7.0 TESTING AND MONITORING PLAN
40 CFR 146.90

CASS SEQUESTRATION

Facility Information

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[redacted]

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7.0 Testing and Monitoring Plan

7.1 Overall Strategy and Approach for Testing and Monitoring

This Testing and Monitoring Plan describes how Cass Sequestration, LLC ("Cass Sequestration") will monitor the Cass Sequestration site pursuant to 40 CFR 146.90.

The Testing and Monitoring Plan has been developed to reduce the risks associated with carbon dioxide (CO_2) injection into the deep geologic subsurface at this site. Goals of the monitoring strategy include:

- Protecting underground sources of drinking water (USDWs),
- Ensuring that the injection well is operating as planned,
- Providing data to validate and calibrate the geological and dynamic models used to predict the distribution of CO_2 within the injection zone,
- Supporting data for Area of Review (AoR) re-evaluations over the course of the project at a minimum of every 5 years,
- Meeting the regulatory requirements of 40 CFR 146.90.

The Testing and Monitoring Plan will be adaptive over time; the plan will be adjusted to respond:

- As project risks evolve over the course of the project
- If significant differences between the monitoring data and predicted dynamic modeling results are identified
- If key monitoring techniques indicate anomalous results related to well integrity or the loss of containment

[redacted] **Figure 7-1** illustrates the AoR at the end of the Post Injection Site Care (PISC) period, the conceptual location of the IZM and AZM well, and the conceptual location of seismicity stations. The IZM and AZM well design and plug and abandonment well bore diagrams are documented in Appendix 7.B.

A stratigraphic test well (STW), Logansport #1 test well [redacted] was drilled to acquire site-specific subsurface geologic characterization. **Figure 7-2** shows the stratigraphic column derived from the data acquired in the STW. The STW will be converted to the proposed injection well for this project.

Regional and site-specific data and computational techniques were used to model the growth of the CO_2 plume during injection and the post-injection period, with details found in Permit Section 2.0 - AoR and Corrective Action Plan.

These data sets and computational models were utilized to develop this Testing and Monitoring Plan and will be used for future re-evaluations of the AoR during the pre-operational, injection, and post-injection phases of the project (40 CFR 146.84 (e)).

If specified events occur while implementing the testing and monitoring plan, as described below, that initiate an action, the response actions will follow those described in Permit Section 10.0 - Emergency and Remedial Response Plan (40 CFR 146.94 (a)).

The Testing and Monitoring Plan will utilize several direct and indirect monitoring technologies throughout the injection and PISC phases that can be categorized in three ways:

- Operational monitoring - continuous activities of the injection operations – pressures, temperatures, injection rates
- Assurance monitoring – activities to confirm CO_2 containment beneath the confining formation. These include injection well integrity, above zone monitoring and groundwater monitoring
- Verification monitoring – activities to confirm the projected development of both the pressure plume and CO_2 plume over time. These include direct in zone monitoring and indirect plume monitoring

Operational monitoring will establish the chemical composition, including water content, of the CO_2 stream which will be sampled and analyzed (40 CFR 146.90 (a)). Corrosion coupons, composed of the same material as the well components, will be in the stream and analyzed on a quarterly basis for signs of corrosion and loss of mass that may be indicative of future potential well integrity issues (40 CFR 146.90 (c)).

Continuous recording instruments will monitor injection pressure, temperature, volume, annular pressure and fluid volume, and mass flowrate (40 CFR 146.90 (b)) near the wellhead. The injection mass flowrate will be directly measured at the surface near the wellhead to monitor the cumulative mass of injected CO_2 and ensure compliance with the permit injection limits. The storage formation injection volume will be calculated using the mass flowrate including the pressure and temperature conditions in the storage formation. The injection volumes, pressures, and temperatures will be used to update the computational models at designated intervals throughout the injection phase of the project. The annular pressure between the tubing and the injection (long-string) casing and the annular fluid volumes will be monitored on a continuous basis (40 CFR 146.90 (b)). The injection operations will be linked to a Supervisory Control and Data Acquisition (SCADA) system to monitor and record the operations data, control injection rates, and initiate system shutdown, if required. The SCADA system may be used to adjust the annular pressure in the annular space to meet the operational and regulatory objectives.

[redacted]

Pressure fall-off (PFO) tests will be conducted in the storage formation of the injection well to confirm the hydrogeologic characteristics of the storage formation and to confirm the internal mechanical integrity of the injection well. Prior to injection, an internal MIT will be performed on the injection well to confirm internal integrity as per Permit Section 5.0 - Pre-Operational Testing Plan, (40 CFR 146.82(a)(8), 146.87). During the injection phase of the project, a PFO test will be conducted in the injection well at least once every five years, or more frequently if required by the UIC Program Director [40 CFR 146.90(f)]. If there is a significant injection pressure increase over a one-year period, compared to the computational model, and the increase can not be otherwise reasonably explained or remedied, then a PFO test may be conducted at the next opportunity, (40 CFR 146.90 (f)). The formation characteristics obtained through the PFO testing will be compared to the results from previous tests to identify any changes over time and will be used to calibrate the computational models.

Assurance monitoring is intended to show the absence of CO_2 above the caprock and will consist of a fluid monitoring program in a network of groundwater wells within the AoR. Cass Sequestration will install groundwater wells within the AoR to sufficiently monitor groundwater quality and geochemical changes. To establish a baseline dataset, sampling is planned to be conducted prior to the start of CO_2 injection. Throughout the injection and PISC phases of the project, the results of the aqueous geochemistry will be compared to the baseline conditions for any indication of CO_2 or brine migration into the shallow groundwater aquifer. If indications of CO_2 or brine are found in the shallow groundwater aquifer, it will trigger the emergency response actions found in Permit Section 10.0 - Emergency and Remedial Response Plan.

[redacted]

Figure 7-1: Map of Cass Sequestration project showing injection well [redacted], In Zone (IZM-1) and Above Zone (AZM-1) monitor wells, conceptual location of seismicity stations and AoR. The satellite base image is unaltered and includes all required components of 40 CFR 146.82(a)(2).

[redacted]

Figure 7-2: Stratigraphic column and gamma ray log plot with lithology for Cass Sequestration derived from the STW.

Verification monitoring of the development of the CO_2 plume and the associated pressure front through the injection and post-injection project phases (40 CFR 146.90 (g)) will be achieved using several methods. Verification monitoring processes are in place as they expect to encounter both the pressure front and CO_2 within the target injection formation over the life of the project.

For the direct monitoring requirement, the fluid geochemistry of the storage formation in the IZM will be monitored and assessed for CO_2 movement through the storage formation, per 40 CFR

146.90 (d). [redacted]

[redacted] The location of individual stations within this network will be adjusted as required in response to monitoring results or future AoR re-evaluations.

The facility is in an area with low rates of seismic activity and risk (Permit Section 1.0 - Project Narrative). The primary goals of continuous background seismicity monitoring are:

- Addressing public and stakeholder concerns related to induced seismicity with the project
- Monitoring the spatial extent of the pressure front from the distribution of seismic events
- Identifying activity that may indicate failure of the confining zone(s) and possible containment loss

The general schedule and spatial extent for the monitoring activities in the baseline and injection phases of the project are shown in **Table 7-1**. Baseline timing varies depending on the monitoring method. **Table 7-1** shows the specifics with the beginning of any monitoring effort beginning no more than one year prior to injection and in consultation with the UIC Program Director. The monitoring plans related to the PISC phase are discussed in Permit Section 9.0 - PISC and Site Closure Plan. Changes to the monitoring schedule may occur over time as the project evolves. For instance, if anomalous results are identified in the collected monitoring data, confirmation sampling will be conducted, and additional monitoring data may be acquired through subsequent investigations into the anomalous results. Likewise, if the CO_2 plume behaves in a stable and predictable manner for many years through the injection phase of the project, the monitoring frequency of applicable parameters may be requested to be reduced. Any such changes to the Testing and Monitoring Plan will be made in consultation with the UIC Program Director (40 CFR 146.90 (j)).

Monitoring Activity	**Baseline Data Frequency**	**Injection Phase Frequency**	**Location**
Assurance Monitoring:			
USDW Groundwater Sampling & Geochemical Analysis	[redacted]	[redacted]	AoR groundwater well network
Pressure Sensors	[redacted]	[redacted]	[redacted]
Operational Monitoring:			
CO_2 Stream Analysis	[redacted]	[redacted]	CO_2 delivery pipeline
Corrosion Coupon Analysis	NA	[redacted]	CO_2 delivery pipeline
Injection Pressure	NA	Continuous	Injection well (Wellhead and downhole)
Mass Injection Rate	NA	Continuous	Injection wellhead
Injection Volume (Calculated)	NA	Continuous	Injection wellhead
Annular Pressure	NA	Continuous	Injection wellhead
Annular Fluid Volume	NA	Continuous	Injection wellhead
Temperature Measurement [redacted]	[redacted]	Continuous	Injection well
PFO Tests	[redacted]	[redacted]	Injection well

Monitoring Activity	Baseline Data Frequency	Injection Phase Frequency	Location
Verification Monitoring:			
Fluid Sampling and Analysis	[redacted]	[redacted]	AZM well
		[redacted]	IZM well[1]
Pressure & Temperature Sensors	[redacted]	[redacted]	AZM well
			IZM well
Temperature Log (External Mechanical Integrity Test)	Once	[redacted]	IZM well
[redacted]	Once	Continuous	Injection Well
Seismicity Monitoring	Prior to injection	Continuous	Seismic stations
[redacted]	[redacted]	[redacted]	Surface
[redacted]			

Table 7-1: General schedule and spatial extent for the testing and monitoring activities for Cass Sequestration.

7.1.1 Quality Assurance Procedures

Data quality assurance and surveillance protocols adopted by the project have been designed to facilitate compliance with the requirements specified in 40 CFR 146.90 (k). Quality assurance (QA) requirements for direct measurements within the storage formation, above the confining zone, and within the shallow USDW aquifer are described in the Quality Assurance and Surveillance Plan (QASP) in Appendix 7.A. These measurements will be performed based on best industry practices and the QA protocols recommended by the service contractors selected to perform the work.

7.1.2 Reporting Procedures

Results of all testing and monitoring activities will be reported to the EPA in compliance with the requirements under 40 CFR 146.91 on a semi-annual basis. Additional reporting procedures are documented in Appendix 7.A.

7.2 Carbon Dioxide Stream Analysis (40 CFR 146.90 (a))

The CO_2 stream will be analyzed during the injection phase of the project to provide data representative of its chemical characteristics and to meet the requirements of 40 CFR 146.90 (a).

This section describes the measurements and sampling methodologies that will be used to monitor the chemical characteristics of the CO_2 injection stream.

7.2.1 Sampling Location and Frequency

The CO_2 stream has been sampled from the [redacted] Permit Section 6.2 – Well Operations Plan.

7.2.2 Analytical Parameters

The CO_2 stream will be analyzed with sufficient frequency to yield data representative of its chemical and physical characteristics (40 CFR 146.90(a)). These characteristics include fluid composition (i.e., percentage of CO_2 and other constituents measured on a volumetric or mass basis at a known temperature and pressure), temperature, and pressure. Additional characteristics are documented in Appendix 7.A. If prompted, additional parameters may be acquired if needed for further correlation of potential interactions between the injectate and the formation.

7.2.3 Sampling Method – CO_2 Injection Stream Gases

Collected samples of the CO_2 stream will be submitted to an accredited laboratory for analysis of the constituents present in the injection stream. Representative samples of the CO_2 stream will be collected from the pipeline at a location between the capture system and the injection well, using a properly sized sampling port and sample cylinders, applicable for the stream parameters, provided by a nationally accredited environmental laboratory (example shown in **Figure 7-3**). The following details an example of one type of sampling method that may be used. Quick-connect fittings are attached to the cylinder's ¼-inch national pipe thread (NPT) fittings, and the cylinder is connected into the system. The CO_2 stream flows from the pipeline by opening a ball valve, through a pressure reducer, into the cylinder. The pressure regulator will reduce the pressure of the CO_2 stream to approximately [redacted] so that the CO_2 is in the gaseous state when collected rather than a super-critical liquid. The three-way valve upstream from the cylinder allows for greater control of the pressure in the system. Cylinders will be purged with sample gas (i.e., CO_2) at least five times prior to sample collection to remove laboratory-added helium gas and ensure a representative sample. During purging, the outlet of the sample cylinder will be connected to a ventilation line and vented to the atmosphere. Proper sampling technique is critical, and care must be taken to ensure that the cylinder is not contaminated by atmospheric gas and the sample is representative of the CO_2 in the pipeline. A standard sampling procedure is shown below in **Figure 7-4**. Samples will be shipped to the lab after collection in accordance with the standard operating procedures (SOPs) found in Section B2 of the QASP (Appendix 7.A). Further details related to sampling methods can be found in Section B2 of the QASP.

Figure 7-3: Example of double-ended gas sample cylinder. Actual sample cylinder used may vary.

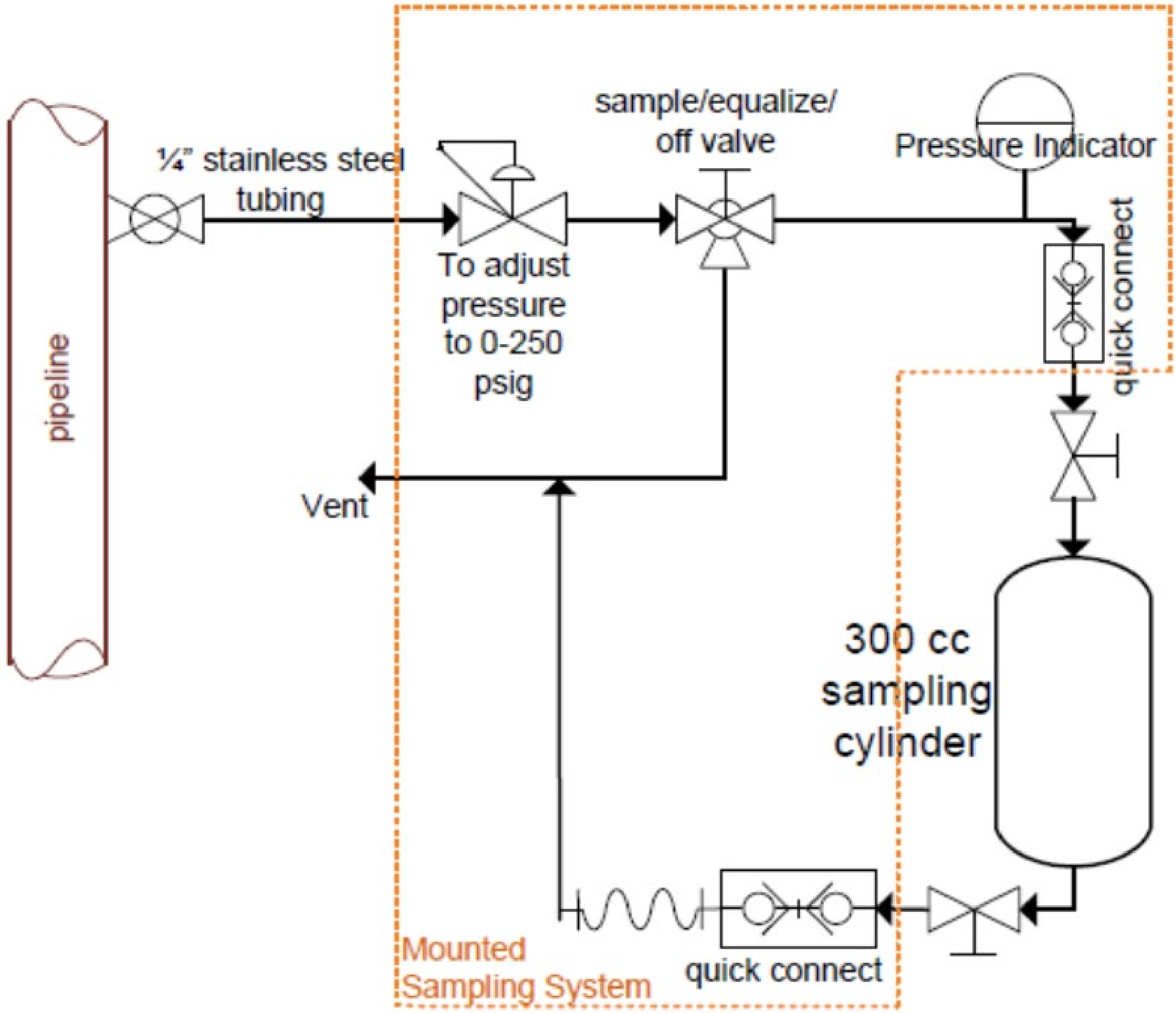

Figure 7-4: Schematic of gas sampling system using a high-pressure cylinder (Atlantic Analytical Laboratory, 2021). The actual system used may vary.

7.2.4 Laboratory to be Used/Chain of Custody and Analysis Procedures

A nationally accredited environmental laboratory will be selected to analyze the CO_2 stream samples as well as provide the appropriate sampling equipment. The laboratory will follow standard sample handling and chain-of-custody guidance (EPA 540-R-09-03, or equivalent). Details can be found in the QASP (Appendix 7.A).

7.3 Continuous Recording of Operational Parameters (40 CFR 146.88 (e)(1), 146.89 (b), and 146.90(b))

Continuous recording instrumentation will be installed and used to monitor injection pressure, mass injection rate; the pressure of the annulus between the tubing and the long-string casing; the annulus fluid volume added; and the temperature of the CO_2 stream, as required at 40 CFR 146.88 (e)(1), 146.89 (b), and 146.90 (b). The details are described in the following sections.

7.3.1 Monitoring Location and Frequency

Activities identified in **Table 7-1** will be performed to monitor operational parameters and verify internal mechanical integrity of the injection well. All operating monitoring will take place at the locations and frequencies shown in **Table 7-1**. The data recorded on a continuous basis will be communicated to the main facility Control Room through a SCADA system. The hourly average value of the parameter being continuously monitored and logged shall be recorded for purposes of reporting. If the electronic data logging system is out of service, field monitoring of manual gauges and annulus pressure will be recorded at least twice per day during operations.

7.3.2 Monitoring Details

7.3.2.1 Continuous Recording of Injection Pressure

The CO_2 injection pressure and temperature will be monitored on a continuous basis in the injection well both downhole at the packer and at the wellhead to ensure that downhole injection pressures do not exceed 90% of the fracture propagation pressure of the storage formation (40 CFR 146.88 (a)). Further details are found in Permit Section 6.0 - Well Operation Plan. If pressure gauges are operating correctly and downhole injection pressure temporarily exceeds 90% of the storage formation fracture pressure, then the injection rate will be automatically slowed down or automatically shut down in accordance with the Well Operations Program.

Any anomalies outside of the normal operating specifications will be assessed for wellbore issues, such as a loss of mechanical integrity or blockage in the tubing. Anomalous pressure measurements would trigger the need for further investigation of the cause (40 CFR 146.89 (b)). The wellhead injection pressure data will also be used to calibrate the computational modeling throughout the injection phase of the project.

The wellhead pressure of the injected CO_2 will be continuously measured by an electronic pressure transducer with analog output mounted on the CO_2 line near the injection well. The transmitter will be electronically connected to the SCADA system and tied into 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 manufacturer.

7.3.2.2 Continuous Recording of Injection Mass Flowrate

The mass flowrate of CO_2 injected into the well will be measured by a mass flow meter. This flow meter will be placed in the CO_2 delivery line near the wellhead. The meter will have an analog output (i.e., Endress & Hauser Promass-Q or F Series, Micro Motion Coriolis Flow and Density Meter Elite Series, or equivalent). The flow meter will be connected to the SCADA system for continuous monitoring and recording of the CO_2 injection rate into the well. The mass flow meters will be calibrated according to manufacturer specifications.

7.3.2.3 Injection Volume

The injection volume into the storage formation will be calculated on a continuous basis based on the injection mass rate and the pressure and temperature conditions in the storage formation. The calculated volumes will be used in computational models to determine storage formation capacity and flow.

7.3.2.4 Continuous Recording of Tubing Annulus Pressure

As described in Permit Section 6.0 - Well Operation Plan, [redacted]

Annular pressures are expected to fluctuate 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. If annular pressure fluctuates outside of operatable measurements during injection, a wellhead annulus monitoring system (WAMS) may be utilized to regulate the pressure.

7.3.2.5 Continuous Recording of Annulus Fluid Volume

As described in Permit Section 6.0 - Well Operation Plan, the volume of the annulus fluid between the injection tubing and the long-string casing will be measured using the accumulator levels and the brine reservoir level on the well control system. [redacted]

The annular fluid volume is expected to fluctuate as atmospheric and injection stream temperatures change. These changes are expected to be most dramatic during startup and shutdown operations. If annular volume fluctuates outside of operatable measurements, a wellhead annulus monitoring system may be utilized.

7.3.2.6 Continuous Recording of CO_2 Stream Temperature

The temperature of the CO_2 injection stream will be continuously measured using an electronic thermocouple. The thermocouple will be mounted in a temperature well in the CO_2 line at a location close to the pressure transmitter near the wellhead. The transmitter will be electronically connected to the SCADA system. The transmitter will be calibrated prior to installation during the pre-injection period and calibrated according to manufacturer specifications. The thermocouple for measuring surface injection temperature will be recalibrated according to manufacturer specifications or it will be replaced with a calibrated thermocouple.

7.3.2.7 Flowline Pressure and Temperature

Flowline pressure and temperature will be monitored during injection. These data will be used with the mass flowrate to calculate the volume injection rate of the CO_2 into the storage formation.

7.4 Corrosion Monitoring (40 CFR 146.90 (c))

To meet the requirements of 40 CFR 146.90 (c), associated well materials (**Table 7-2**) and piping components will be monitored 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 for the life of the project. This section presents the procedures that will be followed to monitor the corrosion of well materials used in the casing and tubing. For Class VI injection wells, corrosion monitoring of the well materials is required on a quarterly basis (40 CFR 146.90 (c)).

7.4.1 Monitoring Location and Frequency

Corrosion coupons will be retrieved and analyzed quarterly. If the coupons show significant evidence of corrosion, the injection wellbore may be assessed for signs of corrosion using additional well logging techniques such as multi-finger caliper logging or an ultrasonic casing evaluation tool.

[redacted]

Table 7-2: List of equipment coupons with material of construction.

7.4.2 Sample Description

The coupons will be made from the same materials as the long-string casing and tubing (**Table 7-2**). Prior to placement of the corrosion coupons in a loop in the pipeline for exposure to the CO_2

stream, they will be weighed and measured for thickness, width, and length as a baseline measurement.

7.4.3 Monitoring Details

Corrosion monitoring of well materials will be conducted using coupons placed in a loop in the CO_2 piping (**Figure 7-5)**. The coupons will be representative of the materials used for the long-string casing and other well and piping materials. The coupons will be removed quarterly and assessed for corrosion using American Society for Testing and Materials (ASTM) G1-03: Standard Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens (ASTM, 2017) by a corrosion analytical laboratory. This method measures the corrosivity of steel and chrome alloys to both aqueous and non-aqueous liquids. Upon removal, coupons will be inspected visually for evidence of corrosion, which may include pitting, cracking, and loss of mass or thickness. The weight and size (thickness, width, length) of the coupon will also be measured and recorded each time it is removed and compared to the baseline measurements. The corrosion rate will be calculated as the weight loss during the exposure period divided by the duration (i.e., weight loss method).

If the analysis from the coupons indicates a significant potential for corrosion in the well materials, the wellbore may be evaluated using wireline tools such as a multi-finger caliper or ultrasonic casing evaluation tool. The frequency of running these tubing and casing inspection logs will be contingent on the corrosion data from the coupon monitoring program. Wireline tools are lowered into the well to directly measure properties of the well casing that indicate corrosion. For example, multi-finger wireline calipers have several fingers and are capable of recording information measured by each finger so that the data can be used to produce detailed three-dimensional (3D) images of the well. Ultrasonic wireline tools are capable of measuring wall thickness in addition to the inner diameter of the well tubular. Other suitable wireline technologies may also be run to assess the well corrosion. Consequently, these tools can also provide information about the outer surface of the casing.

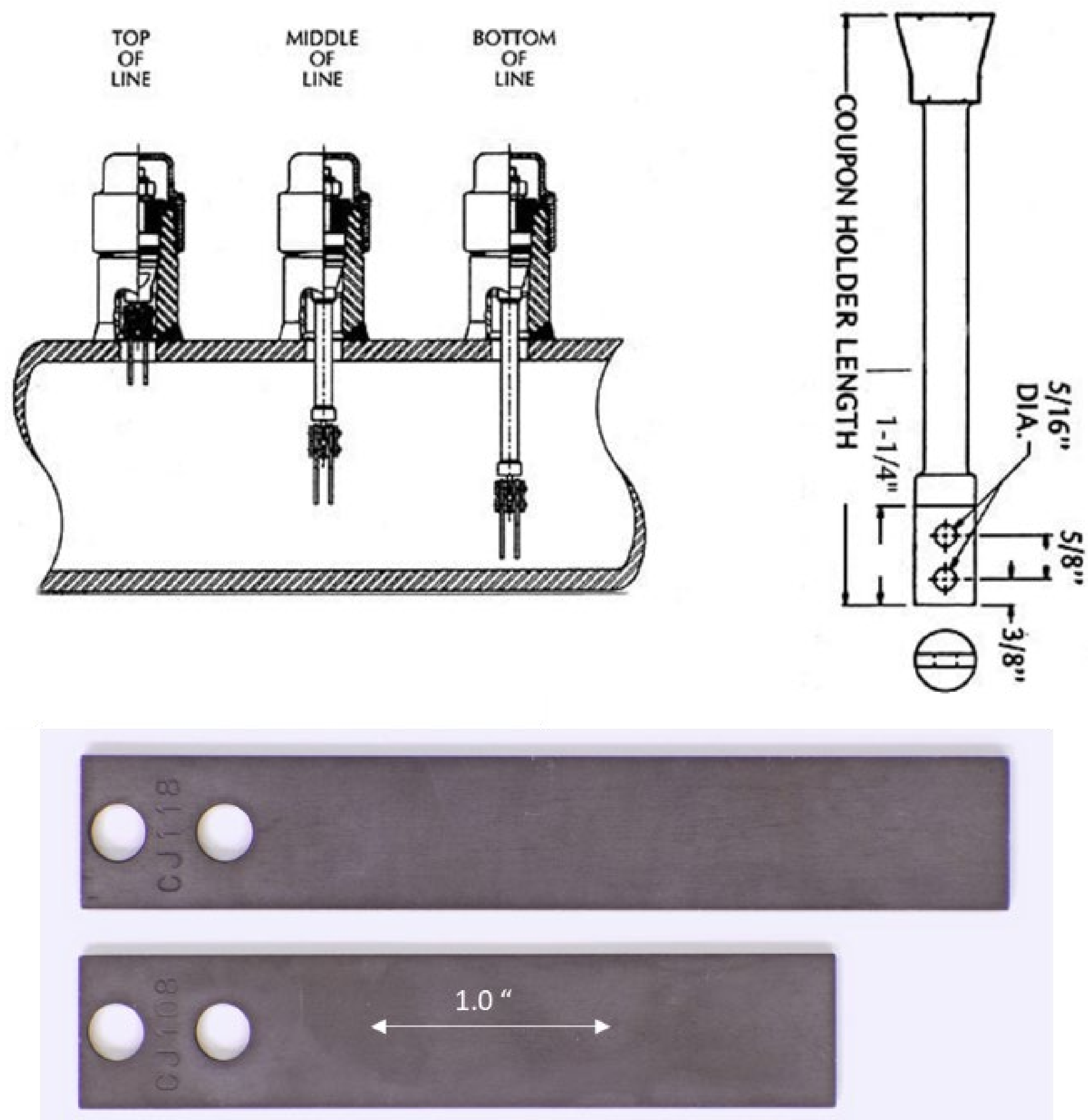

Figure 7-5: Type Corrosion coupon illustration in piping (top), types of coupons to be used for corrosion monitoring (below) (Cosasco, 2021).

7.5 Above Zone Monitoring (40 CFR 146.90 (d))

[redacted] to meet the requirements of 40 CFR 146.90 (d).

7.5.1 Monitoring Location and Frequency

[redacted] (**Figure 7-2**). Baseline measurements will be taken once prior to injection and then annually (40 CFR 146.90 (d)).

Baseline shallow groundwater samples will be collected from the groundwater well network within the AoR. Baseline samples will be collected [redacted] and then on a [redacted] during the injection operations (40 CFR 146.90 (d)). **Table 7-3** shows the proposed location and frequency of the groundwater monitoring program.

The downhole pressure and temperature in the AZM well will be continuously monitored and recorded to identify any potential migration of CO_2 or displaced brine into the first permeable formation above the confining zone. [redacted] the confining formation is occurring. While all variations in pressure or temperature will be evaluated, an increase in pressure or temperature greater than [redacted] above baseline values for an extended duration will warrant additional assessments to detect the possibility of fluid leakage out of the storage formation. An increase in pressure or temperature would initiate additional fluid sampling from the aquifer and analysis of the geochemical parameters. An unaccountable increase in pressure or temperature in an aquifer above the confining zone would also trigger additional external well integrity procedures in the injection or deep monitor well.

[redacted]

Table 7-3: Monitoring schedule for the AZM and shallow groundwater monitoring wells during the pre-operational and injection phases of the project.

The accumulation of CO_2 or displaced brine in an overlying aquifer may result in the following:

- Aqueous geochemistry including pH and TDS
- Reaction of cements, mineral surface coatings, and clay particles with the CO_2 may liberate cations and anions into the aqueous phase.
- Geochemical signatures may be used to differentiate between existing CO_2 sources (if present) within the AoR and the injected CO_2

If anomalous changes in the aqueous geochemistry are observed in the AZM samples, new samples will be obtained to verify the changes. The frequency with which fluid samples are obtained for analysis may be increased. As a precautionary measure, the fluid sampling frequency for the shallow groundwater monitoring wells may also be increased. Anomalous changes may also trigger the need for additional well integrity testing in both the IZM well and the injection well to ensure that no well integrity issues have developed since the last set of external MITs.

7.5.2 Analytical Parameters

Fluid samples collected from the AZM well and shallow groundwater wells will be analyzed for the geochemical parameters shown in **Table 7-4** along with the EPA recommended analytical methods. As shown in the table, the fluid samples will be analyzed for major anions and cations, select trace metals, pH, total dissolved solids (TDS), density, carbon dioxide, and specific conductivity. If anomalous changes of these key geochemical parameters are detected, additional appropriate sample analysis may be utilized. Key geochemical parameters will be reviewed quarterly for the years of injection operations.

The relative importance of each analytical measurement will be evaluated throughout the design and initial injection testing phase of the project to identify the analytes best suited to meeting project monitoring objectives under site-specific conditions. If specific analytical measurements are shown to be of limited use, they will be removed from the analyte list for continued analysis through the operational phases of the project. Any modification to the parameter list in **Table 7-4** will be made in consultation with the UIC Program Director.

[redacted]

Table 7-4: Summary of analytical and field parameters for fluid samples.

7.5.3 Monitoring and Sampling Methods

[redacted] The sensors will deliver real-time surface readouts of the bottomhole pressure and temperature measurements which will be communicated and recorded through the SCADA system. The sensors will be programmed to measure and record pressure and temperature every minute and averaged daily data for storage.

For sampling of fluid from groundwater AZM, and IZM wells, a bailer or pump system, or similar, will be used to collect the water samples. Prior to sample collection the well will be purged to remove stagnant water from the well and ensure a representative water sample is collected from the formation. The amount of water that will be purged will be determined by the volume of water and/or field parameter stabilization. The fluid purged from the well will be tested onsite for field parameters, such as pH, specific conductance, and temperature, using a calibrated water quality meter (Horiba U-53, or similar). Once these parameters stabilize, a representative formation fluid will be sample collected.

Preservation, preparation methods, container type, and holding times for the analyte classes are presented in **Table 7-5**. The analytical methods for the metals in solution require acidification of a filtered sample with nitric acid. The remainder of the analyses do not require preparation or preservation other than chilling the samples. The samples will be collected in either glass or polyethylene bottles ranging in size from 50 milliliters (mL) to 1.5 liters (L). Hold times from the analytes range from 7 days for TDS to 1 year for the oxygen and hydrogen isotopes.

[redacted]

Table 7-5: Preservation methods, container type, and holding times for analyte classes.

7.5.4 Laboratory to be Used/Chain of Custody Procedures

The geochemical and isotopic analyses will be performed by accredited laboratories. Samples will be tracked using appropriately formatted chain-of-custody forms. See the QASP for additional information (Appendix 7.A).

7.6 Mechanical Integrity Testing (MIT)

Demonstrating and maintaining the mechanical integrity of a well is a key aspect of protecting USDWs from possible endangerment due to injection activities.

7.6.1 Internal Mechanical Integrity Testing (MIT)

Internal mechanical integrity refers to the casing integrity or seal between the long-string casing, tubing, and packer. The quality of this seal is confirmed by performing an MIT and continuous monitoring of the annular pressure. These methods will be performed pre-injection for the MIT and both methods will be conducted during the injection phase of this project to monitor and confirm internal mechanical integrity. **Table 7-6** presents the details for conducting the annular pressure MIT and the annular pressure monitoring.

Testing/Monitoring Method	Frequency	Location of Monitoring	Parameters Measured
Annular Pressure MIT	After completion and after workovers	Tubing/casing annulus	Ability to hold pressure testing
Annular Pressure Monitoring	Continuous	Tubing/casing annulus	Pressure, temperature, annular fluid volume

Table 7-6: Internal mechanical integrity monitoring details.

Details of the proposed internal MIT are given in Permit Section 5.0 - Pre-Operation Testing Program (Section 5.2.2).

The annular pressure MIT test will be repeated any time the packer has been released, for instance, during well workovers or if unattributable (cannot be explained by changing operational conditions) annular pressure changes are greater than the UIC Program Director approved minimum change. An annular pressure test may also be repeated if there is an indication of lost internal integrity.

In addition to the internal MIT, the annular pressure will be continuously monitored and recorded throughout the injection period and communicated to the SCADA control system. Once injections commence, injection pressure, annular pressure, and annular fluid volumes will be monitored continuously to ensure that internal well integrity and proper annular pressure are maintained.

If a significant change in the annular pressure or annular fluid volume is observed, an analysis will occur, noting that variations in the injection stream and ambient temperatures will impact the temperature and therefore pressure of the annular space. Initial review would focus on correlations between the temperature of the injection stream and the variations in annular pressure. If this analysis indicates the change in annular pressure or fluid volume is due to a loss of internal mechanical integrity, then refer to the procedures in Permit Section 10.0 – Emergency and Remedial Response Plan.

7.6.2 External Mechanical Integrity Testing (40 CFR 146.90 (e))

External integrity testing will be conducted annually to meet the requirements of 40 CFR 146.89(c) and 146.90(e).

External mechanical integrity refers to the absence of fluid movement through conduits between the long-string casing and the borehole or the intermediate casing string. Migration of fluids through this zone could result in contamination of USDWs; therefore, the external integrity of the injection well will be verified throughout the injection phase of the project. Temperature data acquired within the injection and monitor wells will be used to verify external mechanical integrity.

[redacted]

[redacted] These data will be compared to baseline measurements to determine wellbore temperature anomalies. If anomalies are observed, or primary temperature sensors fail, temperature logs, such as oxygen-activation log, will be performed to attribute the variance. **Table 7-7** details the proposed external mechanical integrity tests.

[redacted]

Table 7-7: External mechanical integrity tests.

7.7 Pressure Fall-Off Testing (40 CFR 146.90 (f))

Pressure Fall-Off (PFO) tests will be performed during the injection phase as described below to meet the requirements of 40 CFR 146.90(f).

PFO testing involves the measurement and analysis of the reservoir pressure after the well is shut in. PFO tests provide the following information:

- Confirmation of hydrogeologic storage formation properties such as injectivity and average effective permeability
- Formation damage (skin) near the wellbore, which can be used to diagnose the need for well remediation/rehabilitation
- Changes in storage formation performance over time, such as long-term pressure buildup in the storage formation, that may indicate formation damage or a boundary condition
- Average storage formation pressure that can be used to calibrate modeled predictions of storage formation pressure to verify that the operation is responding as modeled/predicted

7.7.1 Testing Location and Frequency

PFO testing will be performed in the injection well once every five years during the injection operations. PFO testing may be performed opportunistically if the capture plant is down for an extended amount of time for a maintenance event, or during a scheduled PFO testing. The scheduled PFO tests will likely be aligned with scheduled maintenance events to prevent additional system downtime.

During the PFO, downhole sensors in the injection and IZM will continuously monitor storage formation pressure and temperature.

7.7.2 Testing Details

A PFO test includes a duration of injection followed by a duration of shut in. The on-going injection at the well satisfies the injection requirement duration, so long as it has been relatively stable. The bottom-hole pressure is monitored and recorded for sufficient time during both phases of the testing to make a valid observation of the pressure fall-off curve. The optimal duration for the shut-in periods will be determined through the previous PFO test, if available. To reduce the wellbore storage effects attributable to the piping and surface equipment, the well will be shut-in at the wellhead in coordination with the capture facility operator. A steady injection rate will be required prior to the PFO test. Additional data from the month prior to shut-in will also be included in the analysis of the PFO test. Downhole and near wellhead sensors will be used to record and monitor pressures during the injection period and the fall-off period. Specifications for the pressure sensors are provided in the Appendix 7.A - QASP.

Bottom-hole pressure will be measured throughout the test period, including the pressures immediately following the shutdown of injection. The fall-off period will continue until radial flow conditions are observed as indicated by stabilization of the surface pressure and the plateau of the pressure derivative curve. The PFO test may also be truncated if boundary effects are encountered or if radial flow conditions are not observed over a reasonable amount of time. In addition to the radial flow regime, other flow regimes may be observed from the PFO test including spherical flow, linear flow, and fracture flow. Any data that may have been collected during previous PFO tests will be used to assess the duration of this phase of the test. Analysis of PFO test data will be done using transient-pressure analysis techniques that are consistent with EPA guidance for conducting PFO tests (EPA, 1998, 2002).

Pressure gauges that are used for the purpose of the PFO test will be calibrated according to the recommendations of the manufacturer and current calibration certificates will be provided with the test results to EPA.

A report containing the PFO data and interpretation of the storage formation ambient pressure within the radius of investigation will be submitted to the permitting agency within 30 days of the test.

7.8 Carbon Dioxide Plume and Pressure Front Tracking (40 CFR 146.90 (g))

[redacted]

7.8.1 Plume Monitoring Location and Frequency

Table 7-8 presents a summary of the methods that will be used to monitor the growth of the CO_2 plume, including the activities, locations, and frequencies.

[redacted]

Table 7-8: CO_2 plume monitoring activities.

A program of [redacted] are proposed as the primary indirect technique to monitor the development of the CO_2 plume during and after injection. A series of [redacted] have been acquired over the site as part of the site characterization (Permit Section 1.0 - Project Narrative) which will form the basis for the seismic program.

When fluid sampling and analysis is needed, the parameters to be analyzed for fluid sampling from the injection zone and associated analytical methods are presented in **Table 7-4**. The corresponding QA procedures for these methods are presented in the QASP. Fluid samples will be obtained for analysis from the injection intervals in accordance with Permit Section 5.0 - Pre-Operational Testing Plan. The final sampling interval will be determined from the analyzed well logs at the injection well.

7.8.2 Plume Monitoring Details

[redacted]

As CO_2 is injected into the formation, the geochemistry of the fluids is expected to change. Geochemical modeling will be used to predict the geochemical changes to the storage formation fluids once data from the pre-operational testing have been analyzed. The geochemical analytical results of the fluid sampled from the IZM will be delivered in the form of laboratory reports.

If the CO_2 plume monitoring data diverges significantly from the modeled plume predictions, it may result in a reassessment of the AoR per Permit Section 2.0 - AoR and Corrective Action Plan.

7.8.3 Pressure-Front Monitoring Location and Frequency

Table 7-9 presents the methods that will be used to monitor the position of the pressure front, including the activities, locations, and frequencies. QA procedures for these methods are presented in the Appendix 7.A - QASP.

[redacted] The sensors will be real-time surface readout sensors connected and recorded through the SCADA system. The sensors will be programmed to measure and record pressure and temperature every minute and rolled up to daily data for storage.

[redacted]

Table 7-9: Pressure plume monitoring activities.

[redacted] These data will be sent to a cloud-based service via a cellular connection for data processing and archiving. Baseline seismicity data will be acquired prior to the start of injection operations.

[redacted] However, if the AoR is reassessed over the injection phase of the project, Permit Section 7.0 - Testing and Monitoring Plan will be reassessed.

7.8.4 Pressure-Front Monitoring Details

[redacted] (**Table 7-9**). The sensors will be real-time surface readout sensors connected and recorded through the SCADA system. The sensors will be programmed to measure and record pressure and temperature every minute and averaged daily data for storage. Refer to the QASP for technical information on the potential pressure sensors (Appendix 7.A).

The pressure data will be stored as time-stamped data pairs. The pressures in the injection interval are expected to increase once injection operations commence. These data will be used to calibrate the computational modeling results over the injection and PISC phases of the project. Calibrating the computational model with pressure and temperature data from the storage formation will lead to more accurate predictions of pressure plume behavior over time. The AoR and Corrective Action Plan further describes how the pressure and temperature data will be used to calibrate the computational modeling, and how it might be used to trigger an early reassessment of the AoR (Permit Section 2.0).

[redacted]. Each standalone station will likely consist of a seismometer, digitizer, solar panel with battery backup, and a cell modem/ antenna. Triggered data will be processed to provide event magnitude and location information, and results will be reviewed by a data processor and event data will be received by the project daily. The event locations will be incorporated in the SEM. Seismic activity will provide qualitative information on the spatial extent of pressure plume over time.

7.9 Testing and Monitoring Plan Review (40 CFR 146.90 (j))

The Testing and Monitoring Plan will be periodically reviewed to incorporate monitoring data collected under this subpart, operational data collected as part of injection operations (40 CFR 146.88), and the most recent AoR reevaluation performed (40 CFR 146.84). The Testing and Monitoring Plan to be reviewed no less than once every five years. Based on this review, an amended Testing and Monitoring Plan shall be submitted or demonstrated to the UIC Program Director that no amendment to the Testing and Monitoring Plan is needed. Any amendments to the Testing and Monitoring Plan must be approved by the UIC Program Director, must be incorporated into the permit, and are subject to the permit modification requirements pursuant to 40 CFR 144.39 or 40 CFR 144.41, as appropriate. Amended plans or demonstrations shall be submitted to the UIC Program Director as follows:

(1) Within one year of an AoR reevaluation

(2) Following any significant changes to the project, such as addition of monitoring wells or newly permitted injection wells within the AoR, on a schedule determined by the UIC Director

(3) When required by the UIC Program Director.

7.10 References

American Society of Testing and Materials, 2017. Standard Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens, G1-03. 9

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Cosasco Two-Inch System Installation, Operation & Maintenance Manual, Cosasco, 2021. P/N 740075, https://studylib.net/doc/8901412/chapter-4-field-handling-and-cleaning-of-corrosion-coupons

EPA (United States Environmental Protection Agency). "UIC Pressure Falloff Testing Guideline." EPA Region 6, August 8, 2002, Third Revision. https://www.epa.gov/sites/default/files/2015-07/documents/guideline.pdf

EPA (United States Environmental Protection Agency)."Determination of Mechanical Integrity of Injection Wells." EPA Region 5, February, 2008. https://www.epa.gov/sites/default/files/2015-09/documents/r5-deepwell-guidance5-determation-mechanical-integrity-200802.pdf

EPA (United States Environmental Protection Agency), Contract Laboratory Program Guidance for Field Samplers, EPA 540-R-09-03. https://semspub.epa.gov/work/HQ/177977.pdf

EPA (United States Environmental Protection Agency), 2013. Geologic Sequestration of Carbon Dioxide: Underground Injection Control (UIC) Program Class VI Well Testing and Monitoring Guidance, EPA 816-R-13-001. 142 p.

Appendix 7.A Quality Assurance and Surveillance Plan

The Quality Assurance and Surveillance Plan is presented in a separate document accompanying this permit application.

Appendix 7.B Monitoring Well Design and Plug & Abandonment

The monitoring well designs and plug and abandonment diagrams are presented in a separate document accompanying this permit application.