Plan revision number: 1
Plan revision date: 12/20/2023

ATTACHMENT D: TESTING AND MONITORING PLAN
40 CFR 146.90

DONALDSONVILLE SITE

Facility Information

Facility name: Ciel
CIEL NO.1

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Well location: Donaldsonville, Ascension, Louisiana
NAD 1927 (Louisiana South Zone) X: 2,114,245.33′; Y: 511,857.41′

This Testing and Monitoring Plan describes how BKVerde, LLC (BKVerde) will monitor the Ciel facility site pursuant to 40 CFR 146.90. In addition to demonstrating that the well is operating as planned, the CO_2 plume and pressure front are moving as predicted, and there is no endangerment to underground source of drinking water (USDW). The monitoring data will be used to validate and adjust the geocellular model to predict the distribution of the CO_2 within the storage interval to support area of review (AoR) re-evaluations and a non-endangerment demonstration.

Results of the testing and monitoring activities described below may trigger action according to the Emergency and Remedial Response Plan.

Overall Strategy and Approach for Testing and Monitoring

This plan describes the monitoring, reporting, and verification (MRV) protocol for injecting CO_2 at the Ciel facility and the requisite geochemical, geophysical, mechanical, and hydraulic components therein. The MRV consists of direct and indirect monitoring processes designed to protect the USDW and confirm the injectate's containment within the injection interval (upper confining zone through the basal confining zone). Impact on the near-surface environment is not expected due to the rigorous investigation of the subsurface environment at the Donaldsonville site, an area characterized by a lack of faulting, and the MRV protocol to provide ongoing confirmation of containment during the entirety of the project. In addition, the Louisiana Gulf Coast is not a tectonically or seismically active region.

The injection and monitoring wells associated with the Donaldsonville site will be monitored with direct and indirect methods for the entirety of this project to characterize factors such as CO_2 plume extent, pressure plume extent, wellbore integrity, pressure, temperature, CO_2 injectate composition, and fluid composition. The frequency of data collection has been considered and ranges from continuous to daily, monthly, quarterly, semi-annually, and annually based on modeled predictions, real-time sensitivity, and long-duration events. The combination of monitoring results from the injection interval and the interval from the surface to the upper confining zone is designed to provide the first indication of any unanticipated containment breach. These monitoring results will be utilized to inform the model to verify and improve its predictive ability during the long-term tenure of the project.

The CO_2 plume will be monitored indirectly with vertical seismic profiles (VSP) and newly acquired sonic velocity data correlated to the original 3D seismic data interpretation. Thirty-five square miles of 3D seismic, one 2D line, and multiple electric logs were combined to create a regional and local structural interpretation that, when processed through a computational model, estimated the size and direction of the CO_2 plume migration with time. VSP will be acquired and tied to seismic and sonic data to monitor the migration of the CO_2 plume throughout the entirety of this project.

USDW non-endangerment is a primary objective of the MRV program. Direct monitoring of the USDW aquifers is required by 40 CFR 146.90(d). Indirect monitoring methods will also be utilized to predict and model any unanticipated breaches of injectate containment. Shallow groundwater monitoring, soil-gas monitoring, microseismic monitoring, and atmospheric monitoring will be implemented in addition to direct monitoring of the lowermost USDW aquifer. The shallow monitoring locations will provide for the assessment of baseline conditions and spatially designed monitoring locations that will be routinely sampled during the life of the project. The shallow monitoring locations will provide adequate areal coverage with a focus on areas of higher leak potential, such as the areas in the immediate vicinity of injection wellbores, wellbores penetrating the injection interval, and abandoned well locations.

Re-evaluation of the MRV program and monitoring requirements will be an ongoing process throughout the design, operational, post-site closure, and abandonment phases of the project. In the event that in-zone deep monitoring data indicates that a loss or potential loss of containment may have occurred, then a re-evaluation will be conducted that may require a more extensive monitoring design.

QUALITY ASSURANCE PROCEDURES

The Quality Assurance and Surveillance Plan (QASP) provides additional details to the Testing and Monitoring plan such as project management, data generation and acquisition, assessment and oversight, and Data validation and usability. The QASP is attached as Appendix C.

Reporting Procedures

BKVerde will report the results of all testing and monitoring activities to the EPA in compliance with the requirements under 40 CFR 146.91.

Carbon Dioxide Stream Analysis [40 CFR 146.90(a)]

BKVerde will monitor and analyze the CO_2 stream injection rate, injection pressure, cumulative volumes, CO_2 composition and annulus pressure during the operation period to yield data representative of its chemical and physical characteristics and to meet the requirements of 40 CFR 146.90(a).

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Sampling Location and Frequency

BKVerde will monitor the CO_2 content daily. Sampling will take place quarterly, by the following dates each year: 3 months after the date of authorization of injection, 6 months after the date of authorization of injection, 9 months after the date of authorization of injection, and 12 months after the date of authorization of injection.

Modifications to the sampling frequency will be implemented for events such as a change in CO_2 content, change in rate of corrosion of materials or a change in injectivity in the injection zone. BKVerde will monitor and analyze parameters to ensure that operating conditions remain within permitted limits. Any deviation from the average of baseline parameters or samples will be reported to the regulatory authorities. An analysis of the information and determination of a course of action or corrective action will be submitted to the regulatory authorities for approval.

Analytical Parameters

BKVerde will sample the CO_2 injectate at the meter run immediately upstream of the wellhead. BKVerde will analyze the CO_2 for the constituents, at minimum, identified in Table 1, using the methods listed.

Table 1. Summary of analytical parameters for CO_2 stream.

Parameter	Analytical Method(s)
Oxygen	ISBT 4.0 (GC/DID) GC/TCD
Nitrogen	ISBT 4.0 (GC/DID) GC/TCD
Carbon monoxide	ISBT 5.0 Colorimetric ISBT 4.0 (GC/DID)
Oxides of nitrogen	ISBT 7.0 Colorimetric
Total hydrocarbons Methane	ISBT 10.0 THA (FID) ISBT 10.1 (GC/FID)
Acetaldehyde	ISBT 11.0 (GC/FID)
Sulfur dioxide Total sulfur	ISBT 14.0 (GC/SCD)
Hydrogen sulfide	ISBT 14.0 (GC/SCD)
Ethanol	ISBT 11.0 (GC/FID)
CO_2 purity	ISBT 2.0 Caustic absorption Zahm-Nagel ALI method SAM 4.1 subtraction method (GC/DID) GC/TCD
Water	
Notes: ISBT, International Society of Beverage Technologists; GC, gas chromatography; DID, Discharge Ionization Detector, TCD, Thermal Conductivity Detector	

BKVerde will utilize materials, equipment for sampling, chain of custody, detection limits, and procedures as described in the QASP.

Sampling Methods

The CO2 composition sample will be collected near the CO2 meter run upstream of the wellhead. The CO2 meter run and flowline will be composed of appropriate corrosion resistant materials. Gas sampling cylinders composed of corrosion resistant materials will be utilized to collect the CO2 samples. Sample collection procedures are described in the QASP (Appendix C)

Laboratory to be used/chain of custody and analysis procedures.

CO2 samples will be analyzed at EPA-certified and approved laboratories. The collection and reporting of the samples will be documented in accordance with the EPA chain of custody procedures. A listing of EPA-certified and approved laboratories, chain of custody, and detection limits for analytical methods are described in the QASP.

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

BKVerde will install and use continuous recording devices to monitor injection pressure, rate, and volume; the pressure on the annulus between the tubing and the long string casing; the annulus fluid volume added or removed; and the temperature of the CO_2 stream, as required at 40 CFR 146.88(e)(1), 146.89(b), and 146.90(b). A listing of sampling devices, locations, and frequency is provided in Table 2.

Monitoring Location and Frequency

BKVerde will perform the activities identified in Table 2 to monitor operational parameters and verify the internal mechanical integrity of the injection well. All monitoring will occur at the locations and frequencies shown in the table.

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

Parameter	Device(s)	Location	Minimum Sampling Frequency	Minimum Recording Frequency
tubing pressure/casing-tubing (annulus) pressure/tubing temperature	Electronic & Face gauge	Ciel No. 1, Lune No. 1 Schexnayder No. 1 Soleil No. 1	5 seconds	5 seconds
Ciel No.1 injection rate	Coriolis Meter and Orifice Meter	Surface Facility (Ciel No. 1)	5 seconds	5 seconds
Ciel No.1 injection volume	Coriolis Meter and Orifice Meter	Surface Facility (Ciel No. 1)	5 seconds	5 seconds

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Parameter	Device(s)	Location	Minimum Sampling Frequency	Minimum Recording Frequency
Ciel No.1 annulus fluid volume	Turbine flow meter and Tank measurements	Surface Facility (Ciel No. 1)	5 seconds	5 seconds
Bottomhole pressure & temperature	Electronic gauge	Ciel No. 1, Soleil No. 1	5 seconds	5 seconds
Ambient temperature	Electronic gauge & face gauge	Surface facility (Ciel No. 1)	5 seconds	5 seconds
Ciel No.1 shut in	All devices as mentioned above	At each location as mentioned above	5 seconds	5 seconds

Monitoring Details

Injection Rate and Pressure Monitoring

BKVerde will monitor injection operations using a process control system as described. The surface facility equipment and control system will limit the maximum flow to 3,500 metric tons/day and monitor the wellhead pressure in the injection permit that corresponds to the regulatory requirement not to exceed 90% of the injection zone fracture pressure. Injection operations will be continuously monitored and controlled by BKVerde operations staff using the process control system. The process control system will continuously monitor, control, record, alarm, and shut down if control parameters exceed their normal operating range.

All critical system parameters, e.g., pressure, temperature, and flow rate, will have continuous electronic monitoring with signals transmitted back to a master control system. BKVerde personnel will have the capability to monitor the status of the entire process control system from (1) the onsite office, (2) the BKVerde Houston office, and (3) remote locations via the mobile application available on cell phones, tablets, and personal computers.

Calculation of Injection Volumes

Flow rate will be measured on a mass basis (kg/h). The downhole pressure and temperature data will be used to calculate injectate density at downhole injection perforation rates. Surface meter run pressure, differential pressure and temperature data associated with the Coriolis meter and orifice meter run will be used to calculate the surface injection rates.

The injection rate and volume of CO_2 injected will be calculated from the mass flow rate obtained from the Coriolis mass flowmeter installed on the surface injection line. The mass flow rate will be divided by density and multiplied by injection time to determine the volume injected.

Density will be calculated using the correlation developed by Ouang (2011) or a similar fluid property calculation software may be used to determine the density. The Quang correlation uses the temperature and pressure data collected to determine the carbon dioxide density. The density correlation is given by,

$$\text{Density} = A_0 + A_1 * P + A_2 * P_2 + A_3 * P_3 + A_4 * P_4$$

where P is the pressure in psi, and A are coefficients determined by the equations:

$$A_i = b_{i0} + b_{i1} * T + b_{i2} * T_2 + b_{i3} * T_3 + b_{i4} * T_4$$

T is the temperature in degrees Celsius and the b coefficients are presented in

Table 3 and Table 4.

Table 3. Injection volume calculation b coefficients, pressure < 3,000 psi.

Value of i	b_{i_0}	b_{i_1}	b_{i_2}	b_{i_3}	b_{i_4}
i=0	-2.14832208E+05	1.168116599E+04	-2.302236659E+02	1.9674289401E+00	-6.184842764E-03
i=1	4.757146002E+02	-2.619250287E+01	5.2151342068E-01	-4.494511089E-03	1.4230587959E-05
i=2	-3.71390018E-01	2.0724888765E-02	-4.169082831E-04	3.6229756741E-06	-1.155050860E-08
i=3	1.228907393E-04	-6.930063746E-06	1.4063172066E-07	-1.230995287E-09	3.9484174280E-12
i=4	-1.46640801E-08	8.3380086513E-10	-1.704242447E-11	1.5008788618E-13	-4.838826574E-16

Table 4. Injection volume calculation b coefficients, pressure > 3,000 psi.

Value of i	b_{i_0}	b_{i_1}	b_{i_2}	b_{i_3}	b_{i_4}
i=0	6.897382693E+02	2.730479206E+00	-2.2541023E-02	-4.65119614E-03	3.43970223E-05
i=1	2.213692462E-01	-6.547268255E-03	5.98225888E-05	2.274997412E-06	-1.8883613E-08
i=2	-5.118724890E-05	2.0196970176E-06	-2.3113320E-08	-4.07955740E-10	3.89359964E-12
i=3	5.517971126E-09	-2.415814703E-10	3.12160348E-12	3.171271084E-14	-3.5607855E-16
i=4	-2.184152941E-13	1.0107037060E-14	-1.4066206E-16	-8.95773113E-19	1.21581046E-20

The final volume basis will be calculated as follows:

$$\text{Volume basis } (m^3/h) = \text{Mass basis } (kg/h)/\text{density } (kg/m^3)$$

Continuous Monitoring of Annulus Pressure

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

1) The annulus between the tubing and the long string of the casing will be filled with brine. The brine will have a density of 10 lb/gal. The hydrostatic pressure gradient is 0.52 psi/ft. The brine will contain a corrosion inhibitor.

2) The surface annulus pressure will be kept at a minimum of 100 psi during injection.

3) During well shut-ins, the surface annulus pressure will be kept at a minimum pressure to maintain a pressure differential of at least 100 psi between the annular fluid directly above (higher pressure) and below (lower pressure) the injection tubing packer.

4) The pressure within the annular space over the interval from above the packer to the confining layer will be greater than the pressure of the injection zone at all times.

5) The pressure in the annular space directly above the packer will be maintained at least 100 psi higher than the adjacent tubing pressure during injection.

The annular monitoring system consists of a continuous annular pressure gauge, an annulus fluid tank, fluid pump, annulus fluid rate meter, pressure regulators, and a continuously monitored tank fluid level. The annulus system will maintain annulus pressure with an electric fluid pump and fluid bleed system connected to the annulus fluid tank.

Any changes to the composition of annular fluid will be reported in the next report submitted to the permitting agency.

If system communication is lost for greater than 30 minutes, personnel will perform field monitoring of manual gauges for both the wellhead surface pressure and annulus pressure and record hard copies of the data until communication is restored.

Average annular pressure and annulus tank fluid level will be recorded daily. The volume of fluid added or removed from the system will be recorded.

Casing - Tubing (Annulus) Pressure Monitoring

BKVerde will monitor the wellhead casing-tubing pressure. During the injection timeframe of the project, the wellhead casing-tubing pressure will be monitored and recorded in real-time. As detailed in the Emergency and Remedial Response Plan (Attachment G to this permit), significant changes in the wellhead casing-tubing annular pressure attributed to well mechanical integrity will be investigated.

Collection and recording of the wellhead casing-tubing pressure data will occur at the frequencies described in Table 2.

Instrument calibration standards, precision, and tolerances are provided in the QASP (Attachment C). Data deviation from baseline, predicted, or average values will be monitored continuously by the measurement devices as described and compared to real-time average, historical average, and predicted values. Unexpected changes in casing-tubing pressure or fluid volumes injection or removal from the casing-tubing annulus may indicate a loss of mechanical integrity. Deviation from expected values will initiate an alarm on the process control system, resulting in an immediate shut-in or data review. Changes in injection rate or annular pressure that result in unexpected results may trigger additional sample collection in the above confining zone monitoring wells, (Lune No. 1 and C. Schexnayder etal. No. 1 (API 170052026500))) or mechanical integrity testing of the Ciel No. 1

Corrosion Monitoring

To meet the requirements of 40 CFR 146.90(c), BKVerde will monitor well materials during the operation period for loss of mass, thickness, cracking, pitting, and other signs of corrosion to ensure that the well components meet the minimum standards for material strength and performance.

BKVerde will monitor corrosion using the corrosion coupon method and collect samples according to the description below.

Monitoring Location and Frequency

The monitoring will occur quarterly, by the following dates each year: 3 months after the date of authorization of injection, 6 months after the date of authorization of injection, 9 months after the date of authorization of injection, and 12 months after the date of authorization to inject.

Sample Description

Samples of materials used in the construction of the compression equipment, pipeline, and injection well that encounter the CO2 stream will be included in the corrosion monitoring program either by using actual material and/or conventional corrosion coupons. The samples consist of those items listed in Table 5. Each coupon will be weighed, measured, and photographed prior to initial exposure.

Table 5. List of equipment with material of construction.

Equipment Coupon	Material of Construction
Long string surface casing (surface–2,000 ft)	Carbon steel
Long string intermediate casing (surface–3,800 ft)	Carbon steel
Long string injection casing (surface–3,800 ft)	Carbon steel
Long string injection casing (3,800 ft–11,100 ft)	Chrome alloy

Equipment Coupon	Material of Construction
Long string injection casing (11,100 ft – 11,500 ft)	Carbon Steel
Long string tubing	Chrome alloy
Wellhead	Chrome alloy
Packers	Chrome alloy

Sample Handling and Monitoring

The coupons will be handled and assessed for corrosion using the American Society for Testing and Materials (ASTM) G1-03, Standard Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens (ASTM 2011). The coupons will be photographed, visually inspected with a minimum of 10x power, dimensionally measured (to within 0.0001), and weighed (to within 0.0001).

Groundwater Quality Monitoring

BKVerde will monitor groundwater quality and geochemical changes in the deepest USDW sand and the first sand above the upper confining zone during the operation period to meet the requirements of 40 CFR 146.90(d). Water samples will be collected from three shallow groundwater monitoring wells (GM), two USDW wells, and two above zone monitoring wells. These wells will be drilled within ~2,200 feet from the proposed injection well. Water samples will be collected from the wells prior to the start of CO_2 injection to establish a baseline. Additional samples will be collected on an annual time frame during the injection period and every 5 years after the cessation of injection. Annual sampling will occur up to 45 days before the anniversary date of authorization of injection each year.

Details of the to-be-drilled shallow groundwater monitoring and USDW wells are provided in Table 6.

Table 6. Details of the planned groundwater monitoring wells.

Well Name	X NAD 1927 South Zone	Y NAD 1927 South Zone	Distance from Ciel No.1 (feet)	Depth (feet)
GM1	2,115,765.31	511,917.89	1,521	250
GM2	2,114,216.08	513,797.04	1,940	250
GM3	2,114,413.90	511,986.19	212	250
USDW1	2,114,146.22	511,870.68	100	1,000
USDW2	2,114,139.76	513,961.60	2,104	1,000
Schexnayder No. 1	2,114,131	513,910	2056	4,020
Lune No.1	2,114,195.78	511,864.05	50	4,020

The wells will be placed in a triangular design around the injector such that a water sample will be collected where the injected CO_2 is expected to migrate. The purpose of this is to ensure good lateral coverage for sampling. A map of the proposed shallow groundwater monitoring wells is provided in Figure 1.

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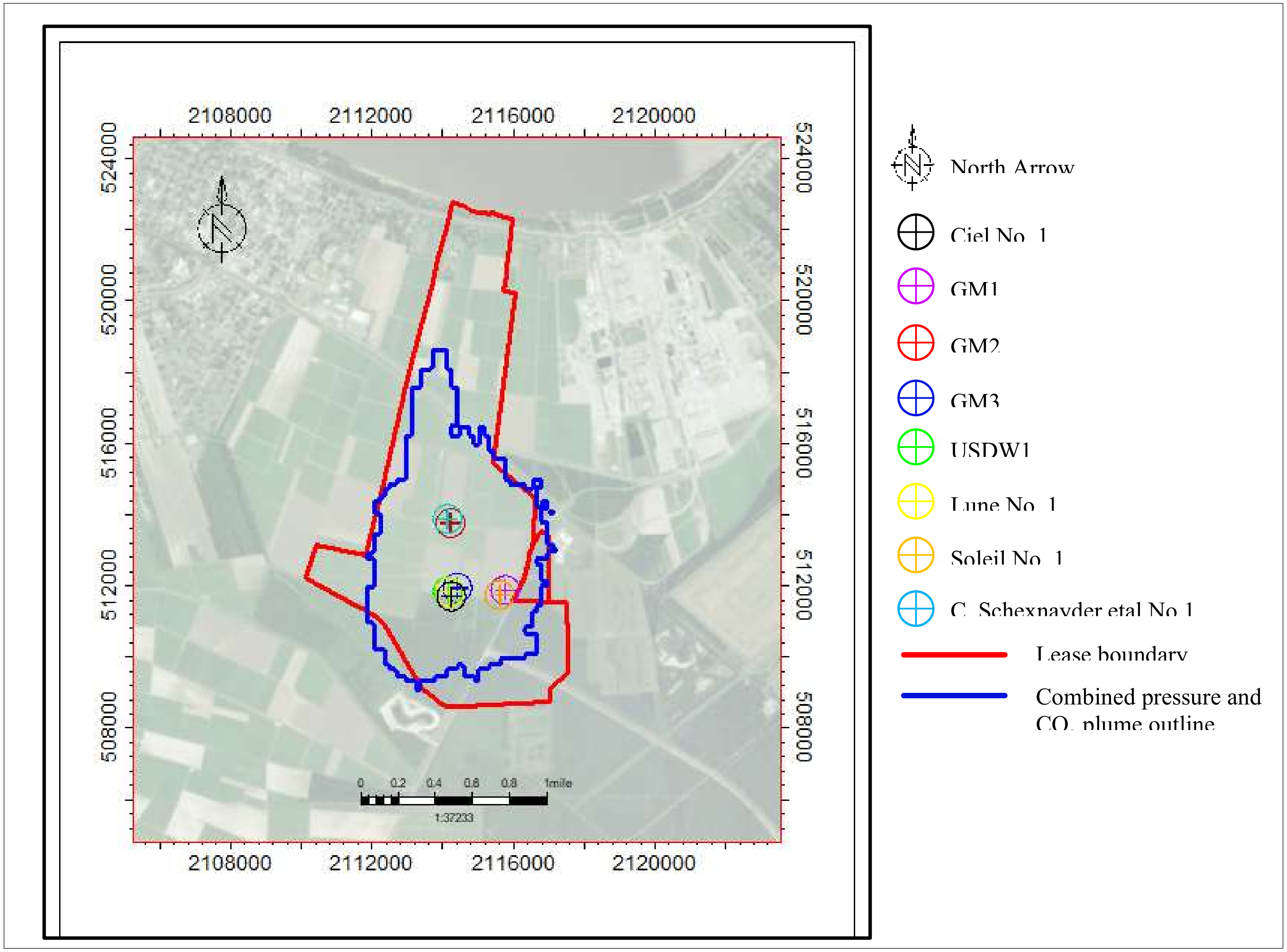

Figure 1: Map of the Donaldsonville Site, showing the location of proposed groundwater monitoring wells.

To meet the requirements at 40 CFR 146.95(f)(3)(i), BKVerde will monitor groundwater quality, geochemical changes, and pressure in the USDW immediately above the injection zone(s).

Table 7The planned monitoring methods, locations, and frequencies for groundwater quality and geochemical monitoring above the confining zone are described in Table 7. A map showing monitoring well locations relative to the AoR delineation is presented in Figure 1.

Table 7. Monitoring of groundwater quality and geochemical changes above the confining zone.

Target Formation	Monitoring Activity	Monitoring Location(s)	Spatial Coverage	Frequency
Mississippi River Alluvial Aquifer USDW Bottom Sand (Miocene) =Sand Above UCZ (Miocene)	Fluid sampling (all wells)	GM1 (Soleil No. 1) GM2 (Schexnaydar No. 1) GM3 (Ciel No. 1) USDW1 (Ciel No 1) USDW 2 (Schexnaydar No. 1) Lune No. 1 Schexnaydar No. 1	Near wellbore (all wells)	Baseline Annual Baseline Annual Baseline Quarterly for Schexnaydar No. 1 Annual for Lune No. 1
Miocene	Bottomhole pressure/temperature	Lune No.1 Soleil No.1 Ciel No.1	Near wellbore Near wellbore Near wellbore	Annual Continuous Continuous
Miocene	Wellhead Temperature-pressure: tubing/annulus/surface casing/intermediate casing/injection casing	Lune No.1 Soleil No.1 Ciel No.1	Near wellbore Near wellbore Near wellbore	Continuous Continuous Continuous
Miocene	Pulsed neutron log	Soleil No.1 Ciel No.1 Lune No. 1 Schexnaydar No. 1	Near wellbore Near wellbore Near wellbore	Baseline Annual

The network of monitoring wells is sufficient to monitor geochemical changes in groundwater quality above the confining zone throughout the AoR. The groundwater monitoring wells are located near each injection and monitoring well that penetrates the injection interval. The groundwater and USDW wells are located near the Ciel No. 1 in the direction of groundwater recharge. The AZM wells are located near the Ciel No. 1 (Lune No. 1) and at the C. Schexnaydar etal No. 1 (API 1700520265) to monitor any changes in the first sand above the upper confining zone (UCZ).

Data deviation from baseline, predicted, or average values will be monitored continuously by the measurement devices as described and compared to real-time average, historical average, and predicted values. Unexpected changes may indicate a loss of upper confining zone integrity. Deviation from expected values may require collecting additional samples beyond the scheduled sampling frequency to confirm results, determine root causes, and initiate changes to sufficiently identify leaks, and characterize groundwater quality above the confining zone.

Indirect monitoring activities in the Ciel No. 1, Soleil No. 1, Lune No. 1, C. Schexnayder etal. No. 1 (API 170052026500) and VSP monitoring in the Soleil No. 1 and C. Schexnayder etal. No. 1 (API 170052026500) will provide CO2 plume and pressure plume monitoring in addition to direct monitoring in the groundwater monitoring wells. These monitoring activities will provide a comprehensive leak detection/groundwater monitoring strategy.

Phased monitoring based on predicted plume migration within the AoR will be considered based on monitoring results during the project timeframe.

Analytical Parameters

Table 8he parameters to be monitored and the analytical methods BKVerde will employ are illustrated in Table 8.

Table 8. Summary of analytical and field parameters for groundwater samples.

Parameters	Analytical Methods
Mississippi River Alluvial Aquifer & Miocene zones	
Cations:	ICP-MS
Al, Ca, Mn, As, Cd, Cr, Cu, Pb, Sb, Se, and TI	EPA Method 6020
Cations:	ICP-OES,
Ca, Fe, K, Mg, Na, and Si	EPA Method 6010B
Anions:	Ion Chromatography,
Br, Cl, F, NO3, and SO4	EPA Method 300.0
Dissolved CO_2	Coulometric titration, ASTM D513-11
Total Dissolved Solids	Gravimetry; APHA 2540 C
Alkalinity	APHA 2320B
pH (field)	EPA 150.1
Specific conductance (field)	APHA 2510
Temperature (field)	Thermocouple
Lowermost USDW Sand	
Same parameters as above in Table 2	

Sampling will be performed as described in section 2.0 of the QASP; this section of the QASP describes the groundwater sampling methods to be employed, including sampling SOPs (section 2.2.1) and sample preservation (section 2.2.6).

Sample handling and custody will be performed as described in section 2.3 of the QASP. Quality control will be ensured using the methods described in section 2.5 of the QASP.

Sampling Methods

Sampling container material will meet or exceed the requirements for sampling conditions. Sampling container material and procedures are described in section 2.2.5 and 2.2.1.2 of the QASP.

Laboratory to be Used and Chain of Custody Procedures

Laboratories used shall be approved by the regulatory agency. Chain of custody procedures and detection limits for analytical methods are presented in section 2.3.5 and 2.5.2 of the QASP.

External Mechanical Integrity Testing

BKVerde will conduct at least one of the tests presented in Table 9 during the injection phase to verify external mechanical integrity as required at 40 CFR 146.89(c) and 146.90. Mechanical integrity tests (MITs) will be performed annually, up to 45 days before the anniversary date of authorization of injection each year or scheduled with the prior approval of the Underground Injection Control (UIC) Program Director.

Table 9. MITs.

Test Description	Location
Noise log	Ciel No. 1, Soleil No.1, Lune No. 1, Schexnayder No.1 (API 1700520265)
Pulsed neutron log	Ciel No. 1, Soleil No.1, Lune No. 1, Schexnayder No.1 (API 1700520265)
Oxygen Activation (OA Logging)	Ciel No. 1, Soleil No.1, Lune No. 1, Schexnayder No.1 (API 1700520265
Temperature Logging	Ciel No. 1, Soleil No.1, Lune No. 1, Schexnayde r No.1 (API 1700520265

Pulsed Neutron Logging (PNL) using Wireline

To ensure the mechanical integrity of the casing of the injection well, data may be recorded using the pulsed neutron logging tool will be recorded from the surface to total depth to establish a baseline. Subsequent PNL logging will provide a time sequence for comparison to the baseline established prior to the initiation of injection operations. The following procedures will be employed for PNL logging:

1. Move-in and rig-up electrical logging unit with a lubricator.
2. Run-in-hole while acquiring temperature to depth required.
3. Run on Minitron.

4. Log main pass at 1,800 feet per hour.
5. Log repeat pass at 1,800 feet per hour.
6. POOH.
7. Rig-down electrical logging unit.
8. Interpret the data: Data interpretation involves comparing the baseline PNL log to subsequent PNL logs "Time-Lapse logging" to identify changes and differences in measurements that may indicate a failure of wellbore integrity. An increase in carbon dioxide saturation, above or below the injection zone as detected by the PNL could indicate unplanned fluid movement in the annulus or outside the casing.

Temperature logging using wireline to ensure the mechanical integrity of the casing of the injection well, temperature data may be recorded across the wellbore from the surface down to the primary upper confining zone. Bottomhole pressure and temperature data near the packer will also be provided. The following procedures will be employed for temperature logging:

1. Maintain the well in a state of injection for at least 6 hours prior to commencing operations to cool injection zones.
2. Move in and rig up an electrical logging unit with a lubricator.
3. Run a temperature survey from the top of the upper confining zone (or higher) to the deepest point reachable in the injection zone while injecting at a rate that allows for safe operations.
4. Stop injection, pull tool back to shallow depth, and wait 1 hour.
5. Run a temperature survey over the same zone as step 3.
6. Pull tool back to shallow depth, wait 2 hours.
7. Run a temperature survey over the same zone as step 3.
8. Pull tool back to shallow depth, wait 2 hours.
9. Run a temperature survey over the same zone as step 3.
10. Evaluate data to determine if additional passes are needed for interpretation. Should CO_2 migration be interpreted in the topmost section of the log, additional logging runs over a higher interval will be required to find the top of migration.
11. If additional passes are needed, repeat temperature surveys every 2 hours until 12 hours, over the same interval as step 3.
12. Rig down the logging equipment.
13. Interpret the data: Data interpretation involves comparing the time-lapse wellbore temperature profiles and looking for temperature anomalies that may indicate a failure of well integrity, i.e., tubing leak or movement of fluid behind the casing. As the well cools, the temperature profile along the length of the tubing string is compared to the baseline.

Any unplanned fluid movement into the annulus or outside the casing creates a temperature anomaly compared to the baseline cooling profile.

Noise Logging

To ensure the mechanical integrity of the casing of the injection well, logging data will be recorded across the wellbore from the surface down to the primary upper confining zone. Bottomhole pressure data near the packer will also be provided. Noise logging will be carried out while injection is occurring. If ambient noise is greater than 10 mv (milli volts), injection will be halted. The following procedures will be employed:

1. Move in and rig up an electrical logging unit with a lubricator.
2. Run a noise survey from the base of the upper confining zone (or higher) to the deepest point reachable in the Miocene injection zones while injecting at a rate that allows for safe operations.
3. Make noise measurements at intervals of 100 feet to create a log on a coarse grid.
4. If any anomalies are evident on the coarse log, construct a finer grid by making noise measurements at intervals of 20 feet within the coarse intervals containing high noise levels.
5. Make noise measurements at intervals of 10 feet through the first 50 feet above the injection interval and at intervals of 20 feet within the 100-foot intervals containing:
    a. The base of the lowermost bleed-off zone above the injection interval.
    b. The base of the lowermost USDW.
    c. Additional measurements may be made to pinpoint depths at which noise is produced.
6. Use a vertical scale of 1 or 2 inches per 100 feet.
7. Rig down the logging equipment.
8. Interpret the data: Determine the base noise level in the well (dead well level). Identify departures from this level. An increase in noise near the surface due to equipment operating at the surface is expected in many situations. Determine the extent of any movement; flow into or between USDWs indicates a lack of mechanical integrity, and flow from the injection zone into or above the confining zone indicates containment failure.

Oxygen Activation (OA) Logging

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

1. Move in and rig up an electrical logging unit with a lubricator.

2. Conduct a baseline gamma ray log and casing collar locator log from the top of the injection zone to the surface prior to taking the stationary readings with the OA tool.

   The gamma ray log is necessary to evaluate the contribution of naturally occurring background radiation to the total gamma radiation count detected by the OA tool. Different types of natural radiation are emitted from various geologic formations or zones, and the natural radiation may change over time.

3. Prepare for the OA log.

   The OA log will be used only for casing diameters greater than 1-11/16 inches and less than 13-3/8 inches.

   All stationary readings should be taken with the well injecting fluid at the normal rate with minimal rate and pressure fluctuations.

   Prior to taking the stationary readings, properly calibrate the OA tool in a "no vertical flow behind the casing" section of the well to ensure accurate, repeatable tool response and for measuring background counts.

4. At a minimum, take a 15-minute stationary reading adjacent to the confining interval located immediately above the injection interval. This must be at least 10 feet above the injection interval so that turbulence does not affect the readings.

5. At a minimum, take a 15-minute stationary reading at a location approximately midway between the base of the lowermost USDW and the confining interval located immediately above the injection interval.

6. At a minimum, take a 15-minute stationary reading adjacent to the top of the confining zone.

7. At a minimum, take a 15-minute stationary reading at the base of the lowermost USDW.

8. If flow is indicated by the OA log at a location, move up hole or downhole as necessary at no more than 50-foot intervals and take stationary readings to determine the area of fluid migration.

9. Interpret the data: Identify differences in the activated water's measured gamma ray count-rate profile versus the expected count-rate profile for a static environment. Differences between the measured and expected may indicate flow in the annulus or behind the casing. The flow velocity is determined by measuring the time the activated water passes a detector.

<u>Pressure Falloff Testing</u>

BKVerde will perform pressure falloff tests in the Ciel No. 1 prior to the initiation of CO_2 injection as described below to meet the requirements of 40 CFR 146.90(f). Since the injection period per zone is less than 1.5 years, no additional falloff will be performed in the Ciel No. 1. The detailed plan and procedure for pressure falloff testing are provided in the pre-operational testing section of the document, Attachment B.

Testing Location and Frequency

BKVerde will perform pressure falloff tests in each injection zone in the Ciel No. 1 prior to initiating CO2 injection in that injection zone to meet the requirements of 40 CFR 146.90 (f).

Testing Details

The detailed plan and procedure for pressure falloff testing are provided in the pre-operational testing section of the document, Attachment B. Downhole and wellhead pressure and temperature electronic gauges and a Coriolis meter (CO_2 injection rate) will be used during pressure fall-off testing.

Carbon Dioxide Plume and Pressure Front Tracking

BKVerde will employ direct and indirect methods to track the extent of the CO_2 plume and the presence or absence of elevated pressure during the operation to meet the requirements of 40 CFR 146.90(g).

Plume Monitoring Location and Frequency

The direct and indirect methods that BKVerde will use to monitor the position of the CO_2 plume, including the activities, locations, and frequencies BKVerde will employ, are presented in Table 10. The parameters to be analyzed as part of fluid sampling in the injection zone and associated analytical methods are shown in Table 11.

Quality assurance procedures for these methods are presented in Appendix C (Section 2.3) INSERT SECTION X of the QASP. The depth or elevation below the mean sea level of each monitoring zone is presented in **Table 1.1** of the **Application Narrative**.

Phased monitoring based on predicted plume migration within the AoR will be considered based on monitoring results during the project timeframe.

Plume Monitoring Details

Direct & Indirect Monitoring Methods

The CO_2 plume will be monitored directly at the Ciel No.1 and Lune No.1 wells and at any additional monitoring wells that may be installed due to adapting to changing conditions during the lifespan of the project. Direct methods will include CO_2 gas detection tubes and bottom-hole pressure (P) and temperature (T) monitoring. Baseline data allows for comparison of prior, during, and after injection operational data.

The Soleil No. 1 will monitor the CO_2 plume directly via bottomhole pressure measurement in the injection zone. Upon arrival of the CO_2 plume at the Soliel No. 1, the gas detection tubes will be utilized to directly measure and detect its arrival. While injecting CO_2 at the Ciel No. 1, the pressure response at the Soleil No. 1 is a direct measurement of the resultant pressure transient effects. The Soleil No. 1 and C. Schexnayder No. 1 (API 1700520265) utilize fiber optic cables to indirectly monitor the areal extent of the CO_2 plume via VSP.

Table 10 presents the methods that BKVerde will use to monitor the position of the CO_2 plume using bottomhole pressure and gas detection tubes, including the activities, locations, and frequencies that data will be gathered.

Time-lapse 3D Vertical Seismic Profiling (VSP), as per Gasperikova et al. (2020), recognizes seismic reflection methods as more sensitive to mapping CO_2 in the subsurface than electromagnetic and gravitational methods. The seismic reflection methods used for subsurface imaging are 3D surface seismic and 3D VSP. For this project, time-lapse 3D VSP is the method proposed to map the CO_2 plume over time (3D surveys acquired in time-lapse are often referred to as 4D).

The main difference between 3D VSP surveying and conventional 3D surface seismic acquisition is that for 3D VSP, the receivers are in the borehole rather than placed in a grid pattern on the surface. Having the receivers in the borehole can significantly reduce the noise commonly associated with seismic surveys and typically also delivers an increased high-frequency component to the recorded seismic. The planned receiver type is a type of fiber optic cable known as distributed acoustic sensing (DAS).

To confirm that time-lapse 3D VSP will be able to adequately image the CO_2 plume, the seismic response will be modeled using the following inputs:

- Downhole DAS fiber configuration.
- Locations of the seismic sources on the surface.
- Subsurface velocity field from the velocity model.
- Reflections mapped in the existing 3D surface seismic survey.

The areal coverage of the seismic sources is the modeling parameter typically adjusted to ensure seismic coverage of the CO_2 plume.

Before CO_2 injection begins, a baseline 3D VSP survey will be acquired using currently accepted industry-standard techniques. The acquired seismic data will then undergo seismic processing to produce a seismic image of the subsurface as it exists before injection. At the specified time after injection begins, the first time-lapse 3D VSP will be acquired. The original baseline 3D VSP survey is typically reprocessed with the same parameters as the time-lapse survey to ensure that the amplitudes of the two surveys match as closely as possible. The seismic reflection magnitudes depend on the P-wave velocity and density. Velocity and density are affected by the presence of CO_2, so the reflected amplitudes will change over time as the CO_2 is injected. The differences in seismic reflection amplitudes between the baseline survey and each successive time-lapse survey are calculated and used to determine the extent of the plume.

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Table 10. Plume monitoring activities.

Target Formation	Monitoring Activity	Monitoring Location(s)	Spatial Coverage	Frequency
DIRECT PLUME MONITORING				
Miocene (current injection zone)	CO_2 Gas Detection Tubes	Lune No. 1 tubing Soleil No.1 tubing Schexnayder No. 1 tubing	Near wellbore	Weekly
Injection Zones	Bottomhole P/T	Soleil No. 1	Near Wellbore	Continuous
Injection Zones	Bottomhole P/T	Ciel No. 1	Near Wellbore	Continuous
INDIRECT PLUME MONITORING				
Injection Zones	Bottomhole P/T	Ciel No.1	AoR	Continuous
Injection Zones	Bottomhole P/T	Soleil No.1	AoR	Continuous
Upper confining zone: First sand above the upper confining zone: USDW to surface and Miocene injection zones	Pulse Neutron Logging	C. Schexnayder etal. No.1	Near wellbore—continuous to full well depth	Baseline Between each injection zone re-completion
All formations	Time-lapse VSP seismic survey	Ciel No.1 Soleil No. 1	Modeled plume area	Baseline Year 5, 10 15

Table 11: Summary of analytical and field parameters for fluid sampling in the injection zone.

Parameters	Analytical Methods
FORMATION NAME: First sand above the Upper Confining Zone: USDW to surface	
Cations: AL, Ba, Mn, As, Ce, Cr, Cu, Pb, Sb, Se, & TI Cations:	ICP-MS, EPA Method 6020

Ca, Fe, K, Mg, Na, & Si	ICP-OES, EPA Method 6010B
Anions:	
Br, Cl, F, NO3, & SO4	Ion Chromatography, EPA Method 300.0
Dissolved CO2	Coulometric titration, ASTM D513-11
Isotopes: δ13X of DIC	Isotope ratio mass spectrometry
Total Dissolved Solids	Gravimetry; APHA 2540C
Water Density (Field)	Oscillating body method
Alkalinity	APHA 2320B
PH (Field)	EPA 150.0
Specific Conductance (Field)	APHA 2510
Temperature (Field)	Thermocouple

Pressure-front Monitoring Location and Frequency

The pressure-front measurements from the injection zone bottomhole pressure and temperature gauges at the Soleil No.1 will be used to compare with the computational model results and to inform the model with directly measured pressure data.

The downhole pressure in the injection zone will be monitored at the Ciel No.1 and the Soleil No.1. Baseline pressure monitoring from these wells will occur up to 1 year prior to the initiation of injection operations. These pressure measurements will confirm near wellbore pressures and temperatures directly while gradient and pressure transient methods will be used to indirectly measure the pressure within the AoR area. The Soleil No.1 will be completed as a multizone pressure-front monitoring well located within the computationally modeled CO_2 plume and pressure-front plume. Table presents the methods that BKVerde will use to monitor the position of the pressure front, including the activities, locations, and frequencies BKVerde will employ. Pressure and temperature measurements will be continuous with a minimum time interval of 5 seconds and a minimum recording interval of 5 seconds. While the monitoring locations of these two wells are fixed, phased or adaptive monitoring will be considered based on data analysis.

Quality assurance procedures for these methods are presented in SECTION 2.1.1.1 of the QASP.

Pressure-front Monitoring Details

The pressure in the injection zone will be monitored directly by downhole pressure-temperature gauges installed in the injection zone on the Soleil No.1. The Soleil No.1 will measure the pressure front approximately 1,300 feet from the Ciel No.1 location. The pressure front will be monitored by downhole pressure-temperature gauges installed outside the tubing and connected to the surface process control system by a tubing-encapsulated cable to enable continuous measurement. In addition, the Soleil No.1 downhole injection zone pressure measurements will also measure the pressure falloff after injection operations have ceased for a specific injection zone. Pressure transient methods can indirectly model the pressure falloff and build-up within the AoR.

The Soleil No. 1 well will be completed with four zones being monitored simultaneously as illustrated in Table 12. Packers, sliding sleeves, profile nipples, and downhole retrievable tubing plugs will be employed to accomplish this task. The injection zone will be monitored for pressure build-up, while the other three completions monitor the initial reservoir or pressure fall-off due to prior injection activities. The sequence of recompletions in the Soleil No. 1 and pressure monitoring is presented in Table 12. Initially, the deepest zone will be completed to monitor the current injection zone. Once injection ceases in the current injection zone, a sliding sleeve will be closed or a plug will be set to isolate the injection zone. Pressure fall-off measurement will then be monitored in the zone. The Ciel No. 1 will be completed up hole to the next available injection zone. The Soleil No. 1 will be recompleted to the next injection zone by opening a sliding sleeve. In this manner, both the pressure build-up in any current injection zone as well as the pressure fall-off in the prior injection zone will be monitored simultaneously in the Soleil No. 1. The Soleil No. 1 will be recompleted in this manner until the current injection zone in the Ciel No. 1 is recompleted above the top monitoring zone in the Soleil No. 1. At this time, a remedial workover operation will be initiated to recomplete the Soleil No. 1 in sequence into the next four uphole zones. Based on computational modeling results and industry experience in the Miocene formation, BKVerde expects each injection zone's pressure fall-off to be a different value with similar standard decline characteristics. Computational modeling results indicate an average fall-off and return to initial reservoir pressure in 115 days.

The pressure measurements from the downhole gauges at the Soleil No.1 will be compared with the computational model results and baseline measurements to inform the model with directly measured pressure data.

Quality assurance procedures for these methods are presented in Section 2.1.1.1 of the QASP.

Seismic Monitoring Details

A passive seismic monitoring station installed on the surface will be used to detect seismic events over magnitude 1.0 in the AoR. The station will be modeled, using the subsurface velocities and expected location of the plume and pressure boundaries to ensure that events above the threshold magnitude (1.0) within the AoR are recorded and located.

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Table 12. Pressure-front monitoring activities.

Target Formation	Monitoring Activity	Monitoring Location(s)	Spatial Coverage	Frequency
DIRECT PRESSURE-FRONT MONITORING				
Miocene	Bottomhole Pressure/ temperature	Ciel No. 1 Soleil No. 1	Near Well bore	Continuous
INDIRECT PRESSURE-FRONT MONITORING				
All formations	Passive seismic	Surface monitoring stations as determined by modeling	Passive seismic monitoring network will capture events of magnitude 1.0 and greater within the AoR.	Continuous
Miocene	Bottomhole Pressure/Temperature	Soleil No. 1 Ciel No. 1	AoR (Pressure transient and Gradient correlation)	Continuous during injection. Continuous after injection until pressure fall-off returns below critical pressure. Continuous during injection

Soil Gas Monitoring/Other Testing and Monitoring

BKVerde will monitor surface air and soil gas per federal rule (40 CFR 146.9 (h)) and the Louisiana rule (LAC 43.XVII.3625.A.8, attached) to detect movement of CO_2 that could impact the USDW. If any CO_2 is emitted by surface leakage, BKVerde will report to the EPA. Soil gas monitoring will be used to check chemical compositions of the near-surface environment and soil vadose zone. These environments are subjected to strong seasonal effects and are influenced by various natural processes and human activities. BKVerde will install soil gas monitoring stations at least 6 months before injection to better understand baseline conditions through multiple seasons. Best industry practice has shown that fixed soil-gas profile stations provide the most accurate data. The location of the stations will be selected to minimize the agricultural impacts of plowing, planting, irrigation, and harvesting. Samples will be collected and sent to a EPA approved laboratory for analysis. Quality assurance and traceability methods will ensure proper handling of samples and laboratory techniques.

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