CLASS VI PERMIT TESTING AND MONITORING PLAN

LAC 43:XVII §3625 & LCFS Protocol Subsection C.4.1(a)

STRATEGIC BIOFUELS
LOUISIANA GREEN FUELS PORT OF COLUMBIA FACILITY

Prepared By:
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Revision No. 2
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1.0 FACILITY INFORMATION

Facility Name:	Louisiana Green Fuels, Port of Columbia Facility Three Class VI Injection Wells
Facility Contact:	Bob Meredith, COO 303 Wall St., Caldwell, LA 71418 (318) 649-6401 bob.meredith@strategicbiofuels.com
Well Locations:	Port of Columbia, Caldwell Parish, Louisiana **Name: Latitude / Longitude** Well 1 (W-N1): 32.18812141510 / -92.10986101060 Well 2 (W-N2): 32.18686691570 / -92.05915551900 Well 3 (W-S2): 32.1639375970 / -92.08754320370

This *Testing and Monitoring Plan* describes how the Louisiana Green Fuels, Port of Columbia Facility will monitor its Sequestration Project pursuant to the Louisiana Statewide Order No. 29-N-6 [LAC 43:XVII §3625, §3627, and §3629] and the Carbon Capture and Sequestration (CCS) Protocol under the California Air Resources Board (CARB) Low-Carbon Fuel Standard (LCFS) (Subsections C.2.5 and C.4.3.2.2; CARB, 2018). This plan also meets the requirements of the *Monitoring, Measurement, and Verification Plan* required under LCFS Subsection C.4.3.2.

In addition to demonstrating that the injection wells are operating as expected, that the supercritical carbon dioxide plume and pressure front are moving as predicted, and there is no endangerment to underground sources of drinking water (USDWs), the monitoring data will be used to validate and guide any required adjustments to the geologic and dynamic models used to predict the distribution of supercritical carbon dioxide within the storage complex, supporting Area of Review (AoR) evaluations and a non-endangerment demonstration. Additionally, the testing and monitoring components include a leak detection plan to monitor and account for any movement of the carbon dioxide outside of the storage reservoir.

In accordance with §3625 (A)(10) and LCFS Protocol Subsection C.4.1(a)(16) this testing and monitoring plan will be re-evaluated every 5 years (at a minimum) or more frequently at the direction of the Underground Injection Control (UIC) Commissioner. The review process will evaluate whether the current plan will require an amendment.

If the AoR re-evaluation or change in the Testing and Monitoring Plan is required, an amended plan will be submitted within 12 months of an AoR evaluation [LAC 43:XVII §3623 (A)(10)(a)]. Amendment to the Testing and Monitoring Plan may include significant changes to the project including additional monitoring wells, new injection wells, or changes to monitoring technologies that may be available in the future. All amendments will be approved by the Commissioner and incorporated into the currently authorized operating permit.

Results of the testing and monitoring activities described below may also trigger response actions according to the Emergency and Remedial Response Plan [LAC 43:XVII §3623] and LCFS Protocol Subsection C.6.1.

2.0 OVERALL STRATEGY AND APPROACH

This Testing and Monitoring Plan is adapted to Port of Columbia Facility area and considers the following site-specific strategy and approach:

- The Primary Injection Zone is comprised of the Upper Tuscaloosa / Paluxy Formation, which consists of a stacked package of porous and permeable sandstone that are separated by local clay/shale baffles.
- The performance of the multiple sandstones of the Upper Tuscaloosa / Paluxy Formation in accepting injection fluids is well known. Multiple intervals have been injection tested to compute transmissibility (permeability-thickness/viscosity) in the Whitetail Operating, LLC, Louisiana Green Fuels #1 (stratigraphic test well). Test fluids consisted of municipal water mixed with a clay stabilizing surfactant. Additionally, the Lower Tuscaloosa Formation has hosted an extensively monitored DOE-funded sequestration injection project at the Cranfield Oil Field near Natchez, Mississippi, and has also been the primary reservoir targeted by tertiary carbon dioxide enhanced oil recovery in multiple oil producing fields by Denbury Resources.
- The project area is free of faulting at seismic resolution. A number of reprocessed two-dimensional seismic lines are located across the immediate project area and were used in the site characterization work. Interpretation of the data indicates that there is no faulting across either the Injection Zone or the Confining Zone (i.e., the Sequestration Complex).
- The Austin Chalk / Eagleford Equivalent is of regional extent and forms the Primary Upper Confining Zone for the Project. The interval is approximately 250 feet thick beneath the Port of Columbia Facility, forming an impermeable top seal to the sequestration complex. The ductile shales and tight limestones of the Austin Chalk / Eagleford Equivalent are free of transecting faults in the area and have the lithologic properties to limit vertical fracturing.
- The Paleocene Midway Shale is of regional extent and forms the Secondary Upper Confining Zone for the Project. The Midway Shale is approximately 600 feet thick beneath the Port of Columbia Facility, forming an impermeable top seal to the sequestration complex. The ductile Midway Shale is free of transecting faults in the area and has the lithologic properties to limit vertical fracturing in the subsurface.

- The Eocene Wilcox Formation overlying the Midway Shale is composed of approximately 1,300 feet of highly transmissive sandstones that are interbedded with regionally extensive shales and local mudstone baffles. In the northeast Louisiana area, the multiple sandstones of the Wilcox Formation typically contain saltwater. In certain limited areas minor volumes of thermogenic methane, generated from thin lignite beds developed predominantly within the Lower Wilcox, have been encountered trapped within thin Wilcox channel sands. In addition, minor volumes of methane have been produced from two of the lignite source beds, which are also called "coalbed methane" reservoirs in the Caldwell Parish area. Small coalbed methane gas fields such as the Riverton Field, within the and just east of the Port of Columbia Facility area, were initially drilled 20-30 years ago and have since been abandoned.

  Wilcox sandstones have also been utilized for Class I injection of produced oilfield effluents (predominantly brine produced as a consequence of oilfield production operations) in East Louisiana and Southwest Mississippi. The thick sand/shale sequence of the Wilcox Formation thus serves as a series of alternating saline buffer aquifers and impermeable shales positioned between the top of the Sequestration Complex and the lowermost underground source of drinking water (USDW). As such, this thick sand/shale sequence serves to further limit vertical fluid movement and allow for the dissipation of pressure from any injectate that may reach the top of the Secondary Upper Confining Zone.

- The Sparta aquifer is well known as a groundwater resource in northern Louisiana. It is separated from the underlying Wilcox Formation by the Cane River and Tallahatta Formations, both of which are containment layers. The Cane River Formation is an impermeable clay/shale and confines the overlying Sparta aquifer from the underlying Wilcox Formation. The Tallahatta Formation is comprised of an interlaminated series of marls and hard quartzitic lenses, that are typically poor in porosity and permeability, and essentially impermeable calcareous shales that also serve as a laminated confining layer.

- Natural seismicity in the area is exceedingly low, with no recorded historical earthquakes in either Caldwell Parish or the immediately adjacent parishes. The closest recorded earthquakes are located more than 125 kilometers away from the Port of Columbia Facility, near the Arkansas-Louisiana State Line. Induced seismicity risk is also low due to the lack of any nearby faults and because of high transmissivity of the sandstones in the Upper Tuscaloosa / Paluxy Primary Injection Zone. Previous measurements of induced seismicity in Department of Energy supported research projects along the Gulf Coast (the afore-mentioned Mississippi Cranfield Project, for example), have not detected seismic events resulting from the injection of large volumes of supercritical carbon dioxide. Regardless, Strategic Biofuels plans to install a microseismic array covering the modeled plume area (extending outward in a "star" pattern to the general extent of the calculated 20-year plume expansion perimeter). This microseismic array, installed after construction of the sequestration complex is complete, will serve to not only monitor "local" seismicity but also plume expansion. Only if a change in frequency of seismic events occurs will additional site-specific monitoring be undertaken by the Port of Columbia Facility.

- Surface and near-surface monitoring at the Port of Columbia Facility is designed to be responsive to the near-surface setting. The area is dominated by complex surface conditions including tree and grass-dominated high areas, intermittently flooded freshwater wetland, and riparian zones. The area is expected to be dynamic in terms of seasonal carbon dioxide production and uptake from active environments, including wetland bottom sediments, intermittently saturated soils, plant and animal activities, and other activities which are likely to change over time. The determination of the baseline spatial distribution of atmospheric and soil gas monitoring stations will be determined on a site-specific basis and will consist of repeat measurements at several fixed and variable sites, and over a period of at least one year, to capture any seasonal or diurnal variations (LCFS Protocol Subsection C.4.1).
- The three proposed injection wells will create a composite supercritical carbon dioxide plume and a single area of elevated subterranean pressures underlying the active facility. Both the supercritical carbon dioxide plume and the AoR perimeter will grow over time and the expanding plume has the potential to intersect a minimal number of existing (legacy) wells, all of which are dry holes. Validation of the magnitude and area of pressure increase during injection is, therefore, a monitoring focus, as is documenting the extent of the carbon dioxide plume through stabilization during the post-injection monitoring period.

The proposed monitoring network for the project is composed of the following elements, listed from deepest and closest to the point of injection, to the furthest away and shallowest. The overall concept for the monitoring program is presented in Figure 1 and project monitoring well locations are shown in Figure 2.

In-Zone Monitoring (IZMI Monitoring)

Direct Monitoring

- In-Zone monitoring conducted at the injection wells will assure that the wells are performing as intended, which is to deliver the supercritical carbon dioxide to the subsurface storage reservoir intervals (Injection Zone), while measuring the pressure response in those reservoir intervals, a key model match parameter. Downhole pressure gauges and injection logging in the constructed injection wells will be used to collect real-time, continuous data that will be used to assess reservoir response to injection (LCFS Protocol Subsection C.2.5(b)(2)). Gauges will be referenced to ground level at each well.
- In-Zone pressure (IZ) monitoring wells will validate the model of growth of sequestered carbon dioxide plume and the growth of the AoR over time. Real-time, continuous IZ pressure-monitoring will be performed initially outside of the carbon dioxide plume. Monitoring will leverage the data collected from the recently drilled and tested Whitetail Operating, LLC, Louisiana Green Fuels #1 stratigraphic test well (SN975841), located approximately 5,273 feet southeast of the proposed injection wells. In addition to that well, three other dry holes within the AOR will be re-entered and converted to monitoring wells:
    - Artificial Penetration No 76 - Bass Keahey No.1 (SN165395) well, located approximately 13,730 feet northeast and up dip of the facility;
    - Artificial Penetration No. 101 - Southern Carbon USA No. 1 (SN34225) well, located approximately 37,850 feet east- southeast of the facility; and
    - Artificial Penetration No. 276 - Murphy Meredith No. 1 (SN23356) well, located approximately 28,150 feet east-southeast of the facility.

A new In-Zone Monitor Well ("M-1") will also be drilled to 7,000 feet and completed at a location immediately south of the surface location of Artificial Penetration No. 69 - Bradford-

Brown Trust Shipp No. 1 (SN137783) well, located approximately 10,152 feet north and up dip of the facility. Each well will be completed for monitoring across the entire Upper Tuscaloosa / Paluxy interval. At a minimum, each well will be fitted with a downhole pressure / temperature gauge (said gauge to be referenced to ground level). During each completion, native Upper Tuscaloosa / Paluxy formation brine will be sampled initially upon the completion of each monitoring well (with the brine analysis including the detection of dissolved and free gases) for baseline characterization purposes per LAC 43:XVII §3607 (C)(2)(e) and LCFS Protocol Subsection C.2.3(a)(9)(A). Note that such baseline sampling and analysis have already been completed in the Whitetail Operating, LLC, Louisiana Green Fuels #1 (SN975841) well.

These five In-Zone monitor wells will also provide direct measurement, when or if, the sequestered supercritical carbon dioxide plume ever reaches one of the monitoring well locations [per LAC 43:XVII §3626 (A)(7)(a) and LCFS Protocol Subsection C.2.5(b)(2)]. Should the monitoring wells detect the presence of encroaching supercritical carbon dioxide (either by a substantive change in downhole pressure and temperature or surface pressure and temperature), an adaptive fluid sampling program will be triggered in the affected well(s). Work will be conducted by a qualified vendor and the selected analytical laboratory will be compliant with the Louisiana Environmental Laboratory Accreditation Program[1]. Once carbon dioxide is detected at a monitoring well, it will either be plugged back and repurposed for ongoing indirect monitoring or will be permanently plugged.

Indirect Monitoring

- Indirect monitoring will be used to assess the performance of the Sequestration Complex to ensure that it is operating as intended. Indirect plume monitoring will be employed in the injection wells and the In-zone monitoring wells to define the location, extent, and thickness of the sequestered supercritical carbon dioxide. Pulsed neutron capture logs will be used to monitor carbon dioxide saturation at the injection wells and in the two Upper Tuscaloosa / Paluxy Primary Injection Zone Monitoring Wells once carbon dioxide is detected or otherwise determined to be in close proximity to the wells. Saturation logging

[1] https://deq.louisiana.gov/page/la-lab-accreditation

in the Upper Tuscaloosa / Paluxy Primary Injection Zone monitoring wells will aid in understanding the larger scale flow distribution in the Upper Tuscaloosa and Paluxy sequestration reservoirs away from the facility site.

The areal distribution of the carbon dioxide plume in the Upper Tuscaloosa / Paluxy Primary Injection Zone will be determined using time-lapse seismic techniques.

The displacement of brine by supercritical carbon dioxide within sandstone reservoirs, such as those of the Upper Tuscaloosa and Paluxy Formations, at similar project depths is well documented to produce a strong change in acoustic impedance (Vasco et al., 2019). Leading-edge techniques for time-lapse imaging of carbon dioxide plumes that were developed during the implementation of the Regional DOE Partnership projects include time-lapse vertical seismic profiling (Daley and Korneev, 2006; Gupta, et al., 2020), azimuthal vertical seismic profiling (Gordon, et al., 2016), and sparse array walk-away surveys or scalable, automated, semipermanent seismic array ("SASSA") surveys (Roach, et al., 2015; Burnison, et al., 2016; Livers, 2017; Adams, et al., 2020).

At a minimum, during the acquisition of walk-away vertical seismic profiling and sparse array walk-away surveys, the array of acoustic source sites will be oriented along the maximum and minimum orientations of the modeled expanding carbon dioxide plume and will be adjusted following a review of the results of each survey. Survey frequency will be dependent on the monitoring method chosen and reevaluated after each survey (adaptive program). It is expected that for walk-away vertical seismic profiling g and sparse array walk-away techniques, the survey frequency will be an initial baseline survey, followed by repeat surveys at the end of 1 year, 3 years, 5 years, and then every 5 years thereafter.

Above-Confining-Zone Monitoring Interval (ACZMI) Monitoring

- Above-Confining-Zone Monitoring Interval (ACZMI) monitoring will occur in four wells installed within the modeled sCO2 plume area. The ACZMI Monitoring zone for the sequestration project is the Annona Sandstone, a marine "blanket" sand that extends throughout the Area of Review. In-Zone Monitoring and Above-Confining-Zone Monitoring wells are expected to be engineered as dedicated single zone (i.e., either IZ or ACZMI) completions.

In the ACZMI Monitoring zone, each well will be fitted with real-time, continuously recording downhole pressure/temperature gauge (LCFS Protocol Subsection C.2.5(b)(2)). Gauges will be referenced to ground level at each well. Alternately, a "light" fluid column to allow monitoring and recording pressures at surface will be used. Native formation water in the Annona Sandstone will be sampled initially upon well construction (including for dissolved and free gases) for baseline characterization purposes (sampling and analyses have been completed in the Whitetail Operating, LLC, Louisiana Green Fuels #1) per LAC 43:XVII §3607 (C)(2)(e) and LCFS Protocol Subsection C.2.3(a)(9)(B). At a minimum, a native formation brine will be sampled initially (including for dissolved and free gases) for baseline characterization purposes in the repurposed Bradford-Brown Trust Shipp No. 1 (SN20131) and the cleaned out and repurposed Magnolia Petroleum Co. O.N. Reynolds No. 1 (SN57466) during recompletion operations, and in a proposed New ACZMI Drill Well to be located 150' north of the proposed Injection Well W-N2. In addition, when the sCO2 plume reaches the Whitetail Operating, LLC, Louisiana Green Fuels #1 (SN 975841) (initially completed as an In-Zone Monitoring Well), the well will be immediately plugged back and recompleted uphole as an Annon Sand ACZMI Well.

Substantive well-to-well changes in native brine composition are not expected in the ACZMI Monitoring zone. However, the ACZMI Zone Monitor wells will provide direct measurement if injectate movement out of Upper Tuscaloosa / Paluxy Injection Zone occurs. Should the monitor wells detect the presence of carbon dioxide (either by change in downhole pressure and temperature or surface pressure and temperature), an adaptive fluid sampling program will be triggered and initiated. Sampling work will be conducted by a qualified vendor and the selected analytical laboratory will be compliant with the Louisiana Environmental Laboratory Accreditation Program.

Underground Sources of Drinking Water Monitoring (USDW Monitoring)

- Aquifers in the area consist of the shallow Mississippi River Valley Alluvial (MRVA) Aquifer, the mid-depth Cook Mountain and Cockfield Aquifers, and the deeper Sparta Aquifer (another aquifer informally (and incorrectly) named the "Montgomery" aquifer in one water supply well is actually the MRVA Aquifer). Public drinking water supply in the area is supplied by the East Columbia Water District with supply from the MRVA, Cook

Mountain, and Cockfield Aquifers. In addition, while it is currently not used as a source of public drinking water, the Sparta Aquifer is used for agricultural and industrial purposes within the AoR and surrounding area. The Louisiana Department of Health routinely monitors these aquifers for constituents in the drinking water according to Federal and State laws. The Port of Columbia Facility will secure split samples from the municipal water wells when they are sampled by the East Columbia Water District. These samples will be used to establish the baseline per LAC 43:XVII §3607 (C)(2)(e) and LCFS Protocol Subsection C.2.5(b)&(c)&(d)&(e) and will be monitored on an ongoing basis for any indicated long-term changes in measured parameters.

Surface and Near-surface Monitoring

- Atmospheric monitoring across the AoR will be conducted utilizing a single, broad-range eddy covariance system and a portable gas meter to define natural background variability, including seasonal and diurnal trends, and to detect potential atmospheric carbon dioxide leakage and/or potential movement of carbon dioxide that may endanger the local USDW (LCFS Protocol Subsection C.4.3.2.2(a)). An ecosystem and land-use survey based on satellite imagery analysis and focused ground-based vegetation surveys will be conducted over the surface projection of the AoR and certain predetermined reference areas to establish background vegetative conditions at the surface and to measure potential vegetative stress resulting from substantially elevated carbon dioxide concentrations in the soil. Limited soil gas monitoring at up to 15 representative locations throughout the surface projection of the AoR will be conducted to define the baseline molecular and isotopic compositions of the shallow soil gas, characterize natural background variability, including seasonal and diurnal trends, and to serve as reference and comparison to operational soil gas monitoring, if needed, to assist in the detection, validation, and quantification of potential carbon dioxide leakage (LCFS Protocol Subsection C.4.3.2.2(b)).

2.1 QUALITY ASSURANCE PROCEDURES

A quality assurance and surveillance plan (QASP) for all testing and monitoring activities, required pursuant to §146.90(k), is provided in Appendix 1 – Quality Assurance and Surveillance Plan (QASP) to this Testing and Monitoring Plan.

2.2 MONITORING DETAILS

The Louisiana Green Fuels, Port of Columbia Facility will sample and record injection and monitoring operations using a SCADA (or similar) distributive control system. Operations will be monitored at a central Control Room and the data will be recorded in real-time. An archiver may be used to reduce the data stream size for longer term data storage. The distributive control system will consist of safe-set controls and alarms at values safely below regulatory requirements so that permit limits are not exceeded. All gauges and equipment will be calibrated per manufacture's specifications and calibration records will be maintained at the facility.

2.3 REPORTING PROCEDURES

The Louisiana Green Fuels, Port of Columbia Facility will report the results of all testing and monitoring activities to the Commissioner in compliance with the requirements under LAC 43:XVII §3629 and LCFS Protocol Subsection C. 1.1.3.

Table 1 is an overview of the frequency and monitoring for each monitoring activity identified within this Testing and Monitoring Plan for the Louisiana Green Fuels Port of Columbia Facility.

Table 1: Testing and Monitoring Reporting Overview

Parameters Monitored	Monitoring Program	Monitoring & Reporting Frequency [a]
Carbon Dioxide Stream Analysis [LAC 43:XVII §3625 (A)(1) & LCFS Subsection C. 4.3.1.1.]		
Chemical and Physical Composition of CO_2 Stream	Compositional analysis of the injected CO_2 stream using non-destructive chromatographic detector	Quarterly or as process changes or additional sources are included in the injection stream
Continuous Recording of Operational Procedures [LAC 43:XVII §3625 (A)(2) & LCFS Subsection C. 4.1(a)(2)]		
Injection Parameter Monitoring	Pressure and temperature gauge, mass flow meter with alarms for measurements outside of the normal operating conditions	Continuous monitoring. Summary monthly statistics prepared and reported quarterly
Annulus Pressure Monitoring	Annulus pressure gauge	

Parameters Monitored	Monitoring Program	Monitoring & Reporting Frequency [a]
	Annular Fluid Volume Measurements	
Corrosion Monitoring [LAC 43:XVII §3625 (A)(3) & LCFS Subsection C. 4.1(a)(3)]		
Coupon Testing	Flow-through corrosion coupon using injection well construction materials Utilize Corrosion inhibitors in all fluids during well workovers	Quarterly analysis during injection operations Additionally, as new sources are added to stream
In-Zone Tuscaloosa/Paluxy Monitoring – IZ Monitoring – 5 Wells		
Upper Tuscaloosa / Paluxy sands	Temperature, Pressure fluid analysis only if triggered by pressure or temperature signal	Continuous real time pressure monitoring Fluid samples on an as-needed basis
Upper Tuscaloosa / Paluxy sands	Water analysis (if triggered)	Quarterly analysis during injection operations Annual analysis during post-injection operations
Above Primary Upper Confining Zone Monitoring -AZMI (Annona Sand Monitoring) – 4 Wells LCFS Protocol Subsection C.2.5(b)(2)		
Annona Sand	Temperature, Pressure Fluid analysis only if triggered by pressure or temperature signal	Continuous real time pressure monitoring Fluid samples on an as-needed basis
Annona Sand	Water analysis	Quarterly analysis during injection operations Annual analysis during post-injection operations
USDW Monitoring – 2 Wells [LAC 43:XVII §3625 (A)(4)]		
USDW Monitoring Well (Public Water Supply)	Water analysis	Minimum quarterly analysis during injection operations Annual analysis during post-injection operations

Parameters Monitored	Monitoring Program	Monitoring & Reporting Frequency [a]
External Mechanical Integrity **[LAC 43:XVII §3625 (A)(5) and §3627 (A)(3) & LCFS Protocol Subsection C.4.2(a)&(b)]**		
Well Integrity	Annulus Pressure Tests, Radioactive Tracer Survey, Temperature Survey, OA Survey	Annually and after all well workover operations that change well configuration
Pressure Falloff Test **[LAC 43:XVII §3625 (A)(6) & LCFS Protocol Subsection C.2.3.1(i)(1)]**		
Reservoir transmissivity and pressure.	Pressure Falloff Test, Static and Flowing Bottomhole Pressure Tests	Baseline test after well completion Annual test, years 1 to 5; Every 5 years thereafter
CO2 Pressure and Plume Front **[LAC 43:XVII §3625 (A)(7) & LCFS Protocol Subsection C.4.1(a)(9)(A)]**		
Upper Tuscaloosa / Paluxy In-Zone Monitor Wells	Direct pressure monitoring	Continuous
Injection Wells Pulsed Neutron Logging Walk-Away Seismic Surveys (Performed at regular intervals)	Indirect Monitoring	Baseline, 1 year, 3 years, 5 years, and then every 5 years thereafter
Atmospheric Monitoring **[LAC 43:XVII §3625 (A)(8) & CARB LCFS Protocol Subsections C.2.5(c)(d) and C.4.3.2.2(d)(e)]**		
Atmosphere, continuous	Eddy Covariance Tower (fixed location): • CO_2, CH_4, H_2O, and N_2O concentrations; • Net CO_2 flux across ecosystem within tower footprint; • Wind direction and speed; • Soil conditions (i.e., moisture, temperature, and heat flux); • Net radiation across surface; • Meteorological conditions (i.e., relative humidity, barometric pressure, ambient temperature, and precipitation)	Continuous monitoring during baseline and injection
Atmosphere, intermittent	Landfill gas meter (variable locations): CO_2, O_2, and CH_4 concentrations	Baseline: monthly Injection: quarterly

Parameters Monitored	Monitoring Program	Monitoring & Reporting Frequency [a]
Ecosystem Stress Monitoring [CARB LCFS Protocol Subsections C.2.5(c)(d) and C.4.3.2.2(f)]		
Ecosystem Stress	Satellite Imagery (site-wide)	Baseline: Single analysis (3-year retrospective from baseline date) Onset of injection: annually
Soil Gas Monitoring [LAC 43:XVII §3625 (A)(8) & CARB LCFS Protocol Subsections C.2.5(c)(d) and C.4.3.2.2(g)]		
Soil Gas, intermittent	Soil gas probes (fixed locations) Molecular composition: CO_2, CH_4, N_2, and O_2 concentrations; C1-C5 hydrocarbons	Baseline: monthly Injection: quarterly
	Soil gas probes (fixed locations) Isotopic composition: $\delta^{13}C$ and C^{14} of CO_2 and CH_4; δD of CH_4	Baseline: quarterly Injection: quarterly

[a] *Data archiver may be used to reduce data streams*

3.0 CARBON DIOXIDE STREAM ANALYSIS

The Louisiana Green Fuels, Port of Columbia Facility will analyze the composite supercritical carbon dioxide stream during the operational period to derive data representative of its chemical and physical characteristics and to meet the requirements of LAC 43:XVII §3625 (A)(1) (State of Louisiana), and LCFS Protocol Subsection C.4.1(a)(1). A baseline sample of the carbon dioxide stream will be evaluated and tested prior to initiation of injection operations at the facility.

3.1 CARBON DIOXIDE SAMPLING LOCATION AND FREQUENCY

The injected carbon dioxide will be continuously monitored at the surface for pressure, temperature, and flow volumes. Sampling will be performed upstream or downstream of the flowmeter. Sampling procedures will follow protocols to ensure the sample is representative of the injected supercritical carbon dioxide stream.

The frequency of carbon dioxide sampling will be conducted on a quarterly basis commencing with the initiation of injection operations. This equates to a schedule as follows:

1. Sample No. 1: 3 months after start of injection
2. Sample No. 2: 6 months after start of injection
3. Sample No. 3: 9 months after start of injection
4. Sample No. 4: 12 months after start of injection

The schedule will then be repeated using this quarterly sample cycle. When known changes to the injected stream occur (*i.e.,* source changes and/or additions/deletions to the existing stream), sampling will also be performed for verification of the chemical and physical properties of the modified stream. This will determine if there are changes to the stream that need to be accounted for and tested to update and compare to the baseline conditions. The proposed sample frequency is sufficient to characterize the carbon dioxide stream and account for any potential changes to representative data.

Changes in density measurements at the mass flow meter deemed greater than normal variability and not correlated to thermal variations also will trigger sampling of the injection stream. The isotopic composition of carbon in CO_2 ($\delta C^{12}/C^{13}$) ratio and C^{14} will be measured for baseline characteristics and such measurements will be repeated only if new sources are later added.

3.2 CARBON DIOXIDE ANALYTICAL PARAMETERS

The Louisiana Green Fuels, Port of Columbia Facility will contract a vendor to analyze the carbon dioxide for the constituents identified in Table 2 using the methods listed (or equivalent). If the constituents are not found in initial analysis or are screened out at the source prior to injection, this will be documented and with the prior approval of the Commissioner, they will be removed from the list of analytical parameters.

Table 2: Summary of analytical parameters for CO_2 stream.

Parameter	Analytical Method(s)[1]
Carbon Dioxide (CO_2)	ISBT[2] 2.0 Caustic absorption Zahm-Nagel ALI method SAM 4.1 subtraction method (GC/DID) GC/TCD
Oxygen (O_2)	ISBT 4.0 (GC/DID) GC/TCD
Nitrogen (N_2)	ISBT 4.0 (GC/DID) GC/TCD
Hydrogen Sulfide (H_2S)	ISBT 14.0 (GC/SCD)
Sulfur Dioxide (SO_2)	ISBT 10.1 (GC/FID)
Methane (CH_4)	ISBT 10.1 (GC/FID)
Total hydrocarbons (C_2H_6, C_3H_8+)	ISBT 10.0 THA (FID)
Hydrogen (H_2)	ISBT 4.0 (GC/DID) GC/TCD
Carbon Monoxide (CO)	ISBT 5.0 Colorimetric ISBT 4.0 (GC/DID)
Nitrogen Oxides (any (NO_x)	ISBT 7.0 Colorimetric
Carbon isotopic composition δC^{13} and C^{14}	Measured once and when a significant new source is added; used for attribution during monitoring

Note 1: *An equivalent method may be employed with the prior approval of the Commissioner, such as ASTM Standards*

Note 2. *International Society of Beverage Technologists (ISBT) Carbon Dioxide Guidelines MBAA TQ vol. 39, no. 1, 2002, pp. 32-35 as cited in ISO/TR 27921:2020(en). Carbon dioxide capture, transportation, and geological storage — Cross Cutting Issues — CO_2 stream composition*

3.3 CARBON DIOXIDE SAMPLING METHODS

Sampling will be performed from a tap located upstream or downstream of the flowmeter and will follow protocols to ensure the sample is representative of the injected carbon dioxide stream. Sample collection procedures will be provided in detail by a certified laboratory vendor to be determined prior to injection authorization. Sampling methods and equipment will meet the standards and limits provided within the attached QASP.

3.4 CARBON DIOXIDE ANALYSIS PROCEDURES AND CHAIN OF CUSTODY

Samples will be analyzed by a third party laboratory accredited by the Louisiana Department of Environmental Quality (https://internet.deq.louisiana.gov/portal/divisions/lelap/accredited-laboratories) using standardized procedures for gas chromatography, mass spectrometry, detector tubes, and photo ionization. Detection limits will be dependent on equipment facilitated for the analytical methods by the selected qualified vendor. However, all vendors will meet the minimum levels set forth in the QASP (Appendix 1).

The sample chain-of-custody procedures will be dependent on vendor selection as the vendor will assume custody of the samples. The procedures will document and track the sample transfer to the laboratory, the analyst, to testing, to storage, to disposal (at a minimum). A sample chain of custody procedures is contained in the QASP (Appendix 1).

A semi-annual report to the Louisiana Commissioner and the United States Environmental Protection Agency (USEPA) will contain any changes to the physical, chemical, or any other relevant parameters of the injected stream (CO_2) per 43:XVII §3629 (A)(1)(a)(i).

4.0 CONTINUOUS RECORDING OF OPERATIONAL PROCEDURES

The Louisiana Green Fuels, Port of Columbia Facility will install and use continuous recording devices to monitor injection pressure, injection rate (mass flow), and volume; the pressure on the annulus between the tubing and the long string casing; the annulus fluid volume added; and the temperature of the carbon dioxide stream, as required by the State of Louisiana Guidance LAC 43:XVII §3625, §3621.A.6.a, 3627.A.2, and 3625.A.2 and LCFS Protocol Subsection C.4.1(a)(2) and LCFS Protocol Subsection C.4.3.1.2.

Injection rates and pressures will be set by permit. All aspects of the injection processes will be monitored, recorded, and if necessary, shut down in the event of a detected exceedance. Surface pressure and temperature will be measured continuously. The volume will be determined from a mass flow meter installed on the injection supply line.

During periods of approved workovers by the commission, continuous monitoring is not required [§3625 (A)(2) and §3621 (A)(5)].

4.1 MONITORING LOCATION AND FREQUENCY

The Louisiana Green Fuels, Port of Columbia Facility will perform the activities identified in Table 3 to monitor operational parameters and to verify internal mechanical integrity of the injection well. All monitoring will take place at the locations and frequencies shown in Table 3.

Table 3: Sampling devices, locations, and frequencies for continuous monitoring

Parameter	Device(s)	Location	Min. Sampling[1] Frequency	Min. Recording[2] Frequency
Injection Pressure (surface)	Pressure Gauge	Wellhead/Flowline	1 minute	30 minutes
Injection Pressure (downhole)	Quartz Pressure Gauge	Near Perforations	1 minute	30 minutes
Injection Rate	Mass Flow Meter/Computer	Flowline	1 minute	30 minutes
Injection Volume	Mass Flow Meter/Computer	Flowline	1 minute	30 minutes
Annulus Pressure	Pressure Gauge	Wellhead	1 minute	30 minutes

Parameter	Device(s)	Location	Min. Sampling[1] Frequency	Min. Recording[2] Frequency
Annulus Fluid Volume	Fluid Level Measure	Annulus Tank	1 minute	Daily
CO_2 Stream Temperature	Mass Flow Meter/Computer	Wellhead/Flowline	1 minute	30 minutes
Downhole Temperature	Temperature Gauge	Near Perforations	1 minute	30 minutes
If Deployed on Injection Wells				
Changes in *Rayleigh* Scattering resulting from distributed strain, indicative of wave arrival	DAS optical fiber	Installed on outside of casing	As designed for acoustic survey	As designed for acoustic survey
Changes in *Rayleigh* Scattering indicative of temperature change	DAS optical fiber	Installed on outside of casing	Hourly	Daily

[1] Sampling frequency refers to how often the monitoring device obtains data from the well for a particular parameter. For example, a recording device might sample a pressure transducer monitoring injection pressure once every two seconds and save this value in memory.

[2] Recording frequency refers to how often the sampled information gets recorded to digital format (such as a computer hard drive). For example, the data from the injection pressure transducer might be recorded to a hard drive once every minute. Note that a data archiver may be used to reduce data stream size for long-term data storage.

Continuously recorded injection parameters will be reviewed and interpreted on a regular basis to evaluate the injection stream parameters against permit requirements. Trend analysis will also help evaluate the performance (*e.g.,* drift) of the instruments, suggesting the need for maintenance or calibration. Continuous recording devices will function with digital recording and be comprised of weatherproof material or otherwise housed in weatherproof enclosures in areas of exposed environmental conditions [§3621 (A)(6)(b)].

Basic calibration standards, precision, formulas, conversion factors, and tolerances for measuring devices and analysis are included in the attached QASP but will be dependent on specific qualified vendor selection. Calibrations will be made according to manufacturers' specifications and frequency.

4.2 MONITORING DETAILS

For each of the parameters that are required to be continuously monitored, such as injection pressure, injection rate, injection volume, annular pressure, annulus fluid volume, and carbon dioxide stream temperature, these parameters will be monitored and recorded using a SCADA distributive control system (DCS) or similar equipment. Results of the monitoring activities will be submitted in a semi-annual report for each of the following parameters:

- Monthly average, maximum, and minimum values for injection pressure, flow rate, and volume [§3629 (A)(1)(a)(ii)].
- Monthly average, maximum, and minimum values for annulus pressure [§3629 (A)(1)(a)(ii)].
- A description of any event that exceeds operating parameters for annular pressure or injection pressure specified in the permit, in compliance with [§3629 (A)(1)(a)(iii)].
- A description of any event that triggers a shut-off device required pursuant to [§3629 (A)(1)(a)(iv)] and the response taken.
- The monthly volume and/or mass of the carbon dioxide stream injected over the reporting period and volume injected cumulatively over the life of the project [§3629 (A)(1)(a)(v)] and LCFS Protocol Subsection C.4.3.1.2.
- Monthly annulus fluid volume added or gained [§3629 (A)(1)(a)(vi)].
- Raw data from the continuous monitoring devices in digital format [§3629 (A)(1)(a)(viii)].

Automatic alarm and automatic shutoff systems will be designed and installed to trigger an audible alarm in the event that pressures, flow rates, or other parameters designated by the Commissioner exceed a range or gradient specified in the injection permit per LAC 43:XVII §3621 (A)(7)(a). Strategic Biofuels will test all critical systems, including alarms and testing of the shutdown systems and validating the response times every six months. The testing of the systems will be documented and available for inspection by an agent of the Officer of Conservation per §3621 (A)(7)(c).

If an alarm or shutdown is triggered, Strategic Biofuels will immediately investigate and identify the cause of the alarm or shutoff and said alarm event will be reported to the Commissioner within 24 hours per §3629 (A)(7)(c)(iii). Please see the Emergency and Remedial Response Plan [LAC 43:XVII §3623] for details on additional individual responses base upon such potential events.

4.2.1 Injection Rate, Volume, and Pressure Monitoring

Injection rates, volumes, and pressures will be set and limited to safe operating values below those specified in the authorized permit. All gauges, pressure sensing devices, and recording devices will be tested and calibrated as specified by the manufacturer. Test and calibration records will be maintained at the facility. All instruments will be housed in weatherproof enclosures, where appropriate, to limit damage from outside elements and events [§3621 (A)(6)(b)]. The flow meters and pressure gauges will continuously record data that will be sent to a distributive control system.

Downhole flowing pressures into the reservoir will be monitored by a gauge installed near the perforations in each of the injection wells (LCFS Protocol Subsection C.4.3.1.3(a)). Gauges will be referenced to ground level at each well. Downhole pressure monitoring will protect the Injection Zone against over-injection as the density of the injected carbon dioxide increases. If retrievable gauges are used, such pressure gauges will be periodically calibrated according to manufacturer's instructions and corrected for drift. If permanent (unretrievable) downhole gauges are used, those gauges will be calibrated by comparison to a wireline deployed gauge run to the same depth in concert with mechanical integrity testing events. Static gradient stops will be made with the wireline deployed gauge to verify fluid column density for pressure-to-depth corrections. Downhole pressure gauge data will provide real-time information for verification of model predictions and periodic AoR reevaluations.

4.2.2 Annulus System Monitoring

The annulus system will maintain a positive pressure on the tubing by casing annulus in excess of the tubing pressure [§3621 (A)(4)]. Standard operating procedures identify this as being at least 100 psi over the tubing pressure. This will prevent fluid movement from the tubing out into the casing, which in turn will prevent the possible contamination of uphole freshwater sands in the event of a well casing or injection tubing failure.

The integrity of the well's annulus system is achieved by the monitoring of the annulus system at the wellhead. Annulus monitoring equipment used for each injection well includes an annulus tank, an annulus pump (small volume/high pressure), well flow meters, pressure monitoring cells, and pressure control valves. Alternate annulus construction may use a pressurized nitrogen system to maintain a constant pressure on the annulus [LCFS Protocol Subsection C.4.3.1.3(f)]. Annulus pressures will be monitored continuously. Substantive deviations from expected changes could indicate a potential loss of mechanical integrity in the well annulus system. Such observed deviations will trigger a well shutdown and investigation to determine the root cause of the observed deviation. Details are contained in the Emergency and Remedial Response Plan [LAC 43:XVII §3623] in Module E.

Annulus brine tank fluid levels (and volumes) will be monitored for indications of system losses/gains and recorded daily.

5.0 CORROSION MONITORING

Per requirements of LAC 43:XVII §3625.A.3 and LCFS Protocol Subsection C.4.1(a)(3), the Louisiana Green Fuels, Port of Columbia Facility will monitor material in the well that may come into contact with the injectate during the operational period. This will be accomplished by using corrosion coupons of well construction materials, which will be monitored for loss of mass and thickness, and will be visually inspected for evidence of cracking, pitting, and other signs of corrosion. This testing will ensure that the well components meet the minimum standards for material strength and performance. The coupon monitoring program is described in the following sections.

5.1 MONITORING LOCATION AND FREQUENCY

Coupon samples of the well construction materials (well casing, tubing and any other well parts in contact with carbon dioxide such as the packer and wellhead) will be mounted in a tray located in the common flowline to the injection wells, upstream of the flow distribution header. The tray of coupons will be in contact with the carbon dioxide stream during all injection operations. This will ensure that the tray location will provide representative exposure of the samples to the carbon dioxide composition, temperature, and pressures that will be seen at the wellhead and injection tubing. The holders and location of the system will be included in the pipeline design and will allow for continuation of injection during sample removal for testing.

The frequency of corrosion coupon collection and testing will be conducted on a quarterly basis per §3625 (A)(3). Baseline measurements on all coupon samples will be made prior to the initiation of carbon dioxide injection. Commencing with the initiation of injection operations, the initial monitoring event will occur at the end of the first calendar quarter (even if the end of the first calendar quarter occurs in less than 3 months). Subsequent monitoring will occur at the end of each calendar quarter. This equates to a schedule as follows:

1. March 31 – End of Calendar 1st Quarter
2. June 30 – End of Calendar 2nd Quarter
3. September 31 – End of Calendar 3rd Quarter
4. December 31 – End of Calendar 4th Quarter

The schedule will then be repeated using this quarterly sample cycle for the lifetime of the injection operations. Coupon compositions and details will be specified as part of conveyance pipeline and final well design.

5.2 SAMPLE DESCRIPTION

The Louisiana Green Fuels, Port of Columbia Facility is proposing that a corrosion coupon (weight loss) technique will be used for monitoring purposes, as it is the best known and simplest of all corrosion monitoring techniques (the alternative is to use flow line loops). The corrosion monitoring system will be located downstream of all process compression/dehydration/pumping equipment (*i.e.,* at the beginning of the flow distribution header to the injection wells). This will allow for monitoring at a single location for each of the operating injection wells. Corrosion coupons representative of the well construction materials (Table 4) will be inspected, photographed, and weighed prior to placement into the flowline establish a baseline. Prior to installation of the corrosion monitoring system, the following information will be recorded:

1. Coupon Serial Number;
2. Installation date;
3. Identification of the location of the system; and
4. Orientation of the coupon holder.

The coupon method involves exposing a specimen sample of material (the coupon) to a process environment for a given duration, then removing the specimen for analysis. The Corrosion Monitoring Plan will be implemented following initial installation of the test coupons in the flowline, as follows:

- Consult maintenance schedule to determine when to remove test coupons from corrosion monitoring holders (coincident with end of calendar quarter);
- Remove and inspect coupons on a calendar quarterly basis and quantitatively evaluate for corrosion according to ASTM G1 – 03 (2017) or NACE Standard RP0775-2005 Item No. 21017 standards guidelines;
- Place coupons in proper receptacle for safe transport to measurement and weighing

equipment;

- Photograph each coupon as received. Visually inspect each corrosion coupon for any pitting, stress corrosion cracking or scale buildup. Analyze corrosion coupons by weighing each coupon (to nearest 0.0001 gm) and measuring length, width and height of the coupon (to nearest 0.0001 inch);
- Record information for each coupon including date of measurement, coupon identity (coupon number and metal grade) and coupon weight in grams, and include any observations of excessive weight loss or pitting, stress corrosion cracking or scale buildup;
- Determine if the current corrosion coupon can be returned to the monitoring test holder; if so, make a note of coupon return; or if not returnable, record installation of a new coupon.

Baseline coupons, which are pristine coupons not exposed to such environments, will be initially inspected visually and photographed and weighed prior to insertion into the test loop. The quarterly coupon weight will then be measured against the initial (pristine) condition of the coupons.

Table 4: List of equipment coupon with material of construction

Equipment Coupon	**Material of Construction**
Surface Piping	“as built” material in contact with CO_2
Wellhead	Chrome 22, or “as built” trim material in contact with CO_2
Injection Tubing	Chrome 22 material, which is in contact with CO_2
Packer	Chrome 22 trim material, which is in contact with CO_2

Please note: the current proposed well design includes 22CR65 injection tubing and packer assemblies. The final wellhead material and surface piping specifications are still in final design. Once the materials of construction for these items are known, Table 4 will be updated, and the corresponding corrosion coupons will become part of the test loop.

Samples will be collected by trained and authorized personnel and submitted to a third-party analytical laboratory for analysis. Results of the analysis will be compared to the pre-project baseline of the coupons. Basic details regarding the laboratory analysis are explained in the attached QASP, however, specific details will be provided and updated by the selected corrosion laboratory vendor. Results will be submitted through the GSDT semi-annual reporting tool. The

Commissioner will independently assess the results of the corrosion monitoring to assess the integrity of the injection well.

5.3 ALTERNATIVE TESTS

Per §3625 (A)(3)(c) and LCFS Protocol Subsection C.4.3.1.4, the Louisiana Green Fuels, Port of Columbia Facility, with approval from the commissioner, may also run a casing inspection log(s) to determine the presence or absence of corrosion in the protection casing whenever the tubing is pulled from the well, or at the request of the Commissioner. Proposed casing inspection logs may include multi-finger caliper, ultrasonic imaging, magnetic flux leakage, and electromagnetic imaging tools as they are industry standard for determining casing thickness and identifying internal and external corrosion. Such log(s) will then be compared to those run during the initial construction of the well [§3617 (B)(1)(d)(iv)]. An additional inspection logging program may be implemented should any coupons exhibit undue corrosion in excess of the design-life criteria.

Alternative testing other than those listed above may be conducted with the written approval of the Commissioner. To obtain approval for alternative testing, the Louisiana Green Fuels, Port of Columbia Facility will submit a written request to the Commissioner setting forth the proposed test and all technical data supporting its use ahead of any proposed testing.

6.0 IN-ZONE (IZMI) MONITORING – UPPER TUSCALOOSA / PALUXY FORMATIONS

The Louisiana Green Fuels, Port of Columbia Facility will monitor pressure and temperature in the Upper Tuscaloosa / Paluxy Primary Injection Zone during the operation period (Figures 1 and 2). The Upper Tuscaloosa / Paluxy Primary Injection Zone will be monitored at the Whitetail Operating, LLC, Louisiana Green Fuels #1 stratigraphic test well (SN 975841), located 5,273 feet southeast of the injection wells. The Primary Injection Zone will also be monitored at several other abandoned oil and gas wells (dry holes) that well be re-entered and repurposed, including:

- A new In-Zone monitoring well drilled adjacent to the Artificial Penetration No. 69 - Bradford-Brown Trust Shipp No. 1 (SN137783) well, which is located approximately 10,152 feet north and updip of the facility;
- Artificial Penetration No. 76 - Bass Keahey No.1 (SN165395) well, located approximately 13,730 feet northeast and updip of the facility;
- Artificial Penetration No. 101 - Southern Carbon USA No. 1 (SN34225) well, located approximately 37,850 feet east- southeast of the facility; and
- Artificial Penetration No. 276 - Murphy Meredith No. 1 (SN23356) well, located approximately 28,150 feet south-southeast of the facility.

Each of these offset wells will be re-entered and completed as In-Zone monitoring wells prior to initiating the sequestration of supercritical carbon dioxide. This will allow the Port of Columbia Facility to obtain background / baseline data from the wells per LAC 43:XVII §3607 (C)(2)(e).

6.1 UPPER TUSCALOOSA / PALUXY FORMATIONS – DIRECT MONITORING

The Port of Columbia Facility will perform direct monitoring of the advancing supercritical carbon dioxide plume with the five in-zone monitor wells:

1) Whitetail Operating, LLC, Louisiana Green Fuels #1 stratigraphic test well (SN975841), located 5,273 feet southeast and down dip of the injection wells, and

2) A new In-Zone monitoring well drilled adjacent to the Bradford-Brown Trust Shipp No. 1 (SN137783) well, located approximately 10,152 feet north and updip of the facility;
3) Bass Keahey No.1 (SN165395) well, located approximately 13,730 feet northeast and updip of the facility;
4) Southern Carbon USA No. 1 (SN34225) well, located approximately 37,850 feet east-southeast of the facility; and
5) Murphy Meredith No. 1 (SN23356) well, located approximately 28,150 feet south-southeast of the facility.

The locations of these monitor wells will constrain the maximum plume dimensions until the advancing supercritical carbon dioxide plume intersects one of the wells.

6.1.1 Monitoring Location and Frequency

Direct monitoring will be conducted at the Whitetail Operating, LLC, Louisiana Green Fuels #1 stratigraphic test well, located 5,273 feet southeast and down dip of the facility, at one new In-Zone well drilled adjacent to the Shipp wellm and at three repurposed abandoned oil and gas test wells (dry holes; Figure 2). Table 5 shows the planned monitoring methods, locations, and frequencies for formation water quality and geochemical monitoring within the Upper Tuscaloosa / Paluxy Injection Zone.

Modeling shows that changes in sequestration reservoir pressure represent a robust diagnostic detection method that can be employed in the monitoring of deep confined sequestration reservoirs. Under typical flow gradients in brine-filled formations, the elevated brine pressure "front" will propagate outward farther from the injection point than the sequestered carbon dioxide plume (see Module B). The Louisiana Green Fuels, Port of Columbia Facility will measure and continuously record bottomhole pressure / temperature in at least two proposed In-zone monitoring wells (LCFS Subsection C.4.3.2.1(d)). Pressure / temperature monitoring will detect changes in either parameter that can be used as a trigger to initiate fluid sampling as the expanding pressure front and sequestered supercritical carbon dioxide plume approaches a monitor well.

Table 5: Monitoring in the Upper Tuscaloosa / Paluxy Injection Zone.

Target Formation	Monitoring Activity	Monitoring Location(s)	Spatial Coverage	Frequency
Upper Tuscaloosa / Paluxy	Downhole pressure monitoring	Injection Wells	Well Field	Real time daily read out
Upper Tuscaloosa / Paluxy	Pulsed Neutron Logging	Injection Wells	Well Field	Baseline log at prior to project start
	Pulsed Neutron Logging	Injection Wells	Well Field	Repeat surveys if anomaly is observed
Upper Tuscaloosa / Paluxy	Downhole pressure monitoring	2 offset Monitoring Wells	Over area of review	Real time daily read out
Upper Tuscaloosa / Paluxy	Pulsed Neutron Logging	2 offset Monitoring Wells	Over area of review	Baseline log at prior to project start
	Pulsed Neutron Logging	2 offset Monitoring Wells	Over area of review	Repeat Surveys if anomaly is observed, adaptive thereafter
Upper Tuscaloosa / Paluxy	Baseline geochemical sampling	2 offset Monitoring Wells	Over area of review	Baseline Sample at prior to project start
	Follow-up Geochemical testing if signal is observed	2 offset Monitoring Wells	Over area of review	Repeat sampling if anomaly is observed
Upper Tuscaloosa / Paluxy	Repeat seismic method designed for plume tracking, also detect any fluid above interval	Injection Wells and potentially at Monitor Wells	Azimuthal coverage of the plumes	Baseline, 1 year, 3 years, 5 years, and then every 5 years thereafter

The goal of monitoring in the Upper Tuscaloosa / Paluxy Primary Injection Zone is to constrain the geometry and ascertain the size of the advancing supercritical carbon dioxide plume. These monitor points provide site-specific and immediate data on the presence of injected carbon dioxide in the subsurface. An initial baseline geochemical analysis of the formation fluids will be performed prior to injection operations at the facility per LAC 43:XVII §3607 (C)(2)(e) and the

LCFS Protocol Subsection C.2.3(a)(9)(A).

If an increase in pressure is detected in the monitoring well pressure gauges, this will trigger conditional, adaptive geochemical sampling of the formation fluids as this increase in pressure is expected to be attributable to the imminent arrival of the sequestered carbon dioxide plume. The collected samples will be sealed, dated, and sent to an authorized third-party laboratory for analysis. Sampling will only occur if pressure changes are detected, either downhole or at the wellhead. The frequency of geochemical sampling will be conducted on an "as needed" basis if the pressure signal triggers additional testing.

6.1.2 Analytical Procedures

An initial baseline fluid sample will be collected from the Upper Tuscaloosa / Paluxy Injection Zone during completion and well development activities in the monitor wells prior to injection operations. These fluid samples will provide the baseline measurements for formation fluids and document any spatial variability. Table 6 identifies the parameters to be monitored and the analytical methods the Louisiana Green Fuels, Port of Columbia Facility will use.

Table 6: Summary of analytical and field parameters for ground water samples – Tuscaloosa/Paluxy Injection Zone

Parameters	Analytical Methods
Dissolved CO_2 gas by headspace	Gas Chromatography (GC)
Dissolved CH_4 gas by headspace	Gas Chromatography (GC)
Hydrocarbons	Gas Chromatography (GC)
Dissolved inorganic carbon	Combustion
Bicarbonate	Titration
δD CH_{24}	Gas chromatography combustion isotope ratio mass spectrometry (GC/C/IRMS)
δC^{13} CO_2	Gas chromatography combustion isotope ratio mass spectrometry (GC/C/IRMS)
δC^{13} CH_4	Gas chromatography combustion isotope ratio mass spectrometry (GC/C/IRMS)
C^{14} CO_2	Accelerated mass spectrometry (AMS).
C^{14} Methane	Accelerated mass spectrometry (AMS).
Isotopic composition of selected major or minor constituents (*e.g.*, Sr $^{87/86,}$ S)	Multicollector-Inductively Coupled Plasma Mass Spectrometer (MC-ICPMS)

Parameters	Analytical Methods
Cations: Al, As, B, Ba, Ca, Cd, Cr, Cu, Fe, K, Mg, Mn, Na, Pb, Sb, Se, Si, Ti, Zn,	ICP-MS or ICP-OES, ASTM D5673, EPA 200.8 Ion Chromatography, EPA Method 200.8, ASTM 6919
Anions: Br, Cl, F, NO_3, SO_4,	Ion Chromatography, EPA Method 300.8, ASTM 4327
Total Dissolved Solids	EPA 160.1, ASTMN D5907-10
Alkalinity	EPA 310.1
pH (field)	EPA Method 150.1
Specific Conductance (field)	EPA 120.1, ASTM 1125
Temperature (field)	Thermocouple
Hardness	ASTM D1126
Turbidity	EPA 180.1
Specific Gravity	Modified ASTM 4052
Density	Modified ASTM 4052

The initial parameters identified in Table 6 may be revised and include additional components for testing dependent on the initial geochemical evaluation. The fluid samples will be sent to a third-party laboratory accredited by the Louisiana Department of Environmental Quality (https://internet.deq.louisiana.gov/portal/divisions/lelap/accredited-laboratories) for analysis.

6.1.3 Sampling Methods

The sampling system used to sample and quantify free and dissolved gases and the aqueous phases in equilibrium with these gases will be supplied by a third-party vendor (Schlumberger, Expro, or equivalent vendor using downhole PVT sampler or equivalent tool). Note that most deep sampling is designed for hydrocarbons; this testing should focus on all gases and formation fluids. Downhole samples are preferred; however, surface samples may be collected for expediency.

The following sampling protocol would be to first purge the casing volume to sample fresh fluids that have not reacted with casing and tubing to the sample point within the wellbore. Deploy commercial downhole sampler on slickline to collect a fluid sample at pressure and then close the sampler to retain the gas phases as the sample is retrieved. Conserve gas volumes as samples are stepped to atmospheric pressure for shipping and analysis. Filter and conserve samples following protocols for brine sampling. All sample containers will be labeled with durable labels and indelible markings. A unique sample identification number and sampling date will be recorded on the sample containers, which will then be sealed and sent to an authorized third-party laboratory.

Repeat sampling and frequency (adaptive program) will be determined based on analysis results.

6.1.4 Analysis Procedures and Chain of Custody

Samples will be analyzed by a third party laboratory accredited by the Louisiana Department of Environmental Quality (https://internet.deq.louisiana.gov/portal/divisions/lelap/accredited-laboratories) using standardized procedures for gas, major, minor and trace element compositions. Detection limits will be dependent on equipment used for the analytical methods by the selected qualified vendor and meet the minimum levels set forth in the QASP.

The sample chain-of-custody procedures will be dependent on vendor selection as the vendor will assume custody of the samples. These procedures will document and track the sample transfer to laboratory, to the analyst, to testing, to storage, to disposal (at a minimum). A sample chain of custody procedures is illustrated in Appendix 1. If significant differences in geochemistry between the two monitor wells are observed, each well may be resampled to ensure validity of the baseline analyses.

The initial parameters identified in Table 6 may be revised and include additional components for testing dependent on the initial geochemical evaluation.

6.2 UPPER TUSCALOOSA / PALUXY FORMATIONS – INDIRECT MONITORING

Indirect plume monitoring will be employed in the Injection Wells and the In-Zone monitoring wells to define the location, extent, and thickness of the injected supercritical carbon dioxide plume (LCFS Subsection C.4.3.2.1). Pulsed neutron capture logs will be used to monitor carbon dioxide saturation at the injection wells (qualitative flow distribution) and in the Upper Tuscaloosa / Paluxy Injection Zone monitoring wells once carbon dioxide is detected. Saturation logging within the Upper Tuscaloosa / Paluxy Primary Injection Zone monitoring wells will aid in understanding the flow distribution away from the Port of Columbia Facility injection wells.

The areal distribution of the carbon dioxide plume in the Upper Tuscaloosa / Paluxy Primary Injection Zone will be determined using time-lapse seismic techniques (LCFS Subsection

C.4.3.2.1(c)). The displacement of brine by injected carbon dioxide within sandstones such as the those of the Upper Tuscaloosa and Paluxy Formations, at similar project depths, is well documented to produce a strong negative change in acoustic impedance Vasco et al., 2019). This change in impedance can be detected by many time-lapse seismic methods. Leading-edge techniques for time-lapse imaging of carbon dioxide plumes include time-lapse vertical seismic profiling (Daley and Korneev, 2006; Gupta, et al., 2020), azimuthal vertical seismic profiling (Gordon, et al., 2016), sparse array walk-away surveys or scalable, automated, semipermanent seismic array (SASSA) surveys (Roach, et al., 2015; Burnison, et al., 2016; Livers, 2017; Adams, et al., 2020). These techniques are expected to be robust in monitoring plume growth and less invasive from a surface footprint. At a minimum, the array of acoustic source sites will be oriented along the maximum and minimum orientations of the modeled plume and will be adjusted following each survey results. Frequency will be dependent on the monitoring method chosen. For time-lapse profiling and sparse array walk-away techniques, intervals will be 1 year, 3 years, 5 years, and then every 5 years thereafter. For SASSA surveys, the episodic data to be collected from the array can be obtained using an adaptive monitoring strategy (Burnison, et al., 2016; Livers, 2017; Adams, et al., 2020).

For the vertical seismic profile array type monitoring, distributed acoustic sensing (DAS) fiber may be installed on the injection wells. These fiber cables will be contained within the cement behind the long string casing, sending signal to a surface interrogator to detect acoustic signal. Signals will be produced by radial distribution of well-coupled cement filled pad locations (*e.g.*, a permanent, excavated pit filled with cement). Sources will either be permanently bolted units or intermittently attached during monitoring data collection events. The following considerations will lead to selection of the specific method for plume tracking:

1) Cost-effective and low environmental-footprint monitoring methods are favored over more expensive, larger environmental-footprint methods.
2) Methods with quicker turnaround time to deliver results from data collection to processing are favored over methods that require more robust acquisition and processing, and thus a much longer turnaround time.
3) The anticipated radial geometry and extent of the injected CO_2 plume with time.

4) The presence of wetlands (if any) in the area may preclude the use of numerous source locations on grounds of poor access and the risk of excessive environmental damage during data acquisition. Temporal changes in surface culture could affect surface source distribution, damaging repeatability.
5) Permanent installations for acoustic sources optimize repeatability, which is critical in time-lapse tracking.
6) The availability and demonstrated effectiveness of DAS fiber as an acoustic receiver favors this type of installation.
7) The same arrays will also be used during the PISC period.

Vendors will be contracted to design the area and processing flow, install the DAS fiber, supply interrogators(s) for both temperature and acoustic signals; design the source arrays including frequency and coupling to assure good signal-to-noise to detect impedance contrast at depth and thickness modeled; and conduct data analysis. Results from azimuthal VSPs will be used to track carbon dioxide migration along selected azimuths. These measurements can be plotted against equivalent model outputs and used to validate or correct as needed the fluid flow model and plume tracking predictions to satisfy the requirements of LAC 43:XVII §3625 (A)(7).

In addition, the use of DAS fiber, if deployed, will allow for a wide aperture of the acoustic array and will include surveillance of strata above the sequestered carbon dioxide plume. This will provide further assurance that no out-of-zone migration is occurring within the monitored area.

7.0 ABOVE-CONFINING-ZONE (ACZMI) MONITORING – ANNONA SAND

The Louisiana Green Fuels, Port of Columbia Facility will monitor pressure and temperature in the Annona Sand, located above the Upper Tuscaloosa / Paluxy Primary Injection Zone during the operation period. This will allow for early detection of any out-of-zone movement of either carbon dioxide or intraformational fluids above the Upper Tuscaloosa / Paluxy Primary Injection Zone. The Annona Sand is a blanket marine sand within the area of the injected carbon dioxide plume and the AoR. Monitoring the Annona Sand will thus allow for the monitoring of pressure over a large area. As shown in the injection/falloff test conducted in the Whitetail Operating, LLC, Louisiana Green Fuels #1 stratigraphic test well, the Annona Sand has relatively high permeability (56 millidarcies) that will facilitate the transmission of a pressure signal should carbon dioxide or other injectates start to flow into it.

Above confining zone monitoring will be conducted initially in three dedicated ACZMI wells, each located in an important sector of the modeled sCO_2 plume. These three dedicated ACZMI wells are:

1. Bradford-Brown Trust Shipp No. 1 (AP #69; SN137738) – this legacy dry hole will be re-entered, cleaned out, plugged back to 3,900', cased, and completed in the Annona Sand. The Shipp well is well-positioned in the northwest coalesced plume area to monitor any potential leakage moving up structure from injection well W-N1.
2. Magnolia Petroleum Co. O.N. Reynolds No. 1-S (AP #129; SN57466) – this legacy dry hole will be re-entered, cleaned out, deepened to 4,200', cased, and completed in the Annona Sand. The Reynolds well is well-positioned in the central coalesced plume area to monitor any potential leakage moving up structure from injection well W-S2 (or expanding east or west from injection wells W-N1 and W-N2).
3. New ACZMI Well – will be drilled to 4,200' approximately 150 feet north of the proposed injection well W-N2, cased, and completed in the Annona Sand. This New ACZMI Well will be well-positioned in the northeast coalesced plume area to monitor any potential leakage moving up structure from injection well W-N2.

In addition, the Annona Sand will also be monitored at the Whitetail Operating, LLC, Louisiana Green Fuels #1 (SN975841) stratigraphic test well, located 5,273 feet southeast and down dip of the facility, at such time the well has been plugged back and no longer utilized as an In-Zone monitor well for the underlying Upper Tuscaloosa and Paluxy Primary Injection zone.

All four ACZMI wells are (or will be) located in the heart of the modeled sCO_2 plume area and thus will be well-positioned to detect any out-of-zone vertical movement of injectate.

In the Annona Sand ACZMI Monitoring zone, each monitor well will be fitted with real-time, continuously recording downhole pressure/temperature gauges unless downhole restrictions prevent the installation of such gauges, at which point alternative methods will be utilized to monitor the pressure and temperature as close to the Annona Sand interval as practicable. Gauges will be referenced to ground level at each well. In the event such downhole restrictions prevent the installation and operation of the downhole pressure/temperature gauges, an alternative approach utilizing a "light" (less dense) fluid column to allow monitoring and recording pressures at the surface may be used. In that alternative approach, the density of the annular fluid in the monitor wellbore will be lowered in a controlled manner to a near-balanced (i.e., reservoir) pressure in the annulus. At near-balanced conditions, the influx of any higher-pressure brine or injectate into the casing annulus (via the perforations across the Annona Sand) will be manifested at the surface as an increase in pressure and a possible change in the composition and/or the temperature of the annular fluid in the wellbore. Such a change in static wellbore conditions, should it occur, will trigger additional testing in the monitor well, including the running of wireline gauges and tools and the acquisition of fluid samples to confirm the indicated influx of brine or injectate. Native brine, per LAC 43:XVII §3607 (C)(2)(e) and LCFS Protocol Subsection C.2.3(a)(9)(B), will be sampled initially upon well construction (including for dissolved and free gases) for baseline characterization purposes (Annona Sand reservoir fluids sampling and analyses have already been completed in the Whitetail Operating, LLC, Louisiana Green Fuels #1 stratigraphic test well). The native brine will be sampled initially (including for dissolved and free gases) for baseline characterization purposes in the Annona Sand completions in the repurposed Bradford-Brown Trust Shipp No. 1 (AP #69; SN137738) and Magnolia Petroleum Co. O.N. Reynolds No. 1-S (AP #129; SN57466) wells, and in the New ACZMI Well to be drilled and completed approximately 150 feet north of injection well W-N2.

Changes in water composition are not expected in the Annona Sand ACZMI Monitoring Zone. However, the ACZMI monitoring wells will provide direct measurement, when or if, the sequestered carbon dioxide ever moves out-of-zone and reaches the Annona Sand at any of the monitored well locations. Should the presence of carbon dioxide be detected in any of the monitor wells (either by a change in downhole pressure and temperature or by surface pressure and temperature changes), as noted above, a direct fluid sampling program will be triggered and initiated in each such well. Work will be conducted by a qualified vendor and the selected analytical laboratory will be compliant with the Louisiana Environmental Laboratory Accreditation Program.

7.1 ACZMI MONITORING ABOVE THE UPPER TUSCALOOSA / PALUXY INJECTION ZONE – ANNONA SAND

ACZMI monitoring in the Annona Sand will provide early detection of carbon dioxide and/or inter-formational fluid flow within the Storage Complex. As such, ACZMI monitoring will provide an early warning before injectates may be able to migrate further uphole to the base of the Midway Shale Secondary Upper Confining Zone.

7.1.1 Monitoring Location and Frequency

The Annona Sand will be monitored at the re-entered and repurposed Bradford-Brown Trust Shipp No. 1 (AP #69; SN137738) and Magnolia Petroleum Co. O.N. Reynolds No. 1-S (AP #129; SN57466) wells and at the New ACZMI Well to be drilled and completed approximately 150 feet north of injection well W-N2; later, it will also be monitored at the Whitetail Operating, LLC, Louisiana Green Fuels #1 stratigraphic test well (SN975841), located 5,273 feet southeast and down dip of the injection wells. Table 7 shows the planned monitoring methods, locations, and frequencies for pressure and temperature monitoring in the Annona Sand ACZMI interval.

Modeling shows that changes in overlying reservoir pressure represent a robust diagnostic detection method that can be employed in the monitoring of deep confined sequestration reservoirs. The leakage of brine from one Cretaceous formation to another (such as from the Upper Tuscaloosa / Paluxy Formation up into the Annona Sand) is unlikely to be chemically diagnostic due to the similarity of the native formation brine compositions in the three formations; furthermore, if ambient methane or carbon dioxide is already present in the system (such as beneath the Port of Columbia Facility), the presence of some concentration of carbon dioxide may not be sufficiently diagnostic either. It is anticipated that a large volume of Upper Tuscaloosa / Paluxy formation fluid would have to infiltrate into the Annona Sand for its presence to initiate a meaningful geochemical signal. Therefore, pressure monitoring should be more diagnostic.

The Louisiana Green Fuels, Port of Columbia Facility is proposing to continuously measure and record bottomhole pressure/temperature in the ACZMI monitoring wells. Pressure trends potentially indicative of leakage into the Annona Sand will be readily detected using such methods. A trend of increasing pressure over time that exceeds 200 PSI over prior static background pressure measurements will trigger the running of wireline gauges and tools (pulsed neutron logging and/or other diagnostic tools) and the acquisition of fluid samples (PVT bottomhole fluid sampling) to confirm the indicated influx of brine or injectate. Logging operations during this investigative process may include the running of pulsed neutron logging in the injection wells to determine if one of those wells constitutes a possible leak path.

The pressure response will be measured by a pressure/temperature gauge that will be capable of transmitting real-time, continuous pressure/temperature from the remote monitoring locations to the distributive control system at the facility. Gauges will be referenced to ground level at each well.

Table 7: AZMI Monitoring above the Tuscaloosa/Paluxy Injection Zone – Annona Sand.

Target Formation	Monitoring Activity	Monitoring Location(s)	Spatial Coverage	Frequency
Annona Sand	Downhole pressure monitoring	SN137738, SN57466, and New Drill Well near W-N2 (Initial); SN975841 (Upon PB from In-Zone)	Over area of review	Real time daily read out
Annona Sand	Pulsed Neutron Logging	SN137738, SN57466, and New Drill Well near W-N2 (Initial); SN975841 (Upon PB from In-Zone)	Over area of review	Baseline log at prior to project start
	Pulsed Neutron Logging	SN137738, SN57466, and New Drill Well near W-N2 (Initial); SN975841 (Upon PB from In-Zone)	Over area of review	Repeat Surveys if anomaly is observed
Annona Sand	Baseline geochemical sampling	SN137738, SN57466, and New Drill Well near W-N2 (Initial); SN975841 (Upon PB from In-Zone)	Over area of review	Baseline Sample at prior to project start
	Follow-up Geochemical testing if signal is observed	SN137738, SN57466, and New Drill Well near W-N2 (Initial); SN975841 (Upon PB from In-Zone)	Over area of review	Only if anomaly is observed
Annona Sand	Pulsed Neutron Logging	Injection Wells	Well Field	Baseline log at prior to project start
	Pulsed Neutron Logging	Injection Wells	Well Field	Repeat Surveys during MIT, adaptive if anomaly detected

Target Formation	Monitoring Activity	Monitoring Location(s)	Spatial Coverage	Frequency
Annona Sand	Repeat seismic method designed for plume tracking, also detect any fluid in Annona	Injection Wells and potentially at Monitor Wells	Azimuthal coverage of the plumes	Baseline, 1 year, 3 years, 5 years, and then every 5 years thereafter

The goal of monitoring directly above the Upper Tuscaloosa / Paluxy Primary Injection Zone is to detect either brine or carbon dioxide leakage above the Injection Zone, should it occur. This provides site-specific and immediate data into the potential of a barrier breach and leakage above the Upper Tuscaloosa / Paluxy. An initial geochemical description of the fluids will be evaluated prior to injection operations for this interval. However, pressure changes will be the initial parameter to be observed.

7.1.2 Analytical Procedures

An initial formation brine sample will be collected from the monitoring wells prior to injection operations per LCFS Protocol Subsection C.2.3(a)(9)(B). This initial sample has already been obtained from the White Tail Operating, LLC, Louisiana Green Fuels #1 stratigraphic test well. A baseline brine sample will also be obtained from the converted oil and gas wells (dry holes) on an as-needed basis during reentry and recompletion activities.

These fluid samples will provide the baseline measurements for the Annona Sand and will document any spatial variability. If significant differences in geochemistry between the two monitor wells are observed, one or more wells may be resampled to ensure validity of the baseline analyses.

Table 8 identifies the parameters to be monitored and the analytical methods that will be used by Louisiana Green Fuels, Port of Columbia Facility.

Table 8: Summary of analytical and field parameters for Annona Formation Fluid Samples (AZMI Monitoring Wells)

Parameters	Analytical Methods
Annona Formation	
Dissolved CO_2 gas by headspace	Gas Chromatography (GC)

Parameters	Analytical Methods
Dissolved CH_4 gas by headspace	Gas Chromatography (GC)
Hydrocarbons	Gas Chromatography (GC)
Dissolved inorganic carbon	Combustion
Bicarbonate	Titration
$\delta D\ CH_{24}$	Gas chromatography combustion isotope ratio mass spectrometry (GC/C/IRMS)
$\delta C^{13}\ CO_2$	Gas chromatography combustion isotope ratio mass spectrometry (GC/C/IRMS)
$\delta C^{13}\ CH_4$	Gas chromatography combustion isotope ratio mass spectrometry (GC/C/IRMS)
$C^{14}\ CO_2$	Accelerated mass spectrometry (AMS).
C^{14} Methane	Accelerated mass spectrometry (AMS).
Isotopic composition of selected major or minor constituents (*e.g.*, Sr $^{87/86,}$ S)	Multicollector-Inductively Coupled Plasma Mass Spectrometer (MC-ICPMS)
Cations: Al, As, B, Ba, Ca, Cd, Cr, Cu, Fe, K, Mg, Mn, Na, Pb, Sb, Se, Si, Ti, Zn,	ICP-MS or ICP-OES, ASTM D5673, EPA 200.8 Ion Chromatography, EPA Method 200.8, ASTM 6919
Anions: Br, Cl, F, NO_3, SO_4,	Ion Chromatography, EPA Method 300.8, ASTM 4327
Total Dissolved Solids	EPA 160.1, ASTMN D5907-10
Alkalinity	EPA 310.1
pH (field)	EPA Method 150.1
Specific Conductance (field)	EPA 120.1, ASTM 1125
Temperature (field)	Thermocouple
Hardness	ASTM D1126
Turbidity	EPA 180.1
Specific Gravity	Modified ASTM 4052
Density	Modified ASTM 4052

The initial parameters identified in Table 8 may be revised and include additional components for testing dependent on the initial geochemical evaluation. If fluid samples are collected, then those samples will be sent to a third-party laboratory accredited by the Louisiana Department of Environmental Quality for analysis.

7.1.3 Sampling Methods

The sampling system used to sample and quantify free and dissolved gases and the aqueous phases in equilibrium with these gases will be supplied by a third-party vendor (Schlumberger, Expro, or equivalent vendor using downhole PVT sampler or equivalent tool). Note that most deep sampling is designed for hydrocarbons; this testing should focus on all gases and formation fluids.

The protocol for sampling shall be as follows: purge the casing volume to bring fresh fluids that have not reacted with casing and tubing to the sample point within the wellbore. Deploy a commercial downhole sampler on slickline to collect a fluid sample at pressure and then close to retain gas phases as the sample is transported to the surface. Conserve gas volumes as samples are stepped to atmospheric pressure for shipping and analysis. Filter and conserve samples following protocols for brine sampling. All sample containers will be labeled with durable labels and indelible markings. A unique sample identification number and sampling date will be recorded on the sample containers. The sample container will be sealed and sent to an authorized third-party laboratory.

Repeat sampling and frequency to be determined based on results.

7.1.4 Analysis Procedures and Chain of Custody

Samples will be analyzed by a third party laboratory accredited by the Louisiana Department of Environmental Quality (https://internet.deq.louisiana.gov/portal/divisions/lelap/accredited-laboratories) using standardized procedures for gas, major, minor and trace element compositions. Detection limits will be dependent on equipment used for the analytical methods by the selected qualified vendor and meet the minimum levels set forth in the QASP.

The sample chain-of-custody procedures will be dependent on vendor selection as the vendor will assume the custody of the samples. The procedures will document and track the sample transfer to laboratory, to the analyst, to testing, to storage, to disposal (at a minimum). A sample chain of custody procedures is contained in Appendix 1.

8.0 USDW MONITORING – PUBLIC WATER SUPPLY WELLS

Public drinking water supply in the area is supplied by the East Columbia Water District. The Louisiana Department of Health routinely monitors constituents in the drinking water according to Federal and State laws. The Port of Columbia Facility will secure split samples from the municipal water wells located at the Port of Columbia when they are sampled by the East Columbia Water District. These samples will be used to establish the baseline ground water quality [§3607 (C)(2)(e)] and will be monitored for any indicated long-term changes in measured parameters.

In addition, in the summer of 2024 Strategic Biofuels worked closely with LDENR to design and implement the attempted sampling of 26 water wells indicated by state records to be active wells located within the Louisiana Green Fuels AoR. The intent of the sampling program was to obtain and analyze water well samples from as many different aquifers as possible. The vast majority of the water wells within the AoR produce water from the MRVA, but a few water wells produce water from stratigraphically deeper aquifers, including the Cockfield, Cook Mountain, and Sparta (one well, listed in the state records as producing drinking water from the so-called "Montgomery" aquifer, actually produces its water from the MRVA). Approximately 60% of the wells targeted for sampling were proposed by Strategic Biofuels and the remaining 10 targeted wells were mandated by LDENR. The MRVA is not present outside the floodplain (i.e., west) of the Ouachita River, which transects the AoR; accordingly, nearly all of the targeted wells were located east of the Ouachita River. Wells that were targeted for sampling west of the river produced water from older Eocene aquifers, of varying quality and less producing capacity than the MRVA wells.

Strategic Biofuels selected CENLA Environmental Science, a highly reputable laboratory based in Alexandria, Louisiana, to sample and analyze the water obtained from each sampled well. CENLA is accredited by the Louisiana Environmental Laboratory Accreditation Program ("LELAP"), a division of the Louisiana Department of Environmental Quality (Accreditation #03078). Six analyses were conducted on each water sample; four of these were conducted directly by CENLA, and two of the tests were conducted by Pace Analytical, another highly reputable laboratory based in Ormond Beach, Florida (LELAP Accreditation #05007). The reason Pace Analytical was also involved is CENLA was accredited by LELAP for 3 of the 6 analyses to be performed, while Pace Analytical was accredited by LELAP to perform the other 3 analyses listed.

Analysis Conducted	Accredited Lab / LELAP No.	Location of LELAP Approved Laboratory
Chloride	Pace Analytical / #05007	8 East Tower Circle, Ormond Beach, FL 32174
Dissolved CO_2	CENLA / #03078	3609 Mac Lee Drive, Alexandria, LA 71302
pH	CENLA / #03078	3610 Mac Lee Drive, Alexandria, LA 71302
Specific Gravity	Pace Analytical / #05007	8 East Tower Circle, Ormond Beach, FL 32174
Temperature	Pace Analytical / #05007	8 East Tower Circle, Ormond Beach, FL 32174
Total Dissolved Solids	CENLA / #03078	3610 Mac Lee Drive, Alexandria, LA 71302

Once the proposed sampling program had been reviewed, amended, and approved by LDENR, a diligent attempt was made to sample the water from each targeted water well. This began with the request in writing from each landowner, upon which the targeted wells were located, to obtain permission to enter the premises and sample the well. If permission was denied, or if the landowner did not respond, the premises were not entered and the well was not sampled.

Once permission was granted to enter the premises and sample the targeted well, CENLA's field personnel, accompanied by a representative of Strategic Biofuels, traveled to the wellsite and attempted to sample the well. In some instances, the targeted well was either (i) not present (had been removed or destroyed), or (ii) not in operation or inoperable (due to damage, neglect, or lack of power). In other instances, the landowner suggested an alternate well to be sampled because the original targeted well was inoperable, and that alternate well was sampled instead.

For the reasons cited above, a number of the targeted wells could not be sampled. In each such case, Strategic Biofuels documented the reason(s) for the failure to sample the well (most reasons being inoperable wells or the lack of response (and thus, permission) from the landowner). At the conclusion of the sampling program, 10 of the original 25 wells targeted for sampling could be sampled, and one additional well – an alternate well suggested by the landowner – was added in the field as an eleventh sampled well. Thus the sampling success of the program was 11 out of 26, or 42.3%. Notwithstanding, the sampling program did succeed in sampling a wide range of aquifers across the intended sampling area within the AoR, including the Sparta (2 wells), Cockfield (1 well), and MRVA aquifers (8, including the so-called "Montgomery" aquifer). This distribution of sampled aquifers approximates the usage of such aquifers in the area (noting, however, that the Sparta wells supply water only used for agricultural purposes, not as a source of drinking water).

It should also be noted that the original program of targeted wells had included virtually all of the active water wells within the AoR that had produced from aquifers other than the MRVA; since those "non-MRVA" wells have now either been sampled or determined to not be available (for whatever reason), any subsequent attempt to sample more active water wells within the AoR will only result in the sampling of more wells producing from the MRVA, which already represents the vast majority (72.7%) of the wells already sampled.

Strategic Biofuels has updated its list of sampled wells and its map showing the location of those sampled wells (Figure UIC-60-1). The map also shows the dissolved CO_2 measured in each sample (in the field), at the time each such sample was collected. The analysis of dissolved CO_2 present in the waters of the aquifers thus provides valuable insight into (and a baseline measurement of) the amount of "native" CO_2 present in each sampled aquifer. That amount of "native" dissolved CO_2 ranges from 44 to 211.2 mg/l in the MRVA aquifer; 88 to 105.6 mg/l in the Sparta aquifer; and was measured to be 70.4 mg/l in the lone Cockfield well sampled. Because the degassing of CO_2 from the water begins the moment the water is pumped out of the aquifer, reaches the surface, and is exposed to the atmosphere, it is possible – in fact, likely – the amount of dissolved CO_2 in each aquifer sampled is incrementally higher than that measured "in the field" from a sample extracted from that water at the pump outlet. Regardless, CENLA's lab analysis confirms that the concentrations of dissolved CO_2 in the sampled aquifers can exceed 210 mg/l.

The complete list of the 26 wells originally targeted for sampling – including those (highlighted) wells that were successfully sampled – is shown at the bottom of the map in Figure UIC-60-1. In addition, a complete well file for each sampled well is provided (Appendix______________). Within these well files are the complete CENLA / Pace Analytical laboratory analyses for each sampled well. Also included are complete Chain-of-Custody reports, photographs of the sampled wellsites, and the letters requesting permission to enter the premises sent to each landowner.

Following the commencement of injection operations at the sequestration complex, in the event of a suspected vertical leakage of the injectate, Strategic Biofuels shall adaptively attempt to resample these 11 wells, which include the two MRVA water supply wells located at the Port of Columbia that will be used for routine geochemical testing of the MRVA aquifer near the proposed facility, as described below in Section 8.2.1.

8.1.1 Monitoring Location and Frequency

The Louisiana Green Fuels, Port of Columbia Facility is working with the East Columbia Water District (ECWD), located in Riverton, Louisiana (1 mile south from the facility location). Two MRVA water supply wells located at the Port of Columbia will be used for geochemical testing of the aquifer. Table 11 shows the planned monitoring methods, locations, and frequencies for ground water quality and geochemical monitoring of the MRVA aquifer.

Table 11: Monitoring of ground water quality and geochemical parameters in a USDW – Public Water Supply Wells

Target Formation	Monitoring Activity	Monitoring Location(s)	Spatial Coverage	Frequency
MRVA	Baseline geochemical sampling	Municipal Wells in Riverton (Port of Columbia)	AoR near plant site and Well W-N1	One year prior to project start and sample at start.
MRVA	Follow-up Geochemical testing	Municipal Wells in Riverton (Port of Columbia)	AoR near plant site and Well W-N1	Quarterly during Injection Operations Annually during post-injection site closure phase.

The frequency of groundwater quality sampling will be conducted on a quarterly basis. A baseline will be established [per LAC 43:XVII §3607 (C)(2)(e)] over a period of a year or more ahead of initiation of sequestration (per LCFS Protocol Subsection C.2.5(b)(c)(d)(e)). Commencing with the initiation of injection operations, the initial monitoring event will occur at the end of the first calendar quarter (even if less than 3 months). Subsequent monitoring will occur at the end of each calendar quarter. This equates to a schedule as follows:

1. March 31 – End of Calendar 1st Quarter
2. June 30 – End of Calendar 2nd Quarter
3. September 31 – End of Calendar 3rd Quarter
4. December 31 – End of Calendar 4th Quarter

The schedule will then repeat using this quarterly sample cycle for the duration of injection operations.

For Post-Closure sampling, the frequency of sampling will continue to be performed on a quarterly basis for the first year after closure. Then from second year on, the samples will be collected and tested on an annual basis, within 45 days of the prior sample anniversary, for a determined post-site care closure timeframe.

8.1.2 Analytical Procedures

Table 12 identifies the parameters to be monitored and the analytical methods the Louisiana Green Fuels, Port of Columbia Facility will use for samples from Public / Private Water Supply wells.

Table 12: Summary of analytical and field parameters for ground water samples – Public / Private Water Supply Wells

Parameters	Analytical Methods
MRVA, Cockfield, Sparta Formations	
Chlorides	EPA 300.0
Dissolved CO2	SM45000G (Field)
pH	h 8156 / SM4500
Specific Gravity	SM2710F
Temperature at Time Specific Gravity Measured	SM2550
Total Dissolved Solids	SM 2540 C-2011

Groundwater sampling methods to be employed, including sampling standard operating procedures, are as adapted from Striggow (2017) or as approved by the Commissioner. Sample containers will be new and of an appropriate material and size for the analyte. Sufficient volumes will be collected to complete all of the specified analyses in Table 12. The appropriate preservation of each sample container will be completed upon sample collection (see QASP). Chain-of-custody will be documented using a standardized form from the analytical laboratory and will be retained and archived to allow tracking of sample status. This will include any required duplicates collected and appropriate field and trip blanks included for quality assurance. Completing the field chain-of-custody form is the responsibility of groundwater sampling personnel.

8.1.3 Sampling Methods

The sampling system used to sample and quantify the freshwater constituents will consist of split samples obtained from the East Columbia Water District following their standard sampling methodology. Samples will be filtered and preserved using standard techniques and protocols for freshwater sampling. All sample containers will be labeled with durable labels and indelible markings. A unique sample identification number and sampling date will be recorded on the sample containers. The sample container will be sealed and sent to an authorized third-party laboratory.

8.1.4 Analysis Procedures and Chain of Custody

Samples will be analyzed by a third party laboratory accredited by the Louisiana Department of Environmental Quality (https://internet.deq.louisiana.gov/portal/divisions/lelap/accredited-laboratories) using standardized procedures. Detection limits will be dependent on equipment facilitated for the analytical methods by the selected qualified vendor and meet the minimum levels set forth in Appendix 1.

The sample chain-of-custody procedures will be dependent on vendor selection as the vendor will assume custody of the samples. The procedures will document and track the sample transfer to laboratory, to the analyst, to testing, to storage, to disposal (at a minimum). A sample chain-of-custody procedure is illustrated in Appendix 1.

9.0 EXTERNAL MECHANICAL INTEGRITY TESTING (MIT)

The Louisiana Green Fuels, Port of Columbia Facility will conduct at least one of the tests presented in Table 13 periodically during the injection phase to verify external mechanical integrity in each injection well as required at LAC 43:XVII §3627 (A)(3) and §3625 (A)(5) and LCFS Protocol Subsection C.4.1(a)(7) and LCFS Protocol Subsection C.4.2. A demonstration of mechanical integrity will be made at least once a year during injection operations and until the well is permanently plugged and abandoned.

9.1 TESTING LOCATION AND FREQUENCY

The integrity of the long-string casing, injection tubing, and annular seal shall be tested by means of an approved pressure test for all injection wells. The integrity of the bottom-hole cement may be tested by means of a temperature survey or an approved tracer survey. Alternatively, a noise log may be run in the well to demonstrate containment within permitted injection zones. Pulsed neutron logging will be run to verify the mechanical integrity of the near-well area behind the casing.

Table 13. Mechanical Integrity Testing – Injection Wells

Test Description	Location
Temperature Survey **OR** Tracer Survey	Each Injection Well – Wellbore
	Each Injection Well – Wellbore
Pulsed Neutron Log	Each Injection Well - Wellbore
Annulus Pressure Test	Each Injection Well – Wellhead/Annulus

Mechanical Integrity Tests (MIT's) will be run after the initial construction of the well prior to the initiation of injection operations. During injection operations the MITs will be performed on an annual basis within 45 days of the anniversary of the preceding year's test. The Louisiana Green Fuels, Port of Columbia Facility will notify the Commissioner ahead of testing. This schedule will repeat during the lifetime of the well during injection operations and prior to plugging operations. Should the well require a workover, Strategic Biofuels will submit a permit request form (Form

UIC-17 or successor) to seek well work authorization [§3621 (A)(9)]. Once a well workover is complete, an MIT will be performed prior to placing the well back into service.

9.2 TESTING DETAILS

Prior to running an MIT, the wellbore annulus may be displaced with water or brine, in either case, the well will be allowed to thermally stabilize prior to all testing operations. It is recommended that the well be shut in for 36 hours to allow temperature effects to dissipate, with the exception of the Upper Tuscaloosa / Paluxy Primary Injection Zone. The external MIT logs will be run on all injection wells. Reports will be submitted to the Commissioner and to the USEPA within 30 days of the tests per [per §3629 (A)(1)(b)(i)].

9.2.1 Temperature Survey

A baseline differential temperature survey will be run in the well after allowing the well a period of time to reach approximate static conditions. The temperature log is one of the approved logs for detecting fluid movement outside pipe. A baseline survey will be run during completion operations and will provide an initial baseline temperature curve for future comparisons. The log will include both an absolute temperature curve and a differential temperature curve. The well should be shut in at least 36 hours to allow for temperature stabilization prior to running the temperature survey.

If a distributed temperature sensing fiber is run in the injection wells, the fiber will be used for the temperature testing; otherwise, a wireline truck will be used.

If wireline operations are conducted, the temperature will be logged down from the surface to total depth in the well. Recommended line speed for the logging operations is 30 to 40 feet per minute. A correlation log(s) will be presented in track 1, and the two temperature curves will be presented in tracks 2 and 3. The temperature log will be scaled at or about 20° F (or 10° C degrees) per track. The differential curve will be scaled in a manner appropriate to the logging equipment design but will be sensitive enough to readily indicate temperature anomalies. In general, the procedure for wireline operations will be as follows:

1. Attach a temperature probe and casing collar locator (CCL) tool to the wireline.
2. After a minimum of 36 hours of well static conditions, begin the temperature survey. The tools will be lowered into the wellbore at the speed of 30 to 40 feet/minute, recording the temperature in the wellbore. The temperature survey will be run to the deepest attainable depth (top of solids fill) in the wellbore. The wireline may be flagged, if needed, to assist in depth correlation.
3. Following completion of the temperature survey, the wireline tools will be retrieved from the wellbore.

A temperature log run will be considered successful if there are no unexplained temperature anomalies observed outside of the permitted injection zone.

Interpretation

Confirm the validity of the log at the well site by comparing logs made at or near the same site. When lithology and injectate characteristics are similar, then thermal effects along the well bore should also be very similar. After the temperature effects caused by casing joints, packers, well diameter, casing string differences, and cement have dissipated, the temperature profiles should be similar, although not identical. If construction features are evident, a longer shut-in period is probably needed.

Identification of flow is based on relative differences between logs periodically run in a well. The log can also be compared to temperature logs in other nearby wells, if such logs exist. Although the gradients may be quite different as a result of differing injection history, their relative positions should be obviously consistent. Lithological effects which show up on one log should show up similarly in other wells at the same site. The failure of temperature logs obtained at the same site under conditions which should result in thermal stability to compare coherently constitutes an anomaly.

If there are no logs suitable for comparison, then deviations from a predictable geothermal gradient are anomalies. These may take the form of a nearly constant temperature between reservoir strata. When more than one log is run, these anomalies are likely to grow (be left behind) as the profile returns toward the natural geothermal while relative differences between the traces elsewhere decrease. Areas with active flow will reach a stable temperature more quickly than other areas. If the movement is not related to injection, this temperature should be that of the natural geothermal gradient at the depth of the source reservoir.

If there are anomalies, a failure of mechanical integrity may be indicated. In such a case, an additional new log may be necessary to show whether forms apparent on the log just made are evolving toward the forms established on the log from another well. Comparison of these two new logs should show increasing parallelism along the cased well bore, if not, then there may be flow along a channel adjacent to the well bore. If this flow results in the movement of liquid into unauthorized zones and/or between USDWs, then the well does not have mechanical integrity. In the event that there are unresolved anomalies that might indicate an absence of mechanical integrity, another approved method (radioactive tracer, noise, oxygen activation, or other logs approved by the Commissioner) must be used to confirm the absence of flow into unauthorized zones or between USDWs.

Identification of flow behind the casing is always made from long-term shut-in logs. The resolution of long-term shut-in logs for identifying the presence of flow is greater than that of logs made during injection. The temperature gradient within a well which has been injecting for some time is very shallow as the temperature at the injection zone may be only a few degrees different from that at the surface. The presence of a flow behind the casing will result in a fractional change in this gradient which will be proportional to the ratio of the flow rates within and outside the tubing. Therefore, only a rather substantial flow can be identified using logs made during injection.

If temperature anomalies are observed outside of the permitted zone, additional logging may be conducted to determine whether a loss of mechanical integrity or containment has occurred. Depending on the nature of the suspected movement, radioactive tracer, noise, oxygen activation, or other logs approved by the Commissioner may be required to further define the nature of the fluid movement or to diagnose a potential leak.

9.2.2 Radioactive Tracer Survey

A Radioactive Tracer Survey (RTS) may be run as an alternative to the temperature survey. The tool consists of a gamma detector above the ejector port and one or two detectors below the ejector port. In order to run the RTS, the wellbore annulus will need to be flushed with brine and the test will be conducted using brine to convey the radioactive iodine tracer material. The tool will continuously record gamma ray API units during tracer fluid ejection. The upper detector will be recorded in track 1 at a scale of 0 to 100 or 150 API units, and the lower detector(s) will be recorded in tracks 2 and 3 at a higher (less sensitive) scale, typically 0 to 1,000 API units.

Prior to testing, an initial gamma ray baseline log will be recorded from at least 100 feet above the injection tubing packer to total depth of the well. The initial gamma ray survey can be made under low flow conditions or with the well in static conditions.

A concurrent casing collar locator log for depth correlation will be run on the wireline tool string. Two five (5) minute time drive statistical checks will be run prior to the ejection of tracer fluid. One of the statistical checks will be run in a confining unit immediately above the uppermost perforation in the well. The second check should be run within the injection zone sandstone. The baseline log and statistical checks will be run to determine background radiation prior to tracer fluid ejection.

Brine injection will be initiated or increased during testing operations. During the survey, brine injection rates will be set at the rate at which the fluid will be under laminar flow conditions, while remaining within the maximum permitted operating parameters anticipated for the well. The volume of the tracer fluid slug will be sufficient to cause a gamma curve deflection on the order of 25x background reading as the ejected slug passes the lower detector(s). This would typically be a full-scale deflection.

A constant injection (moving) survey will be run from above the packer to the perforations to check for leaks between those two points. This survey will consist of ejecting a tracer slug above the packer, verifying the tracer ejection, dropping down through the slug, and then logging up through the slug to above where the slug was first ejected. The tool will be successively dropped down through the slug again, and logging will continue upward to above where the slug was encountered on the previous pass. This process will be repeated a minimum of two times, until the slug flows out into the formation. If necessary, the injection rate may be adjusted to accomplish this test.

A stationary survey will be run approximately 20 feet or less above the top of the perforated interval to check for upward fluid migration outside the cemented casing. Flow during the stationary surveys will be at sufficient rates to approximate normal operating conditions anticipated for the well. The procedure consists of setting the tool and logging on time drive, ejecting a slug, verifying the ejection, and waiting an appropriate amount of time that would allow the slug to exit the wellbore and return through channels outside pipe, if present. The time spent at the station will vary but should be at least twice the time estimated to detect the tracer fluid if channeling existed, or for 15 minutes, whichever is greater. If tracer fluid is detected channeling outside of the pipe at any time during the stationary survey, then the survey may be stopped, and the tracer fluid's movement will be documented by logging up on depth drive, until the tracer exits the channel. The stationary survey will be repeated at least once through the same zone.

Additional Stationary or moving surveys may be required, depending upon well construction, test results, or to investigate known problem conditions. At least two repeatable logs of every tracer survey, moving and Stationary, should be run. On completion of the tracer surveys, a final background gamma log will be run for comparison with the initial background log. In general, the test procedure will be as follows:

1. Attach radioactive tracer tools, including casing collar locator (CCL), gamma ray detectors and ejector modules to the wireline. Lower tools in wellbore to deepest attainable depth (top of solids fill). Record the depth of solids fill in the well, if any. Correlate tools on depth with the injection packer and any other cased-hole log(s) run in the well.
2. A baseline gamma log will be run from deepest attainable depth to approximately 4,800 feet (must be at least 100 feet above the packer). Statistical tool checks will be conducted 10 feet above the set depth of the injection packer and approximately 15 feet above the top perforation. (*Specific depths will be identified ad updated after injection well(s) completion*).

3. With the tool set a minimum of 100 feet above the packer, start injecting brine fluid at approximately 50 gpm (or defined acceptable rate). Eject a slug of tracer material and verify ejection.

4. Lower the tool through the slug and log up through the slug. Repeat slug-tracking sequence, following the slug down the tubing and into the injection zone until the slug is dissipated.

Note: It is desired to achieve a minimum of three or more passes below the injection packer before the radioactive slug exits the perforations. Adjust or reduce injection rate if needed to achieve this objective.

5. Repeat Steps 3 and 4.

6. Position lower detector of RTS tool at approximately 15 feet above the top perforation. Initiate and maintain injection at approximately 250 gpm (or defined acceptable rate).

7. Eject a slug of tracer material and record on time drive for a minimum of 15 minutes to determine if upward flow around the casing occurs.

8. Repeat Step 7.

9. Cease pumping, lower the tool to the deepest attainable depth, and run a repeat baseline gamma ray log to verify that the radiation level has returned to background.

10. Dump remaining tracer material from the tool and pump remaining test fluid to flush the tracer material from the wellbore.

11. Retrieve the wireline tools from the wellbore and rig down wireline unit.

<u>Interpretation</u>

Where a measurable amount of tracer material leaks from the tubing, it will be observed as a small area of increased radioactivity after the slug has passed. If an area of elevated radioactivity is observed, additional runs should clarify what becomes of the RA material. This will demonstrate whether only the tubing is leaking, or if both the tubing and casing lack integrity. In most cases, if a well's casing has integrity but a tubing leak exists, pressure equalization and cessation of leaking will occur until a change in injection pressure allows the leak to resume. This is why it is important to ensure a pressure differential between the injection tubing and annulus.

If annulus pressure is lower than injection pressure and both the tubing and casing are leaking, any tracer material that leaks out of the tubing will generally move toward and out through the casing leak. This is because the annulus pressure normally will be higher than the hydrostatic pressures within adjacent formations at all depths. If only the tubing is leaking, the tracer material will remain near the leak, spreading slowly both up and down from the leak location.

Adherence of tracer material to the tubing can be differentiated from a tubing leak because any material adhering to the tubing will eventually be washed away with no movement evident.

If no evidence of leaking is observed, the well has demonstrated part 1 of the MIT. Demonstrations of mechanical integrity using the RTS will be examined very closely, and any conditions which threaten the ability to interpret them accurately must be removed.

9.2.3 Alternative Mechanical Integrity Logging

Noise Log (if run)

Channels along well bores are very rarely uniform. When flow is occurring, irregularities in channel cross section usually result in generation of some turbulence which occurs in the audible range. Sonic energy travels for considerable distances through solids, allowing sensitive microphones to detect the effects of turbulent fluid flow at considerable distances. Different types of turbulence result in sounds having different frequencies. Single phase turbulence results in low frequency sounds, while two phase turbulence usually results in high frequency sounds. High pass filters are used to determine the intensity of detected noise within various frequency ranges.

Procedure

The noise log is a versatile cased-hole diagnostic wireline logging tool, since it may be run while injection is occurring in multiple wells because the inherent flow restriction caused by the presence of the wireline and noise logging tool is typically insufficient to cause turbulence. It is especially desirable to run the noise log while injecting to look for flow resulting from a pressure increase near the top of the injection zone. If ambient noise while injecting is greater than 10 mv, injection should be halted. Logging procedures should include the following steps:

1. Obtain noise measurements at intervals of 100 feet to create a log on a coarse grid;
2. If any anomalies are evident on the initial coarse-gridded noise log, compile a finer grid noise log by making additional noise measurements at intervals of 20 feet within the coarse-gridded depth intervals observed to manifest anomalously high noise levels;
3. Obtain noise measurements at intervals of 10 feet through the first 50 feet above the injection zone and at intervals of 20 feet within the 100-foot intervals containing:
   - the base of the lowermost bleed-off zone above the injection zone,
   - the base of the lowermost USDW, and
   - in the case of varying water quality within the zone of USDW, the top and base of each interval with significantly different water quality from the next interval; while
4. Additional measurements may be made to pinpoint the exact depths that are the sources of the anomalous noise; and
5. The final noise log is created using a vertical scale of 1 or 2 inches per 100 feet.

Interpretation

The interpretation of noise logs for the purpose of demonstrating mechanical integrity is straightforward. The following steps are used:

1. Determine the base noise level in the well (dead well level);
2. Identify significant departures from this base noise level. An increase in noise near the surface due to the operation of equipment on site is to be expected in many situations;
3. Utilize the noise log in an attempt to determine the extent of any fluid / gas movement (this may be difficult when there are few constrictions to flow);
4. If the observed flow is into or between USDWs, a lack of mechanical integrity is indicated. If the observed flow is indicated to be moving upward from the injection zone into or above the confining zone, the failure of containment is indicated.

If the log measurements are ambiguous, the determination of the possible loss of mechanical integrity or containment should be confirmed using another method.

Oxygen Activation Log (if run)

The oxygen activation method is based on the use of the Oxygen Activation Log tool to convert oxygen into an isotope of nitrogen (N16) within a short radial distance of the tool. It is an approved logging method under §3617 (B)(1)(d)(ii). This is accomplished by the emission of high energy neutrons from the tool's neutron source. N16 is an unstable isotope of nitrogen which is also referred to as “activated oxygen”. The half-life of activated oxygen is just 7.13 seconds, and the release of gamma rays as the activated oxygen decays into oxygen can be measured. If the tool is stationary and oxygen is activated, detectors placed near the activator device will detect increased gamma radiation. The intensity of the additional radiation will be inversely proportional to the square of the distance of the activated oxygen from the detector. Most of the elemental oxygen near the tool is bound in the surrounding water (H2O), which may be mobile or static depending on wellbore conditions. If the water containing such activated oxygen is actively moving (flowing), the measured intensity of gamma radiation will increase if the water containing activated oxygen moves closer to a tool detector, and will lessen as it moves further away from the other detector on the tool. By comparing the intensity of gamma radiation measured at the two detectors on the oxygen activation tool, the probable direction and velocity of water movement can be determined. Studies under controlled conditions indicate water velocities between 2 to 120 feet per minute can be measured.

Procedure

All measurements should be taken for periods of at least five minutes with the well injecting at the maximum normal rate. A total of at least 15 minutes measurement time is required at each station. This total time may be accumulated in one, two, or three operations. If open hole caliper logs are available, the caliper log should be used to ensure all readings are taken at depths where the wellbore is in gauge. The method for obtaining measurements shall conform to optimum procedures contained in the operator's manual for the tool. The following steps are recommended for demonstrating mechanical integrity using the oxygen activation log tool:

1. Obtain a reference log for lithology determination. If no such log is available, run a cased-hole gamma ray-neutron log to aid in the identification of porous intervals;

2. If required for tool calibration, background checks will be run with no injection occurring in an interval where no flow is thought to occur. Background calibration should be run for each interval of varying well construction;

3. Take measurements at stations at least 10 feet above the open injection interval;

4. Take measurements at the top of the confining zone and at two or three formation changes between the confining zone and the base of the USDW;

5. Take measurements within 50 feet below the base of each USDW, within 50 feet of the top of the first underlying aquifer, and at least one depth between these two points;

6. If activated oxygen anomalies are found, additional readings, including readings made while the well is injecting (if the original measurements were made while not injecting, or not injecting if the original measurements were made while injecting), should be made above and below the depth of the anomaly to confirm the anomalous reading and determine the extent of fluid movement; and

7. If flow is indicated, another cased-hole diagnostic log may be used to confirm the measurement and define the extent of flow. The choice for the confirmation log to be used should be based on all wellbore and environmental factors, and the tool choice must be approved by the Commissioner prior to commencing testing operations.

Interpretation

A 3 or 4 : 1 ratio of the short-spaced flow indicator results to a standard deviation indicates flow. Indicated water-flow velocities should be in excess of two feet per minute; lower values should be viewed with skepticism. Velocities near and above two feet per minute have been measured at several depths at several sites; however, other diagnostic logs did not indicate flow. In some cases the occurrences were repeatable, at least during the period of one logging operation. Although the cause of such false or misleading measurements is not known, the assumption is that the logging tool was not properly calibrated for the interval being tested.

To minimize false positives, it is recommended that all measurements be confirmed at several nearby depths and/or measurements be taken under a minimum of 3 varying injection rates, *i.e.* at 75%, 50%, and 25% of maximum permitted injection rates. Before costly remedial measures are undertaken, such anomalies should be confirmed by the acquisition of other logs.

9.2.4 Pulsed Neutron Logging

Pulsed neutron logging will be run to verify the mechanical integrity and to determine carbon dioxide saturations in the near-wellbore area behind the casing in the injection wells. A baseline survey will be run during completion operations (with the injection well in completion configuration) and will provide an initial baseline log for future comparisons. Should the downhole well completion change at any time, a new baseline log will be run. The pulsed neutron survey will be run from the Wilcox Formation below a depth of 2,400 feet below ground down to the total depth of the well and will be run in gas-sigma-hydrogen mode. The sigma measurement is used to determine porosity, differentiate between saline water and carbon dioxide, and calculate formation saturation in the Tuscaloosa/Paluxy Injection Zone. The Port of Columbia Facility will run the Pulsed Neutron log annually for the first five years, and then every 5 years after that throughout the life of the wells. The Commissioner may require more frequent monitoring to further define the nature of potential fluid movement along the casing-borehole wall or to diagnose potential leaks.

9.2.5 Annulus Pressure Test

In conjunction with annual mechanical integrity testing, an annulus pressure test (APT) of the casing by tubing annulus will be made to evaluate the absence of significant leaks [§3627 (A)(2)(a)]. An APT will be performed after initial well construction as well as after any remedial work over event that involves unseating the tubing or the packer.

Pressures will be recorded on a time-drive recorder for at least 60 minutes in duration and the chart or digital printout of times and pressures will be certified as true and accurate. The pressure scale on the chart will be low enough to readily show a 5 percent change from the starting pressure. In general, the test procedure will be as follows:

1. Connect a high-resolution pressure transducer to the annulus and increase annulus pressure to at least 200 psig over the permitted maximum tubing/injection pressure. Conduct Annulus Pressure Test (APT) by holding annular pressure a minimum of 100 psi above the well's maximum permitted surface injection pressure for a minimum of 60 minutes.
2. At the conclusion of the APT, annular pressure will be lowered to the well's normal, safe differential pressure value and pressure recording equipment will be removed from the well system.

A successful pressure test will "PASS" if the pressure holds to +/-5 percent of the starting pressure. If the test can't hold pressure for a selected time period, then the test will be considered a "FAIL". The test will be repeated and if the well continues to "FAIL", the construction of the well may have lost its integrity. Additional tests at progressively lower pressures may be run to identify the pressure at which the annulus can hold a differential. Continuous monitoring of the annulus system will be reviewed to identify if there is any data that may lead to a potential leak and assist in diagnosing potential issues with the annulus.

10.0 TRANSIENT PRESSURE FALLOFF TEST

The Louisiana Green Fuels, Port of Columbia Facility will perform pressure fall-off tests during the injection phase as described below to meet the requirements of LAC 43:XVII §3625 (A)(6) and LCFS Protocol Subsection C.2.3.1(i)(1) and LCFS Protocol Subsection C.4.1(a)(8). Pressure fall-off testing will be conducted upon completion of each injection well to characterize baseline formation properties, as well as determine near well/reservoir conditions that may impact the injection of carbon dioxide.

10.1 FALL-OFF TESTING LOCATION AND FREQUENCY

The Louisiana Green Fuels, Port of Columbia Facility will perform an initial (baseline) pressure fall-off test in each injection well using brine or municipal water mixed with a clay stabilizer to avert clay swelling. This will allow for baseline characterization of the transmissibility to fluid within the Upper Tuscaloosa / Paluxy Primary Injection Zone. The initial pressure fall-off testing will be repeated using carbon dioxide within the first 60 days of initiation of injection operations. This will allow for comparison to the baseline fluid-to-fluid test with the change in the injection fluid from brine water to carbon dioxide.

A pressure fall-off test will be performed annually (within approximately +/-45 days of the anniversary of the previous test), at a minimum, during the first five years of injection and then at subsequent 5-year intervals, thereafter, for the lifetime of injection operations [§3625 (A)(6) LCFS Protocol Subsection C.4.3.1.5]. Periodic testing is expected to provide insight into performance of the Storage Complex and potentially aid in assessing the dimensions of the expanding carbon dioxide plume, based on the expected lateral change from supercritical carbon dioxide near the wellbore to native formation brine beyond the plume. The Commissioner may request more frequent testing which will be dependent on test results. A final pressure fall-off test will be run after the cessation of injection into each injection well.

10.2 FALLOFF TESTING DETAILS

Testing procedures will follow the methodology detailed in "*EPA Region 6 UIC Pressure Falloff Testing Guideline-Third Revision (August 8, 2002)*"[2]. Bottomhole pressure measurements near the perforations are preferred due to phase changes within the column of carbon dioxide in the tubing. A surface pressure gauge may also serve as a monitoring tool for tracking the test progress.

The pressure gauge can be either installed as part of the completion or can be deployed via wireline. If a wireline-deployed gauge is used, the wireline should be corrosion resistant (such as MP-35 line), and the deployed gauges should consist of a surface read-out gauge with a memory backup. Gauge specifications should be as follows or similar:

Table 14: Injection/Falloff Pressure Gauge Information – Wireline Testing Operations

Pressure Gauge	Property	Value
Surface Readout Pressure Gauge	Range Resolution	0 – 10,000 psi/356 °F +/-0.01 psi/0.01 °F
	Accuracy	+/-0.03% of full scale (+/-3 psi/+/-0.1 °F)
	Manufacturer's Recommended Calibration Frequency	Minimum Annual
Memory Pressure Gauge	Range Resolution	0 – 10,000 psi/356 °F +/-0.01 psi/0.01 °F
	Accuracy	+/-0.03% of full scale (+/-3 psi/+/-0.1 °F)
	Manufacturer's Recommended Calibration Frequency	Minimum Annual

The general testing procedure is as follows (and presumes that a wireline-deployed unit is used for the testing). **NOTE**: a dedicated downhole monitoring gauge may be used if installed on each of the injection wells:

[2] https://www.epa.gov/sites/default/files/2015-07/documents/guideline.pdf

1. Mobilize wireline unit to the injection well and rig up on wellhead.

2. Rig up a wireline lubricator containing a calibrated downhole surface-readout pressure gauge (SRO) with memory gauge installed in the tool string as a backup, to the adapter above the crown valve. Each gauge should have an operating range of 0 - 10,000 psi. Reference the gauge to kelly bushing (KB) reference elevation as well as the elevation above ground level.

3. Open crown valve, record surface injection pressure, and run in hole with SRO to just above the shallowest perforations in the completion while maintaining injection at a constant rate. Steady rates of injection should be maintained for at least 24 hours ahead of the planned shut-in of the injection well. Any offset injection well(s) should be either shut-in ahead of the testing or should maintain a constant rate of injection for the entire duration of the testing. This will minimize cross-well interference effects.

4. With the SRO positioned just above the perforations, monitor the bottom-hole injection pressure response for ±1 hour to allow the gauge to stabilize (temperature and pressure stabilization). Ensure that the injection rate and pressure are stable.

5. Cease injection as rapidly as possible (controlled quick shut-in); close the control valve and the manual flowline valve at well site (start with the valve **closest** to the wellhead so that wellbore storage effect in early time is minimized). Conduct the pressure fall-off test for approximately 24 hours, or until bottomhole pressures have stabilized.

6. Lock out all valves on the injection annulus pressure system so that annulus pressure cannot be changed during the falloff period. Ensure that valves on flow line to the injection well are closed and locked to prevent flow to the well during the fall-off period.

7. After 24 hours, download data and make preliminary field analysis of the fall-off test data with computer-aided transient test software to estimate if or when radial flow conditions might be reached. If sufficient data acquisition is confirmed, end fall-off test. If additional data is required, extend fall-off test until radial flow conditions are confirmed. After confirmation of sufficient data acquisition, end fall-off test.

8. Pull SRO tool up out of the well at 1,000-foot increments and allow the gauge to stabilize (5 minutes each stop). Record stabilized temperature and pressure. Repeat the process to

collect stabilized pressure data (5-minute stops) at 1,000-foot intervals and in the lubricator.

In performing a fall-off test analysis, a series of plots and calculations will be prepared to QA/QC the test, identify flow regimes, and determine well completion and reservoir parameters. It will also be used to compare formation characteristics such as transmissivity and skin factor of the near wellbore for changes over time. Skin effects due to drilling and completion activities (due to possible damage from well perforation) will be assessed for the wells injectivity and potential well cleanouts in the future. Data reduction and analyses will follow USEPA's *UIC Pressure Falloff Testing Guidelines – Third Revision* (https://www.epa.gov/sites/default/files/2015-07/documents/guideline.pdf). These tests can also measure drops in pressure due to potential damage/leakage over time. In CO_2, it is anticipated that pressure drops may indicate multiple fluid phases. The analysis will be designed to consider all parameters.

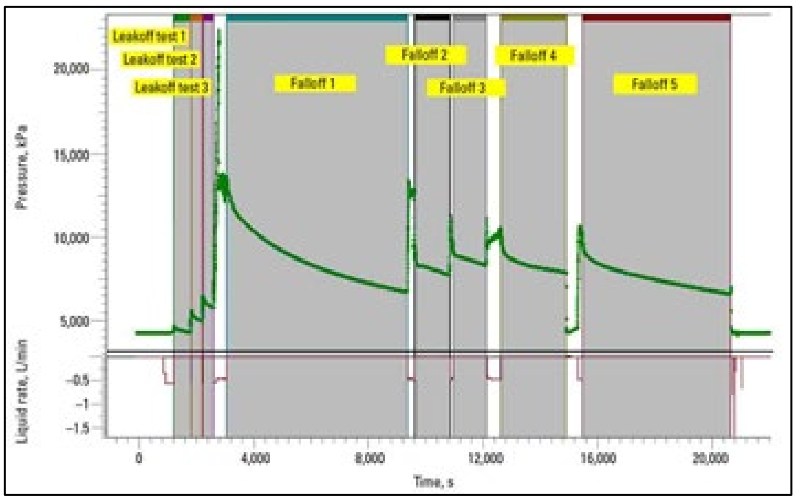
Reports will be submitted to the commissioner and the USEPA within 30 days of the test [per §3629 (A)(1)(b)].

10.3 FRACTURE / PARTING PRESSURE TESTING

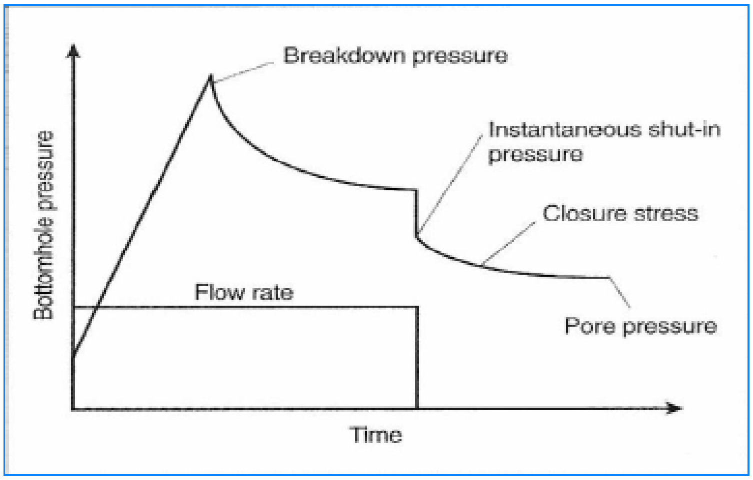
Per LCFS Protocol Subsection C 2.3(a)(3)(A) ad C.2.3.1(h), the fracture/parting pressure of the sequestration zone and primary confining layer and the corresponding fracture gradients determined via step rate or leak-off tests must be performed in the wellbore. These testing and logging activities may be undertaken during the drilling of an injection or monitoring well(s) to determine the state of stress of the injection zone and caprock.

Mini-frac

During drilling of the injection and/or observation well(s), an open hole Schlumberger Modular Dynamics Tester (MDT), or equivalent, mini- frac will be completed to determine the minimum horizontal stress of the formation. The mini-frac operations will be performed using a dual packer setup and will be conducted on both the injection zone and overlying confining zone To determine the maximum horizontal stress. The adjacent illustration shows an annotated example of a typical testing sequence that can be used to determine the propagation pressure, closure pressure, and reopening pressure, which then define the minimum horizontal stress in the subsurface.



Mini-frac testing will be conducted with the Schlumberger MDT tester in Dual-Packer Mode to determine the breakdown pressure gradient. For stress testing to provide accurate information on the state of stress and breakdown pressure for the injection zone and caprock, the tested interval must have no pre-existing weaknesses, such as natural fractures. Proposed test intervals will be screened with the Formation Imager Tool to select packer setting depths for testing.



Diagnostic Fracture Injection Test (DFIT) - Confining Zone

In a diagnostic fracture injection test (DFIT), a relatively small volume of fluid is injected into the subsurface, creating a hydraulic fracture. The testing is essentially similar to the mini-frac test, but the test is conducted in the open hole or the cased hole with dual packers straddling the test interval. After the end of injection, the pressure in the wellbore is monitored for durations of hours to days. The pressure measurements from the injection and recovery periods are used to infer properties of the formation, including the leakoff coefficient, permeability, fracture closure pressure (which is related to the magnitude of the minimum principal stress and the net pressure), and formation pressure.

During the initial injection period, where a fracture has not formed and wellbore storage controls the pressure behavior, pressure increases with increasing injection volume. At formation breakdown, a fracture is initiated in the formation. At breakdown, either a new fracture will be created causing a decrease in pressure or expansion of an already existing fracture will cause a pressure plateau. Following breakdown, continued injection causes the fracture to extend out into the formation (propagation pressure), reached at #3, and the ISIP (initial shut-in pressure) is reached at #4. DFIT analysis is primarily interested in analyzing the trends in pressure that occur in the hours and days after shut-in.

The DFIT procedure shall be as follows:

1. In a cased hole, perforate the well (small interval or full set).
2. Install high-resolution surface electronic memory gauges on wellhead and run high-resolution gauges downhole (set recording rate set to 1 second intervals). High resolution gauges will ensure that all pressure changes are recorded (recommend 0.1 to 0.001 psi psi gauge resolution.
3. Load hole with water (KCl or brine water with minimal additives as needed (avoid clay swelling etc.)) to fill up the wellbore.
4. Start recording before pumping starts and end recording after the fall-off (pressure recovery) is complete.
5. Start the pump to start injection and record the flow rates. The injection rate should be high enough to breakdown the perforations and create a small fracture. After breakdown, fluid rate should be increased up to maximum pressure limit and injection should be constantly pumped at a steady rate for 3 to 5 minutes.
6. Step down to 75%, 50%, and optionally 30% of maximum rate. Each step down can be as short as 10 seconds.
7. Shut-down the pump quickly, recording the total volume pumped, and isolate the wellhead.
8. Rig down the pumping equipment without disturbing the isolated electronic gauges.
9. Collect the data from the pump unit as well as the acquisition setup.

Step-rate Testing - Injection Zone

Step-rate testing is fundamentally similar to mini-frac testing but is performed in the full wellbore using open hole packers set on work string while injection is provided by a pumping unit. Per LCFS Protocol Subsection C 2.3(a)(3)(A), a step-rate test must meet the following requirements:

1. Real-time downhole pressure recording must be employed.
2. Bottom-hole pressure must be recorded at a zero-injection rate for at least one full time step before the first step of the step rate test, and before one full time step after the last step of the step rate test.
3. Step rate test data reported must be raw and unaltered, and include the injection rate, bottom-hole pressure, surface pressure, pump rate volume, and time recorded continuously

at a rate of every one second during the step rate test.

General procedures for step-rate testing is contained in "*EPA Region 8 Step-rate Test Procedure (January 12, 1999)*"[3].

10.4 FRACTURE TEST ANALYSIS

The analysis of mini-frac test data is performed in two parts: pre-closure analysis and after-closure analysis. Pre-closure analysis consists of identifying closure and analyzing the early pressure falloff period while the induced fracture is closing. One of the most critical parameters in fracture treatment design is the closure pressure.

The following parameters are determined from the post-closure analysis:

- Fracture closure pressure (pc)
- Instantaneous Shut-In Pressure (ISIP) = Final injection pressure - Pressure drop due to friction
- ISIP Gradient = ISIP / Formation Depth
- Closure Gradient = Closure Pressure / Formation Depth
- Net Fracture Pressure (Δpnet) – Net fracture pressure is the additional pressure within the frac above the pressure required to keep the fracture open. It is an indication of the energy available to propagate the fracture.
    - Δpnet = ISIP - Closure Pressure
- Fluid efficiency – Fluid efficiency is the ratio of the stored volume within the fracture to the total fluid injected. A high fluid efficiency means low leak-off and indicates the energy used to inject the fluid was efficiently utilized in creating and growing the fracture. Low leak-off is also an indication of low permeability. For mini-frac after-closure analysis, high fluid efficiency is coupled with long closure durations and even longer identifiable flow regime trends

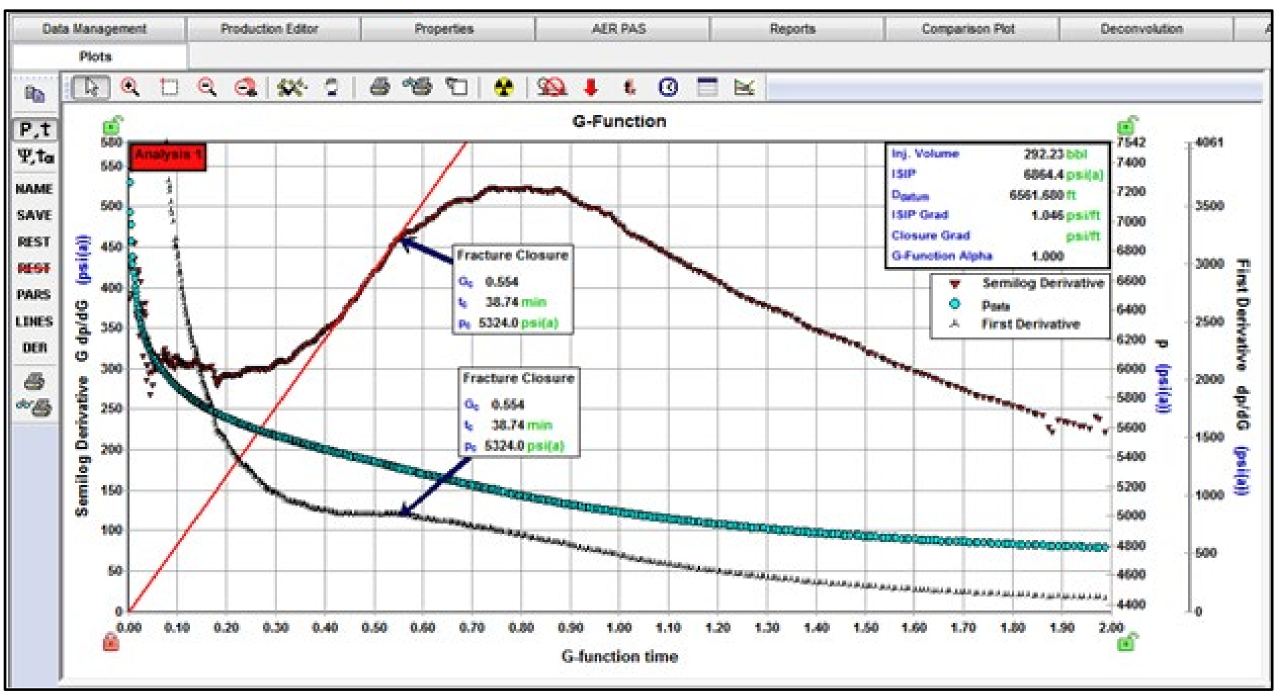
[3] https://www.epa.gov/sites/default/files/2015-08/documents/r8_guideline_-_step_rate_testing.pdf

- Gc is the G-function time at fracture closure
- Formation leakoff characteristics and fluid loss coefficients.

<u>G-Function Analysis</u>

Post-injection (pre-closure) pressure falloff analysis can be performed using the "G-function" and root time methods. The G-function is a dimensionless time function designed to linearize the pressure behavior during normal fluid leak-off from a bi-wing fracture. Any deviations from this behavior can be used to characterize other leak-off mechanisms. The root time plot exhibits similar behavior and can be used to support the G-function analysis.

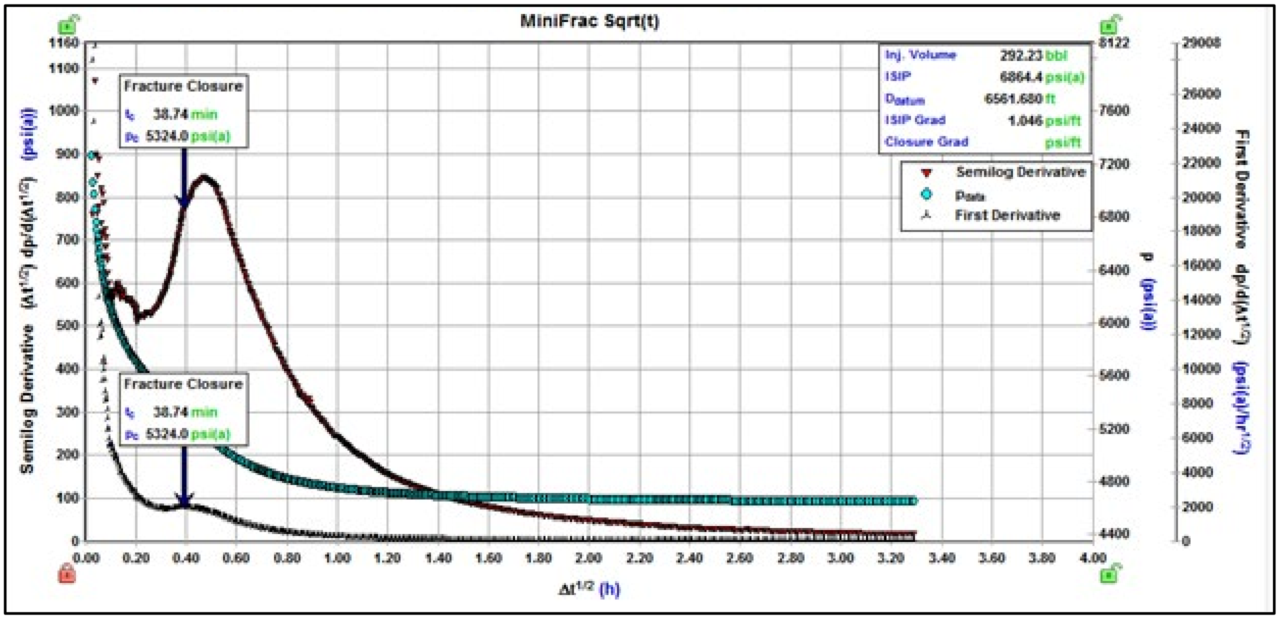
A straight-line trend of the G-function derivative (Gdp/dG) is expected where the slope of the derivative is still increasing. Position the Fracture Closure Identification line, which is anchored to the origin by default, through the straight-line portion of the G-Function derivative. Fracture closure is identified as the point where the G-Function derivative starts to deviate downward from the straight line as shown in the following graphic.



https://www.ihsenergy.ca/support/documentation_ca/WellTest/content/html_files/analysis_types/minifrac_test_analyses/minifrac-pre-closure_analysis.htm

Square Root Time Analysis

Fracture closure can be identified by the peak of the first derivative on the Sqrt(t) plot, which corresponds to an inflection point on the pressure curve. The semi-log derivative behaves similar to the G-Function Analysis. A user-defined (Sqrt(t)) analysis line may be added to the sqrt(t) plot to help identify the point of inflection.



https://www.ihsenergy.ca/support/documentation_ca/WellTest/content/html_files/analysis_types/minifrac_test_analyses/minifrac-pre-closure_analysis.htm

Fluid Leakoff Types

The G-Function plots can be used to determine the type of leak-off during the testing. Four common leak-off types are:

1. Normal leak-off occurs when the fracture area is constant during shut-in and the leak-off occurs through a homogeneous rock matrix, diagnosed by:
    - A constant pressure derivative (dP/dG) during fracture closure.
    - The G-Function derivative (G dP/dG) lies on a straight line that passes through the origin.
2. Pressure-dependent leak-off (PDL) indicates the existence of secondary fractures intersecting the main fracture and is identified by a characteristic "hump" in the G-Function derivative that lies above the straight line fit through the normal leak-off data.

This hump indicates fluid is leaking off faster than expected for a normal bi-wing fracture. The interception of secondary fractures, which could be natural or induced, facilitates this additional leak-off by providing a larger surface area exposed to the matrix.

- A characteristic large "hump" in the G-Function derivative; G dP/dG lies above the straight line that passes through the origin.
- Subsequent to the hump, the pressure decline exhibits normal leakoff.
- The portion of the normal leakoff lies on a straight line passing through the origin.
- The end of the hump is identified as "fissure opening pressure".

3. Transverse Storage/Fracture Height Recession is determined when the G-Function derivative G dP/dG falls below a straight line that extrapolates through the normal leak-off data, exhibiting a concave up-trend. This indicates fluid is leaking off slower than expected for a normal bi-wing fracture and suggests that the fracture has some pressure support. Two scenarios can explain this trend as discussed below.

    - Transverse storage occurs when the main fracture intercepts a secondary fracture network, which could be natural or induced. This differs from pressure-dependent leak-off in that the dominant effect of the secondary fractures is to provide pressure support to the main fracture, rather than additional surface area for leak-off. There can be cases where transverse storage (pressure support) dominates, followed by a period of pressure-dependent leak-off before closure of the main fracture occurs.

    - Fracture height recession occurs if the fracture propagates through adjoining impermeable layers (above or below the test zone) during injection. In the normal leak-off scenario, fluid can leak off from the entire surface area of the fracture. For fracture height recession, leak-off can only occur in the portion of the fracture which is in communication with the permeable zone. As a result, the leak-off rate is slower than the normal case. Eventually, the fracture area in the impermeable layer(s) starts closing (height recession), and during this period the rate of pressure decline increases. Once the fracture height recedes to the edge of the permeable zone, the entire area of the frac contributes to leak off, and a period of normal leak-off ensues.

4. Fracture tip extension occurs when a fracture continues to grow even after injection is stopped and the well is shut-in. It is a phenomenon that occurs in very low permeability reservoirs, as the energy which normally would be released through leak-off is transferred to the ends of the fracture resulting in fracture tip extension. The characteristic signatures for a fracture tip extension are:

    - The G-Function derivative G dP/dG initially exhibits a large positive slope that continues to decrease with shut-in time, yielding a concave-down curvature.
    - Any straight line fit through the G-Function derivative G dP/dG intersects the y - axis above the origin.

Until the main fracture closes, the G-Function derivative behaves similarly to PDL, and it is difficult to distinguish between PDL and fracture tip extension.

11.0 CARBON DIOXIDE PLUME AND PRESSURE FRONT TRACKING.

The Louisiana Green Fuels, Port of Columbia Facility will employ both direct and indirect methods to track the geometry and extent of the carbon dioxide plume with time and the areal distribution in pressures within and above the Sequestration Complex to meet the requirements of LAC 43:XVII §3625 (A)(7) and LCFS Protocol Subsection C.4.1(a)(9)(A).

Table 15: Pressure-front and Plume-front Monitoring - Direct [§3625 (A)(7)(a)]

Target Formation	Monitoring Activity	Monitoring Location(s)	Spatial Coverage	Frequency
PRESSURE-FRONT MONITORING-DIRECT				
Upper Tuscaloosa / Paluxy Primary Injection Zone	Pressure & Temperature	Injection Wells & 2 In-Zone Updip Monitor Wells; 3 other Monitor Wells in Pressure Front	Injection Well Field & Updip Monitor Wells: 10,152 feet up dip and 5,273 feet southeast	Continuous
ACZMI Annona Sand	Pressure & Temperature	3-4 ACZMI Monitor Wells	Distributed evenly throughout plume area	Continuous
PLUME-FRONT MONITORING-DIRECT				
Upper Tuscaloosa / Paluxy Injection Zone	Fluid Sampling	2 In-Zone Updip Monitor Wells; 3 other Monitor Wells in Pressure Front	Updip Monitor Wells: 10,152 feet up dip and 5,273 feet southeast	Adaptive, if triggered
ACZMI Annona Sand	Fluid Sampling	3-4 ACZMI Monitor Wells	Distributed evenly throughout plume area	Adaptive, if triggered
Freshwater Aquifer(s)	Fluid Sampling	Public Water Supply Wells	Area of Review	Baseline and quarterly (2), adaptive, if triggered (>2 wells)

Table 16: Pressure-front and Plume-front Monitoring – Indirect [§3625 (A)(7)(b)]

Target Formation	Monitoring Activity	Monitoring Location(s)	Spatial Coverage	Frequency
PRESSURE-FRONT MONITORING-INDIRECT				
NONE				
PLUME-FRONT MONITORING-INDIRECT				
Upper Tuscaloosa / Paluxy Injection Zone	Pulsed Neutron	Injection Wells & In-Zone Updip Monitor Wells	Injection Well Field & Updip Monitor Wells: 10,152 feet up dip and 5,273 feet southeast	Annually in Injection Wells Years 1 to 5 and every 5 years thereafter Adaptive, if triggered at Monitor Wells
ACZMI Annona Sand	Pulsed Neutron	Injection Wells & 3-4 ACZMI Monitor Wells	Injection Well Field & Updip Monitor Wells: 10,152 feet up dip and 5,273 feet southeast	Annually in Injection Wells Years 1 to 5 and every 5 years thereafter Adaptive, if triggered at Monitor Wells
Upper Tuscaloosa / Paluxy Injection Zone	Temperature	Injection Wells	Injection Well Field	Annually in Injection Wells Years 1 to 5 and every 5 years thereafter
ACZMI Annona Sand	Temperature	Injection Wells	Injection Well Field	Annually in Injection Wells Years 1 to 5 and every 5 years thereafter
Sequestration Complex	Microseismic, Time-lapse / Walk-Away VSPs	Injection Wells	CO_2 Plume	Real-Time (Microseismic), Annual (VSPs)

11.1 PLUME FRONT

11.1.1 Plume Monitoring Location and Frequency

Table 17 summarizes the methods that the Louisiana Green Fuels, Port of Columbia Facility will use to monitor the migration of the sequestered carbon dioxide plume, including the activities, locations, and frequencies that will be employed. The parameters to be analyzed as part of fluid sampling in the Upper Tuscaloosa / Paluxy Primary Injection Zone and the associated analytical methods are presented in Table 18.

Quality assurance procedures for these methods are presented in Appendix 1.

Direct In-Zone monitoring conducted in wells completed in the Upper Tuscaloosa / Paluxy Primary Injection Zone will be used to detect and define the dimensions of the carbon dioxide plume during well injection operations (§3625 (A)(7)(a) and LCFS Protocol Subsection C.4.1(a)(9)). The stratigraphic test well and the three abandoned oil and gas wells (dry holes) will be re-entered, deepened (if necessary), and/or repurposed by completion across sandstones within the Upper Tuscaloosa / Paluxy interval. A fifth new 7,000' drill well will also be completed adjacent to the Bradford Shipp well (AP #69) in the northwestern sector of the AoR. Several of these monitor wells appear to be optimally located in the direct plume path of the carbon dioxide to be sequestered. The other monitor wells are located in and around the anticipated dimensions of the carbon dioxide plume. Real-time, continuous pressure monitoring will be performed in the wells, which will be configured to allow for fluid sampling, if needed, in the event carbon dioxide reaches the monitor wellbore.

Monitoring will also leverage the installed Whitetail Operating, LLC, Louisiana Green Fuels #1 stratigraphic test well, located approximately 5,273 feet southeast and downdip of the facility. This existing well will also be fitted with downhole pressure gauges (gauges will be referenced to ground level at each well) and will be configured to allow for fluid sampling, if needed, in the event carbon dioxide reaches the wellbore. Each well will also have a transmitter gauge at surface to continuously record tubing pressure. Experience from previously-implemented carbon capture and sequestration projects indicates that carbon dioxide will rapidly evacuate the wellbore fluids in a monitoring well that is open to the Primary Injection Zone, which will result in increased wellhead pressures due to the lighter column of gas replacing the brine fluid column.

11.1.2 Plume Monitoring Details

Indirect plume monitoring in the Upper Tuscaloosa / Paluxy Primary Injection Zone will include pulsed neutron capture logging to monitor the lateral and vertical saturation of carbon dioxide [§3625 (A)(7)(b)]. The Port of Columbia Facility is also considering the use of certain time-lapse seismic techniques, as the displacement of native brine with encroaching CO_2 within sandstones at similar project depths is well documented to produce a strong negative change in acoustic impedance (normal polarity). Leading-edge techniques for time-lapse imaging of carbon dioxide plume include time-lapse walk-away vertical seismic profiling, azimuthal vertical seismic profiling, sparse array walk-away surveys, and microseismic arrays. At a minimum, the acoustic source sites will be oriented along the maximum and minimum orientations of the modeled plume and will be adjusted following each survey results. Distributed acoustic sensing (DAS) fiber may be installed in the injection well, which will facilitate data acquisition activities. Baseline and subsequent time-lapse surveys will be processed using a technique that will resolve the differences between the surveys, which will be mapped to show the change in plume extent over time.

A microseismic array will be installed following construction of the sequestration complex. This microseismic array will deploy sensitive solar-powered geophones in a "star" pattern radiating outward from the injection wells. A Surface Linear Vibrator (SLV) seismic source will propagate acoustic waves downward (on a routine schedule) that will be reflected upward from sedimentary impedance contrasts such as those known to exist (from synthetic seismogram analysis) at various levels within the Upper Tuscaloosa and Paluxy intervals. The reflected acoustic waves will be detected by the microseismic array and processed to illuminate any changes in impedance contrasts that may occur and be attributable to the outward expansion of the CO_2 plume. The microseismic array will also record, in real time, any natural seismic event that may occur (although the likelihood of that occurrence in the AoR is very remote). Certain microseismic array sensors available for deployment have dynamic ranges of 130dB and up to 4kHz frequency bandwidth.

Table 17 Summary of analytical and field parameters for fluid sampling in the Tuscaloosa/Paluxy Injection Zone

Parameters	Analytical Methods
Tuscaloosa/Paluxy Formation	
Dissolved CO_2 gas by headspace	Gas Chromatography (GC)
Dissolved CH_4 gas by headspace	Gas Chromatography (GC)
Hydrocarbons	Gas Chromatography (GC)
Dissolved inorganic carbon	Combustion
Bicarbonate	Titration
δD CH_{24}	Gas chromatography combustion isotope ratio mass spectrometry (GC/C/IRMS)

Parameters	Analytical Methods
δC^{13} CO_2	Gas chromatography combustion isotope ratio mass spectrometry (GC/C/IRMS)
δC^{13} CH_4	Gas chromatography combustion isotope ratio mass spectrometry (GC/C/IRMS)
C^{14} CO_2	Accelerated mass spectrometry (AMS)
C^{14} Methane	Accelerated mass spectrometry (AMS)
Isotopic composition of selected major or minor constituents (*e.g.*, Sr $^{87/86,}$ S)	Multicollector-Inductively Coupled Plasma Mass Spectrometer (MC-ICPMS)
Cations: Al, As, B, Ba, Ca, Cd, Cr, Cu, Fe, K, Mg, Mn, Na, Pb, Sb, Se, Si, Ti, Zn,	ICP-MS or ICP-OES, ASTM D5673, EPA 200.8 Ion Chromatography, EPA Method 200.8, ASTM 6919
Anions: Br, Cl, F, NO_3, SO_4,	Ion Chromatography, EPA Method 300.8, ASTM 4327
Total Dissolved Solids	EPA 160.1, ASTMN D5907-10
Alkalinity	EPA 310.1
pH (field)	EPA Method 150.1
Specific Conductance (field)	EPA 120.1, ASTM 1125
Temperature (field)	Thermocouple
Hardness	ASTM D1126
Turbidity	EPA 180.1
Specific Gravity	Modified ASTM 4052
Density	Modified ASTM 4052

11.2 PRESSURE FRONT

11.2.1 Pressure Front Monitoring Location and Frequency

Table 18 presents the methods that the Louisiana Green Fuels, Port of Columbia Facility will use to monitor the position of the pressure front, including the activities, locations, and frequencies that the Port of Columbia Facility will employ.

Quality assurance procedures for these methods are presented in Appendix 1.

Direct pressure monitoring in the Upper Tuscaloosa / Paluxy Injection Zone will be used to measure the injection induced pressure buildup with time in the Sequestration Complex. Pressure monitoring using down-hole pressure/temperature gauges, will be conducted in each of the active injection wells. Gauges will be referenced to ground level at each well. These monitor points will be used to evaluate the pressure buildup with time within the injection well field. Additionally, direct pressure and temperature monitoring will be conducted in five project "In-Zone" monitoring wells completed in the Upper Tuscaloosa / Paluxy Primary Injection Zone. Two of the proposed monitor wells are optimally located in an updip location within the expected plume path of the sequestered carbon dioxide. Real-time, continuous pressure and temperature monitoring will be performed in such wells. Additionally, the already installed Whitetail Operating, LLC, Louisiana Green Fuels #1 stratigraphic test well, located approximately 5,273 feet southeast and downdip of the facility will be used for monitoring and early detection of the injected carbon dioxide. These monitor points will also be used to evaluate the pressure decay with distance away from the injection well field (i.e., monitor the pressure front). The wells will also be fitted with downhole pressure gauges (gauges will be referenced to ground level at each well) and will be configured to allow for fluid sampling, if needed.

Table 18 Summary of Monitoring Intervals Depths – Below Ground Level Reference

Monitoring Zone	In-Zone Legacy Wells (4) (feet BGL)	LGF #1 SN975841 (feet BGL)	Shipp #1 SN137738 (feet BGL)	Reynolds #1-S SN57466 (feet BGL)	New IZ Drill Well Adjacent To Shipp #1	New ACZ Drill Well Adjacent To Inj. W-
Annona Sand ACZMI Zone	-Not Monitored-	4,135 to 4,175	3,751 to 3,779	4,043 to 4,073	-Not Monitored-	~4,000 to ~4,025
Upper Tusc / Paluxy Injection Zone	4,290 to ~7,000	4,895 To 5,615	-Not Monitored-	-Not Monitored-	4,410 To ~6,300	-Not Monitored-

These measured pressures from the injection wells and the offset monitor locations will be used to assess the performance of the Upper Tuscaloosa / Paluxy Primary Injection Zone to ensure that the project is operating as permitted and these pressures also will form the basis for the periodic re-evaluation of the extent of the AoR. Recorded pressures at the injection wells and the monitor locations will be compared to model predictions to determine if actual data deviate from baseline predictions. Significant departures of actual pressure data above model predictions will be used to trigger an adaptive re-assessment of the AoR, in addition to the minimum 5-year re-assessment time frame specified for periodic review. In addition to a re-assessment of the AoR, real-time data from the overlying monitoring will also be re-evaluated to ensure continued containment of the injected carbon dioxide within the Sequestration Complex.

The locations of the injection wells (bottomhole locations) and Upper Tuscaloosa / Paluxy Primary Injection Zone monitoring wells are shown in Figure 2. The anticipated plume geometry and the AoR Pressure Front over time are presented in Module B - Area of Review and Corrective Action.

The downhole pressure and temperature data will be transmitted to the distributed control system for evaluation and storage. A data archiver may be used to permanently store data sets for later recovery.

Table 19: Minimum Gauge Specifications – Downhole Gauges

Pressure Gauge	Property	Value
Surface Readout/Downhole Pressure Gauge	Range Resolution	0 – 10,000 psi/125 ºC +/-0.1 psi/0.01 ºC
	Accuracy	+/-0.2% of full scale-Pressure +/-0.5% of full scale-Temperature
	Gauge Stability	+/-0.2% of full scale per Annum

11.2.2 Pressure Front Monitoring Details

The Port of Columbia Facility will measure injection pressure buildup in the Upper Tuscaloosa / Paluxy Injection Zone in each of the installed facility wells. Additionally direct monitoring of the pressure buildup at distance away from the point of injection will be monitored with five in-zone monitor wells:

1) Whitetail Operating, LLC, Louisiana Green Fuels #1 stratigraphic test well (SN975841), located 5,273 feet southeast and down dip of the injection wells, and
2) New In-Zone Drill Well located adjacent to Bradford-Brown Trust Shipp No. 1 (SN137783) well, located approximately 10,152 feet north and up dip of the facility;
3) Bass Keahey No.1 (SN165395) well, located approximately 13,730 feet northeast and up dip of the facility;
4) Southern Carbon USA No. 1 (SN34225) well, located approximately 37,850 feet east- southeast of the facility; and

5) Murphy Meredith No. 1 (SN23356) well, located approximately 28,150 feet east-southeast of the facility.

These wells will provide control/monitor points along the developed pressure decay curve extending outward in the injected sandstones. In addition to the In-zone monitoring, shallower monitoring of the Annona Sand (ACZMI Monitor Zone) will provide early detection of any potential upward movement of carbon dioxide and/or formation brines out from the Tuscaloosa/Paluxy Injection Zone. The Annona Sand monitoring provides a "first line of defense" within the Sequestration Complex for protection of the USDWs. Collectively, the direct monitoring program ensures protection of USDWs above the Sequestration Complex.

Table 20: Pressure front monitoring activities

Target Formation	Monitoring Activity	Monitoring Location(s)	Spatial Coverage	Frequency
Upper Tuscaloosa / Paluxy	Downhole pressure monitoring	Facility Injection Wells	Well Field	Real time daily read out
Upper Tuscaloosa / Paluxy	Downhole pressure monitoring	2 In-Zone Updip Monitor Wells; 3 other Monitor Wells in Pressure Front	Over area of review	Real time daily read out
Annona	Downhole pressure monitoring	3-4 dedicated offset monitoring wells	Over area of review	Real time daily read out

12.0 SURFACE AND NEAR-SURFACE MONITORING

The Louisiana Green Fuels, Port of Columbia Facility will monitor the surface and near-surface for potential carbon dioxide leakage, in accordance with applicable regulations and guidelines set forth by the State of Louisiana per LAC 43:XVII §3625(A)(8) and LCFS Protocol Subsection C.4.1(a)(11).

The primary objective of the surface and near-surface monitoring program is to confirm containment of carbon dioxide within the deep subsurface to: 1) demonstrate no endangerment to public health or the environment, 2) confirm conformance with the proposed injection plan, and 3) validate calculations of total sequestered carbon dioxide volumes within the deep subsurface. Accordingly, the proposed surface and near-surface program includes the following elements: i) determine baseline physical and chemical conditions and natural background variability at the surface above the storage complex, ii) detect changes in conditions that might be indicative of an environmental impact and therefore warrant further investigation, iii) attribute those changes to either natural variability or actual anthropogenic impacts, and iv) if needed, assist in the quantification and subsequent remediation of the potential carbon dioxide leak.

The proposed surface and near-surface monitoring program consists of three key monitoring components during the baseline and/or operational phases of the project: 1) atmospheric monitoring, 2) ecosystem stress monitoring, and/or 3) soil gas monitoring. These monitoring components will allow for early detection of potentially anomalous levels of carbon dioxide and other gases at the surface and/or near-surface. Details regarding each monitoring component are provided below.

12.1 ATMOSPHERIC MONITORING

Atmospheric monitoring may be used to identify carbon dioxide concentrations above ambient background levels and help determine locations of potential carbon dioxide leaks (NETL, 2009). Per the LCFS Protocol Subsections C.2.5(c)&(d) and C.4.3.2.2(d)&(e), continuous and intermittent atmospheric monitoring at the surface above the storage complex during the baseline and operational phases of the project will be conducted to i) define the baseline physical and chemical atmospheric conditions at the surface above the storage complex, ii) characterize natural background variability, including seasonal and diurnal trends, and iii) detect potential atmospheric carbon dioxide leakage and/or potential movement of carbon dioxide that may endanger any USDW, including the most important local USDW, the MRVA.

Continuous air monitoring will be conducted utilizing eddy covariance flux measurement techniques via an advanced, stationary LI-COR® air quality and weather observation tower, equipped with eddy covariance (EC) and bio meteorological detectors. Intermittent atmospheric monitoring will be conducted at additional locations throughout the Area of Review utilizing a portable, handheld Landtec® infrared detector to supplement the continuous EC system monitoring data.

12.1.1 Monitoring Location and Frequency

The advanced LI-COR® EC system has an aerial coverage of up to 2- to 2.5-mile radius; therefore, a single tower set to a height of approximately 30 feet will be positioned at the location of the initial injection well (INJ #1) to provide site-wide monitoring of the Area of Review (see Figure 3). The EC system will collect data on a continuous basis during the 1- to 2-year baseline period and the estimated 20-year operational period.

Intermittent ground-surface gas concentrations will be manually collected monthly and quarterly during the baseline and operational phases, respectively, by a qualified vendor. Intermittent atmospheric monitoring will be conducted at locations of proposed injection wells, monitoring wells, and soil gas monitoring sites.

Due to the relative absence of deep artificial penetrations (e.g., oil and gas dry holes; see Figure 3) and other potential point sources (e.g., faults; see Section 2.0), additional continuous or intermittent atmospheric monitoring locations are not anticipated. During the post-injection site care phase, supplemental continuous and/or intermittent atmospheric monitoring may be considered as part of a post-injection site care leak detection strategy, based upon final approval of the demonstration of plume stability.

12.1.2 Analytical Instrumentation and Procedures

As further described below, LI-COR® EC systems are a low-impact, non-invasive technology that include precision, high-speed instruments capable of analyzing various near-surface and surface parameters (e.g., total gas concentrations, ambient carbon dioxide concentrations). The high-frequency data collected by the EC system are used to facilitate automated calculations of the net gas exchange (flux) between the ecosystem and the atmosphere. The EC tower will be fitted with the following instrumentation to analyze total gas concentrations, meteorological conditions, and soil conditions:

- LI-7500DS open-path CO_2/H_2O infrared gas analyzer and pressure transducer (barometric pressure);
- LI-7700 open-path CH_4 analyzer;
- LI-7820 N_2O trace gas analyzer;
- Gill R3-50 3-axis ultrasonic anemometer for the measurement of wind direction and speed; and
- Biomet sensors for the analysis of soil moisture and temperature (Hydra Probe II soil sensor), soil heat flux (Hukseflux HFP01 thermal sensor); relative humidity (Vaisala HUMICAP® 180R sensor), precipitation (TR-525M Rainfall Sensor), and ambient temperature (HMP155 probe), and net radiation across the surface (Kipp & Zonen NR-Lite).

The raw data from the EC system will be processed utilizing EddyPro® software and the on-site SmartFlux® System to derive representative real-time flux data for the Site. Tovi® Software will then be utilized to post-process the EC flux data, which will provide consistent, reproducible, and transparent data collection.

The Landtec® portable, handheld GEM2000 landfill gas analyzer is a simple, direct measurement technology that is capable of analyzing for ambient CO_2, CH_4, and O_2 concentrations (as percent volume) in the atmosphere and requires no data processing or post-processing. The portable gas analyzer will be calibrated regularly to a gas standard according to manufacturer specifications per the attached QASP.

Local ambient air carbon dioxide concentrations can vary spatially and temporally depending on factors including vegetation, changes in soil respiration, changes in atmospheric pressure, and the presence of other industrial processes (NETL, 2009). In addition, global atmospheric carbon dioxide concentrations are projected to rise an additional 9% over the next 18 years, from 412.5 ppm presently to ~450 ppm in 2040 (NASA, 2022). To better identify false-positive carbon dioxide detections, the presence of natural (e.g., soil and vegetation) and anthropogenic (e.g., industrial processes) sources of carbon dioxide in the vicinity of the site will need to be well understood during the life of the project (NETL, 2009). A routine inventory of (i) potential anthropogenic carbon dioxide sources unrelated to carbon dioxide leakage from the target reservoir (e.g., nearby industrial facilities, pipelines), (ii) nearby oil and gas-related production or injection wells, and (iii) an assessment of nearby land use classifications and recent development activities will be conducted on an annual basis within a 4-mile radius of the initial injection well. As discussed below in Section 12.3, natural near-surface sources of carbon dioxide (e.g., microbial respiration, carbonate dissolution, etc.) will be characterized during baseline soil gas monitoring and may be further assessed at any point during the operational phase of the project, if needed.

Continuous and intermittent atmospheric monitoring data collected during the operational phase will be utilized to detect potential anomalous changes in surface conditions, which will be identified as an exceedance of a leakage detection threshold – to be defined after baseline background variability has been assessed (and with consideration of projected global increases in atmospheric carbon dioxide concentrations over time). If continuous and/or intermittent atmospheric monitoring data indicate a statistically significant departure between observed and baseline/seasonal parameter patterns in the surface air conditions, the anomaly will be further evaluated by one or more of the following responses: 1) detailed inspection and calibration of the EC tower and instrumentation; 2) detailed evaluation of potential effects of recent changes, if any, to the land use, vegetative conditions, local carbon dioxide sources, artificial penetrations, CCS-related operations, etc.; 3) supplemental testing of the atmosphere, targeting injection wells, monitoring wells, and other potential point sources; 4) testing of the soil gas to determine the presence of natural and/or anthropogenic carbon dioxide; and 5) if needed, attribution of the carbon dioxide detection to either natural variability or an anthropogenic source. If it is determined that the anomaly appears to be related to a potential carbon dioxide leak from the target reservoir, additional testing of the USDW may be conducted. If further testing confirms potential leakage into the strata overlying the Confining Zone, then injection operations will cease and the procedures set out in the "*Emergency Remedial and Response Plan*" will be triggered.

The elements of the atmospheric monitoring program may be modified throughout the baseline and operational phases of the CCS project, as needed, as more data and information become available for the Site.

12.2 ECOSYSTEM STRESS MONITORING

Per the USEPA UIC Program Site Characterization Guidance Subsection 2.3.11 and LCFS Protocol Subsections C.2.5(c)(3) and C.2.5(d)(1)(A), site characteristics including vegetation type and density in and around the storage complex should be defined during the baseline phase of the CCS project to establish the background vegetative conditions at the surface. Additionally, per LCFS Protocol Subsection C.4.3.2.2(f), ecosystem stress monitoring must be conducted in the form of annual vegetation surveys to measure potential stress resulting from elevated carbon dioxide in soil. As further discussed below, seasonal composite satellite images will be assessed retrospectively for three years prior to the end of baseline, and annually thereafter during operation. These evaluations will assess key metrics (e.g., biomass and vegetation health/stress) pre-injection and provide a mechanism for potential carbon dioxide release detection once the injection phase commences. To capture vegetation type and diversity metrics, a limited ground-based vegetation survey will be conducted during baseline to serve as a reference point if a future anomaly occurs, requiring ground-based verification. In addition to this temporal comparison of vegetative conditions, a spatial comparison will be conducted using surrounding pre-selected reference areas to account for other anomalous factors that may impact vegetation conditions within each assessment year.

12.2.1 Technology Selection

Satellite imagery will be used to evaluate vegetative conditions at the surface of the storage complex and its surrounding reference areas. This technology provides a mature, common, and frequently updated source of information for evaluating surface conditions. Satellite data will be acquired from high-resolution and publicly available imaging platforms including Landsat 8 and

9 where data will be provided by the National Aeronautics and Space Administration (NASA) and the United Stated Geological Survey (USGS), and Sentinel-2 provided where data will be obtained from the European Space Agency (ESA). Qualitative and quantitative assessments of satellite imagery and derived indices will be performed to assess key vegetative health metrics such as plant biomass and health/stress. Qualitative assessments will consist of analyzing and comparing standard three-color composite images (e.g., natural color and false color) temporally, to baseline conditions, and spatially, to reference areas. Indices such as the Normalized Difference Vegetation Index (NDVI) and Enhanced Vegetation Index (EVI) will be utilized as quantitative indicators of vegetation conditions.

12.2.2 Reference Areas

Three reference areas surrounding the AoR will be used to compare vegetative conditions spatially per assessment timeframe (see Figures 3 and 4). These areas are representative of conditions outside the AoR and will thus serve as a comparison to vegetation not overlying the projected carbon dioxide plume. Three distinct reference areas, as opposed to one, were defined to enable statistically robust comparisons to be made between surrounding areas and the AoR and examine trends as a function of distance. Each reference area was selected based on characteristics that allow for direct comparisons to the AoR including size, EPA-defined Level III and Level IV Ecoregion designations, and land use characteristics. Each reference area will have a surface area approximately equal to the AoR (i.e., for a projected 1.5-mile radius plume, approximately 7 square miles). Reference areas will capture similar Ecoregions including Level III regions (the Mississippi Alluvial Plain and South-Central Plains) and Level IV regions (the Arkansas/Ouachita River Backswamps, Arkansas/Ouachita River Holocene Meander Belts, and Southern Tertiary Uplands) (see Figure 4). Finally, reference areas will capture similar land use characteristics as that of the AoR where land is primarily agricultural and/or undeveloped with few residential parcel properties (see Figure 3).

12.2.3 Monitoring and Assessment Methodology

Monitoring and assessment of ecological stress through vegetative conditions will take place at the AoR and the surrounding reference areas during the baseline and injection phases of the CCS project. A ground-based vegetation survey, satellite imagery, and imagery data processing products will measure vegetative conditions through key metrics pre-injection and be capable of detecting any anomalous changes to vegetation during injection.

A baseline analysis will consist of one focused ground-based vegetation survey during the peak growing season of spring, focusing on the key metric of primary plant diversity and type. The survey will be conducted utilizing a "quadrant"-like approach, where similar vegetation and terrain areas will be characterized by their primary vegetation types in the AoR and surrounding reference areas, pending appropriate land access agreements. Additionally, as part of the baseline analysis, satellite imagery assessments will be conducted for three years of data retrospectively from the end of the baseline phase to capture both seasonal and annual variations of pre-injection vegetative conditions. During the operational phase, a similar satellite imagery analysis will take place on an annual basis. All available images will be processed into quarterly composite images, representative of each season. From these composite images, a variety of post-processing techniques will be used to develop various indices that can be used to quantify key vegetation-related attributes such as plant biomass and health/stress. Standard 3-color composite images (e.g., true color, false color) will support a qualitative analysis of vegetative conditions where significant anomalies in vegetation can be initially and quickly screened. Additionally, quantitative metrics will be calculated for satellite-derived images using standard algorithms developed by NASA, USGS, and ESA. NDVI, as well as a variety of other standard indices, will be used to quantify vegetation by greenness which provides information on plant density, biomass, and health.

Operation phase imagery and derived indices will be compared temporally to the three-year baseline satellite data, and spatially to surrounding reference areas in that same year. Since vegetative stress signals due to a carbon dioxide release have various potential confounding factors (e.g., droughts, floods, freezes, plant diseases, insect infestations, agricultural crop rotations, etc.), characterizing an anomaly attributed to injection will follow a tiered approach. As this tiered approach progresses, characterization of potential anomalies become more granular. If in an early tier no anomaly is detected, progression to the second and third tiers is not necessary. However, if moving through all three tiers is necessary and the anomaly cannot be attributed to an injection-related factor, further field verification may be conducted to assess the vegetative state of the Area of Review. The tiered "Anomaly Characterization" approach is further described below.

1) Anomaly Characterization Tier 1
    - Qualitative assessment of standard 3-color composite images from current year to baseline conditions and surrounding reference areas.
    - Quantitative analysis of key satellite-derived indices such as NDVI and EVI from current assessment year to baseline conditions and surrounding reference areas.
2) Anomaly Characterization Tier 2 (if anomaly is detected in Tier 1 analysis)
    - Statistically evaluate ancillary data (e.g., climate indices, weather, local flux measurements) from various sources (e.g., local EC tower, the National Oceanic and Atmospheric Administration (NOAA), United States Department of Agriculture (USDA), United States Army Corp of Engineers (USACE), the National Weather Service, and United States Fish and Wildlife Service (USFWS)) to potentially attribute anomaly source to a non-injection related process.
    - Conduct an initial site area characterization analysis to determine if any non-injection-related factors not well-characterized by the available ancillary data have presented in the current assessment year. Such non-injection-related factors may include a unique crop rotation, significant land use changes, other anthropogenic factors, etc.
3) Anomaly Characterization Tier 3 (if anomaly in Tier 2 cannot be attributed to an ancillary source)
    - Retrospective analysis of the Area of Review and surrounding reference areas beyond that of the baseline assessment (e.g., 10-yr retrospective).
    - If Tier 1 anomalies are within range of historical variability (i.e., 10^{th}-90^{th} percentile), the anomalies will not be attributed to carbon dioxide release.

If further verification is required (i.e., all three tiers were assessed and no anomaly source was defined), then a ground-based site survey may be conducted to verify and validate the influence of CCS activities, if any, to this anomaly, pending appropriate land access agreements. Baseline limited vegetation survey data may be referenced to compare vegetation type and diversity metrics to the current assessment year.

The elements of the ecosystem stress monitoring program may be modified throughout the baseline and operational phases of the CCS project, as needed, as more data and information become available for the facility site.

12.3 SOIL GAS MONITORING

Soil gas data can be used to quantify the bulk chemical composition of gases in the near-surface soil layers and discern the source(s) of detected carbon dioxide as being sourced from either natural or anthropogenic sources (NETL, 2009). Per the LCFS Protocol Subsections C.2.5(c)&(d)&(e) and C.4.3.2.2(g), the requirement for continuous and/or intermittent soil gas monitoring is contingent upon one or more of the following conditions:

1) Results of the site-specific risk assessment, pursuant to LCFS Protocol Subsection C.2.2, and/or computational modeling, pursuant to LCFS Protocol Subsection C.2.4.1, indicate that "any property of the storage complex, groundwater, overburden, or surface projection of the storage complex" may "potentially be impacted by injection operations" (CARB, 2018).
2) Results of baseline or subsequent "deep subsurface or atmospheric monitoring suggests that atmospheric carbon dioxide leakage may occur or has occurred," (CARB, 2018) or that "movement of the carbon dioxide could endanger a USDW" (40 CFR §146.90(h)).

At this site, it is anticipated that soil gas monitoring will not be *required* during the baseline and operational phases of the project, due to the following site-specific conditions:

1) The project area is free of faulting at seismic resolution across either the Injection Zone or the Upper or Lower Confining Zones. No faulting was observed in wells within the AoR.
2) No artificial penetrations (*e.g.,* legacy oil and gas test or SWD wells) within a 1.5-mile radius of the initial Injection Well (to be drilled onsite at the facility) penetrated the Upper Tuscaloosa / Paluxy Formations, with the exception of the following oil and gas wells (dry holes):
    a. Artificial Penetration No. 69 - Bradford-Brown Trust Shipp No. 1 (SN137738), a dry hole that had an original reported depth of 4,519 feet below ground level but is

scheduled to be re-entered, plugged back, cased and converted to an Annona Sand ACZMI monitoring well, and

b. Artificial Penetration No. 137 - Whitetail Operating, LLC, Louisiana Green Fuels #1 stratigraphic test well (SN975841), which is scheduled to be converted to an In-Zone monitoring well for the Upper Tuscaloosa / Paluxy Primary Injection Zone, and

c. Artificial Penetration No. 129 - Magnolia Odie N. Reynolds No. S-1 (SN57466), which has a reported depth of 4,118 feet below ground level (just below the base of the Annona Sand; 700 feet above the top of the Upper Tuscaloosa) but is scheduled to be re-entered, deepened to 4,200 feet, cased and repurposed as an Annona Sand ACZMI monitoring well.

3) The presence of numerous thick confining layers, such as the Cane River and Tallahatta Formations, the Midway Shale (the Secondary Upper Confining Zone), the Upper Selma Chalk, the Middle Chalk, and the Austin Chalk / Eagleford Equivalent (the Primary Upper Confining Zone) (a combined thickness of approximately 1,600 feet), as well as the tight limestones of the Washita-Fredericksburg Formation and the numerous interbedded shales of the Paluxy Formation, combine to provide an optimal quality of containment.

4) The alternating layers of saline sandstones and impermeable shales within the Wilcox Formation serve as a series of alternating buffer aquifers situated between the top of the Upper Confining Zone and the lowermost USDW; as such, the Wilcox Formation serves as a "second line of defense" for protection of the USDWs.

It should be noted that several natural processes in the near surface soil layers (e.g., biological respiration, microbial oxidation of methane, etc.) can contribute to significant temporal variability in carbon dioxide concentrations. Background carbon dioxide concentrations and isotopic compositions in soils are largely "dependent on exchange with the atmosphere, organic matter decay, uptake by plants, root respiration, deep degassing, release from groundwater due to depressurization, and microbial activities (Oldenburg and Lewicki, 2004)" (EPA, 2013b). Therefore, some component of soil gas monitoring during the baseline phase of the project is useful to (i) define the baseline molecular and isotopic compositions of the shallow soil gas, and (ii) characterize natural background variability, including seasonal and diurnal trends. The results of the baseline soil gas monitoring may then be used for future reference and comparison to operational soil gas monitoring, if needed, to assist in the detection, validation, and quantification of potential carbon dioxide leakage. To this end, a limited intermittent soil gas monitoring program will be conducted during baseline monitoring operations utilizing permanent soil gas probes as an active [whole air] sample collection method.

12.3.1 Monitoring Location and Frequency

Permanent subsurface soil gas probes will be installed at 12 to 15 representative locations throughout the surface projection of the AoR. The baseline soil gas monitoring network will depend on appropriate land access agreements, and will include, at a minimum, three probe sites in the vicinity of the initial injection well site, and one probe site at each of the three proposed injection well sites, the five Upper Tuscaloosa / Paluxy In-Zone monitoring wells, and the three Annona Sand Above-Confining Zone monitoring wells. One or more probes may also be installed within the ecosystem stress monitoring reference areas. The remaining locations of the soil gas probe sites will be determined as more data and information become available for the site during the baseline and operational phases of the project. It is anticipated that the baseline soil gas monitoring network will be utilized during the operational phase as well, as needed.

Soil gas samples will be collected manually from the soil gas probe sites on a monthly and quarterly basis during the 1- to 2-year baseline and estimated 20-year operational phases, respectively. During the post-injection site care phase, supplemental soil gas monitoring may be considered as part of a post-injection site care leak detection strategy, based upon final approval of the demonstration of plume stability.

12.3.2 Soil Gas Probe Construction Procedures

Soil gas probe sites will be installed to a depth of approximately 10 feet below ground level, dependent upon the depth to shallow groundwater and presence of low-permeability (e.g., clay) zones, utilizing traditional direct-push or hand-auger drilling technologies and equipment. During borehole advancement, a continuous soil core will be collected and logged in accordance with Unified Soil Classification System (USCS) guidelines to determine soil type. Additionally, soil samples will be collected in general accordance with EPA Method LSASDPROC-300-R4 (EPA, 2020a) for the laboratory analysis of soil moisture and salinity according to Standard Methods (SM) 2540G and 2520B, respectively, and for total organic carbon (TOC) content according to the Walkley Black 9060A method. Table 21 below identifies the parameters to be monitored and the analytical methods the Louisiana Green Fuels, Port of Columbia Facility will use for the soil samples.

Soil gas probes will be constructed in general accordance with operating procedures set forth in EPA Method LSASDPROC-307-R4 (EPA, 2020b), and will consist of stainless-steel vapor implant points attached securely to 1/8th-inch Nylaflow® tubing and lowered to the bottom of the borehole. A sand pack using U.S. mesh interval 20/40 sand will be installed to approximately 6-inches above the vapor implant point. The remainder of the borehole will be backfilled with granular bentonite to the ground surface and hydrated to create an annular seal. The upper 1-foot of tubing will be encased within 1-inch diameter, schedule 40 polyvinyl chloride (PVC) pipe at the surface. The tubing will be threaded through a drilled, tight-fitting PVC slip cap and sealed from atmospheric air utilizing a stainless-steal Swagelok® capping fitting. The tubing at the surface will be concealed within a 6-inch steel, flush mount manway, individually installed with a concrete pad, for protection and easy accessibility. Detailed soil gas probe location and construction information will be recorded at each site.

12.3.3 Soil Gas Sampling and Testing Methods

Soil gas sampling will be conducted in general accordance with operating procedures set forth in EPA Method LSASDPROC-307-R4 (EPA, 2020b). During sample collection, a vacuum will be applied to the tubing on the surface to first purge the full length of the tubing, and second collect a soil gas sample in a 0.3-L IsoBag® Gas Bag using 60 mL gas-tight syringes, equipped with a 3-way valves. During soil gas sampling, a leakage test will be conducted by releasing helium gas as a tracer gas within a shroud over each soil gas sampling site.

Soil gas samples will be submitted for the laboratory analysis of various geochemical methods, including natural tracers (isotopes of carbon [C]). Table 21 below identifies the parameters to be monitored and the analytical methods the Louisiana Green Fuels, Port of Columbia Facility will use for the soil gas samples.=

Table 21: Summary of analytical parameters for soil and soil gas samples

Parameter	Analytical Method
Surface Soil	
Percent Moisture	ASTM D2216
Fraction Organic Carbon	ASTM D2974-87
Salinity	Total Soluble Salts (TSS)
Soil Gas	
CO_2, CH_4, N_2, O_2	Gas chromatography
C1-C5 Hydrocarbons	Gas chromatography
Helium	Gas chromatography
$\delta^{13}C$ of CO_2 and CH_4	Gas chromatography/ combustion/ isotope ratio mass spectrometry
C^{14} of CO_2 and CH_4	Accelerated mass spectrometry
δD of CH_4	Gas chromatography/ combustion/ isotope ratio mass spectrometry

Following baseline monitoring, protocols and thresholds for carbon dioxide leak detection will be developed for the operational phase of the project, which will include process-based methods utilizing gas ratios of CO_2, O_2, N_2, and CH_4 and isotopic compositions of CO_2 and CH_4.

An anomalous detection of carbon dioxide above background levels in soil gas "does not necessarily demonstrate that USDWs have been endangered, but it may indicate that a leakage pathway or conduit exists" (EPA, 2013b). Therefore, if it is determined that a statistically significant departure between observed and baseline/ seasonal parameter patterns appears to be related to a potential carbon dioxide leak from the target reservoir, additional testing of the atmosphere, and the USDW may be conducted. If further testing confirms potential leakage into the strata overlying the Confining Zone, then injection operations will cease and the procedures set out in the *"Emergency Remedial and Response Plan"* will be triggered.

The elements of the soil gas monitoring program may be modified throughout the baseline and operational phases of the project, as needed, as more data and information become available for the Site.

12.3.4 Analysis Procedures and Chain of Custody

Soil and soil gas samples will be collected into the appropriate lab-supplied, method-specific sample containers, properly preserved (as needed), and shipped within 24 hours of collection for analysis by third party laboratories accredited by the Louisiana Department of Environmental Quality (https://internet.deq.louisiana.gov/portal/divisions/lelap/accredited-laboratories) using standardized procedures. Detection limits will be dependent on equipment facilitated for the analytical methods by the selected qualified vendor and meet the minimum levels set forth in Appendix 1.

The sample chain-of-custody procedures will be dependent on vendor selection as the vendor will assume custody of the samples. The procedures will document and track the sample transfer to laboratory, to the analyst, to testing, to storage, and to disposal (at a minimum). A sample chain-of-custody procedure-s is illustrated in the attached QASP (Appendix 1).

The initial parameters identified in Table 21 may be revised and include additional components for testing dependent on the initial geochemical evaluation.

13.0 SEISMICITY MONITORING

Natural seismicity in the project area is exceedingly low, with no recorded earthquakes in either Caldwell Parish or the immediately adjacent parishes (https://earthquake.usgs.gov/earthquakes/search/). The closest recorded earthquakes are located more than 125 kilometers away from the Port of Columbia Facility, near the Arkansas-Louisiana State Line.

Induced seismicity risk is also low because of the high transmissivity of the Upper Tuscaloosa / Paluxy sandstones and the relative lack of very brittle rocks within, above, or below the Upper Tuscaloosa / Paluxy Injection Zone. Previous measurements of induced seismicity in Department of Energy supported research projects along the Gulf Coast (the Mississippi Cranfield Project, for example), have not detected induced seismicity events resulting from the injection of large volumes of supercritical carbon dioxide.

Notwithstanding the very low risk of such occurrences, a microseismic array will be installed following construction of the sequestration complex. As described previously in Section 11.1.2, this microseismic array will deploy sensitive solar-powered geophones in a "star" pattern radiating outward from the injection wells. The microseismic array will record, in real time, any natural seismic event that may occur. It will also be capable of tracking plume growth and detecting any induced fracturing that might occur. The microseismic array will be used and maintained throughout the operational phase of the project.

14.0 APPENDIX: QUALITY ASSURANCE AND SURVEILLANCE PLAN

The QASP is submitted as Appendix 1 to this Testing and Monitoring Plan.

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FIGURES

Appendix 1: Quality Assurance and Surveillance Plan

CLASS VI INJECTION WELL: APPENDIX 1 - QUALITY ASSURANCE AND SURVELLIANCE PLAN

Appendix to the Testing and Monitoring Plan –
LAC 43:XVII §3625 & LCFS Protocol Subsection C.4.1(a)

STRATEGIC BIOFUELS
LOUISIANA GREEN FUELS PORT OF COLUMBIA FACILITY

Prepared By:
GEOSTOCK SANDIA, LLC

Revision No. 1
April 2024

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TITLE AND APPROVAL SHEET

This Quality Assurance and Surveillance Plan (QASP) is approved for use and implementation at Louisiana Green Fuels – Port of Columbia Facility. The signatures below denote the approval of this document and intent to abide by the procedures outlined within it.

Add lines as needed to include all appropriate staff.

Signature [INSERT TYPED NAME] [INSERT TITLE]	Date
Signature [INSERT TYPED NAME] [INSERT TITLE]	Date
Signature [INSERT TYPED NAME] [INSERT TITLE]	Date

DISTRIBUTION LIST

The following project participants will receive the completed Quality Assurance and Surveillance Plan (QASP) and all future updates for the duration of the project.

Distribution:

Add lines as needed to include all appropriate staff.

[INSERT TYPED NAME] [INSERT TITLE]	Date
[INSERT TYPED NAME] [INSERT TITLE]	Date
[INSERT TYPED NAME] [INSERT TITLE]	Date

A. PROJECT MANAGEMENT

A.1. Project/Task Organization

A.1.a/b. Key Individuals and Responsibilities

The Louisiana Green Fuels project is led by Strategic Biofuels and includes participation from several subcontractors. The Testing and Monitoring activities responsibilities will be shared between Louisiana Green Fuels and their designated subcontractors, and conducted in the following subcategories:

I) Sampling and analysis of the carbon dioxide stream, required at a frequency that will yield information on the chemical composition and physical characteristics of the injectate [§3625 (A)(1)].

II) Monitoring of operational parameters (injection pressure, rate, and volume, pressure on the annulus, and annulus fluid volume) through the use of continuous recording devices [§3625 (A)(2)].

III) Corrosion monitoring of injection well materials, required on a quarterly basis [§3625 (A)(3)].

IV) Monitoring of ground water quality and geochemical changes above the confining zone(s), at a site-specific frequency and spatial distribution [§3625 (A)(4)].

V) External Mechanical Integrity Testing (MIT), at least once per year [§3625 (A)(5)].

VI) Pressure fall-off testing, at least once every five years [§3625 (A)(6)].

VII) Testing and monitoring to track the extent of the carbon dioxide plume and the presence or absence of elevated pressure (e.g., pressure front) [§3625 (A)(7)].

VIII) Continuous and intermittent surface air, and intermittent soil gas monitoring [§3625 (A)(8) (State of Louisiana); CARB LCFS Subsections C.2.5 and C.4.3.2.2; USEPA, 2013a;b].

IX) Baseline soil sampling for site characterization [CARB LCFS Subsection C.4.3.2.2; USEPA, 2013a, Subsection 2.3.11].

X) Ecosystem stress monitoring in the form of vegetation surveys [CARB LCFS Subsections C.2.5 and C.4.3.2.2; USEPA, 2013a, Subsection 2.3.11]

XI) Any additional monitoring that the Commissioner determines to be necessary to support, upgrade, and improve computational modeling of the AoR evaluation under §3615 (B)(3) and to determine compliance with standards under §3619 [§3625 (A)(9)].

A.1.c. Independence from Project QA Manager and Data Gathering

The majority of the physical samples collected and data gathered as part of the Monitoring, Verification, and Accounting (MVA) program will be analyzed, processed, or witnessed by third parties independent and outside of the project management structure.

A.1.d. QA Project Plan Responsibility

Louisiana Green Fuels is responsible for developing, maintaining and distributing an official, approved Quality Assurance project plan. Louisiana Green Fuels will periodically (no less than once every five years) (CARB, 2018, p. 79) review the Quality Assurance and Surveillance Plan (QASP) and consult with the U.S. Environmental Protection Agency (USEPA) and the California Air Resources Board (CARB) if/when changes to the plan are warranted.

A.1.e. Organizational Chart for Key Project Personnel

Figure 1 shows the organization structure of the project. Louisiana Green Fuels will provide to the Underground Injection Control (UIC) Commissioner a contact list of individuals fulfilling these roles.

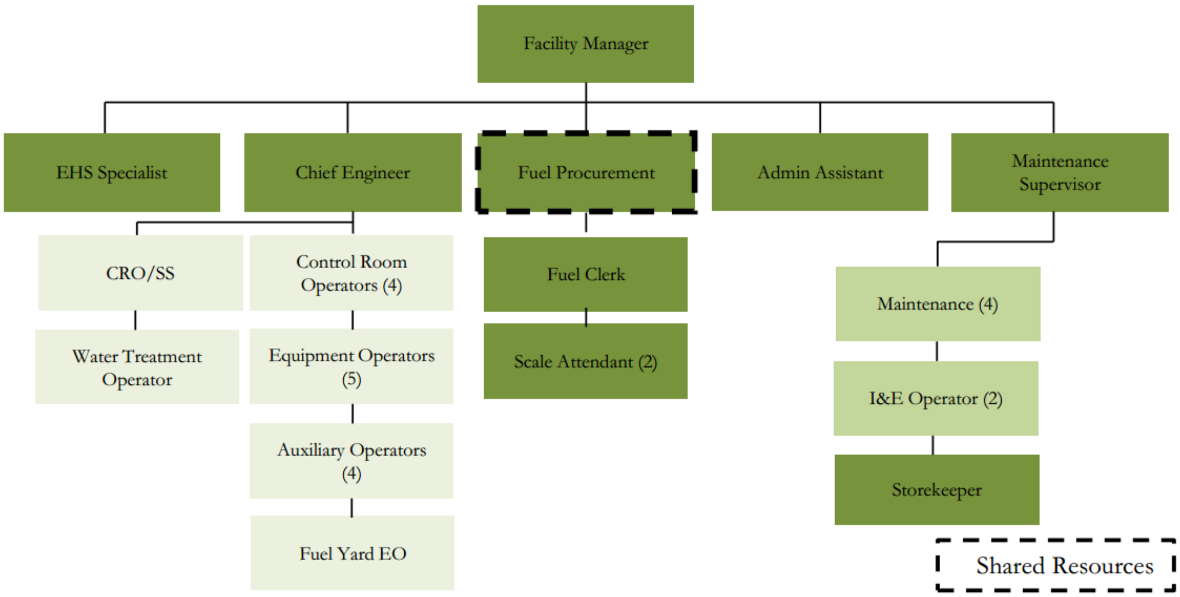

Figure 1. Louisiana Green Fuels Organization.

A.2. Problem Definition/Background

A.2.a. Reasoning

This QASP is aimed at supporting the Testing and Monitoring (T&M) plan included in the Class VI permit request submitted by Louisiana Green Fuels for the geological sequestration of the carbon dioxide produced at their Louisiana Green Fuels Port of Columbia Facility in Caldwell Parish, Louisiana. The T&M plan addresses the requirements of the Class VI Rule specifications and the Carbon Capture and Sequestration (CCS) Protocol under the USEPA and CARB Low-Carbon Fuel Standard (LCFS) (Subsections C.2.5 and C.4.3.2.2; CARB, 2018), respectively, and employs best practices developed in similar CO_2 injection and storage projects.

The primary goal of the Monitoring, Verification, and Accounting (MVA) program is to demonstrate that project activities are protective of human health and the environment. This QASP was developed to help achieve this goal and ensure the quality standards of the Testing and Monitoring program meet the requirements of the U.S. Environmental Protection Agency's (USEPA) Underground Injection Control (UIC) program for Class VI wells and the California CCS LCFS protocol. A robust risk-based MVA program has been developed for the Louisiana

Green Fuels project based on the knowledge and experience gained through the analysis of the comprehensive dataset acquired in the stratigraphic test well and the preparation of the permit application modules which assure with a high level of confidence that the storage units will be capable to accept and permanently retain the injectate.

The Louisiana Green Fuels project's MVA program has operational monitoring, verification, and environmental monitoring components. Operational monitoring will be used to ensure safety with all procedures associated with fluid injection and monitor the response of storage units and the movement of the CO_2 plume. Key monitoring parameters include the pressure of injection well tubing and annulus, storage units, above seal strata, and lowermost underground source of drinking water (USDW) reservoir. Other monitoring parameters include injection rate, total mass and volume injected, injection well temperature profile, and passive seismic. The verification component will provide information to evaluate if leakage of CO_2 through the caprock is occurring. This includes pulse neutron logging, pressure, and temperature monitoring. The environmental monitoring component will determine if the injectate is being released into the shallow subsurface or biosphere. This monitoring includes pulse neutron logging, ground water, surface air, soil gas, and ecosystem stress monitoring.

A.2.b. Reasons for Initiating the Project

The T&M plan goals are to comply with the Class VI Rule and CARB LCFS protocols and document via targeted data collection that the prediction made during subsurface characterization and modeling are correct and that the CO_2 and brine solutions will remain in the Injection zone, isolated from the USDW, near-surface and atmosphere.

A.2.c. Regulatory Information, Applicable Criteria, Action Limits

The Class VI Rule and CARB LCFS Protocol require owners or operators of Class VI injection wells to perform several types of activities during the lifetime of the project in order to ensure that each injection well maintains its mechanical integrity, that fluid migration and the extent of pressure elevation are within the limits described in the permit application, and that underground sources of drinking water (USDWs) are not endangered. These monitoring activities include Mechanical Integrity Tests (MITs), injection well testing during operations, monitoring of ground water quality above the Confining zone, tracking of the CO_2 plume and associated pressure front, surface air, soil gas, and ecosystem stress monitoring. This document details the measurements that will be taken as well as the steps to ensure that data quality is such that data can be used with confidence in making decisions during the life of the project.

A.3. Project/Task Description

A.3.a/b. Summary of Work to be Performed

Table 1 describes the testing and monitoring tasks, including locations, analytical techniques, methods, responsible parties, and purposes. Note that the testing frequency is provided in the T&M plan. Tables 2 and 3 summarize the instrumentation and geophysical surveys, respectively.

Table 1. Summary of Testing and Monitoring.

Activity	Location(s)	Method	Analytical Technique	Lab/Custody	Purpose
Carbon dioxide stream analysis	Flowline	High-pressure vessel	Standard laboratory gas analyses	lab accredited by the LDEQ	Monitor injectate quality
Injection rate/volume	Injection well(s) – After compressor	Flow meter	Direct continuous measurement	N/A	Monitor rate/volume
Injection pressure	Injection well(s) – Wellhead	Pressure gauge	Direct continuous measurement	N/A	Monitor injection pressure at surface
Injection temperature	Injection well(s) – Wellhead	Temperature gauge	Direct continuous measurement	N/A	Monitor injection temperature at surface
Annular pressure	Injection well(s) – Wellhead	Pressure gauge	Direct continuous measurement	N/A	Monitor annular pressure at surface
In Zone Downhole pressure/temperature	Injection well(s)	Wireline downhole pressure/temperature gauge	Direct continuous measurement	N/A	Monitor reservoir response
Corrosion monitoring	Flowline – After compressor	Weight loss in holder, and observation	ASTM G1-03 and/or NACE Standard RP0775-2005 Item No. 21017	3rd Party	Monitor corrosion risk

Activity	Location(s)	Method	Analytical Technique	Lab/Custody	Purpose
Distributed Temperature Sensing (DTS) fiber optics[1]	Injection well(s)	Fiber optic cable	Direct continuous measurement	3rd Party	Monitor wellbore integrity
Mechanical integrity (casing)	Injection well(s)	Various	LAC 43:XVII §3625 (A)(5); §3627	3rd Party	Monitor wellbore integrity and detect potential leakage through casing
Mechanical integrity (cement)	Injection well(s)	Wireline cement evaluation logging	Provided by Vendor	3rd Party	Monitor wellbore integrity and detect potential leakage through cement
Pressure fall-off testing	Injection well(s)	EPA Region 6 UIC Pressure Fall-off Testing Guideline – Third Revision (August 8, 2002)	EPA Region 6 UIC Pressure Fall-off Testing Guideline – Third Revision (August 8, 2002)	3rd Party	Monitor wellbore integrity and assess injectivity
Wireline logging – Pulsed Neutron Logging	Injection well(s)	Wireline formation evaluation logging	Provided by vendor	3rd Party	Identify zones that are accepting CO_2
In-zone pressure monitoring – Tuscaloosa	2 selected wells	Downhole pressure/temperature gauge	Direct continuous measurement	N/A	Monitor in-zone pressure/temperature

Activity	Location(s)	Method	Analytical Technique	Lab/Custody	Purpose
Above-Confining Zone pressure monitoring (ACZMI) – Annona Sand	3 selected wells	Downhole pressure/temperature gauge	Direct continuous measurement	N/A	Monitor above-zone pressure within Sequestration Complex
Adaptive Sampling-Annona	3 selected wells	Swab or other method	Chemical/Physical Analyses	Lab accredited by the LDEQ	Monitor Sequestration Complex
Sampling-Public Water Supply	East Columbia Water District	Pumping or other method	Chemical/Physical Analyses	Lab accredited by the LDEQ	Monitor groundwater
CO_2 plume tracking	Injection & Monitoring wells	Time-lapseVertical Seismic Profiles (VSP) or other method	Provided by vendor	3rd Party	Track CO_2 plume size and monitor changes in subsurface
Atmospheric monitoring	1 onsite tower and selected sites in AoR	Surface air sampling and net CO_2 flux calculation	Direct measurement	3rd Party	Monitor environmental changes
Ecosystem Stress monitoring	AoR and Reference Areas	Vegetation surveys	Satellite imagery analysis	3rd Party	Monitoring environmental changes
Soil Gas monitoring	12-15 discrete points in AoR	Soil gas sampling	Standard laboratory analyses (gas chromatography and mass spectrometry)	Istotech Laboratories and Beta Analytics	Monitoring environmental changes

Activity	Location(s)	Method	Analytical Technique	Lab/Custody	Purpose
Soil Characterization	12-15 discrete points in the AoR	Soil Sampling	Standard laboratory analyses	Eurofins Houston	Establish site soil characteristics

[1] If deployed

Table 2. Instrumentation Summary.

Monitoring Location	Instrument Type	Monitoring Target (Formation or Other)	Data Collection Location(s)	Explanation
CO_2 facility	High-pressure vessel	Surface/Flowline	Tap on Flowline	Monitor injectate quality
	Flow meter	Surface/Flowline	Flowline	Monitor injectate rate/volume
Injection well(s)	Pressure/temperature gauge (on tubing)	Wellhead	Wellhead tap	Monitor injection conditions; safety and compliance
	Pressure gauge (on annulus)	Wellhead	Wellhead tap	Monitor injection conditions; safety and compliance
	Wireline downhole pressure/temperature gauge	Upper Tuscaloosa / Paluxy Primary Injection Zone	Perforations	Monitor downhole conditions; safety and compliance
	Weight loss coupons in holder	Surface/Flowline	ASTM G1-03 and/or NACE Standard RP0775-2005 Item No 21017	Monitor corrosion
	Distributed Temperature Sensing (DTS) fiber-optic cable	Whole formation section down to Confining Zone	Dedicated server (VSP array)	Monitor wellbore integrity
	Wireline cement evaluation logging	Whole formation section	Casing	Monitor wellbore integrity
	EPA Region 6 UIC Pressure Fall-off Testing Guideline – Third Revision (August 8, 2002)	Upper Tuscaloosa / Paluxy Primary Injection Zone	EPA Region 6 UIC Pressure Fall-off Testing Guideline – Third Revision (August 8, 2002)	Monitor wellbore integrity and assess injectivity

Monitoring Location	Instrument Type	Monitoring Target (Formation or Other)	Data Collection Location(s)	Explanation
	Wireline formation evaluation logging tools	Whole formation section	Open Hole	Track formation property changes
	Distributed Acoustic Sensing (DAS) fiber-optic cable[1]	Whole formation section	Dedicated server (VSP array)	CO_2 plume tracking and well integrity
In-Zone monitoring wells	Pressure/temperature gauge (on tubing)	Upper Tuscaloosa / Paluxy Formation Sandstones	Wellhead	Safety and compliance
	Downhole pressure/temperature gauge	Upper Tuscaloosa / Paluxy Formation Sandstones	Perforations	Monitor downhole conditions of pressure/temperature in the Injection Zone
Above-Confining Zone pressure monitoring (ACZMI) – Annona Sand	Pressure/temperature gauge (on tubing)	Annona Sand	Wellhead	Safety and compliance
	Downhole pressure/temperature gauge	Annona Sand	Perforations	Verify that no fluid is escaping from the Tuscaloosa Injection Zone
VSP stations / microseismic array	Time-lapse VSP / microseismic array geophones	Reservoir – Plume Tracking	Surface and in Wellbore	Monitor CO_2 plume size and reservoir integrity
Atmospheric monitoring tower and testing sites	Eddy covariance tower	Surface Air	Dedicated Server	Identify CO_2 concentrations above ambient background levels
	Landfill gas meter			
Ecosystem Stress monitoring	Satellite imagery from Landsat 9 and Sentinel-2 imaging platforms	Vegetative Conditions	Dedicated Server	Measure potential stress resulting from elevated CO_2 in soil

Monitoring Location	Instrument Type	Monitoring Target (Formation or Other)	Data Collection Location(s)	Explanation
Soil gas sampling sites	Soil gas probe	Shallow Soil Gas	Dedicated server	Identify potential CO_2 leaks and discern the source(s) of detected CO_2 to either natural or anthropogenic sources
Soil sampling sites	Direct push drill rig/ hand auger	Shallow Soil	Dedicated server	Establish baseline site soil characteristics.

[1] If deployed

Table 3. Geophysical Survey Summary.

Monitoring Location	Instrument Type	Monitoring Target (Formation or Other)	Data Collection Location(s)	Explanation
In-zone monitoring wells	Time-lapse VSP / microseismic array	Upper Tuscaloosa / Paluxy	Surface and in Wellbore	Monitor plume extent and potential out of zone movement
		Annona		

A.3.c. Geographic Locations

The injection wells will be located at the Port of Columbia Facility and shown in Figure 2 of the Testing and Monitoring Plan. Direct monitoring in two wells completed into the Upper Tuscaloosa / Paluxy Primary Injection Zone will be used to detect and define the dimensions of the carbon dioxide plume during well operations. The Bradford-Brown Trust Shipp No. 1 (SN20131) well, located approximately 10,152 feet up dip of the injection wells, will be re-entered and repurposed by recompletion of the well across the entire Upper Tuscaloosa / Paluxy Primary Injection Zone (well originally penetrated only the upper one-third of the Upper Tuscaloosa interval). This well is optimally located in the direct plume path (up dip) of the sequestered carbon dioxide. Real-time, continuous pressure-monitoring will be performed in the well and the well will be completed to allow for fluid sampling, if needed. A second monitoring well will leverage the installed Whitetail Operating, LLC, Louisiana Green Fuels #1 stratigraphic test well, located approximately 5,273 feet southeast of the proposed injection wells. The well will also be fitted with downhole pressure gauges (gauges will be referenced to ground level at each well) and will be configured to allow for fluid sampling, if needed, based on carbon dioxide encountering the wellbore. Each well will also have a transmitter gauge at surface to continuously record tubing pressure. Experience shows, such as at the Frio Project, that carbon dioxide will rapidly evacuate the wellbore fluids in a monitoring well that is open to the Injection Zone, which will result in increased wellhead pressures due to the lighter column of gas replacing the brine fluid column.

Above-Confining-Zone Monitoring Interval (ACZMI) will occur in three wells installed in areas where In-Zone monitoring is already occurring. The initial ACZMI Monitoring reservoir for the sequestration project is the Annona Sandstone. The Annona Sandstone is a well-distributed shallow marine sand that extends throughout the Area of Review. Injection Zone (IZ) Monitoring and AZMI Monitoring wells are expected to be engineered as multi-zone completions, if feasible.

Atmospheric monitoring will occur continuously at an Eddy Covairance tower adjacent to proposed Injection Well #1 (W-N1), and intermittently via a portable gas meter adjacent to proposed injection wells, monitoring wells, and soil gas monitoring sites.

Ecosystem stress monitoring will be assessed via satellite imagery and limited ground-based vegetation surveys which will capture the entirety of the AoR and surrounding reference areas, and "quadrants" of similar vegetaion and terrain, respectively.

Permanent subsurface soil gas probes will be installed at 12 to 15 representative locations including, at a minimum, three probe sites in the vicinity of the initial injection well site, and one probe site at each of the remaining two proposed injection well sites, the three Upper Tuscaloosa / Paluxy / Annona Sand monitoring wells, the four In-Zone monitoring wells, and the single Lower Wilcox monitoring well. One or more probes may also be installed within the ecosystem stress monitoring reference areas. The remaining locations of the soil gas probe sites will be determined as more data and information become available for the site during the baseline and operational phases of the project. Soil characterization samples will be collected concurrently at these soil gas probe locations during their installation.

Figure 1 of the Testing and Monitoring Plan presents a cross sectional view of the deep subsurface monitoring network. Figures 3 and 4 of the Testing and Monitoring Plan present the ecosystem stress monitoring areas that will be assessed.

A.3.d. Resource and Time Constraints

No additional resource or time constraints have been identified for the Testing and Monitoring plan beyond project funding levels and the proposed timeline.

A.4. Quality Objectives and Criteria

A.4.a. Performance/Measurement Criteria

The objective of the QASP is to develop and implement procedures for surface, near-surface, and subsurface testing and monitoring, field sampling, laboratory analyses, and reporting which will provide results allowing to track and meet the requirements of the non-endangerment goals of the project. Groundwater monitoring will be conducted during the pre-injection, injection, and post-injection phases of the project. Public water supply wells operated by the East Columbia Water District will be selected as locations for routine water quality sampling. In addition, water samples from 11 active water wells located within the AoR were obtained and analyzed in 2024 to establish baseline levels for six different water properties. Should a leak event occur, Strategic Biofuels plans to attempt to obtain additional samples from the 11 wells sampled in 2024 on an adaptive, as needed basis, to aid in the determination of whether extraneous injectate has moved upward and reached the USDW. The analytical and field parameters for fluid samples are listed in Table 4. Tables 5 and 6 provide the analytical parameters for carbon dioxide stream monitoring and corrosion coupon assessment, respectively, while Table 7 details the measurement parameters for the field gauges. Atmospheric, ecosystem stress, and soil gas monitoring will be conducted during the pre-injection and injection phases of the project. Additionally, soil samples will be collected during soil gas probe installation in the pre-injection phase. Analytical and field parameters for continuous and intermittent surface air testing are presented on Tables 8 and 9, respectively. Tables 10 and 11 provide the analytical and field parameters for soil gas and soil samples, respectively. The testing and monitoring outputs are presented in Table 12.

Quality objectives for satellite imagery data and associated indices utilized for ecosystem stress monitoring are met by: i) standard imagery source reliability by accredited agencies such as the United States Geological Survey (USGS) and the European Space Agency (ESA); and ii) imagery processing product reliability tailored to these sources (Dwyer et al., 2018; Vermote et al., 2016; ESA Product Types (web); IDB Project, 2022).

Note that these tables will be periodically updated as the vendor selection and onboarding process advance. Adjustments will also be needed as the relevant scope of work is adopted and implemented.

Table 4. Summary of Analytical and Field Parameters for Fluid Samples in Wilcox. All analysis will be performed by an Accredited Louisiana Laboratory.

Parameters	Analytical Methods(1)	Detection Limit/Range	Typical Precisions	QC Requirements
Cations: Al, Ba, Mn, As, Cd, Cr, Cu, Pb, Sb, Se, and Tl	ICP-MS, EPA Method 6020	0.001 to 0.1 mg/L (analyte, dilution, and matrix dependent)	±15%	Daily calibration; duplicates and matrix spikes at 10% or greater frequency
Ca, Fe, K, Mg, Na, and Si	ICP-OES, EPA Method 6010B	0.005 to 0.5 mg/L (analyte, dilution, and matrix dependent)	±15%	Daily calibration; duplicates and matrix spikes at 10% or greater frequency
Anions: Br, Cl, F, NO_3, and SO_4	Ion chromatography, EPA Method 300.0	0.02 to 0.13 mg/L (analyte, dilution, and matrix dependent)	±15%	Daily calibration; duplicates and matrix spikes at 10% or greater frequency
Dissolved CO_2	Coulometric titration, ASTM D513-11	25 mg/L	±15%	Duplicate measurements; standards at 10% or greater frequency
Alkalinity	APHA 2320B	4 mg/L	±3 mg/L	Duplicate analysis
Total dissolved solids	Gravimetry, APHA 2540C	12 mg/L	±10%	Balance calibration, duplicate analysis
Isotopes: $\delta^{13}C$ of DIC	Isotope ratio mass spectrometry(2)	12.2 mg/L HCO_3^- for $\delta^{13}C$	±0.15‰ for $\delta^{13}C$	10% duplicates; 4 standards per batch
Water density (field)	Oscillating body method	0.0000 to 2.0000	±0.0002 g/mL	Duplicate measurements

pH (field)	EPA Method 150.1	2 to 12 pH units	±0.2 pH unit	User calibration per manufacturer recommendation
Specific conductance (field)	APHA 2510	0 to 200 mS/cm	±1% of reading	User calibration per manufacturer recommendation
Temperature (field)	Thermocouple	-5 to 50 ºC	±0.2 ºC	Factory calibration

Note 1: An equivalent method may be employed with the prior approval of the Commissioner.
Note 2: Gas evolution technique by Atekwana and Krishnamurthy (1998), with modifications made by Hackley et al (2007).
Note 3: ICP = inductively coupled plasma; MS = mass spectrometry; OES = optical emission spectrometry

Table 5. Summary of Analytical Parameters for CO_2 Stream at the surface. All analysis will be performed by an Accredited Louisiana Laboratory.

Parameters	Analytical Methods[1]	Detection Limit/Range	Typical Precisions	QC Requirements
Carbon Dioxide	ISBT 2.0 Caustic Absorption Zahm-Nagel	99.00 to 99.99%	±10% of reading	User calibration per manufacturer recommendation
	ALI Method SAM 4.1 Subtraction Method (GC/DID)	1 ppm for each target analyte (analyte dependent)	5-10% relative across the range	Duplicate analysis within 10% of each other
	GC/TCD	0.1 to 100%	5-10% relative across the range, RT±0.1 min	Standard with every sample, duplicate analysis within 10% of each other
Oxygen	ISBT 4.0 (GC/DID) GC/TCD	1 to 5,000 µL/L (ppm by volume)	±10% of reading	Daily standard within 10% of calibration, secondary standard after calibration
		0.1 to 100%	5-10% relative across the range, RT±0.1 min	Daily standard, duplicate analysis within 10% of each other
Nitrogen	ISBT 4.0 (GC/DID)	5 to 100 µL/L (ppm by volume)	±20% of reading	Daily standard within 10% of calibration, secondary standard after calibration
	GC/TCD	0.1 to 100%	5-10% relative across the range, RT±0.1 min	Daily standard, duplicate analysis within 10% of each other

Carbon Monoxide	ISBT 5.0 Colorimetric ISBT 4.0 (GC/DID)	1 to 5,000 µL/L (ppm by volume) 1 to 5,000 µL/L (ppm by volume)	±10% of reading ±10% of reading	Duplicate analysis Daily standard within 10% of calibration, secondary standard after calibration
Hydrogen Sulfide	ISBT 14.0 (GC/SCD)	0.01 to 50 µL/L (ppm by volume) – dilution dependent	5-10% of reading relative across the range	Daily blank, daily standard within 10% of calibration, secondary standard after calibration
Nitrogen Oxides	ISBT 7.0 Colorimetric	0.2 to 5 µL/L (ppm by volume)	±20% of reading	Duplicate analysis
Sulfur Dioxide	ISBT 14.0 (GC/SCD)	0.01 to 50 µL/L (ppm by volume) – dilution dependent	5-10% of reading relative across the range	Daily blank, daily standard within 10% of calibration, secondary standard after calibration
Methane	ISBT 10.1 (GC/FID)	0.1 to 1,000 µL/L (ppm by volume) – dilution dependent	5-10% of reading relative across the range	Daily blank, daily standard within 10% of calibration, secondary standard after calibration
Total Hydrocarbons	ISBT 10.0 THA (FID)	1 to 10,000 µL/L (ppm by volume) – dilution dependent	5-10% of reading relative across the range	Daily blank, daily standard within 10% of calibration, secondary standard after calibration
Acetaldehyde	ISBT 11.0 (GC/FID)	0.1 to 100 µL/L (ppm by volume) – dilution dependent	5-10% of reading relative across the range	Daily blank, daily standard within 10% of calibration, secondary standard after calibration

Ethanol	ISBT 11.0 (GC/FID)	0.1 to 100 µL/L (ppm by volume) – dilution dependent	5-10% of reading relative across the range	Daily blank, daily standard within 10% of calibration, secondary standard after calibration
Water, Hydrogen, Carbonyl Sulfide, Argon, Glycol				

Note 1: An equivalent method may be employed with the prior approval of the Commissioner.

Table 6. Summary of Analytical Parameters for Corrosion Coupons.

Parameters	Analytical Methods	Detection Limit/Range	Typical Precisions	QC Requirements
Mass	NACE Standard RP0775-2005 Item No. 21017	0.005 mg	±2%	Annual calibration of scale (3rd party)
Thickness	NACE Standard RP0775-2005 Item No. 21017	0.001 mm	±0.005 mm	Factory calibration

Table 7. Summary of Measurement Parameters for Field Gauges.

Parameters	Methods	Detection Limit/Range	Typical Precisions	QC Requirements
Booster pump discharge pressure (PIT-012)	ANSI Z540-1-1994	±0.001 psi / 0-3,000 psi	±0.01 psi	Annual calibration of scale or to manufacturers specs (3^{rd} party)
Injection tubing temperature (TIT-019)	ANSI Z540-1-1994	±0.001 F / 0-500 F	±0.01 F	Annual calibration of scale or to manufacturers specs (3^{rd} party)
Annulus pressure (PIT-014)	ANSI Z540-1-1994	±0.001 psi / 0-3,000 psi	±0.01 psi	Annual calibration of scale or to manufacturers specs (3^{rd} party)
Injection tubing pressure (PIT-009)	ANSI Z540-1-1994	±0.001 psi / 0-3,000 psi	±0.01 psi	Annual calibration of scale or to manufacturers specs (3^{rd} party)
Injection mass flow rate (FIT-006)	Direct measurement	±0.1% of rate/50,522-303,133 lbs/hr	±0.01 lbs/hr	Annual calibration of scale or to manufacturers specs (3^{rd} party)
Downhole pressure	Direct measurement	±0.1 psi / 0-10,000 psi	±0.2% of scale	Annual calibration of scale or verification against wireline gauge
Downhole temperature	Direct measurement	±0.01 ºC/125 ºC	±0.5% of scale	Annual calibration of scale or verification against wireline gauge

Table 8. Summary of Analytical Parameters for Continuous Surface Testing.

Parameters	Analytical Methods	Detection Limit/Range	Typical Precisions	QC Requirements
Carbon Dioxide	Non-dispersive infrared spectroscopy	0.11 ppm/ 0 to 3000 ppm	±1%	Windows® based software supports all setup, configuration, and calibration functions through Ethernet connection
Methane	Single-mode tunable near-infrared laser	5 ppb/ 0 to 25 ppm at -25 °C or 0 to 40 ppm at 50 °C	< 1% to 2%	Windows® based software supports all setup, configuration, and calibration functions through Ethernet connection
Hydrogen Dioxide	Non-dispersive infrared spectroscopy	4.7 ppb/ 0 to 60 ppm	±1%	Windows® based software supports all setup, configuration, and calibration functions through Ethernet connection
Nitrous Oxide	Laser-based absorption spectroscopy	1 ppb/ 0 to 100 ppm	0.2 to 0.4 ppb	Built in web server based software supports all setup, configuration, and calibration functions through Ethernet connection
Wind Direction	Ultrasonic sound pulse between upper and opposite lower transducers	0 to 359°	< ±1° RMS	Pre-custom calibration
Wind Speed		0 to 45 m/s	< 1% RMS	

Parameters	Analytical Methods	Detection Limit/Range	Typical Precisions	QC Requirements
Soil Moisture	Electromagnetic signal	Dry to fully saturated	±0.01 to ±0.03	Pre-custom calibration
Soil Temperature		-10 to 55 °C	±0.1 °C	
Soil Heat Flux	Differential temperature across the ceramics-plastic composite body of thermopile	+2000 to -2000 Wm^{-2}	within +5 to -15%	
Net Radiation	Net pyrradiometer: thermopile detector fitted with PTFE coated conical absorbers	200 nm to 100 μm	Not specified	Pre-custom calibration and follow-up manufacturer calibration every 2 years
Relative Humidity	Polymer sensor deposited between two conductive electrodes	0 to 100%RH	±1%RH (0 – 90 %RH) and ±1.7 %RH (90 – 100 %RH) from 15 to 25 °C ±(1.0 + 0.008 x reading) %RH from -20 to 40 °C ±(1.2 + 0.012 x reading) %RH from -40 to -20 °C and from 40 to 60 °C ±(1.4 + 0.032 x reading) %RH from -60 to -40 °C	Manual calibration using a pc with a USB cable, the push buttons, or the MI70 indicator
Barometric Pressure	Pressure tranducer	50 to 110 kPa	0.4 kPa	Pre-custom calibration

Parameters	Analytical Methods	Detection Limit/Range	Typical Precisions	QC Requirements
Ambient Temperature	Polymer sensor deposited between two conductive electrodes	-80 to 60 °C	±(0.226 - 0.0028 x temperature) °C from -80 to 20 °C ±(0.055 + 0.0057 x temperature) °C from 20 to 60 °C	Pre-custom calibration
Precipitation	Remote tipping bucket	Up to 2" per hour	±1%	Routine cleaning of debris from filter screen and occasional manual calibration verification

Table 9. Summary of Analytical Parameters for Intermittent Surface Air Testing.

Parameters	Analytical Methods	Detection Limit/Range	Typical Precisions	QC Requirements
Carbon Dioxide	Dual wavelength infrared cell	0 to 100%	0-5%: ±0.3% 5-15%: ±1.0% 15% - Full Scale: ±3.0%	User calibration per manufacturer recommendation
Methane	Dual wavelength infrared cell	0 to 100%	0-5%: ±0.3% 5-15%: ±1.0% 15% - Full Scale: ±3.0%	User calibration per manufacturer recommendation
Oxygen	Internal electrochemical cell	0 to 25%	0-5%: ±1.0% 5-15%: ±1.0% 15% - Full Scale: ±1.0%	User calibration per manufacturer recommendation

Table 10. Summary of Measurement Parameters for Soil Gas Samples.

Parameters	Methods	Detection Limit/Range	Typical Precisions	QC Requirements
CO_2, N_2, O_2	Gas chromatography	CO_2: 50 ppm N_2 and O_2: 100 ppm	for CO2 (> 1.5%) ±0.6% (of measured value) for CO2 (< 0.05%) ±1.7% (of measured value) for N2 and O2 (>10%) ±0.5% (of measured value)	At a rate of 20% of the samples analyzed: A lab check standard or sample duplicate is analyzed every 5th run with a lab standard being run first every day. Method based on ASTM D1945.
CH_4, C1-C5	Gas chromatography	CH_4: 2 ppm C2 - C6+: 1ppm	CH4: ±0.4 to 1% (of measured value) C2 - C4: ±0.4 to 1% (of measured value) C5 - C6+: ±2 to 4% (of measured value)	At a rate of 20% of the samples analyzed: A lab check standard or sample duplicate is analyzed every 5th run with a lab standard being run first every day. Method based on ASTM D1945.
Helium	Gas chromatography	50 ppm	±2%	At a rate of 20% of the samples analyzed: A lab check standard or sample duplicate is analyzed every 5th run with a lab standard being run first every day. Method based on ASTM D1945.

δ^{13}C of CO_2 and CH_4	High precision, dual inlet IRMS	CO_2 and CH_4: 0.25%	CO_2 and CH_4: ±0.1%	At a rate of 20% of the samples analyzed: A lab check standard or sample duplicate is analyzed every 5th run with a lab standard being run first every day. Method similar to Edman, J.D., 2007, Newsletter of the Rocky Mountain Association of Geologists, v. 56, no. 8.
δD of CH_4	High precision, dual inlet IRMS	CH_4: 0.5%	CH_4: ±3.5%	At a rate of 20% of the samples analyzed: A lab check standard or sample duplicate is analyzed every 5th run with a lab standard being run first every day. Method similar to Edman, J.D., 2007, Newsletter of the Rocky Mountain Association of Geologists, v. 56, no. 8.
^{14}C of CO_2 and CH_4	Accelerated mass spectrometry	0.44 pMC/ 0.44 pMC – 198 pMC	0.02 pMC - 0.5 pMC	NIST suite, IAEA standards, AMS wheel, and QA report

Table 11. Summary of Analytical Parameters for Soil Samples.

Parameters	Analytical Methods	Detection Limit/Range	Typical Precisions	QC Requirements
Total Organic Carbon (TOC)	Walkley Black 9060A	0.02 wt%	±20%	Lab Control/ Lab Control Duplicate, Matrix Spike/ Matrix Spike Duplicate samples, instrument calibration, field duplicates
Salinity	SM 2520B	5 umhos/cm	±20%	Lab Control/ Lab Control Duplicate samples, instrument calibration, field duplicates
Percent Moisture	SM 2540G	0.1 - 100%	±20%	Instrument calibration, field duplicates

Table 12. Actionable Testing and Monitoring Outputs.

Activity or Parameter	Project Action Limit	Detection Limit	Anticipated Reading
External mechanical integrity (DAS/DTS fiber-optic cable) [(4)]	Measure thermal and acoustic anomalies between normal and shut-in operations to detect potential leakage into USDW through vertical channels adjacent to injection wellbore(s)	(1)	(1)
Internal mechanical integrity (pulsed neutron logging)	Measure response to neutron pulse, through casing, to detect potential leakage in casing, tubing, or packer	Tool Logging Mode and logging speed dependent	No statistically significant difference from baseline log run.
Surface pressure gauges	Pressure approaching modeled or permitted limit	(1)	(1)
Downhole pressure gauges	Pressure approaching modeled or permitted limit	(1)	(1)
Groundwater and environmental parameters (including surface air, ecosystem stress, and soil gas)	A statistically significant departure between observed and baseline/ seasonal parameter patterns	(2)	Within statistical test of baseline/seasonal values (Fed Reg v. 53, No. 196, 39720-39731)
Water quality measurements in ACZMI Wilcox Sand	A statistically significant departure between observed and baseline/ seasonal parameter patterns	(1)	Within statistical test of baseline/seasonal values (Fed Reg v. 53, No. 196, 39720-39731)

Activity or Parameter	Project Action Limit	Detection Limit	Anticipated Reading
Mismatch between modeled and observed in-zone pressure response	Action when pressure response is outside of bounds model outcomes by 1.5X or approaching maximum permit values	(1)	Formation pressures within bounds of model outcomes
Mismatch between modeled and observed plume migration	Action when plume is outside of bounds of the Sequestration Complex	Dependent of rock properties and contrast in density due to fluid saturations	Plume geometry within bounds of model outcomes

Note 1: These data are to be negotiated during well engineering design, after assessment of available instruments.
Note 2: The methodology for anomaly detection and attribution requires data collection over several years to identify natural and spatial variation and comparison to fluid, surface air, and soil gascompositions and vegetatitve conditions to identify a leakage signal. This will be added to the monitoring plan and used to follow up incident or allegation to attribute signal.
Note 3: Actual mismatch between modeled and observed in-zone pressure response and plume tracking depends on recalibration of the model with new data, followed by a forward model to determine any unacceptable outcomes, result from the production of pressure and plume evolution.

Note 4: If deployed

A.4.b. Precision

Precision will be determined after the different vendors and contractors are selected, per their individual standard operating procedures. Tables 13 to 18 summarize the detailed specifications for the downhole and field gauges. In the wellbore, the downhole gauges include pressure and temperature measurements. At the surface, the field gauges include injection tubing pressure and temperature, annulus pressure, and CO_2 mass flow rate.

Table 13. Pressure and Temperature—Downhole Gauge Specifications.

Parameter	Value
Calibrated working pressure range	Atmospheric to 10,000 psi
Initial pressure accuracy	±0.2% over full scale
Pressure resolution	±0.1 psi
Pressure drift stability	±0.2% over full scale per annum
Calibrated working temperature range	0-125 ºC
Initial temperature accuracy	±0.5% over full scale
Temperature resolution	±0.01 ºC
Temperature drift stability	±0.2% over full scale per annum
Max temperature	±125 ºC
Instrument calibration frequency	Annual verification or per manufactures specification

Table 14. Pressure Field Gauge—Injection Tubing Pressure.

Parameter	Value
Calibrated working pressure range	0 to 3,000 psi
Initial pressure accuracy	<±0.25% over full scale
Pressure resolution	<±1 psi
Pressure drift stability	To be determined

Table 15. Pressure Field Gauge—Annulus Pressure.

Parameter	Value
Calibrated working pressure range	0 to 3,000 psi
Initial pressure accuracy	<±0.25% over full scale
Pressure resolution	<±1 psi
Pressure drift stability	To be determined

Table 16. Temperature Field Gauge—Injection Tubing Temperature.

Parameter	Value
Calibrated working temperature range	0 to 500 ºF
Initial temperature accuracy	<±0.4% over full scale
Temperature resolution	<±4 ºF
Temperature drift stability	To be determined

Table 17. Mass Flow Rate Field Gauge—CO_2 Mass Flow Rate.

Parameter	Value
Calibrated working flow rate range	± 100 bar
Initial mass flow rate accuracy	±0.1 % of rate - liquid
Mass flow rate repeatibility	±0.05 % of rate - liquid
Mass flow rate drift stability	To be determined after first year

Table 18. Representative Logging Tool Specifications.

Parameter	Pulsed Neutron	Cement Bond	Casing Imager
Logging speed	3.600 ft/hr	3,600 ft/hr	Variable 400 to 4,500 ft/hr
Vertical resolution	15 inches	3 feet	6 inches
Investigation	Fluid Saturation	Quality of bond	Evaluation of casing and cement
Temperature rating	350 ºF	350 ºF	350 ºF
Pressure rating	15,000 psi	20,000 psi	20,000 psi

A.4.c. Bias

Laboratory assessment of analytical bias will be the responsibility of the individual laboratories per their standard operating procedures and analytical methodologies. For gauge and logging measurements, no bias is reasonably expected.

A.4.d. Representativeness

For groundwater, surface air, soil gas, and soil sampling, data representativeness expresses the degree to which data accurately and precisely represents a characteristic subset of a given population, parameter variations at a sampling point, a process condition, or an environmental condition. The groundwater, surface air, soil gas, and soil sampling networks have been designed to provide data representativeness of site conditions. For analytical results of individual groundwater samples, representativeness will be estimated by ion and mass balances. Ion balances with ±10% error or less will be considered valid. Mass balance assessment will be used in cases where the ion balance show an error greater than ±10% to help determine the source of error. For a sample and its duplicate, if the relative percent difference is greater than 10, the sample may be considered non-representative.

Similarly, vegetation surveys will be conducted utilizing a "quadrant"-like approach, where similar vegetation and terrain areas will be characterized by their primary vegetation types in the Area of Review and surrounding reference areas. For each analysis during pre-injection and injection, all available satellite images will be processed into quarterly composite images to be representative of each season.

A.4.e. Completeness

For groundwater, surface air, soil gas, and soil sampling and ecosystem stress monitoring, data completeness is a measure of the amount of valid data obtained from a measurement system compared to the amount that was expected to be obtained under normal conditions. It is anticipated that data completeness of 90% will be acceptable to meet the project's monitoring goals. For direct pressure and temperature measurements and continuous surface air monitoring, it is expected that data will be recorded no less than 90% of the time.

A.4.f. Comparability

Data comparability expresses the confidence with which one dataset can be compared to another. The datasets to be generated by this project will be very comparable to future datasets because of the systematic use of standard methods and the level of QA/QC effort. If historical groundwater quality, surface air, soil gas, and soil data become available from other sources, their applicability to the project and their level of quality will be assessed prior to use. Direct pressure, temperature, and logging measurements are directly comparable to previously obtained data. If necessary, historical satellite imagery may be obtained and directly compared to imagery obtained during the baseline and operational phases of the project.

A.4.g. Method Sensitivity

The sensitivity of the testing and monitoring methods employed for this project will be discussed with the Commissioner after the draft of the Testing and Monitoring Plan has been approved.

A.5. Special Training/Certifications

A.5.a. Specialized Training and Certifications

The geophysical survey equipment and wireline logging tools will be operated by trained, qualified, and certified personnel, with documentation provided by the selected vendors. The subsequent data will be processed and analyzed according to industry standards. No specialized certifications are required for personnel conducting groundwater, surface air, soil gas, or soil sampling, but field sampling will be conducted by trained personnel according to the project specific sampling procedures which will be provided by Louisiana Green Fuels.

A.5.b/c. Training Provider and Responsibility

Training for personnel will be provided by the operator or subcontractor responsible for the data collection activity.

A.6. Documentation and Records

A.6.a. Report Format and Package Information

A semi-annual report from Louisiana Green Fuels to the USEPA and CARB will contain all required project data, including testing and monitoring information as specified by the UIC Class VI permit and LCFS Protocol. Data will be provided in electronic or other formats as requested by the UIC or CARB Program Director.

A.6.b. Other Project Documents, Records, and Electronic Files

Other documents, records, and electronic files such as well logs, test results, or other data will be provided as requested by the Commissioner.

A.6.c/d. Data Storage and Duration

Louisiana Green Fuels or a designated contractor will maintain the required project data as provided elsewhere in the permit.

A.6.e. QASP Distribution Responsibility

Louisiana Green Fuels will be responsible for ensuring that all those on the distribution list will receive the most current copy of the approved Quality Assurance and Surveillance Plan.

B. DATA GENERATION AND ACQUISITION

B.1. Sampling Process Design

Discussion in this section focuses on fluid, soil, and soil gas sampling and does not address monitoring methods that do not gather physical samples (e.g., logging, seismic monitoring, pressure/temperature monitoring, atmospheric monitoring, and ecosystem stress monitoring).

During the pre-injection and injection phases, groundwater sampling and testing are planned to include an extensive set of chemical parameters to establish aqueous geochemical reference data. Parameters for public drinking water supply wells will include selected constituents that: (1) have primary and secondary USEPA drinking water maximum contaminant levels, (2) are the most responsive to interaction with CO_2 or brine, (3) are needed for water quality control, and (4) may be needed for geochemical modeling. The full set of parameters for each sampling interval is given in Table 4. After a sufficient baseline is established, monitoring scope during the post-injection phase may shift to a subset of indicator parameters that are (1) the most responsive to interaction with CO_2 or brine and (2) are needed for water quality control. Implementation of a reduced set of parameters will be done in consultation with the USEPA and CARB. Similarly, during the pre-injection and injection phases, soil gas sampling and testing are planned to include an extensive set of chemical parameters (see Table 10) to establish near-surface geochemical reference data. Parameters will include selected constituents that are the most responsive to interaction with CO_2. During soil gas probe site installation, soil samples will be collected in general accordance with EPA Method LSASDPROC-300-R4 (USEPA, 2020a) for the laboratory analysis of soil moisture, organic carbon content, and salinity according to USDA methods to establish site characteristics pre-injection.

Isotopic analyses can be performed on baseline groundwater and soil gas samples to the degree that the information helps verify a condition or establish an understanding of non-project related variations. In fact, baseline isotopic analyses of soil gas will be conducted to help determine natural background variability. For non-baseline samples, isotopic analyses may be reduced in all monitoring wells and soil gas probe sites if a review of the historical project results or other data determines that further sampling for isotopes is not needed. During any period where a reduced set of analytes is used, if statistically significant trends are observed that are the result of unintended CO_2 or brine migration, the analytical list will be expanded to the full set of monitoring parameters.

The groundwater, soil, and soil gas samples will be analyzed by third-party laboratories meeting the requirements under the Louisiana Environmental Laboratory Accreditation Program. All other samples will be analyzed by the operator or a third-party laboratory. Dissolved CO_2 will be analyzed using methods consistent with Test Method B of ASTM D513-06, "Standard Test Methods for Total and Dissolved Carbon Dioxide in Water" or equivalent. Isotopic analysis will be conducted using established methods.

<u>B.1.a. Design Strategy</u>

CO_2 Stream Monitoring Strategy

The primary purpose of analyzing the carbon dioxide stream is to evaluate the potential interactions of carbon dioxide and/or other constituents of the injectate with formation solids and fluids. This analysis can also identify (or rule out) potential interactions with well materials. Establishing the chemical composition of the injectate also supports the determination of whether the injectate meets the qualifications of hazardous waste under the Resource Conservation and Recovery Act (RCRA), 42 U.S.C. §6901 et seq. (1976), and/or the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), 42 U.S.C. §9601 et seq. (1980). Additionally, monitoring the chemical and physical characteristics of the carbon dioxide (e.g., isotopic signature, other constituents) may help distinguish the injectate from the native fluids and gases if unintended leakage from the storage reservoir occurred.

Injectate monitoring is required at a sufficient frequency to detect changes to any chemical and physical properties that may result in a deviation from the permitted specifications. Analyses of the injected stream will occur quarterly or when a demonstrated change in the process that could affect stream composition occurs.

Calibration of transmitters used to monitor pressures, temperatures, and flow rates of CO_2 into the injection well(s) at the injection well(s) and at the monitoring well(s) will be conducted annually.

Reports will specify test equipment used to calibrate the transmitters, including test equipment manufacturers, model numbers, serial numbers, calibration dates, and expiration dates.

Corrosion Monitoring Strategy

Corrosion coupon analyses will be conducted quarterly to aid in ensuring the mechanical integrity of the equipment in contact with the carbon dioxide. Coupons will be sent quarterly to a third-party laboratory for analysis conducted in accordance with NACE Standard RP0775-2005 Item No. 21017 (or similar such as ASTM G1 – 03 (2017)) to determine and document corrosion wear rates based on mass loss.

Shallow Groundwater Monitoring Strategy

Dedicated monitoring of East Columbia Water District public water supply wells will be chosen for shallow groundwater monitoring. These wells will be carefully selected to provide a spatial distribution around the planned CO_2 injection well location(s). In addition, water samples from 11 active water wells located within the AoR were obtained and analyzed in 2024 to establish baseline levels for six different water properties. Should a leak event occur, Strategic Biofuels plans to attempt to obtain additional samples from the 11 wells sampled in 2024 on an adaptive, as needed basis, to aid in the determination of whether extraneous injectate has moved upward and reached the USDW.

Deep Groundwater Monitoring Strategy

Quarterly fluid sampling in the Annona Sand that immediately overlies the Austin Chalk Equivalent / Eagleford Confining Zone will be used in combination with pressure monitoring and temperature monitoring to determine if leakage is occurring at or near the injection well(s). The annona Sand reservoir has sufficient permeability such that pressure monitoring at the monitoring wells would detect a failure of the confining zone should it occur. MIT testing and DTS/DAS monitoring at the injection well(s), if installed, will also provide data to insure the mechanical integrity of the well(s) is maintained.

With the planned sampling initiated one year ahead of injection and quarterly monitoring frequencies, it is expected that baseline conditions can be documented, natural variability in the baseline conditions can be characterized, unintended brine or CO_2 leakage could be detected if it occurred, and sufficient data can be collected to demonstrate that the effects of CO_2 injection are limited to the intended storage reservoir.

Soil Gas Monitoring Strategy

Soil gas sampling will be conducted during i) baseline on a monthly basis (with isotopic analyses conducted quarterly) to establish natural background variability within the Area of Review, and ii) injection on a quarterly basis to monitor any changes in the environmental conditions that could be a consequence of a leakage from the storage reservoir. Permanent subsurface soil gas probes will be installed at 12 to 15 representative locations throughout the surface projection of the Area of Review. The baseline soil gas monitoring network will depend on appropriate land access agreements, and will include, at a minimum, three probe sites in the vicinity of the initial injection well site, and one probe site at each of the remaining four proposed injection well sites, the two Tuscaloosa/Annona Sand monitoring wells, and the single Lower Wilcox monitoring well. One or more probes may also be installed within the ecosystem stress monitoring reference areas. The remaining locations of the soil gas probe sites will be determined as more data and information become available for the site during the baseline and operational phases of the project. It is anticipated that the baseline soil gas monitoring network will be utilized during the operational phase as well, as needed.

Soil Characterization Strategy

Soil sampling will occur concurrently with soil gas probe installation sites. The purpose of collecting these samples is to characterize pre-injection soil conditions that may be referenced as a baseline dataset, as needed, for support in leakage detection strategies.

B.1.b. Type and Number of Samples/Test Runs

To be updated when Commissioner has approved draft permit.

B.1.c. Site/Sampling Locations

To be updated when Commissioner has approved draft permit.

B.1.d. Sampling Site Contingency

To be updated when Commissioner has approved draft permit.

B.1.e. Activity Schedule

To be updated when Commissioner has approved draft permit.

B.1.f. Critical/Informational Data

During both groundwater, soil gas, and soil sampling and analytical efforts, detailed field and laboratory documentation will be taken. Documentation will be recorded in field and laboratory forms and notebooks. Critical information will include date and time of activity, person/s performing activity, location of activity (well vs. field sampling) or instrument (lab analysis), field or laboratory instrument calibration data, and field parameter values. For laboratory analyses, much of the critical data are generated during the analysis and provided to end users in digital and printed formats. Noncritical data may include appearance and odor of the sample, problems with well or sampling equipment, and weather conditions.

B.1.g. Sources of Variability

Potential sources of variability related to monitoring activities include (1) natural variation in fluid quality, soil gas composition, soil, formation pressure and temperature, and seismic activity; (2) variation in fluid quality, soil gas composition, soil, formation pressure and temperature, and seismic activity due to project operations; (3) changes in recharge due to rainfall, drought, and snowfall; (4) changes in instrument calibration during sampling or analytical activity; 5) different staff collecting or analyzing samples; (6) differences in environmental conditions during field sampling activities; (7) changes in analytical data quality during life of project; and (8) data entry errors related to maintaining project database.

Activities to eliminate, reduce, or reconcile variability related to monitoring activities include (1) collecting long-term baseline data to observe and document natural variation in monitoring parameters, (2) evaluating data in timely manner after collection to observe anomalies in data that can be addressed, resampled or reanalyzed, (3) conducting statistical analysis of monitoring data to determine whether variability in a dataset is the result of project activities or natural variation, (4) maintaining weather-related data using on-site weather monitoring data or data collected near project site (such as from local airports), (5) checking instrument calibration before, during and after sampling or sample analysis, (6) thoroughly training staff, (7) conducting laboratory quality assurance checks using third-party reference materials, and/or blind and/or replicate sample checks, and (8) developing a systematic review process of data that can include sample-specific data quality checks (i.e., cation/anion balance for aqueous samples).

B.2. Sampling Methods

Discussion in this section applys to physical samples and does not apply to logging, seismic monitoring, pressure/temperature monitoring, atmospheric monitoring, and ecosystem stress monitoring.

B.2.a/b. Sampling SOPs

Groundwater samples will be collected primarily using a low-flow sampling method or similar, that is consistent with ASTM D6452-99, Yeskis and Zavala (2002), or Puls and Barcelona (1996). If a flow-through cell is not used, field parameters will be measured in grab samples. Groundwater wells will be purged to ensure samples are representative of formation water quality. Static water levels in each well will be determined using an electronic water level indicator before any purging or sampling activities begin. Dedicated pumps (e.g., bladder pumps) may be installed in each monitoring well to minimize potential cross-contamination between wells. Groundwater pH, temperature, specific conductance, and dissolved oxygen will be monitored in the field using portable probes and a flow-through cell consistent with standard methods (e.g., APHA) given sufficient flow rates and volumes. Field chemistry probes will be calibrated at the beginning of each sampling day according to equipment manufacturer procedures using standard reference solutions. When a flow-through cell is used, field parameters will be continuously monitored and will be considered stable when three successive measurements made three minutes apart meet the criteria listed in Table 19.

After field parameters have stabilized, samples will be collected. Samples requiring filtration will be filtered through 0.45 µm flow-through filter cartridges as appropriate and consistent with ASTM D6564-00. Prior to sample collection, filters will be purged with a minimum of 100 mL of well water (or more if required by the filter manufacturer). For alkalinity and total CO_2 samples, a special effort will be made to minimize exposure to the atmosphere during filtration, collection in sample containers, and analysis. Samples will be properly preserved per analyte requirements.

Table 19. Stabilization Criteria of Water Quality Parameters During Shallow Well Purging.

Field Parameter	Stabilization Criteria
pH	±0.2 units
Temperature	±1 ºC
Specific conductance	±3% of reading in µS/cm
Dissolved oxygen	±10% of reading or 0.3 mg/L whichever is greater
Turbidity	Clarity

Soil gas sampling will be conducted in general accordance with operating procedures set forth in EPA Method LSASDPROC-307-R4 (USEPA, 2020a). During sample collection, a vacuum will be applied to the tubing on the surface to first purge the full length of the tubing, and second collect a soil gas sample in a 0.3-L IsoBag Gas Bag® using 60 mL gas-tight syringes, equipped with a 3-way valves. During soil gas sampling, a leakage test will be conducted by releasing helium gas as a tracer gas within a shroud over each soil gas sampling site.

Soil samples will be collected in general accordance with EPA Method LSASDPROC-300-R4 (USEPA, 2020b) during soil gas probe installation. Sample intervals will target various depths along the length of the boring to establish site soil characteristics pre-injection.

B.2.c. In-situ Monitoring

In-situ monitoring of groundwater and soil gas chemistry parameters is not currently planned.

B.2.d. Continuous Monitoring

Continuous monitoring of groundwater and soil gas chemistry parameters is not currently planned.

B.2.e. Sample Homogenization, Composition, Filtration

Sampling procedures is described in Section B.2.a/b.

B.2.f. Sample Containers and Volumes

Soil gas samples will be collected in 0.3-L IsoBag Gas Bag® supplied by the selected geochemical laboratory. Soil samples will be collected in 4 oz. clear glass jars.

A summary of sample containers is presented in Tables 20 through 22.

B.2.g. Sample Preservation

For groundwater and other aqueous samples, the preservation methods provided in Tables 19 and 20 will be used. No preservation is required for soil gas samples.

B.2.h. Cleaning/Decontamination of Sampling Equipment

No cleaning or decontamination will be required for soil gas samples, as a brand new 60-mL gas-tight syringe will be utilized to collect each sample, and each soil gas probe site will include dedicated sampling tubing.

B.2.i. Support Facilities

Required support facilities will be determined in consultation with the selected sampling vendor.

B.2.j. Corrective Action, Personnel, and Documentation

Field staff will be responsible for properly testing equipment and performing corrective actions on broken or malfunctioning field equipment. If corrective action cannot be taken in the field, then equipment will be returned to the manufacturer for repair or replaced. Significant corrective actions affecting analytical results will be documented in field notes.

B.3. Sample Handling and Custody

Discussion in this section applys to physical samples, section does not apply to logging, seismic monitoring, pressure/temperature monitoring, atmospheric monitoring, and ecosystem stress monitoring.

Sample holding times given in Tables 19 thruough 21 are consistent with those described by USEPA (1974; 2020), American Public Health Association (APHA, 2005), Wood (1976), and

ASTM Method D6517-00. After groundwater sampling, the samples will be placed in ice chests in the field and maintained thereafter at a preservation temperature of approximately 4°C until analysis. The samples will be transported to the designated laboratory within 24 hours. Analysis of the samples will be completed within the holding times listed in Tables 19 and 20. As appropriate and if required, alternative options to the sample containers and preservation techniques, approved by the Commissioner, will be implemented to meet analytical requirements.

B.3.a. Maximum Hold Time/Time Before Retrieval

See Tables 20 to 23.

B.3.b. Sample Transportation

Sampling transportation is described in the introduction of Section B.3.

B.3.c. Sampling Documentation

An analysis authorization form will be provided with each CO_2 gas stream sample for testing in the laboratory using the laboratory's standard form. Field notes will be collected for all groundwater, soil gas, and soil samples, then retained and archived for reference. The sample documentation is the responsibility of the groundwater, soil gas, and soil sampling personnel (third party vendor).

B.3.d. Sample Identification

All sample containers will have waterproof labels with information (as relevant) denoting project, sampling date, sampling location, sample identification number, sample type (e.g., freshwater or brine), analyte, volume, filtration used (if any), and preservative used (if any) using the analytical laboratory's standard sample identification form.

Table 20. Summary of Sample Containers, Preservation Treatments, and Holding Times for CO2 Gas Stream Analysis.

Sample	Volume/Container Material	Preservation Technique	Sample Holding time (max)
CO_2 gas stream	75 cc Mini Cylinder	None	5 Days

Table 21. Summary of Anticipated Sample Containers, Preservation Treatments, and Holding Times for Ground Water Samples.

Target Parameters	Volume/Container Material	Preservation Technique	Sample Holding Time
Cations: Al, Ba, Mn, As, Cd, Cr, Cu, Pb, Sb, Se, and Tl Ca, Fe, K, Mg, Na, and Si	250 ml/HDPE	Filtered, nitric acid, cooled to 4°C	28 days
Anions: Br, Cl, F, NO3, and SO4	250 ml/HDPE	Filtered, nitric acid, cooled to 4°C	28 days
Dissolved CO_2	60 ml/HDPE	Filtered, cooled to 4°C	28 days
Alkalinity	500 ml/HDPE	Filtered, cooled to 4°C	28 days
Total dissolved solids	500 ml/HDPE	Cooled to 4°C	7 Days
Isotopes:	60 ml/HDPE	Filtered, cooled to 4°C	28 days

Field Confirmation: Water density pH Specific conductance Temperature	200 ml Glass	None	<1 hour

Table 22. Summary of Sample Containers, Preservation Treatments, and Holding Times for Soil Gas Samples.

Target Parameters	Volume/Container Material	Preservation Technique	Sample Holding Time
CO_2, CH_4, N_2, O_2 C1-C5 hydrocarbons Helium $\delta^{13}C$ of CO_2 and CH_4 δD of CH_4 C^{14} of CO_2 and CH_4	0.3-L IsoBag Gas Bag®	None	Value to be confirmed with selected vendor

Table 23. Summary of Sample Containers, Preservation Treatments, and Holding Times for Soil Samples.

Target Parameters	Volume/Container Material	Preservation Technique	Sample Holding Time
Total Organic Carbon (TOC)	4 oz. clear glass jar	Cooled to 4°C	28 days
Percent Moisture	4 oz. clear glass jar	Cooled to 4°C	60 days
Salinity	4 oz. clear glass jar	Cooled to 4°C	6 months

B.3.e. Sample Chain-of-Custody

For CO_2 gas stream samples, a laboratory analysis authorization form will accompany each sample to the designated lab at which point a chain-of-custody follows the sample through the testing processes.

For groundwater, soil gas, and soil samples, the chain-of-custody will be documented using a standardized form. Copies of the form will be provided to the person/lab receiving the samples as well as the person/lab transferring the samples. All the forms will be retained and archived to allow simplified tracking of sample status. The chain-of-custody form and the record-keeping task are the responsibilities of the groundwater, soil gas, and soil sampling personnel.

B.4. Analytical Methods

Discussion in this section appies to physical samples and does not apply to logging, seismic monitoring, pressure/temperature monitoring, atmospheric monitoring, and ecosystem stress monitoring.

B.4.a. Analytical SOPs

Analytical SOPs for groundwater, soil gas, and soil are referenced in Tables 4, 10, and 11, respectively. If needed, other laboratory-specific SOPs will be determined after a contract with the selected laboratory has been established. Upon request Louisiana Green Fuels can provide all SOPs implemented for specific parameters using appropriate standard methods. Each laboratory technician conducting the analyses on the samples will be trained on the SOP developed for each standard method. Louisiana Green Fuels will include the technician's training certification with the semi-annual report.

B.4.b. Equipment/Instrumentation Needed

Equipment and instrumentation are specified for all analytical methods referenced in Tables 4, 10, and 11.

B.4.c. Method Performance Criteria

Method performance criteria will be designated once the third-party analytical laboratory is selected and contracted, based on their quality assurance and quality control specifications.

B.4.d. Analytical Failure

Each laboratory conducting the analyses listed in Table 4, 10, and 11 will be responsible for appropriately addressing analytical failure according to the SOPs.

B.4.e. Sample Disposal

Each laboratory conducting the analyses listed in Table 4, 10, and 11 will be responsible for appropriate sample disposal according to the SOPs.

B.4.f. Laboratory Turnaround

Laboratory turnaround may vary by laboratory, but generally turnaround of verified analytical results within one month will be suitable for project needs.

B.4.g. Method Validation for Nonstandard Methods

Nonstandard methods are not anticipated for this project. If nonstandard methods are needed or proposed in the future, the USEPA and CARB will be consulted on additional appropriate actions to be taken.

B.5. Quality Control

Discussion in this section appies to physical samples. Seismic monitoring, pressure/temperature monitoring, atmospheric monitoring, and ecosystem stress monitoring do not apply to this section. For logging quality control, refer to the Schlumberger Wireline Log Quality Control Reference Manual (LQCRM), for example (or the manual used by the selected logging vendor). The Wireline Log Quality Control Reference Manual (LQCRM) is used by Schlumberger (Attachment 1). It concisely provides information for the acquisition of high-quality data at the wellsite and its delivery within defined standards. The LQCRM also facilitates the validation of Schlumberger wireline logs at the wellsite or in the office.

B.5.a. QC activities

Blanks

For shallow groundwater sampling, field blanks will be collected and analyzed for the inorganic analytes listed in Table 4 at a frequency of 10% or greater. Blanks will also be collected for deep groundwater baseline sampling and analyzed for the inorganic analytes listed in Table 4 at a frequency of 10% or greater. Field blanks will be exposed to the same field (equipment) and transport (trip) conditions as the groundwater samples. Blanks will be used to detect contamination resulting from the collection and transportation processes. No collection of field blanks is required for soil gas or soil sampling.

Duplicates

For each shallow groundwater and soil gas sampling round, duplicate samples will be collected from a designated well and soil gas probe site, respectively, on a rotating schedule. Duplicate samples will be collected from the same source immediately after (i.e., groundwater) or during i.e., soil gas) the original sample in different containers and processed as all the other samples. Duplicate samples will be used to assess sample heterogeneity and analytical precision.

One duplicate for every 10 soil samples will be collected during the single proposed soil sampling event occurring concurrently will soil gas probe installation.

B.5.b. Exceeding Control Limits

If the groundwater sample analytical results exceed control limits (i.e., ion balances > ±10%), further examination of the analytical results will be done by evaluating the ratio of the measured total dissolved solids (TDS) to the calculated TDS (i.e., mass balance) per APHA method. The method indicates which ion analyses should be considered suspect based on the mass balance ratio. Suspect ion analyses will be then reviewed in the context of historical data and interlaboratory results, when available. Suspect ion analyses will be brought to the attention of the analytical laboratory for confirmation and/or reanalysis. The ion balance will be recalculated, and if the error is still not resolved, suspect data will be identified and potentially given less importance in data interpretations.

B.5.c. Calculating Applicable QC Statistics

Charge Balance

The analytical results will be evaluated to determine the correctness of the analyses based on anion-cation charge balance calculations. Because all potable waters are electrically neutral, the chemical analyses should yield equally negative and positive ionic activity. The anion-cation charge balance will be calculated using the following formula:

$$\%\,difference = 100\frac{\sum cations - \sum anions}{\sum cations + \sum anions} \qquad \text{(Equation 1)}$$

where the sums of the ions are represented in milliequivalents (meq) per liter and the criteria for acceptable charge balance is ±10%.

Mass Balance

The ratio of the measured TDS to the calculated TDS will be calculated in instances where the charge balance acceptance criteria are exceeded using the following formula:

$$1.0 < \frac{Measured\ TDS}{Calculated\ TDS} < 1.2. \qquad \text{(Equation 2)}$$

Outliers

The determination of one or more statistical outliers is essential prior to the statistical evaluation of groundwater samples. This project will use the USEPA's Unified Guidance (March 2009) as a basis for selection of recommended statistical methods to identify outliers in groundwater chemistry datasets as appropriate. These techniques include Probability Plots, Box Plots, Dixon's test, and Rosner's test. The EPA-1989 outlier test may also be used as another screening tool to identify potential outliers.

B.6. Instrument/Equipment Testing, Inspection, and Maintenance

Discussion in this section appies to physical samples and does not apply to logging, seismic monitoring, pressure/temperature monitoring, atmospheric monitoring, and ecosystem stress monitoring. Logging tool equipment will be maintained as per industry best practices (see For logging quality control, refer to the Schlumberger Wireline Log Quality Control Reference Manual (LQCRM), for example (or the manual used by the selected logging vendor).

For groundwater, soil gas, and soil sampling, field equipment will be maintained, factory-serviced, and factory-calibrated per manufacturer's recommendations. Spare parts that may be needed during sampling will be included in supplies available on-hand during field sampling.

For all laboratory equipment, testing, inspection, and maintenance will be the responsibility of the analytical laboratory per standard practices, method-specific protocols, or NELAP requirements.

B.7. Instrument/Equipment Calibration and Frequency

Discussion in this section appies to physical samples and does not apply to logging, seismic monitoring, pressure/temperature monitoring, atmospheric monitoring, and ecosystem stress monitoring.

B.7.a. Calibration and Frequency of Calibration

Pressure/temperature gauge calibration information is located in Table 13 to Table 18. Logging tool calibration will be at the discretion of the service company providing the equipment, following standard industry practices provided in the Schlumberger Wireline Log Quality Control Reference Manual (LQCRM), for example (or the manual used by the selected logging vendor). Calibration frequency will also be determined by standard industry practices.

For groundwater sampling, portable field meters or multiprobe sondes used to determine field parameters (e.g., pH, temperature, specific conductance, and dissolved oxygen) are calibrated according to manufacturer recommendations and equipment manuals (Hach, 2006) each day before sample collection begins. Recalibration is performed if any components yield atypical values or fail to stabilize during sampling.

No calibration of field sampling equipment for soil gas or soil is required.

B.7.b. Calibration Methodology

Logging tool calibration methodology will follow standard industry practices as noted in the Schlumberger Wireline Log Quality Control Reference Manual (LQCRM), for example (or the manual used by the selected logging vendor).

For groundwater sampling, standards used for calibration are typically 7 and 10 for pH, a potassium chloride solution yielding a value of 1,413 microsiemens per centimeter (µS/cm) at 25°C for specific conductance, and a 100% dissolved O_2 solution for dissolved oxygen. Calibration is performed for pH meters per manufactuer's specifications using a 2-point calibration bounding the range of the sample. For coulometry, sodium carbonate standards (typically yielding a concentration of 4,000 mg CO_2/L) are routinely analyzed to evaluate instrument.

No calibration of field sampling equipment for soil gas or soil is required.

B.7.c. Calibration Resolution and Documentation

Logging tool calibration resolution and documentation will follow standard industry practices as noted in the Schlumberger Wireline Log Quality Control Reference Manual (LQCRM), for example (or the manual used by the selected logging vendor)..

For groundwater sampling, calibration values are recorded in daily sampling records and any discrepancies in calibration are noted. For parameters where calibration is not acceptable, redundant equipment may be used to ensure that loss of data is minimized.

No calibration of field sampling equipment for soil gas or soil is required.

B.8. Inspection/Acceptance for Supplies and Consumables

B.8.a/b. Supplies, Consumables, and Responsibilities

Supplies and consumables for field and laboratory operations will be procured, inspected, and accepted as required from vendors approved by Louisiana Green Fuels or the respective subcontractor responsible for the data collection activity. Acquisition of supplies and consumables related to groundwater, soil gas, and soil analyses will be the responsibility of the laboratory per established standard methodology or operating procedures.

B.9. Nondirect Measurements

B.9.a. Data Sources

For time-lapse seismic surveys, repeatability is paramount for accurate differential comparison. Therefore, to ensure survey quality, the locations of the shots and the acquisition methodology of sequential surveys will remain consistent. Once the surveys are conducted, they will be compared to a baseline survey to track and monitor the plume development.

B.9.b. Relevance to Project

Time-lapse seismic surveys will be used to track changes in the CO_2 plume propagation in the subsurface. Processing and comparing subsequent surveys to a baseline will allow project managers to monitor plume growth, as well as to ensure that the plume does not move outside of the intended Storage Complex. Numerical modeling will be used to predict the CO_2 plume growth and migration over time by combining the processed seismic data with the existing geologic model. In-zone pressure monitoring data will also be used in numerical modeling to predict the plume and pressure front behavior and confirm the plume stage within the AOR.

B.9.c. Acceptance Criteria

Following standard industry practices will ensure that the gathered seismic data are used for accurate modeling and monitoring. Similar ground conditions, shot points located within tolerable limits, functional geophones, and similar seismic input signal will be used from survey to survey to ensure repeatability. To the extent possible, source stations my be fabricated concrete pads that can be periodically reoccupied. This will ensure consistent signal generation stations for the project.

When processing seismic data, several quality assurance checks will be performed in accordance with industry standards, including reformatting to Omega structured files, geometry application, amplitude compensation, predictive deconvolution, elevation statics correction, root mean square (RMS) amplitude gain, velocity analysis every 2 km, normal move out (NMO) application using picked velocities, common mid-point (CMP) stacking, random noise attenuation, and instantaneous gain.

B.9.d. Resources/Facilities Needed

Louisiana Green Fuels will subcontract all necessary resources and facilities for seismic monitoring, in-zone pressure monitoring, and groundwater sampling.

B.9.e. Validity Limits and Operating Conditions

For seismic surveys and numerical modeling, intraorganizational checks between trained and experienced personnel will ensure that all surveys and numerical modeling are conducted conforming to standard industry practices.

B.10. Data Management

B.10.a. Data Management Scheme

Louisiana Green Fuels or a designated contractor will maintain the required project data as provided in the permit. Data will be backed up on tape or held on secure servers.

B.10.b. Recordkeeping and Tracking Practices

All records of gathered data will be securely held and properly labeled for auditing purposes.

B.10.c. Data Handling Equipment/Procedures

All equipment used to store data will be properly maintained and operated according to proper industry techniques. Louisiana Green Fuels IT system and vendor data acquisition systems will interface with one another and all subsequent data will be held on a secure server.

B.10.d. Responsibility

The primary project managers will be responsible for ensuring proper data management is maintained.

B.10.e. Data Archival and Retrieval

All data will be held by Louisiana Green Fuels, maintained and stored for auditing purposes as described in Section B.10.a.

B.10.f. Hardware and Software Configurations

All Louisiana Green Fuels and vendor hardware and software configurations will be appropriately interfaced.

B.10.g. Checklists and Forms

Checklists and forms will be procured and generated as necessary.

C. ASSESSMENT AND OVERSIGHT

C.1. Assessments and Response Actions

C.1.a. Activities to be Conducted

Refer to Table 1 in Section A.3.a/b for the summary of testing and monitoring to be performed.

Groundwater quality, atmospheric, ecosystem stress, and soil gas composition data will be collected at the frequency outlined in the table. Soil samples will only be collected suring soil gas probe installation during the pre-injection phase to establish site soil characteristics. After completion of the sample analyses, the results will be reviewed for QC criteria as noted in Section B.5. If the data quality fails to meet the criteria set in Section B.5, the samples will be reanalyzed, if within holding time criteria. If outside of holding time criteria, additional samples may be collected or sample results may be excluded from data evaluations and interpretations. Evaluation for data consistency will be performed according to procedures described in the USEPA 2009 Unified Guidance (USEPA, 2009).

C.1.b. Responsibility for Conducting Assessments

Organizations gathering data will be responsible for conducting their internal assessments. All stop work orders will be handled internally within individual organizations.

C.1.c. Assessment Reporting

All assessment information should be reported to the project managers of the individual organizations outlined in Section A.1.a/b.

C.1.d. Corrective Action

All corrective action affecting only an individual organization's data collection responsibility should be addressed, verified, and documented by the individual project managers and communicated to the other project managers as necessary. Corrective actions affecting multiple organizations should be addressed by all members of the project leadership and communicated to other members on the distribution list stated for the QASP. Assessments may require integration of information from multiple monitoring sources across several organizations (operational, in-zone monitoring, and above-zone monitoring) to determine whether correction actions are required and/or the most cost-efficient and effective action to implement. Louisiana Green Fuels will coordinate multiorganization assessments and corrective actions as warranted.

C.2. Reports to Management

C.2.a/b. QA status Reports

Quality assurance status reports should not be needed. However, if any testing or monitoring techniques are changed, the QASP will be reviewed and updated as appropriate in consultation with USEPA and CARB. Revised QASPs will be distributed by Louisiana Green Fuels to the full distribution list provided at the beginning of this document.

D. Data Validation and Usability

D.1. Data Review, Verification, and Validation

D.1.a. Criteria for Accepting, Rejecting, or Qualifying Data

Groundwater quality, soil gas composition, and soil quality data validation will include the review of the concentration units and sample holding times, and the review of duplicates, blanks, and other appropriate QA/QC results. All groundwater quality, soil gas composition, and soil quality results will be entered into a database or spreadsheet with periodic data review and analysis. Louisiana Green Fuels will retain copies of the laboratory analytical test results and/or reports. Analytical results will be reported on the frequency based on the approved UIC permit conditions. In the periodic reports, data will be presented in graphical and tabular formats as appropriate to characterize general groundwater quality and identify intrawell variability with time. After sufficient data have been collected, additional methods, such as those described in the USEPA 2009 Unified Guidance (USEPA, 2009), will be used to evaluate intrawell or inrtaprobe variations for groundwater and soil gas constituents, respectively, and if significant changes have occurred that could be the result of CO_2 or brine seepage beyond the intended storage reservoir.

D.2. Verification and Validation Methods

D.2.a. Data Verification and Validation Processes

See Sections B.5 and D.1.a.

Appropriate statistical software will be used to determine data consistency.

D.2.b. Data Verification and Validation Responsibility

Louisiana Green Fuels or its designated subcontractor will verify and validate groundwater, soil gas, and soil sampling data.

D.2.c. Issue Resolution Process and Responsibility

Louisiana Green Fuels or its designated coordinator will oversee the groundwater, soil gas, and soil data handling, management, and assessment process. Staff involved in these processes will consult with the coordinator to determine actions required to resolve any possible issues.

D.2.d. Checklist, Forms, and Calculations

Checklists and forms will be developed to meet specific permit requirements.

D.3. Reconciliation with User Requirements

D.3.a. Evaluation of Data Uncertainty

Statistical software will be used to determine groundwater, soil gas, and soil data consistency using methods consistent with USEPA 2009 Unified Guidance (USEPA, 2009).

D.3.b. Data Limitations Reporting

The organization-level project managers will be responsible for ensuring that data developed by their respective organizations is presented with the appropriate data-use limitations.

Louisiana Green Fuels will use the current operating procedure for utilizing, sharing, and presenting results and/or data for the Louisiana Green Fuels project. The procedure has been developed to ensure quality and internal consistency, and facilitate tracking and record keeping of data end users and associated publications.

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ATTACHMENT 1

SCHLUMBERGER WIRELINE LOG QUALITY CONTROL REFERENCE MANUAL