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CLASS VI INJECTION WELL: QUALITY ASSURANCE AND SURVEILLANCE PLAN

October 2024

Prepared by:

Aera Energy LLC

File Name	Version	Date	Description of Change
Aera CCS Quality Assurance and Surveillance Plan.pdf	1	January 19, 2023	Original document
Attachment E – Appendix A – Quality Assurance and Surveillance Plan V2 04182024.pdf	2	April 18, 2024	Revisions made based on additional monitoring well and design of seismicity monitoring network
Attachment E – Appendix A – Quality Assurance and Surveillance Plan V3 10152024.pdf	3	October 15, 2024	Revisions made based on EPA Technical Review comments from September 12, 2024

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TITLE AND APPROVAL SHEET

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

Name Title	Date
Name Title	Date
Name Title	Date

DISTRIBUTION LIST

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

1. PROJECT MANAGEMENT

1.1 Project/Task Organization

1.1.1 Key Individuals and Responsibilities

The project, led by Aera Energy LLC (Aera), includes participation from several subcontractors. The testing and monitoring activities responsibilities will be shared between Aera and their designated subcontractors and the program will be broken in six subcategories:

1. Subsurface Fluid Sampling
2. Well Logging
3. Mechanical Integrity Testing (MIT)
4. Pressure/Temperature Monitoring
5. Carbon Dioxide (CO_2) Stream Analysis
6. Geophysical Monitoring

1.1.2 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.

1.1.3 QA Project Plan Responsibility

Aera will be responsible for maintaining and distributing the official, approved Quality Assurance and Surveillance Plan (QASP). Aera will periodically review this QASP and consult with U.S. Environmental Protection Agency (EPA) if/when changes to the plan are warranted.

1.2 Problem Definition/Background

1.2.1 Reasoning

The Aera CarbonFrontier Carbon Capture and Sequestration (CCS) Project's MVA program has operational monitoring, verification, and environmental monitoring components. Operational monitoring is used to ensure safety with the procedures associated with fluid injection, determine the response of the injection zone, and the movement of the CO_2 plume. Aera will use its existing Supervisory Control and Data Acquisition (SCADA) system to monitor injection. Key monitoring parameters include the pressure of injection well tubing and annulus, injection zone geochemistry, above confining zone geochemistry, and seismicity. Other monitoring parameters include injection rate, total mass and volume injected, injection well temperature profile, and pressure front tracking.

The verification component will provide information to evaluate if leakage of CO_2 through the confining zone is occurring. This includes pulsed neutron logging, subsurface fluid monitoring, and pressure and temperature monitoring.

The environmental monitoring components will determine if the injectate were potentially released into the shallow subsurface. This monitoring includes pulsed neutron logging, subsurface fluid monitoring, and seismicity monitoring.

The primary goal of the CarbonFrontier MVA program is to demonstrate that project activities are protective of human health and the environment. To help achieve this goal, this QASP was developed to establish the quality standards of the testing and monitoring program to meet the requirements of the EPA's Underground Injection Control (UIC) Program for Class VI wells.

1.2.2 Reasons for Initiating the Project

The goal of the CarbonFrontier CCS Project is to inject and retain CO_2 for permanent geologic sequestration. In order to demonstrate that this can be done safely, a rigorous MVA plan is proposed to demonstrate that the injected CO_2 is retained within the intended storage reservoir.

1.2.3 Regulatory Information, Applicable Criteria, Action Limits

The Class VI Rule requires owners or operators of Class VI wells to perform several types of activities during the lifetime of the project in order to demonstrate that the injection wells maintain their mechanical integrity, that fluid migration and the extent of pressure elevation are within the limits described in the permit application, and that underground sources of drinking water (USDWs) are not endangered. These monitoring activities include mechanical integrity tests (MITs), injection well testing during operation, monitoring of subsurface fluid quality, and tracking of the CO_2 plume and associated pressure front. This document details both the measurements that will be taken as well as the steps to demonstrate that the quality of the data is such that the data 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 describes the testing and monitoring activities, reasoning, responsible parties, locations, methods, techniques, and purpose. **Tables 2** and **3** summarize the instrumentation and geophysical surveys, respectively.

The Testing and Monitoring Plan (**Attachment E**) contains the schedule for the activities listed in the tables mentioned above.

Table 1: Summary of Testing and Monitoring

Activity	Location(s)	Method	Pre-Injection Frequency	Injection Frequency	PISC Frequency	Analytical Technique	Lab/Custody	Purpose
CO_2 stream analysis	After compression and processing and before injection wellheads	Direct sampling	Once	Quarterly	N/A	Chemical analysis	California certified lab	Monitor injectate
Injection rate and volume	Before wellhead	Flow meter	N/A	Continuous	N/A	Direct measurement	N/A	Monitor injectate rate and volume
Injection temperature/ pressure	Before wellhead	Temperature/ pressure gauge	N/A	Continuous	N/A	Direct measurement	N/A	Monitor injectate temperature, pressure, and well integrity
Annular pressure	Wellhead	Pressure gauge	N/A	Continuous	None	Direct measurement	N/A	Monitor annular pressure and well integrity
Downhole pressure/ temperature	Injection wells	Downhole gauge and DTS	Continuous	Continuous	None	Direct measurement	N/A	Monitor reservoir pressure/injection temperature/well integrity
	Monitoring wells	Downhole gauge and DTS	Continuous	Continuous	Quarterly	Direct measurement	N/A	Monitor reservoir pressure/injection temperature/well integrity
Internal mechanical integrity	Injection wells and Monitoring wells	Annulus pressure test via annulus pressure gauge	Once	Every five years	None	Direct measurement	N/A	Monitor internal mechanical integrity of wellbore
External mechanical integrity	Injection wells	Temperature log, acoustic log, or oxygen activation log	Once	Annual	Once, prior to plugging	Physical analysis	N/A	Monitor external mechanical integrity
	Monitoring wells	Temperature log, acoustic log, or oxygen activation log	Once	As needed	As needed	Physical analysis	N/A	Monitor external mechanical integrity
	Injection wells	Ultrasonic casing/ cement log	Once	As needed	None	Physical analysis	N/A	Monitor well integrity
Corrosion monitoring	After compression	Coupon	Once	Quarterly	None	Physical analysis	N/A	Monitor well integrity
Pressure fall-off testing	Injection wells	Pressure gauge	Once	Every 5 years	None	Direct Measurement	N/A	Monitor well and reservoir integrity

Activity	Location(s)	Method	Pre-Injection Frequency	Injection Frequency	PISC Frequency	Analytical Technique	Lab/Custody	Purpose
Geochemistry monitoring	Monitoring wells: Agua Sandstone (I-28N, 25-26N); Lower Carneros Sandstone (35X-27N)	Fluid sampling	Once	Annually	Every two years	Chemical analysis	California certified lab	Monitor for CO_2 leakage
CO_2 plume tracking	Monitoring wells: 64 Zone (I-28N, 39-26N, 27-1N)	Fluid sampling	Once	Annually	Every two years	Direct Measurement	California certified lab	Directly monitor CO_2 plume migration
	Monitoring wells: 64 Zone (I-28N, 39-26N, 27-1N)	Pulsed neutron wireline log	Once	Quarterly until plume identified, then annually	Every two years	Indirect measurement	N/A	Indirectly monitor CO_2 plume migration
	Monitoring wells: Agua Sandstone (I-28N, 25-26N, 27-1N)	Pulsed neutron wireline log	Once	Annually	Every two years	Indirect measurement	N/A	Monitor for CO_2 leakage
Pressure front tracking	Monitoring wells: 64 zone (I-28N, 39-26N, 27-1N); Agua Sandstone (I-28N, 25-26N); Lower Carneros Sandstone (35X-27N)	Pressure gauge	Continuously	Continuously	Quarterly	Direct Measurement	N/A	Monitor pressure front migration
Seismic activity monitoring	AoR and within 1 mile radius of injection wells	Seismometer network	Continuous	Continuous	None	Indirect measurement	N/A	Monitor natural and induced seismic activity of magnitude 0.5-1.0 and greater for reservoir, well, facility, and pipeline integrity
	AoR and within 1 mile radius of injection wells	California Integrated Seismic Network	Continuous	Continuous	Continuous	Indirect measurement	N/A	Monitor seismic activity of magnitude 2.7 or greater for reservoir, well, facility, and pipeline integrity

3D: three dimensional
DTS: distributed temperature sensing
N/A: not applicable
PISC: post-injection site care

Table 2: Instrumentation Summary

Monitoring Location	Instrument Type	Monitoring Target (Formation or Other)	Data Collection Location(s)	Purpose
CO_2 facility	Pressure/temperature gauge	CO_2 stream	Plant, after compression	Monitor operation, equipment, and permit parameters
	Flowmeter	CO_2 stream	Plant, after compression	Monitor operation, equipment, and permit parameters
Monitoring wells	Pressure gauge	AoR	Wellbore (all wells)	Pressure front tracking and dissipation zone pressure monitoring
	Pulsed neutron logging tool		Logged interval total depth (TD) to surface casing	Well integrity and CO_2 plume migration
	DTS fiber optic		Wellbore (1-28N, 39-26N, 25-26N, and 27-1N)	Well integrity and CO_2 plume migration
Injection wells	Pressure/temperature gauge	Injectate	Wellhead	Monitor operation, equipment, and permit parameters
	Pressure/temperature gauge	64 Zone	1 point location, below injection packer	Monitor operation, equipment, and permit parameters
	Pressure gauge	Injection well annular pressure	Wellhead	Monitor operation, equipment, and permit parameters, integrity of casing, tubing and packer
	Fluid level acoustic sensor	Injection well annular fluid level	Wellhead	Monitor equipment, integrity of casing, tubing and packer
	DTS fiber optic	AoR	Wellbore	Monitor operation, equipment, and permit parameters; well integrity
AoR Seismicity	Three-component geophones	AoR	Shallow offset wells within AoR	Monitor natural and induced seismicity for reservoir, well, facility, and pipeline integrity

AoR: area of review

Table 3: Geophysical Surveys Summary

Monitoring Activity	Tool or Survey Description	Monitoring Location	Monitoring Target (Formation or Other)	Purpose
Well logs	Triple Combo	New injection wells	Surface to TD	Reservoir and fluid properties, correlations
	Pulsed neutron	Monitoring wells	Injection zone, primary confining layer, and first permeable layer above primary confining layer	Well integrity and CO_2 plume saturation
	Cement bond log/ultrasonic casing cement inspection log	Injection wells	All casing strings	Well integrity

TD: total depth

1.3.2 Geographic Locations

The planned location of injection and monitoring wells are provided in **Table 4** and are shown in **Figure 1.**

Table 4: Location of Injection and Monitoring Wells

Injection Wells	Latitude	Longitude
CI1-64Z-27N	35°33'9.4877"N	119°48'26.3702"W
CI2-64Z-35N	35°32'32.6713"N	119°47'37.0682"W
CI3-64Z-35N	35°32'11.6457"N	119°47'7.5912"W
CI4-64Z-35N	35°31'55.4154"N	119°46'51.7864"W
27R-27N	35°33'2.4280"N	119°48'28.6103"W
55-26N	35°32'43.2520"N	119°47'32.7755"W
64-35N	35°31'44.3600"N	119°46'44.9788"W
9-1N	35°31'31.6480"N	119°46'37.0154"W
64-27N	35°32'38.0979"N	119°47'54.6576"W
Monitoring Wells		
39-26N	35°32'54.8149"N	119°47'35.1082"W
1-28N	35°33'22.7757"N	119°48'51.4527"W
25-26N	35°33'1.2506"N	119°47'43.8785"W
27-1N	35°31'18.6498"N	119°46'21.0202"W
35X-27N	35°32'59.1538"N	119°48'06.3812"W

1.3.3 Resource and Time Constraints

No resource or time constraints have been identified during the pre-construction phase.

1.4 Quality Objectives and Criteria

1.4.1 Performance/Measurement Criteria

The overall objective of quality assurance for monitoring is to develop and implement procedures to provide results that meet the site characterization and non-endangerment requirements set for the Class VI permit.

Table 5 summarizes parameters for analytical and field monitoring of subsurface fluid quality. Subsurface fluid monitoring will be conducted during the pre-injection, injection, and post-injection phases of the project in both the injection zone and above confining zone. Monitoring wells will be used to gather water-quality samples and pressure data. **Tables 6** and **7** summarize the analytical parameters for CO_2 stream monitoring and corrosion coupon assessment. The list of analytes may be reassessed periodically and adjusted to include or exclude compounds based on their effectiveness to the overall monitoring program goals. **Table 8** summarizes the specifications for field gauges.

Table 9 summarizes the typical outcome of testing and monitoring results, including activity levels of each parameter, project action limits, detection limits, and anticipated readings. This will serve as a reference for data review, validation, and taking corrective actions.

Key testing and monitoring areas include:

- Subsurface fluid sampling
    - Aqueous chemical concentrations
- Well logging
    - Pulsed neutron logging
- Corrosion monitoring
- Mechanical integrity testing (MIT)
    - Pressure, temperature and acoustic logging
    - Pulsed neutron logging
    - Cement and casing evaluation logging
- Pressure/temperature monitoring
    - Pressure/temperature from in-situ gauges
    - Pressure/temperature from surface gauges
    - Temperature from distributed temperature sensing
- CO_2 stream analysis
    - Carbon dioxide (CO_2, volume per volume [v/v])
    - Moisture (H_2O, parts per million [ppm] v/v)
    - Oxygen (O_2, ppm v/v)
    - Nitrogen (N_2, ppm v/v)
    - Argon (Ar, ppm v/v)
    - Hydrogen (H_2, ppm v/v)
    - Carbon monoxide (CO, ppm v/v)
    - Nitrogen oxides (NOx, ppm v/v)
    - Ammonia (NH_3, ppm v/v)
    - Total hydrocarbons (THC, ppm v/v as CH_4)
    - Methane (CH_4, ppm v/v)
    - aromatic hydrocarbons (ppm v/v)
    - Total sulfur (TS, ppm v/v)

  - Sulfur dioxide (SO_2, ppm v/v)
  - Hydrogen sulfide (H_2S, ppm v/v)
  - Isotope δ13C (per mil, ‰)
  - Ethanol (ppm v/v)
- Seismicity monitoring
  - Shallow borehole seismometer network

Table 5: Summary of Analytical and Field Parameters for Fluid Sampling

Parameters	**Analytical Methods**$^{(1)}$	**Detection Limit/Range**$^{(2)}$	**Typical Precisions (Laboratory Control Limit)** $^{(2)}$	**Typical Quality Control (QC) Requirements**
Cations/metals (aluminum, barium, calcium, manganese, sodium, potassium, iron, arsenic, magnesium, silica, cadmium, chromium, copper, lead, selenium, titanium, zinc)	EPA Method 200.7/200.8 by inductively coupled plasma optical emission spectroscopy (ICP-OES) or mass spectroscopy (ICP-MS)	0.01 to 2 mg/L (analyte, dilution, and matrix dependent; scanning or selective ion monitoring mode dependent)	85-115%	Daily calibration; blanks, duplicates, QC check std, and matrix spikes at 10% or greater frequency
Anions (chloride, sulfate, sulfide, bromide, fluoride, nitrate)	EPA Method 300.0/300.1 by ion chromatography; SM 4500-S^{2-}-D for sulfide by colorimetry	0.1 to 1 mg/L for 300.0/300.1; 0.05 mg/L for SM 4500-S^{2-}-D (sulfide) (analyte, dilution, and matrix dependent)	90-110%; 70-130% for sulfide	Daily calibration; blanks, duplicates, QC check std, and matrix spikes at 10% or greater frequency
Dissolved CO_2	Coulometric titration or RSK-175 by gas chromatography/flame ionization detector (GC/FID)	5 µg/L	80-120%	Daily calibration; blanks, duplicates, QC check std, and matrix spikes at 10% or greater frequency
Dissolved CH_4	RSK-175 by GC/FID	1 µg/L	80-120%	Daily calibration; blanks, duplicates, QC check std, and matrix spikes at 10% or greater frequency
Dissolved O_2	SM 4500 OG by Membrane Electrode Method or RSK-175 by GC/FID	0.01 mg/L	80-120%	Daily calibration; blanks, duplicates, QC check std, and matrix spikes at 10% or greater frequency
Dissolved H_2S (field)	Field Test Kit	Dependent on selected field test kit	Dependent on selected field test kit	Dependent on selected field test kit
Total dissolved solids	EPA Method 160.1/SM 2540 C by gravimetry	1 mg/L	84-108 %	Balance calibration, duplicate analysis, QC check std
Alkalinity	SM 2320 B/EPA Method 310.1 by titration	5 mg/L	80-120%	Daily calibration of pH, blanks, duplicates, QC check std

Parameters	Analytical Methods[1]	Detection Limit/Range[2]	Typical Precisions (Laboratory Control Limit) [2]	Typical Quality Control (QC) Requirements
pH (field)	EPA Method 150.2/SM4500-H+B electrometrically	Dependent on field meter selected	Dependent on field meter selected	User calibration per manufacturer recommendation, QC check std
Specific conductance (field)	EPA Method 120.1 by conductivity meter	Dependent on field meter selected	Dependent on field meter selected	User calibration per manufacturer recommendation, QC check std
Temperature (field)	Thermocouple	Dependent on field meter selected	Dependent on field meter selected	Factory calibration
Hardness	SM 2340C by titration	7.05 mg/L	Dependent on selected laboratory	Daily calibration; blanks, duplicates, QC check std, and matrix spikes at 10% or greater frequency
Turbidity	SM 2130B by nephelometry	0.05 NTU	90-110%	Daily calibration; blanks, duplicates, QC check std, and matrix spikes at 10% or greater frequency
Specific gravity	SM 2710F by calculation	0.05	Dependent on selected laboratory	Daily calibration; blanks, duplicates, QC check std, and matrix spikes at 10% or greater frequency
Water density	SM 2710F by calculation	0.05g/cc	Dependent on selected laboratory	Daily calibration; blanks, duplicates, QC check std, and matrix spikes at 10% or greater frequency
Dissolved inorganic carbon isotopes ($\delta^{13}C$)	Industry Best Practices[3]. Gas stripping followed by gas chromatograph isotope ratio mass spectrometry (GC-IRMS)	–50 to 3 ‰	±0.1 ‰	Quality assurance information to be provided by the contracted laboratory

Note 1: An equivalent method may be employed with the prior approval of the UIC Program Director.
Note 2: Detection limits and precision (laboratory control limits) are typical for these analytical methods and were provided by Eurofins Environment Testing.
Note 3: Isotope ratio mass spectrometry to be conducted in accordance with analytical best practices (Dunn and Carter, 2018, and Singleton, 2012).
µg/L: microgram per liter
g/cc: gram per cubic centimeter
mg/L: milligrams per liter
NTU: Nephelometric turbidity unit

Table 6: Summary of Analytical Parameters for CO_2 Stream

Parameters	**Analytical Methods**[(1)]	**Detection Limit/Range**	**Typical Precisions**	**QC Requirements**[(2)]
Carbon dioxide (CO_2)	ASTM D1945-14 (2019). Gas Chromatography (GC) with thermal conductivity detector (TCD).	0.01-20 mol.%	0.01-0.10% repeatability and 0.02-0.15% duplicability between 0-20 mol.%	Routine calibrations per ASTM standards; blanks, duplicates, QC check standards by the contracted laboratory
Moisture (H_2O)	ISBT 3.0. electrometric moisture analyzer.	0-100 ppm. v/v	5-10% @ 10 ppm v/v	Routine calibrations per ISBT standards; blanks, duplicates, QC check standards by the contracted laboratory
Oxygen (O_2)	ASTM D1945-14 (2019). GC/TCD.	0.01-20 mol.%	0.01-0.10% repeatability and 0.02-0.15% reproducibility between 0-20 mol.%	Routine calibrations per ASTM standards; blanks, duplicates, QC check standards by the contracted laboratory
Nitrogen (N_2)	ASTM D1945-14 (2019). GC/TCD.	0.01-100 mol.%	0.01-0.10% repeatability and 0.02-0.15% reproducibility between 0 – 100 mol.%	Routine calibrations per ISBT standards; blanks, duplicates, QC check standards by the contracted laboratory
Argon (Ar)	ISBT 4.0. GC with discharge ionization detector (DID).	0-100 ppm. v/v	5-10% @ 30 ppm v/v	Routine calibrations per ISBT standards; blanks, duplicates, QC check standards by the contracted laboratory
Hydrogen (H_2)	ASTM D1945-14 (2019). GC/TCD.	0.01-10 mol.%.	0.01-0.08% repeatability and 0.02-0.12% reproducibility between 0 – 10 mol.%	Routine calibrations per ASTM standards; blanks, duplicates, QC check standards by the contracted laboratory
Carbon monoxide (CO)	ISBT 5.0. GC with pulsed discharge ionization detector (PDID).	0-50 ppm. v/v	5-10% @ 10 ppm v/v	Routine calibrations per ISBT standards; blanks, duplicates, QC check standards by the contracted laboratory
Nitrogen oxides (NO_x)	ISBT 7.0. colorimetric tubes to detect NO and NO_2.	0.2-10 ppm. v/v	5-30% of full scale	Routine calibrations per ISBT standards; blanks, duplicates, QC check standards by the contracted laboratory
Ammonia (NH_3)	ISBT 6.0. ammonia-specific colorimetric detector tube.	0.5-5 ppm. v/v	5-30% of full scale	Routine calibrations per ISBT standards; blanks, duplicates, QC check standards by the contracted laboratory
Total hydrocarbons (THCs)	ISBT 10.0. GC with flame ionization detector (FID).	0-100 ppm. v/v	1-2% @ 20 ppm v/v	Routine calibrations per ISBT standards; blanks, duplicates, QC check standards by the contracted laboratory
Methane (CH_4)	ASTM D1945-14 (2019). GC/TCD.	0-100 mol.%	0.01-0.10% repeatability and 0.02-0.15% reproducibility between 0 – 100 mol.%	Routine calibrations per ISBT standards; blanks, duplicates, QC check standards by the contracted laboratory

Parameters	Analytical Methods[1]	Detection Limit/Range	Typical Precisions	QC Requirements[2]
Aromatic hydrocarbons	ISBT 12.0. GC with photoionization detector (PID). 0-5 ppm	0-0.20 ppm	5-10% @ 0.020 ppm v/v	Routine calibrations per ISBT standards; blanks, duplicates, QC check std, and matrix spikes at 10% or greater frequency
Total sulfur	ISBT 13.0. GC with sulfur chemiluminescent detector (SCD).	0-5 ppm. v/v	5-10% @ 0.10 ppm	Routine calibrations per ISBT standards; blanks, duplicates, QC check standards by the contracted laboratory
Sulfur dioxide (SO_2)	ISBT 14.0. GC/SCD.	0-5 ppm. v/v.	5-10% @ 0.10 ppm v/v	Routine calibrations per ISBT standards; blanks, duplicates, QC check standards by the contracted laboratory
Hydrogen sulfide (H_2S)	ASTM D1945-14 (2019), GC/TCD.	0.3 - 30 mol.%	0.04-0.10% repeatability and 0.07-0.15% reproducibility between 0.3 – 30 mol.%	Routine calibrations per ASTM standards; blanks, duplicates, QC check standards by the contracted laboratory
Ethanol EtOH	EPA Method 8260B. GC with mass spectroscopy (MS).	25-500 ppb, v/v	10-13% between 25-500 ppb v/v	Routine calibrations per EPA recommendations; blanks, duplicates, QC check standards by the contracted laboratory
^{13}C isotope	Industry Best Practices.[3] GC with dual-inlet isotope ratio mass spectrometry (GC-IRMS)	–50 to 3 ‰	±0.1 ‰	Quality assurance information to be provided by the contracted laboratory

Note 1: An equivalent method may be employed with the prior approval of the UIC Program Director.
Note 2: Key elements for quality assurance (QA) include: employing knowledgeable and responsible personnel to perform sample analysis, documentation, and reporting, establishing a QA team with experienced and dedicated reviewers to review results, and appropriate maintenance and calibration of equipment involved.
Note 3: Isotope ratio mass spectrometry to be conducted in accordance with analytical best practices (Dunn and Carter, 2018).
ppb: parts per billion

Table 7: Summary of Analytical Parameters for Corrosion Coupons

Parameters	Analytical Methods[1]	Detection Limit/Range	Typical Precisions	QC Requirements
Mass	NACE RP0775-2005	0.005 mg	+/- 2%	Annual calibration of scale
Thickness	NACE RP0775-2005	0.001 mm	+/- 0.005 mm	Factory calibration

Note 1: An equivalent method may be employed with the prior approval of the UIC Program Director.
mm: millimeter

Table 8: Summary of Measurement Parameters for Field Gauges

Parameters	Methods	Detection Limit/Range	Typical Precisions	QC Requirements
Booster pump discharge pressure	ANSI Z540-1-1994	+/- 0.001 psi / 0-3000 psi	+/- 0.01 psi	Annual calibration of scale
Injection tubing temperature	ANSI Z540-1-1994	+/- 0.001 ºF / 0-500 ºF	+/- 0.01 ºF	Annual calibration of scale
Annulus pressure	ANSI Z540-1-1994	+/- 0.001 psi / 0-3000 psi	+/- 0.01 psi	Annual calibration of scale
Injection tubing pressure	ANSI Z540-1-1994	+/- 0.001 psi / 0-3000 psi	+/- 0.01 psi	Annual calibration of scale
Wellhead pressure	ANSI Z540-1-1994	+/- 0.001 psi / 0-3000 psi	+/- 0.01 psi	Annual calibration of scale
Downhole temperature	ANSI Z540-1-1994	+/- 0.001 ºF / 0-500 ºF	+/- 0.01 ºF	Annual calibration of scale
Injection mass flow rate	Unknown	Dependent on selected meter	Depended on selected meter	Based on manufacturer specifications

psi: pounds per square inch

Table 9: Actionable Testing and Monitoring Outputs

Activity or Parameter	Project Action Limit	Anticipated Reading
Seismic Activity	Action taken based on magnitude and felt report or local observation as per Seismic Response System established in Emergency and Remedial Response Plan (**Attachment I**)	No seismic event greater than M2.5 within 1 mile of injection wells
Mechanical integrity (pulsed neutron log)	Action taken when pulsed neutron measurements indicate CO_2 outside of expected range / zone	No measurement change from baseline caused by CO_2 in annular space, above injection zone, or in formation above confining zone
Surface pressure / temperature	Action taken when pressures and temperatures are well outside of modeled / expected range	Pressures/temperatures within proposed operational ranges
Downhole pressure / temperature	Action taken when pressures and temperatures are well outside of modeled / expected range	Pressures/temperatures within proposed operational ranges
Subsurface fluid quality	Action taken when changes in fluid constituent concentrations indicate movement of CO_2 or brines into or above the confining zone	No statistically significant difference between observed and baseline geochemical parameter patterns in Agua Sandstone or Lower Carneros Sandstone formation
Above confining zone pressure	Action taken when pressures are well outside of modeled / expected range	Pressures within proposed operational range
Injection well annular volume	Action taken when annular volume is well outside of modeled / expected range	No expected annular volume change not related to temperature

1.4.2 Precision

Assessment of analytical precision can be made through the use of field generated duplicate samples as well as laboratory generated duplicate samples.

1.4.3 Accuracy and Bias

Data accuracy and bias will be assessed by analyzing standards of known concentrations and measuring its actual recovery in analysis versus the expected recovery. Laboratory assessment of analytical accuracy and bias will be the responsibility of the individual laboratories per their standard operating procedures (SOPs) and analytical methodologies and will be evaluated through the use of laboratory control samples, matrix spikes, and surrogates (where applicable). Assessment of bias in the field can be ascertained through collection of field blanks. Field blanks will be collected no less than one per sampling event to screen for sample bottle contamination. For direct pressure or logging measurements, there is no potential for bias with the instruments used to collect data.

1.4.4 Representativeness

Data representativeness expresses the degree to which data accurately and precisely represents a characteristic of a population, parameter variations at a sampling point, a process condition, or an environmental condition. The sampling network has been designed to provide data representative of site conditions. For analytical results of individual subsurface fluid 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 is 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.

1.4.5 Completeness

Data completeness is a measure of the amount of valid data obtained from a measurement system compared to the amount that was expected to be obtained under normal conditions. It is anticipated that data completeness of 90% for liquid 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 expresses the confidence with which one data set can be compared to another. The data sets to be generated by this project will be comparable to future data sets because of the use of standard sample collection and analytical methods and the level of QA/QC effort. If historical subsurface fluid data become available from other sources, their applicability to the project and level of quality will be assessed prior to use with data gathered on this project. Direct pressure, temperature, and logging measurements will be directly comparable to previously obtained data.

1.4.7 Method Sensitivity

Tables 10 through **15** provide additional details on gauge specifications and sensitivities. Values may change depending on vendor, service provider, and specific item chosen at time of operation.

Table 10: Pressure and Temperature – Downhole Gauge Specifications.

Parameter	Value
Calibrated working pressure range	Atmospheric to 10,000 psi
Initial pressure accuracy	<+/- 2 psi over full scale
Pressure resolution	0.005 psi at 1-s sample rate
Pressure drift stability	<+/- 1 psi per year over full scale
Calibrated working temperature range	77–266 °F
Initial temperature accuracy	<+/- 0.9°F per +/-0.27 °F
Temperature resolution	0.009 °F at 1-s sample rate
Temperature drift stability	<+/- 0.1 °F per year at 302 °F
Max temperature	302 °F

Table 11: Representative Logging Tool Specifications

Parameter	Pulsed Neutron	Cement Bond Log	Ultrasonic casing / cement inspection
Logging speed	Up to 3,600 ft/hr	Up to 3,600 ft/hr	400 to 4,500 ft/hr
Vertical resolution	15 inches	3 ft	0.6 to 6.0 inches
Investigation	Formation fluid saturation, annular space, mechanical integrity	Cement bond (cement-casing, cement-formation)	Casing and cement (cement-casing, cement-formation and annular coverage)
Temperature rating	350 °F	350 °F	350 °F
Pressure rating	15,000 psi	20,000 psi	20,000 psi

ft/hr: feet per hour

Table 12: Pressure Field Gauge—Injection Tubing Pressure

Parameter	Value
Calibrated working pressure range	0 to 3,000 psi
Initial pressure accuracy	< 0.04375 %
Pressure resolution	0.001 psi
Pressure drift stability	To be determined after first year

Table 13: Pressure Field Gauge—Annulus Pressure

Parameter	Value
Calibrated working pressure range	0 to 3000 psi
Initial pressure accuracy	< 0.04375 %
Pressure resolution	0.001 psi
Pressure drift stability	To be determined after first year

Table 14: Temperature Field Gauge—Injection Tubing Temperature

Parameter	Value
Calibrated working temperature range	0 to 500 °F
Initial temperature accuracy	< 0.0055 %
Temperature resolution	0.001 °F
Temperature drift stability	To be determined after first year

Table 15: Mass Flow Rate Field Gauge—CO_2 Mass Flow Rate

Parameter	Value
Calibrated working flow rate range	50,522 to 303,133 lb/hr
Initial mass flow rate accuracy	< 0.18 %
Mass flow rate resolution	0.0001 lb/hr
Mass flow rate drift stability	To be determined after first year

lb/hr: pounds per hour

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. No specialized certifications are required for personnel conducting subsurface fluid sampling, but field sampling will be conducted by personnel trained to understand and follow the project specific sampling procedures. Upon request, Aera will provide the agency with the laboratory SOPs developed for the specific parameter using the appropriate standard method. Each laboratory technician conducting the analysis on the samples will be trained on the SOP developed for each standard method. Aera will include the technician's training certification with the annual report.

1.5.2 Training Provider and Responsibility

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

1.6 Documentation and Records

1.6.1 Report Format and Package Information

Aera will submit an annual report containing the required project data, including testing and monitoring information as specified by the Class VI permit. Data will be provided in electronic or other formats as required by the UIC Program Director.

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 UIC Program Director.

1.6.3 Data Storage and Duration

Aera or a designated contractor will maintain the required project data as specified in the Class VI permit.

1.6.4 QASP Distribution Responsibility

The Aera Plant Manager will be responsible for ensuring that those included on the distribution list will receive the most current copy of the approved QASP.

2. DATA GENERATION AND ACQUISITION

2.1 Sampling Process Design

Discussion in this section is focused on subsurface 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 and injection phases, subsurface fluid sampling is planned to include an extensive set of chemical parameters to establish aqueous geochemical baseline data. 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 modeling. The full set of parameters is presented in **Table 5**. 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.

Implementation of a reduced set of parameters would be done in consultation with the EPA. Isotopic analyses will be performed on baseline samples to the degree that the information helps verify a condition or establish an understanding of non-project related variations. For non-baseline samples, isotopic analyses may be reduced in the monitoring wells if a review of the historical project results or other data determines that further sampling for isotopes is not needed. During a 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, then the analytical list would be expanded to the full set of monitoring parameters. The fluid samples will be analyzed using a laboratory meeting the requirements under the EPA National Environmental Laboratory Accreditation Program (NELAP). The other samples will be analyzed by the operator or a third-party laboratory.

Dissolved CO_2 will be analyzed by methods consistent with Test Method B of ASTM D 513-11 or equivalent. Isotopic analysis will be conducted using established methods.

2.1.1 Design Strategy

2.1.1.1 CO_2 Stream Monitoring Strategy

The primary purpose of 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 the determination of whether the injectate meets the qualifications of hazardous waste under the Resource Conservation and Recovery Act (RCRA), 42 United States Code (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 CO_2 (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 physical and chemical properties that may result in a deviation from the permitted specifications.

Calibration of transmitters used to monitor pressures, temperatures, and flow rates of CO_2 into the injection well shall be conducted annually. Reports will contain test equipment used to calibrate the transmitters, including test equipment manufacturers, model and serial numbers, calibration dates, and expiration dates.

2.1.1.2 Corrosion Monitoring Strategy

Corrosion coupon analyses will be conducted quarterly to aid in demonstrating the mechanical integrity of the equipment in contact with the CO_2. Coupons shall be sent quarterly to a qualified company for analysis and an analysis conducted in accordance with NACE Standard RP-0775 (or similar) to determine and document corrosion wear rates based on mass loss.

2.1.1.3 Above Confining Zone Monitoring Strategy

Aera will monitor subsurface fluid composition for potential geochemical changes above the confining zone during the operation period to meet the requirements of 40 CFR 146.90(d).

Monitoring will be conducted in the following zones:

- Agua Sandstone, approximately 7,500 to 7,800 feet (ft) true vertical depth (TVD): zone immediately above the primary confining layer (Lower Santos Shale)
- Lower Carneros Sandstone, approximately 6,550 to 7,150 ft TVD: zone directly above the secondary confining layer (Upper Santos Shale)

The monitoring wells 1-28N and 25-26N will be used for fluid sampling of the groundwater in the Agua Sandstone at prescribed frequencies in **Attachment E**. Monitoring well 35X-27N will be used for fluid sampling of the groundwater in the Lower Carneros Sandstone. Monitoring wells 1-28N, 25-26N, 29-26N, and 27-1N will be used for continuous temperature and pressure monitoring, with 35X-27N used for pressure monitoring. These wells are selected to allow for early detection of potential leakage from the injection zone into the permeable Agua or Lower Carneros Sandstones, which directly overlie the primary and secondary confining layers, respectively.

Samples will be analyzed for constituents listed in **Table 5** to document baseline fluid chemistry and to detect changes in fluid chemistry that could result from the movement of brine or CO_2 from the storage interval through the seal formation.

2.1.1.4 Injection Zone Fluid Monitoring Strategy

The primary method for direct plume monitoring will be fluid sampling from the injection zone to detect changes from baseline values, indicative of the CO_2 plume's presence. Monitoring wells 1-28N, 39-26N, and 27-1N will be used for fluid sampling of the reservoir fluid in the injection zone. The parameters to be analyzed and the analytical methods are presented in **Table 5**.

2.1.2 Type and Number of Samples/Test Runs

Subsurface fluid sampling plans are detailed in **Attachment E** and summarized in **Tables 16** and **17**. CO_2 stream analysis plans are also detailed in **Attachment E**.

2.1.3 Site/Sampling Locations

Table 16 shows the planned monitoring methods and locations for subsurface fluid composition and geochemical monitoring above the confining zone. **Table 17** shows the planned monitoring methods and locations for subsurface fluid composition and geochemical monitoring in the injection zone. The locations of the monitoring wells are shown in **Figure 1**. Wells are located based on the AoR modeling to allow for tracking of the CO_2 plume and pressure front and early warning of leakage from the injection zone into the Agua Sandstone or Lower Carneros sandstone.

CO_2 stream sampling will occur after the pre-combustion and post-combustion sources have compressed and comingled so that the sample will be representative of the composition of the injectate.

Table 16: Monitoring of Fluid Composition and Geochemical Changes Above the Confining Zone

Target Formation	Monitoring Activity	Monitoring Location(s)	Spatial Coverage
Agua Sandstone (approximately 7,500-7,800 ft TVD)	Fluid sampling	Monitoring wells 1-28N and 25-26N	Northern half of injection area
	Temperature (DTS) and Pressure Monitoring	Monitoring wells 1-28N and 25-26N	Above injection zone
	Temperature (DTS) Monitoring	Monitoring wells 39-26N and 27-1N	Along wellbore
	Pulsed neutron logging	Monitoring wells 1-28N, 25-26N, 27-1N	Along wellbore

Target Formation	Monitoring Activity	Monitoring Location(s)	Spatial Coverage
Lower Carneros Sandstone (approximately 6,550–7,150 ft MD)	Fluid sampling	Monitoring well 35X-27N	Above injection zone
	Pressure	Monitoring well 35X-27N	Above injection zone

MD: measured depth

Table 17: Monitoring of Fluid Composition and Geochemical Changes in the Injection Zone

Target Formation	Monitoring Activity	Monitoring Location(s)	Spatial Coverage
64 Zone	Fluid sampling	1-28N	1 Point Location: ~8,029 - 8,358 ft MD
		39-26N	1 Point Location: ~7,975 - 8,243 ft MD
		27-1N	1 Point Location: ~8,001 - 8,302 ft MD
	Pulsed neutron logging	1-28N	Survey log: ~7,505 - 8,450 ft MD
		39-26N	Survey log: ~7,667–8,300 ft MD
		27-1N	Survey log: ~7,594 - 8,278 ft MD
	DTS	1-28N, 39-26N, and 27-1N	Entire Wellbore

2.1.4 Sampling Site Contingency

The proposed monitoring wells are located on property owned by Aera and access permissions have already been granted. No problems with site accessibility are anticipated. If inclement weather makes site access difficult, sampling schedules will be reviewed, and alternative dates may be selected that would still meet permit-related conditions.

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

2.1.5 Activity Schedule

The subsurface fluid sampling activities are summarized in **Table 5** with schedules in **Tables 16** and **17**. The CO_2 stream sampling activities are summarized in **Table 6**. CO_2 stream sampling will be conducted quarterly.

2.1.6 Critical/Informational Data

During both 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 time and date of activity, person/s performing activity, location of activity (well or field sampling location), method (instrument or lab analysis), field or laboratory instrument calibration data, and field parameter values. For laboratory analyses, the laboratory will provide a report containing critical data generated during the analysis and provide to end users in digital and printed formats. Noncritical field data may include appearance and odor of the sample, problems 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 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 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, be resampled or reanalyzed, (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 (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).

2.2 Sampling Methods

2.2.1 Sampling SOPs

2.2.1.1 Analytical Parameters

Table 5 identifies the parameters to be monitored and the analytical methods Aera will use for subsurface fluid sampling. If new information or updates to the geochemical modeling based on pre-operational testing raises additional concerns about subsurface geochemical processes (e.g., potential changes in subsurface properties or potential contaminant mobilization), the list of analytical parameters may need to be updated to ensure that the applicable parameters are included.

Subsurface fluid sampling data will be compared to baseline data to identify changing conditions in the subsurface, including fluid leakage. Abnormalities suggestive of leakage could include increased total dissolved solids (TDS), change in cation and/or anion signature(s), increase in CO_2 concentrations, pH changes, or changes in dissolved metal concentrations that indicate leaching of the geological formation.

Table 6 identifies the parameters to be monitored and the analytical methods Aera will use for CO_2 stream sampling. Revisions to the methods may be made in consultation with the UIC Program Director.

2.2.1.2 Sampling Methods

Fluid sampling will likely be performed using a U-tube sampling system to collect large volume samples recovered at the surface at reservoir pressure using a positive gas displacement pump driven with nitrogen gas. A downhole check valve allows fluid to flow into a loop of stainless-steel tubing, after which fluid is driven to the surface with compressed ultra-pure nitrogen gas. The sample is then collected at formation pressure at a volume of up to 100 liters. This sampling method prevents off-gassing and isolates the sample from ambient air. Samples will be depressurized for collection and submitted for laboratory analysis according to standard shallow groundwater analysis methods, described below, with temperature and pressure corrections calculated. Pressurized samples may become degassed, with gas analyzed, pending development of a project-specific SOP, as no EPA standard analytical methods are known for deep subsurface fluid. If U-tube sampling is determined to be infeasible in the monitoring well (which can occur if fines or precipitates accumulate in the system, for example), alternate sampling methods will be evaluated.

Depending on the developed laboratory project-specific SOP for analysis of pressurized samples, Aera will follow traditional groundwater sampling SOPs as needed. Samples requiring filtration will be filtered through 0.45-micrometer flow-through filter cartridges as appropriate and consistent with ASTM D6564-00. Before sample collection, filters will be purged with a minimum of 100 mL of well water (or more if required by the filter manufacturer). For field parameters, additional efforts will be made to minimize exposure time to the atmosphere during filtration, collection, and analysis.

Sample holding times will be consistent with those described in EPA (1974), American Public Health Association (APHA [2005]), Wood (1976), and ASTM Method D6517-00 (2005). After collection, samples will be placed in ice chests in the field and maintained thereafter at ≤6 °C, but not frozen, until analysis. The samples will be maintained at their preservation temperature and hand-delivered or shipped via overnight carrier to the designated laboratory within 24 hours. The sample bottles will have waterproof labels with information denoting project, sampling date and time, sampling location, sample identification number, sample type (fresh water or brine), analyte, volume, filtration used (if any), and preservative used (if any).

2.2.2 In-situ Monitoring

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

2.2.3 Continuous Monitoring

Pressure data will be collected from monitoring wells on a continuous basis (e.g., hourly to daily) using dedicated pressure transducers with data loggers to characterize pressure trends.

2.2.4 Sample Homogenization, Composition, Filtration

Described above in **Section 2.2.1**.

2.2.5 Sample Containers and Volumes

For subsurface fluid samples, new sample bottles will be used. Sample bottles and bags for analytes will be used as received (ready for use) from the vendor or contract analytical laboratory for the analyte of interest. A summary of sample containers is presented in **Table 18**.

For CO_2 stream monitoring, samples will be collected in a clean sample container rated for the appropriate collection pressure (i.e., mini cylinders or polybags). Details are summarized in **Table 19**.

2.2.6 Sample Preservation

For subsurface fluid samples, the preservation methods in **Table 18** will be used. No preservation is required or used for CO_2 stream, and additional details of sampling requirements are shown in **Table 19**.

Corrosion coupon sampling only requires that the coupons be physically separated (e.g., sleeves, baggies) during transportation to prevent physical abrasion.

2.2.7 Cleaning/Decontamination of Sampling Equipment

Pumps and related equipment and materials necessary for subsurface fluid sampling will be selected based on site needs and cleaned and decontaminated according to standard guidelines.

The 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.

CO_2 stream sampling containers will be either disposed of or decontaminated by the analytical laboratory.

2.2.8 Support Facilities

For subsurface fluid sampling, the following are required: air compressor, vacuum pump, generator, multi-electrode water quality sonde, analytical meters (pH, specific conductance, etc.). Field activities are usually completed in field vehicles and portable laboratory trailers located on site.

Sampling tubing, connectors and valves required to sample the CO_2 stream will be supplied by the analytical lab providing the sampling containers. Sampling will occur within the CO_2 compression unit.

Field gauges will be removed from injection and monitoring wells utilizing existing standard industry tools and equipment. Deployment and retrieval of verification well gauges will be done using procedures and equipment recommended by the vendor, subcontractor, or per standard industry practice.

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

2.3 Sample Handling and Custody

Logging, geophysical monitoring, and pressure/temperature monitoring does not apply to this section and is omitted.

Sample holding times will be consistent with those described in EPA (1974), APHA (2005), Wood (1976), and ASTM Method D6517-00 (2005). After collection, samples will be placed in ice chests in the field and maintained thereafter at ≤6 °C but not frozen until analysis. The samples will be maintained at their preservation temperature and hand-delivered or shipped via overnight carrier to the designated laboratory within 24 hours. Analysis of the samples will be completed within the holding time listed in **Tables 18** and **19**. As appropriate, alternative sample containers and preservation techniques approved by the UIC Program Director will be used to meet analytical requirements.

CO_2 stream sampling occurs under high pressure. Impurities in CO_2 may be improperly measured due to partitioning coefficient of CO_2 when in sampling system. It is a significant factor for consistently obtaining accurate analytical results. The point in the system where vaporization occurs must be well managed to prevent impurity partitioning and avoid over or under-reporting of impurities. ISBT 2.0 standard recommends that the vaporization devices including the pressure regulators remain heated during sample collection and analysis. Precautions should be taken to prevent icing at the vaporization point. Samples should be analyzed as soon as practically possible after collection to minimize potential sample adulteration.

2.3.1 Maximum Hold Time/Time Before Retrieval

See **Tables 18** and **19** for maximum sample holding time for subsurface fluid samples and CO_2 stream samples.

2.3.2 Sample Transportation

See description at the beginning of this section.

2.3.3 Sampling Documentation

Field notes will be collected for the subsurface fluid samples collected. These forms will be retained and archived as reference. The sample documentation is the responsibility of sampling personnel.

An analysis authorization form will be provided with each CO_2 stream sample provided for analysis.

2.3.4 Sample Identification

The sample bottles will have waterproof labels with information denoting project, sampling date and time, sampling location, sample identification number, sample type (fresh water or brine), analyte, volume, filtration used (if any), and preservative used (if any).

Table 18: Summary of Anticipated Sample Containers, Preservation Treatments, and Holding Times for Subsurface Fluid Samples

Target Parameters	Volume/Container Material	Preservation Technique	Sample Holding Time
Cations/metals (aluminum, barium, calcium, manganese, sodium, potassium, iron, arsenic, magnesium, silica, cadmium, chromium, copper, lead, selenium, titanium, zinc)	250 ml/HDPE	Filtered, nitric acid, 4 °C	180 days
Anions (chloride, sulfate, sulfide, bromide, fluoride, nitrate)	125 ml/ HDPE	4 °C	28 days (48 hours for nitrate)
Dissolved gases CO_2 CH_4 O_2	 2 X 40-mL VOA vials 2 X 40-mL VOA vials 500 mL amber glass	 4 °C, no headspace HCl, 4 °C, no headspace 4 °C, no headspace	 7 days 14 days 15 minutes
TDS	1-liter HDPE	4 °C	7 days
Alkalinity	250 ml/HDPE	4 °C	14 days
Hardness	250 ml/HDPE	Nitric acid	180 days
Turbidity	125 ml/ HDPE	4 °C	48 hours
Specific gravity	250 ml/HDPE	4 °C	28 days
Water density	250 ml/HDPE	4 °C	28 days
Dissolved inorganic carbon isotopes ($\delta^{13}C$)	Dependent on selected analytical laboratory		

HDPE: high-density polyethylene

Table 19: Summary of Sample Containers, Preservation Treatments, and Holding Times for CO_2 Stream Analysis

Sample	Volume/Container Material	Preservation Technique	Sample Holding time (max)
CO_2 stream	(2) 2L MLB Polybags (1) 75 cc Mini Cylinder	Sample Storage Cabinets	5 days

2.3.5 Sample Chain-of-Custody

For fluid samples, 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. These forms will be retained and archived to allow simplified tracking of sample status. The chain-of -custody form and record keeping is the responsibility of sampling personnel.

For CO_2 stream analysis, an analysis authorization will accompany the sample to the laboratory at which point a chain-of-custody accompanies the sample through their processes.

2.4 Analytical Methods

Logging, geophysical monitoring, and pressure/temperature monitoring does not apply to this section and is omitted.

2.4.1 Analytical SOPs

Analytical SOPs are referenced in the laboratory methods provided in **Tables 5 and 6**. Other laboratory specific SOPs utilized by the laboratory will be determined after a contract laboratory has been selected. Upon request, Aera will provide the agency with the laboratory SOPs developed for the specific parameter using the appropriate standard method. Each laboratory technician conducting the analysis on the samples will be trained on the SOP developed for each standard method. Aera will include each technician's training certification with the annual report.

2.4.2 Equipment/Instrumentation Needed

Equipment and instrumentation are specified in **Tables 5 and 6** for the individual analytical methods.

2.4.3 Method Performance Criteria

Tables 5 through **7** list the analytes specific to each method along with the associated performance criteria, including reporting limits, method detection limits, and accuracy and precision limits. Nonstandard method performance criteria are not anticipated for this project.

2.4.4 Analytical Failure

Each laboratory conducting the analyses in **Tables 5** through **7** will be responsible for appropriately addressing analytical failure according to their individual SOPs.

2.4.5 Sample Disposal

Each laboratory conducting the analyses in **Tables 5** through **7** will be responsible for appropriate sample disposal according to their individual SOPs.

2.4.6 Laboratory Turnaround

Laboratory turnaround will vary by laboratory, but generally turnaround of verified analytical results within one month 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 EPA will be consulted on additional appropriate actions to be taken.

2.5 Quality Control

Geophysical monitoring and pressure/temperature monitoring does not apply to this section and is omitted. For log quality control, please refer to specific vendors at time of logging, following industry standard practices.

2.5.1 Field Quality Control Samples

2.5.1.1 Blanks

For subsurface fluid sampling, a field blank will be collected and analyzed for the inorganic analytes in **Table 5** at a frequency of 10% or greater. Field blank samples consist of laboratory supplied, reagent-free water that are collected in the field. Field blanks will be exposed to the same field and transport conditions as the subsurface fluid samples. Field blanks will be used to detect contamination resulting from the collection process. Trip blanks will be included with each set of samples being transported to analytical laboratories to detect contamination resulting from the transportation process.

2.5.1.2 Duplicates

For each subsurface fluid sampling event, a duplicate subsurface fluid sample will be collected from a well from a rotating schedule at 10% or greater frequency. Duplicate samples will be collected from the same source immediately after the original sample in different sample containers and processed as the other samples. Duplicate samples will be used to assess 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 TDS to the calculated TDS (i.e., mass balance) per the American Public Health Association (APHA) method. The method indicates which ion analyses should be considered suspect based on the mass balance ratio. Suspect ion analyses will then be reviewed in the context of historical data and interlaboratory results, if available. Suspect ion analyses will then 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 during data validation and may be given less importance in data interpretations.

2.5.3 Calculating Applicable QC Statistics

2.5.3.1 Charge Balance

The analytical results will be evaluated to determine correctness of analyses based on anion-cation charge balance calculation. Because the 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 formula:

$$\%\ difference = 100 \text{ x } \frac{\sum cations - \sum anions}{\sum cations + \sum anions},$$

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:

$$1.0 < \frac{measured\ TDS}{calculated\ TDS} < 1.2,$$

where the anticipated values are between 1.0 and 1.2.

2.5.3.3 Outliers

Identification of statistical outliers is essential prior to the statistical evaluation of fluid chemistry. This project will use the EPA's Unified Guidance (March 2009) as a basis for selection of recommended statistical methods to identify outliers in subsurface fluid chemistry data sets 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.

2.6 Instrument/Equipment Testing, Inspection, and Maintenance

Logging tool equipment will be maintained as per wireline industry best practices and standards.

For subsurface fluid 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 the laboratory equipment, testing, inspection, and maintenance will be the responsibility of the analytical laboratory per standard practice, method-specific protocol, or NELAP requirement.

2.7 Instrument/Equipment Calibration and Frequency

2.7.1 Calibration and Frequency of Calibration

Pressure/temperature gauge calibration information is located in **Tables 10** through **15**. Logging tool calibration will be performed at the discretion of the service company providing the equipment, following standard industry practices. Calibration frequency will be determined by standard industry practices.

For subsurface fluid sampling and CO_2 stream sampling, calibration requirements are specific to each method and given in **Tables 5** and **6**, respectively.

2.7.2 Calibration Methodology

Logging tool calibration methodology will follow standard industry practices.

For subsurface fluid sampling and CO_2 stream sampling, calibration methodology is given in **Tables 5** and **6**, respectively.

2.7.3 Calibration Resolution and Documentation

Logging tool calibration resolution and documentation will follow standard industry practices.

For subsurface fluid sampling and CO_2 stream sampling, calibration resolution and documentation requirements are specific to each method and given in **Tables 5** and **6**, respectively.

2.8 Inspection/Acceptance for Supplies and Consumables

2.8.1 Supplies, Consumables, and Responsibilities

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

2.9 Non-Direct Measurements

Aera will employ direct and indirect methods to track the extent of the CO_2 plume and the presence or absence of elevated pressure. Non-direct methods include pulsed neutron logging, DTS, and seismicity monitoring by shallow borehole seismometers.

2.9.1 Pulsed Neutron Logging

The CO_2 plume location will be tracked using pulsed neutron logging that will provide high-resolution vertical data around the wellbore of the Agua Sandstone (I-28N, 25-26N) and 64 Zone (1-28N, 39-26N, and 27-1N) monitoring wells. The saturation of CO_2 in the target formation will be estimated by measuring the die-away time of a short neutron pulse. The die-away time is a function of the porosity and the fluid types in the rock. The exact precision and accuracy of the data will depend on the selected tool and the logging environment of each well, but representative pulsed neutron logging tool specifications are given in **Table 21**.

An initial pulsed neutron log will be created before the CO_2 plume reaches the monitoring well and will serve as a baseline that future measurements will be compared against. Increases in CO_2 saturation relative to baseline will indicate when and where the plume has reached the monitoring well. These data will also be used in reevaluations of the AoR.

2.9.2 Distributed Temperature Sensing

DTS allows for continuous temperature profiles over the installed depth rather than measurements at fixed points. The continuous temperature data can be analyzed to provide information about the specific depths that the CO_2 enters the formation. Abnormal temperature profiles may indicate mechanical integrity concerns or unexpected leakage of CO_2. DTS fiber optic cable will be installed in the 64 Zone monitoring wells, 1-28N, 39-26N, and 27-1N, to identify temperature changes that may indicate the CO_2 plume's arrival at that location. DTS fiber optic will also be installed in the Agua sandstone monitoring well 26-25N to evaluate temperature fluctuation above the injection zone.

2.9.3 Seismicity Monitoring

Aera intends to monitor seismicity with a network of shallow borehole seismometers in the AoR with potential surface seismometers for location verification. This network will be implemented to monitor seismic activity near the project site. The seismometers will be able to detect events with a magnitude 0.5 to 1.0 and above and will be installed at least one year prior to injection to provide baseline seismicity. Additionally, the California Integrated Seismic Network will be monitored continuously for indication of an earthquake of magnitude 2.7 or greater occurring within a radius of one mile of injection operations from commencement of injection activity to its completion. Aera will respond to seismic events with an epicenter in the AoR in accordance with the Seismic Response System for seismic events >M1.0 established in the Emergency and Remedial Response Plan (**Attachment I).** A summary of the seismic monitoring locations and frequencies is given in **Table 10**. Direct pressure monitoring of the storage reservoir will be used in conjunction with the passive seismic monitoring to demonstrate that there are no seismic events affecting CO_2 containment.

2.9.3.1 Network Design

Sensor locations will be determined following evaluation. At least three borehole seismometers will be installed in offset wells within the AoR with two potential surface stations outside of the AoR to provide location verification. Each location will have high-sensitivity 3-component geophones. The systems will be designed with capability of detecting and locating events of magnitude 0.5 to 1.0 and above. A velocity model will be derived from nearby vertical seismic profiles (VSPs), sonic well logs, and check shots.

Monitoring will begin at least 1 year prior to injection to establish an understanding of the baseline seismic activity within the area of the project. Historical data from the California Integrated Seismic Network will be reviewed to assist in establishing the baseline. Data will help establish historical natural seismic event depth, magnitude, and frequency in order to distinguish between naturally occurring seismicity and induced seismicity resulting from CO_2 injection.

2.9.3.2 Network Operation

After design, the microseismic network will be installed and tested. After testing is completed, the network will be operational to monitor for microseismic events continuously during baseline and injection operations. Waveform data will be transmitted in near real-time via cellular modem or other wireless means and archived in a database. Event notification will be automatically sent to required personnel to ensure compliance with the Emergency and Remedial Response Plan (**Attachment I**).

Table 20: Summary of Passive Seismic Monitoring System

Target Formation	Monitoring Activity	Monitoring Location(s)	Spatial Coverage	Frequency
Multiple	Seismic events of magnitude 0.5-1.0 and above	Shallow borehole seismometers within offset wells in AoR	AoR, within 1-mile radius of injection wells	Continuous
Multiple	Seismic events over magnitude 2.7	California Integrated Seismic Network	AoR, within 1-mile radius of injection wells	Continuous

2.10 Data Management

2.10.1 Data Management Scheme

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

2.10.2 Recordkeeping and Tracking Practices

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

2.10.3 Data Handling Equipment/Procedures

The equipment used to store data will be properly maintained and operated according to proper industry techniques. Aera's supervisory control and data acquisition (SCADA) and vendor data acquisition systems will interface with one another, and all subsequent data will be held on a secure server.

2.10.4 Responsibility

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

2.10.5 Data Archival and Retrieval

The data will be held by Aera. These data will be maintained and stored for auditing purposes as described in **Section 2.10.1**.

2.10.6 Hardware and Software Configurations

Aera and vendor hardware and software configurations will be appropriately interfaced.

2.10.7 Checklists and Forms

Checklists and forms will be procured and generated as necessary.

3. ASSESSMENT AND OVERSIGHT

3.1 Assessments and Response Actions

3.1.1 Activities to be Conducted

Subsurface fluid data will be collected at the frequency outlined in **Table 1**. After completion of sample analysis, results will be reviewed for QC criteria as noted in **Section 2.5**. If the data quality fails to meet criteria set in **Section 2.5.**, samples will be reanalyzed, if still 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 EPA 2009 Unified Guidance (EPA, 2009).

3.1.2 Responsibility for Conducting Assessments

Organizations gathering data will be responsible for conducting internal assessments. Stop-work orders will be handled internally within individual organizations.

3.1.3 Assessment Reporting

The assessment information will be reported to the individual organizations' project manager outlined in **Section 1.1**.

3.1.4 Corrective Action

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

3.2 Reports to Management

3.2.1 QA Status Reports

QA status reports are not expected to be required. If any testing or monitoring techniques are changed, the QASP will be reviewed and updated as appropriate in consultation with EPA. Revised QASPs will be distributed by Aera to the full distribution list at the beginning of this document.

4. DATA VALIDATION AND USABILITY

4.1 Data Review, Verification, and Validation

4.1.1 Criteria for Accepting, Rejecting, or Qualifying Data

Subsurface fluid data validation will include the review of the concentration units, sample holding times, and the review of duplicate, blank, and other appropriate QA/QC results. The results will be entered into a database or spreadsheet with periodic data review and analysis. Aera will retain copies of the laboratory analytical test results and/or reports. Analytical results will be reported on a frequency based on the approved Class VI permit conditions. In the periodic reports, data will be presented in graphical and tabular formats as appropriate to characterize general subsurface fluid quality and identify intrawell variability with time. After sufficient data have been collected, additional methods, such as those described in the EPA 2009 Unified Guidance (EPA, 2009), will be used to evaluate intrawell variations for subsurface fluid constituents, to evaluate if significant changes have occurred that could be the result of CO_2 or brine seepage beyond the storage reservoir.

4.2 Verification and Validation Methods

4.2.1 Data Verification and Validation Processes

See **Sections 2.5** and **4.1.1**. Appropriate statistical software will be used to determine data consistency.

4.2.2 Data Verification and Validation Responsibility

Aera or its designated subcontractor will verify and validate subsurface fluid sampling data.

4.2.3 Issue Resolution Process and Responsibility

Aera or its designated representative will oversee the subsurface fluid data handling, management, and assessment process. Staff involved in these processes will consult with Aera or its designated representative to determine actions required to resolve issues.

4.2.4 Checklist, Forms, and Calculations

Checklists and forms will be developed specifically to meet Class VI permit requirements.

4.3 Reconciliation with User Requirements

4.3.1 Evaluation of Data Uncertainty

Statistical software will be used to determine subsurface fluid data consistency using methods consistent with EPA 2009 Unified Guidance (EPA, 2009).

4.3.2 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.

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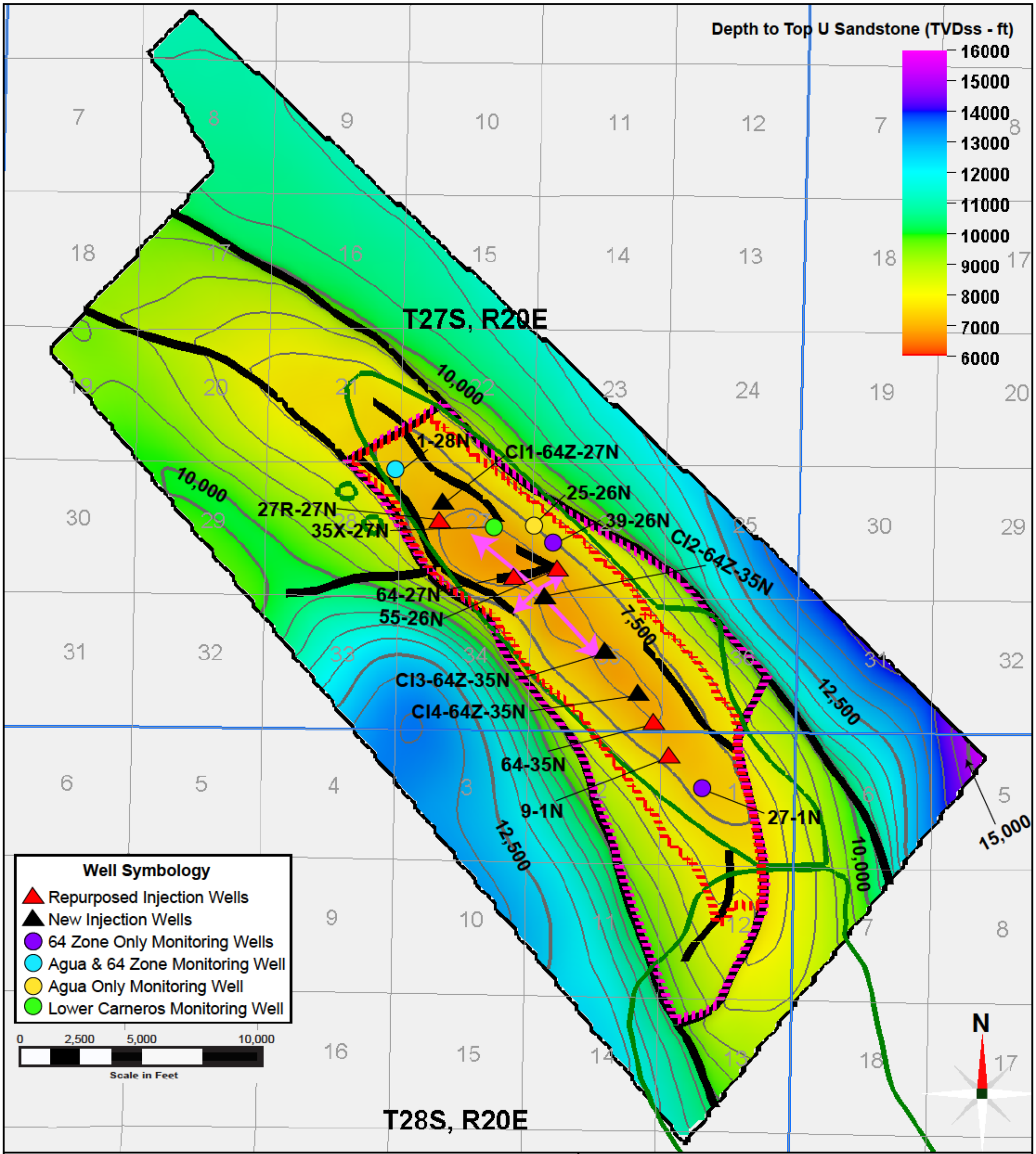
Figures



Legend:

▭ Area of Interest

— Township/Range Boundaries

— Section Boundaries

— 1973/74 Oil Field Boundaries

— Fault Traces

— Elevation Contours (500 ft CI)

▦ Area of Review

▦ Modeled CO_2 Plume Extent

↔ Anticline Axis

Explanation:

ft - feet

TVDss - true vertical depth sub sea (ft)

CI - contour interval

CO_2 - carbon dioxide

Notes:

Surface artifacts due to interpolation across faults and structural model grid.

Location Map of Repurposed and New Wells

North Belridge Oil Field
Western Kern County
California

Geosyntec consultants

CarbonFrontier

October 2024

Figure

1