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ATTACHMENT 9: POST-INJECTION SITE CARE AND SITE CLOSURE PLAN 40 CFR 146.93(a)

HOOSIER #1 PROJECT

Facility Information

Project Name: Hoosier #1

Facility Name: Cardinal Ethanol

Facility Contact: Jeremey Herlyn, Project Manager
Cardinal Ethanol

Well Location: 1554 N. 600 E.
Union City, IN 47390
CO_2 Injection Well Location for CCS1
Latitude 40.186587°
Longitude -84.864284°

Operator Name: One Carbon Partnership, LP
1554 N. 600 E.
Union City, IN 47390

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List of Acronyms

2D	Two-Dimensional
3D	Three-Dimensional
ACZ	Above Confining Zone
ACZ1	Proposed Above Confining Zone Well
AoR	Area of Review
BHFP	Bottomhole Flowing Pressure
BHP	Bottomhole Pressure
CCS1	Proposed Injection Well
CO_2	Carbon Dioxide
DIC	Dissolved Inorganic Carbon
EPA	Environmental Protection Agency
ERRP	Emergency and Remedial Response Plan
FOT	Fall-off Test
ICP	Inductivity Coupled Plasma
IDNR	Indiana Department of Natural Resources
kT/Y	kiloton per year
kv/kh	vertical/horizontal permeability
Mc	Magnitude of Completeness
MD	Measured Depth
MIT	Mechanical Integrity Test
MS	Mass Spectrometry
NRMS	Normalized Root Mean Square
OBS1	Deep Observation Well
OCP	One Carbon Partnership, LP
OES	Optical Emission Spectrometry
PISC	Post Injection Site Care and Site Closure
PNL	Pulsed Neutron Logging
QASP	Quality Assurance and Surveillance Plan
TBD	To Be Determined
TDS	Total Dissolved Solids
UIC	Underground Injection Control
USDW	Underground Source of Drinking Water
USDW1	Proposed Lowermost USDW Monitor Well

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This Post-Injection Site Care and Site Closure (PISC) plan describes the activities that the Hoosier#1 Project will perform to meet the requirements of 40 CFR 146.93. The project is proposing an alternative timeframe of ten years. The position of the carbon dioxide (CO_2) plume, pressure front, and shallow ground water quality will be monitored for the 10-year PISC period over which CO_2 plume and pressure front are expected to stabilize based on current computational modeling (Section 4.0).

1.0 Pre- and Post-Injection Pressure Differential [40 CFR 146.93(a)(2)(i)]

Based on the computational modeling performed as part of the Area of Review (AoR) delineation (Section 4.2), the injection zone pressure is expected to decrease to pre-injection levels after approximately two years. Additional information on the projected post-injection pressure declines and differentials is presented in the AoR and Corrective Action Plan (Attachment 2: AoR and Corrective Action, 2022).

The pressure plume is defined as the area where the delta pressure is greater than the critical pressure. The critical pressure is the increase in pressure necessary to allow fluids to migrate up an open conduit to the lowermost Underground Source of Drinking Water (USDW). Critical pressure, in this case, is 227 psi. The computational modeling demonstrates that the pressure will rapidly decline in the two years following the cessation of injection and that the pressure plume will decrease in size until pressures decrease below the critical pressure after approximately two years. Within 250 feet of the injection well, the maximum pressure rise is estimated to be 378 psi at the end of the injection period.

2.0 Predicted Position of the CO_2 Plume and Associated Pressure Front at Site Closure [40 CFR 146.93(a)(2)(ii)]

Figure 1 shows the predicted extent of the plume and pressure front at the end of the PISC timeframe that represents the maximum extent of the plume and pressure front. This map is based on the final AoR delineation modeling results submitted pursuant to 40 CFR 146.84. A list of water wells located within the AoR are provided in the AoR and Corrective Action Plan (Attachment 2: AoR and Corrective Action, 2022).

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[redacted]

Figure 1. Map of the predicted extent of the CO_2 plume and pressure front at site closure.

3.0 Post-Injection Monitoring Plan [40 CFR 146.93(b)(1)]

The PISC monitoring, which includes shallow groundwater, above confining zone (ACZ), injection zone pressures, and geophysical monitoring (as described in the following sections), will meet the post injection monitoring requirements of 40 CFR 146.93(b)(1). The results of all the post-injection monitoring will be submitted annually, within thirty days of the conclusion of the activities or receipt of processed data, whichever is later, as described under "Schedule for Submitting Post-Injection Monitoring Results," following.

A Quality Assurance and Surveillance Plan (QASP) for all testing and monitoring activities during the injection and post injection phases is provided (Attachment 11: QASP, 2022).

Table 1 summarizes the monitoring activities that will take place during the PISC phase of the project. The project will continue to monitor pressures within the Mt. Simon Sandstone in the Proposed Injection Well (CCS1) and Deep Observation Well (OBS1) until the pressures drop to below the critical pressure rise of 227 psi. The pressure within the Mt. Simon Sandstone is expected to begin to dissipate once CO_2 injection ceases based on the computation modelling (Section 4.0). The injection zone pressure measurements are expected to verify the modeling results. This pressure data will be used to further calibrate the computational modelling in the PISC phase.

Downhole pressure is to be monitored continuously in both wells for two years or until the bottomhole pressure (BHP) change in CCS1 is below the critical pressure (227 psi), whichever occurs later. At this point, annual static gradient surveys will be collected from CCS1, and pressure monitoring will cease in OBS1.

The ACZ monitoring zone pressures will also continue to be monitored to confirm the containment of CO_2 within the injection zone. Fluid samples will be taken from the ACZ monitoring zone once per year for geochemical and isotopic analysis to further verify CO_2 containment. Shallow groundwater fluid samples will also be obtained each year for geochemical and isotopic analysis.

Any potential microseismic activity will likely fall-off once the injection phase of the project is complete and the associated pressure plume begins to dissipate. The microseismic monitoring will likely be phased out as activity decreases. This will be evaluated in the first months of the project's PISC phase. The Underground Injection Control (UIC) Program Director will be consulted prior to ceasing any monitoring activities during the PISC phase of the project.

The project proposes to acquire two time-lapse three-dimensional (3D) surface seismic surveys in the PISC phase of the project. One will be acquired the year either at the end of the injection phase or at the start of the PISC phase of the project. The last survey will be acquired in the eighth (8^{th}) year of the PISC phase of the project. The objectives of these two surveys include:

- Verification of continued CO_2 containment in the injection zone,
- Demonstration of the stability of the CO_2 plume after the injection phase of the project,
- To provide data for the calibration and verification of the computational modelling.

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Plan revision date: N/A

Table 1: Summary of proposed testing and monitoring activities to take place during the PISC phase of the project.

Monitoring Activity	PISC Frequency*	Location	Depth Range (MD ft)**
Groundwater Monitoring			
Groundwater Sampling	Annual (Q2 of each year)	Sensitive, Confidential, or Privileged Information [redacted]	Varying
Isotope Analysis	Annual (Q2 of each year)	[redacted]	Varying
Pressure Monitoring		[redacted]	
Downhole Pressure	Continuous*	[redacted]	Above Packer (TBD) Mt. Simon Sandstone (TBD)
Wellhead Pressure	Continuous	[redacted]	Knox Formation (TBD)
Mechanical Integrity Tests		[redacted]	
Mechanical Integrity Test (MIT) Part I: Annulus Pressure Test	Year 5 Year 10	[redacted]	Surface Surface
MIT Part II: Temperature Logging	Year 5 Year 10	[redacted]	TBD
Plume Verification Monitoring		[redacted]	
Pulsed Neutron Logging (PNL)	Year 1, Year 3, Year 5, Year 7, Year 9	[redacted]	To the Packer TBD
Microseismic Monitoring	Continuous	[redacted]	Injection Zone Confining Zone
Time-lapse 3D Surface Seismic Data	Q2 Year 0 Q2 Year 8	[redacted]	Imaging of CO_2 plume and overburden

*Downhole pressure is to be monitored continuously in both wells for two (2) years, or until the BHP change in CCS1 is below the critical pressure (227 psi), whichever occurs later. At this point, annual static gradient surveys will be collected from CCS1, and pressure monitoring will cease in OBS1.

** To be confirmed after well is drilled

Cardinal Ethanol owns the land on which CCS1, OBS1, and the Proposed Above Confining Zone Well (ACZ) are located and also owns (or will have surface access rights to) the land that the shallow groundwater wells are located on. Access to the wells for testing is not anticipated to be a problem as surface access will be negotiated as part of the landowner leases for the project.

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3.1 Monitoring Above the Confining Zone

The monitoring plan for the PISC is designed to be adaptive and respond to evolving project risks over time. At this point in the project, no phased monitoring has been planned for ACZ1 groundwater monitoring; however, this may be re-assessed as the project progresses. No changes will be made to the PISC without informing the UIC Program Director (40 CFR 146.93 (a)(3)).

Table 2 presents the proposed ACZ groundwater monitoring methods, locations, and frequencies. The ACZ monitoring zone will likely be in the Knox Formation with the exact depth to be determined through the Pre-Operational Testing Program (Attachment 5: Pre-Op Testing Program, 2022). For fluid sampling, a bailer system that maintains the formation pressure of the sample, will be used to collect water samples to be analyzed for dissolved inorganic carbon, alkalinity, pH, and the isotopic analyses. Samples for all other analytes will be collected with an open-ended bailer. Prior to sample collection the well will be swabbed to remove stagnant water from the well and ensure representative water is collected from the formation. The fluid swabbed from the well will be monitored for field parameters, such as pH, specific conductance, and temperature, using a calibrated water quality meter. Once these parameters stabilize, it will be an indication that representative formation fluid is in the well at the time the sample is collected.

Further detail on specifications, sample collection methods, analytical techniques, detection limits, and means of storing and transporting fluid samples is provided in the QASP (Attachment 11: QASP, 2022).

Table 2. ACZ1 Monitoring of ground water quality and geochemical changes above the confining zone.

Target Formation	Monitoring Activity	Monitoring Location(s)	Spatial Coverage	Frequency
Shallow Groundwater	Aqueous geochemistry and stable isotopes	Sensitive, Confidential, or Privileged Information [redacted]	[redacted]	Annual (Q2/yr)
Knox Formation	Aqueous geochemistry and stable isotopes	[redacted]	[redacted]	Annual (Q2/yr)

Table 3 identifies the initial groundwater parameters to be monitored and the analytical methods that will be used for the samples in the baseline analysis of the data.

Table 3. Summary of analytical and field parameters for ground water samples.

Parameters	Analytical Methods[1]
Cations: Al, Ba, Mn, As, Cd, Cr, Cu, Pb, Sb, Se, Zn, Ti, Ca, Fe, K, Mg, Na, and Si	ICP[2]-MS[3], EPA Method 6020 ICP-OES[4], EPA Method 6010B
Anions: Br, Cl, F, NO_3, and SO_4	Ion Chromatography EPA Method 300.0
Dissolved CO_2	Coulometric Titration ASTM D513-11
Isotopes: $\delta^{13}C$ Dissolved Inorganic Carbon (DIC)	Isotope ratio mass spectrometry[5]
Total Dissolved Solids	Gravimetry APHA 2540C
Water Density (field)	Oscillating body method
Alkalinity	APHA 2320B
pH (field)	EPA 150.1
Conductivity/Resistivity (field)	APHA 2510
Temperature (field)	Thermocouple

Note 1: An equivalent method may be employed with the prior approval of the UIC Program Director.
Note 2: Inductivity Coupled Plasma
Note 3: Mass Spectrometry
Note 4: Optical Emission Spectrometry
Note 5: Gas evolution technique by Atekwana and Krishnamurthy (1998), with modifications made by Hackley et al. (2007)

At this time, a laboratory has not been selected for the groundwater sampling and analysis. However, all sampling and analytical measurements will be performed in accordance with project quality assurance requirements. Samples will be tracked using appropriately formatted chain-of-custody forms (Attachment 11: QASP, 2022).

The results of the geochemical and isotope analysis will be delivered in the form of lab reports. If anomalous changes in the aqueous geochemistry are observed in ACZ, lowermost USDW, or shallow groundwater monitoring zones, new samples will be obtained from the affected zone to verify the changes. The frequency with which fluid samples are obtained for analysis from that zone will also be increased.

As a precautionary measure, the fluid sampling frequency for the shallow groundwater monitoring wells will also be increased. If the injected CO_2 has a unique isotopic signature from the existing isotopes in the overlying formation, a new round of samples will be collected for isotopic analysis from the affected formation. Anomalous changes may also trigger the need for additional well integrity testing in both the CCS1 and OBS1 to ensure that no well integrity issues have developed since the last set of external mechanical integrity tests. A combination of anomalous pressure, geochemical, and well integrity testing results may result in the decision to acquire a time-lapse 3D surface seismic survey before the survey scheduled in year eight of the PISC to determine the size of the leakage accumulation (Table 1).

Table 4 presents information about the wellhead pressure monitoring to be used in the ACZ1 well. Further detail and specifications on the equipment to be used in the ACZ1 well is provided in the QASP. The pressure data will be stored as time stamped data. Migration of injection zone fluids into the deep ACZ zone will likely first be identified through pressure changes in the formation. An increasing pressure trend in the ACZ zone would suggest that migration of injection zone fluids beyond the confining zone has occurred. While any increasing trend in pressure will be evaluated, an increase in pressure greater than 5% above baseline values will warrant additional monitoring and inspections to rule out the possibility of fluid migration out of the injection zone. Such an increase in pressure would initiate more frequent fluid sampling and analysis for geochemical parameters from the formation and require additional external well integrity investigations for CCS1 or OBS1.

Table 4. Sampling and recording frequencies for continuous monitoring in ACZ1

Parameter	Device(s)	Location	Minimum Sampling Frequency	Minimum Recording Frequency
Pressure	Wellhead Pressure Gauge	Sensitive, Confidential, or Privileged Information [redacted]	Continuous (every hour)	Continuous (every hour)

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.

3.2 CO_2 Plume and Pressure Front Tracking [40 CFR 146.93(a)(2)(iii)]

The project will employ direct and indirect methods to track the extent of the CO_2 plume and the presence or absence of elevated pressure throughout the PISC phase.

Table 5 presents the direct and indirect methods that will be used to monitor the CO_2 plume including the activities, locations, and frequency of sampling.

The quality assurance procedures for seismic monitoring methods will be performed as described in (Attachment 11: QASP, 2022).

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Table 5. Post-injection phase CO_2 plume monitoring

Target Formation	Monitoring Activity	Monitoring Location(s)	Spatial Coverage	Frequency
Direct Plume Monitoring				
Knox, Eau Claire, and Mt. Simon Formations	Pulsed Neutron Logging	Sensitive, Confidential, or Privileged Information [redacted]		Year 1, Year 3, Year 5, Year 7, Year 10
Indirect Plume Monitoring				
Overburden, Eau Claire, and Mt. Simon Formations	Time-lapse 3D Surface Seismic Data	Sensitive, Confidential, or Privileged Information [redacted]		Q2, Year 0 Q2, Year 8

The Pulsed Neutron Logging (PNL) will be received as LAS files and interpreted products that can be imported into the static model. PNL will be used to monitor the distribution and saturation of CO_2 adjacent to the wellbore in OBS1. In CCS1, it is expected that the near wellbore zone will be saturated with CO_2 and the plume will take up the entire injection zone, so there will be little value in running the PNL through the injection zone. However, the PNL will be run through the ACZ monitoring zone to verify that there are no accumulations of CO_2 adjacent to the wellbore above the confining layer in CCS1. Technical details on PNL tools can be found in the QASP (Attachment 11: QASP, 2022).

Surface seismic data is delivered in a variety of formats including acquisition and processing reports and SEG-Y data files from a variety of points in the processing flow. In the context of time-lapse analysis, an assessment will be provided on the differences between the baseline and time-lapse surveys as well as data files that can be incorporated into the static model. The injection of CO_2 and expansion of the plume is expected to change the acoustic impedance of intervals within the Mt Simon Sandstone and increase the time it takes seismic waves to travel through the CO_2 plume over time. Both the acoustic impedance and travel time changes will be used to track CO_2 plume during the PISC phase of the project. In addition, time-lapse analysis metrics such as normalized root mean square (NRMS) and predictability can be used to track the plume. The time-lapse surface seismic data will also be monitored for changes that may suggest that CO_2 has migrated past the confining layer and into the ACZ monitoring zone.

At this time, no direct fluid sampling is planned for the injection zone for the PISC phase of the project. The CO_2 plume is expected to intersect OBS1 within three years of the start of injection operations (Figure 2). Once free phase CO_2 breaks through at OBS1, the project will stop taking fluid samples and analyzing for isotopes from the Mt Simon Sandstone.

Table 6 presents the direct and indirect methods that will be used to monitor the pressure front.

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[redacted]

Figure 2: Time-lapse CO_2 plume development map over 3, 12, 20, and 30 years of injection as well as 10- and 50-years post injection. Note the relative stability of the CO_2 plume radius after injection operations cease.

Table 6. Post-injection phase pressure-front monitoring

Target Formation	Monitoring Activity	Monitoring Location(s)	Spatial Coverage	Frequency
Direct Pressure-Front Monitoring				
Mt Simon Sandstone	Pressure Monitoring	Sensitive, Confidential, or Privileged Information [redacted]		Continuous (Minimum every one (1) minute)*
Indirect Pressure-Front Monitoring				
Eau Claire Formation Mt. Simon Sandstone	Microseismic Monitoring	Sensitive, Confidential, or Privileged Information [redacted]		Continuous (Minimum every 10 seconds)
*Downhole pressure is to be monitored continuously in both wells for two years, or until the BHP change in CCS1 is below the critical pressure (227 psi), whichever occurs later. At this point, annual static gradient surveys will be collected from CCS1, and pressure monitoring will cease in OBS1.				

The downhole pressure sensors will be programmed to measure and record pressure and temperature data in one-minute intervals. The downhole pressure will be monitored in both wells for two years, or until the bottom hole pressure change in CCS1 is below the critical pressure (227 psi), whichever occurs later. After this time, annual static gradient surveys will be collected from CCS1 via wireline, and pressure monitoring will cease in OBS1.

Should either of the well's BHP gauge fail during the first two-year period, positive pressure readings at the wellhead will be used to verify continued pressure fall-off until the gauge can be replaced. Should positive pressure at the wellhead no longer be present, a suitable, periodic method of determining hydrostatic fluid level (i.e., shooting fluid levels or similar method) will be used to calculate the BHP until the gauge can be replaced.

The final monitoring interval in both wells will be determined after CCS1 has been drilled and the well logs have been analyzed (Attachment 5: Pre-Op Testing Program, 2022).

The results of the aqueous geochemistry and isotope analysis, PNL, and time-lapse 3D surface seismic data will all be integrated to develop a comprehensive understanding of the CO_2 plume behavior during the PISC phase. PNL and time-lapse 3D surface seismic data can be incorporated into the static model for comparison to the computational modeling predictions at different points in time. The data can be used to constrain the computational modeling results and produce better plume predictions over the course of the project.

The PNL data will be used to calibrate the computational modeling and provide information on the vertical and horizontal plume behavior as well as supply more detailed and direct measurement of CO_2 saturations than indirect seismic methods. The time-lapse 3D surface seismic data will be used to update the models after the data has been analyzed. If the CO_2 plume monitoring data diverges significantly from the modeled plume predictions, it may result in a reassessment of the AoR as per the AoR and Corrective Action Plan (Attachment 2: AoR and Corrective Action, 2022).

Based on the current computational modeling results, the CO_2 plume is expected to stabilize quickly during the PISC phase of the project (Figure 2). Time-lapse 3D surface seismic surveys acquired during Q2 in Year 0 and Year 8 of the PISC phase of the project will demonstrate the stabilization of the CO_2 plume and be used to verify the computational modelling results.

3.3 Schedule for Submitting Post-Injection Monitoring Results [40 CFR 146.93(a)(2)(iv)]

All PISC monitoring data and results obtained using the methods described above will be submitted to EPA in annual reports. These reports will contain information and data generated during the reporting period (i.e., well-based monitoring data, sample analysis, and results from updated site models).

4.0 Alternative PISC Timeframe [40 CFR 146.93(c)]

The project will conduct post-injection monitoring for a ten-year period following the cessation of injection operations. A justification for this alternative PISC timeframe is provided following.

4.1 Computational Modeling Results – 40 CFR 146.93(c)(1)(i)

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[redacted] Gas trapping and CO_2 dissolution in water will continue to increase over time and will mitigate the buoyancy effect to some extent. Expansion after 50-years post injection is negligible. Additional figures and cross sections on the CO_2 plume development can be found in (Attachment 2: AoR and Corrective Action, 2022).

The kv/kh (vertical/horizontal permeability) ratio is a key uncertainty given the lack of deep well data in the region. From pressure transient analysis of well test data from the INEOS (BP Lima) UIC Project, it was estimated that kv/kh is approximately 0.003. Sensitivity cases were run with kv/kh values equal to 0.01 and 0.1 (Figure 3). The individual simulations indicated that the CO_2 plume would be smaller with increasing values of kv/kh (Table 7). As kv/kh values increase the rate of vertical migration of the CO_2 is higher resulting in more residual gas trapping. A very low kv/kh would be representative of a higher number of baffles in the formation that would prevent upward migration of the CO_2 and encourage horizontal migration. Currently, it is believed that the value 0.003 is a realistic but conservative estimate given the results from the INEOS (BP Lima) UIC Project. These results will be re-assessed once as site specific data is collected over the pre-operational and operational phases of the project.

Table 7: Impact of varying kv/kh values on the CO_2 plume radius

Kv/kh	CO_2 Plume Radius (mi)
0.003	1.32
0.01	1.23
0.1	1.02

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[redacted]

Figure 3: Effect of kv/kh ratio on CO_2 plume size. Increasing kv/kh results in smaller CO_2 plume size as a result of higher rates of residual gas trapping. a. kv/kh = 0.003, b. kv/kh = 0.01, c. kv/kh = 0.1

4.2 Predicted Timeframe for Pressure Decline – 40 CFR 146.93(c)(1)(ii)

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[redacted]

The pressure plume decline is sensitive to the average flow capacity (kh) of the injection site. A higher kh would result in a more rapid decline, while a lower kh would result in a slower decline. In any event, the decline period is expected to be short based on the current computational modeling.

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[redacted]

Figure 4: Delta pressure at time = 0-, 30-, 365-, and 730-days post injection. The pressure plume, which is defined by a delta p of 227 psi, is undetectable at 730-days post injection.

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[redacted]

Figure 5: CO_2 injection rate, cumulative production, and BHFP for injection well during injection period and 50 years post injection.

4.3 Predicted Rate of Plume Migration – 40 CFR 146.93(c)(1)(iii)

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[redacted]

4.4 Site-Specific Trapping Processes – 40 CFR 146.93(c)(1)(iv)-(vi)

The primary trapping mechanisms considered for this project are structural, residual gas, CO_2 dissolution in water, and mineral dissolution and precipitation. Figure 6 illustrates how the impact of each trapping mechanism changes with time according to the results of the computational modeling.

Initially, a large percentage, 61%, of the supercritical CO_2 injected will be trapped in the injection zone by the confining layer. Gas in hydrocarbon reservoirs has been known to have been trapped for millions of years providing confidence that long-term storage is possible in formations with a competent seal. Confining layer integrity and containment is a critical component of a CO_2 storage project. The computational modeling incorporated geomechanical information from INEOS (BP Lima) UIC Project to predict the increase in pressure on the confining zone within the pressure plume to assess the suitability of the confining zone (Attachment 1: Narrative, 2022). The estimated effective stress for the top of the injection zone/

base of the confining zone is 966 psi while the increase in pressure associated with 30 years of CO_2 injection is approximately 378 psi. This indicates that the confining zone is a suitable barrier to fluid migration out of the injection zone over a 30-year period.

Residual gas trapping occurs when the CO_2 is carried by convection currents away from the wellbore and begins to rise due to gravity segregation between the CO_2 and water. The CO_2 can become discontinuous in small pore spaces and residual amounts are trapped. The computational modeling estimated that 17% of the CO_2 injected would be trapped through residual gas trapping by the end of the injection period; however, over time a significant percentage of the total injected CO_2 is trapped through this mechanism (Figure 6). Initially, the water saturation in the pore space decreases as CO_2 is injected (drainage) but increases as CO_2 migrates upwards (imbibition). The imbibition relative permeability curve is different from the drainage relative permeability curve; this difference is known as relative permeability hysteresis. Hysteresis modeling data for a two-phase system involves a bounding drainage curve, Krg, and a trapping mechanism function with associated parameters. The trapping function determines the bounding/scanning imbibition curves. The computational modeling used the Carlson and Land model for the residual gas trapping calculations.

Gas solubility trapping is a slower process than residual gas trapping but is also an important mechanism in long-term storage. The computational modeling estimated that 22% of the CO_2 injected would be trapped by this mechanism by the end of the injection period (Figure 6). Solubility trapping is dependent on pressure, temperature, salinity, and surface area contact with the water. The percentage of gas trapped by dissolution increases significantly over time. The solubility correlations are based on Henry’s Law, and various models are available in the modeling software including Li-Nghiem and Harvey. The effect of salinity can be modeled by either the Cramer or Bakker correlations.

Mineral dissolution and precipitation reactions are very slow, and it is estimated that significant amounts of trapping will occur only after hundreds or thousands of years post injection. In this study, anorthite, calcite, and kaolinite were considered as precipitates. After 100-years post injection, the mineralization of CO_2 accounted for only 0.4% of the total gas trapped. Figure 7 shows the mole change of each mineral over time.

It has been speculated, and generally accepted by the CCS community, that over a period of 10,000 years 90% of the injected CO_2 will be immobilized in the injection zone because of the mechanisms described above. The remaining 10% will continue to be trapped by the confining layer until eventually all the CO_2 becomes immobile.

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[redacted]

Figure 6: Breakdown of CO_2 mols for free phase supercritical, dissolved, and trapped phases during the injection period and 100 years post injection. Mineralization is negligible during this period.

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[redacted]

Figure 7: Mineral mole change over time for anorthite, calcite, and kaolinite. Initially, calcite is dissolved, but then starts to precipitate again and becomes the primary mineral trapping mechanism. Mineralization becomes an important trapping mechanism over thousands of years (not shown) post injection.

4.5 Confining Zone Characterization – 40 CFR 146.93(c)(1)(vii)

The Eau Claire Shale will serve as a competent confining zone for the project and supports the demonstration of the alternative PISC timeframe based on the following characteristics:

- [redacted]
- It is laterally extensive and extends across Indiana, Ohio, and Illinois, as well as parts of Kentucky,
- It has relatively consistent formation properties (facies, porosity, and permeability) across the region,
- It displays only minor variation in thickness,
- It is not penetrated by any known major faulting.

[redacted] Current knowledge of the Eau Claire Shale does not indicate that it will be reactive with the injected CO_2, and it is not anticipated that prolonged contact with CO_2 will compromise the integrity of the formation. The geomechanical modeling indicates that the pressure exerted on the confining zone within the AoR will not be high enough to compromise the integrity of the formation even if the project were to inject at much higher annual rates (Section 4.4). In the post injection phase of the project, injection zone pressures are predicted to decline quickly and return to pre-injection levels within two years. The risks to confining zone integrity will also decrease significantly as injection zone pressures decrease.

The Project Narrative and the AoR and Corrective Action Plan include further information on the site characterization and computational modeling work that has been completed to support the project (Attachment 1: Narrative, 2022; Attachment 2: AoR and Corrective Action, 2022). As site specific data is collected through the Pre-Operational Testing Program the static and computational modeling will be updated, and the conclusions regarding the confining zone suitability will be verified or re-evaluated.

4.6 Assessment of Fluid Movement Potential – 40 CFR 146.93(c)(1)(viii)-(ix)

The existing two-dimensional (2D) surface seismic data does not indicate that there are any faults in the immediate area that impact the confining zone (Attachment 1: Narrative, 2022). There are no known artificial penetrations of the confining zone within the project AoR. [redacted] As a result, no corrective action has been planned for the project. The requirement for corrective active will be re-assessed should the AoR change over the course of the project.

[redacted] The project plans to monitor the wellhead pressure of ACZ1 and take fluid samples from an ACZ interval within the Knox Formation during the injection and

PISC phases of the project. If any indicators of injection formation fluids are identified within the ACZ monitoring interval, the project wells will be investigated for any potential well integrity issues. It is expected that any migration of injection zone fluids into the ACZ monitoring interval will be identified before any injection zone fluids can intersect one of the Knox Formation well penetrations.

Figure 9 shows the distribution of shallow groundwater wells in the AoR. The project will continue to monitor a subset of shallow groundwater wells distributed around the for indications that injection zone fluids have migrated past the confining layer during the PISC phase on an annual basis.

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[redacted]

Figure 8: Deep well penetrations within the AoR. The deepest well penetration is IN144860 that reaches a depth of 2,310 ft into the Knox Formation.

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[redacted]

Figure 9: Shallow groundwater and oil and gas wells that have been converted to groundwater wells in the AoR.

When CCS1 is drilled and completed, the long string casing will be cemented to surface (Attachment 4: Well Construction, 2022). After cementing is complete, the cement integrity will evaluated along the length of the well using a cement bond log with radial arms, and an ultrasonic cement evaluation tool will be used to evaluate the cement through the injection zone, confining layer, and ACZ interval (Attachment 5: Pre-Op Testing Program, 2022).

Through the injection phase of the project, the well integrity of CCS1 will regularly be assessed through continuous wellhead pressure (calibrated using downhole pressure measurements), annular pressure and fluid volume, annual mechanical integrity tests, and periodic pressure fall-off tests (Attachment 7: Testing And Monitoring, 2022). During the PISC phase of the project, the well integrity of CCS1 will continue to be monitored through continuous wellhead pressure (and downhole pressure as stipulated in previous sections), and temperature logging every five years (Table 1). PNL will also be used every second year to identify any CO_2 accumulations adjacent to the wellbore in CCS1.

4.7 Location of USDWs – 40 CFR 146.93(c)(1)(x)

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[redacted]

During the post injection phase of this project, the vertical extent of injected CO_2 is relatively consistent, and the CO_2 is expected to remain in the injection zone.

5.0 Non-Endangerment Demonstration Criteria

Prior to approval of the end of the post-injection phase, One Carbon Partnership, LLC (OCP) will submit a demonstration of non-endangerment of USDWs to the UIC Program Director, per 40 CFR 146.93(b)(2) and (3).

The owner or operator will issue a report to the UIC Program Director. This report will make a demonstration of USDW non-endangerment based on the evaluation of the site monitoring data used in conjunction with the project's computational model. The report will detail how the non-endangerment demonstration evaluation uses site-specific conditions to confirm and demonstrate non-endangerment. The report will include all relevant monitoring data and interpretations upon which the non-endangerment demonstration is based, model documentation and all supporting data, and any other information necessary for the UIC Program Director to review the analysis. The report will include the following sections:

5.1 Introduction and Overview

A summary of relevant background information will be provided, including the operational history of the injection project, the date of the non-endangerment demonstration relative to the post-injection period outlined in this PISC and Site Closure Plan, and a general overview of how monitoring and modeling results will be used together to support a demonstration of USDW non-endangerment.

5.2 Summary of Existing Monitoring Data

A summary of all previous monitoring data collected at the site, pursuant to the Testing and Monitoring Plan and this PISC and Site Closure Plan, including data collected during the injection and post-injection phases of the project, will be submitted to help demonstrate non-endangerment (Attachment 7: Testing And Monitoring, 2022). Data submittals will be in a format acceptable to the UIC Program Director [40 CFR 146.91(e)], and will include a narrative explanation of monitoring activities, including the dates of all monitoring events, changes to the monitoring program over time, and an explanation of all monitoring infrastructure that has existed at the site. Data will be compared with baseline data collected during site characterization [40 CFR 146.82(a)(6) and 146.87(d)(3)].

5.3 Summary of Computational Modeling History

The computational modeling demonstrates non-endangerment of USDWs in several ways:

- CO_2 plume stabilizes quickly once injection operations cease,
- Injection zone pressures decline rapidly once injection operations cease and will fall below the delta pressure of 227 psi after two years,
- Residual gas and gas solubility trapping of the CO_2 will increase with time and trap the CO_2 more effectively than structural trapping alone
- Geomechanical modeling shows that integrity of the confining layer will be maintained even at much higher annual injection rates.

Table 8 summarizes the monitoring data that will be used to verify and calibrate the computational modeling and support the demonstration of non-endangerment of USDWs.

Table 8: Summary of monitoring data that will be used to verify and calibrate the computational modeling and support the demonstration of non-endangerment of USDWs

Monitoring Data	Location	Demonstration of Non-Endangerment
Injection Zone Pressure	Sensitive, Confidential, or Privileged Information [redacted]	Monitor and verify that injection zone pressures are declining as predicted
PNL		Monitor vertical plume development adjacent to OBS1
Time-lapse 3D Surface Seismic Data		Stabilization of the CO_2 plume once injection operations cease
Microseismic Monitoring		Decrease in induced seismic events will demonstrate declining pressures in the injection zone

The monitoring data will be compared predicted properties from the computational model such as vertical and horizontal plume location, rate of movements, and pressure decline. These data will verify that the computational model predictions accurately represent CO_2 and pressure plume behavior and can be used as a proxy for future plume behavior. The monitoring and modeling results will be compared using maps and graphs of the CO_2 and pressure plume development over time. If there is major disagreement between monitoring and modeling results at the time of the demonstration, the models will be updated to reflect the monitoring results.

5.4 Evaluation of Reservoir Pressure

Injection zone pressures will be monitored on a continuous basis in CCS1 and OBS1 (Table 8) until the pressure change is below the critical pressure rise, or after two years, whichever happens later. At that point, static gradient surveys will be performed annually in CCS1. BHP will no longer be monitored in OBS1. Injection zone pressures are predicted to decay below the delta pressure of 227 psi in the first two years after injection operations cease. Pressure decreases predicted by the model can be compared to the monitor data at regular intervals to verify and calibrate the model during the PISC phase.

If microseismic events are generated because of the CO_2 injection operations, it is expected that the rate of the events generated will decrease as injection zone pressure decreases. The rate of microseismic activity will provide further qualitative information about the decrease in pressure throughout the injection zone during the PISC phase.

Increased pressure in the injection zone is one of the main drivers for fluid migration through the confining layer through conduits such as well penetrations. As the injection zone pressure decreases during the PISC phase so too will the risk of fluid migration out of the injection zone and the potential risk to USDWs.

5.5 Evaluation of CO_2 Plume

Table 8 summarizes the monitoring data that will be used to evaluate the extent of the CO_2 plume every second year starting in Year 1 of the PISC phase. PNL logging will be used to monitor the distribution and saturation of CO_2 adjacent to the wellbore OBS1. In CCS1, it is expected that the near wellbore zone will be saturated with CO_2 and the plume will take up the entire injection zone, so there will be little value in running the PNL through the injection zone. However, the PNL will be run through the ACZ monitoring zone to verify that there are no accumulations of CO_2 adjacent to the wellbore above the confining layer in CCS1.

The time-lapse 3D surface seismic data will be acquired in Year 0 and Year 8 of the PISC phase. Data from these surveys will be used demonstrate the stabilization of the CO_2 plume predicted by the computational modeling once injection ceases. The data will also be used to confirm the continued absence of any accumulations of CO_2 above the confining zone within the AoR.

5.6 Evaluation of Emergencies or Other Events

Table 9 provides a summary of the monitoring data that will be used to demonstrate that injection zone fluids have not migrated above the confining layer; this includes CO_2 or brines. Data acquired through the injection and PISC phases of the project will be compared to the baseline data gathered for the project to ensure that there are no indications that injection zone fluids have migrated into the ACZ monitoring interval or to the lowermost USDW. If the PISC monitoring data shows no significant changes from the baseline data, it will demonstrate the integrity of the confining layer and that injection zone fluids are not an endangerment to USDWs.

Plan revision number: N/A

Plan revision date: N/A

Table 9: Summary of monitoring data that will be used to demonstrate of non-endangerment of USDWs above the confining zone

Monitoring Data	Location	Demonstration of Non-Endangerment
ACZ Pressure	[redacted]	• No pressure increases that could indicate fluid migration out of injection zone
ACZ Fluid Sampling		• No geochemical indicators of fluid migration out of injection zone • Includes changes to salinity
Lowermost USDW Fluid Sampling		• No geochemical indicators of fluid migration out of injection zone
Temperature Logging		• No CO_2 migration along the wellbores
PNL		• No CO_2 accumulations adjacent to wellbores • No increase in salinity adjacent to wellbores
Time-lapse 3D Surface Seismic Data		• Verify the absence of CO_2 accumulations
Microseismic Monitoring		• Monitor for microseismic events in the confining layer that might indicate issues with confining zone integrity

The closest artificial penetration to the project wells in the injection zone is [redacted] to the southwest. [redacted] No other conduits for fluid flow beyond the confining layer have been identified in the AoR at this time.

The well integrity of the CCS1 will be thoroughly assessed during the Pre-Operational Testing Program using Cement Bond Logs and Variably Density Logs (CBL-VDL) as well as ultrasonic cement evaluation tools that will be run specifically over the injection zone, confining layer, and ACZ monitoring interval (Attachment 5: Pre-Op Testing Program, 2022).

During the injection phase, the well integrity of CCS1 will be continuously monitored using wellhead pressure gauges and annular pressure and fluid volume levels for any indications that there may be problems (Attachment 7: Testing And Monitoring, 2022). Wellhead and downhole pressures will continue be monitored in CCS1 during the PISC phase. The project will continue to run temperature logs at a maximum of every five years, and PNL logs every second year starting in Year 1 to ensure that CCS1 and OBS1 are not providing a conduit for injection zone fluids to migrate above the confining layer.

The Emergency and Remedial Response Plan (ERRP) includes further discussion of how emergencies or other events will be addressed by the project (Attachment 10: ERRP, 2022).

Plan revision number: N/A

Plan revision date: N/A

6.0 Site Closure Plan

OCP will conduct site closure activities to meet the requirements of 40 CFR 146.93(e) as described below. Cardinal Ethanol will submit a final Site Closure Plan and notify the permitting agency at least 120 days prior of its intent to close the site. Once the permitting agency has approved closure of the site, OCP will plug the monitoring wells and submit a site closure report to EPA. The activities, as described below, represent the planned activities based on information provided to EPA. The actual site closure plan may employ different methods and procedures. A final Site Closure Plan will be submitted to the UIC Program Director for approval with the notification of the intent to close the site.

6.1 Plugging Monitoring Wells

As discussed in the testing and monitoring section of the application, there will be several dedicated monitoring wells. Of those presented in the section, the OBS1 and ACZ1 wells will be plugged as part of the site closure process.

This subsection serves to provide the methods and procedures that will be utilized to plug each of the wells. In addition to discussing the methodology and procedures to be utilized, schematics displaying the anticipated layout of the well following completion of the plugging and abandonment (P&A) operations are provided. The cost estimates developed for these activities are provided in the Financial Assurance section of this application.

6.1.1 OBS1 Plugging and Abandonment

The techniques used to P&A OBS1 will be similar to those applied to the CCS1 well, as discussed in the P&A section for the injection well (Attachment 8: Well Plugging, 2022). CO_2 resistant cement will be placed from the bottom of the well, to above the confining zone, then normal cement will be placed above that.

Cement volumes are anticipated to be lower than those used for the injection well as OBS1 will use smaller sized tubulars. The cement volumes to be used to P&A the OBS1 well will be finalized following the installation of the well.

A figure displaying the proposed P&A schematic for OBS1 is provided in Figure 10.

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[redacted]

Figure 10. OBS1 Well Plugging and Abandonment Schematic

6.1.2 ACZ1 Plugging and Abandonment

The techniques used to P&A ACZ1 will be similar to those applied to OBS1 and CCS1 above the confining zone (Attachment 8: Well Plugging, 2022). Normal cement will be placed from the bottom of the well to surface.

Cement volumes are anticipated to be lower than those used for the injection well as ACZ1 will use smaller sized tubulars. The cement volumes to be used to P&A the ACZ1 well will be finalized following the installation of the well.

A figure displaying the P&A schematic for ACZ1 is provided in Figure 11.

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[redacted]

Figure 11: ACZ1 Well Plugging and Abandonment Schema

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Plan revision date: N/A

6.2 Site Closure Report

In accordance with 40 CFR 146.93(f), a site closure report will be prepared and submitted within 90 days following site closure, documenting the information required by 40 CFR 146.93(f), as applicable, including but not limited to the following:

- Plugging of the verification and geophysical wells (and the CCS1 if it has not previously been plugged),
- Location of sealed CCS1 on a plat of survey that has been submitted to the local zoning authority,
- Notifications to state and local authorities as required at 40 CFR 146.93(f)(2),
- Records regarding the nature, composition, and volume of the injected CO_2, and
- Post-injection monitoring records.

In accordance with 40 CFR 146.93(g), OCP will record in the real property records of the county where the project is located notice of the property tracts integrated for the storage facility and proper notice of the CCS1 well that will include the following:

- That the property was used for CO_2 sequestration,
- The name of the local (state, federal, etc.) agency to which a plat of survey with CCS1 location was submitted,
- The volume of fluid injected,
- The formation into which the fluid was injected, and
- The period over which the injection occurred.

In accordance with 40 CFR 146.93(h), the site closure report will be submitted to the permitting agency (EPA) and maintained by the owner or operator for a period of 10 years following site closure. Additionally, the owner or operator will maintain the records collected during the post-injection period for a period of 10 years after which these records will be delivered to the UIC Program Director.

6.3 Quality Assurance and Surveillance Plan

The Quality Assurance and Surveillance Plan is presented in (Attachment 11: QASP, 2022).

Plan revision number: N/A

Plan revision date: N/A

References

(2022). *Attachment 1: Narrative.* Class VI Permit Application Narrative; Hoosier#1 Project, Vault 4401.

(2022). *Attachment 10: ERRP*. Emergency And Remedial Response Plan; Hoosier#1 Project, Vault 4401.

(2022). *Attachment 11: QASP*. Hoosier#1 Project, Vault 4401.

(2022). *Attachment 2: AoR and Corrective Action.* Area Of Review And Corrective Action Plan; Hoosier#1 Project, Vault 4401.

(2022). *Attachment 3: Financial Assurance.* Financial Responsibility; Hoosier#1 Project, Vault 4401.

(2022). *Attachment 4: Well Construction.* Injection Well Construction Plan; Hoosier#1 Project, Vault 4401.

(2022). *Attachment 5: Pre-Op Testing Program.* Pre-Operational Formation Testing Program; Hoosier#1 Project, Vault 4401.

(2022). *Attachment 6: Well Operations.* Well Operation Plan; Hoosier#1 Project, Vault 4401.

(2022). *Attachment 7: Testing And Monitoring.* Testing And Monitoring Plan; Hoosier#1 Project, Vault 4401.

(2022). *Attachment 8: Well Plugging.* Hoosier#1 Project, Vault 4401.

(2022). *Attachment 9: Post-Injection Site Care.* Post-Injection Site Care And Site Closure Plan; Hoosier#1 Project, Vault 4401.