APPENDIX A: QUALITY ASSURANCE AND SURVEILLANCE PLAN
LAC 43:XVII.3625(A)(11)

Project Name: Live Oak CCS Hub

Facility Information

Facility Contact: Live Oak CCS, LLC
14302 FNB Parkway
Omaha, Nebraska 68154
402-691-9500

OOC Code No.: L1135

Well Locations:

Well Name	Latitude (WGS84)	Longitude (WGS84)	Parish	State
LO-01 M[1]	Claimed as PBI [redacted]	[redacted]	West Baton Rouge	Louisiana
LO-01 F[1]	Claimed as PBI [redacted]	[redacted]	West Baton Rouge	Louisiana
LO-02 M	Claimed as PBI [redacted]	[redacted]	West Baton Rouge	Louisiana
LO-03 M	Claimed as PBI [redacted]	[redacted]	Iberville	Louisiana
LO-04 F-M	Claimed as PBI [redacted]	[redacted]	Iberville	Louisiana
LO-05 M	Claimed as PBI [redacted]	[redacted]	Iberville	Louisiana
LO-06 M[1]	Claimed as PBI [redacted]	[redacted]	Iberville	Louisiana
LO-06 F[1]	Claimed as PBI [redacted]	[redacted]	Iberville	Louisiana

[1] For shared well pads, surface hole location spacing is set to a minimum of 15 feet.

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List of Acronyms

°C	Degrees Celsius
°F	Degrees Fahrenheit
µm	Micrometer
µS	Microsiemens
Al	Aluminum
AOB-#	Above-Zone Observation wells
AoR	Area of Review
APHA	American Public Health Association
As	Arsenic
ASTM	American Society for Testing and Materials
Ba	Barium
Br	Bromine
Ca	Calcium
CB	Cement Bond
CCS	Carbon Capture and Storage
Cd	Cadmium
CI	Casing Inspection
Cl	Chlorine
cm	Centimeter
CO_2	Carbon Dioxide
Cr	Chromium
Cu	Copper
DH	Down Hole
DTS	Distributed Temperature Sensing
EPA	Environmental Protection Agency
Fe	Iron
ft	Feet
GC-P	Gas Chromatography-Pyrolysis
GW-#	Shallow Groundwater Wells
HDPE	High Density Polyethylene
hr	Hour
ICP	Inductively Coupled Plasma
ID	Identification
IOB-#	In-Zone Observation wells
ISBT	International Society of Beverage Technologists
K	Potassium

L	Liter
Mg	Magnesium
mg	Milligram
MIT	Mechanical Integrity Testing
ml	Milliliter
mm	Millimeter
MMscf/d	Million Standard Cubic Feet/Day
Mn	Manganese
MS	Mass Spectrometry
MLB	Multi-Layer Barrier
Mt/d	Thousand Tonnes per Day
Na	Sodium
NO_3	Nitrate
OES	Optical Emission Spectrometry
Pb	Lead
pH	Potential of Hydrogen
PNC	Pulsed Neutron Capture
ppm	Parts Per Million
psi	Pounds Per Square Inch
pu	Porosity Units
QA	Quality Assurance
QA/QC	Quality Assurance and Quality Control
QASP	Quality Assurance and Surveillance Plan
Sb	Antimony
Se	Selenium
Si	Silicon
SO_4	Sulfate
SOP	Standard Operating Procedure
T	Temperature
t/d	Metric Ton per Day
TBD	To be Determined
TDS	Total Dissolved Solids
Ti	Titanium
LO#	Live Oak CCS Hub Injection Wells
OC	Louisiana Department of Energy and Natural Resources' Office of Conservation
uL	Microliter
UOB-#	Deep Observation Wells
USDW	Underground Source of Drinking Water

Title and Approval Sheet

This Quality Assurance and Surveillance Plan (QASP) is approved for use and implementation at Live Oak CCS Hub. The signatures below denote the approval of this document and intent to abide by the procedures outlined within it.

Signature Ryan Choquette Project Manager	Date
Signature TBD Operations Manager	Date

1. Project Management

1.1. Project/Task Organization

1.1.1. Key Individuals and Responsibilities

The Live Oak CCS Hub in Iberville and West Baton Rouge parishes, Louisiana (project) is owned and operated by Live Oak CCS, LLC, who will serve as the lead on all project tasks while supervising the performance of subcontractors when required for individual tasks. The Project Manager will be responsible for implementation of this Quality Assurance and Surveillance Plan (QASP) during pre-operational testing, and the Operations Manager will be responsible for implementation of this QASP during injection and post-injection. The Testing and Monitoring Plan is broken into seven subcategories:

1. Shallow Groundwater Sampling
2. Formation Water and Deep Groundwater Sampling
3. Well Logging
4. Mechanical Integrity Testing (MIT)
5. Pressure/Temperature Monitoring
6. CO_2 Stream Analysis
7. Geophysical Monitoring

1.1.2. Independence from Project QA Manager and Data Gathering

Most physical samples collected and the data gathered as part of the testing and monitoring program are analyzed, processed, or witnessed by third parties independent of the project management structure. Live Oak CCS, LLC will provide the Louisiana Department of Energy and Natural Resources' Office of Conservation (OC) with the name and credentials of any vendors, subcontractors, or testing laboratories used for testing and monitoring protocols during each quarterly reporting period.

1.1.3. QA Project Plan Responsibility

Live Oak CCS, LLC will be responsible for maintaining and distributing the official, approved QASP. Live Oak CCS, LLC will periodically review this QASP and consult with the OC if/when changes to the QASP are required.

1.2. Problem Definition/Background

1.2.1. Reasoning

This QASP was developed to ensure the quality and standards of the Testing and Monitoring Plan, in accordance with LAC 43:XVII.3625(A)(11) for the project's Class VI permits.

The objectives of the Testing and Monitoring Plan include:

- Protecting Underground Sources of Drinking Water (USDW);
- Meeting the regulatory requirements of LAC 43:XVII.3625;
- Ensuring that the injection wells are operating as designed;
- Providing data to validate and calibrate the geological and dynamic models used to predict the distribution of Carbon Dioxide (CO_2) within the injection zone; and
- Support Area of Review (AoR) re-evaluations during the course of the project.

1.2.2. Reasons for Initiating the Project

The objective of the project is to develop a safe and commercially viable CO_2 storage site available to CO_2 emitters in the region while ensuring protection of groundwater resources, environmental and public health.

1.2.3. Regulatory Information, Applicable Criteria, Action Limits

Regulations at LAC 43:XVII.36 require owners or operators of Class VI wells to perform several types of activities during the lifetime of the project in order to ensure that the 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 USDWs are not endangered. These monitoring activities include MITs, injection well testing during operation, monitoring of groundwater quality in several zones, and tracking of the CO_2 plume and associated pressure front (full details of monitoring activities are provided in the Testing and Monitoring Plan). This QASP details both the measurements that will be taken, as well as the steps to ensure that the quality of all the data so it can be used with confidence in making decisions during the life of the project.

1.3. Project/Task Description

1.3.1. Summary of Work to be Performed

Table 1 outlines the plan for the injection and monitoring wells, Table 2 describes the testing and monitoring activities, location, and purpose, and Table 3 summarizes the instrumentation.

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Table 1: Project Well Summary

Well Types	Well Acronym	CCS System Zone	Zone Formation	Zone Depth (ft MD)	Quantity
Shallow Groundwater (GW)	GW-1	Shallow USDW	Chicot Aquifer System	TBD	1
Deep Observation (UOB)	UOB-01, UOB-04, UOB-06	Lowermost USDW	Jasper Equivalent Aquifer System	UOB-01: ~2,500 UOB-04: ~2,500 UOB-06: ~2,500	3
Above-Zone Observation (AOB)	AOB-01, AOB-04, AOB-06	1st Permeable Zone	Middle Miocene Sands	AOB-01: ~5,019 AOB-04: ~4,307 AOB-06: ~3,940	3
In-Zone Observation (IOB)	IOB-01, IOB-02, IOB-03, IOB-04, IOB-05, IOB-06, IOB-07	Reservoir	Lower Miocene Sands (M)	IOB-01: ~6,127 IOB-02: ~4,871 IOB-03: ~5,070 IOB-04: ~5,840 IOB-05: ~5,327 IOB-06: ~5,049 IOB-07: ~5,732	7
			Frio Formation (F)	IOB-01: ~10,440 IOB-02: ~8,921 IOB-03: ~9,221 IOB-04: ~11,060 IOB-05: ~10,002 IOB-06: ~9,222 IOB-07: ~9,821	
Injection	LO-01 M, LO-01 F, LO-02 M, LO-03 M, LO-04 F-M, LO-05 M, LO-06 M, LO-06 F	Reservoir	Lower Miocene Sands (M)	LO-01 M: ~6,289 LO-02 M: ~6,115 LO-03 M: ~6,020 LO-04 F-M: ~6,135 LO-05 M: ~5,976 LO-06 M: ~5,793	8
			Frio Formation (F)	LO-01 F: ~10,730 LO-04 F-M: ~10,842 LO-06 F: ~9,565	

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Table 2. Summary of Testing and Monitoring.

Activity	Method	Location(s)	Analytical Technique	Purpose
CO_2 Stream Analysis[1]	Gas Chromatograph and Injectate Sampling	Downstream of all CO_2 source points prior to the storage complex pipeline manifold	Chemical analysis	Analysis of injectate LAC 43:XVII.3625(A)(1)
Corrosion Monitoring	Corrosion Coupons Analysis	Upstream of wellhead, prior to the mass flow meters, and downstream of the injection well control valve	Chemical analysis	Corrosion monitoring LAC 43:XVII.3625(A)(3)
Formation Water and Groundwater Quality and Geochemistry[1]	Fluid Sampling and Analysis and BH Pressure Gauges	Lowermost USDW, Above-Zone, In-Zone during pre-operational testing only	Chemical analysis and continuous direct measurement	Groundwater quality and geochemistry monitoring LAC 43:XVII.3625(A)(4)
Injection Rate and Volume	Mass Flow Meter	Injection wells: LO-01 M, LO-01 F, LO-02 M, LO-03 M, LO-04 F-M, LO-05 M, LO-06 M, LO-06 F	Continuous measurement	Continuous monitoring of injection rate and volume LAC 43:XVII.3625(A)(2)
Injection Pressure	Tubing pressure gauge and downhole pressure gauge	Injection wells: LO-01 M, LO-01 F, LO-02 M, LO-03 M, LO-04 F-M, LO-05 M, LO-06 M, LO-06 F; In-zone observation wells: IOB-01 through 07	Continuous measurement	Continuous monitoring of injection pressure LAC 43:XVII.3625(A)(2)
Annular Pressure	Annular pressure gauge	Injection wells: LO-01 M, LO-01 F, LO-02 M, LO-03 M, LO-04 F-M, LO-05 M, LO-06 M, LO-06 F	Continuous measurement	Continuous monitoring of annular pressure LAC 43:XVII.3625(A)(2)
Annular Volume	Annular volume gauge and record	Injection wells: LO-01 M, LO-01 F, LO-02 M, LO-03 M, LO-04 F-M, LO-05 M, LO-06 M, LO-06 F	Continuous direct measurement	Continuous monitoring of annulus fluid volume LAC 43:XVII.3625(A)(2)
Mechanical Integrity	Internal – Annular pressure gauge monitoring injection wells	Injection wells: LO-01 M, LO-01 F, LO-02 M, LO-03 M, LO-04 F-M, LO-05 M, LO-06 M, LO-06 F	Direct measurement	Demonstration of internal and external mechanical integrity of the wellbore LAC 43:XVII.3625(A)(5)

Activity	Method	Location(s)	Analytical Technique	Purpose
Mechanical Integrity	External – DTS, AND/ OR[2] *one of:* Temp. Log, PNC Log, Ultra Sonic Cement Bond (CB) Log, Electromagnetic Casing Inspection (CI) Logs	Injection wells: LO-01 M, LO-01 F, LO-02 M, LO-03 M, LO-04 F-M, LO-05 M, LO-06 M, LO-06 F	Distributed indirect measurement	
Pressure Falloff Testing	Pressure gauge	Injection wells: LO-01 M, LO-01 F, LO-02 M, LO-03 M, LO-04 F-M, LO-05 M, LO-06 M, LO-06 F	Direct measurement	Pressure falloff testing LAC 43:XVII.3625(A)(6)
CO_2 Plume and Pressure Front Monitoring	DTS	Injection wells: LO-01 M, LO-01 F, LO-02 M, LO-03 M, LO-04 F-M, LO-05 M, LO-06 M, LO-06 F; In-zone observation wells: IOB-01 through 07	Direct and indirect measurements	CO_2 plume imaging and pressure front tracking LAC 43:XVII.3625(A)(7)
	Downhole (DH) pressure gauge	Injection wells: LO-01 M, LO-01 F, LO-02 M, LO-03 M, LO-04 F-M, LO-05 M, LO-06 M, LO-06 F; In-zone observation wells: IOB-01 through 07; Above zone observation wells: AOB-01, AOB-04, AOB-06; Deep observation wells: UOB-01, UOB-04, UOB-06		
	Pulsed Neutron Capture (PNC)[3]	Injection wells: LO-01 M, LO-01 F, LO-02 M, LO-03 M, LO-04 F-M, LO-05 M, LO-06 M, LO-06 F; In-zone observation wells: IOB-01 through 07;		

[1]Annual sampling and analysis is planned for the shallow groundwater observation well (Sampling and analysis frequencies may be reduced in consultation with the OC based on project-specific benchmarks that will be defined from baseline monitoring data and/or injection phase monitoring data).

[2]LO-01 F, LO-04 F-M and LO-06 F will only include DTS fiber optic deployment in the top cemented long string casing but not in the liner. For the liner sections, external MIT will involve temperature logging.

[3]Apart from injection wells, PNC logging or equivalent will only occur in wells with CO_2 breakthrough or wells with detected containment loss.

Table 3. Instrumentation Summary.

Instrument Type	Monitoring and Data Collection Location(s)	Monitoring Target (Formation or Other)	Explanation
Gas Chromatograph; Injectate Sampling and Analysis	Downstream of all CO_2 source points prior to the storage complex pipeline manifold	N/A	Used to analyze the chemical characteristic of the injectate stream to ensure compliance with the operators expected injectate stream composition
Mass Flow Meter	Each Injection Well Pad (LO-01 M & LO-01 F, LO-02 M, LO-03 M, LO-04 F-M, LO-05 M, LO-06 M & LO-06 F)	Lower Miocene Sands and Frio Formation	Used to record total mass of CO_2 injected
Pressure Gauges	Injection wells: LO-01 M, LO-01 F, LO-02 M, LO-03 M, LO-04 F-M, LO-05 M, LO-06 M, LO-06 F; In-zone observation wells: IOB-01 through 07; Above-zone observation wells: AOB-01, AOB-04, AOB-06; Deep observation wells: UOB-01, UOB-04, UOB-06	Lower Miocene Sands and Frio Formation, Jasper Equivalent Aquifer System, Middle Miocene Sands	Used to monitor communication with groundwater zones, annulus pressure, injection zone direct pressure front evolution, and for containment loss detection.
DTS	Injection wells: LO-01 M, LO-01 F, LO-02 M, LO-03 M, LO-04 F-M, LO-05 M, LO-06 M, LO-06 F; In-zone observation wells: IOB-01 through 07	Lower Miocene Sands and Frio Formation	Injection well external mechanical integrity, identify the vertical intervals taking injectate within the reservoir for use in computational model updates, and containment loss detection.
PNC Logging[1]	Injection wells: LO-01 M, LO-01 F, LO-02 M, LO-03 M, LO-04 F-M, LO-05 M, LO-06 M, LO-06 F; In-zone observation wells: IOB-01 through 07; Above-zone observation Wells: AOB-01, AOB-04, AOB-06; Deep observation wells: UOB-01, UOB-04, UOB-06	Lower Miocene Sands and Frio Formation	Pre-injection baseline, CO_2 containment loss detection/verification, & vertical CO_2 saturation profiling for use in computational model updates

Instrument Type	Monitoring and Data Collection Location(s)	Monitoring Target (Formation or Other)	Explanation
Formation Water and Groundwater Sampling and Analysis	1. Injection wells: LO-01 M, LO-01 F, LO-02 M, LO-03 M, LO-04 F-M, LO-05 M, LO-06 M, LO-06 F 2. Above zone observation wells: AOB-01, AOB-04, AOB-06 3. Deep observation wells: UOB-01, UOB-04, UOB-06	1. Jasper Equivalent Aquifer System 2. Middle Miocene Sands	*All Wells:* Identify pre-injection groundwater quality and geochemistry *1:* Early CO_2 and reservoir brine containment loss detection/verification *2:* CO_2 and reservoir brine containment loss detection/verification

[1] Apart from injection wells, PNC logging or equivalent will only occur in wells with CO_2 breakthrough or wells with detected containment loss at the frequency specified in the table above.

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1.3.2. Geographic and Stratigraphic Locations

Surface locations within the AoR of all injection and observation wells, identified containment loss risks, and the CO_2 plume extents throughout the project are shown in Figure 1 and Figure 2. Project stratigraphy and expected elevations are shown in Figure 3. Table 1 outlines the well type, well names, objective monitoring zones, and approximate depths of zones.

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Claimed as PBI

[redacted]

Figure 1. Map of Injection and Monitoring well locations for the project with the AoR (red line), Miocene 30-year plume (purple line), oil and gas wells, and water wells (blue dots).

Claimed as PBI

[redacted]

Figure 2. Map of Injection and Monitoring well locations for the project with the AoR (red line), Frio 30-year plume (purple line), oil and gas wells, and water wells (blue dots).

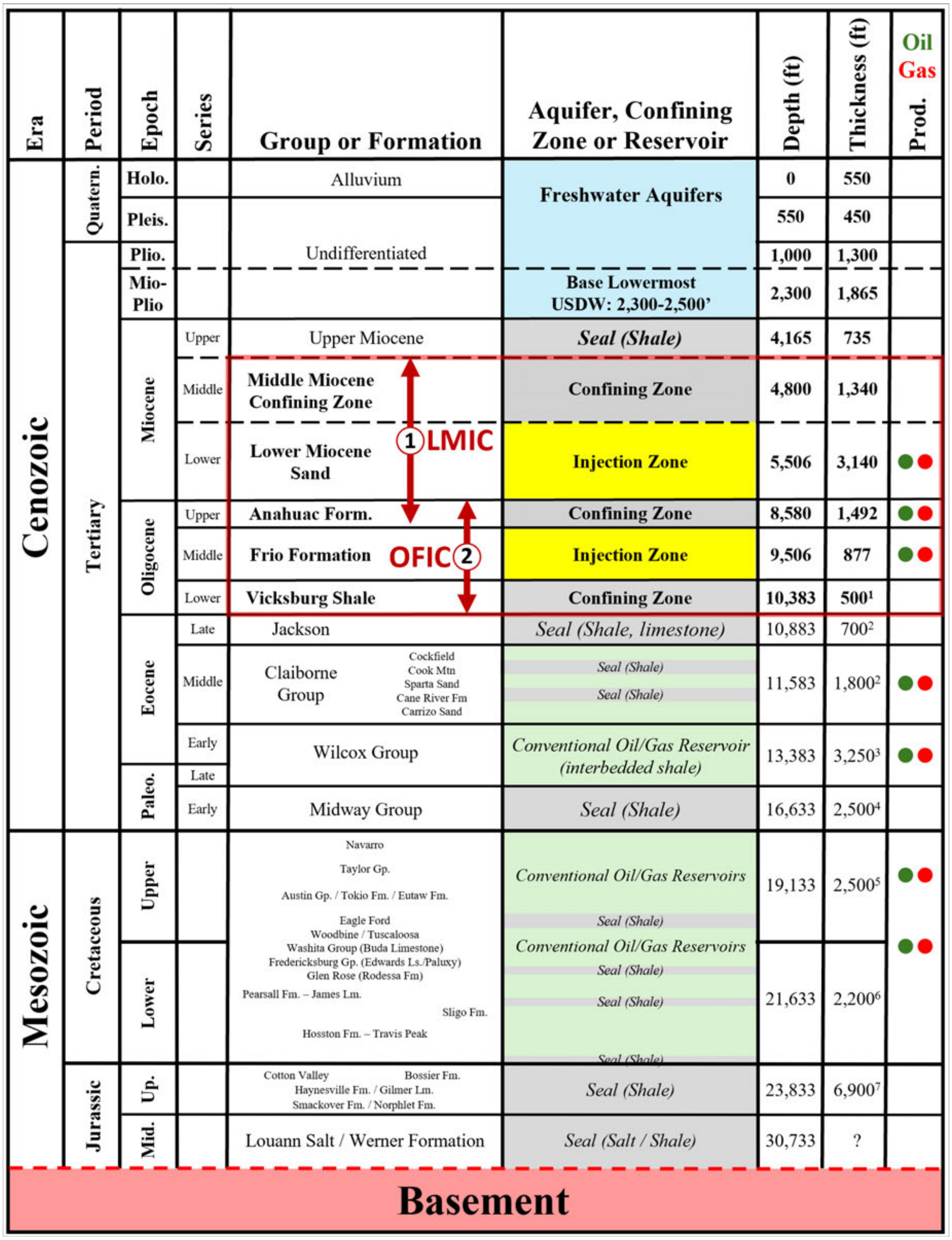

Figure 3. Generalized stratigraphic column identifying the (1) LMIC and (2) OFIC storage complexes with corresponding storage reservoirs and confining zones at the project injection wells. Lowermost USDW is also identified for reference. (*Depth is to the top of the Stratigraphic Unit (SU).

1.3.3. Resource and Time Constraints

Live Oak CCS, LLC will coordinate deployment and uses of the monitoring and testing equipment described in the Testing and Monitoring Plan and in this QASP appropriate for field operations, service company availability (where necessary), other field-level logistics and operations, CO_2 source and pipeline operations, and community input.

1.4. Quality Objectives and Criteria

1.4.1. Performance/Measurement Criteria

Groundwater analytical and field monitoring parameters for each interval are listed in Table 4. Table 5, Table 6, and Table 7 show analytical parameters for CO_2 stream gas monitoring, corrosion coupon assessment, and gauge specifications. Table 8 shows the monitoring outputs. The list of analytes may be reassessed periodically and adjusted to include or exclude analytes based on their effectiveness to the overall monitoring program goals.

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Table 4. Summary of Analytical and Field Parameters for Fluid Samples in Shallow USDW, Deep USDW, and Above-Zone Fluid Sampling.

Parameters	Analytical Methods	Detection Limit/Range	Typical Precisions	QC Requirements
Cations: Al, Ba, Mn, As, Cd, Cr, Cu, Pb, Sb, Se, and Tl	ICP-MS EPA Method 6020B (U.S. EPA, 2014a) or EPA Method 200.8 (U.S. EPA, 1994a)	0.001 to 0.1 mg/L (Analyte, dilution, and matrix dependent)	±15%	Daily Calibration; blanks, duplicates, and matrix spikes at 10% or greater frequency
Cations: Ca, Fe, K, Mg, Na, and Si	ICP-OES EPA Method 6010D (U.S. EPA, 2014b) or EPA Method 200.7 (U.S., EPA, 1994b)	0.005 to 0.5 mg/L (Analyte, dilution, and matrix dependent)	±15%	Daily Calibration; blanks, duplicates, and matrix spikes at 10% or greater frequency
Anions: Br, Cl, F, NO_3, and SO_4	Ion Chromatography EPA Method 300.0 (U.S. EPA, 1993)	0.02 to 0.13 mg/L (Analyte, dilution, and matrix dependent)	±15%	Daily Calibration: blanks and duplicates at 10% or greater frequency
Dissolved CO_2	Coulometric Titration ASTM 513-16 (ASTM, 2016)	25 mg/L	±15%	Duplicate measurement; standards at 10% or greater frequency
Total Dissolved Solids	Gravimetry APHA 2540C (APHA)	12 mg/L	±15%	Balance calibration, duplicate analysis
Water Density (field)	Oscillating Body Method	0.0000 to 2.0000	±0.0002 g/mL	Duplicate measurements
Alkalinity	APHA 2320B (APHA 1997)	4 mg/L	±3 mg/L	Duplicate Analysis
pH (field)	EPA 150.1 (U.S. EPA, 1982)	2 to 12 pH units	±0.2 pH unit	User Calibration per manufacturer recommendation
Specific Conductance (field)	APHA 2510 (APHA, 1992)	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
Isotopes: $\delta^{13}C$ of DIC	Isotope Ratio Mass Spectrometry	12.2mg/L HCO_3^- for $\delta^{13}C$	±0.15% for $\delta^{13}C$	10% duplicates; 4 standards/batch

Abbreviations: ICP = inductively coupled plasma; MS = mass spectrometry; OES = Optical emission spectrometry; GC-P = Gas chromatography-Pyrolysis

Table 5. Summary of Analytical Parameters for CO_2 Stream.

Parameters	Method	Detection Limit/Range	Typical Precisions	QC Requirements
CO_2 Purity	ISBT 2.0 Caustic absorption Zahm-Nagel or online gas quality equipment	90.00% to 99.99%	± 10% of reading	User calibration per manufacturer
Water Content	Online gas quality equipment	To be updated with manufacturer specifications	To be updated with manufacturer specifications	To be updated with manufacturer specifications
Total Hydrocarbons	ISBT 10.0 THA (FID) or online gas quality equipment	1 uL/L to 10,000 uL/L (ppm by volume)	5 - 10% of reading relative across the range	daily blank, daily standard within 10% of calibration, secondary standard after calibration
Total Organic Carbon	SW846 9060A or equivalent	> 0.2 uL/L (ppm by volume)	± 20% of reading	duplicate analysis
Inert Gasses (N_2, Ar, O_2)	ISBT 4.0 (GC/DID) GC/TCD or online gas quality equipment	1 uL/L to 5,000 uL/L (ppm by volume)	± 10% of reading	daily standard within 10% of calibration, secondary standard after calibration
Alcohols	ISBT 9.0 (GC) or online gas quality equipment	5 uL/L to 100 uL/L (ppm by volume)	± 20% of reading	duplicate analysis
Aldehydes, Esters	ISBT 11.0 (GC) or online gas quality equipment	0.01 uL/L to 50 uL/L (ppm by volume)- dilution dependent	5 – 10% of reading relative across the range	duplicate analysis
Glycol	ISBT 11.0 (GC) or online gas quality equipment	2 uL/L to 100 uL/L (ppm by volume)- dilution dependent	10% of reading relative across the range	duplicate analysis
Hydrogen Sulfide	ISBT 14.0 (GC/SCD) or online gas quality equipment	0.1 uL/L to 100 uL/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 Sulfur	ISBT 14.0 (GC/SCD) or online gas quality equipment	0.01 uL/L to 50 uL/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
Hydrogen	ISBT 4.0 (GC/DID) GC/TCD or online gas quality equipment	1 uL/L to 5,000 uL/L (ppm by volume)	± 10% of reading	daily standard within 10% of calibration, secondary standard after calibration

Parameters	Method	Detection Limit/Range	Typical Precisions	QC Requirements
Carbon Monoxide	ISBT 5.0 Colorimetric ISBT 4.0 (GC/DID) or online gas quality equipment	5 uL/L to 100 uL/L (ppm by volume)	± 20% of reading	duplicate analysis

Note: Analytical parameters presented are for physical bottle sampling and laboratory analysis. A gas chromatograph will be installed to continuously detect CO_2 purity, total hydrocarbons, inert gases, hydrogen, alcohols, oxygen, carbon monoxide, and glycol. Annual bottle analysis will be performed to analyze the CO_2 stream for hydrogen sulfide and total sulfur. The detection range, accuracy, precision, and calibration requirements of the gas chromatograph will be shared with the OC as requested.

Table 6. Specifications for MITs and Geophysical Monitoring Technology.

Logging Tool	Analytical Methods	Detection Limit/Range	Typical Precisions	QC Requirements	Calibration Frequency
Ultrasonic Cement Bong Log (SLB USI Tool)	Vendor best practice	0-10 MRayl[1]	±0.5 MRayl	Vendor Calibration (3rd party)	Per Vendor Discretion
PNC Logging (SLB RST Tool)	Vendor best practice	Porosity: 0 to 60 pu	TBD	Vendor Calibration (3rd party)	Per Vendor Discretion
Distributed Temperature Sensing	Vendor best practice	-40 ºF to 149 ºF	0.01 ºC	Vendor Calibration (3rd party)	Per Vendor Discretion

[1]A rayl is a pascal-second per meter, a unit of specific acoustic impedance.

Table 7. Summary of Analytical Parameters for Corrosion Coupons.

Parameters	Analytical Methods	Detection Limit/Range	Typical Precisions	QC Requirements
Mass	NACE RP0775-2018 (NACE, 2018)	0.005 mg	±2%	Annual Calibration of Scale (3rd Party)
Thickness	NACE RP0775-2018 (NACE, 2018)	0.001 mm	±0.005 mm	Factory calibration

Table 8. Summary of Measurement Parameters for CO_2 Injection Process Monitoring.

Parameters	Methods	Detection Limit/Range	Vendor Specified Accuracy	QC Requirements
Operational Annular Pressure Monitoring	ISO/IEC 17025 (2017)	0-3,000 psi	± 0.5% FS	Annual Calibration of Scale (3rd party)
Wellhead Injection pressure (e.g., PPS PPS31 Wellhead Pressure Logger or similar product)	ISO/IEC 17025 (2017)	0-5,000 psi	±0.03% FS	Annual Calibration of Scale (3rd party)
Injection mass flow rate (e.g., Emerson Coriolis mass flow meter or similar product)	AGA Report 3 API Chapter 14 Part 3 (API, 2016)	547.95-3,561.64 mt/day	±0.1% of rate for liquid ±0.35% of rate for gas	Annual Calibration of Scale (3rd party)
Downhole Pressure (e.g., Baker Hughes SureSENS QPT ELITE pressure/temperature gauge of similar product)	Unknown	200 psi to 10,000 psi	± 0.015% FS	Initial Manufacturer Calibration

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Table 9. Actionable Testing and Monitoring Outputs.

<table>
<tr><th>Activity or Parameter</th><th>Project Action Limit</th><th>Detection Limit</th><th colspan="3">Anticipated Reading</th></tr>
<tr><td>DTS</td><td>Action to be taken when a temperature anomaly is observed</td><td>Refer to Table 6</td><td colspan="3">Difference between profiles observed during baseline & injection stream temperature</td></tr>
<tr><td>PNC logging</td><td>Action to be taken when a CO_2 saturation anomaly is observed</td><td>Refer to Table 6</td><td colspan="3">TBD during baseline</td></tr>
<tr><td rowspan="9">Injection rate</td><td rowspan="9">Injection rate is reduced if max instantaneous rate is reached</td><td rowspan="9">Refer to Table 8</td><td>Well</td><td>LMIC max. injection rate [MMt/y]</td><td>OFIC max. injection rate [MMt/y]</td></tr>
<tr><td>LO-01 M</td><td>3.5</td><td>NA</td></tr>
<tr><td>LO-01 F</td><td>NA</td><td>1.5</td></tr>
<tr><td>LO-02 M</td><td>3.5</td><td>NA</td></tr>
<tr><td>LO-03 M</td><td>3.5</td><td>NA</td></tr>
<tr><td>LO-04 F-M</td><td>3.5</td><td>1.5</td></tr>
<tr><td>LO-05 M</td><td>3.5</td><td>NA</td></tr>
<tr><td>LO-06 M</td><td>3.5</td><td>NA</td></tr>
<tr><td>LO-06 F</td><td>NA</td><td>1.5</td></tr>
<tr><td rowspan="9">Surface/downhole pressure</td><td rowspan="9">Injection stops if MASP[1] is reached</td><td rowspan="9">Refer to Table 8</td><td>Well</td><td>Max. surface pressure [psig]</td><td>Max. downhole pressure at perforations [psig]</td></tr>
<tr><td>LO-01 M</td><td>2,220</td><td>4,641</td></tr>
<tr><td>LO-01 F</td><td>2,220</td><td>7,919</td></tr>
<tr><td>LO-02 M</td><td>2,220</td><td>4,513</td></tr>
<tr><td>LO-03 M</td><td>2,220</td><td>4,443</td></tr>
<tr><td>LO-04 F-M</td><td>2,220</td><td>4,528</td></tr>
<tr><td>LO-05 M</td><td>2,220</td><td>4,410</td></tr>
<tr><td>LO-06 M</td><td>2,220</td><td>4,275</td></tr>
<tr><td>LO-06 F</td><td>2,220</td><td>7,059</td></tr>
<tr><td>Annular pressure</td><td><5% pressure loss over 1 hour</td><td>Refer to Table 8</td><td colspan="3">>5% pressure loss over 1 hour</td></tr>
<tr><td>Annular volume</td><td>10% loss of annular volume or continuous fluid make up exceeding 24 hours</td><td>Tank fluid level indicator</td><td colspan="3">Annular fluid make up is expected when temperature of the fluid changes</td></tr>
<tr><td>Annular pressure/volume</td><td>Action to be taken when annulus pressure is below 100 psig, above 2,320 psig, or less than injection pressure downhole in injection wells</td><td>Refer to Table 8</td><td colspan="3">100-2,320 psig at surface
Volume TBD during baseline</td></tr>
</table>

Activity or Parameter	Project Action Limit	Detection Limit	Anticipated Reading
Above-zone water quality (fluid sampling)	Action to be taken when chemical profile anomaly is observed	Refer to Table 4	Profiles TBD during baseline
Above-confining-zone pressure	Action will be taken when a pressure/temperature anomaly occurs	Refer to Table 4	Profiles TBD during baseline
CO_2 plume monitoring	Action to be taken if CO_2 plume is observed outside of expected/modelled spatial limits/geologic intervals	Dependent upon geologic conditions	Profiles TBD during baseline

NA = Not applicable
[1] Maximum allowable surface pressure. For more details see summary of requirements, operating and reporting conditions sections.

1.4.2. Precision

Groundwater sampling data accuracy will be assessed by the collection and analysis of field blanks to test sampling procedures and matrix spikes to test lab procedures. Field blanks will be taken no less than one per sampling event to spot check for sample bottle contamination. Laboratory assessment of analytical precision will be the responsibility of the individual laboratories. Third party laboratories used will be EPA approved and certified laboratories or accredited by the Louisiana Environmental Laboratory Accreditation Program.

1.4.3. Bias

Laboratory assessment of analytical bias will be the responsibility of the individual laboratories per their standard operating procedures and analytical methodologies. Routine gauge or instrument calibration as identified in subsection 2.7 should help identify and remove any measurement biases.

1.4.4. Representativeness

Data representativeness expresses the degree to which data accurately and precisely represent population characteristics, individual sampling point parameter variations, or process or environmental conditions. The sampling network has been designed to provide data representative of site conditions. For analytical results of individual groundwater samples, representativeness will be estimated by ion and mass balances, where ion balances with ±10% error or less will be considered valid. Mass balance assessment will be used in cases where the ion balance is greater than ±10% to help determine the error source. For a sample and its duplicate, if the relative percent difference is greater than 10%, the sample may be considered non-representative.

1.4.5. Completeness

Data completeness is a measure of the amount of valid data obtained from a measurement system compared to the expected amount under normal conditions. It is anticipated that data completeness of 90% for groundwater sampling will be acceptable to meet monitoring goals. For direct pressure and temperature measurements, it is expected that data will be recorded no less than 90% of the time.

1.4.6. Comparability

Data comparability is the confidence with which one dataset can be compared to another. Datasets for the project will be generated in accordance with a consistent methodology so that each dataset is comparable to another. This allows for appropriate data comparison and identification of anomalies if present. To ensure appropriate QA/QC standards, direct pressure, temperature, and logging measurements obtained through the proposed operations will be directly comparable to data previously obtained.

1.4.7. Method Sensitivity

The sensitivities and specifications of example gauges used for measurements in this project are described in detail in Table 10, Table 11, Table 12, and Table 13. Specific tools and measurement specifications may change during the detailed design phase following collection and characterization of data gathered during the pre-operational testing phase of the project. See further detail in the Pre-Operational Testing Program.

Table 10. Pressure—Downhole Gauge Specifications.

Parameter	Value
Calibrated working pressure range	200 psi to 10,000 psi
Initial pressure accuracy	+-0.015% (1.5 psi at full scale)
Pressure resolution	0.0001 psi
Pressure drift stability	2.0 psi per year at full scale

Note: Specifications from the *Baker Hughes SureSENS QPT ELITE Pressure Gauge* are provided as an example of typical specifications from a vendor. A similar product may be used.

Table 11. Representative Logging Tool Specifications.

Parameter	Ultrasonic Imager Log	PNC/ Reservoir Saturation Tool	DTS
Logging speed	1,800 ft/hr.	150 ft/hr.	NA
Vertical resolution	6 inches	24 inches	*25-50 cm
Investigation	Casing-to-cement interface	4-6 inches	At fiber location
Temperature rating	350°F (175°C)	300°F (150°C)	149ºF
Pressure rating	20,000 psi	15,000 psi	20 psi

Table 12. Pressure and Temperature Field Gauge Specifications.

Parameter	Value
Calibrated working pressure range	0-5,000 psi
Initial pressure accuracy	±0.05% FS
Pressure resolution	0.03% FS
Pressure drift stability	< 3.0 psi
Calibrated working temperature range	-20 ºF to 200 ºF
Initial temperature accuracy	±0.15 ºF (0.5 ºC)
Temperature resolution	0.1 ºF (0.01 ºC)
Max temperature	200 ºF

Note: Specifications from a *PPS PPS31 Wellhead Pressure Logger* are provided as an example of typical specifications from a vendor. A similar product may be used.

Table 13. Mass Flow Rate Field Gauge – CO_2 Mass Flow Rate Vendor Specifications.

Parameter	Value
Calibrated working flow rate range	65.4-2,100 Mt/d
Mass flow rate accuracy	±0.50% of rate (liquid), ±1.0% of rate (gas)
Mass flow rate repeatability	±0.50% of rate (liquid), ±1.% of rate (gas)
Mass flow rate drift stability	To be determined

1.5. Special Training/Certifications

1.5.1. Specialized Training and Certifications

The geophysical survey equipment and wireline logging tools will be operated by trained, qualified, and certified personnel, according to the service company that provides the equipment. The subsequent data will be processed and analyzed according to industry standards. Formation water and groundwater chemical analysis will be evaluated by an EPA certified laboratory or a laboratory accredited by the Louisiana Environmental Laboratory Accreditation Program that employs qualified and experienced personnel who understand and regularly follow environmental sampling/chemical analysis standard operating procedures and quality control protocols. Live Oak CCS, LLC will provide relevant certifications for all vendor/subcontractor staff upon request.

1.5.2. Training Provider and Responsibility

Live Oak CCS, LLC or the designated subcontractor for the data collection activities will provide necessary training for personnel.

1.6. Documentation and Records

1.6.1. Report Format and Package Information

A quarterly report from Live Oak CCS, LLC to the OC and EPA will contain all required project data, including testing and monitoring information in accordance with LAC 43:XVII.3629(A)(1)(a). Data will be provided in electronic or other formats as required by the OC. Further reporting and recordkeeping details can be found in subsection 1.5 of the Testing and Monitoring Plan.

1.6.2. 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 required by the OC and maintained for 10 years post site closure.

1.6.3. Data Storage and Duration

Pursuant to LAC 43:XVII.3629(A)(4), any monitoring data collected through implementation of the Testing and Monitoring Plan will be retained for at least ten years after it is collected. All site characterization data, data on the nature and composition of all injected fluids, well plugging reports, post-injection site care data, and the site closure report will be retained for at least ten years following site closure. Pursuant to 43:XVII.3625(B)(2)(a), calibration and maintenance records and all original strip chart recordings for continuous monitoring instrumentation shall be retained for at least three years from the date of the sample or measurement. Live Oak CCS, LLC or a designated contractor will maintain the required project data as provided elsewhere in the permit.

1.6.4. QASP Distribution Responsibility

The Live Oak CCS, LLC Project Manager will be responsible for creating a distribution list prior to the start of construction, maintaining it through the pre-operational testing period, and distributing the current approved QASP to those on the distribution list during the pre-operational testing period. The Operations manager will be responsible for creating a distribution list prior to the start of injection, maintaining it through the injection and post-injection periods, and distributing the current approved QASP to those on the distribution list during the injection and post-injection periods.

2. Data Generation and Acquisition

2.1. Sampling Process Design

This section describes the monitoring network that will be used to support collection of the various characterization and monitoring measurements needed to ensure safe and nominal CO_2 injection operations, track the development of the CO_2 plume and elevated pressure front, and identify/quantify any potential leakage of CO_2. Based on the current conceptual understanding of project geology, this strategy was developed to ensure safe, long-term containment of CO_2 within the injection interval and non-endangerment of USDWs.

2.1.1. Design Strategy

2.1.1.1. CO_2 Stream Monitoring Strategy

The objective of routinely analyzing the CO_2 stream is to evaluate the potential interactions of CO_2 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 regulatory determinations under the Resource Conservation and Recovery Act (RCRA, 1976) and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, 1980). Additionally, monitoring the chemical and physical characteristics of the CO_2 may help distinguish the injectate from the native fluids and gases if unintended leakage from the storage reservoir occurred.

Live Oak CCS, LLC expects multiple sources of CO_2 from the region, with additional sources to be added throughout the life of the project. Each source will have a different gas stream composition, and the composition of the final injected gas stream will change slightly depending on which sources are operational. To detect any significant changes in the physical or chemical properties of the CO_2 stream that may result in a deviation from the permitted specifications, Live Oak CCS, LLC will analyze the CO_2 stream continuously (every 24 hours) with a gas chromatograph located downstream of all CO_2 sources or at the wellhead points prior to the storage complex pipeline manifold at the injection wells. Physical samples will also be taken through a sampling port near the gas chromatograph at injection wells.

2.1.1.2. Corrosion Monitoring Strategy

To meet the requirements of LAC 43:XVII.3625(A)(3)(a), Live Oak CCS, LLC will monitor well materials during the operation period for loss of mass, thickness, cracking, pitting, and other signs of corrosion to ensure that the well components meet the minimum standards for material strength and performance using the corrosion coupon method. Coupons shall be sent out quarterly for analysis, which will be conducted in accordance with the NACE RP0775-2018 (NACE, 2018) standard to determine and document corrosion wear rates based on mass loss.

2.1.1.3. Shallow Groundwater Monitoring Strategy

Shallow groundwater monitoring will be performed on a quarterly basis during the year-long pre-injection period, to capture seasonal variations in the groundwater geochemistry of the Chicot Aquifer System. The monitoring program will meet the requirements of LAC 43:XVII.3625(A)(4) and will include baseline groundwater samples to characterize variations in water quality within the AoR prior to the start of CO_2 injection. This well will not be sampled and analyzed during the injection phase but may be used to provide additional evidence for groundwater protection should the operator or OC deem it necessary.

2.1.1.4 Formation Water and Deep Groundwater Monitoring Strategy

Three above-zone observation wells: AOB-01, AOB-04, AOB-06 will be completed in the Lower Miocene Sands and Frio Formation and three deep USDW observation wells: UOB-01, UOB-04, UOB-06 will be completed in the lowermost USDW (Jasper Equivalent Aquifer System). The above-zone observation wells will serve to detect any early leakage above the confining zone, and the deep USDW observation wells will monitor the formation fluid geochemistry of the lowermost USDW. In addition to baseline sample collection and analysis prior to the start of injection, pressurized fluid samples will be collected from these observation wells during the injection phase. MIT and downhole temperature monitoring at the injection wells will also provide data to ensure the mechanical integrity of the well is maintained. With the planned sampling and monitoring frequencies, baseline conditions will be documented, natural variability in conditions will be characterized, unintended brine or CO_2 leakage will be detected, and sufficient data will be collected to demonstrate that the effects of CO_2 injection are limited to the intended Lower Miocene Sands and Frio Formation storage reservoirs.

Parameters will include selected constituents that: (1) have primary and secondary EPA drinking water maximum contaminant levels, (2) are the most responsive to interaction with CO_2 or brine, (3) are needed for quality control, and (4) may be needed for geochemical modelling. After a sufficient baseline is established, monitoring scope 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 quality control to accurately test for and monitor the presence (or lack thereof) of CO_2 migration. Implementation of a reduced set of parameters would be done in consultation with the OC. 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 would be expanded to the full set of monitoring parameters. All groundwater and formation fluid samples will be analyzed using a laboratory meeting the requirements under the EPA Environmental Laboratory Accreditation Program or Louisiana Environmental Laboratory Accreditation Program. The full list of analytical parameters and selected methods is provided in Table 4.

2.1.1.4. Direct CO_2 Plume and Pressure Front Monitoring Strategy

Downhole pressure gauges will be used in all deep monitoring and injection wells to directly monitor the formation pressure of the injection reservoirs (Lower Miocene Sand and Frio Formation) and above-zone interval. Downhole and surface pressure gauges will continuously monitor for any changes in injection pressure or in-zone and above-zone pressure.

2.1.1.5. Indirect CO_2 Plume and Pressure Front Monitoring Strategy

Several technologies will be deployed within the injection, above-zone, in-zone, and deep observation wells to indirectly monitor the presence/absence of the CO_2 plume and elevated pressure front. At the injection wells, a fiberoptic line with DTS capabilities will be run along the outside of the cemented long-string casing through the Middle Miocene Confining Zone (primary confining zone) to continuously record temperature variations. For the in-zone observation wells, the fiber optic DTS line will run through the two injection intervals. External mechanical integrity at injection and in-zone wells will be monitored continuously using DTS. For LO-01F, LO-04 F-M, and LO-06 F wells with tapered casing design, the temperature log will be run annually along the uncemented sections to verify external mechanical integrity. PNC logging techniques will be utilized to verify external MIT for each injection and in-zone well by detecting the presence or absence of CO_2 in critical formations. PNC logging will also serve to track the CO_2 plume progression in the in-zone observation wells. For the above-zone and deep observation wells, PNC logging may occur in wells if a CO_2 breakthrough is detected.

2.1.2. Type and Number of Samples/Test Runs

The types and frequencies of sampling and testing activities are shown in Table 2.

2.1.3. Site/Sampling Locations

The site and sampling locations are shown in Table 2.

2.1.4. Sampling Site Contingency

The shallow and deep groundwater monitoring wells will be sited at or near their projected locations in such a way to allow regular access to perform testing activities.

No problems of site inaccessibility are anticipated for CO_2 gas or corrosion coupon sampling. If inclement weather makes site access difficult, sampling schedules will be revised, and alternative dates may be selected that would still meet permit-related conditions.

2.1.5. Activity Schedule

Please refer to the Testing and Monitoring Plan for a schedule of sampling and test runs.

2.1.6. Critical/Informational Data

During sampling and analysis activities, detailed field and laboratory documentation will be collected in standard forms or notebooks. Critical information will include the time, date, and location of the activity; personnel involved; analytical equipment used; and a record of the analytical parameters, calibrations, and standards. For laboratory analyses, many critical data are generated during the analysis process and provided to end users in digital and printed formats. Noncritical data may include appearance and odor of the sample, issues with well or sampling equipment, and weather conditions.

2.1.7. Sources of Variability

Potential sources of variability related to monitoring activities include: (1) natural variation in fluid quality, formation pressure, temperature and seismic activity; (2) variation in fluid quality, formation pressure, temperature, and the possibility of 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 and/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 by resampling and/or reanalyzing, (3) conducting statistical analysis of monitoring data to determine whether variability in a data set 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, (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).

2.2. Sampling Methods

2.2.1. Sampling Standard Operating Procedure (SOP)s

The primary groundwater sampling method will be a low-flow sampling method consistent with ASTM D6452-99 (ASTM, 2005) or Puls and Barcelona (Puls, et. al., 1996). If a flow-through cell is not used, field parameters will be measured in grab samples. Prior to sampling, wells will be purged to ensure samples are representative of formation fluids. Before any purging or sampling activities begin, static water levels will be measured using an electronic water level indicator. Each groundwater monitoring well will contain a dedicated pump (e.g., bladder pumps) to minimize potential cross contamination between wells. Given sufficient flow rates and volumes, field parameters such as 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 (APHA, 2005). 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 14.

Table 14. Stabilization Criteria of Water Quality Parameters During Shallow Well Purging.

Field Parameter	Stabilization Criteria
pH, temperature, specific conductance, dissolved oxygen, turbidity	*Parameter measurement until ±10% value stabilization

*Exact parameter stabilization threshold will depend on which purge method is selected from the ASTM standard.

Groundwater samples will be collected after field parameters have stabilized. Flow-through filter cartridges (0.45 µm) will be utilized as required and consistent with ASTM D6564-00 (ASTM, 2017). 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, efforts will be made to minimize exposure to the atmosphere during filtration, collection in sample containers, and analysis.

2.2.2. In-situ Monitoring

In-situ monitoring of groundwater chemistry is not planned for this project.

2.2.3. Continuous Monitoring

2.2.3.1 Injection Process Monitoring

Data related to the operational process (injection rate and volume and annular pressure and volume) will be continuously monitored with pressure gauges, flow meters, and the annulus monitoring system, all of which will be linked to the surface control system controlled by Live Oak CCS, LLC. This operational data will ensure that injection is operating safely, efficiently, and not posing a risk to any USDWs. Additionally, continuously monitored operational parameters will feed into reservoir and computational models to validate that the CO_2 plume and pressure front are behaving as expected.

2.2.3.2 DTS

DTS technology will continuously collect temperature data along a fiberoptic line installed along the outside of the long-string casing. The DTS line will collect temperature data along the long-string casing at set intervals of time which will be used when running external mechanical integrity tests to verify mechanical integrity and monitor the presence or absence of the CO_2 plume.

2.2.3.3 Pressure Gauges

Downhole pressure gauges will be deployed within all deep wells to continuously measure pressure variations within the injection interval and the above-zone monitoring interval. Downhole pressure gauges will directly monitor the presence or absence of the elevated pressure front.

2.2.4. Sample Homogenization, Composition, Filtration

Please see subsection 2.2.1.

2.2.5. Sample Containers and Volumes

All samples will be collected in new containers using industry-accepted standards and practices. Container type and size for each sample type are listed in Table 15 and Table 16.

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Table 15. Summary of Sample Containers, Preservation Treatments, and Holding Times for CO_2 Gas Stream Analysis.

Sample	Volume/Container Material	Preservation Technique	Sample Holding time (max)
CO_2 gas stream	(2) 2L Multi-Layer Barrier (MLB) Polybags (1) 75 cc Mini Cylinder	Sample Storage Cabinets	5 Business Days

Table 16. Summary of Anticipated Sample Containers, Preservation Treatments, and Holding Times for Groundwater Samples.

Target Parameters	Volume/Container Material	Preservation Technique	Sample Holding Time
Cations: Ca, Fe, K, Mg, Na, Si, Al, Ba, Mn, As, Cd, Cr, Cu, Pb, Sb Se, Tl	250 ml/HDPE[1]	Filtered, nitric acid, cool 4°C	60 days
Dissolved CO_2	2 × 60 ml/HDPE	Filtered, cool 4°C	14 days
Isotopes: 3H, δD, δ18O, δ34S, and δ13C	2 × 60 ml/HDPE	Filtered, cool 4°C	4 weeks
Isotopes: δ34S	250 ml/HDPE	Filtered, cool 4°C	4 weeks
Isotopes: δD, δ18O, δ13C	60 ml/HDPE	Filtered, cool 4°C	4 weeks
Alkalinity, anions (Br, Cl, F, NO_3, SO_4)	500 ml/HDPE	Filtered, cool 4°C	45 days
Field Confirmation: Temperature, dissolved oxygen, specific conductance, pH	200 ml/glass jar	None	< 1 hour
Field Confirmation: Density	60 ml/HDPE	Filtered	< 1 hour

[1]High Density Polyethylene

2.2.6. Sample Preservation

Sample preservation methods are outlined in Table 15 and Table 16.

2.2.7. Cleaning/Decontamination of Sampling Equipment

Dedicated pumps (e.g., bladder pumps) will be installed in each groundwater monitoring well to minimize potential cross contamination between wells. These pumps will remain in each well throughout the project period except for maintenance. Prior to installation, the pumps will be cleaned externally with a non-phosphate detergent. Pumps will be rinsed a minimum of three times with deionized water and a minimum of 1 L of deionized water will be pumped through the pump and sample tubing for cleaning. Individual cleaned pumps and tubing will be placed in plastic bags for transport to the field for installation. All field glassware (pipets, beakers, filter holders, etc.) will be cleaned with tap water to remove any loose dirt, washed in a dilute nitric acid solution, and rinsed three times with deionized water before use.

2.2.8. Support Facilities

The following tools may be needed to sample groundwater: generator, vacuum pump, compressor, multi-electrode water quality sonde, and various meters to take analytical measurements such as pH and electrical conductance. Analytical field activities may take place in field vehicles and/or portable onsite trailers. Well gauges used for verification will be handled using industry standard best practices and procedures recommended from the vendor.

Coupons consisting of material that will directly contact the CO_2 stream will be placed within a flowline. Each sample will be attached to an individual holder and inserted in a flowthrough pipe arrangement, exposing the samples to the CO_2 stream, and allowing access for removal and testing. The flowthrough pipe arrangement will be located at the well location downstream of all process compression, dehydration, and pumping equipment. A parallel stream of high-pressure CO_2 will be routed from the flowline through the corrosion monitoring system. This loop will operate while injection is occurring, providing representative exposure of the samples to the CO_2 composition, temperature, and pressures that will be seen at the wellhead and injection tubing. Injection will be able to continue while samples are removed for testing.

2.2.9. 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. If defective equipment causes disruptions to the sampling schedule, Live Oak CCS, LLC will contact the OC.

2.3. Sample Handling and Custody

Sample handling and hold times will be congruent with US EPA (US EPA, 1974), APHA (APHA, 2005), Wood (Wood, 1976), and ASTM Method D6517-00 (ASTM, 2005) standards. Samples will be kept at their preservation temperature and sent to the selected laboratory within 24 hours of collection. Analysis of the samples will be completed within the holding time specified in Table 15. If alternative sampling methods become necessary, these methods will be discussed with the OC prior to sampling.

2.3.1. Maximum Hold Time/Time Before Retrieval

Please refer to Table 15 and Table 16.

2.3.2. Sample Transportation

Samples will be transported in coolers with ice maintained to approximately 4 degrees Celsius and sent to approved laboratory within 24 hours of sampling.

2.3.3. Sampling Documentation

Sampling personnel will compile field documentation for all groundwater samples collected. Field notes will be archived.

2.3.4. Sample Identification

Each groundwater sample container will have a label with the following information: project name/number, sample date and location, sample ID number, fresh or brine water, volume taken, analyte, filtration used (if applicable), and preservative used (if any).

2.3.5. Sample Chain-of-Custody

A standardized form will be used to document groundwater sample chain-of-custody. Copies of this form will be provided to laboratory personnel upon delivery of groundwater samples for analysis. These forms will be archived for future reference.

2.4. Analytical Methods

2.4.1. Analytical SOPs

Analytical standard operating procedures are referenced in Table 4 through Table 8. Other laboratory specific standard operating procedures utilized by the laboratory will be determined after a contract laboratory has been selected. Upon request, Live Oak CCS, LLC will provide the OC with all laboratories' standard operating procedures developed for the specific parameter using the appropriate standard method. Each laboratory technician conducting the analysis on the samples will be trained on the standard operating procedure developed for each standard method.

2.4.2. Equipment/Instrumentation Needed

Equipment and instrumentation are specified in the individual analytical methods referenced in Table 4 through Table 8**.**

2.4.3. Method Performance Criteria

Nonstandard method performance criteria are not anticipated for this project.

2.4.4. Analytical Failure

Each laboratory conducting the analyses in Table 4 through Table 8 will be responsible for appropriately addressing analytical failure according to their individual standard operating procedures.

2.4.5. Sample Disposal

Each laboratory conducting the analyses in Table 4 through Table 8 will be responsible for appropriate sample disposal according to their individual standard operating procedures.

2.4.6. Laboratory Turnaround

Laboratory turnaround will vary by laboratory, but turnaround of verified analytical results within two months will be suitable for project needs.

2.4.7. Method Validation for Nonstandard Methods

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

2.5. Quality Control

2.5.1. QC activities

2.5.1.1 Blanks

Field blanks will be utilized for both shallow and deep groundwater sampling to identify potential contamination due to the collection and transportation processes. Field blanks will be collected and analyzed for the inorganic analytes listed in Table 4 at a frequency of 10% or more. The field and transportation conditions for field blanks will be the same as those of the groundwater samples.

2.5.1.2 Duplicates

During each round of shallow groundwater sampling, a second groundwater sample is collected from one well, selected based on a rotating schedule. These duplicate samples are collected from the same source and at the same time as the original sample in a different, yet identical, sample container. Duplicate samples are processed with all other samples and are used to determine sample heterogeneity and analytical precision.

2.5.2. Exceeding Control Limits

If the 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 are then reviewed in the context of historical data and interlaboratory results, if available. Suspect ion analyses are then brought to the attention of the analytical laboratory for confirmation and/or reanalysis. The ion balance is recalculated, and if the error is still not resolved, suspect data are identified and may be given less importance in data interpretations.

2.5.3. Calculating Applicable QC Statistics

2.5.3.1 Charge Balance

The groundwater sample analytical results are evaluated to determine correctness of analyses based on anion-cation charge balance calculation. All potable waters are electrically neutral; thus, the chemical analyses should produce equally negative and positive ionic activity. The anion-cation charge balance will be calculated using the formula shown in equation 1:

$$\%\, difference = 100 * \frac{\sum cations - \sum anions}{\sum cations + \sum anions} \quad \textbf{Eq 1}$$

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

2.5.3.2 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 formula shown in equation 2:

$$1.0 < * \frac{measured\ TDS}{calculated\ TDS} < 1.2 \quad \text{.........} \quad \textbf{Eq 2}$$

with anticipated values between 1.0 and 1.2.

2.5.3.3 Outliers

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

2.6. Instrument/Equipment Testing, Inspection, and Maintenance

Logging tool equipment will be maintained as per wireline industry best practices. Pressure gauges will be maintained to manufacturer standards. For groundwater 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 on-hand during field sampling. For laboratory equipment, all testing, inspection, and maintenance will be the responsibility of the analytical laboratory per standard practice or method-specific protocol.

2.7. Instrument/Equipment Calibration and Frequency

2.7.1. Calibration and Frequency of Calibration

Pressure gauge calibration information is in Table 11 and Table 12**.** All field and downhole gauges will be calibrated prior to use by the equipment supplier. Gauges will be recalibrated as needed based on results of inspection, or after any repairs or maintenance. Logging tool calibration will be at the discretion of the service company providing the equipment, following standard industry practices. Calibration frequency will be determined by standard industry practices. CO_2 flow meters will be calibrated using industry standards and at a frequency recommended by the manufacturer.

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

For CO_2 stream sampling, the gas chromatograph will be calibrated based on the manufacturer's guidance.

2.7.2. Calibration Methodology

Calibration of the orifice flow meters will be carried out using the carrier gas to validate the characteristics of the approved CO_2 composition using methods described in Table 8 (API MPMS, 2016). Logging tool and all field and downhole gauge calibration methodology will follow standard industry practices recommended by the respective manufacturers.

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

2.7.3. Calibration Resolution and Documentation

Logging tool calibration resolution and documentation will follow standard industry practices. Groundwater sampling equipment calibration occurs regularly, and values are recorded in sampling records, with any errors in calibration noted. For parameters where calibration is not acceptable, redundant equipment may be used so loss of data is minimized.

2.8. Inspection/Acceptance for Supplies and Consumables

2.8.1. Supplies, Consumables, and Responsibilities

Individual vendors and subcontractors selected and approved by Live Oak CCS, LLC will be responsible for ensuring that all supplies and consumables for field and laboratory operations are inspected and acceptable for data collection activities. Procurement of supplies and consumables related to groundwater analyses will be the responsibility of the laboratory conducting water analyses in accordance with the established standard methodologies and operating procedures.

2.9. Non-Direct Measurements

2.9.1. Data Sources

Plume development will also be monitored via DTS and PNC logs. PNC logs detect CO_2 concentration surrounding the wellbore and repeat logging runs will be compared to the baseline conducted before injection operations begin. DTS monitors variations in temperature along the wellbore at a high resolution, measured every 10 minutes.

2.9.2. Relevance to Project

Scheduled PNC logging will be used to track CO_2 plume movement. After initial baseline testing is conducted prior to injection, processing and comparison of subsequent surveys will allow Live Oak CCS, LLC to monitor the extent of the plume, ensuring that the plume is contained and behaving as expected. Numerical modeling will be updated with new seismic, pressure, and saturation data throughout the project to best characterize the CO_2 plume growth and movement over time.

2.9.3. Acceptance Criteria

Gauges and other logging equipment used to collect non-direct measurements will be checked periodically and maintained according to manufacturer recommendations for equipment care and operation, to ensure the accuracy of readings as they are incorporated into the model.

2.9.4. Resources/Facilities Needed

Live Oak CCS, LLC will subcontract all necessary resources and facilities for logging, in-zone pressure monitoring, and groundwater sampling.

2.9.5. Validity Limits and Operating Conditions

Intraorganizational verification by trained and experienced personnel will ensure that any required numerical modeling is conducted according to industry standards.

2.10. Data Management

2.10.1. Data Management Scheme

Live Oak CCS, LLC or a designated contractor will maintain the required project data provided for in the permit. Data will be backed up on secure servers.

2.10.2. Recordkeeping and Tracking Practices

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

2.10.3. Data Handling Equipment/Procedures

All equipment used to store data will be properly maintained and operated according to proper industry techniques. Live Oak CCS, LLC will ensure that all necessary supervisory control and data acquisition (SCADA) systems and vendor data acquisition systems will interface with one another, and that all subsequent data will be held on a secure server. Meter data will be captured via the flow computer.

2.10.4. Responsibility

Live Oak CCS, LLC Project Manager will be responsible for ensuring proper data management is maintained during pre-operational testing and the Operations Manager for the injection and post-injection periods.

2.10.5. Data Archival and Retrieval

All data will be held and maintained by Live Oak CCS, LLC. Data will be backed up on secure servers to be accessed by project personnel as required.

2.10.6. Hardware and Software Configurations

All Live Oak CCS, LLC and vendor hardware and software configurations will interface appropriately.

2.10.7. Checklists and Forms

Checklists and forms will be generated and completed as necessary based on project needs.

3. Assessment and Oversight

3.1. Assessments and Response Actions

3.1.1. Activities to be Conducted

Refer to Table 2 and Table 3 for a summary of work to be performed and proposed work schedule. After completion of groundwater sample analysis, the results will be reviewed for quality control criteria as noted in subsection 2.5. If the data fails to meet the established quality criteria, samples will be reanalyzed if still within the 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 EPA 2009 Unified Guidance.

3.1.2. Responsibility for Conducting Assessments

Each organization gathering data will be responsible for conducting their own internal assessments. All stop work orders will be handled internally within each individual organization.

3.1.3. Assessment Reporting

All assessment information will be reported to the Live Oak CCS, LLC Project Manager during pre-operational testing or Operations Manager during injection and post-injection.

3.1.4. Corrective Action

All corrective actions which may affect a single organization's data collection responsibility shall be addressed, verified, and documented by the individual project managers, and communicated to others, as necessary. Corrective actions affecting multiple organizations should be addressed by all members of the project leadership and communicated to other members on the QASP distribution list maintained by the Project Manager during pre-operational testing or Operations Manager during injection and post-injection. Integration of information from multiple monitoring sources (operational, in-zone monitoring, above-zone monitoring) may be required to determine whether data and/or measurement method corrections are required, as well as the most effective and cost-efficient action to implement. Live Oak CCS, LLC will coordinate multiorganization assessments and corrective actions as needed.

3.2. Reports to Management

3.2.1. QA status Reports

QA status reports are not required unless there are significant adjustments to the methods and procedures listed above. If any testing or monitoring techniques are changed, this QASP will be reviewed and updated appropriately after consultation with the OC. The revised QASP will be distributed by Live Oak CCS, LLC to the full distribution list maintained by the Project Manager during pre-operational testing or Operations Manager during injection and post-injection.

4. Data Validation and Usability

4.1. Data Review, Verification, and Validation

4.1.1. Criteria for Accepting, Rejecting, or Qualifying Data

Validation of data will include a review of concentration units, sample holding times, and the review of duplicate, blank, and other appropriate QA/QC results. Live Oak CCS, LLC will maintain copies of all the laboratory's analytical test results and/or reports. Analytical results will be reported as described in the Testing and Monitoring Plan (subsection 1.5). In the periodic reports, groundwater analysis data will be presented in graphical and tabular formats as appropriate to characterize general groundwater quality and identify intra-well variability with time. After sufficient data have been collected, additional methods, such as those described in the EPA 2009 Unified Guidance will be used to evaluate intra-well variations for groundwater constituents, to determine if significant changes have occurred that could be the result of CO_2 or brine seepage beyond the intended storage reservoir.

4.2. Verification and Validation Methods

4.2.1. Data Verification and Validation Processes

See subsections 2.5 and 4.1. Appropriate statistical software will be utilized to determine data consistency.

4.2.2. Data Verification and Validation Responsibility

Live Oak CCS, LLC or its designated subcontractor will verify and validate groundwater sampling data.

4.2.3. Issue Resolution Process and Responsibility

The Live Oak CCS, LLC Project Manager during pre-operations testing or the Operations Manager during injection and post-injection will oversee the groundwater data handling, management, and assessment process. Staff involved in these processes will consult with the Project Manager or Operations Manager to determine actions required to resolve any issues.

4.2.4. Checklist, Forms, and Calculations

Checklists and forms will be developed specifically to meet permit requirements. These checklists will depend on the parameters that are being tested as well as standard operating procedures of the subcontractors and laboratories that will be gathering the data and conducting the analyses. Live Oak CCS, LLC will provide these forms and checklists to the OC upon request. Table 17 provides an example of the type of information that may be used for data verification of groundwater quality data.

Table 17. Example of criteria used to evaluate data quality.

MVA ID	Anion charge	Cation charge	Charge balance	CB rating	Calculated TDS	Measured TDS	TDS Ratio	TDS Rating
ICCS_10B_01A	14.4	13.60	-2.84	pass	760.50	785	1.0	pass

4.3. Reconciliation with User Requirements

4.3.1. Evaluation of Data Uncertainty

Statistical software will be used to determine groundwater data consistency using methods consistent with EPA 2009 Unified Guidance.

4.3.2. Data Limitations Reporting

Each vendor or subcontractor's project manager will be responsible for ensuring that data presented by their respective organizations is developed with the appropriate data-use limitations. Live Oak CCS, LLC will ensure that the data-use limitations are known and presented properly.

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