E.4 Post Injection Site Care and Site Closure
40 CFR 146.93

Vernon One CCS Site

Facility name: Vernon One CCS Site

[redacted]

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[redacted]

This Post-Injection Site Care and Site Closure (PISC) plan describes the activities that CapturePoint Solutions, LLC will perform to meet the requirements of 40 CFR 146.93. CapturePoint Solutions, LLC will monitor ground water quality and track the position of the carbon dioxide plume and pressure front for a PISC timeframe of 50-years. CapturePoint Solutions, LLC may not cease post-injection monitoring until a demonstration of non-endangerment of USDWs has been approved by the UIC Program Director pursuant to 40 CFR 146.93(b)(3). Following approval for site closure, CapturePoint Solutions, LLC will plug all monitoring wells, restore the site to its original condition, and submit a site closure report and associated documentation.

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1.0 PRESSURE DIFFERENTIALS

Pressure differentials at the injection wells is presented in the following section per the EPA 40 CFR 146.93(a)(2)(i) standard. Based on the modeling of the pressure front as part of the AoR delineation, pressure at the injection well is expected to decrease to pre-injection levels within 15-years of post-closure, as described below. Additional information on the projected post-injection pressure declines and differentials is presented in Module B "*AoR and Corrective Action Plan*".

Preliminary estimates of the CO_2 plume size were determined using Equation 1 and are based on the volume of injectate, its viscosity, water saturation, formation volume factor and matrix porosity:

Equation 1 → $R_{plume} = \sqrt{\frac{V_i \cdot B_g}{(1-S_w)\cdot \emptyset \cdot \pi \cdot H}}$

Pressure front radius estimates (a measure of transient pressure) resulting from injection were determined using Equation 2 and are based on time and matrix properties such as pore compressibility, porosity and permeability:

Equation 2 → $R_{pf} = \frac{kt}{\emptyset (uc_t) r_w^2}$

Pressure differential estimates for AoR evaluation were developed using Equation 3 and are based on fluid densities, pressure and the vertical distance between the injection zone and USDW.

Equation 3 → $P = P_u + \rho_i g (Z_u - Z_i)$

The estimation methods described above were utilized to determine an estimate of plume size, delineate the preliminary AoR, and calculate the pressures above hydrostatic that are required within the modeled pressure front radius where vertical fluid migration could occur within the AoR. In the case of the targeted injection zones the calculated differential pressure above the hydrostatic pressure that is required to cause fluids to migrate vertically into an overlying USDW is approximately [redacted] as shown below in **Figure 1**.

Figure 1 Differential Pressures for Injection Zones

[redacted]

2.0 PREDICTED POSITION OF PLUME AND PRESSURE AT CLOSURE

The predicted plume and pressure front at time of closure for the Vernon One CCS site is presented in the following section per the EPA 40 CFR 146.93(a)(2)(ii) standard.

Figures 2 through 5 show the predicted extent of the plume and pressure front at the end of the PISC timeframe 30 years post injection, representing the maximum extent of the plume. and pressure front for each injection zone. These maps are based on the initial AoR delineation estimation and modeling results submitted pursuant to 40 CFR 146.84.

Figure 2. AoR and Extent of Plumes 30 Years Post-Injection

[redacted]

Figure 3. – Sparta Formation AoR and Extent of Plume 30 Years Post-Injection

[redacted]

Figure 4. – Upper Wilcox Formation AoR and Extent of Plume 30 Years Post-Injection

[redacted]

Figure 5. – Lower Wilcox Formation AoR and Extent of Plume 30 Years Post-Injection

[redacted]

3.0 POST-INJECTION MONITORING PLAN

Performing ground water quality monitoring and plume and pressure front tracking as described in the following sections during the post-injection phase will meet the requirements of 40 CFR 146.93(b)(1). The results of all post-injection phase testing and monitoring will be submitted annually, within 60 days of the anniversary date on which injection ceases, as described under “Schedule for Submitting Post-Injection Monitoring Results,” below. All monitoring wells are located on CapturePoint Solutions, LLC property and therefore access is guaranteed. Post Injection lease agreements will also grant Ingress/Egress until site closure has been approved by the UIC Program Director pursuant to 40 CFR 146.93(b)(3).

A quality assurance and surveillance plan (QASP) for all testing and monitoring activities during the injection and post injection phases is provided in the Appendix to the Testing and Monitoring Plan.

Post injection monitoring will evaluate the pressure differential between the pre-injection and predicted post-injection pressures within the targeted injection zones ([redacted]). Predicted post-injection pressures will be derived from the most up to date AoR model results and will be compared to measured/observed pressure readings. The post-injection monitoring plan will include three wells at the injection site that were initially completed and used as injection wells to be converted to monitoring wells for the post-injection monitoring period. Bottomhole pressure and temperature in these wells will be collected on an annual basis. This plan will ensure that at least two wells per targeted injection zone are in-place for post-injection pressure monitoring in order to evaluate the pressure differential until such time as the pressure within the injection zones is demonstrated to have stabilized.

In addition to monitoring pressure and temperature, cased-hole saturation logs will be run in the offset in-zone monitoring well (Well #1) on an annual basis during the post-injection monitoring period. Mechanical integrity tests will be conducted on each of the four monitoring wells on an annual basis as to ensure that the wells have mechanical integrity and that there is no endangerment to safety, the environment or to USDWs. The in-zone monitoring well and converted injection wells, will be accessible for collecting data and samples during the requested PISC timeframe.

Indirect monitoring of the CO_2 plume will require gravity surveys to be collected for the designated AoR. A baseline gravity survey will be conducted prior to the commencement of injection. Commiserate gravity surveys will then be conducted at the end of injection and then again at five-year intervals. Gravity surveys will be used to delineate the subaerial extent of the plume over-time and it is expected that plume stabilization will occur within the first 15 years post-injection.

It is expected that post injection site monitoring will occur for a period of 50 years and that annual reports detailing the monitoring activities and results will be prepared and submitted to the UIC Program Director. Annual reports will be submitted within 60 days of the anniversary date of the end of injection. In the event that monitoring indicates that more time is needed to demonstrate pressure and plume stabilization has occurred, an amended post-injection site care and site closure plan will be prepared that details the how the site monitoring and site care will continue until stabilization can be demonstrated. This amendment will be prepared and submitted to the UIC Program Director. At any time during the life of the injection project if a change to the post-injection site care plan is deemed necessary the UIC Program director will be notified within 30 days of such a change.

Groundwater quality will be monitored in the first permeable layer above the confining zone ([redacted]) and also in the deepest locally utilized USDW ([redacted]). Groundwater quality monitoring will occur on a quarterly basis for the first-year post-injection and then annually until the end of the PISC timeframe.

3.1 MONITORING ABOVE THE CONFINING ZONE

Table 1 presents the monitoring methods, locations, and frequencies for monitoring above the confining zone. **Table 2** identifies the parameters to be monitored and the analytical methods CapturePoint Solutions, LLC will employ. Sampling and analysis will be performed as described in the accompanying Testing and Monitoring Plan and associated Quality Assurance and Surveillance Plan (QASP). The QASP describes the groundwater sampling methods to be used, including sampling SOPs and sample preservation. Sample handling, custody and quality control will also be performed as described in the QASP. In the event that monitoring detects the presence and migration of fluids from below the confining zone, actions detailed in the Emergency and Remedial Response Plan will be initiated.

Groundwater quality monitoring will occur in the first permeable layer above the confining zone ([redacted]) in Monitoring Well #8 which is saline at the project site. The [redacted] resides approximately 1,226 feet above the top of the shallowest targeted injection zone. Groundwater quality monitoring of one of the shallow USDW's will occur in the [redacted] aquifer in monitoring wells #2 and #5. Within the AoR the [redacted] occurs at 1,054 feet below mean sea level and is approximately 3,403 feet above the top of the shallowest injection zone. Sampling, chain of custody, analysis procedures and quality assurance for the post-injection groundwater quality monitoring will follow the protocols detailed in the Testing and Monitoring Plan and the Quality Assurance and Surveillance Plan (QASP).

Table 1 Monitoring of ground water quality and geochemical changes above the confining zone

Target Formation	Monitoring Activity	Monitoring Location(s)	Spatial Coverage	Frequency
[redacted]	Direct Fluid Sampling	Injection Site (MW #5) and at Off-Set Monitoring Site (MW #2)	AoR	Quarterly for first year post-injection and then annually for the duration of the PISC timeframe
[redacted]		Injection Site (MW #6)	Injection Site	

Table 2 Summary of analytical and field parameters for ground water samples

Parameters	Analytical Methods
Carnahan Bayou (USDW) and Cockfield (First Permeable Interval Above Confining Zone)	
Cations: Al, Ba, Mn, As, Cd, Cr, Cu, Pb, Sb, Se and Tl	ICP-MS, EPA Method 6020
Cations: Ca, Fe, K, Mg, Na and Si	ICP-OES, EPA Method 6010B
Anions: Br, Cl, NO_3 and SO_4	Ion Chromatography, EPA Method 300.0
Dissolved CO_2	Coulometric titration, ASTM D513-11
Total Dissolved Solids	Gravimetry, APHA 2540C
Alkalinity	APHA 2320B
pH (Field)	EPA 150.1

Parameters	Analytical Methods
Specific Conductance (Field)	APHA 2510
Temperature (Field)	Thermocouple

3.2 CO_2 PLUME AND PRESSURE FRONT TRACKING

CapturePoint Solutions, LLC will employ direct and indirect methods to track the extent of the CO_2 plume and the presence or absence of elevated pressure in accordance with 40 CFR 146.93(a)(2)(iii). Deviations from baseline are described in Section 8 of the Testing and Monitoring Plan.

Table 3 presents the direct and indirect methods that CapturePoint Solutions, LLC will use to monitor the CO_2 plume, including the activities, locations, and frequencies CapturePoint Solutions, LLC will employ. Monitoring of the CO_2 plume will be accomplished by running saturation logs in the offset in-zone monitoring well annually and via gravity surveys of the AoR collected every 5 years post injection during the PISC timeframe of 50 years or until stabilization of the plume is demonstrated to have occurred. Logging will occur on an annual basis within 45 days of the anniversary of the end of injection. An alternative logging schedule will require the approval of the UIC Program Director.

Table 3 Post-injection phase plume monitoring

Target Formation	Monitoring Activity	Monitoring Location(s)	Spatial Coverage	Frequency
DIRECT PLUME MONITORING				
[redacted] [redacted] [redacted]	Saturation and temperature logs	Offset In-Zone Monitoring Well	AoR	5 Years
INDIRECT PLUME MONITORING				
[redacted] [redacted] [redacted]	Gravity Surveys	AoR	AoR	5 Years

Table 4 presents the direct and indirect methods that CapturePoint Solutions, LLC will use to monitor the pressure front, including the activities, locations, and frequencies CapturePoint Solutions will employ. Monitoring of saturation and temperature for all three injection zones will occur by running cased hole saturation and temperature logs in the in-zone monitoring well (Well #1). Pressure and temperature will also be monitored for each targeted zone at the injection site using injection wells converted into monitoring wells (wells selected to be converted has yet to be determined) post-injection. Pressure and temperature data will be collected using wireline gauges and sensors and will occur on an annual basis. Pressure monitoring results will be compared to modeling and simulation forecast predictions of expected pressure behavior for each zone. If there are significant deviations the modeling and simulation forecasts will be updated with the observed and recorded pressure data in order to update forecast predictions of the pressure decline post-injection. Pressure monitoring will occur during the PISC time frame of 50 years or until pressure stabilization is demonstrated to have equilibrated.

Table 4 Post-injection phase pressure-front monitoring

Target Formation	Monitoring Activity	Monitoring Location(s)	Spatial Coverage	Frequency
DIRECT PRESSURE-FRONT MONITORING				
[redacted]	In-Zone Pressure Monitoring and Bottom Hole Pressure Measurements	Offset and Injection Site Monitoring Wells	AoR	Continuous In-Zone Monitoring and Annual Bottomhole Monitoring
[redacted]				
[redacted]				
INDIRECT PRESSURE-FRONT MONITORING				
[redacted]	Gravity Surveys	AoR	AoR	5 Years
[redacted]				
[redacted]				

Plume and pressure front monitoring information regarding equipment used *(i.e.* logging procedures) is detailed in the "*Testing and Monitoring Plan*" and in the QASP. If a deviation from the predicted plume and or pressure front behavior occurs, protocols detailed in the Emergency and Remedial Response Plan will be implemented.

Monitoring will occur near the top of each of the targeted injection zones. The depths of the respective injection zones and monitoring intervals are shown in **Table 5.**

Table 5. Monitoring Depths

Monitoring Zone	Measured Depth
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]

Note: Depths are derived from the type-log Figure 2-22 provided in the Site Characterization- Section 2.0 of the "*Project Narrative Report*" in Module A. Actual site-specific depths will be updated after well construction. True measured depths will be provided following well construction and will be provided as an update to this PISC.

3.3 SCHEDULE FOR SUBMITTING POST-INJECTION MONITORING RESULTS

All post-injection site care monitoring data and monitoring results collected using the methods described above will be submitted to EPA in reports submitted annually, within 60 days following the anniversary date on which injection operations ceased. The reports will contain information and data generated during the reporting period, *i.e.* well-based monitoring data, sample analysis, and the results from updated site models.

4.0 ALTERNATIVE PISC TIMEFRAME

CapturePoint Solutions, LLC will conduct post-injection monitoring 50-year timeframe following the cessation of injection operations as presented in this alternative PISC (40 CFR 146.93(c)).

A justification for this alternative PISC timeframe is provided in and supported by results in the initial modeling contained in the "*Area of Review and Corrective Action Plan*" submitted in Module B. Regardless of the alternative PISC timeframe, monitoring and reporting as described in the sections above will continue until CapturePoint Solutions, LLC demonstrates, based on monitoring and other site-specific data, that no additional monitoring is needed to ensure that the project does not pose an endangerment to any USDWs, per the requirements at 40 CFR 146.93(b)(2) or (3).

CapturePoint Solutions, LLC will conduct post-injection monitoring until site closure at the injection site is authorized for the approved alternate PISC time period upon a successful non-endangerment demonstration. If any of the information on which the demonstration was based changes or the actual behavior of the site varies significantly from modeled predictions, e.g., as a result of an AoR reevaluation, CapturePoint Solutions, LLC may update this PISC and Site Closure Plan pursuant to 40 CFR 146.93(a)(4). CapturePoint Solutions, LLC will update the PISC and Site Closure Plan within six (6) months of ceasing injection or demonstrate that no update is needed and as necessary during the duration of the PISC timeframe.

CapturePoint Solutions plans on drilling a site characterization well for site specific data acquisition. The computational model is based upon conservative estimates using offset well analogs and regional core data. Site specific data is expected to improve the model and reduce the uncertainties. The current model outputs are conservative in nature and represent a "worst-case" scenario using limited data sets. The updated model will provide valid computational model results to support an Alternative PISC timeframe of 15 years. At the present time, monitoring will occur for the designated PISC timeframe of 50 years.

CapturePoint Solutions, LLC 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.

4.1 COMPUTATIONAL MODELING RESULTS

Site characterization (submitted in the "*Project Narrative Plan*" submitted in Module A), estimation methods, and preliminary computational modeling results leads CapturePoint Solutions, LLC to believe that a reduced PISC timeframe of 15 years for the Vernon One CCS Site would be warranted. As shown with the pressure decline curves in **Section 1.0**, the upper most injection zone [redacted] and the primary injection zone [redacted] both have the pressure falloff reaching the original reservoir pressure within 5 years. The current model for [redacted] shows it reaches original reservoir pressure within 11 years.

The initial AoR model as discussed in Module B ("*AoR and Corrective Action Plan*") is a conservative projection based on limited data available for the site. We expect this to improve substantively with the porosity, permeability data from the core and well log data from the Site Characterization Well. It is expected that the additional data and adjustments to injection rates and volumes when incorporated into a revised computational model will result in a more definitive AoR delineation and pressure decline responses post-injection, which should reduce the uncertainty regarding predictions of plume migration, post-injection pressure decline and CO_2 trapping. We expect the Lower Wilcox to also show pressure stabilization within a 10-to-15-year time period. Additionally, as discussed in **Section 1** and **Figure 1**, the Nominal Pressure Differentials required at the [redacted] to have any upward mobility of CO_2 or other formation brine, is [redacted]. As per the pressure decline curve for [redacted] this is reached within 15 years from injection in the current model results. Preliminary modeling results for the three injection zones are summarized below.

Once CapturePoint Solutions, LLC has acquired site-specific data, the static and dynamic model will be updated, providing a refined AoR for the Vernon One CCS Site. CapturePoint will then perform detailed sensitivity analysis to meet the requirements for an Alternative PISC timeframe demonstration per the resulting refined computational results will then be used to update and justify the request for an Alternative PISC timeframe. If it is deemed as necessary, CapturePoint Solutions, LLC may reduce the current modeled injection rates in the [redacted] to ensure full compliance of requirement for clear demonstration of an Alternative PISC timeframe of 15-years.

4.2 PREDICTED PRESSURE DECLINE TIMEFRAME

The formation pressure at the injection well is predicted to decline rapidly within the first several years following cessation of injection. Based on the modeling of the pressure front as part of the AoR delineation, pressure is expected to decrease to below established pressure differential thresholds before the end of the PISC timeframe (pressure differential estimation is described in **Section 1**). Additional information on the projected post-injection pressure declines and differentials is presented in Module B "*AoR and Corrective Action Plan*".

Pressure response curves for the three targeted injection zones are shown in **Figures 6, 7 and 8,** and presented in **Table 6.** The pressure decline is almost immediate for each injection zone and is interpreted to be homogenous in the initial computational model. Following the collection of additional site data from the logs and core taken in the Site Characterization Well, in combination with adjustments to injection parameters, the computational model will be updated in order to optimize operational parameters for all three injection zones. A discussion of each zone's pressure response following injection is included below [40 CFR 146.93(c)(1)(ii)].

Table 6 – Pressure Declines Timeframes after a 20-year injection period

Injection Zone	Injection Rate (mmscf/day)	Pressure Decline Timeframe (years)	Estimated Original Formation Pressure (psi)
[redacted]	50	5	~ 1,871
[redacted]	75	5	~ 2,457
[redacted]	70	11	~ 3,300

Additional data that is to be collected and adjustments to proposed injection operational parameters will be incorporated into an updated model. The preliminary model that is presented at this point in the permit application process is based on a limited amount of available data inputs and is based on maximized operational parameters. Given that, preliminary model results do show that for each of the three targeted injection zones the CO_2 plumes are contained within the designated AoR (**Figure 2**), post-injection pressure declines occur rapidly within the first 5 years and that the differential pressures for each of the injection zones pose no hazard to USDWs during or after the PISC timeframe.

4.2.1 Injection Zone 1 – [redacted]

Injection into the Sparta Formation was modeled using [redacted] using an average daily rate of [redacted] for each well for a modeled period of 20 years (7,304 days). The model results predict that the post-injection pressure recovery back towards original formation pressure of [redacted] psi would begin immediately following the cessation of injection (See **Figure 6**).

[redacted]

Figure 6 - Pressure decline in CCS Injection Well [redacted])

After injections stops, it is projected that it will take 5 years for the pressure to decay back to the original static pressure at the wells. Based on computational modeling the differential pressure for the [redacted] psi (**see Figure 1**). This is the pressure required to reverse flow fluids vertically from the injection zone. The decay past the assumed original static pressure is an artifact of the algorithm used in the simulation model. This will be addressed in the subsequent AoR delineation following drilling of a site characterization well.

4.2.2 Injection Zone 2 – [redacted]

Injection into the Upper Wilcox Formation was modeled using [redacted] using an average daily rate of [redacted] for each well for a modeled period of 20 years (7,304 days). The model results predict that the post-injection pressure recovery back towards original formation pressure of [redacted] psi would begin immediately following the cessation of injection (See **Figure 7).**

[redacted]

Figure 7 - Pressure decline in CCS Injection Well [redacted])

After injections stops, it is projected that it will take 5 years for the pressure to decay back to the original static pressure at the wells. Based on computational modeling the differential pressure for the [redacted] (**see Figure 1**). This is the pressure required to reverse flow fluids vertically from the injection zone. The decay past the assumed original static pressure is an artifact of the algorithm used int the simulation model. This will be addressed in the subsequent AoR delineation following drilling of a site characterization well.

4.2.3 Injection Zone 3 – [redacted]

Injection into the Lower Wilcox Formation was modeled using [redacted]. This was modeled using an average daily rate of [redacted]. Total modeled period of 20 years (7,304 days) for each well into the formation. The model results predict that the post-injection pressure recovery back towards original formation pressure of [redacted] psi would begin immediately following the cessation of injection (**See Figure 8).**

[redacted]

Figure 8 - Pressure decline in CCS Injection Well [redacted]

After injections stops, it is projected the pressure will drop below the differential pressure within 11 years. The differential pressure, based on modeling for the [redacted] psi (see **Figure 1**). The decay past the assumed original static pressure is an artifact of the algorithm used int the simulation model. This will be addressed in the subsequent AoR delineation following drilling of a site characterization well.

4.3 PREDICTED PLUME MIGRATION RATE

Figures 27 through 32 in the *"AoR and Corrective Action Plan"* shows the predicted extent of the plumes at 10-year intervals post injection. This map is based on preliminary modeling as described in the "*AoR and Corrective Action Plan*" submitted in Module B. It is important to note that only capillary pressure trapping mechanisms were used for CO_2 were in the initial model iteration, and that the plume extents shown in **Figure 9** represent maximum potential plume sizes.

[redacted]

Figure 9. Plume Extents Within the Designated AoR

Post shut-in plume migration is primarily to the North of the injection wells due to regional dip and density contrast. There is essentially no migration to the South, nor to the East and West of the injection wells. Due to the dip, and the exclusion of physical behavior that mitigate plume migration in the model, the plume continues to drift at the rate of less than 100 feet per year. The rate of migration is estimated from the detail data referenced above.

Tables 7 through 9 shows the northern plume extent at 10-year intervals, after injection stops, for each injection interval.

Table 7: Plume Migration Post Closure Rates for Injection Zone 1 – [redacted]

Year	dt Post Injection (years)	dx (feet)	dx/dt rate (ft/year)
20	--	--	--
30	10	1,500	150
40	10	2,000	200
60	30	7,000	233

Table 8: Plume Migration Post Closure Rates for Injection Zone 2 – [redacted]

Year	dt Post Injection (years)	dx (feet)	dx/dt rate (ft/year)
20	--	--	--
30	10	1,000	100
40	10	500	50
60	30	1,500	50

Table 9: Plume Migration Post Closure Rates for Injection Zone 3 – [redacted]

Year	dt Post Injection (years)	dx (feet)	dx/dt rate (ft/year)
20	--	--	--
30	10	500	50
40	10	500	50
60	30	500	17

It is expected that the inclusion of saturation trapping and imbibition in the model in future model iterations and using site specific data will show the plume stabilization. These features will be included using information provided by the site study well.

4.4 SITE SPECIFIC CO_2 TRAPPING PROCESSES

Predictive modeling of CO2 trapping mechanisms in saline sandstone reservoirs is a challenging task to accomplish. Work by Balashov and others in 2013 evaluated several reactive transport models and summarized their findings. Key trapping mechanisms which permit the in-situ trapping of CO2 in saline formations include the following 1) solubility trapping, 2) capillary trapping and 3) mineral trapping.

Solubility trapping of CO2 in formation fluids accounts for a significant portion of the injected CO2. This is a function of fluid-fluid compatibility between the formation fluids and the CO2. Some models predict that up to 50 percent of the dense phase CO2 is permanently stored via solubility trapping. Additionally, this trapping mechanism consumes CO2 at a very high rate as the CO2 is readily taken up by formation fluids upon contact. The reaction of solubility trapping results in both a dissolved CO2 component and the formation bicarbonate (HCO3).

Capillary trapping of CO2 within a formation also accounts for a significant volume of permanently stored CO2. Capillary trapping is a function of two components, the first being the buoyancy affect and rate of vertical migration of the CO2 and second has to do with pore throat size and capillary pressures within the rock matrix of the formation into which the CO2 is injected. The phenomenon of capillary trapping like solubility trapping also occurs at a high rate.

A much slower process is the reaction between CO2 and the minerals within the formation, this is referred to as mineral trapping. The most common result of mineral trapping is the formation and precipitation of calcite.

Its important to note that although all three of the mentioned CO2 trapping mechanisms are occurring at the same time, it is difficult to quantify the total rate of CO2 trapping within a formation over time. In terms of preliminary reservoir and injection modeling only capillary trapping is considered. Consequently the rate of plume migration as determined by the model represents a significant overestimation for the distribution and saturation of the CO2 plume and both the vertical and lateral migration of the CO2.

Site specific trapping processes for the Vernon One CCS [40 CFR 146.93(c)(1)(iv)-(vi)] will be developed in more detail in future model iterations. No structural trapping mechanisms (such as faults) were modeled, as none exist in the local or extended area of interest around the Vernon One CCS site. The trapping processes employed in the initial model for the Vernon One CCS site is capillary pressure trapping only. This is due to limited available data general assumptions about the site-specific geology. This process is when the CO_2 is no longer mobile in the pore space and movement suppressed by the surrounding brine, and therefore reduces the rate of plume migration. For the Vernon Site, the uncertainties surrounding the additional trapping mechanisms will be reduced with data collected from the stratigraphic test well. Additional chemical trapping processes (such as solubility) and physical processes (such as lateral baffles in the zones) will be address in the next model iteration and will provide more constraints on the current predicted pressure and plume fronts. Note: that no structural trapping related to faulting or domes is expected within the Site.

Details on the proposed data acquisition is contained in "*Pre-Operational Testing and Logging Plan*" submitted in Module D. Additionally, the computational model will be updated and the AoR, pressure fronts, and plume fronts will be refined and revised.

4.5 CONFINING ZONE CHARACTERIZATION

In accordance with 40 CFR 146.93(c)(1)(vii) the confining zone has been determined to be a laterally extensive and sufficiently low permeability and low porosity layer that prevents the vertical flow of the injectate. The absence of faults within the AoR in the Cenozoic sediments supports the Cook Mountain Confining Zone as one of the four regional containment systems in the Paleocene through early Oligocene sediments within the Gulf Coast Region. Specifically, the [redacted] within the AoR is 343 feet thick with an expected 11 percent effective porosity and a permeability estimated at 0.0021 mD.

Per a regional review, the [redacted] formation's lower unit is a glauconitic mudstone dominated by a clay matrix and often fossiliferous. The Cook Mountain's confining integrity will not be impacted by the contact of CO_2 At this time there are no known effects or compatibility issues related to prolonged contact of the CO_2 with the formation or saline fluids.

The static model set all confining zones as impermeable barriers with 0 percent porosity and 0 md permeability. Information collected as detailed in the "*Pre-Operational Testing and Logging Plan*" (submitted in Module D) will be used to validate the site-specific characterization of the confining zone. This new information will be used to refine and update the model and AoR delineation.

Per the "*Pre-Operational Testing and Logging Plan*", newly acquired data, particularly core analysis of samples from the primary confining layer and geophysical log data will be used to further assess and characterize the confining zone.

4.6 ASSESSMENT OF FLUID MOVEMENT POTENTIAL

There are no faults or other geologic features that would permit the vertical migration of CO_2 or formation fluids into USDWs. These wells have been evaluated and will be re-plugged as described in the Corrective Action section discussed in the "*Area of Review and Corrective Action Plan*" submitted in Module B.

The Confining Zone Characterization (above) and the AoR and Corrective Action Plan have identified three artificial penetrations through the confining zone that have been thoroughly evaluated and will be mitigated accordingly prior to injection. All sequestration infrastructure related to this gas storage (GS) project will be properly remediated post-injection.

Within the designated AoR there are three existing artificial penetrations through the primary confining zone that prior to injection will be mitigated as detailed in the AoR and Corrective Action Plan. Site monitoring is designed to ensure that all possible events that could result in leakage as a result of injection are identified and properly assessed during injection and post-injection, this is described in the Monitoring above the Confining Zone (above) and in the Testing and Monitoring Plan.

A total of [redacted] wells that will penetrate the confining zone will be constructed as part of this geologic sequestration project. **Figure 2-22** in Site Characterization (Section 2.0 of the "*Project Narrative Report*" in **Module A**) shows the locations of all wells within the AoR. This includes [redacted] injection wells and one monitoring well. Construction of these wells and risk prevention regarding potential fluid migration into USDWs is detailed in the Well Construction Plan and Pre-Operational Testing and Logging Plan.

Per 40 CFR 146.93(c)(1)(ix) injection wells are designed to meet and or exceed the regulations set forth in 40 CFR 146.82(a)(12) and 146.86(b). Details of injection well construction are described in the Well Construction Plan (submitted in the "*Project Narrative Report*" in **Module A**) and precautions during drilling are described in the Emergency and Remedial Response Plan (**submitted in Module E**).

The injection wells will be constructed to Class VI standards and will undergo annual Mechanical Integrity Testing as described in **Module E** "*Testing and Monitoring Plan*". The wells will be thoroughly investigated and plugged to Class VI standards. If an injection well loses integrity or poses a potential pathway to a USDW, CapturePoint Solutions, LLC has developed an "*Emergency and Remedial Response Plan*" (submitted in **Module E**) to address these issues. An "*Injection Plugging Plan*" (submitted in **Module E**) has been developed to mitigate any potential issues after cessation of injection and the closure of the site.

A detailed description of the well site geology in combination with available geophysical well logs and studies provide certainty that the Vernon One CCS site is ideally located, which is supported by the t information is detailed in the Site Characterization narrative. The targeted injection zones are thick and occur throughout the Gulf Coast Region, the site is located in a seismically stable region with several competent and regionally extensive confining zones that exist between the targeted injection zones and the overlying USDWs and there is no indication of faulting within the designated AoR. Additionally, there are several thousand feet of vertical separation between the targeted injection zones and utilized groundwater resources within the AoR.

Provided the limited number of artificial penetrations, site geology and planned injection well construction and monitoring protocols, the risk of fluid migration from below the confining zone is not likely to occur. Furthermore, modeling and simulation forecasts do not indicate the potential of injectate reaching any conduits that have not undergone the corrective active plan that would permit the migration of fluids during and post-injection.

Information pertaining to the potential of fluid movement from the injection zone into an overlying USDW is addressed in the "*AoR and Corrective Action Plan"* and the "*Pre-Operational Testing and Logging Plan*". Mitigation of such an event is addressed in the "*Emergency and Remedial Response Plan".*

4.7 LOCATION OF USDW'S

A detailed discussion regarding USDWs is contained in the Site Characterization portion of the Project Information Tracking document. In summary, the nearest USDWs is the and [redacted], both approximately 25 miles to the north-northwest (**Figure 2-43** in Site Characterization). Vertically, the [redacted] zone is 2,741 feet below the USDW and separated by two confining zones that when combined are over 900 feet in thickness.

Log header information from [redacted] wells drilled within the AoR were used to establish formation resistivity cutoffs. Therefore, it is conservatively calculated that the sands with a formation resistivity of greater than 2.0 ohm-m are USDWs. The USDWs are vertically isolated from the targeted injection zones and can only communicate with the injection zones through behind pipe migration. The "*Pre-Operational Testing and Logging Plan*", "*Well Construction Plan*", "*Injection Plugging Plan*", and the "*Testing and Monitoring Plan*" meets the requirements set forth by EPA for the proposed Vernon One CCS project will be protective of all USDWs and thereby support the alternate PISC time frame.

5.0 NON-ENDANGERMENT DEMONSTRATION CRITERIA

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

CapturePoint Solutions, LLC 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*" (Submitted in **Module E** – "*Project Plan Submissions"*) 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. 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)]. No monitoring data currently exists for the Vernon One CCS Site.

5.3 SUMMARY OF COMPUTATIONAL MODELING HISTORY

The modeling is intended to present a conservative estimate of pressure build-up and plume extent over the injection and post injection life of the project. The data used in the model is derived from regional data, and from wells in near proximity to the project site. Until information is obtained from site specific wells, input data is used to create a conservative estimate (larger) of pressure build-up and plume extent. The current model represents a preliminary scenario for computational modeling at the Vernon One CCS Site and will be updated to a final simulation scenario following acquisition of additional data from a planned site characterization well.

5.4 EVALUATION OF RESERVOIR PRESSURE

The current model assumes an initial reservoir pressure for each injection zone. Initial static pressures will be obtained in each injection well and within the stratigraphic test well (future use as an in-zone monitoring well). The reservoir pressures will be collected during annul Mechanical Integrity Testing and compared to the computational modeling results. Since the model is conservative and uses a "worst-case" scenario approach, the actual predicted pressure data is expected to be less than the modeled pressure. The collected reservoir pressure data will be used to update and re-evaluate the model at the required 5-year intervals to provide an operational model and a new projected modeled pressure for a future time-series and post-closure period.

5.5 EVALUATION OF CO_2 PLUME

Evaluation of the CO_2 plume at the Vernon One CCS Site will involve both scheduled gravity surveys and data to be collected from groundwater monitoring wells during and post injection. Prior to injection a gravity survey and ground water quality analysis will be conducted in order to establish a baseline. Subsequent gravity surveys will be collected every 10 years. Water quality data will be collected per the noted schedule in the "*Testing and Monitoring Plan*" submitted in Module E. Results of the gravity surveys and the ground water quality analysis will provide for a comparative analysis to track the CO_2 plume and verify that there is no endangerment to USDW's.

5.6 EVALUATION OF EMERGENCIES OR OTHER EVENTS

CapturePoint Solutions, LLC has developed a plan to evaluate emergencies related to the Vernon One CCS site as detailed in "*E.4 – Emergency and Remedial Response Plan*" submitted in Module E. This plan accounts for potential emergency and events at three phases of the project: 1) during the construction of the injection wells, 2) during the operation of the injection wells, 3) during the site closure and post closure monitoring of the site. This includes, but not limited to, the continued sampling and analysis of the local USDW and other groundwater systems with the AoR.

5.7 NEAREST POTENTIAL CONDUITS

There are no faults or other geologic features that would permit the vertical migration of CO_2 or formation fluids into USDWs. Three wells (artificial penetrations) have been found to lie within the maximum plume extent. Each artificial penetration (active/abandoned) was evaluated as to the adequacy of construction and plugging to determine the potential of the penetration to convey fluid from an injection zone into the overlying USDWs (non-endangerment) and the potential of the penetration to convey injected effluent out of the injection zone (no migration) [40 CFR 146.84 (c)(3)]. Each of the three artificial penetrations have been evaluated and will be re-plugged to meet Class VI plugging standards as described in the Corrective Action as discussed in the "*Area of Review and Corrective Action Plan*" submitted in Module B. Therefore, these wells will not provide pathways to the USDW and pose no threat to the non-endangerment criteria.

6.0 SITE CLOSURE PLAN

CapturePoint Solutions, LLC will conduct site closure activities to meet the requirements of 40 CFR 146.93(e) as described below. CapturePoint Solutions, LLC 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, CapturePoint Solutions, LLC 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

The planned monitoring plan calls for [redacted] Class VI injection wells at the Vernon One CCS Site to be converted to monitoring wells during the Post Injection Site Care period. Each of the [redacted] wells will individually monitor the intended injection zone in conjunction with the offset in-zone monitoring well that monitors all three zones. Upon demonstration of non-endangerment and at the close of the designated PISC timeframe these monitoring wells in conjunction with the above confining layer groundwater monitoring well and subsequent USDW monitoring wells will also be plugged. In-zone monitoring wells and groundwater monitoring wells will be plugged in accordance with all regulatory requirements as to ensure non-endangerment to USDWs.

6.1.1 Plugging Procedures

Plugging procedures for the in-zone monitoring wells will follow the procedures detailed in the "Injection Well Plugging Plan" submitted in **Module E**. A general summary of the plugging procedures is provided below.

Preparation Procedures for Monitoring Wells to be Plugged:

1. After ceasing monitoring, bottomhole pressure measurements will be taken by running wireline pressure gauges prior to starting the P&A process on the well. Use the recorded bottomhole pressure to calculate the density of workover fluid required to safely complete the proposed plug and abandon procedure.
2. Run active pulsed-neutron log. Production logging tools (PLTs) such as tracers, noise or temperature logs could be run in substitution.
3. Move rig in. Pump into well with the calculated density of the workover fluid based on BHP survey in Step 1. A minimum of three tubing volumes will be injected into the formation without exceeding the fracture pressure.
4. The injection wells all have a well head and tubing installed. A permanent packer is set in the casing within 75' of the top of the perforations. Test casing/ tubing annulus to 1,000 psi or pressure required. Bleed casing pressure to 0 psi.
    a. If a loss of mechanical integrity is discovered, the well will be repaired prior to proceeding further with the plugging operations.
    b. All casing in the well has been cemented to surface at the time of construction and will not be retrievable at abandonment.
    c. If the tubing and casing pressure measures 0 psi, continue with well plugging procedures for the zone.

1. ND tree and NU BOP's. Test BOPs per regulations. Pull injection tubing. Permanent packer will remain in casing.
2. Set cement retainer above permanent packer and within 100 feet of the perforations. RIH with work string and sting into cement retainer.
3. Squeeze perforations with required volume of CO_2 resistant cement allowing for 100 sacks of cement to be squeezed into perforations and leave 600 feet of cement on top of retainer (approximately 300' above the Cook Mountain confining zone). Displace cement with calculated workover fluid (TBD). Allow cement to set.
4. Tag top of cement (TOC) and pressure test to 1,000 psi.
5. Set balance plug using required volume of CL H cement plus additives for the appropriate depths to isolate the surface casing and into the Jackson-Vicksburg confining zone. Displace with calculated workover fluid (TBD). Allow cement to set. Tag top of plug.
6. Set balance plug using required volume of CL H cement plus additives from noted depth to 5' to isolate the top of the surface casing. Allow cement to set.
7. Cut casing off 5 feet below ground level. Clean cellar and weld on plate with well information

6.1.2 Well Testing Prior to Plugging

A bottomhole reservoir pressure will be determined prior to commencing monitor well plugging operations [40 CFR 146.92(b)(1)]. Prior to running bottomhole pressure tests (BHP), the well will be flushed with a buffer fluid first [40 CFR 146.92(a)].

BHP measurements will be taken by running wireline pressure gauges prior to starting any P&A procedure on the wells. The bottomhole pressure measurement will be used to calculate the density of the workover fluid required to safely complete the plug and abandonment procedure. Determination of BHP is described in Section 4 of the "*Injection Well Plugging Plan*" submitted in Module D for each well to be plugged.

An active pulsed-neutron log will be run and then the well will be pressure-tested to ensure integrity both inside and outside of the casing prior to plugging. Production logging tools (PLTs), tracers, noise or temperature logs could be run as substitutions.

Pulsed-neutron logs are used to evaluate the CO_2 or water saturations over time and the temperature surveys could detect the movement of fluid behind cement and casing. If such a condition is detected the location of fluid movement in the well can be evaluated and corrected. Pressure tests are used to ensure the casing is sufficiently sealed to prevent the loss or addition of formation fluids into the well. If a pressure decrease is observed, it may indicate that the well does not have sufficient mechanical integrity and that the well needs repaired.

If a loss of mechanical integrity is discovered, the well will be further evaluated and repaired prior to proceeding further with the plugging operations. Testing criteria to determine whether mechanical integrity test results are successful or not is described in **Module E** "*Testing and Monitoring Plan*", Details for MITs are also described in Section 4 of the "*Injection Well Plugging Plan*" submitted in **Module E**.

All casing strings in each well will have been cemented to the surface at the time of construction and will not be retrievable at abandonment.

Details regarding equipment, precision and MITs are described in Section 6.6 of the "*Testing and Monitoring Plan*" submitted in Module E.

6.1.3 Site Restoration

Full remediation and reclamation of the Vernon One CCS Site will be conducted in a manner sufficient to meet all federal, state and local regulatory requirements. This will be performed for all well site locations developed for this gas storage project.

6.2 SITE CLOSURE REPORT

A site closure report will be prepared and submitted within 90 days following site closure, documenting the following

- Plugging of the verification and geophysical wells (and the injection well if it has not previously been plugged),
- Location of sealed injection well 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.

CapturePoint Solutions, LLC will record a notation to the property's deed on which the injection well was located that will indicate the following

- That the property was used for carbon dioxide sequestration,
- The name of the local agency to which a plat of survey with injection well location was submitted,
- The volume of fluid injected,
- The formation into which the fluid was injected, and
- The period over which the injection occurred.

The site closure report will be submitted to the permitting agency and maintained by CapturePoint Solutions, LLC for a period of 10 years following site closure. Additionally, CapturePoint Solutions, LLC 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 SITE REFERENCES

Balashov, V.N., Guthrie, G.D., Hakata, J.A., Lopano, C.L., Rimstidt, J.D and Brantley, S.L., 2013. Predictive modeling of CO2 sequestration in deep saline sandstone reservoirs: Impacts of geochemical kinetics. Earth and Environmental Systems Institute, Department of Geosciences, Virginia Polytechnic Institute and State University, 42 p.