Underground Injection Control Carbon Sequestration
Class VI Permit Application

PRE-OPERATIONAL TESTING PROGRAM
40 CFR 146.85
Section 6.0

Four Corners Carbon Storage, LLC
San Juan Basin, New Mexico Carbon Sequestration Project

June 2023

Prepared by:

Kevin Bush (Subsurface Director)
Katy Larson (UIC Coordinator)
Four Corners Carbon Storage, LLC
4200 West 115th Street
Leawood, KS 66211

Numeric Solutions, LLC.
1536 Eastman Ave., Suite D
Ventura, CA 93003

PRE-OPERATIONAL TESTING PROGRAM
40 CFR 146.85

Four Corners Carbon Storage, LLC – Injector 1

Facility Information

Facility name: **San Juan Basin, New Mexico Carbon Sequestration Project**
Injector 1

Facility contacts:

Kyle Quackenbush | Segment President – Liquids
Four Corners Carbon Storage, LLC
370 Van Gordon Street
kyle.quackenbush@tallgrass.com

Kevin Bush | Director Subsurface
Four Corners Carbon Storage, LLC
370 Van Gordon Street
kevin.bush@tallgrass.com

Katy Larson | UIC Coordinator
Four Corners Carbon Storage, LLC
370 Van Gordon Street
katy.larson@tallgrass.com

Well location: San Juan County, New Mexico
[redacted]

[1] North American Datum 1983

TABLE OF CONTENTS

TABLE OF CONTENTS 3
LIST OF TABLES 4
ACRONYMS AND ABBREVIATIONS 4
6 PRE-OPERATIONAL TESTING PROGRAM 6
6.1 Introduction 6
6.2 Pre-Injection Testing Plan—Injector 1 10
6.2.1 Deviation Checks 11
6.2.2 Tests and Logs 11
6.2.3 Demonstration of Mechanical Integrity 13
6.3 Pre-Injection Testing Plan – Deep Monitoring Well (Monitor 1) 13
6.3.1 Deviation Checks 13
6.3.2 Tests and Logs 14
6.4 Annulus Pressure Test Procedures for Injection Well (Injector 1) 15
6.5 Annulus Pressure Test Procedures for Monitoring Well (Monitor 1) 16
6.6 Pressure Fall-Off Test Procedures 16
6.7 Quality Assurance and Surveillance Plan 16

LIST OF TABLES

Table 6.1—Summary of injection and monitoring well conventional coring, open hole, and cased hole logging plans. 6
Table 6.2—Summary of required geomechanical characterization per 40 CFR 146.82(a)(3)(iv), and forthcoming data to address requirements. 7
Table 6.3—Summary of required rock properties of the confining and injection zone per 40 CFR 146.82(a)(3)(iii) and forthcoming data to address requirements. 9
Table 6.4—Open hole logging program. 11
Table 6.5—Planned core analyses and how the data will be used to refine static and dynamic models. 12
Table 6.6—Cased hole logging program for Injector 1. 13
Table 6.7—Pre-operational testing schedule. 13
Table 6.8—Cased hole logging program. 15
Table 6.9—Mechanical Integrities 15

ACRONYMS AND ABBREVIATIONS

3D	three-dimensional
°	degree
A	
AoR	area of review
B	
BHL	bottom hole location
C	
CFR	Code of Federal Regulations
CO_2	carbon dioxide
E	
EOS	equation-of-state
EPA	U.S. Environmental Protection Agency
F	
ft	feet/foot
°F/ft	Fahrenheit per foot
G	
GR	gamma ray
GSDT	Geologic Sequestration Data Tool
L	
lbm/ft^3	pound mass per cubic foot
M	
mD	millidarcy
MDT	Modular Formation Dynamics Tester
mg/L	milligrams per liter
MEM	mechanical earth model
MICP	mercury injection capillary pressure

MIT	mechanical integrities
MMSFC	million standard cubic feet
MMSFD/D	million standard cubic feet per day
N	
NMR	nuclear magnetic resonance
O	
OCD	Oil Conservation Division
OSE	Office of the State Engineer
P	
PEF	photoelectric factor
psi	pounds per square inch
psi/ft	pounds per square foot
R	
RCA	routine core analyses
S	
SCAL	special core analysis
SHmin	minimum horizontal stress
SP	spontaneous potential
T	
TCS	triaxial compressive strength
TD	total depth
TVD	true vertical depth
TVDSS	true vertical depth sub sea
U	
UIC	Underground Injection Control
USDW	underground source of drinking water
USIT	ultra sonic imager tool

6 PRE-OPERATIONAL TESTING PROGRAM

6.1 Introduction

Four Corners Carbon proposes drilling and completing a carbon sequestration injection well (Injector 1) and monitoring well (Monitor 1) for the safe sequestration of carbon dioxide (the "Project") [redacted] San Juan County, approximately [redacted]. Strat 1[2] is utilized as the project characterization well. Strat 1 was drilled to collect core and log data in the region of the proposed injection well. Interpretation of the core data and petrophysical logs is ongoing and will be integrated into the static and dynamic reservoir models as results are made available. In addition to the injection well, an additional stratigraphic test and a monitoring well, Monitor 1, will be an in-zone monitoring well. Extensive logging suites are planned for Injector 1 and conventional cores will be obtained from the confining and injection zone. These will be analyzed via routine core analyses (RCA) and special core analyses (SCAL). Details of these planned tests are explained herein. **Table 6.1** provides an overview of planned data collection activities.

Table 6.1—Summary of injection and monitoring well conventional coring, open hole, and cased hole logging plans.

Well	Conventional Core	Rotary Sidewall Core	Basic Logs	Advanced Logs	Cased Hole
Strat 1	Y		Y		Y
Injector 1		Y	Y	Y	Y
Monitor 1			Y		Y

Note: Basic logging is equivalent to a "triple combo" logging suite including gamma ray, SP, resistivity, neutron-density porosity logs, and PEF. Advanced logging suites include crossed dipole sonic, resistivity and sonic image logs, NMR logs.

Extensive logging and coring operations are planned to address the requirements of 40 CFR 146.82(a)(3)(iii) and CFR 146.82(a)(3)(iv) as detailed in **Table 6.2** and **Table 6.3.**

Extensive conventional core was cut in Strat 1 [redacted] Core plugging for RCA/SCAL is underway and follows activities summarized in Table 6.2 and Table 6.3. Due to hole conditions in Strat 1, an abbreviated logging suite was run. The equivalent of a triple combo logging suite plus [redacted] were run using [redacted]. After the casing was set, a [redacted] log was run to provide additional information about mineralogy of the confining and injection zones. The complete suite of logs now planned for Injector 1 are summarized in Table 6.2 and Table 6.3 and discussed later in this section.

[redacted]

Table 6.2—Summary of required geomechanical characterization per 40 CFR 146.82(a)(3)(iv), and forthcoming data to address requirements.

UIC-Class VI requirements for 40 CFR 146.82(a)(3)(iv)	Data Acquisition Planned for the Injector 1 Well	
	Wireline	Core
Fractures	[redacted]	[redacted]
Ductility	[redacted]	[redacted]

UIC-Class VI requirements for 40 CFR 146.82(a)(3)(iv)	Data Acquisition Planned for the Injector 1 Well	
	Wireline	Core
Rock strength	[redacted]	[redacted]
In situ stress field	[redacted]	[redacted]
Pore pressure	[redacted]	[redacted]

Table 6.3—Summary of required rock properties of the confining and injection zone per 40 CFR 146.82(a)(3)(iii) and forthcoming data to address requirements.

UIC-Class VI required data [40 CFR 146.82(a)(3)(iii)]	Data Acquisition Planned for the Injector 1	
	Wireline	Core
Mineralogy	[redacted]	[redacted]
Porosity	[redacted]	[redacted]
Permeability	[redacted]	[redacted]

UIC-Class VI required data [40 CFR 146.82(a)(3)(iii)]	Data Acquisition Planned for the Injector 1	
	Wireline	Core
Capillary pressure	[redacted]	[redacted]
Geology/facies changes	[redacted]	[redacted]

6.2 Pre-Injection Testing Plan—Injector 1

During the drilling phase of the injection well, the tests and logs listed in **Table 6.4** are planned to be conducted during drilling, casing installation, and after casing installation in accordance with the testing required under 40 CFR §146.87(a), (b), (c), and (d). The tests and procedures are described in the following text and in Section 5.0 (Proposed Injection Well Construction Information) of this application.

Table 6.4—Open hole logging program.

Open Hole Logging Program			
Run	Interval	Log	Purpose
1	[redacted]	[redacted]	[redacted]
2+	[redacted]	[redacted]	[redacted]

6.2.1 Deviation Checks

The injection well will be drilled vertically and surveyed to obtain an accurate measurement of the bottom hole location (BHL) and borehole deviations between the BHL and surface.

6.2.2 Tests and Logs

6.2.2.1 During Drilling

The Injector 1 well will first be drilled to a depth of [redacted] where a surface casing as detailed in Section 5 will be set and cemented to surface to protect underground source of drinking water (USDW). All components of the drilling mud will be chosen so not to contaminate any USDW. A [redacted] will be used to characterize the baseline quality of the annular cement bond to the formation and the annular cement bond to the casing. Following this, drilling will continue to the top of the first core interval. Conventional whole core will be cut from [redacted] core will be cut from select intervals; core will be collected through the entirety of the [redacted]

(confining layer), [redacted] (injection zone). Planned RCA and SCAL experiments are detailed in **Table 6.5**.

Table 6.5—Planned core analyses and how the data will be used to refine static and dynamic models.

Conventional Core Analysis	
Core Property	**Purpose**
Routine Core Analysis	Porosity, permeability
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]

Drilling will continue to total depth (TD) at which stage the remaining logs listed in Table 6.5 will be recorded from TD to the surface casing shoe. Prior to running the production casing, a [redacted] log will be run over the surface casing interval to get a baseline for casing condition after drilling, and to confirm the casing string is adequately bonded with cement to the formation.

In-Situ Testing

In-Situ testing will be performed to characterize in-situ stress and pore pressure, in the primary injection zone and confining layers, mini-frac, and pore-pressure tests. Open hole logs will be used to select test intervals to ensure representative intervals are evaluated.

6.2.2.2 During and After Casing Installation

After the surface casing is cemented in place and the well drilled to TD, radial bond and ultra-sonic cement evaluation logs will be run over the surface casing interval prior to running inner casing and cementing. Once the inner casing is cemented in place, the same segmented radial bond and ultra-sonic cement evaluation logs will be run from production casing shoe to surface to ensure the annular cement is well bonded to the surface casing and formation and to the inner casing. Furthermore, to characterize the baseline condition of the inner casing, a [redacted] tool and [redacted] tools will be run which will aid in identifying anomalies in subsequent surveillance logging runs. **Table 6.6** summarizes which logs will be run over which intervals.

Table 6.6—Cased hole logging program for Injector 1.

Cased Hole Logging Program		
Interval (ft)	Log	Purpose
[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]
	[redacted]	[redacted]
	[redacted]	[redacted]
	[redacted]	[redacted]

6.2.3 Demonstration of Mechanical Integrity

Table 6.7 is a summary of the mechanical integrities (MITs) and pressure fall-off tests to be performed prior to injection:

Table 6.7—Pre-operational testing schedule.

Class VI Rule Citation	Rule Description	Test Description	Program Period
40 CFR 146.89(a)(1)	MIT - Internal	500 psi fluid pressure, less than 10% loss over 30 minutes minimum	Prior to perforating
40 CFR 146.87(a)(4)	MIT - External	Temperature log	After casing cemented
40 CFR 146.87(e)(1)	Testing prior to operating	Injectivity Test	After perforating

Four Corners Carbon will notify U.S. Environmental Protection Agency (EPA) at least thirty days prior to conducting the test and provide a detailed description of the testing procedure. Notice and the opportunity to witness these tests/logs shall be provided to EPA at least 48 hours in advance of a given test/log.

6.3 Pre-Injection Testing Plan – Deep Monitoring Well (Monitor 1)

Located [redacted] miles from the injection well, the monitoring well (Monitor 1) will be installed to monitor pressures and temperatures of the injection and confining zones and enable sampling of the fluids in the injection zone.

6.3.1 Deviation Checks

The monitoring well will be drilled vertically. A deviation survey will be conducted to precisely locate the wellbore in the subsurface.

6.3.2 Tests and Logs

6.3.2.1 During Drilling

After the well is drilled to the surface casing depth, a suite of logs will be run as detailed in logging run no. 1 in **Table 6.8**. After logging is complete, the surface casing will be run and cemented in place.

Table 6.8—Open hole logging program.

Openhole Logging Program			
Run	Interval (ft)	Log	Purpose
1	[redacted]	[redacted]	[redacted]
2+	[redacted]	[redacted]	[redacted]

* if water based mud

6.3.2.2 During and After Casing Installation

After the surface casing is cemented in place and the well drilled to TD, a [redacted] cement evaluation logs will be run over the surface casing interval. After open-hole logging is completed, the production casing will be run and cemented in place. The same [redacted] evaluation logs will be run from production casing shoe to surface. Furthermore, to characterize the baseline condition of the well, a [redacted] tool and [redacted] tools will be run which will aid in identifying anomalies in subsequent surveillance logging runs (**Table 6.8**).

Table 6.8—Cased hole logging program.

Cased Hole Logging Program		
Interval (ft)	Log	Purpose
[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]
	[redacted]	[redacted]
	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]
	[redacted]	[redacted]

6.3.2.3 Demonstration of Mechanical Integrity

Table 6.9 describes methodologies used to demonstrate MIT and will be performed on the deep monitoring well(s), Monitor 1, after installation and prior to commencing CO_2 injection operations:

Table 6.9—Mechanical Integrities

Test Name	Test Description	Program Period
MIT - Internal	500 psi fluid pressure, less than 10% loss over 30 minutes minimum	Prior to perforating
MIT - External	Temperature log	After casing cemented

Notice and the opportunity to witness the test/log shall be provided to EPA at least 48 hours in advance of a given test/log.

6.4 Annulus Pressure Test Procedures for Injection Well (Injector 1)

Annulus pressure tests will be performed after the well is completed but prior to injection and after any workover where the tubing and packer are removed. If the tubing is not pulled, the annulus pressure test will be performed every five years. The annular pressure will be at least 100 pounds per square inch (psi) higher than the tubing injection pressure and will be continuously monitored at the wellhead for abnormal pressure fluctuations. This continuous monitoring will identify any significant leaks to or from the annulus. The annular pressure test will be conducted by performing the following steps:

1) Establish a steady state injection rate for 72 hours to stabilize the annular temperature profile along the length of the well. This can be verified by no change in the downhole and surface injection temperature gauges.
2) Isolate the annulus by closing annular valves.
3) Monitor and record surface and bottom hole temperature and annular pressure for a minimum of 30 minutes.

4) A successful test result is no more than a 10% pressure decline in 30 minutes.
5) Annulus pressure test results will be reported to the administrator within 30 days of testing.

6.5 Annulus Pressure Test Procedures for Monitoring Well (Monitor 1)

Before the injection phase begins and every five years after, pressure tests will be performed. The annular pressure test will be conducted by pressuring the annulus to 500 psi of fluid pressure. With annulus isolated, the pressure will be monitored and recorded with a digital gauge. A successful pressure test will result in less than 10% loss of pressure over a minimum of 30 minutes. The results of the test will be reported to the administrator within 30 days of testing, or within 24 hours in situations where mechanical integrity is not achieved.

6.6 Pressure Fall-Off Test Procedures

Four Corners Carbon will conduct a baseline pressure fall-off test on Injector 1 prior to injection and every five years after injection has started in order to estimate injectivity and any change to the near wellbore environment.

The time-lapse pressure fall-off tests will provide information regarding changes in reservoir pressure, and injectivity by quantifying near wellbore skin, that may impede injection rates.

6.7 Quality Assurance and Surveillance Plan

Two BHP gauges will be used (primary and backup) to continuously monitor pressure with the well shut in. Monitoring will continue until radial flow conditions are observed on a semi-log plot of pressure vs. time. The results will be submitted to the administrator within 30 days of testing. The pre-operational logging and testing plan, the testing and monitoring plan outlines monitoring and finally the post injection site care plans provide details for data collection during all phases of the injection well from project planning to monitoring after injection has ceased and the well(s) are abandoned. Details of which can be found in the Quality Assurance and Surveillance Plan (QASP).