PRE-OPERATIONAL TESTING PROGRAM
40 CFR 146.87

Project Name: Tri-State CCS Buckeye 1

Facility Information

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

Well location: Carroll County, Ohio

Well Name	Latitude (WGS 84)	Longitude (WGS 84)
TB1-1	40.66628014	-81.07152167
TB1-2	40.64546393	-81.01533077
TB1-3	40.61071400	-81.02898600
TB1-4	40.51123391	-81.02586036

Table of Contents

List of Figures

List of Tables

List of Acronyms

AoR	Area of Review
CBL	Cement Bond Log
CCS	Carbon Capture and Storage
CO_2	Carbon Dioxide
DTS	Distributed Temperature Sensing
ft	Feet
FTS	Flow Through Sampler
KIC	Knox Injection Complex
MEM	Mechanical Earth Model
MIT	Mechanical Integrity Test
MIC	Medina Injection Complex
MMt/y	Million Metric Tonnes per Year
MWD	Measurement While Drilling
NMR	Nuclear Magnetic Resonance
OAC	Ohio Administrative Code
ORC	Ohio Revised Code
PFO	Pressure Fall-Off
psi/psig	Pounds Per Square Inch, Gauge
RSWC	Rotary Side Wall Cores
SAPT	Standard Annular Pressure Test
SP	Spontaneous Potential
TBD	To Be Decided
TB1-(#)-(#)	Tri-State CCS Buckeye 1 injection well number
TB1-AOB-(#)	Above-Zone Observation Well number
TB1-GW-(#)	Shallow Groundwater Wells
TB1-IOB-(#)	In-Zone Observation Well Number
TB1-UOB-(#)	Underground Source of Drinking Water Observation Well Number
UIC	Underground Injection Control

USDW	Underground Source of Drinking Water
U.S. EPA	U.S. Environmental Protection Agency
XRD	X-Ray Diffraction

1. Introduction

Tri-State CCS, LLC plans to drill four injection wells (TB1-1, TB1-2, TB1-3, TB1-4), each targeting two injection intervals, i.e., Medina Injection Complex (MIC) and Knox Injection Complex (KIC), at Tri-State CCS Buckeye 1 in Carroll County, Ohio (the “project”; Figure 1). This Pre-Operational Testing Program will be implemented to obtain the chemical and physical characteristics of the injection and confining zones and to meet the testing requirements of 40 CFR 146.87 and the well construction requirements of 40 CFR 146.86. This program will include a combination of logging, coring, formation hydrogeologic testing (e.g., a pump test and/or injectivity tests), and other activities during the drilling and construction phases of the project’s proposed observation and CO_2 injection wells listed in Table 1 and shown in Figure 1. Tri-State CCS, LLC will obtain a permit to drill each observation well from the Ohio Department of Natural Resources (ODNR) and will construct the observation wells in compliance with state requirements at ORC 1509 and OAC 1501:9.

Table 1: List of all wells for Tri-State CCS Buckeye 1.

Well Types	Well Acronym	CCS System Zone	Zone Formation	Zone Depth (ft, TVD)	Quantity
Shallow Groundwater (GW)	TB1-GW-1, TB1-GW-2, TB1-GW-3, TB1-GW-4	Shallow USDW	Pennsylvanian	TBD	Up to 4
Deep Observation (UOB)	TB1-UOB-1, TB1-UOB-2, TB1-UOB-3, TB1-UOB-4	Lowermost USDW	Sharon Sandstone	~ 753, ~ 715, ~ 902, ~ 1,051	4
Above-Zone Observation (AOB)	TB1-AOB-1, TB1-AOB-2, TB1-AOB-3	1st Permeable Zone	TBD	TBD	3
In-Zone Observation (IOB)	TB1-IOB-1, TB1-IOB-2, TB1-IOB-3, TB1-IOB-4	Reservoir	Medina Group	~ 5,524, ~ 5,643, ~ 5,787, ~ 5,901	4
			Knox Group	~ 8,426, ~ 8,634, ~ 8,832, ~ 9,075	
Injection	TB1-1, TB1-2, TB1-3, TB1-4	Reservoir	Medina Group	~ 5,557, ~ 5,615, ~ 5,892, ~ 6,069	4
			Knox Group	~ 8,505, ~ 8,693, ~ 8,963, ~ 9,258	

The Pre-Operational Testing Program will determine or verify the depth, thickness, mineralogy, lithology, porosity, permeability, and geomechanical information of the upper confining zones (Rochester Shale Formation, Wells Creek Formation) and the lower confining zones (Queenston Shale, Conasauga Group), and the injection intervals (Medina Group, and Knox Group). In addition, formation fluid characteristics will be obtained from both the Medina Group and the Knox Group to establish baseline data against which future measurements may be compared after the start of injection operations. Up to nineteen injection and observation wells will be drilled (Table 1). In addition to the injection wells, in-zone and above-zone observation wells [TB1-IOB-1, TB1-IOB-2, TB1-IOB-3, TB1-IOB-4, TB1-AOB-1, TB1-AOB-2, TB1-AOB-3] may be used to obtain additional site characterization data for the project. Each injection well site will include a single injection well targeting the two injection intervals, i.e., KIC and MIC. An extensive well logging program will be implemented in the injection and in-zone observation wells along with a rotary side wall coring (RSWC) program in the four injection wells. The results of the testing activities, including interpretation work, will be documented in separate reports for each injection well and submitted to the UIC Program Director. Per U.S. EPA guidance, Tri-State CCS, LLC will submit these reports within 60 days after completion of each injection well (U.S. EPA, 2018).

Similarly, injection fall-off testing would be conducted in all four injection wells. These tests are used to determine reservoir and confining unit fracture gradients. Detailed geomechanical information gained from core and log analysis will be input into a 1-dimensional Mechanical Earth Model (1-D MEM) to provide understanding of formation mechanical properties and fracture gradients of the formations within the Medina Group and Knox Group and their corresponding confining units.

Tri-State CCS, LLC will rely on information from geologic and petrophysical tests in the observation wells (TB1-IOB-1, TB1-IOB-2, TB1-IOB-3, TB1-IOB-4, TB1-AOB-1, TB1-AOB-2 and TB1-AOB-3) as well as the four injection wells to satisfy the requirements of 40 CFR 146.87. Tri-State CCS, LLC will use the Wells Creek Formation, Knox Group, Conasauga Group, Rochester Shale Formation, Medina Group, and Queenston Shale Formation sidewall core samples collected from TB1-1, TB1-2, TB1-3, and TB1-4 to satisfy the requirement of 40 CFR 146.87(b). Planned sidewall rotary cores are identified in Table 3. In addition, depending on subsurface data collected from CarbonSAFE stratigraphic test wells, additional sidewall cores may be acquired in other formations, such as the Copper Ridge Dolomite Formation, and the Beekmantown Dolomite Formation.

Note that the testing activities at the identified wells described in this plan are restricted to the pre-injection phase. Testing and monitoring activities during the injection and post-injection phases are described in the project’s Testing and Monitoring Plan, along with other non-well related pre-injection baseline activities such as geochemical monitoring.

The remainder of this page intentionally left blank.

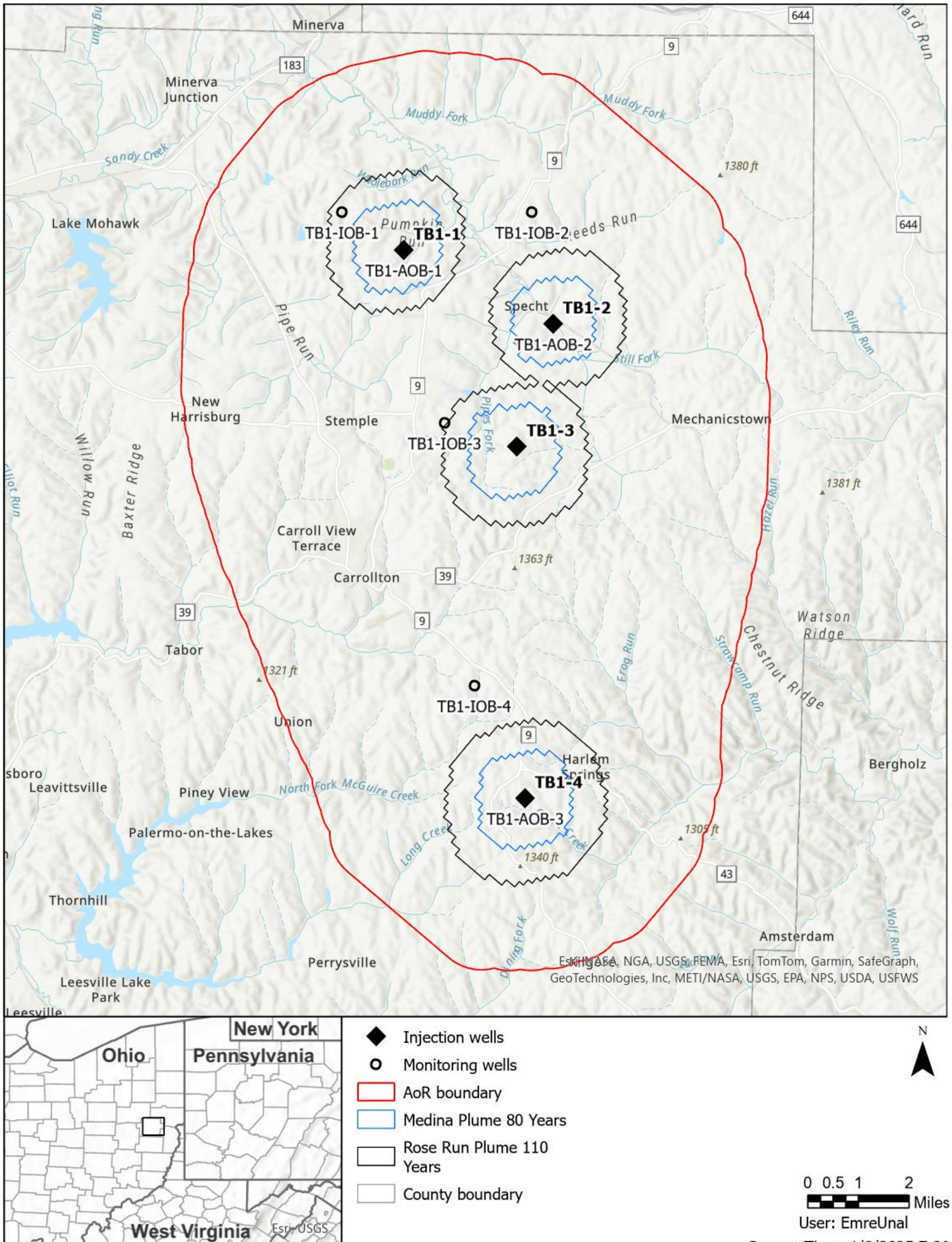

Figure 1: Locations of proposed injection and in-zone observation wells at Tri-State CCS Buckeye 1.

2. Pre-Injection Testing Plan – Injection and Observation Wells

This section describes the tests, core collection, and logging activities that will be conducted during drilling and casing installation and after casing installation in accordance with the testing required under 40 CFR 146.87(a), (b), (c), and (d).

2.1. Deviation Checks

Deviation measurements (single shot survey) will be conducted at appropriate depth intervals during construction, in accordance with 40 CFR 146.87(a)(1). A well collision avoidance management plan will be developed for injection and observation wells located in proximity to existing oil and gas wells. The drilling program will be designed to prevent any accidental collisions.

2.2. Well Logs

Open-borehole logs will be collected in the injection wells to obtain in-situ structural, stratigraphic, physical, chemical, and geomechanical information for the confining zones and the injection zones. Logs, surveys, and tests will be used to ensure conformance with the injection well construction requirements according to 40 CFR 146.86 and establish accurate baseline data for future comparison. Open-borehole characterization logs will be obtained after reaching the surface casing point within long-string casing point (i.e., total borehole depth) in the vertical borehole.

Mug logging is planned in all the injection and in-zone observation wells during the drilling operations. Wireline logging will be completed in all injection and in-zone observation wells to verify depth placement of the injection and monitoring intervals.

A description of each logging method that will be included in the logging program for the injection and in-zone monitoring wells is as follows:

2.2.1. Geologic Description (Mud Log)

A mud log will provide a continuous visual description of the drill cuttings-based lithology of the formations as the well is drilled. Physical cuttings sample datasets are typically collected and cataloged every 20-50 ft for future assessment. Sample collection frequency may be adjusted based on drilling speed, formation type, formation of interest, drilling conditions, and wellbore stability. Mud logs are also used to evaluate any hydrocarbon or natural gas shows encountered while drilling the well.

2.2.2. Open Hole Logs

- **Triple Combination** – Includes three principal measurements: density, porosity, and resistivity. At a minimum, single-axis caliper measurement is also typically included with this service which gives an indication of borehole diameter and quality, in addition to natural gamma ray and borehole temperature. Logs provide in situ petrophysical and geotechnical information about the formation.
- **Acoustic Log (i.e., Dipole Sonic)** – This acoustic log measures elastic properties axially, radially, and azimuthally to support geomechanical, geophysical, fractures, and

petrophysical modeling. Furthermore, sonic logs, like compressional sonic (DT), can be used along with density logs for preparing synthetic seismic logs.

- **High Resolution Resistivity Imaging Tool** – Provides micro-resistivity formation images when using water-based mud. Borehole images can reveal bedding planes and associated contacts, fractures (open, healed, and induced), and reservoir textures (sedimentary structures). A multi-arm caliper run with this tool provides information on hole shape and is used for subsurface stress analysis. The tool also provides borehole inclination and azimuthal information which complement the deviation check surveys taken while drilling the well.
- **Nuclear Magnetic Resonance** – This log provides nuclear magnetic resonance (NMR) measurements of the buildup and decay of the polarization of hydrogen nuclei (protons) in the liquids contained in the pore space of rock formations. One key measurement provided by this log is the total formation porosity. Permeability and effective porosity can be estimated from the free-fluid to bound-fluid ratio and the pore-size distribution. NMR measurement can also be used for fluid identification because this log also provides a hydrogen index measurement.
- **Pulsed Neutron Spectroscopy** – This logging tool is used for measurements and definitions of mineralogy and matrix properties of injection and confining zones. The data from spectroscopy logging can be used to estimate mineral-based permeability, determine well-to-well correlations from geochemical stratigraphy, and determine sigma matrix for case hole and open hole sigma saturation analysis, among others. Elemental analysis or similar processing of these logs yields the volumetric proportions of mineral composition and pore fluids. For example, these logs can reveal the relative proportions of clay minerals, quartz, calcite, and fluid volume in the formation.
- **Wireline Formation Testing** – This wireline tool suite has the capacity to collect reservoir pressure measurements, static fluid levels, and fluid samples that can be kept at formation pressures representative of downhole conditions. The tool can also be run to conduct a *mini-frac* test. These tests provide fracture pressure estimates and far field stress directions (in conjunction with the high-resolution resistivity imaging tools). Wireline test data can be used as calibration for other stress measurements (sonic logs).
- **Caliper Log** – This tool provides a continuous measurement of the size and shape of a borehole along its depth. The measurements that are recorded can be an important indicator of washouts, cave-ins, or shale swelling in the borehole, which are instrumental in processing and interpreting the results of other well logs.
- **Spontaneous Potential Log** – Spontaneous potential (SP) logs are useful for characterizing formation rock properties. Specifically, they provide indications of permeable formations and their boundaries as well as formation water resistivity. SP logs will only be run if wells are drilled with water-based mud. In its absence, a combination of measurements from other logs, such as Triple Combination, will provide necessary information regarding lithology, formation water properties, and rock permeability.

2.2.3. Cased Hole Logs

- **Ultrasonic Imaging Tool** – This log can provide estimates of well integrity and zonal isolation through measurement of cement acoustic impedance. The information from this log can be used to create maps of the casing integrity and cement, to identify corrosion or casing damage, and determine if there is solid (cement), liquid, or gas in between the casing and formation. Modern acoustic cement-evaluation tools, such as ultrasonic logs, are comprised of monopole (axisymmetric) transmitters (one or more) and receivers (two or more). They operate on the principle that acoustic amplitude is rapidly attenuated in good cement bond but not in partially bonded or free pipe. The ultrasonic tool can also provide a casing thickness interpretation.

- **Cement Bond Log (CBL)** – CBL tools use sonic waves to interrogate the integrity of the well's cement. CBLs use acoustic transmitters and receivers to measure signal attenuation to provide a measure of how well the casing and the cement are bonded. CBLs provide an indication of the cement-to-formation bond in the form of a variable density log. Typically, CBLs provide an average measurement, but they can also provide maps where logging tools with multiple transmitters and receivers on pads are used.
- **Temperature Logging Surveys** – The temperature log provides a subsurface temperature profile necessary for characterizing in-situ conditions. Temperature logging is used to identify the top of cement after cementing to help ensure wellbore integrity.

Table 2 lists the various Surface and Long String Casing wireline logging tools that will be deployed in injection and in-zone observation wells as well as planned mud logging activities in these wells.

Table 2: Wireline and mud logging program for injection and in-zone observation wells.

Approximate Depth Interval (ft)	Log	Log Type	Purpose/ Comments
Surface Casing			
0 – 803	Mud Log	Open Hole	Monitor and ensure uninterrupted drilling process as well as provide lithologic information while drilling
0 – 803	SP Log	Open Hole	Characterize rock formation properties.
0 – 803	Cement Bond Log	Cased Hole	Evaluate cement integrity
Intermediate Casing			
803 – 1,978	Mud Log	Open Hole	Monitor and ensure uninterrupted drilling process as well as provide lithologic information while drilling
803 – 1,978	Borehole Profile/ Caliper	Open Hole	Evaluate borehole condition prior to cementing.
0 – 1,978	Temperature Log	Cased Hole	Determine natural geothermal gradient outside well for comparison to future temperature logs for external mechanical integrity evaluations. Baseline log is run a minimum of 30 days after drilling and casing/ cementing the well because temperature anomalies due to circulation of drilling fluid and/or open-borehole injection testing will persist for several weeks to months.
803 – 1,978	Triple Combination	Open Hole	Characterize basic geology (Lithology, formation tops, porosity, etc.).
803 – 1,978	SP Log	Open Hole	Characterize rock formation properties.
0 – 1,978	Cement Bond Log	Cased Hole	Evaluate cement integrity

Approximate Depth Interval (ft)	Log	Log Type	Purpose/ Comments
Long String Casing			
1,978-9,061	Mud Log	Open Hole	Monitor and ensure an uninterrupted drilling process as well as provide lithologic information while drilling
1,978-9,061	Borehole Profile/Caliper	Open Hole	Evaluate borehole condition prior to cementing
1,978-9,061	Temperature Log	Cased Hole	Determine natural geothermal gradient outside well for comparison to future temperature logs for external mechanical integrity evaluations. Baseline log is run a minimum of 30 days after drilling and casing/ cementing the well because temperature anomalies due to circulation of drilling fluid and/or open-borehole injection testing will persist for several weeks to months.
1,978-9,061	Triple Combination	Open Hole	Characterize basic geology (Lithology, formation tops, porosity, etc.)
1,978-9,061	Pulsed Neutron Spectroscopy	Open Hole	Characterize basic geology (Gamma Ray, Resistivity, Porosity, Mineralogy)
1,978-9,061	SP Log	Open Hole	Characterize rock formation properties.
1,978-9,061	Nuclear Magnetic Resonance Tool	Open Hole	Enhanced characterization of geologic and geomechanical properties that control injectivity and caprock/seal integrity.
1,978-9,061	High Resolution Resistivity Imaging Tool	Open Hole	Enhanced characterization of geologic and geomechanical properties that control injectivity and caprock/seal integrity.
1,978-9,061	Wireline Formation Testing	Open Hole	Used to characterize downhole formation fluids and reservoir pressures at selected locations of interest
1,978-9,061	Dipole Sonic	Open Hole	Determine the reservoir fracture pressure gradient and geomechanical properties of the confining and injection zones
1,978-9,061	Cement Bond Log/Ultrasonic	Cased Hole	Evaluate cement integrity, internal and external casing condition

[1] Depth estimates are reported as MD. Exact logging depths vary by individual well and will depend on the well locations and well design. The specified depths (intermediate depth and bottom of the well) are approximate values for TB1-1 and should be used as reference.

2.3. Cores

Tri-State CCS, LLC is planning to obtain rotary sidewall cores at injection wells. This rotary sidewall core analysis of samples will be used to evaluate the project's proposed injection and confining intervals and verify rock properties and finalize and update any models prior to CO_2 injection. Whole cores will be collected and analyzed as part of the CarbonSAFE stratigraphic test wells planned near the site.

Tri-State CCS, LLC will attempt to collect rotary sidewall cores in each of the injection wells. The planned distribution of these sidewall cores is provided in Table 3. The exact coring intervals depend on the target formations at the injection wells, i.e., Knox Group and the Medina Group. The exact number of sidewall cores per interval and per well is subject to change based on

Measurement While Drilling (MWD) observations and a thorough evaluation of available characterization data at the site. These sidewall cores will be preserved on-site and shipped to a commercial core testing/analysis laboratory for analysis. Properties analyzed will include routine core analysis (porosity, permeability, grain density, and residual fluid saturation). Specialized core analysis, including X-ray diffraction (XRD) for mineralogical analysis and capillary pressure, will be conducted on selected core samples. If the wireline formation tests fail to determine injection and confining zone mechanical properties, core plug mechanical property tests (e.g., triaxial tests) may be conducted to determine these properties and to estimate fracture pressure. The wireline and/or core mechanical property results will be used to calibrate wireline logs.

Table 3: Planned sidewall core collection by formation in the injection wells. The exact number of sidewall cores per interval is subject to change based on wireline logging results.

Well	Formation	# of Core Plugs
TB1-1, TB1-2, TB1-3, TB1-4	Rochester Shale Formation	5
	Medina Group	12
	Queenston Shale Formation	5
	Wells Creek Formation	5
	Knox Group	20
	Conasauga Group	3
	TOTAL	**50**

2.4. Fluid Sampling

The analysis of reservoir fluid samples will be used to satisfy the requirement of 40 CFR 146.87(c) and ensure that baseline geochemical properties are established for the MIC and KIC in the Area of Review (AoR). Tri-State CCS, LLC will collect fluid samples from the injection wells for the two injection zone formations. Any fluids introduced into the formation during drilling, borehole conditioning, cementing, perforation acid treatment, and/or formation (injection) testing would first need to be removed before representative formation fluid samples can be collected. Consequently, Tri-State CCS, LLC will attempt to collect initial fluid samples during the active drilling phase using a Wireline Formation Testing tool rather than collect samples after well completion. The in-zone fluid samples from injection wells will be collected using a formation testing tool while the hole is open. If fluid samples cannot be taken via the formation testing tool, fluid samples can be collected after well completion by swabbing fluid or pumping through tubing with a packer set just above the perforated interval. After an appropriate volume of fluid is swabbed from the well, samples can be taken via a slickline deployed tool, such as a Kuster Flow Through Sampler (FTS) or equivalent. Both fluid sampling methods will sample reservoir pressure and static fluid levels. Tri-State CCS, LLC will collect quarterly samples from the KIC injection zone prior to start of injection for a period of 1 year. Once KIC injection is complete and the well undergoes recompletion, Tri-State CCS, LLC will sample the MIC injection zone once prior to start of injection.

The analytic and field parameters for fluid sampling are presented in Table 4. These parameters are consistent with the fluid sampling analysis and processes that are detailed in the Testing and Monitoring Plan and the Quality Assurance Surveillance Plan associated with this permit.

Table 4: Summary of analytical and field parameters for fluid sampling in the Medina Group and the Knox Group.

Parameters	Analytical Methods
Cations: **Al, Ba, Mn, As, Cd, Cr, Cu, Pb, Sb, Se, and Tl**	ICP-MS, EPA Method 6020B (U.S. EPA, 2014a) or EPA Method 200.8 (U.S. EPA, 1994a)
Cations: **Ca, Fe, K, Mg, Na, and Si**	ICP-OES, EPA Method 6010D (U.S. EPA, 2014b) or EPA Method 200.7 (U.S. EPA, 1994b)
Anions: **Br, Cl, F, NO3 and SO4**	Ion Chromatography, EPA Method 300.0 (U.S. EPA, 1993)
Dissolved CO2 **Total Dissolved Solids** **Water Density** **Alkalinity** **pH (field)** **Specific conductance (field)** **Temperature (field)**	Coulometric titration, ASTM D513-16 (ASTM, 2016) Gravimetry, APHA 2540C (APHA) Oscillating body method APHA 2320B (APHA, 1997) EPA 150.1 (U.S. EPA, 1982) APHA 2510 (APHA, 1992) Thermocouple

2.5. Demonstration of Mechanical Integrity

Tri-State CCS, LLC will conduct tests and run logs as needed to demonstrate the internal and external mechanical integrity of all injection wells prior to initiating CO_2 injection, satisfying the hydrogeologic testing requirements under 40 CFR 146.87(e). Internal mechanical integrity refers to the absence of leaks in the tubing, packer, and casing above the packer. External mechanical integrity refers to the absence of fluid movement/leaks through channels adjacent to the injection wellbore that could result in fluid migration into an USDW.

Table 5 provides a summary of the mechanical integrity tests (MITs) and pressure fall-off (PFO) tests to be performed prior to injection.

Table 5: Summary of planned MITs and other tests prior to injection.

Class VI Rule Citation	Rule Description	Test Description
40 CFR 146.89(a)(4)	MIT - Internal	Pressure Test
40 CFR 146.87(a)(4)	MIT - External	Casing Inspection Log
40 CFR 146.87(a)(4)	MIT - External	Distributed Temperature Sensing (DTS)/ Temperature Log
40 CFR 146.87(e)	Testing prior to operating	PFO, Injectivity Test

Cement placed in the annular space around the casing will be allowed to set so as to achieve desired compressive strength using approved engineering data for the type of cement used. Prior to drilling out the shoe on each casing string, a casing pressure test will be conducted. The test will be designed not to exceed the rated pressure of the casing. During the test, if any indication of a leak or failure is indicated, then the casing string will be recemented or repaired. Once remedial measures have taken place, the pressure test will be conducted again. After cementing the casing strings, drilling will not commence until adequate time under pressure has passed. All casing pressure tests will be recorded in the driller’s log.

After the completion of the injection wells, which includes the installation of tubing, packer, and annular fluid, a test of each well’s internal mechanical integrity will be performed by conducting a standard annular pressure test (SAPT). The annular pressure test is a short-term test wherein the fluid in the annular space between the tubing and casing is pressurized, the well is shut-in (temporarily sealed up), and the pressure of the annular fluid is monitored for any changes.

The initial annulus pressure test will be conducted to validate well integrity. The test will include pressurizing the fluid-filled annulus to a specified level, which is at least equivalent to the maximum authorized surface injection pressure (For the Medina Group and the Knox Groups, the maximum surface injection pressure based on a maximum injection rate limitation of 0.5 MMt/y is reported in Table 6) and monitoring the pressure throughout a 60-minute test period. Per U.S. EPA Region 5 guidance, a passed test is one where the applied test pressure stabilizes within 3% of the required test pressure for the testing period, whereas a failed test is one where there is a 3% or greater loss of the applied pressure (Guidance for Deep Injection Wells, Guidance #5 (2008)).

Table 6: Summary of maximum surface injection pressures for project injection wells.

Well	Formation	Max. Injection Pressure (psig)
TB1-1	Medina Group	1,751
TB1-2		1,765
TB1-3		1,837
TB1-4		1,882
TB1-1	Knox Group	2,479
TB1-2		2,524
TB1-3		2,588
TB1-4		2,655

2.5.1. Annulus Pressure Test Procedures for Injection and Monitoring Wells:

The general procedure for the annular pressure test is summarized as follows:

1. The tubing/casing annulus (annulus) will be filled with liquid (see subsection 2.7.1 of the Construction Details for each injection well for details on the annular fluid). Temperature stabilization of the well and annulus liquid is necessary prior to conducting the test. For the injection wells, this will be achieved by filling the annulus with liquid and either ceasing injection or maintaining stabilized injection using water (i.e., continuous injection at a constant rate and constant injection fluid temperature) before and through the test. For the observation wells, the annulus will be filled with liquid but no changes will be made to the fluid inside the tubing prior to the actual test. Note that no unapproved substances will be added to the annulus liquid.
2. After stabilization, the annulus will be pressurized to a surface pressure of no less than 300 psig. The exact pressure limit will depend on the casing string being tested. In the injection wells, a positive pressure differential between the pressure in the annular

space and the injection tubing pressure of at least 100 psi will be maintained throughout the entire annulus (from the top of the packer to the surface). Specific gravity differences between liquids in the annulus and the tubing should be accounted for when determining the appropriate test pressure.

3. Following pressurization, the annular system will be isolated from the source of pressure. The annulus system will remain isolated for a period of no less than 60 minutes.
4. After the SAPT test period has been completed, the valve to the annulus will be opened and liquid returns from the annulus observed and measured.

During the active CO_2 injection phase, internal mechanical integrity will be continuously monitored by the well annular pressure maintenance and monitoring system, as discussed in more detail in the Testing and Monitoring Plan.

Tri-State CCS, LLC will also employ various methods to demonstrate external mechanical integrity upon the completion of all injection wells and prior to the start of injection operations. Tri-State CCS, LLC will run DTS temperature surveys on all injection wells to demonstrate external mechanical integrity to provide confidence that there are no pathways for potential CO_2 or brine migration through the wellbore, casing, or cement prior to injection operations, satisfying the requirement of 40 CFR 146.87(a)(4).

Upon cessation of injection activities into the KIC injection zone, and as the well is being recompleted to target the Medina Group, Tri-State CCS, LLC plans to continue using the original DTS fiber for external MIT monitoring. However, due to a break in the fiber below the MIC, there might be some loss of signal at the bottom of the MIC injection zone. Tri-State CCS, LLC will review the status of the DTS fiber upon recompletion of the injection wells to determine if a modified monitoring approach, such as use of temperature logs, is required to satisfy the requirement of 40 CFR 146.87(a)(4).

2.6. Fracture Pressure of Injection and Confining Zone

Based on identified data gaps and results from the stratigraphic test well and other characterization data collected at the site, and prior to installing the long-string casing in one of the in-zone observation wells (TB1-IOB-1, TB1-IOB-2, TB1-IOB-3, or TB1-IOB-4), Tri-State CCS, LLC will use the formation testing tool to conduct formation fracture tests to measure the fracture pressure of the injection formation and the confining unit(s). Then, a minifrac test will be used to locally pressure up a small interval in the test formation to the point where it just starts to fracture. This provides the fracture pressure without causing significant damage to the formation being tested.

In addition, to fully satisfy the requirements of 40 CFR 146.87(d), Tri-State CCS, LLC intends to run a dipole sonic log (Stoneley wave analysis) in the injection wells, which will allow calculation of the injection and confining zone reservoir fracture pressure.

2.7. Hydrogeologic Testing

After the injection wells are complete, including perforating the Rose Run Sandstone injection interval and installing the injection tubing and packer, Tri-State CCS, LLC intends to run an injection test on the injection formation to determine the large-scale composite injectivity (transmissivity) of the KIC injection interval and possible presence of nearby hydrogeologic boundaries (Table 7). Once the injection into KIC is complete and the injection wells are being recompleted to inject into the Medina Group, an injection test will be run in the MIC upon perforation of the identified injection interval. The injectate for this test will be produced formation water (brine) from respective injection formations in the injection wells or fresh water which will serve as a proxy for CO_2 injection. Tri-State CCS, LLC intends to use the extensive wireline logging program to support and corroborate the hydrogeologic properties that are collected via direct fluid sampling from the injection zones. Additionally, Tri-State CCS, LLC will collect reservoir pressure data from the Medina and Knox Groups in the injection wells during the injectivity test.

Table 7: Composite injectivity evaluation testing program.

Test	Description	
Injection Zone Composite Injectivity Evaluation	Objectives	Primary objective: To determine the large-scale transmissivity of the injection zones and possible presence of nearby hydrogeologic boundaries using produced reservoir brine from the injection wells or using fresh water and provide direct information about the injectivity potential of the injection zones within the Medina and Knox Groups.
	Test/Depth Zone	Injection zones in: 1) Medina Group and 2) Knox Group. Approximate depth interval 1) 5,557 ft and 2) 8,505 ft measured depth.[1] Alternatively, this test may be conducted on one or more discrete depth intervals within these stratigraphic groups.
	Test Activity/ Summary	For injection into KIC, injection tubing and packer would be set above the injection formation (Rose Run Sandstone), inside the casing string. After the packer is in place, a constant-rate injection utilizing produced reservoir brine from the injection wells or fresh water will be conducted. At the end of injection, the recovery pressure for the composite zone will be monitored for a period approximately 1.5 times or more of the injection period. For injection into the Medina Group, the same procedure will be replicated once the well has been recompleted.

[1]These depths are approximate and refer to depths of these injection zones associated with TB1-1. Actual test intervals will be finalized once the wells are being drilled and will likely fall within the depth ranges identified in this application.

A pre-operation injection and PFO test will serve as the baseline test for establishing reservoir and well conditions for comparison to results of subsequent PFO tests conducted during the operational period (i.e., during CO_2 injection). Specifically, this comparison is intended to confirm that the pressure increase within the injection interval is less than predicted and ensure that the modeled parameters used in the Area of Review and Corrective Action Plan modeling analysis represent actual conditions.

The PFO tests will be conducted according to the U.S. EPA Region 5 guidance *(UIC Section Regional Guidance #6, Attachment 1 (1998))*. These guidelines define a PFO test as a pressure transient test that consists of shutting in an injection well after a period of prolonged injection and measuring the PFO. The fall-off period is a replay of the injection test preceding it; consequently, it is affected by the magnitude, length, and rate fluctuations of the injection period. Fall-off testing analysis provides reservoir and well parameters, including transmissivity, storage capability, skin factor, and well flowing and static pressures. Establishing a baseline value for these parameters will be useful for identifying changes in the well and/or reservoir properties after CO_2 injection begins; for example, an increasing skin factor may be indicative of formation damage which signals a need for well remediation while a decreasing skin factor may indicate near-wellbore cleanup.

2.7.1. Pressure Fall-Off Test Procedures:

Baseline PFO tests will be conducted as described in the Testing and Monitoring Plan and in this Pre-Operational Testing Program. The objective of the testing is to periodically monitor for changes in the near well bore environment that would impact injectivity or cause injection pressures to increase. Baseline PFO testing will be performed in all the injection wells. A PFO test has a period of injection followed by a period of no-injection or shut-in. Normal injection will be used during the injection period preceding the shut-in portion of the falloff tests. However, if the rate causes relatively large changes in bottomhole pressure, the rate may be decreased. A minimum of one week of relatively continuous injection will precede the shut-in portion of the falloff test. The PFO data will be measured using a downhole gauge sampling at 5-second intervals. The gauges may be those used for day-to-day data acquisition, or a pressure gauge conveyed via wireline. Surface or downhole gauges will be used to inform test duration. The shut-in period of the PFO test will be adequate to assure that enough pressure transient data are collected to calculate the average pressure. Quantitative analysis of the measured data will be used to estimate formation characteristics, including transmissivity, permeability, and skin factor. The measured parameters will be compared to those used in site computational modeling and AoR delineation.

The baseline PFO test will be conducted as part of the post-completion injectivity testing (e.g., constant-rate injection test conducted as either a single-well test and/or multi-well interference test).

2.8. Schedule

Tri-State CCS, LLC will provide the UIC Program Director with the opportunity to witness all logging and testing described in this program. Pursuant to 40 CFR 146.87(f), Tri-State CCS, LLC will submit a schedule of such activities to the UIC Program Director 30 days prior to conducting the first test and submit any changes to the schedule 30 days prior to the next scheduled test. Per U.S. EPA guidance, Tri-State CCS, LLC will provide notice and opportunity to witness testing to the UIC Program Director at least 48 hours in advance of a given test.

2.9. Reporting

Pursuant to 40 CFR 146.87(a), Tri-State CCS, LLC will provide the UIC Program Director with a descriptive report(s) prepared by a knowledgeable analyst(s) that includes an interpretation of the results of the casing and cement integrity, well logging, well testing, and core data for each injection well. These results will be documented in separate reports for each injection well, namely TB1-1, TB1-2, TB1-3, TB1-4, and will be submitted to the UIC Program Director within 60 days after completion of each injection well (U.S. EPA 2018). These report(s) will include:

- The date and time of each pressure test, the date of well bore completion, and the date of installation of all casings and cements, including chart results and interpretations of each cement bond log, cement pressure tests, and any supplemental well data;

- Interpretation of the well logs by a log analyst, including any assumptions, determination of porosity, permeability, lithology, thickness, depth, and formation fluid salinity of relevant geologic formations, and any changes in interpretation of site stratigraphy based on formation testing logs;
- Interpretation of sidewall core analysis results, including any changes in interpretation of site stratigraphy based on core analysis, analytical methods, quality assurance information, tabular and/or graphic data, and photographs;
- Reservoir fluid sampling results, including descriptions of the sampling equipment, sampling methodology, sample preservation methods, field and laboratory results, and any changes in interpretation of site stratigraphy based on fluid sample results;
- Reservoir pressure results and geomechanical results to determine injection and confining zone fracture pressure, including type and location of pressure gauge, type of flow meter and calibration records, raw pressure and flow data, and plot of flow rate versus pressure data, and any changes in geomechanical interpretations based on test results; and
- Hydrogeologic test results, including pressure and flow data, testing parameters, discussion of results, and any changes in interpretation of injectivity and storage potential based on injection/fall-off test results.

3. References

American Public Health Association (APHA), SM 2540 C. “Standard Methods for the Examination of Water and Wastewater”, APHA-AWWA-WPCF, 20th Edition (SDWA) and 21st Edition (CWA).

U.S. EPA, (1982). “Method 150.1: “pH, Electrometric Method; Methods for the Chemical Analysis of Water and Wastes (MCAWW) (EPA/600/4-79/020)”, Revision 2.

American Public Health Association (APHA), SM2510 (1992). “Standard Methods for the Examination of Water and Wastewater”, APHA-AWWA-WPCF, 18th Edition, 1992.

U.S. EPA, (1993). “Method 300.0: “Methods for the Determination of Inorganic Substances in Environmental Samples.” Revision 2.1. Washington, DC.

U.S. EPA, (1993). “Method 300.0: “Methods for the Determination of Inorganic Substances in Environmental Samples.” Revision 2.1. Washington, DC.

U.S. EPA, (1994a). “Determination of Trace Elements in Waters and Wastes by Inductively Coupled Plasma – Mass Spectrometry.” Revision 5.4. Environmental Monitoring Systems Laboratory Office of Research and Development U.S. Environmental Protection Agency, Cincinnati, Ohio.

U.S. EPA, (1994b). “Determination of Trace Elements in Waters and Wastes by Inductively Coupled Plasma – Atomic Emission Spectrometry.” Revision 4.4. Environmental Monitoring Systems Laboratory Office of Research and Development U.S. Environmental Protection Agency, Cincinnati, Ohio.

U.S. EPA, (1996). “Method 6010B: Inductively Coupled Plasma-Optical Emission Spectrometry.” Revision 2. Washington, DC.

US. EPA, (1998). EPA Region 5 Guidance for Deep Injection Wells, Guidance #6: Planning, Executing, and Reporting Pressure Transient Tests.

American Public Health Association (APHA), 2320B (2005). “Titration Method”, APHA-AWWA-WPCF, 21st Edition.

U.S. EPA, (2008). EPA Region 5 Guidance for Deep Injection Wells, Guidance #5: Determination of the Mechanical Integrity of Injection Wells.

ASTM Standard D513-11, (2016). “Standard Test Methods for Total and Dissolved Carbon Dioxide in Water,” ASTM International, West Conshohocken, PA. DOI: 10.1520/D0513-11E01, www.astm.org.

U.S. EPA, (2014a). “Method 6020B (SW-846): Inductively Coupled Plasma-Mass Spectrometry.” Revision 2. Washington, DC.

U.S. EPA, (2014b). “Method 6010D (SW-846): Inductively Coupled Plasma-Optical Emission Spectrometry.” Revision 4. Washington, DC.

U.S. EPA, (2018). Underground Injection Control (UIC) Program Class VI Implementation Manual for UIC Program Directors.