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

40 CFR 146.90

NATURAL STATE RENEWABLES INC.
NIMBUS ARCCS INC.
Ouachita County, Arkansas

Prepared By:
GEOSTOCK SANDIA, LLC

Revision No. 0
April 2025

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ATTACHMENTS

TITLE AND APPROVAL SHEET

This *Quality Assurance and Surveillance Plan* (QASP) is approved for use and implementation at the Natural State Renewables (NSR) – Nimbus ARCCS site. The signatures below denote the approval of this document and intent to abide by the procedures outlined within it.

Date

NSR - Chief Executive Officer 04/15/2025

Date

NSR – Chief Operating Officer 04/15/2025

DISTRIBUTION LIST

The following project participants will receive the completed QASP and all future updates for the duration of the project. The distribution list will be revisited and updated ahead of injection if required.

Distribution:

A. PROJECT MANAGEMENT

A.1. Project/Task Organization

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

The NSR-Nimbus ARCCS sequestration project is led by NSR and includes participation from several subcontractors. The testing and monitoring activities responsibilities will be shared between NSR 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 [40 CFR 146.90(a)].

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 [40 CFR 146.90(b)].

III) Corrosion monitoring of injection well materials, required on a quarterly basis [40 CFR 146.90(c)].

IV) Monitoring of groundwater quality and geochemical changes above the confining zone(s), at a site-specific frequency and spatial distribution [40 CFR 146.90(d); EPA, 2013a;b; EPA, 2016].

V) External Mechanical Integrity Testing (MIT), at least once per year [40 CFR 146.90(e)].

VI) Pressure falloff testing, at least once every five years [40 CFR 146.90(f)].

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) [40 CFR 146.90(g)].

VIII) Any additional monitoring that the UIC Program Director determines to be necessary to support, upgrade, and improve computational modeling of the AoR and to determine compliance with standards under 40 CFR 144.12 [40 CFR 146.90(i)].

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

NSR is responsible for developing, maintaining, and distributing an official, approved Quality Assurance project plan. NSR will periodically (no less than once every five years) review the QASP and consult with the U.S. Environmental Protection Agency (USEPA) if/when changes to the plan are warranted.

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

NSR will provide the Underground Injection Control (UIC) Program Director with a contact list of individuals fulfilling these roles and update the list ahead of injection if required.

A.2. Problem Definition/Background

A.2.a. Reasoning

This QASP is aimed at supporting the "*E.1 - Testing and Monitoring Plan*" (TMP) included in the Class VI permit request submitted by NSR for the geological sequestration of the carbon dioxide. This plan addresses the requirements of the Class VI Rule specifications and the Carbon Capture and Sequestration (CCS) Protocol under the USEPA, and employs best practices developed in similar CO_2 injection and storage projects.

The primary goal of the 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 to ensure the quality standards of the TMP meet the requirements of the USEPA UIC Program for Class VI wells. A robust risk based MVA program has been developed for the NSR-Nimbus ARCCS site based upon the knowledge and experience gained through the analysis of the comprehensive dataset acquired in offset wells 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. This will be confirmed by the data acquired in the injection wells.

The NSR project's MVA program has all the 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 also includes pulse neutron logging, as well as groundwater monitoring.

A.2.b. Reasons for Initiating the Project

The TMP goals are to comply with the Class VI protocols and document, via targeted data collection, that the predictions made during subsurface characterization and modeling are correct and that the CO_2 and brine solutions will remain in the permitted Injection Zones, and isolated from the USDW, the near-surface, and atmosphere.

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

The Class VI Rule requires 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 USDWs are not endangered. These monitoring activities include Mechanical Integrity Tests (MITs), injection well testing during operations, monitoring of groundwater quality immediately above the Confining Zone and within overlying USDWs and tracking of the CO_2 plume and associated pressure front. 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 TMP tasks, including locations, analytical techniques, methods, responsible parties, and purposes. Note that the testing frequency is provided in the TMP. 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	Accredited Lab/Third party	Monitor injectate quality
Injection rate/volume	Flowline – After compressor	Flow meter	Direct continuous measurement	N/A	Monitor rate/volume
Injection pressure	Injection wells – Wellhead	Pressure gauge	Direct continuous measurement	N/A	Monitor injection pressure at surface
Injection temperature	Injection wells – Wellhead	Temperature gauge	Direct continuous measurement	N/A	Monitor injection temperature at surface
Annular pressure	Injection wells – Wellhead	Pressure gauge	Direct continuous measurement	N/A	Monitor annular pressure at surface
In Zone downhole pressure/temperature	Injection wells	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	Third-party	Monitor corrosion risk
Distributed Temperature Sensing (DTS) fiber optics[1]	Injection wells	Fiber optic cable	Direct continuous measurement	Third-party	Monitor wellbore integrity
Mechanical integrity (casing)	Injection wells	Wireline Casing Evaluation and/or Pressure Test	Direct invasive measurement	Third-party	Monitor wellbore integrity and detect potential leakage through casing

Activity	Location(s)	Method	Analytical Technique	Lab/Custody	Purpose
Mechanical integrity (cement)	Injection wells	Wireline cement evaluation logging	Provided by vendor	Third-party	Monitor wellbore integrity and detect potential leakage through cement
Pressure falloff testing	Injection wells	EPA Region 6 UIC Pressure Falloff Testing Guideline – Third Revision (August 8, 2002)	EPA Region 6 UIC Pressure Falloff Testing Guideline – Third Revision (*August 8, 2002*)	Third-party	Monitor wellbore integrity and assess injectivity
Wireline logging – pulsed neutron logging	Injection wells	Wireline formation evaluation logging	Provided by vendor	Third-party	Identify zones that are accepting CO_2
In Zone pressure monitoring	DM-1, DM-2, DM-3, DM-4	Downhole pressure/temperature sensor	Direct continuous measurement	N/A	Monitor In Zone pressure/temperature
Above Confining Zone (ACZ) pressure monitoring Tokio	SM-1	Downhole pressure/temperature gauge	Direct continuous measurement	N/A	Monitor pressure above Confining Zone
ACZ Fluid Sampling	SM-1	Swab or other method	Chemical/physical analyses	Accredited Lab(s) or ISO	Monitor above Sequestration Complex
USDW Monitoring	Onsite water wells	Pumping or other method	Chemical/physical analyses	Accredited Lab(s) or ISO	Monitor environmental changes within groundwater resource
CO_2 plume tracking	Surface Array	Permanent source and receiver array	Provided by vendor	Third-party	Track CO_2 plume size and monitor changes in subsurface

[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 wells	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	Injection Zones	Injection Packer	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[1]	Whole formation section down to Confining Zone	Dedicated server (VSP array)	Monitor wellbore integrity
	Various	Whole formation section	40 CFR §146.87 (a)(4) and 40 CFR §146.89 (c)(2)	Monitor wellbore integrity
	Wireline cement evaluation logging	Whole formation section	Casing	Monitor wellbore integrity
	Wireline downhole gauges Surface readout gauges Or Distributed Acoustic Sensing (DAS) fiber optic cable[1]	Injection Zone	EPA Region 6 UIC Pressure Falloff 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 (IZ) Monitoring Well(s)[2]	Pressure/temperature gauge (on tubing)	Injection Zone	Wellhead	Safety and compliance
	Downhole pressure/temperature gauge	Injection Zone	At Packer	Monitor downhole conditions of pressure/temperature in the Injection Zone
Above Confining Zone (ACZ) Monitoring Well - Tokio Formation	Pressure/temperature gauge (on tubing)	Tokio Formation immediately above Confining Zone	Wellhead	Safety and compliance
	Downhole, submersible pump, or equivalent	Tokio Formation	Perforations in Wellbore	Identify potential CO_2 leaks and discern the source(s) of detected CO_2
	Downhole pressure/temperature gauge	Tokio Formation	At Packer	Verify that no fluid is escaping from the Sequestration Complex
USDW Monitoring Wells	Downhole, submersible pump, or equivalent	Wilcox Formation	Perforations within screened interval or wellhead tap	Identify potential CO_2 leaks and discern the source(s) of detected CO_2
Indirect Monitoring	Permanent source and receiver array	Reservoir – Plume Tracking	Surface	Monitor CO_2 plume size and reservoir integrity

Table 3. Geophysical Survey Summary.

Monitoring Location	Instrument Type	Monitoring Target (Formation or Other)	Data Collection Location(s)	Explanation
Surface array across anticipated plume perimeter	Permanent seismic source and receiver array	Injection Zones	Surface Array	Monitor plume extent and potential out-of-zone movement

A.3.c. Geographic Locations

The injection wells will be located within the property owned by the Natural State Renewables as shown in Figure 1 of the TMP. Direct monitoring in four deep monitoring wells, completed into the active Injection Zone, will be used to detect and define the dimensions of the carbon dioxide plume during well operations. These In-zone monitoring wells (Nimbus DM-1, DM-2, DM-3, and DM-4) will be located up dip from the injection wells on the northern part of the area of review. The In-zone monitor wells will constrain the dimensions and location of the sequestered carbon dioxide plumes. DM-4 will monitor pressure and temperature on the north side of the northern sealed fault to validate containment south of the fault. Each installed In-zone deep monitor will have a gauge at surface to continuously record tubing pressure.

Above Confining Zone (ACZ) monitoring will occur in a well drilled and completed in the Tokio Formation and will also be located on the Natural State Renewables property. The Tokio Formation is a porous Upper Cretaceous sandstone located at a depth of approximately 2,000 feet below ground level. The Tokio Formation is located stratigraphically just above the Lower Cretaceous Unconformity just above the Confining Zone. The ACZ Monitoring Well will be located near the point of carbon dioxide injection, where elevated formation pressure in the Injection Zone is expected to be the greatest.

The lowermost USDW is located with the Wilcox Formation, directly overlying the regionally extensive Midway Shale. Approximate depth to the lowermost USDW at the project site is approximately 850 ft, with the site specific depth confirmed with the drilling of the injection and SM-1 wells at the project site. The Wilcox Formation is separated from the Confining Zone section by the Midway Shale, an extensive, regional shale that extends throughout the Gulf Coast area. The USDW monitoring wells will provide coverage within the facility boundary of the operational carbon dioxide plumes.

A.3.d. Resource and Time Constraints

No additional resource or time constraints have been identified for the TMP 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 near-surface and subsurface testing and monitoring, field sampling, laboratory analyses, and reporting, which will be used 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 using three planned water supply wells. Water quality monitoring in the saline Tokio Formation, immediately above the Confining Zone, will be conducted during the pre-injection, injection, and post-injection phases of the project. The analytical and field parameters for fluid samples from the USDW and Tokio Formation are listed in Tables 4 and 5. Tables 6 and 7 provide the analytical parameters for carbon dioxide stream monitoring and corrosion coupon assessment, respectively, while Table 8 details the measurement parameters for the field gauges. The TMP outputs are presented in Table 9.

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

Table 4. Summary of Analytical and Field Parameters for Fluid Samples in Wilcox USDW

Parameters	Analytical Methods[(1)]	Detection Limit/Range	Typical Precisions	QC Requirements
Lab Parameters				
Total and Dissolved Metals: Ag, Al, As, Ba, Cd, Cd, Co, Cr, Cu, Mn, Mo, Nim Pb, Sb, Se, Sr, Th, Tl, U, V, and Zn	EPA Method 200.8	0.00004 - 0.003 mg/L	± 20%	Frequent calibration, method blank, lab control samples, matrix spikes and sample duplicate
Total and Dissolved Metals: B, Ca, Fe, K, Li, Mg, Na, Si, Sr, Ti	EPA Method 200.7	0.003 - 0.254 mg/L	± 20%	Frequent calibration, method blank, lab control samples, matrix spikes and sample duplicate
Anions: Br, Cl, F, NO_3, and SO_4	Ion chromatography EPA Method 300.0	0.003 – 0.563 mg/L	± 20%	Frequent calibration, method blank, lab control samples, matrix spikes and sample duplicate
Alkalinity (total and bicarbonate)	Standard Method 2320B	4.0 mg/L	± 15%	Frequent calibration, method blank, lab control samples, matrix spikes and sample duplicate
Total Dissolved Solids (TDS)	EPA Method 160.1	10.0 mg/L	± 20%	Frequent calibration, method blank, lab control samples, matrix spikes and sample duplicate
Water density (lab)	Standard Method 2710F	N/A	N/A	Frequent calibration and sample duplicate
pH (lab)	Standard Method 4500 H+B	0.1 S.U.	± 0.1 S.U.	Frequent calibration and sample duplicate

Parameters	**Analytical Methods[(1)]**	**Detection Limit/Range**	**Typical Precisions**	**QC Requirements**
$\delta^{18}O$ and $\delta^{2}H$ of H_2O	Analyzed via CRDS	N/A	$\delta^{18}O$: 0.10 per mil, $\delta^{2}H$: 2.0 per mil	20% of all analyses are either check/reference standards or duplicate analyses.
$\delta^{13}C$ of DIC	GasBench/CF-IRMS	Depends on available sample volume	0.20 per mil	20% of all analyses are either check/reference standards or duplicate analyses.
^{14}C of DIC	AMS	Depends on available sample volume	± 1-2 pMC	Daily monitoring of instrumentation and chemical purity in addition to extensive computer and human cross-checks.
Dissolved Inorganic Carbon (DIC)	Standard Method 5310C	0.198-0.290 mg/L	± 20%	Frequent calibration, method blank, lab control samples, matrix spikes and sample duplicate
Dissolved Organic Carbon (DOC)	Standard Method 5310C	0.198-0.290 mg/L	± 20%	Frequent calibration, method blank, lab control samples, matrix spikes and sample duplicate
Dissolved CO_2	Method B - ASTM D513-06	5 – 800 mg/L	± 20%	Frequent calibration, method blank, lab control samples, matrix spikes and sample duplicate
Volatile Organic Compounds (VOC)	Method 8260D (SW-846)	Lowest quantifiable limits 1-100 ppm, varies by component	C1-C4: ± 5% C5-C6+: ± 10%	20% of all analyses are either check/reference standards or duplicate analyses.
$\delta^{13}C$ of dissolved methane, ethane, propane, and CO_2, $\delta^{2}H$ of methane	High precision (offline) analysis via dual inlet IRMS	Varies by component	$\delta^{13}C$: 0.1 per mil $\delta^{2}H$: 3.5 per mil	20% of all analyses are either check/reference standards or duplicate analyses.
Field Parameters				
pH (field)	Standard Method 4500-H+ B-2000	0 to 14 S.U.	± 0.2 S.U.	User Calibration per manufacturer recommendation

Parameters	**Analytical Methods**[(1)]	**Detection Limit/Range**	**Typical Precisions**	**QC Requirements**
Specific conductance (field)	Standard Method 2510 B	0 to 200 mS/cm	± 0.5% of reading or 0.001 mS/cm, whichever is greater	User Calibration per manufacturer recommendation
Temperature (field)	Thermistor, Standard Method 2550 B-2000	-5 to 70°C (23 to 158°F)	± 0.2°C	User Calibration per manufacturer recommendation
Turbidity (field)	EPA Method 180.1	0 to 1000 NTU	±1% of reading, Or 0.01 NTU Whichever is greater	User Calibration per manufacturer recommendation
Oxidation-Reduction Potential (field)	Standard Method 2580	-1999 to +1999 mV	± 20 mV	User Calibration per manufacturer recommendation
Dissolved oxygen (field)	ASTM Method D888-09 (C)	0 to 50 mg/L	0 to 20 mg/L (±0.1 mg/L or 1% of reading, whichever is greater) 20 – 50 mg/L (±8% of reading)	User Calibration per manufacturer recommendation

Note 1: An equivalent method may be employed with the prior approval of the UIC Program Director.
Note 2: AMS = accelerator mass spectrometer; CRDS= cavity ring-down spectroscopy; ICP = inductively coupled plasma; IRMS = isotope ratio mass spectrometry; MS = mass spectrometry.
Note 3: All analyses will be performed by accredited laboratories or by the International Organization of Standardization (ISO).

Table 5. Summary of Analytical and Field Parameters for Fluid Samples in Tokio Formation

Parameters	Analytical Methods(1)	Detection Limit/Range	Typical Precisions	QC Requirements
Lab Parameters				
Total and Dissolved Metals: Ag, Al, As, Ba, Cd, Cd, Co, Cr, Cu, Mn, Mo, Nim Pb, Sb, Se, Sr, Th, Tl, U, V, and Zn	EPA Method 200.8	0.00004 - 0.003 mg/L	± 20%	Frequent calibration, method blank, lab control samples, matrix spikes and sample duplicate
Total and Dissolved Metals: B, Ca, Fe, K, Li, Mg, Na, Si, Sr, Ti	EPA Method 200.7	0.003 - 0.254 mg/L	± 20%	Frequent calibration, method blank, lab control samples, matrix spikes and sample duplicate
Anions: Br, Cl, F, NO_3, and SO_4	Ion chromatography EPA Method 300.0	0.003 – 0.563 mg/L	± 20%	Frequent calibration, method blank, lab control samples, matrix spikes and sample duplicate
Alkalinity (total and bicarbonate)	Standard Method 2320B	4.0 mg/L	± 15%	Frequent calibration, method blank, lab control samples, matrix spikes and sample duplicate
Total Dissolved Solids (TDS)	EPA Method 160.1	10.0 mg/L	± 20%	Frequent calibration, method blank, lab control samples, matrix spikes and sample duplicate
Water density (lab)	Standard Method 2710F	N/A	N/A	Frequent calibration and sample duplicate
pH (lab)	Standard Method 4500 H+B	0.1 S.U.	± 0.1 S.U.	Frequent calibration and sample duplicate
$\delta^{18}O$ and $\delta^{2}H$ of H_2O	Analyzed via CRDS	N/A	$\delta^{18}O$: 0.10 per mil, $\delta^{2}H$: 2.0 per mil	20% of all analyses are either check/reference standards or duplicate analyses.

Parameters	**Analytical Methods**[(1)]	**Detection Limit/Range**	**Typical Precisions**	**QC Requirements**
$\delta^{13}C$ of DIC	GasBench/CF-IRMS	Depends on available sample volume	0.20 per mil	20% of all analyses are either check/reference standards or duplicate analyses.
^{14}C of DIC	AMS	Depends on available sample volume	± 1-2 pMC	Daily monitoring of instrumentation and chemical purity in addition to extensive computer and human cross-checks.
Dissolved Inorganic Carbon (DIC)	Standard Method 5310C	0.198-0.290 mg/L	± 20%	Frequent calibration, method blank, lab control samples, matrix spikes and sample duplicate
Dissolved Organic Carbon (DOC)	Standard Method 5310C	0.198-0.290 mg/L	± 20%	Frequent calibration, method blank, lab control samples, matrix spikes and sample duplicate
Dissolved CO_2	Method B - ASTM D513-06	5 – 800 mg/L	± 20%	Frequent calibration, method blank, lab control samples, matrix spikes and sample duplicate
Volatile Organic Compounds (VOC)	Method 8260D (SW-846)	Lowest quantifiable limits 1-100 ppm, varies by component	C1-C4: ± 5% C5-C6+: ± 10%	20% of all analyses are either check/reference standards or duplicate analyses.
$\delta^{13}C$ of dissolved methane, ethane, propane, and CO_2, $\delta^{2}H$ of methane	High precision (offline) analysis via dual inlet IRMS	Varies by component	$\delta^{13}C$: 0.1 per mil $\delta^{2}H$: 3.5 per mil	20% of all analyses are either check/reference standards or duplicate analyses.
Field Parameters				
pH (field)	Standard Method 4500-H+ B-2000	0 to 14 S.U.	± 0.2 S.U.	User Calibration per manufacturer recommendation
Specific conductance (field)	Standard Method 2510 B	0 to 200 mS/cm	± 0.5% of reading or 0.001 mS/cm, whichever is greater	User Calibration per manufacturer recommendation

Parameters	**Analytical Methods(1)**	**Detection Limit/Range**	**Typical Precisions**	**QC Requirements**
Temperature (field)	Thermistor, Standard Method 2550 B-2000	-5 to 70°C (23 to 158°F)	± 0.2°C	User Calibration per manufacturer recommendation
Turbidity (field)	EPA Method 180.1	0 to 1000 NTU	±1% of reading, Or 0.01 NTU Whichever is greater	User Calibration per manufacturer recommendation
Oxidation-Reduction Potential (field)	Standard Method 2580	-1999 to +1999 mV	± 20 mV	User Calibration per manufacturer recommendation
Dissolved oxygen (field)	ASTM Method D888-09 (C)	0 to 50 mg/L	0 to 20 mg/L (±0.1 mg/L or 1% of reading, whichever is greater) 20 – 50 mg/L (±8% of reading)	User Calibration per manufacturer recommendation

Note 1: An equivalent method may be employed with the prior approval of the UIC Program Director.
Note 2: AMS = accelerator mass spectrometer; CRDS= cavity ring-down spectroscopy; ICP = inductively coupled plasma; IRMS = isotope ratio mass spectrometry; MS = mass spectrometry.
Note 3: All analyses will be performed by accredited laboratories or by ISO.

Table 6. Summary of Analytical Parameters for CO_2 Stream at the Surface

Parameters	Analytical Methods[(1)]	Detection Limit/Range	Typical Precisions	QC Requirements
Carbon dioxide	ISBT 2.0 Method- 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	1 to 5,000 µL/L (ppm by volume)	±10% of reading	Duplicate analysis
	ISBT 4.0 (GC/DID)	1 to 5,000 µL/L (ppm by volume)	±10% of reading	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
Carbon Isotopes	Isotope ratio mass spectrometry and accelerator mass spectrometry	δ13C and 14C of CO_2	±0.15-0.03%	10% duplicates, 4 samples per batch
Surface Pressure	Permanent Surface Gauge	> 1,600 psi	±0.2% of scale	Annual calibration of scale or verification against wireline gauge
Surface Temperature	Permanent Surface Gauge	>65º and <125ºF	±0.5% of scale	Annual calibration of scale or verification against wireline gauge

Note 1: An equivalent method may be employed with the prior approval of the UIC Program Director.
Note 2: All analyses will be performed by accredited laboratories or by ISO.

Table 7. 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 or ASTM G1-03 (2017)	0.005 mg	±2%	Annual calibration of scale (third-party)

Parameters	Analytical Methods	Detection Limit/Range	Typical Precisions	QC Requirements
Thickness	NACE Standard RP0775-2005 Item No. 21017 or ASTM G1-03 (2017)	0.001 mm	±0.005 mm	Factory calibration

Table 8. Summary of Measurement Parameters for Field Gauges

Parameters	Methods	Detection Limit/Range	Typical Precisions	QC Requirements
Annulus pressure	Direct measurement via WAMS unit	±0.001 psi / 0-3,000 psi	±0.01 psi	Annual calibration of scale or to manufacturers specs (third-party)
Injection tubing pressure	Direct measurement Permanent gauge	±0.001 psi / 0-3,000 psi	±0.01 psi	Annual calibration of scale or to manufacturers specs (third-party)
Injection mass flow rate	Direct measurement Permanent gauge	±0.1% of rate/50,522-303,133 lbs./hr	±0.01 lbs./hr	Annual calibration of scale or to manufacturers specs (third-party)
Downhole pressure	Direct measurement Permanent gauge	±0.1 psi / 0-10,000 psi	±0.2% of scale	Annual calibration of scale or verification against wireline gauge
Downhole temperature	Direct measurement Permanent gauge	±0.01 ^{o}C/125 ^{o}C	±0.5% of scale	Annual calibration of scale or verification against wireline gauge

Table 9. Actionable Testing and Monitoring Outputs

Activity or Parameter	Project Action Limit	Detection Limit
External mechanical integrity (DAS/DTS fiber optic cable)	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)
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
Surface pressure gauges	Pressure approaching modeled or permitted limit	(1)
Downhole pressure gauges	Pressure approaching modeled or permitted limit	(1)
Groundwater and environmental parameters	A departure between observed and baseline/ seasonal parameter patterns	(2)
Water quality measurements in ACZ Monitoring Well Tokio Formation	A departure between observed and baseline/ seasonal parameter patterns	(2)
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)
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

Note 1: These data limits are to be determined during well engineering design, after assessment of available instruments.

Note 2: The methodology for anomaly detection and attribution requires data collection to identify natural and spatial variation and comparison to fluid compositions to identify a leakage signal. This will be added to the monitoring plan and used to follow up on an 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.

A.4.b. Precision

Precision will be determined after the different vendors and contractors are selected, per their individual standard operating procedures. Tables 10 to 15 summarize examples of 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 10. 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 11. 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 12. 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 13. 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 14. Mass Flow Rate Field Gauge - CO_2 Mass Flow Rate

Parameter	Value
Calibrated working flow rate range	±100 liters per minute
Initial mass flow rate accuracy	±1.5 % of rate - liquid
Mass flow rate repeatability	±0.05 % of rate - liquid
Mass flow rate drift stability	To be determined after first year

Table 15. Representative Logging Tool Specifications

Parameter	Pulsed Neutron	Cement Bond	Casing Imager
Logging speed	1,500 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, 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 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 indicates 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.

A.4.e. Completeness

For groundwater, 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. For direct pressure and temperature measurements, 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 data becomes 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.

A.4.g. Method Sensitivity

The sensitivity of the methods employed for this project will be discussed with the UIC Program Director after the draft of the TMP 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 ground water sampling, but field sampling will be conducted by trained personnel according to the project specific sampling procedures which will be provided by NSR.

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 NSR to the USEPA will contain all required project data, including testing and monitoring information as specified by the UIC Class VI permit. Data will be provided in electronic or other formats as requested by the UIC Program Director.

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

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

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

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

A.6.e. QASP Distribution Responsibility

NSR will be responsible for ensuring that all those on the distribution list will receive the most current copy of the approved QASP.

B. DATA GENERATION AND ACQUISITION

B.1. Sampling Process Design

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

During the pre-injection phase, groundwater samples will be collected in general accordance with EPA Method SESDPROC-301-R4 (EPA, 2017) and analyzed for a suite of chemical and isotopic parameters to establish baseline reference data. Parameters 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/or (4) may be needed for geochemical modeling. The full set of parameters for USDW and Tokio Formation sampling and testing is presented in Tables 4 and 5, respectively. After baseline is established, monitoring scope during the injection and post-injection phases will 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 UIC Program Director.

During any period where a reduced set of analytes is used, if it is determined that a departure between observed and baseline parameter patterns appears to be related to potential carbon dioxide leakage or brine migration from the target reservoir, an adaptive sampling program may be initiated in consultation with the UIC Program Director that includes additional analytical parameters.

The groundwater samples will be analyzed by third-party laboratories meeting the requirements of the accredited lab or the ISO. 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.

B.1.a. Design Strategy

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 “know” 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 at the injection well 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 USDW Groundwater Monitoring Strategy

Three water supply wells will be drilled at the Nimbus Fuels site at time of construction. These wells will be drilled down into the USDW and be used as sampling points for the TMP. Well locations will be within the facility boundaries and specific locations will be determined from the facility construction plans. Initial fluid samples (baselines) will be collected at time of the water well construction. Fluid samples will be collected quarterly prior to injection operations at the facility, quarterly for the first 3 years of injection, and then revert to annual sampling thereafter. These wells will also be sampled if tracers or the presence of CO_2 is determined from sampling in SM-1. Annual groundwater sampling will continue during the post-injection site care phase of the project.

Deep Groundwater Monitoring Strategy

Quarterly fluid sampling in the Tokio Formation that immediately overlies the Confining Zone will be used in combination with pressure monitoring and temperature monitoring to determine if leakage is occurring at or near the injection wells. Quarterly sampling will be conducted for the first 3 years of injection and revert to annual sampling thereafter. The Tokio Formation interval 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 wells, if installed, will also provide data to ensure the mechanical integrity of the wells is maintained.

With the planned sampling prior to authorization of injection with 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.

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

To be updated when UIC Program Director has approved draft permit.

B.1.c. Sampling Site Contingency

To be updated when UIC Program Director has approved draft permit.

B.1.d. Activity Schedule

Quarterly for the first 3 years and then annually thereafter, to be updated when UIC Program Director has approved draft permit.

B.1.e. Critical/Informational Data

During both groundwater 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, persons performing activity, location of activity (well locations) or instrument (lab analysis), field or laboratory instrument calibration data, and field parameter values. For laboratory analyses, much of the critical data is 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.f. Sources of Variability

Potential sources of variability related to monitoring activities include (1) natural variation in fluid quality, formation pressure and temperature, and seismic activity; (2) variation in fluid quality, 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 well 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 a 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 applies to physical samples and does not apply to logging, seismic monitoring, and pressure/temperature monitoring.

B.2.a/b. Sampling Standard Operating Procedures (SOPs)

Groundwater samples will be collected primarily using a low-flow sampling method or similar, that is consistent with EPA Method SESDPROC-301-R4 (EPA, 2017). 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 facilitate collection of representative samples. Groundwater pH, temperature, specific conductance, dissolved oxygen, and oxidation-reduction potential (ORP) will be monitored in the field using portable probes and/or a flow-through cell consistent with standard methods (e.g., APHA) given sufficient flow rates and volumes. Groundwater turbidity will be measured in the field utilizing a portable turbidity meter. 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 16.

After field parameters have stabilized, samples will be collected. Samples requiring filtration (e.g., metals) 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). Samples will be properly preserved per analyte requirements.

Table 16. Stabilization Criteria of Water Quality Parameters During Shallow Well Purging

Field Parameter	Stabilization Criteria
pH	±0.2 units
Temperature	±10% of reading
Specific conductance	±3% of reading
Oxidation-Reduction Potential	±10 mV of reading
Dissolved oxygen	±10% of reading or 0.3 mg/L whichever is greater
Turbidity	±10% of reading or below 10 NTU

B.2.c. In-situ Monitoring

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

B.2.d. Continuous Monitoring

Continuous monitoring of groundwater chemistry parameters is not currently planned.

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

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

B.2.f. Sample Containers and Volumes

A summary of sample containers is presented in Tables 17 and 18.

B.2.g. Sample Preservation

For groundwater and other aqueous samples, the preservation methods provided in Tables 17 and 18 will be used.

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

A solution of Liquinox® and deionized water will be used to decontaminate drilling rods, hand augers, hand tools, and other non-dedicated sampling equipment utilized for groundwater and soil sampling.

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 replacement. Significant corrective actions affecting analytical results will be documented in field notes.

B.3. Sample Handling and Custody

Discussion in this section applies to physical samples, section does not apply to logging, seismic monitoring, and pressure/temperature monitoring.

Sample holding times given in Tables 17 and 18 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 17 and 18. As appropriate and if required, alternative options to the sample containers and preservation techniques, approved by the UIC Program Director, will be implemented to meet analytical requirements.

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

See Tables 17 and 18.

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 samples, then retained and archived for reference. The sample documentation is the responsibility of the groundwater 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 17. 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 18. Summary of Anticipated Sample Containers, Preservation Treatments, and Holding Times for Fluid Samples

Target Parameters	Volume/Container Material	Preservation Technique	Sample Holding Time
Cations: Al, Ba, Mn, As, Cd, Cr, Cu, Pb, Sb, Se, Sr, Li, and Ti	250 mL/HDPE	Filtered, nitric acid, cooled to 4°C	180 days
Cations: Ca, Fe, K, Mg, Na, and Si			
Anions: Br, Cl, F, and SO_4	250 mL/HDPE	Cooled to 4°C	28 days
Anions: NO_3			48 hours
Alkalinity (total and bicarbonate)			14 days
pH (lab)			Immediately
Total dissolved solids	500 mL/HDPE	Cooled to 4°C	7 days
Water density (lab)	500 mL/Amber Glass	Cooled to 4°C	28 days
Dissolved Inorganic Carbon (DIC)	250 mL/Amber Glass	Filtered, cooled to 4°C	28 days
$^{228}Ra/^{226}Ra$	1 L/HDPE	Nitric acid, cooled to 4°C	180 days
$^{87}Sr/^{86}Sr$	30 mL/HDPE	None	> 365 days
$\delta^{18}O$ and $\delta^{2}H$ of H_2O	250 mL/HDPE	Filtered, cooled to 4°C	> 365 days
$\delta^{13}C$ of DIC			28 days
^{14}C of DIC			28 days
Dissolved CO_2, N_2, Ar, O_2, He, C1 - C6+ by headspace	0.6 L IsoFask®	None	180 days

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, 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 sampling personnel.

B.4. Analytical Methods

Discussion in this section applies to physical samples and does not apply to logging, seismic monitoring, and pressure/temperature monitoring.

B.4.a. Analytical SOPs

Analytical SOPs for groundwater are referenced in Tables 4 and 5. If needed, other laboratory-specific SOPs will be determined after a contract with the selected laboratory has been established. Upon request NSR 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. NSR 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 and 5.

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 and 5 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 and 5 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 will be consulted on additional appropriate actions to be taken.

B.5. Quality Control

Discussion in this section applies to physical samples. Seismic monitoring and pressure/temperature monitoring do not apply to this section. For logging quality control, NSR will 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 USDW sampling, field blanks will be collected and analyzed for the inorganic analytes listed in Table 4 at a frequency of one blank per 10 normal samples. 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 and transport conditions as the groundwater samples. Blanks will be used to detect contamination resulting from the collection and transportation processes.

Duplicates

For each shallow groundwater sampling round, duplicate samples will be collected from a designated well on a rotating schedule (approximately one duplicate per 10 normal samples). Duplicate samples will be collected from the same source immediately after 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.

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 analysis 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 applies to physical samples and does not apply to logging, seismic monitoring, and pressure/temperature monitoring. Logging tool equipment will be maintained per the manual used by the selected logging vendor.

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 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 applies to physical samples and does not apply to logging, seismic monitoring, and pressure/temperature monitoring.

B.7.a. Calibration and Frequency of Calibration

Pressure/temperature gauge calibration information is located in Table 10 to Table 15. Logging tool calibration will be at the discretion of the service company providing the equipment, following 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, oxidation-reduction potential (ORP), turbidity, and dissolved oxygen) and will be calibrated according to manufacturer recommendations and equipment manuals each day before sample collection begins. Recalibration is performed if any components yield atypical values or fail to stabilize during sampling.

B.7.b. Calibration Methodology

Logging tool calibration methodology will follow 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 oxygen solution for dissolved oxygen. Calibration is performed for pH meters per manufacture's specifications using a 2-point calibration bounding the range of the sample.

B.7.c. Calibration, Resolution and Documentation

Logging tool calibration, resolution and documentation will follow 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.

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 NSR or the respective subcontractor responsible for the data collection activity. Acquisition of supplies and consumables related to groundwater analyses will be the responsibility of the laboratory per established standard methodology or operating procedures.

B.9. Non direct Measurements

B.9.a. Data Sources

NSR is anticipating deployment of an autonomous, real-time permanent source and receiver array within and beyond the dimensions of the carbon dioxide plume. The system will use one or more permanent surface sources and an autonomous receiver array with the receivers emplaced underground, just below the surface to improve ground-coupling. The receivers will be used to monitor ray paths that will allow for dense sampling over time. System flexibility allows for sensors and/or source geometry to be optimally redeployed further away from the injection wells as the plume gets larger. Baseline and subsequent time-lapse surveys will be processed using a technique that will resolve the differences between the surveys. NSR will map the changes in plume extent over time.

B.9.b. Relevance to Project

NSR is also considering the use of certain time-lapse seismic techniques for indirect monitoring. The displacement of brine by injected carbon dioxide within sedimentary strata 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" (Roach, et al., 2015; Burnison, et al., 2016; Livers, 2017; Adams, et al., 2020).

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 permanent seismic data gathered during the acquisition of the indirect monitoring is used for accurate modeling and monitoring. As the system will be deployed on the plant site, similar ground conditions, ray paths, and similar receiver and source setups will be used, which will ensure consistency of measurements.

B.9.d. Resources/Facilities Needed

The system will use one or more permanent surface sources and an autonomous receiver array with the receivers emplaced underground.

B.9.e. Validity Limits and Operating Conditions

The autonomous seismic system is an effective, reliable and low-cost 4D seismic for CO_2 plume migration tracking with permanent sources and receivers.

B.10. Data Management

B.10.a. Data Management Scheme

NSR 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. NSR 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 NSR, maintained, and stored for auditing purposes as described in Section B.10.a.

B.10.f. Hardware and Software Configurations

All NSR 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 activities to be performed.

Groundwater quality data will be collected at the frequency outlined in the table. 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. NSR 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. Revised QASPs will be distributed by NSR 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 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 results will be entered into a database or spreadsheet with periodic data review and analysis. NSR 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 variations for groundwater 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

NSR or its designated subcontractor will verify and validate groundwater sampling data.

D.2.c. Issue Resolution Process and Responsibility

NSR or its designated coordinator will oversee the groundwater 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 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.

NSR will use the current operating procedure for utilizing, sharing, and presenting results and/or data for the NSR 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.

REFERENCES

Adams, D., Barajas-Olalde, C., Bosshart, N., Hamling, J. A., Jin, L., and Peck, W. D., 2020; CO2 Injection Monitoring with a Scalable, Automated Sparse Seismic Array: AIChE Annual Meeting (https: //www.aiche.org/academy/videos/conference-presentations/co2-injection-monitoring-scalable-automated-sparse-seismic-array)

APHA, 2005, Standard methods for the examination of water and wastewater (21st edition), American Public Health Association, Washington, DC.

ASTM, 2010, Method D7069-04 (reapproved 2010), Standard guide for field quality assurance in a ground-water sampling event, ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA.

ASTM, 2010, Method D6911-03 (reapproved 2010), Standard guide for packaging and shipping environmental samples for laboratory analysis, ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA.

ASTM, 2005, Method D6517-00 (reapproved 2005), Standard guide for field preservation of ground-water samples, ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA.

ASTM, 2005, Method D6564-00 (reapproved 2005), Standard guide for field filtration of ground-water samples, ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA.

ASTM, 2005, Method D6452-99 (reapproved 2005), Standard Guide for Purging Methods for Wells Used for Ground-Water Quality Investigations, ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA.

ASTM, 2002, Method D513-11, Standard test methods for total and dissolved carbon dioxide in water, ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA.

ASTM, 2002, Method D6771-02, Standard guide for low-flow purging and sampling for wells and devices used for ground-water quality investigations, ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA.

Burnison, S. A., Livers, A. J., Hamling, J. A., Slaako, O., and Gorecki, C. D., 2016, Design and implementation of a scalable, automated, semi-permanent seismic array for detecting CO2 extent during geologic CO2 injection: 13th International Conference on Greenhouse Gas Control Technologies, GHGT-13, 14-18 November 2016, Lausanne, Switzerland, p. 3879-3888.

Daley, T. M., and Korneev, V. A., 2006, In-situ borehole seismic monitoring of injected CO2 at the Frio Site: Proceedings, CO2SC Symposium Lawrence Berkeley National Laboratory, Berkeley, California, March 20-22, 2006, p. 36 – 38.

Dwyer, J.L., Roy, D.P., Sauer, B., Jenkerson, C.B., Zhang, H., and Lymburner, L., 2018, Analysis ready data—Enabling analysis of the Landsat archive: Remote Sensing, v. 10, no. 9, art. no. 1363. doi.org/10.3390/rs10091363

EPA, 2013a, Geologic Sequestration of Carbon Dioxide Underground Injection Control (UIC) Program Class VI Well Site Characterization Guidance, U.S. Environmental Protection Agency Office of Water, EPA 816-R-13-004, May 2013.

EPA, 2013b, Geologic Sequestration of Carbon Dioxide Underground Injection Control (UIC) Program Class VI Well Testing and Monitoring Guidance, U.S. Environmental Protection Agency Office of Water, EPA 816-R-13-001, March 2013.

EPA, 2016, Geologic Sequestration of Carbon Dioxide Underground Injection Control (UIC) Program Class VI Well Plugging, Post-Injection Site Care, and Site Closure Guidance, U.S. Environmental Protection Agency Office of Water, EPA 816-R-16-006, December 2016.

EPA, 2017, Groundwater Sampling: SESDPROC-301-R4. Region 4 U.S. Environmental Protection Agency Science and Ecosystem Support Division, Athens, Georgia, 20 April 2017.

ESA, Sentinel Online Product Types, https://sentinel.esa.int/web/sentinel/user-guides/sentinel-2-

msi/product-types

Gibb, J.P., R.M. Schuller, and R.A. Griffin, 1981, Procedures for the collection of representative water quality data from monitoring wells, Illinois State Geological Survey Cooperative Groundwater Report 7, Champaign, IL, 61 p.

Gordon, A., Lawton, D. C., and Eaton, D. W., 2016, VSP azimuthal travel time analysis at the Field Research Station near Brooks, Alberta: CREWES Research Report, Vol. 28, 20 p.

Gupta, N., Kelley, M., and Haagsma, A., 2020, Time-Lapse Vertical Seismic Profiling (VSP) for CO2 Storage in a Depleted Oil Field in Northern Michigan: United States: N. p., 2020. Web. doi: 10.2172/1773352.

Hach Company, February 2006, Hydrolab DS5X, DS5, and MS5 Water Quality Multiprobes User Manual, Hach Company, 73 p.

Index DataBase (IDB), 2022, Sensor: Sentinel-2A, https://www.indexdatabase.de/db/s-single.php?id=96

Larson, D.R., B.L. Herzog, and T.H. Larson, 2003, Groundwater geology of DeWitt, Piatt, and Northern Macon Counties, Illinois. Illinois State Geological Survey Environmental Geology 155, 35 p.

Livers, A. J., 2017, CO2 Injection Monitoring with a Scalable, Automated Sparse Seismic Array: U.S. Department of Energy, National Energy Technology Laboratory, Mastering the Subsurface Through Technology Innovation, Partnerships and Collaboration: Carbon Storage and Oil and Natural Gas Technologies Review Meeting August 1–3, 2017.

Locke II, R., D. Larssen, W. Salden, C. Patterson, J. Kirksey, A. Iranmanesh, B. Wimmer, I. Krapac. Preinjection reservoir fluid characterization at a CCS demonstration site: Illinois Basin – Decatur Project, USA. Proceedings of the 11th International Conference on Greenhouse Gas Technologies, November 18–22, 2012, Kyoto, Japan. Energy Procedia v. 37, 2013, p. 6,424–6,433. http://dx.doi.org/10.1016/j.egypro.2013.06.572

O'Dell, J.W., J.D. Pfaff, M.E. Gales, and G.D. McKee, 1984, Test Method—The Determination of Inorganic Anions in Water by Ion Chromatography-Method 300, U.S. Environmental Protection Agency, EPA-600/4-84-017.

Orion Research Inc., 1990, CO2 Electrode Instruction Manual, Orion Research Inc., 36 p.

Puls, R.W., and M.J. Barcelona, 1996, Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedures. U.S. Environmental Protection Agency, EPA-540/S-95/504.

Roach, L. A. N., White, D. J., and Roberts, B, 2015, Assessment of 4D seismic repeatability and CO2 detection limits using a sparse permanent land array at the Aquistore CO2 storage site: Geophysics, v. 80, n. 2.

U.S. Environmental Protection Agency (US EPA), 2009, Statistical analysis of groundwater monitoring data at RCRA facilities—Unified Guidance, US EPA, Office of Solid Waste, Washington, DC.

U.S. Environmental Protection Agency (US EPA), 1974, Methods for chemical analysis of water and wastes, US EPA Cincinnati, OH, EPA-625-/6-74-003a.

Vasco, D. W., Alfi, M., Hosseini, S. A., Zhang, R., Daley, T., Ajo-Franklin, J. B., and Hovorka, S. D., 2019, The seismic response to injected carbon dioxide: Comparing observations to estimates based upon fluid flow modeling: JGR Solid Earth, v. 124, n. 7. P. 6880-6907.

Vermote, E., Justice, C., Claverie, M., & Franch, B. (2016). Preliminary analysis of the performance of the Landsat 8/OLI land surface reflectance product. Remote Sensing of Environment, 185, 46-56.

Wood, W.W., 1976, Guidelines for collection and field analysis of groundwater samples for selected unstable constituents, In U.S. Geological Survey, Techniques for Water Resources Investigations, Chapter D-2, 24 p.

Yeskis, D., and Zavala, B, 2002, Ground-Water Sampling Guidelines for Superfund and RCRA Project Managers: Groundwater Forum Issue Paper, Technology Innovative office of Solid Waste and Emergency Response, US EPA, Washington, DC

ATTACHMENT 1

SCHLUMBERGER WIRELINE LOG QUALITY CONTROL REFERENCE MANUAL