PRE-OPERATIONAL TESTING PROGRAM
40 CFR 146.82(a)(8), 146.87

Sugarberry CCS Hub

Facility Information

Facility Name: Sugarberry CCS Hub

Facility Contact: Sugarberry CCS, LLC
14302 FNB Parkway
Omaha, NE 68154

RRC Organization Report Number: 102245

Well Locations: Projection WGS84

Well	County/State	Latitude	Longitude
SB-01	Hopkins, TX	33.202707	-95.338539
SB-02	Hopkins, TX	33.189225	-95.375952
SB-03	Hopkins, TX	33.196028	-95.405035
SB-04	Hopkins, TX	33.219565	-95.434859
SB-05	Hopkins, TX	33.207361	-95.385666

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List of Acronyms/Abbreviations

AoR	Area of Review
CCS	Carbon Capture and Sequestration
CFR	Code of Federal Regulations
CO_2	Carbon Dioxide
CT	Computerized Tomography
DAS	Distributed Acoustic Sensor
DTS	Distributed Temperature Sensor
EPA	Environmental Protection Agency
FT-BGS	Feet Below Ground Surface
FOT	Pressure Fall-off Test
MIT	Mechanical Integrity Test
pH	Potential of Hydrogen (acidity or basicity of aqueous solutions)
PNC	Pulsed Neutron Capture
TBD	To Be Determined
UIC	Underground Injection Control
USDW	Underground Source of Drinking Water
VSP	Vertical Seismic Profile

A. Introduction

The pre-operational testing program is limited to data collected during drilling and completion of the injection wells for the purpose of ensuring conformance with the testing standards in 40 CFR 146.87 and 16 TAC 5.203(f) and the construction standards in 40 CFR 146.86 and 16 TAC 5.203(e). The testing program includes a combination of logs, surveys, cores, reservoir testing and integrity testing to provide site-specific subsurface data and to establish a baseline against which future measurements may be compared. Testing and monitoring activities, which will be conducted during the injection and post-injection phases are described in the **Testing and Monitoring Plan (Section 7)**. If deemed necessary to enhance injectivity, a Stimulation Program is provided in **Section 4** in conformance with 40 CFR 146.82(a)(9).

Notification of each step of the pre-operational testing plan will be provided to the UIC Program Director for witness opportunity. In accordance with 40 CFR 146.87(f), Sugarberry CCS, LLC will provide the UIC Program Director with the opportunity to witness all logging and testing by this subpart. Sugarberry CCS, LLC will submit a schedule of such activities a minimum of 30 days prior to conducting the first test and submit any changes to the schedule 30 days prior to the next scheduled test. The results of the testing activities will be documented in a report and submitted to the UIC Program Director within 30 days after the well drilling and testing activities have been completed.

As discussed in the **Site Characterization Narrative (Section 1)**, existing local geologic data are limited for the proposed sequestration complex. Results of pre-operational testing will be used to confirm assumptions made through correlation of these currently available geologic data to reduce uncertainty in the geologic characterization and model inputs. Sugarberry CCS, LLC understands that if pre-operational data conflict with geologic characterization data and model inputs presented in this application, revisions to the computational model and the Area of Review (AoR) will be necessary prior to obtaining approval to initiate injection.

B. Pre-Injection Testing Plan

The following tests and logs will be conducted during drilling, casing installation and after casing installation in accordance with 40 CFR 146.87, detailed below and specified for either or both injection and deep monitoring wells. Tests and procedures are summarized herein and described in greater detail in the **Injection Well Construction Plan (Section 4)**. Table 5-1 summarizes pre-injection testing for the proposed Sugarberry CCS Hub injection and monitoring wells. A figure depicting the location of all wells is provided in the **Testing and Monitoring Plan (Section 7).**

Table 5-1. Summary of Pre-Operational Tests by Well

Target Formation	Well Identifier	Estimated Elevation (ft-bgs)	Pre-Operational Tests
USDW	UOB-01 UOB-04	-780 (est top) -710 (est top)	Deviation surveys, logging
Above-Zone	AOB-01 AOB-04 AOB-05	-3,080 to -3,180 -3,060 to -3,160 -3,100 to -3,200	Deviation surveys, logging
In-Zone	IOB-01 IOB-02 IOB-03 IOB-04	-3,460 to -4,110 (Woodbine), -5,000 to -5,200 (Paluxy) -3,480 to -4,130 (Woodbine), -4,980 to -5,230 (Paluxy) -3,860 to -4,360 (Woodbine), -5,360 to -5,660 (Paluxy) -3,500 to -4,150 (Woodbine), -5,000 to -5,250 (Paluxy)	Deviation surveys, formation and fluid samples, whole cores, logging, fiber optic, MITs
Injection	SB-01 SB-02 SB-03 SB-04 SB-05	-3,480 to -4,130 (Woodbine), -4,980 to -5,230 (Paluxy) -3,520 to -4,170 (Woodbine), -5,020 to -5,270 (Paluxy) -3,780 to -4,280 (Woodbine), -5,280 to -5,580 (Paluxy) -3,510 to -4,160 (Woodbine), -5,010 to -5,260 (Paluxy) -3,600 to -4,000 (Woodbine), -5,100 to -5,400 (Paluxy)	Deviation surveys, formation and fluid samples, sidewall cores, logging, fiber optic, MITs, reservoir tests

B.1. Deviation Surveys

In conformance with 40 CFR 146.87(a)(1), deviation checks will be performed on all injection wells and monitoring wells. Deviation surveys are the measurement of a borehole's departure from vertical. Each well borehole will be drilled plumb and straight to optimize borehole to casing cement bond. The deviation shall be monitored using standard industry practices at the time of drilling so that the deviation is not more than 0.5 of one (1) degree between any two consecutive surveys, and not more than one degree over the entire well length. Any deviation from vertical greater than 0.5 of one degree will be corrected as drilling progresses. Drift indicator data and plots will be maintained by Sugarberry CCS, LLC for the duration of drilling and supplied with the daily drilling logs. The indicator will be inspected and disassembled, recalibrated, or tested as necessary. The requirements for a non-deviated hole may be modified if deviations result due to subsurface conditions and all reasonable care to avoid deviation has been exercised, the deviation will not materially affect the usefulness or performance of the well or further drilling operations (including setting of casings and future testing).

B.2. Mud Logging / Formation Samples and Testing

In accordance with 40 CFR 146.87(d), formation samples will be collected at selected intervals, based on the variation in formations, during pilot hole drilling of each injection and deep monitoring well. More frequent collection will begin in the upper sands of the Eagle Ford Formation (the above-zone monitoring interval, and continue through the Eagle Ford (the regional seal), the Woodbine, the Fredricksburg and Washita shales (the pressure dissipation zone between the injection intervals) and the Paluxy sands. Representative cutting samples will be collected and catalogued for future assessment.

B.3. Fluid Samples and Analyses

Prior to injection, Sugarberry CCS, LLC will collect representative fluid samples from the injection zones via the injection and deep monitoring wells required under 40 CFR 146.87(d). Samples will yield information necessary for geochemical analysis and characterization to: a) demonstrate compatibility of the formation fluids with injected CO_2; b) examine potential for geochemical interactions and resulting effects on storage capacity, and; c) verify that the injection zones are not underground sources of drinking water (USDW). Samples will be analyzed by a certified laboratory and parameters will include but not be limited to fluid temperature, pH, and conductivity. Sugarberry CCS, LLC will also measure reservoir pressure and static fluid level in the injection zones.

B.4. Formation Samples and Analyses

In accordance with 40 CFR 146.87(b), Sugarberry CCS, LLC will collect whole cores during the drilling of the in-zone monitoring wells to characterize the injection and confining zones. These data will be supplemented by sidewall cores obtained from the injection wells and will collectively provide confirmation that the injection zones will support the proposed injection schedule and that the caprock will be sufficient as a primary confining zone for the project.

Whole cores will be collected in core barrels of approximately four (4) inches in diameter and ten (10) or more feet in length, outfitted with a core bit appropriate for the formation(s). Sidewall cores will be approximately one (1) inch in diameter. The depths of the intervals to be cored will be selected based on evaluation of rock cuttings and will be analyzed by a laboratory specializing in core analyses. Analyses will include fluid saturation, porosity, grain density, sieve analysis, horizontal and vertical permeability, x-ray diffraction, computerized tomography (CT) scan, acoustic velocity, compressive strength testing, steady state permeability, mercury injection capillary pressure, resistivity, and fracture pressure. Core handling procedures will be conducted in accordance with the "Sample Examination Manual," Methods in Exploration Series published by the American Association of Petroleum Geologists, or equivalent. The core analyses will be provided to the UIC Program Director.

Table 5-2 presents the solid phase data collected from cores to be used for varying site characterization activities within the AoR.

Table 5-2. Core Collection Program

Interval	Formation	Elevation Range (ft-bgs)	Purpose
Primary Confining	Eagle Ford (shale members)	-3,030 to -3,480	• Characterize porosity, permeability, relative permeability, and capillary pressure and verify these parameters support confinement of CO_2 and formation fluids • Characterize solid phase assemblage and potential for geochemical interactions with injected CO_2 that may affect integrity • Characterize geomechanical properties including ductility, rock strength brittleness, and pore pressure
Injection	Woodbine	-3,480 to -4,170	• Characterize porosity, permeability, relative permeability, and capillary pressure and verify these parameters support injectivity of CO_2 • Characterize solid phase assemblage and degree of mineral precipitation, compatibility with injected CO_2, and potential for geochemical interactions and effects on storage capacity • Characterize geomechanical properties including ductility, rock strength brittleness, and pore pressure
Pressure Dissipation Zone (Baffle)	Fredricksburg and Washita Shales	-4,170 to -4,980	• Characterize porosity, permeability, relative permeability, and capillary pressure and verify these parameters support confinement of CO_2 and formation fluids • Characterize solid phase assemblage and potential for geochemical interactions with injected CO_2 that may affect integrity • Characterize geomechanical properties including ductility, rock strength brittleness, and pore pressure
Injection	Paluxy	-4,980 to -5,580	• Characterize porosity, permeability, relative permeability, and capillary pressure and verify these parameters support injectivity of CO_2 • Characterize solid phase assemblage and degree of mineral precipitation, compatibility with injected CO_2, and potential for geochemical interactions and effects on storage capacity • Characterize geomechanical properties including ductility, rock strength brittleness, and pore pressure

B.5 Geophysical Logging

In conformance with 40 CFR 146.87(a)(2), (3) and (4), Sugarberry CCS, LLC will conduct geophysical logging on all injection wells and monitoring wells before and upon installation of the casing strings. Open borehole logging will provide in-situ subsurface geologic and hydrologic information to total depth. Cased borehole logging will provide information on well integrity and cement bonding. Logging will be conducted in the surface and long string boreholes but will not be conducted in the large-diameter conductor borehole. The logging program provided below in Table 5-3, reflects required logs under 40 CFR 146.87.

Table 5-2. Logging Program

Interval	Section	Log
Conductor[1]	Open Borehole	None
	Cased Hole	None
Surface[1]	Open Borehole	Resistivity, spontaneous potential, caliper
	Cased Hole	Cement bond, variable density, temperature
Long String[1]	Open Borehole	Gamma ray, resistivity, spontaneous potential, caliper, fracture finder
	Cased Hole	Cement bond, variable density, temperature, casing inspection

(1) *Approximate depths and casing sizes provided in **Injection Well Construction Plan (Section 4)***

To facilitate logging, wellhead equipment will be furnished with a stripper head (wireline packoff) assembly. The stripper head assembly will be securely attached to the wellhead to prevent flow from the well when under pressure. The stripper head assembly will be sized to accommodate the width and length of the longest geophysical tool used for conducting the tests and surveys. The wellhead will be furnished with bleed and isolation valves so the stripper head assembly can be shut-in and isolated from the wellhead equipment. The assembly will include a pressure gauge and appurtenances for monitoring well pressure during testing.

Geophysical logs will be performed by a company licensed and experienced in the performance of such logs and interpretation will be performed by a qualified geophysical log analyst. Logs and interpretations will be provided to the UIC Program Director.

B.6. Permanent Fiber Optic Monitoring System

Downhole deployment of fiber optic provides temperature, strain, and acoustic data measurements at high spatial and temporal resolutions with full wellbore coverage through distributed acoustic sensors (DAS) and distributed temperature sensors (DTS). The data is used for reservoir characterization based on reflection and refraction seismic, CO_2 plume detection with time-lapse vertical seismic profile (VSP), detection and location of micro-seismic events, well integrity and leak detection. The cable is to be permanently attached to the casing using cross-coupling clamps that both protect and secure the cable in place. Mid-joint clamps with extra mass are installed at intervals within the planned perforation (i.e., injection) zone. These clamps are used to locate the cable position around the long string casing prior to the perforation process. On the surface, the cable will be positioned through the casing hanger and out of the wellhead to a surface enclosure. The enclosure is used to host and protect the optical splices connecting the downhole cable to the surface cable, which is routed to a data acquisition system.

B.7. Demonstration of Mechanical Integrity and Reservoir Tests

Below is a summary of mechanical integrity tests (MITs) and reservoir tests to be performed on each injection well prior to operation, in accordance with 40 CFR 146.87(a)(4) and 40 CFR 146.87(e). MITs will also be conducted on each deep monitoring well prior to operation.

The purpose of the MIT is to confirm casing integrity (internal MIT, conducted through a standard annulus pressure test) and cement seal integrity (external MIT, conducted using temperature logs, fiber optic monitoring, and casing inspection logs). Reservoir tests are conducted through pressure fall-off tests (FOT) and injectivity or pump tests to obtain information on hydrologic reservoir properties. This information is used to determine the pressure build up at the wellbore and real-time storage capacity. A list of the tests and testing frequency is provided in Table 5-3.

Temperature logs, casing inspection logs, and FOTs will be conducted through wireline deployment of tools to confirm long string casing integrity using experienced and licensed personnel with the appropriate equipment to complete all testing phases. Standard annulus pressure tests will be conducted at the wellhead under qualified personnel using either liquid or gas to confirm tubing to long string casing integrity. Fiber optic monitoring will be installed outside of the casing in the injection and deep monitoring wells as described in the **Testing and Monitoring Plan (Section 7).** Injectivity and pump tests will be conducted at the wellhead using pump trucks and monitoring gauges appropriate for real-time monitoring and recording of data.

Table 5-3. Pre-Operational Testing Summary

Class VI Rule Citation	Rule Description	Test Description	Program Period
40 CFR 146.89(a)(1)	MIT - Internal	Standard Annulus Pressure Test	Prior to operation, annually, following corrective action
40 CFR 146.87(a)(4)	MIT - External	Temperature Log	Prior to operation, annually, following corrective action
40 CFR 146.87(a)(4)	MIT - External	Fiber Optic Monitoring System	Prior to operation, annually, following corrective action
40 CFR 146.87(a)(4)	MIT - External	Casing Inspection Log	Prior to operation, following corrective action
40 CFR 146.87(e)(1)	Reservoir Test	FOT	Prior to operation, every five years
40 CFR 146.87(e)(1)	Reservoir Test	Injectivity or Pump Test	Prior to operation

B.8. Internal Mechanical Integrity

Internal mechanical integrity will be performed via a standard annulus pressure test to confirm the well's ability to maintain pressure in the fluid-filled annular space between the tubing and casing. As described in EPA's guidance for standard annulus pressure tests, the annular space will be pressurized, and pressure readings will be recorded for a minimum of one (1) hour. Internal mechanical integrity will be confirmed if the pressure gain or loss does not exceed 3% of the initial test pressure.

B.9. External Mechanical Integrity

External mechanical integrity will be performed using temperature logs, fiber optic monitoring, and casing inspection logs to confirm that there are no external influences on the cemented long string casing. While fiber optics will sense downhole acoustic changes, temperature logs may also be used to identify fluid movement through the confining zone adjacent to the well borehole and can identify casing leaks. Noise logs or pulsed neutron capture (PNC) logs may be used if anomalies are identified in the temperature logs. Data from the logging runs will be used to determine the extent of CO_2 migration, if any, and if the integrity of the well casing and/or cement has been compromised.

B.10. Pressure Fall-Off Testing

Hydrologic characteristics of the storage reservoir can be determined by conducting pressure fall-off testing. This test measures the relative time lapse between pressure fall-off in a stressed reservoir against the ambient formation pressure.

B.11. Injection or Pump Testing

Injection testing provides hydrogeologic characteristics of the injection zone and validates the numerical modeling used to estimate the lateral extents of the AoR. Freshwater will be injected into the well at a constant and measured rate. The injectivity test may be conducted as a constant rate test or at incrementally increasing rates (step-rate testing) to determine the pressure response within the injection interval. Data obtained from step-rate testing will be used to validate the calculations of formation fracture pressure at the top of the injection zone (conservatively correlative to the base of the confining zone).

C. Reporting

All test records and reports, prepared by knowledgeable analysts, will be provided to the UIC Program Director within 30 days of testing, in accordance with 40 CFR 146.91(b) and 16 TAC 5.207(a)(1). Reports will include but not be limited to: date and time of each test, results and interpretations, assumptions, analytical methods, quality assurance information, tabular and/or graphic data, photographs, descriptions of sampling equipment, sampling methodology, sample preservation methods, calibration records, and any changes in interpretation of injectivity and storage potential based on test results.

D. References

American Association of Petroleum Geologists. 1981. AAPG Sample Examination Manual, Methods in Exploration Series. Accessed online at: https://store.aapg.org/detail.aspx?id=DD0053

U.S. EPA Region 5 (2008). Determination of the Mechanical Integrity of Injection Wells. UIC Regional Guidance #5. February 2008. Accessed online at: http://www.epa.gov/r5water/uic/r5guid/r5_05_2008.htm.

U.S. EPA Region 6 (2002). UIC Pressure Falloff Testing Guideline, 3rd Revision. Accessed online at: https://www.epa.gov/sites/default/files/2015-07/documents/guideline.pdf

U.S. EPA Region 8 (1999). Step-Rate Test Procedure. Accessed online at: https://www.epa.gov/sites/default/files/2015-08/documents/r8_guideline_-_step_rate_testing.pdf