Identification of differences in the activated water’s measured gamma ray count-rate profile versus the expected count-rate profile for a static environment. Differences between the measured and expected may indicate flow in the annulus or behind the casing. The flow velocity is determined by measuring the time that the activated water passes a detector.

NOTE: Marquis will run one or more of the listed logging tests to verify external mechanical integrity and confirm that there is no upward flow behind casing above the injection zone. It is not anticipated that conducting more than one of the listed logging tests will be necessary to confirm external mechanical integrity; however additional testing may be necessary in some circumstances; for example, when there are temperature log inconsistencies.

The range, precision, and QC requirements of the different gauges used for MIT testing are presented in section A.4. of the QASP.

Pressure Fall-Off Testing

Marquis will perform pressure fall-off tests during the injection phase as described below to meet the requirements of 40 C.F.R. § 146.90(f) and with Section N(8) of this permit. Pressure fall-off testing will be performed during system operation every 5 years and at the end of system operation.

Pressure Fall-off Test Procedure

1) Injection of normal injectate at the normal rate is preferred.
2) The injection period should be at least 50% longer than the planned shut-in time, or at minimum as long as operationally possible. During this time injection at a constant rate (+/- 10%) should be attempted.
3) The pressure gauge utilized for the pressure transient test shall have been calibrated no more than one year prior to the test date.
4) Place the pressure gauge downhole at approximately the top of the permitted injection zone at least one hour prior to ceasing injection.
5) Following at least one hour of pressure data collection during injection, shut-in the well as quickly as possible.
6) Collect data at a frequency of at least one data point every 10 seconds for at least the first five minutes after shut-in; between five and 30 minutes at no less than one reading every 30 seconds; and the operator can reduce frequency as required after 30 minutes.
7) End pressure measurements when pressure is relatively stable, when operational necessity dictates, when sufficient radial flow dominated data has been collected to allow evaluation of Henry's law constant (kh) and extrapolation of pressure to infinite shut-in time is possible, or if boundary effects are observed.
8) The test shall include a written report by a knowledgeable well test analyst. Such report must explain any anomalies shown in the results.
9) The test report shall include an up-to-date well schematic, a copy of the dated calibration certificate for the gauge utilized, and digital pressure data in a spreadsheet format.
10) The test report shall include a tabulation of values for the following background parameters: EPA permit number, porosity, net thickness (ft), viscosity (cp), formation compressibility (per psi), long string casing inner diameter (in), open hole diameter (in), and Kelly bushing elevation (ft). The test report shall also include a tabulation of values for the following test specific parameters: test start date/time, test end date/time, test length (hr), depth reference (Kelly bushing or ground level), specific gravity of test fluid, test fluid compressibility (per psi), gauge depth (ft), gauge calibration date, pressure required to maintain tubing fluid to the surface (psi), final tubing fluid level (ft), final flow rate immediately prior to shut-in (gpm), cumulative volume injected since last pressure equalization (gal), permeability- thickness (md-ft), skin factor, radius of investigation (ft), final measured flowing pressure (psi), final measured shut-in pressure (psi), and p* pressure (psi). Pressure gauge units (psia or psig) shall be specified.
11) The test must conclusively demonstrate its objectives and satisfy the Director to

be considered a completed test.

Carbon Dioxide Plume and Pressure Front Tracking

Marquis will employ direct and indirect methods (listed in Table 7) to track the extent of the carbon dioxide plume and the presence or absence of elevated pressure during the operation period to meet the requirements of 40 C.F.R. § 146.90(g) and Section N(5) of this permit. The primary location for direct tracking of the carbon dioxide plume and pressure front will be Galesville, Gunter, Eau Claire, and Mt. Simon Formations at MCI MW2 and MCI ACZ1. The primary location for indirect tracking of the carbon dioxide plume and pressure front will be the entire formation from surface to total depth via time-lapse 3D seismic taken at the surface covering the entire AoR. MCI MW2 is roughly 1500 ft west of MCI CCS3, and MCI ACZ1 is less than 500 ft east of MCI CCS3. Periodic fluid samples will be analyzed for the presence of carbon dioxide to further refine plume tracking. Pressure and temperature sensors in the deep monitoring well (MCI MW 2) will be used to measure variations in the storage formation in the pre-operational, injection, and post-injection phases of the project (40 C.F.R. § 146.90(g)). These sensors will continuously record data. This deep monitoring well will also be used to collect fluid samples from the storage formation to monitor for changes in the water chemistry over time and verify when the leading edge of the CO_2 plume reaches the MCI MW 2 well.

Plume monitoring location and frequency

Marquis will conduct fluid sampling and analysis to detect changes in formation fluids in order to directly monitor the carbon dioxide plume. The parameters to be analyzed as part of fluid sampling in the injection zone are listed in Table 8. Marquis will deploy pressure/temperature monitors and DTS to directly monitor the position of the pressure front. Indirect plume monitoring will be employed using pulsed neutron capture/RST logs to monitor carbon dioxide saturation. 3D seismic profiles will be used to image the developing carbon dioxide plume for indirect plume monitoring. The seismic survey will be acquired at regular intervals (every 5 years or 4 million metric tons injected), immediately preceding the cessation of injection and prior to the post-injection control period, and at the 5 and 10-year post-injection control period.

Plume monitoring details

For information concerning the type and specification of gauges used for the continuous monitoring of the Plume, please see the QASP in Attachment K.

Table 7: Plume monitoring activities

Target Formation	Monitoring Activity	Monitoring Location(s)	Spatial Coverage	Frequency
DIRECT PLUME MONITORING				
Upper Mt. Simon	Fluid sampling	MCI MW2	3,225 ft	Annual
Upper Mt. Simon	Isotope analysis	MCI MW2	3,225 ft	Continuous
INDIRECT PLUME MONITORING				
Entire formation (0-TD)	Time- lapse 3D seismic	Surface	Over project AoR	Every five years or 4 million metric tons of CO_2 injection, whichever occurs first
Galesville, Gunter, Eau Claire and Mt. Simon Formations	PNC logging	MCI MW2 and MCI ACZ 1	2,118- TD ft 2,118- TD ft	Continuous

Table 8: Summary of analytical and field parameters for fluid sampling in the injection zone.

Parameters	Analytical Methods (Note 1)	Detection Limit/Range	Typical Precisions	QC Requirements
Cations: Na, Ca, Mg, Ba, Sr, Fe, K	ASTM D1976	<1 to 8 mg/L (analyte, dilution, and matrix dependent)	±10%	Daily calibration; blanks, duplicates, and matrix spikes at 10% or greater frequency
Anions: Cl, Br, SO4	ASTM D4327	0.03 to 0.13 mg/L (analyte, dilution, and matrix dependent)	±15%	Daily calibration; blanks and duplicates at 10% or greater frequency
Dissolved Inorganic Carbon	EPA 9060	0.2 mg/L	±20%	Duplicate measurement; standards at 10% or greater frequency
Total Dissolved Solids	ASTM D5907	12 mg/L	±10%	Balance calibration, duplicate analysis
Alkalinity	ASTM D3875	1 mg/L	±10%	Daily calibration; blanks, duplicates, and matrix spikes at 10% or greater frequency
pH	ASTM D1293	1 to 13 pH units	0/2 pH unit	
Density	ASTM D4052	0.01 g/mL	±10%	
Conductivity/Resistivity	ASTM D1125	0 to 100	±1%	
Stable C, H, O Isotopes	CRDS Laser H IRMS for C	200 to 500‰ 50 ppm of DIC	±4‰ ±0.2‰	Duplicates, working standards at 10%
Radiocarbon	AMS	0 to 200 pMC	±0.5 pMC%	
pH (field)	EPA 150.1	2 to 12 pH units	±0.2 pH unit	User calibration per manufacturer recommendation
Specific conductance (field)	APHA 2510	0 to 200 mS/cm	±1% of reading	
Temperature (field)	Thermocouple	-5 to 50°C	±0.2°C	Factory calibration

Note:
1. An equivalent method may be utilized with the prior approval of the UIC Program Director.

<u>Pressure-front monitoring location and frequency</u>

Table 9 presents the methods that Marquis will use to monitor the position of the pressure front, including the activities, locations, and frequencies Marquis will employ.
Quality assurance procedures for these methods are presented in the QASP in Attachment K.

<u>Pressure-front monitoring details</u>

Pressure-front monitoring will occur via continuous monitoring of conditions in the injection zone at Mt. Simon Formation at 3,225 ft of MCI MW2. For information concerning the type and specification of gauges used for the continuous monitoring of the pressure front, please see the QASP.

Marquis must collect baseline data from surface stations in the Eau Claire and Mt. Simon Formations and Precambrian Basement before the start of injection activities. Marquis must record microseismic data from a near surface-based network of sensors on a continuous basis. These data will be sent to a cloud-based service via a cellular connection for data processing and archive. Marquis must collect baseline microseismic data for four to six months prior to the start of injection operations. This baseline data will be used to generate comparative data between the baseline case of the predictive model and expected rate of change in the formation conditions. As measured pressures and temperatures change, the data will be compared to the predicted data from the model. As appropriate, Marquis must conduct re-evaluation of the model, or further investigation of the downhole conditions, to ensure that no major deviation from the expected behavior of the pressure front occurs.

<u>Table 9</u>: Pressure-front monitoring activities.

Target Formation	Monitoring Activity	Monitoring Location(s)	Spatial Coverage	Frequency
DIRECT PRESSURE-FRONT MONITORING				
Mt. Simon Sandstone	Pressure Monitoring	MCI MW2	3,225 ft	Continuous
INDIRECT PRESSURE- FRONT MONITORING				
Eau Claire and Mt. Simon Formations, Precambrian Basement	Microseismic Monitoring	5 Surface Stations	AoR (See Figure 1, below)	Continuous

<u>Figure 1</u>: Pressure-front monitoring activities (taken from Figure 7-10 of the application).