

**APPENDIX A:  
QUALITY ASSURANCE AND SURVEILLANCE PLAN  
47 CSR 13-13.6.2.k.**

**Project Name: Tri-State CCS Redbud 2**

**Facility Information**

Facility Contact:      Tri-State CCS, LLC  
                                 14302 FNB Parkway  
                                 Omaha, NE 68154  
                                 402-691-9500

Well Location:            Marshall County, West Virginia

<b>Well Name</b>	<b>Latitude (WGS 84)</b>	<b>Longitude (WGS 84)</b>
TR2-1	40.016375	-80.606419
TR2-2	40.011884	-80.533589
TR2-3	39.978333	-80.600234
TR2-4	39.956423	-80.635316

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**Acronym List**

°C	Degrees Celsius
°F	Degrees Fahrenheit
µm	Micrometer
µS	Microsiemens
Al	Aluminum
AOB-#	Above-Zone Observation wells
AoR	Area of Review
APHA	American Public Health Association
As	Arsenic
ASTM	American Society for Testing and Materials
Ba	Barium
Br	Bromine
Ca	Calcium
CCS	Carbon Capture and Storage
Cd	Cadmium
Cl	Chlorine
cm	Centimeter
CO <sub>2</sub>	Carbon Dioxide
Cr	Chromium
Cu	Copper
DH	Down Hole
DTS	Distributed Temperature Sensing
EPA	Environmental Protection Agency
Fe	Iron
ft	Feet
FS	Formation Strength
GC-P	Gas Chromatography-Pyrolysis
GW-#	Shallow Groundwater Wells
HDPE	High Density Polyethylene
hr	Hour
ICP	Inductively Coupled Plasma
ID	Identification
IOB-#	In-Zone Observation wells
ISBT	International Society of Beverage Technologists
K	Potassium
L	Liter

LIC	Lockport Injection Complex
Mg	Magnesium
mg	Milligram
MIT	Mechanical Integrity Testing
MIC	Medina Injection Complex
ml	Milliliter
mm	Millimeter
MMscf/d	Million Standard Cubic Feet/Day
Mn	Manganese
MRayl	Mega Rayl
MS	Mass Spectrometry
Mt/d	Thousand Tonnes per Day
Na	Sodium
NO <sub>3</sub>	Nitrate
OES	Optical Emission Spectrometry
Pb	Lead
pH	Potential of Hydrogen
PNC	Pulsed Neutron Capture
ppm	Parts Per Million
psi	Pounds Per Square Inch
pu	Porosity Units
QA	Quality Assurance
QA/QC	Quality Assurance and Quality Control
QASP	Quality Assurance and Surveillance Plan
S&A	Sampling and Analysis
Sb	Antimony
Se	Selenium
Si	Silicon
SO <sub>4</sub>	Sulfate
T	Temperature
TBD	To be Determined
TD	Total Depth
TDS	Total Dissolved Solids
Ti	Titanium
TR2-#	Tri-State CCS Redbud 2 Injection Wells
UIC	Underground Injection Control
uL	Microliter
UOB-#	Lowermost USDW Observation Wells
USDW	Underground Source of Drinking Water

**Title and Approval Sheet**

This Quality Assurance and Surveillance Plan (QASP) is approved for use and implementation at Tri-State CCS Redbud 2. The signatures below denote the approval of this document and intent to abide by the procedures outlined within it.

---

Signature  
**TBD**  
Project Manager (during construction and pre-operational period)

---

Date

---

Signature  
**TBD**  
Operations Manager (during injection and post-injection periods)

---

Date

## **1. Project Management**

### **1.1. Project/Task Organization**

#### **1.1.1. Key Individuals and Responsibilities**

Tri-State CCS Redbud 2 (the “project”) is owned and operated by Tri-State CCS, LLC, who will serve as the lead on all project tasks while supervising the performance of subcontractors when required for individual tasks. The Project Manager will be responsible for implementation of this plan during pre-operational testing, and the Operations Manager will be responsible for implementation of this plan during injection and post-injection. The program will be broken into seven subcategories:

1. Shallow Groundwater Sampling
2. Deep Groundwater Sampling
3. Well Logging
4. Mechanical Integrity Testing (MIT)
5. Pressure/Temperature Monitoring
6. CO<sub>2</sub> Stream Analysis
7. Geophysical Monitoring

#### **1.1.2. Independence from Project QA Manager and Data Gathering**

Most physical samples collected, and the data gathered as part of the testing and monitoring program are analyzed, processed, or witnessed by third parties independent of the project management structure. Tri-State CCS, LLC will provide the Underground Injection Control (UIC) Program Director with the name and credentials of any vendors, subcontractors, or testing laboratories used for testing and monitoring protocols during the reporting period in the Semi-Annual Testing and Monitoring Report.

#### **1.1.3. QA Project Plan Responsibility**

Tri-State CCS, LLC will be responsible for maintaining and distributing the official, approved QASP. Tri-State CCS, LLC will periodically review this QASP and consult with the UIC Program Director if/when changes to the plan are required.

### **1.2. Problem Definition/Background**

#### **1.2.1. Reasoning**

This QASP was developed to ensure the quality and standards of the Testing and Monitoring Plan, in accordance with 47 CSR 13-13.6.2.k., for the project’s Class VI UIC well permit.

The objectives of the Testing and Monitoring Plan include:

- Protecting Underground Sources of Drinking Water (USDW);
- Meeting the regulatory requirements of 47 CSR 13-13.6.2;
- Ensuring that the injection wells are operating as designed;
- Providing data to validate and calibrate the geological and dynamic models used to predict the distribution of Carbon Dioxide (CO<sub>2</sub>) within the injection zone; and
- Supporting Area of Review (AoR) re-evaluations during the course of the project.

### 1.2.2. Reasons for Initiating the Project

The objective of the project is to develop a safe and commercially viable CO<sub>2</sub> storage site available to CO<sub>2</sub> emitters in the region while ensuring protection of groundwater resources and environmental and public health.

### 1.2.3. Regulatory Information, Applicable Criteria, Action Limits

Regulations at 47 CSR 13-13. require owners or operators of Class VI UIC wells to perform several types of activities during the lifetime of the project in order to ensure that the injection well maintains its mechanical integrity, that fluid migration and the extent of pressure elevation are within the limits described in the permit application, and that USDWs are not endangered. These monitoring activities include MITs, injection well testing during operation, monitoring of groundwater quality in several zones, and tracking of the CO<sub>2</sub> plume and associated pressure front (full details of monitoring activities are provided in the Testing and Monitoring Plan). This QASP details both the measurements that will be taken and the steps to ensure quality of all the data so it can be used with confidence in making decisions during the life of the project.

## 1.3. **Project/Task Description**

### 1.3.1. Summary of Work to be Performed

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

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**Table 1: Tri-State CCS Redbud 2 Well Summary (see Figure 1 and Figure 2 for locations and Table 1 in the Testing and Monitoring plan for location and construction details).**

Well Types	Well Acronym	CCS System Zone	Zone Formation	Zone Depth (ft MD)
Shallow Groundwater	TR2-GW-1, TR2-GW-2, TR2-GW-3, TR2-GW-4	Shallow USDW	Pennsylvanian	TBD
Deep Observation	TR2-UOB-1, TR2-UOB-2, TR2-UOB-3, TR2-UOB-4	Lowermost USDW	Mauch Chunk Formation	~ 254, ~ 267, ~ 333, ~ 291
Above-Zone Observation	TR2-AOB-1, TR2-AOB-2	1 <sup>st</sup> Permeable Zone	Oriskany Formation	~ 6,623 ~ 6,656
In-Zone Observation	TR2-IOB-1, TR2-IOB-2, TR2-IOB-3, TR2-IOB-4	Reservoir	Lockport Group	~ 8,513, ~ 8,658, ~ 8,571, ~ 8,580
			Medina Group	~ 9,320, ~ 9,479, ~ 9,390, ~ 9,376
Injection	TR2-1 TR2-2 TR2-3 TR2-4	Reservoir	Lockport Group	~ 8,540, ~ 8,799, ~ 8,780 ~ 8,608
			Medina Group	~ 9,350, ~ 9,604, ~ 9,596 ~ 9,410

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**Table 2: Summary of Testing and Monitoring.**

<b>Activity</b>	<b>Location(s)</b>	<b>Method</b>	<b>Analytical Technique</b>	<b>Purpose</b>
CO <sub>2</sub> Stream Analysis <sup>1</sup>	Downstream of all CO <sub>2</sub> source points prior to the storage complex pipeline manifold	Gas Chromatograph and Injectate Sampling	Chemical analysis	Analysis of injectate 47 CSR 13-13.6.2.a.
Corrosion Monitoring	Upstream of wellhead, prior to the Coriolis mass flow meters, and downstream of the injection well control valve	Corrosion Coupons Analysis	Chemical analysis	Corrosion monitoring 47 CSR 13-13.6.2.c.
Groundwater Quality and Geochemistry <sup>1</sup>	1. TR2-AOB-1, TR2-AOB-2; TR2-UOB-1, TR2-UOB-2, TR2-UOB-3, TR2-UOB-4 2. TR2-1, TR2-2, TR2-3, TR2-4; TR2-IOB-1, TR2-IOB-2, TR2-IOB-3, TR2-IOB-4; TR2-AOB-1, TR2-AOB-2; TR2-UOB-1, TR2-UOB-2, TR2-UOB-3, TR2-UOB-4	1. Fluid S&A 2. Downhole Pressure Gauges	Chemical analysis and continuous direct measurement	Groundwater quality and geochemistry monitoring 47 CSR 13-13.6.2.d.
Injection Rate and Volume	TR2-1, TR2-2, TR2-3, TR2-4	Mass Flow Meter	Continuous measurement	Continuous monitoring of injection rate and volume 47 CSR 13-13.6.2.b.
Injection Pressure	TR2-1, TR2-2, TR2-3, TR2-4	Tubing pressure gauge	Continuous measurement	Continuous monitoring of injection pressure 47 CSR 13-13.6.2.b.
Annular Pressure	TR2-1, TR2-2, TR2-3, TR2-4	Annular pressure gauge	Continuous measurement	Continuous monitoring of annular pressure 47 CSR 13-13.6.2.b.
Annular Volume	TR2-1, TR2-2, TR2-3, TR2-4	Annular volume gauge and record	Continuous direct measurement	Continuous monitoring of annulus fluid volume 47 CSR 13-13.6.2.b.
Injection Zone 1. Pressure 2. Temperature	TR2-1, TR2-2, TR2-3, TR2-4 TR2-IOB-1, TR2-IOB-2, TR2-IOB-3, TR2-IOB-4	1. Downhole Pressure Gauges 2. DTS (Distributed Temperature Sensing)	Direct measurement	Continuous monitoring of injection zone pressure and temperature 47 CSR 13-13.6.2.g.1.

Activity	Location(s)	Method	Analytical Technique	Purpose
Mechanical Integrity	TR2-1, TR2-2, TR2-3, TR2-4	Internal – Annular pressure gauge monitoring injection wells	Direct measurement	Demonstration of internal and external mechanical integrity of the wellbore 47 CSR 13-13.6.2.e.
	<i>Surface to TD:</i> TR2-1, TR2-2, TR2-3, TR2-4 TR2-IOB-1, TR2-IOB-2, TR2-IOB-3, TR2-IOB-4	External – DTS	Distributed indirect measurement	
Pressure Falloff Testing	TR2-1, TR2-2, TR2-3, TR2-4	Pressure gauge	Direct measurement	Pressure falloff testing 47 CSR 13-13.6.2.f.
CO <sub>2</sub> Plume and Pressure Front Monitoring	TR2-1, TR2-2, TR2-3, TR2-4 TR2-IOB-1, TR2-IOB-2, TR2-IOB-3, TR2-IOB-4	DTS	Direct and indirect measurements	CO <sub>2</sub> plume imaging and pressure front tracking 47 CSR 13-13.6.2.g.
	TR2-AOB-1, TR2-AOB-2 TR2-UOB-1, TR2-UOB-2, TR2-UOB-3, TR2-UOB-4	Downhole pressure gauge		
	TR2-1, TR2-2, TR2-3, TR2-4 TR2-IOB-1, TR2-IOB-2, TR2-IOB-3, TR2-IOB-4 TR2-AOB-1, TR2-AOB-2 TR2-UOB-1, TR2-UOB-2, TR2-UOB-3, TR2-UOB-4	Pulsed Neutron Capture (PNC) <sup>2</sup>		

<sup>1</sup> Sampling and analysis frequencies may be reduced based on project-specific benchmarks that will be defined from baseline monitoring data and/or injection phase monitoring data.

<sup>2</sup> Apart from injection wells, PNC logging or equivalent will only occur in wells with CO<sub>2</sub> breakthrough or wells with detected containment loss.

**Table 3: Instrumentation Summary.**

Instrument Type	Monitoring and Data Collection Location(s)	Monitoring Target (Formation or Other)	Explanation
Gas Chromatograph; Injectate Sampling and Analysis	Downstream of all CO <sub>2</sub> source points prior to the storage complex pipeline manifold	N/A	Used to analyze the chemical characteristic of the injectate stream to ensure compliance with the operators expected injectate stream composition
Mass Flow Meter	Each Injection Well Pad (TR2-1, TR2-2, TR2-3, TR2-4)	Lockport Dolomite and Medina Groups	Used to record total mass of CO <sub>2</sub> injected.

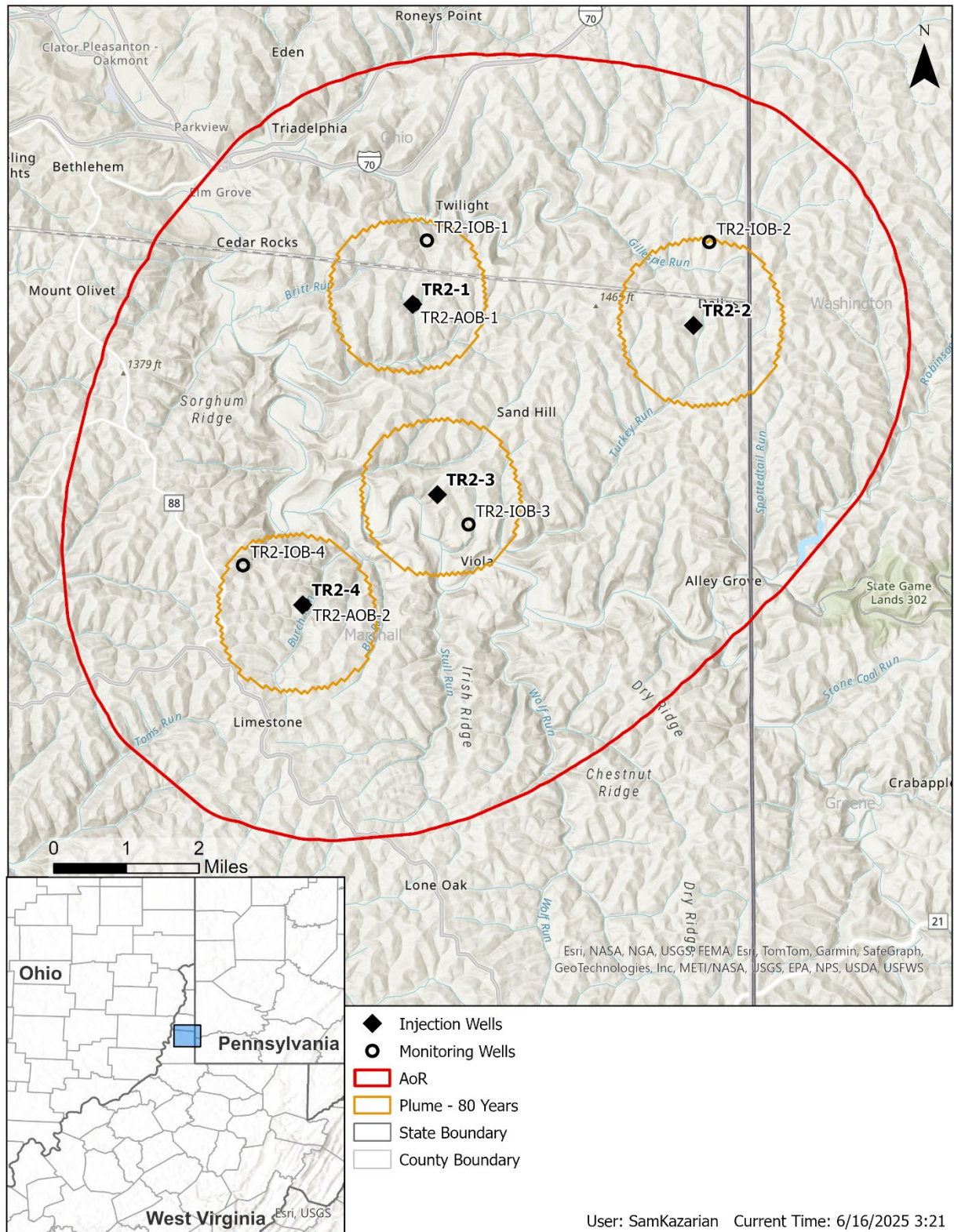
Instrument Type	Monitoring and Data Collection Location(s)	Monitoring Target (Formation or Other)	Explanation
Pressure Gauges	TR2-1, TR2-2, TR2-3, TR2-4 TR2-IOB-1, TR2-IOB-2, TR2-IOB-3, TR2-IOB-4 TR2-AOB-1, TR2-AOB-2 TR2-UOB-1, TR2-UOB-2, TR2-UOB-3, TR2-UOB-4	Lockport Dolomite and Medina Groups, Oriskany Formation, and Mauch Chunk Formation	Used to monitor groundwater quality, annulus pressure, injection zone direct pressure front evolution, and for containment loss detection.
DTS	TR2-1, TR2-2, TR2-3, TR2-4 TR2-IOB-1, TR2-IOB-2, TR2-IOB-3, TR2-IOB-4	Lockport Dolomite and Medina Groups	Injection well external mechanical integrity (TR2-1, TR2-2, TR2-3, TR2-4), identify the vertical intervals taking injectate within the reservoir for use in computational model updates, and containment loss detection.
PNC Logging <sup>1</sup>	TR2-1, TR2-2, TR2-3, TR2-4 TR2-IOB-1, TR2-IOB-2, TR2-IOB-3, TR2-IOB-4 TR2-AOB-1, TR2-AOB-2 TR2-UOB-1, TR2-UOB-2, TR2-UOB-3, TR2-UOB-4	Lockport Dolomite and Medina Groups, Oriskany Formation, and Mauch Chunk Formation	Pre-injection baseline, CO <sub>2</sub> containment loss detection/verification, & vertical CO <sub>2</sub> saturation profiling for use in computational model updates
Groundwater Sampling and Analysis	TR2-AOB-1, TR2-AOB-2 TR2-UOB-1, TR2-UOB-2, TR2-UOB-3, TR2-UOB-4	Oriskany Formation and Mauch Chunk Formation	<i>All Wells:</i> Identify pre-injection groundwater quality and geochemistry <i>1:</i> Record reservoir fluid chemical composition changes due to injection. <i>2:</i> Early CO <sub>2</sub> and reservoir brine containment loss detection/verification <i>3:</i> CO <sub>2</sub> and reservoir brine containment loss detection/verification

<sup>1</sup>PNC logging or equivalent will occur in all wells in the above table during the baseline phase, in injection wells during injection phase, and only in those monitoring wells with CO<sub>2</sub> breakthrough or with detected containment loss during the injection and post injection phases of the project.

### 1.3.2. Geographic and Stratigraphic Locations

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

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**Figure 1: Map of project showing AoR boundary, the proposed injection and observation well locations and the plume at 80 years.**

System	Series	Stratigraphic Unit (Group or Major Formation)	Aquifer, Confining Zone, or Reservoir	Oil Gas Prod.	Average Depth (ft)	Average Thickness (ft)	Depth/Interval Thickness (ft)									
							TR2-1		TR2-2		TR2-3		TR2-4			
							Depth (ft TVD)	Thickness (ft)	Depth (ft TVD)	Thickness (ft)	Depth (ft TVD)	Thickness (ft)	Depth (ft TVD)	Thickness (ft)		
Pennsylvanian		Pennsylvanian (undivided)	Freshwater Aquifers													
		Mauch Chunk Formation	Base Lowest USDW		268		~167		~273		~340		~291			
Mississippian	U	Greenbrier Ls Fm	Seal (Limestone)													
	Lower	Pocono Grp	Big Injun SS	Conventional Oil Reservoir	●●			↑		↑		↑		↑		
			Sunberry Sh	Seal (Shale)												
			Berea SS	Conventional Oil Reservoir	●●											
Devonian	Upper	Ohio Shale Grp	Seal (Shale)		6,154		~6,058 Thick		~6,350 Thick		~6,128 Thick		~6,079 Thick			
		Olentango Shale Fm														
	Middle	Hamilton Grp		Mahantango Shale Fm		Unconventional Oil Reservoir	●●		↓		↓		↓			
				Marcellus Shale Fm												
	Lower		Onondaga Ls Fm	Seal (Limestone)			6,379	326	6,225	315	6,623	353	6,468	328	6,370	301
			Oriskany SS Fm	Conventional Oil/Gas Reservoir		●●	6,703	43	6,540	42	6,976	45	6,802	44	6,671	43
		Helderberg Grp	Seal (Limestone)		6,791	216	6,582	210	7,021	176	6,846	225	6,715	253		
		Bass Islands Dolomite Grp	Seal (Dolomite)		7,007	141	6,792	140	7,197	125	7,071	148	6,968	152		
Silurian	Upper	Salina Grp	Salina "D" – "G"	Upper Confining Zone (Evaporite/Salt)	●●	7,148	1,528	6,932	1,607	7,323	1,457	7,218	1,561	7,120	1,488	
			Salina "A" – "C"													
		Lockport Dolomite Grp ①	Injection Zone		8,677	382	8,540	380	8,779	372	8,780	385	8,608	390		
	Lower	Clinton Grp	Rochester Shale Fm	Middle Confining Zone	●●	9,058	432	8,919	431	9,151	453	9,165	432	8,998	412	
		Dayton/Keefer Fm														
	Medina (Tuscarora SS) Grp ②	Informal – "Clinton" & "Medina" sands	Injection Zone	●●	9,490	194	9,350	199	9,604	201	9,596	193	9,410	184		
Ordovician	Upper	Queenston Shale (Juniata) Fm	Lower Confining Zone	●●	9,685		9,549		9,806		9,790		9,594			
			Utica Shale Fm	Unconventional Oil Reservoir				↑		↑		↑		↑		
			Trenton Grp	Seal (Limestone)			3,251		3,203		3,344		3,243		3,213	
		Black River Ls Grp						↓		↓		↓		↓		
	M	Wells Creek Fm	Upper Confining Zone	●●	12,894	114	12,753	117	13,148	114	13,052	114	12,807	110		
	Cambrian	Upper	Beekmantown Dolomite	Possible Injection Zone	●●	13,000	210									
Rose Run SS ③			Lower Confining Zone	●●	13,220	105										
			Copper Ridge Dolomite Fm		●●	13,325	400									
	Conasauga Grp	Lowest Seal/Confining Unit														

**Figure 2. Generalized stratigraphic column for the project. Primary Injection Complexes: 1 - Lockport Dolomite Injection Interval; 2 - Medina Injection Interval; Proposed secondary Injection Complex: 3 - Rose Run Injection Interval. Modified from Childs, 1985; Patchen et al., 1985b; Riley et al., 2010; Wickstrom et al., 2005; WVGES, 2019.**

### 1.3.3. Resource and Time Constraints

Tri-State CCS, LLC will coordinate deployment and uses of the monitoring and testing equipment described in the Testing and Monitoring Plan and in this QASP appropriate for field operations, service company availability (where necessary), other field-level logistics and operations, CO<sub>2</sub> source and pipeline operations, and community input.

## 1.4. **Quality Objectives and Criteria**

### 1.4.1. Performance/Measurement Criteria

Groundwater analytical and field monitoring parameters for each interval are listed in Table 4. Table 5, Table 6, and Table 7 show analytical parameters for CO<sub>2</sub> stream gas monitoring, corrosion coupon assessment, and gauge specifications. Table 8 shows the measurement parameters, and Table 9 shows the monitoring outputs. The list of analytes may be reassessed periodically and adjusted to include or exclude analytes based on their effectiveness to the overall monitoring program goals.

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

Parameters	Analytical Methods	Detection Limit/Range	Typical Precisions	QC Requirements
Cations: Al, Ba, Mn, As, Cd, Cr, Cu, Pb, Sb, Se, and Tl	ICP-MS EPA Method 6020B (EPA, 2014a) or EPA Method 200.8 (EPA, 1994a)	0.001 to 0.1 mg/L (Analyte, dilution, and matrix dependent)	±15%	Daily Calibration; blanks, duplicates, and matrix spikes at 10% or greater frequency
Cations: Ca, Fe, K, Mg, Na, and Si	ICP-OES EPA Method 6010D (EPA, 2014b) or EPA Method 200.7 (EPA, 1994b)	0.005 to 0.5 mg/L (Analyte, dilution, and matrix dependent)	±15%	Daily Calibration; blanks, duplicates, and matrix spikes at 10% or greater frequency
Anions: Br, Cl, F, NO <sub>3</sub> , and SO <sub>4</sub>	Ion Chromatography EPA Method 300.0 (EPA, 1993)	0.02 to 0.13 mg/L (Analyte, dilution, and matrix dependent)	±15%	Daily Calibration: blanks and duplicates at 10% or greater frequency
Dissolved CO <sub>2</sub>	Coulometric Titration ASTM 513-16 (ASTM, 2016)	25 mg/L	±15%	Duplicate measurement; standards at 10% or greater frequency
Total Dissolved Solids	Gravimetry APHA 2540C (APHA)	12 mg/L	±15%	Balance calibration, duplicate analysis
Water Density (field)	Oscillating Body Method	0.0000 to 2.0000 g/mL	±0.0002 g/mL	Duplicate measurements
Alkalinity	APHA 2320B (APHA 1997)	4 mg/L	±3 mg/L	Duplicate Analysis
pH (field)	EPA 150.1 (EPA, 1982)	2 to 12 pH units	±0.2 pH unit	User Calibration per manufacturer recommendation
Specific Conductance (field)	APHA 2510 (APHA, 1992)	0 to 200 mS/cm	±1% of reading	User calibration per manufacturer recommendation
Temperature (field)	Thermocouple	-5 to 50 °C	±0.2 °C	Factory Calibration
Isotopes: δ <sup>13</sup> C of DIC	Isotope Ratio Mass Spectrometry	12.2mg/L HCO <sub>3</sub> <sup>-</sup> for δ <sup>13</sup> C	±0.15% for δ <sup>13</sup> C	10% duplicates; 4 standards/batch

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

**Table 5: Summary of Analytical Parameters for CO2 Stream.**

Parameters	Method	Detection Limit/Range	Typical Precisions	QC Requirements
<b>CO<sub>2</sub> Purity</b>	ISBT 2.0 Caustic absorption Zahm-Nagel or online gas quality equipment	90.00% to 99.99%	± 10% of reading	User calibration per manufacturer specifications
<b>Water Content</b>	Online gas quality equipment	To be updated with manufacturer specifications	To be updated with manufacturer specifications	To be updated with manufacturer specifications
<b>Total Hydrocarbons</b>	ISBT 10.0 THA (FID) or online gas quality equipment	1 uL/L to 10,000 uL/L (ppm by volume)	5 - 10% of reading relative across the range	daily blank, daily standard within 10% of calibration, secondary standard after calibration
<b>Inert Gasses (N<sub>2</sub>, Ar, O<sub>2</sub>)</b>	ISBT 4.0 (GC/DID) GC/TCD or online gas quality equipment	1 uL/L to 5,000 uL/L (ppm by volume)	± 10% of reading	daily standard within 10% of calibration, secondary standard after calibration
<b>Glycol</b>	ISBT 11.0 (GC) or online gas quality equipment	2 uL/L to 100 uL/L (ppm by volume)-dilution dependent	10% of reading relative across the range	duplicate analysis
<b>Hydrogen Sulfide</b>	ISBT 14.0 (GC/SCD) or online gas quality equipment	0.1 uL/L to 100 uL/L (ppm by volume)-dilution dependent	5 - 10% of reading relative across the range	daily blank, daily standard within 10% of calibration, secondary standard after calibration
<b>Total Sulfur</b>	ISBT 14.0 (GC/SCD) or online gas quality equipment	0.01 uL/L to 50 uL/L (ppm by volume)-dilution dependent	5 - 10% of reading relative across the range	daily blank, daily standard within 10% of calibration, secondary standard after calibration
<b>Hydrogen</b>	ISBT 4.0 (GC/DID) GC/TCD or online gas quality equipment	1 uL/L to 5,000 uL/L (ppm by volume)	± 10% of reading	daily standard within 10% of calibration, secondary standard after calibration
<b>Carbon Monoxide</b>	ISBT 5.0 Colorimetric ISBT 4.0 (GC/DID) or online gas quality equipment	5 uL/L to 100 uL/L (ppm by volume)	± 20% of reading	duplicate analysis

Parameters	Method	Detection Limit/Range	Typical Precisions	QC Requirements
<b>Oxygen</b>	ISBT 4.0 (GC/DID) GC/TCD or online gas quality equipment	1 uL/L to 5,000 uL/L (ppm by volume)	± 10% of reading	daily standard within 10% of calibration, secondary standard after calibration
<b>SO<sub>x</sub></b>	ISBT 14.0 (GC) or online gas quality equipment	0.02 uL/L to 1.0 uL/L (ppm by volume)	5 - 10% of reading relative across the range	daily standard within 10% of calibration, secondary standard after calibration
<b>NO<sub>x</sub></b>	ISBT 7.0 or online gas quality equipment	0.5 uL/L to 5.0 uL/L (ppm by volume)	± 20% of reading	duplicate analysis
<b>Ammonia (NH<sub>3</sub>)</b>	ISBT 6.0 (DT) or online gas quality equipment	0.5 uL/L to 2.5 uL/L (ppm by volume)	1 - 10% of reading relative across the range	duplicate analysis
<b>Amine</b>	DI (cond. and evap.)/UPLC-MSMS or online gas quality equipment	1 uL/L to 10 uL/L (ppm by volume)	± 10% of reading	duplicate analysis
<b>Particulate Matter</b>	Method 5 – Determination of Particulate Matter Emissions from Stationary Sources	To be updated with specifications	To be updated with specifications	Sampling equipment leak check and calibration

**Note:** Analytical parameters presented are for physical bottle sampling and laboratory analysis. A gas chromatograph will be installed to continuously detect CO<sub>2</sub> purity, total hydrocarbons, inert gases, hydrogen, alcohols, oxygen, carbon monoxide, and glycol. Annual bottle analysis will be performed to analyze the CO<sub>2</sub> stream for hydrogen sulfide, total sulfur and particulate matter. The detection range, accuracy, precision, and calibration requirements of the gas chromatograph will be shared with the UIC Program Director as requested.

**Table 6: Specifications for MIT and Geophysical Monitoring Technology.**

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

**Table 7: Summary of Analytical Parameters for Corrosion Coupons.**

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

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**Table 8: Summary of Measurement Parameters for CO<sub>2</sub> Injection Process Monitoring.**

Parameters	Methods	Detection Limit/Range	Vendor Specified Accuracy	QC Requirements	Calibration Frequency
Operational Annular Pressure Monitoring	ISO/IEC 17025 (2017)	0-3,000 psi	± 0.5% FS	Annual Calibration of Scale (3rd party)	As suggested by control system/gauge manufacturer
Wellhead Injection pressure (e.g., PPS PPS31 Wellhead Pressure Logger or similar product)	ISO/IEC 17025 (2017)	0-5,000 psi	±0.03% FS	Annual Calibration of Scale (3rd party)	As suggested by gauge manufacturer
Injection mass flow rate (e.g., Emerson Coriolis mass flow meter or similar product)	AGA Report 3 API Chapter 14 Part 3 (API, 2016)	547.95-3,561.64 Mt/d	±0.1% of rate for liquid ±0.35% of rate for gas	Annual Calibration of Scale (3rd party)	As suggested by gauge manufacturer
Downhole Pressure (e.g., Baker Hughes SureSENS QPT ELITE pressure/temperature gauge or similar product)	AWES Recommended Practice for the Qualification of Downhole Instrumentation / Sensors, RP 3362-01	200 psi to 10,000 psi	± 0.015% FS	Initial Manufacturer Calibration	Per manufacturer recommendation

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**Table 9: Actionable Testing and Monitoring Outputs.**

Activity or Parameter	Project Action Limit	Detection Limit	Anticipated Reading
DTS	Action to be taken when a temperature anomaly is observed	Refer to Table 6	Difference between profiles observed during baseline & injection stream temperature
PNC logging	Action to be taken when a CO <sub>2</sub> saturation anomaly is observed	Refer to Table 6	TBD during baseline
Injection rate	Injection rate is reduced if max instantaneous rate of 1,429 Mt/d per well is reached	Refer to Table 8	Lockport Injection Complex (LIC): 286 Mt/d for TR2-1, 314 Mt/d for TR2-2, 314 Mt/d for TR2-3, and 286 Mt/d for TR2-4 <sup>2</sup>
			Medina Injection Complex (MIC): 343 Mt/d for TR2-1, 429 Mt/d for TR2-2, 371 Mt/d for TR2-3, and 343 Mt/d for TR2-4 <sup>2</sup>
Surface/ downhole pressure	Injection stops if MASP <sup>1</sup> is reached or 90% fracture pressure downhole is reached	Refer to Table 8	LIC: < 2,525 psig (TR2-1), < 2,585 psig (TR2-2), < 2,585 psig (TB1-3), and < 2,545 psig (TR2-4) at surface < 5,431 psig (TR2-1), < 5,581 psig (TR2-2), < 5,582 psig (TB1-3), and < 5,475 psig (TR2-4) downhole (see <i>Summary of Requirements – Class VI Operating and Reporting Conditions</i> )
			MIC: < 2,525 psig (TR2-1), < 2,585 psig (TR2-2), < 2,585 psig (TR2-3), and < 2,545 psig (TR2-4) at surface < 5,674 psig (TR2-1), < 5,833 psig (TR2-2), < 5,830 psig (TR2-3), and < 5,719 psig (TR2-4) downhole (see <i>Summary of Requirements – Class VI Operating and Reporting Conditions</i> )
Annular pressure	<3% pressure loss over 1 hour	Refer to Table 8	<3% pressure loss over 1 hour
Annular volume	10% loss of annular volume or continuous fluid make up exceeding 24 hours	Tank fluid level indicator	Annular fluid make up is expected when temperature of the fluid changes
Annular pressure/ volume	LIC: Action to be taken when annulus pressure is below 100 psi, above 2,625 psi for TR2-1, 2,685 psi for TR2-2, 2,685 psi for TR2-3, 2,645 psi for TR2-4, or less than injection pressure downhole in injection wells	Refer to Table 8	100-2,625 psi for TR2-1, 100-2,685 psi for TR2-2, 100-2,685 psi for TR2-3, 100-2,645 psi for TR2-4 at surface for LIC; Volume TBD during baseline
	MIC: Action to be taken when annulus pressure is below 100 psi, above 2,625 psi for TR2-1, 2,685 psi for TR2-2, 2,685 psi for TR2-3, 2,645 psi for TR2-4, or less than injection pressure downhole in injection wells		100-2,625 psi for TR2-1, 100-2,685 psi for TR2-2, 100-2,685 psi for TR2-3, 100-2,645 psi for TR2-4 at surface for MIC; Volume TBD during baseline

Activity or Parameter	Project Action Limit	Detection Limit	Anticipated Reading
Above-zone water quality (fluid sampling)	Action to be taken when chemical profile anomaly is observed	Refer to Table 4	Profiles TBD during baseline
Above-confining-zone pressure	Action will be taken when a pressure/temperature anomaly occurs	Refer to Table 4	Profiles TBD during baseline
CO <sub>2</sub> plume monitoring	Action to be taken if CO <sub>2</sub> plume is observed outside of expected/modelled spatial limits/geologic intervals	Dependent on geologic conditions	Profiles TBD during baseline

<sup>1</sup> Maximum anticipated surface pressure

<sup>2</sup> Assuming 350 days of injection, accounting for shut-in time

#### 1.4.2. Precision

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

#### 1.4.3. Bias

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

#### 1.4.4. Representativeness

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

#### 1.4.5. Completeness

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

#### 1.4.6. Comparability

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

#### 1.4.7. Method Sensitivity

The sensitivities and specifications of example gauges used for measurements in this project are described in detail in Table 10, Table 11, Table 12, and Table 13. Specific tools and measurement specifications may change during the detailed design phase following collection and characterization of data gathered from the CarbonSAFE stratigraphic test wells.

**Table 10: Pressure - Downhole Gauge Vendor Specifications. <sup>1</sup>**

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

<sup>1</sup> Specifications from the *Baker Hughes SureSENS QPT ELITE Pressure/Temperature Gauge* are provided as an example of typical specifications from a vendor. A similar product may be used.

**Table 11: Representative Logging Tool Specifications. <sup>1</sup>**

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

<sup>1</sup> Specifications from SLB PNC tools.

**Table 12: Wellhead Pressure/Temperature Gauge Vendor Specifications. <sup>1</sup>**

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

<sup>1</sup> Specifications from a *PPS PPS31 Wellhead Pressure Logger* are provided as an example of typical specifications from a vendor. A similar product may be used.

**Table 13: Mass Flow Rate Field Gauge—CO<sub>2</sub> Mass Flow Rate Vendor Specifications. <sup>1</sup>**

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

<sup>1</sup> Specifications from an *Emerson Coriolis Mass Flow Meter* are provided as an example of typical specifications from a vendor. A similar product may be used.

## 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. Groundwater sampling and laboratory chemical analysis will be evaluated by EPA certified laboratories that employ qualified and experienced personnel who understand and regularly follow environmental sampling/chemical analysis standard operating procedures and quality control protocols. Tri-State CCS, LLC will provide relevant certifications for all vendor/subcontractor staff upon request.

### 1.5.2. Training Provider and Responsibility

Tri-State CCS, LLC or the designated subcontractor for the data collection activities will provide necessary training for personnel.

## **1.6. Documentation and Records**

### **1.6.1. Report Format and Package Information**

The Semi-Annual Testing and Monitoring Report from Tri-State CCS, LLC to the UIC Program Director will contain all required project data, including testing and monitoring information in accordance with 47 CSR 13-13.6.3.a.1. Data will be provided in electronic or other formats as required by the UIC Program Director. Further reporting and recordkeeping details can be found in subsection 2.5 of the Testing and Monitoring Plan.

### **1.6.2. Other Project Documents, Records, and Electronic Files**

Other documents, records, and electronic files such as well logs, test results, or other data will be provided as required by the UIC Program Director and maintained for 10 years post site closure.

### **1.6.3. Data Storage and Duration**

Pursuant to 47 CSR 13-13.6.3.a.6.C., any monitoring data collected through implementation of the Testing and Monitoring Plan will be retained for at least 10 years after it is collected. All site characterization data will be retained throughout the life of the geologic sequestration project and for at least 10 years following site closure. Tri-State CCS, LLC or a designated contractor will maintain the required project data as provided elsewhere in the permit. See subsection 2.5 of the Testing and Monitoring Plan for recordkeeping details.

### **1.6.4. QASP Distribution Responsibility**

The Tri-State CCS, LLC Project Manager will be responsible for ensuring those on the distribution list will receive the most current copy of the approved QASP during the pre-operational testing period, and the Operations Manager will be responsible for distribution during the injection and post-injection periods.

## **2. Data Generation and Acquisition**

### **2.1. Sampling Process Design**

This section describes the monitoring network that will be used to support collection of the various characterization and monitoring measurements needed to ensure safe and nominal CO<sub>2</sub> injection operations, track the development of the CO<sub>2</sub> plume and elevated pressure front, and identify/quantify any potential leakage of CO<sub>2</sub>. Based on the current conceptual understanding of project geology, this strategy was developed to ensure safe, long-term containment of CO<sub>2</sub> within the injection interval and non-endangerment of USDWs.

#### **2.1.1. Design Strategy**

##### **2.1.1.1. *CO<sub>2</sub> Stream Monitoring Strategy***

The objective of routinely analyzing the CO<sub>2</sub> stream is to evaluate the potential interactions of CO<sub>2</sub> and/or other constituents of the injectate with formation solids and fluids. This analysis can also identify (or rule out) potential interactions with well materials. Establishing the chemical

composition of the injectate also supports regulatory determinations under the Resource Conservation and Recovery Act (RCRA, 1976) and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, 1980). Additionally, monitoring the chemical and physical characteristics of the CO<sub>2</sub> may help distinguish the injectate from the native fluids and gases if unintended leakage from the storage reservoirs were to occur.

Tri-State CCS, LLC expects multiple sources of CO<sub>2</sub> from the region, with additional sources to be added throughout the life of the project. Each source will have a different gas stream composition, and the composition of the final injected gas stream will change slightly depending on which sources are operational. To detect any significant changes in the physical or chemical properties of the CO<sub>2</sub> stream that may result in a deviation from the permitted specifications, Tri-State CCS, LLC will analyze the CO<sub>2</sub> stream at a minimum every 24 hours with gas chromatographs located downstream of all CO<sub>2</sub> sources or prior to the storage complex pipeline manifold as discussed in subsections 2.3 and 3.1 of the Testing and Monitoring Plan. Physical samples may also be taken through a sampling port near the gas chromatograph.

#### *2.1.1.2. Corrosion Monitoring Strategy*

To meet the requirements of 47 CSR 13-13.6.2.c., Tri-State CCS, LLC will monitor well materials during the operation period for loss of mass, thickness, cracking, pitting, and other signs of corrosion to ensure that the well components meet the minimum standards for material strength and performance using the corrosion coupon method. Coupons shall be sent out quarterly for analysis, which will be conducted in accordance with the NACE RP0775-2018 (NACE, 2018) standard to determine and document corrosion wear rates based on mass loss.

#### *2.1.1.3. Shallow Groundwater Monitoring Strategy*

Shallow groundwater monitoring will be performed during the year-long pre-injection period, to capture seasonal variations in the groundwater geochemistry. The USDW monitoring program will meet the requirements of 47 CSR 13-13.6.2.d. and will include baseline groundwater samples to characterize variations in water quality within the AoR prior to the start of CO<sub>2</sub> injection. These wells will not be sampled and analyzed during the injection phase but may be used to provide additional evidence for groundwater protection should the operator or UIC program director deem it necessary.

#### *2.1.1.4. Above-Zone and Deep Groundwater Monitoring Strategy*

Two above-zone observation wells (TR2-AOB-1 and TR2-AOB-2), will be completed in the first permeable unit above the confining zone (Oriskany Formation), and four deep USDW observation wells (TR2-UOB-1, TR2-UOB-2, TR2-UOB-3, and TR2-UOB-4) will be completed in the lowermost USDW (Mauch Chunk Formation). The above-zone observation wells will serve to detect any early leakage above both the confining zones (Salina Group for the Lockport Dolomite Group or Rochester Shale for the Medina Group), and the deep USDW observation wells will monitor the formation fluid geochemistry of the lowermost USDW. In addition to baseline sample collection and analysis prior to the start of injection, pressurized fluid samples will be collected from the observation wells during the injection phase. MIT and DTS monitoring at the injection wells will also provide data to ensure the mechanical integrity of the well is maintained. With the

planned sampling and monitoring frequencies, baseline conditions will be documented, natural variability in conditions will be characterized, unintended brine or CO<sub>2</sub> leakage will be detected, and sufficient data will be collected to demonstrate that the effects of CO<sub>2</sub> injection are limited to the intended Lockport Dolomite and Medina Groups storage reservoirs.

Parameters will include selected constituents that: (1) have primary and secondary EPA drinking water maximum contaminant levels, (2) are the most responsive to interaction with CO<sub>2</sub> or brine, (3) are needed for quality control, and (4) may be needed for geochemical modelling. After a sufficient baseline is established, monitoring scope may shift to a subset of indicator parameters that are (1) the most responsive to interaction with CO<sub>2</sub> or brine and (2) are needed for quality control to accurately test for and monitor the presence (or lack thereof) of CO<sub>2</sub> migration. Implementation of a reduced set of parameters would be adopted in consultation with the UIC Program Director. During any period where a reduced set of analytes is used, if statistically significant trends are observed that are the result of unintended CO<sub>2</sub> or brine migration, the analytical list would be expanded to the full set of monitoring parameters. All groundwater and formation fluid samples will be analysed using a laboratory meeting the requirements under the EPA Environmental Laboratory Accreditation Program. The full list of analytical parameters and selected methods is provided in Table 4.

#### *2.1.1.5. In-Zone Formation Water Monitoring Strategy*

In-zone formation water quality and geochemistry monitoring will occur through fluid sampling and analysis during the pre-injection phase and through downhole pressure gauges (quality) during the injection phase (see subsection 6.1 of the Testing and Monitoring Plan for more details). During the pre-injection phase of the project, the injection wells (TR2-1, TR2-2, TR2-3, TR2-4) and in-zone observation wells (TR2-IOB-1, TR2-IOB-2, TR2-IOB-3, TR2-IOB-4) will be monitored to obtain a baseline sufficient to distinguish any changes in fluid quality and chemistry due to injection of CO<sub>2</sub>. During the injection phase of the project, downhole pressure gauges on the in-zone observation wells (TR2-IOB-1, TR2-IOB-2, TR2-IOB-3, TR2-IOB-4) will be monitored to detect any loss of containment.

#### *2.1.1.6. Direct CO<sub>2</sub> Plume and Pressure Front Monitoring Strategy*

Downhole pressure gauges will be used in all observation and injection wells to directly monitor the formation pressure of the injection reservoir (Lockport Dolomite Group and Medina Group) and above-zone interval. Downhole pressure gauges will continuously monitor for any changes in injection pressure or in-zone and above-zone pressure.

#### *2.1.1.7. Indirect CO<sub>2</sub> Plume and Pressure Front Monitoring Strategy*

Several technologies will be deployed within the injection and in-zone observation wells to indirectly monitor the presence/absence of the CO<sub>2</sub> plume and elevated pressure front. All injection and in-zone observation wells will contain DTS in the cemented long string casing and record continuous temperature measurements. External mechanical integrity will be monitored continuously using DTS in the injection and in-zone observation wells. PNC logging techniques will be utilized to verify external MIT for each injection and in-zone observation well by detecting the presence or absence of CO<sub>2</sub> in critical formations. PNC logging will also serve to track the CO<sub>2</sub>

plume progression in the in-zone observation wells.

#### 2.1.2. Type and Number of Samples/Test Runs

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

#### 2.1.3. Site/Sampling Locations

The site and sampling locations are shown in Figure 1 and Table 2.

#### 2.1.4. Sampling Site Contingency

The shallow and deep groundwater monitoring wells will be sited at or near their projected locations in such a way to allow regular access to perform testing activities. No problems of site inaccessibility are anticipated for CO<sub>2</sub> gas or corrosion coupon sampling. If inclement weather makes site access difficult, sampling schedules will be revised, and alternative dates may be selected that would still meet permit-related conditions.

#### 2.1.5. Activity Schedule

Please refer to Sections 2 through 8 of the Testing and Monitoring Plan for a schedule of sampling and test runs.

#### 2.1.6. Critical/Informational Data

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

#### 2.1.7. Sources of Variability

Potential sources of variability related to monitoring activities include: (1) natural variation in fluid quality, formation pressure 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 and/or analyzing samples; (6) differences in environmental conditions during field sampling activities; (7) changes in analytical data quality during life of project; and (8) data entry errors related to maintaining project database.

Activities to eliminate, reduce, or reconcile variability related to monitoring activities include: (1) collecting long-term baseline data to observe and document natural variation in monitoring parameters, (2) evaluating data in a timely manner after collection to observe anomalies in data that can be addressed by resampling and/or reanalyzing, (3) conducting statistical analysis of monitoring data to determine whether variability in a data set is the result of project activities or

natural variation, (4) maintaining weather-related data using on-site weather monitoring data or data collected near project site, (5) checking instrument calibration before, during and after sampling or sample analysis, (6) thoroughly training staff, (7) conducting laboratory quality assurance checks using third party reference materials, and/or blind and/or replicate sample checks, and (8) developing a systematic review process of data that can include sample-specific data quality checks (i.e., cation/anion balance for aqueous samples).

## 2.2. Sampling Methods

### 2.2.1. Sampling Standard Operating Procedures

The primary groundwater sampling method will be a low-flow sampling method consistent with ASTM D6452-99 (ASTM, 2005) or Puls and Barcelona (Puls, et. al., 1996). If a flow-through cell is not used, field parameters will be measured in grab samples. Prior to sampling, wells will be purged to ensure samples are representative of formation fluids. Before any purging or sampling activities begin, static water levels will be measured using an electronic water level indicator. Each groundwater monitoring well will contain a dedicated pump (e.g., bladder pumps) to minimize potential cross contamination between wells. Given sufficient flow rates and volumes, field parameters such as groundwater pH, temperature, specific conductance, and dissolved oxygen will be monitored in the field using portable probes and a flow-through cell consistent with standard methods (APHA 2005). Field chemistry probes will be calibrated at the beginning of each sampling day according to equipment manufacturer procedures using standard reference solutions. When a flow-through cell is used, field parameters will be continuously monitored and will be considered stable when three successive measurements made three minutes apart meet the criteria listed in Table 14.

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

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

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

Groundwater samples will be collected after field parameters have stabilized. Flow-through filter cartridges (0.45  $\mu\text{m}$ ) will be utilized as required and consistent with ASTM D6564-00 (ASTM, 2017). Prior to sample collection, filters will be purged with a minimum of 100 mL of well water (or more if required by the filter manufacturer). For alkalinity and total CO<sub>2</sub> samples, efforts will be made to minimize exposure to the atmosphere during filtration, collection in sample containers, and analysis.

### 2.2.2. In-situ Monitoring

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

### 2.2.3. Continuous Monitoring

#### 2.2.3.1. *Injection Process Monitoring*

Data related to the operational process (injection rate and volume and annular pressure and volume) will be continuously monitored with pressure gauges, flow meters, and the annulus monitoring system, all of which will be linked to the surface control system controlled by Tri-State CCS, LLC. This operational data will ensure that injection is operating safely, efficiently, and not posing a risk to any USDWs. Additionally, continuously monitored operational parameters will feed into reservoir and computational models to validate that the CO<sub>2</sub> plume and pressure front are behaving as expected.

#### 2.2.3.2. *Distributed Temperature Sensing (DTS)*

DTS technology will continuously collect temperature data along a fiberoptic line installed along the outside of the long-string casing. The DTS line will collect temperature data along the long-string casing at set intervals of time which will be used when running external mechanical integrity tests to verify mechanical integrity and monitor the presence or absence of the CO<sub>2</sub> plume.

#### 2.2.3.3. *Pressure Gauges*

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

### 2.2.4. Sample Homogenization, Composition, and Filtration

See subsection 2.2.1 above.

### 2.2.5. Sample Containers and Volumes

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

**Table 15: Summary of Sample Containers, Preservation Treatments, and Holding Times for CO<sub>2</sub> Gas Stream Analysis.**

Sample	Volume/Container Material	Preservation Technique	Sample Holding time (max)
CO <sub>2</sub> gas stream	(2) 2L MLB Polybags (1) 75 cc Mini Cylinder	Sample Storage Cabinets	5 Business Days

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

Target Parameters	Volume/Container Material	Preservation Technique	Sample Holding Time
Cations: Ca, Fe, K, Mg, Na, Si, Al, Ba, Mn, As, Cd, Cr, Cu, Pb, Sb Se, Tl	250 ml/HDPE	Filtered, with nitric acid preservative, cool 4°C	60 days
Dissolved CO <sub>2</sub>	2 × 60 ml/HDPE	Unfiltered, cool 4°C	14 days
Isotopes: 3H, δD, δ18O, δ34S, and δ13C	2 × 60 ml/HDPE	Unfiltered, cool 4°C	4 weeks
Isotopes: δ34S	250 ml/HDPE	Unfiltered, cool 4°C	4 weeks
Isotopes: δD, δ18O, δ13C	60 ml/HDPE	Unfiltered, cool 4°C	4 weeks
Alkalinity, anions (Br, Cl, F, NO <sub>3</sub> , SO <sub>4</sub> )	500 ml/HDPE	Filtered, cool 4°C	45 days
Field Confirmation: Temperature, dissolved oxygen, specific conductance, pH	200 ml/glass jar	None	< 1 hour
Field Confirmation: Density	60 ml/HDPE	Filtered	< 1 hour

### 2.2.6. Sample Preservation

Sample preservation methods are outlined in Table 15 and Table 16. Safety Data Sheets will be maintained and available at the project site for any chemicals used in sample preservation.

### 2.2.7. Cleaning/Decontamination of Sampling Equipment

Dedicated pumps (e.g., bladder pumps) will be installed in each groundwater monitoring well to minimize potential cross contamination between wells. These pumps will remain in each well throughout the project period except for maintenance. Prior to installation, the pumps will be cleaned externally with a non-phosphate detergent. Pumps will be rinsed a minimum of three times with 18 megohm purity deionized water and a minimum of 1 L of deionized water will be pumped through the pump and sample tubing for cleaning. Individual cleaned pumps and tubing will be placed in plastic bags for transport to the field for installation. All field glassware (pipets, beakers, filter holders, etc.) will be cleaned with tap water to remove any loose dirt, washed in a dilute nitric acid solution, and rinsed thoroughly, at least three times with deionized water before use.

### 2.2.8. Support Facilities

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

Coupons consisting of material that will directly contact the CO<sub>2</sub> stream will be placed within a flowline. Each sample will be attached to an individual holder and inserted in a flowthrough pipe arrangement, exposing the samples to the CO<sub>2</sub> stream, and allowing access for removal and testing. The flowthrough pipe arrangement will be located at the well location downstream of all process compression, dehydration, and pumping equipment. A parallel stream of high-pressure CO<sub>2</sub> will be routed from the flowline through the corrosion monitoring system. This loop will operate while injection is occurring, providing representative exposure of the samples to the CO<sub>2</sub> composition, temperature, and pressures that will be seen at the wellhead and injection tubing. Injection will be able to continue while samples are removed for testing (see subsection 5.3 of the Testing and Monitoring Plan for more details).

#### 2.2.9. Corrective Action, Personnel, and Documentation

Field staff will be responsible for properly testing equipment and performing corrective actions on broken or malfunctioning field equipment. If corrective action cannot be taken in the field, then equipment will be returned to the manufacturer for repair or replaced. Significant corrective actions affecting analytical results will be documented in field notes. If defective equipment causes disruptions to the sampling schedule, Tri-State CCS, LLC will contact the UIC Program Director.

### 2.3. **Sample Handling and Custody**

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

#### 2.3.1. Maximum Hold Time/Time Before Retrieval

Please refer to Table 15 and Table 16.

#### 2.3.2. Sample Transportation

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

#### 2.3.3. Sampling Documentation

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

#### 2.3.4. Sample Identification

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

### 2.3.5. Sample Chain-of-Custody

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

## 2.4. Analytical Methods

### 2.4.1. Analytical Standard Operating Procedures

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

### 2.4.2. Equipment/Instrumentation Needed

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

### 2.4.3. Method Performance Criteria

Nonstandard method performance criteria are not anticipated for this project.

### 2.4.4. Analytical Failure

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

### 2.4.5. Sample Disposal

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

### 2.4.6. Laboratory Turnaround

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

### 2.4.7. Method Validation for Nonstandard Methods

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

## 2.5. Quality Control

### 2.5.1. QC activities

#### 2.5.1.1. *Blanks*

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

Trip blanks will be used when analyzing samples for volatile organic compounds or dissolved gases. One trip blank will be included with each cooler or shipping container used to transport water samples to the laboratory. The trip blank will consist of a sample container filled with laboratory-grade deionized water that is prepared by the laboratory, sealed, and transported to and from the sampling site unopened. The trip blank will be handled, stored, and analyzed in the same manner as the groundwater samples. The purpose of the trip blank is to determine if contamination was introduced during sample transport and handling.

#### 2.5.1.2. *Duplicates*

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

### 2.5.2. Exceeding Control Limits

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

### 2.5.3. Calculating Applicable QC Statistics

#### 2.5.3.1. *Charge Balance*

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

$$\% \text{ difference} = 100 * \frac{\sum \text{cations} - \sum \text{anions}}{\sum \text{cations} + \sum \text{anions}} \quad \text{Equation 1}$$

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

#### 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:

$$1.0 < * \frac{\text{measured TDS}}{\text{calculated TDS}} < 1.2 \text{ , with anticipated values} \quad \text{Equation 2}$$

between 1.0 and 1.2.

#### 2.5.3.3. *Outliers*

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

### **2.6. Instrument/Equipment Testing, Inspection, and Maintenance**

Logging tool equipment will be maintained as per wireline industry best practices. Pressure gauges will be maintained to manufacturer standards. For groundwater sampling, field equipment will be maintained, factory serviced, and factory calibrated per manufacturer's recommendations. Spare parts that may be needed during sampling will be included in supplies on-hand during field sampling. For laboratory equipment, all testing, inspection, and maintenance will be the responsibility of the analytical laboratory per standard practice or method-specific protocol.

### **2.7. Instrument/Equipment Calibration and Frequency**

#### 2.7.1. Calibration and Frequency of Calibration

Pressure gauge calibration information is presented in Table 11 and

Table 12. All field and downhole gauges will be calibrated prior to use by the equipment supplier. Gauges will be recalibrated as needed based on results of inspection, or after any repairs or maintenance. Logging tool calibration will be at the discretion of the service company providing the equipment, following standard industry practices. Calibration frequency will be determined by standard industry practices. CO<sub>2</sub> flow meters will be calibrated using industry standards and at a frequency recommended by the manufacturer.

For groundwater sampling, portable field meters or multiprobe sondes used to determine field

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

For CO<sub>2</sub> stream sampling, the gas chromatograph will be calibrated based on the manufacturer's guidance.

### 2.7.2. Calibration Methodology

Calibration of the orifice flow meters will be carried out using a carrier gas to validate the characteristics of the approved CO<sub>2</sub> composition using methods described in Table 8 (API MPMS, 2016). Logging tool and all field and downhole gauge calibration methodology will follow standard industry practices recommended by the respective manufacturers.

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

### 2.7.3. Calibration Resolution and Documentation

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

## 2.8. **Inspection/Acceptance for Supplies and Consumables**

### 2.8.1. Supplies, Consumables, and Responsibilities

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

## 2.9. **Non-direct Measurements**

### 2.9.1. Data Sources

Plume development will also be monitored via DTS and PNC logs. PNC logs detect CO<sub>2</sub> concentration surrounding the wellbore and repeat logging runs will be compared to the baseline conducted before injection operations begin. DTS monitors variations in temperature along the wellbore at a high resolution, measured every 10 minutes.

### 2.9.2. Relevance to Project

Scheduled PNC logging will be used to track CO<sub>2</sub> plume movement. After initial baseline testing is conducted prior to injection, processing and comparison of subsequent surveys will allow Tri-State CCS, LLC to monitor the extent of the plume, ensuring that the plume is contained and behaving as expected. Numerical modeling will be updated with new seismic, pressure, and saturation data throughout the project to best characterize the CO<sub>2</sub> plume growth and movement over time.

### 2.9.3. Acceptance Criteria

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

### 2.9.4. Resources/Facilities Needed

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

### 2.9.5. Validity Limits and Operating Conditions

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

## **2.10. Data Management**

### 2.10.1. Data Management Scheme

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

### 2.10.2. Recordkeeping and Tracking Practices

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

### 2.10.3. Data Handling Equipment/Procedures

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

### 2.10.4. Responsibility

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

#### 2.10.5. Data Archival and Retrieval

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

#### 2.10.6. Hardware and Software Configurations

All Tri-State CCS, LLC, and vendor hardware and software configurations will interface appropriately.

#### 2.10.7. Checklists and Forms

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

### 3. Assessment and Oversight

#### 3.1. Assessments and Response Actions

##### 3.1.1. Activities to be Conducted

Refer to Table 2 and Table 3 for a summary of work to be performed and proposed work schedule. After completion of groundwater sample analysis, the results will be reviewed for quality control criteria as noted in subsection 2.5. If the data fails to meet the established quality criteria, samples will be reanalyzed if still within the holding time criteria. If outside of holding time criteria, additional samples may be collected, or sample results may be excluded from data evaluations and interpretations. Evaluation for data consistency will be performed according to procedures described in the EPA 2009 Unified Guidance.

##### 3.1.2. Responsibility for Conducting Assessments

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

##### 3.1.3. Assessment Reporting

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

##### 3.1.4. Corrective Action

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

corrective actions as needed.

## **3.2. Reports to Management**

### **3.2.1. QA Status Reports**

QA status reports are not required unless there are significant adjustments to the methods and procedures listed above. If any testing or monitoring techniques are changed, this QASP will be reviewed and updated appropriately after consultation with the UIC Program Director. The revised QASP will be distributed by Tri-State CCS, LLC to the full distribution list noted 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**

Validation of data will include a review of concentration units, sample holding times, and the review of duplicate, blank, and other appropriate QA/QC results. Tri-State CCS, LLC will maintain copies of all the laboratory's analytical test results and/or reports. Analytical results will be reported as described in subsection 2.5 of the Testing and Monitoring Plan. In the periodic reports, groundwater analysis data will be presented in graphical and tabular formats as appropriate to characterize general groundwater quality and identify intra-well variability with time. After sufficient data have been collected, additional methods, such as those described in the EPA 2009 Unified Guidance will be used to evaluate intra-well variations for groundwater constituents, to determine if significant changes have occurred that could be the result of CO<sub>2</sub> or brine seepage beyond the intended storage reservoir.

### **4.2. Verification and Validation Methods**

#### **4.2.1. Data Verification and Validation Processes**

See subsections 2.5 and 4.1 for appropriate statistical software that will be utilized to determine data consistency.

#### **4.2.2. Data Verification and Validation Responsibility**

Tri-State CCS, LLC or its designated subcontractor will verify and validate groundwater sampling data.

#### **4.2.3. Issue Resolution Process and Responsibility**

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

#### 4.2.4. Checklist, Forms, and Calculations

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

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

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

### 4.3. Reconciliation with User Requirements

#### 4.3.1. Evaluation of Data Uncertainty

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

#### 4.3.2. Data Limitations Reporting

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

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