1.0 PROJECT NARRATIVE
40 CFR 146.81

TEXAS CARBON STORAGE I

Facility Information

Facility name: [redacted]

Facility contact: Kim Do
Director of Financial Planning and Analysis
[redacted]
214-751-2568 | [redacted]

Well name: [redacted]

Well location: [redacted], TEXAS
Latitude: [redacted]
Longitude: [redacted]

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List of Abbreviations

Abbreviation	Description
°	Degree
µm	Micrometer
^{13}CR	Corrosion-resistant chrome
2D	Two-dimensional
3D	Three-dimensional
ACZ	Above confining zone
AoR	Area of Review
Bbls	Barrels
BOP	Blowout preventor
BOPE	Blow out prevention equipment
BTC	Buttress threaded and coupled
C	Celsius
CBL-VDL	Cement bond log – variable density log
CCS	Carbon capture and storage
CFR	Code of Federal Regulations
CO_2	Carbon dioxide
DAS	Distributed Acoustic Sensing
DOE	Department of Energy
DOT	Department of Transportation
DRM	Dynamic Reservoir Model
DTS	Distributed Temperature Sensing
EOD	Environment of deposition
EPA	Environmental Protection Agency
ERRP	Emergency and Remedial Response Plan
F	Fahrenheit
FEMA AE	Federal Emergency Management Agency Adverse Effects
FMEA	Failure, Mode, Effect, Analysis
ft	Feet
FO	Fiber optic
gal	Gallon
ID	Identification
JFE	JFE Steel Corporation
KCl	Potassium chloride
lb	Pound
LCM	Lost circulation material
LTC	Long threaded and coupled
m	Meter
MD	Measured depth
mD	Millidarcy
mg	Milligram
MI	Move-in

mi	Mile
MIT	Mechanical integrity test
mL	Milliliter
MMscf	Million standard cubic feet
ms	Millisecond
MMmt	Million metric tonnes
MVA	Monitoring, Verification, and Accounting
N/A	Not applicable
NACE	National Association of Corrosion Engineers
NaCl	Sodium chloride
NELAP	National Environmental Laboratory Accreditation Program
NETL	National Energy Technology Laboratory
ORP	Oxidation-reduction potential
P&A	Plug and abandonment
PFO	Pressure fall-off
PGA	Peak ground acceleration
PISC	Post-injection site closure
PM	Project Manager
PNC	Pulsed neutron capture
Poz	Pozzolan
ppg	Pounds per gallon
ppm	Parts per million
psi	Pounds per square inch
psig	Pounds per square inch gauge
QA	Quality assurance
QC	Quality control
QASP	Quality Assurance and Surveillance Plan
QR	Quality Representative
RPD	Relative percent difference
RPN	Risk Priority Number
RU	Rig up
SCADA	Supervisory Control and Data Acquisition
SEM	Static Earth Model
SF	Safety factor
SME	Subject matter expert
SOP	Standard operating procedures
SP	Spontaneous potential
SPCC	Spill Prevention, Control, and Countermeasure
SPF	Shots per foot
STC	Short threaded and coupled
STW	Stratigraphic Test Well
TBD	To be determined
TD	Total depth
TDS	Total dissolved solids
TVDss	True vertical depth sub-sea

TW	Test Well
UIC	Underground Injection Control
USDW	Underground source of drinking water
USGS	United States Geological Survey
VSP	Vertical Seismic Profile

1.0 Project Narrative

1.1 Project Background and Contact Information

White Energy Carbon Solutions, LLC ("White Energy") primary goal of the Texas Carbon Storage I project is to sequester anthropogenic carbon dioxide (CO_2) near [redacted] Texas.

The sequestration of anthropogenic carbon dioxide (CO_2) will be sourced from [redacted] CO_2 will be captured onsite and transported via pipeline to the injection site for permanent sequestration. The project is expected to run for [redacted] years and inject an average of [redacted] MT per year. Operations of the capture facility and injection site will be done by White Energy or qualified designee.

An overview of the project site is presented in **Figure 1-1** which shows the location of the proposed injection well ([redacted] #1), local infrastructure and the Area of Review (AoR). The data used in the preparation of this permit application was acquired in a site-specific test well (TW), [redacted] #1, which has been drilled within the AoR (**Figure 1-1**). An extensive suite of wireline logs and sidewall cores were acquired and incorporated into the computational model. Injection well, [redacted] #1, will be drilled to collect additional stratigraphic information and further reduce uncertainty in the characterization of the geomechanical and hydrogeological subsurface at the project site. Extensive wireline logging, coring, fluid sampling, and formation hydrogeologic testing will be performed. These data will be incorporated into the static earth model and dynamic models (Permit Section 2.0).

[redacted]

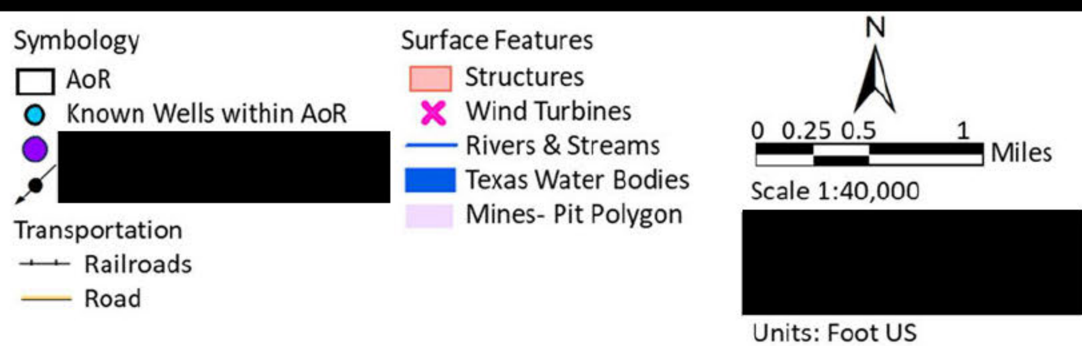


Figure 1-1: Texas Carbon Storage I project showing proposed location injection well ([redacted] #1), existing characterization well ([redacted] #1), AoR, documented wells within the AoR, and local infrastructure.

1.1.1 Project Goals

In this project, White Energy plans to:

- Construct a capture facility [redacted]
- Build the infrastructure needed to transport CO_2 to the injection site
- Drill a second stratigraphic test well ([redacted] #1) to collect additional site-specific data to further support the data requirements of the EPA Class VI rule
- Convert [redacted] #1 to CO_2 injection service
- Utilize the existing [redacted] #1 well as a deep monitoring well
- Monitor the subsurface for any potential impacts to the deepest underground source of drinking water (USDW)
- Upon completion of the injection phase of the project, verify stability of the CO_2 plume and decline of storage formation pressure toward pre-injection levels, verify plume predictions made by the computational modelling, demonstrate non-endangerment of USDWs, safely plug all injection wells, and decommission associated infrastructure

1.1.2 Partners/Collaborators

Key partners and collaborators on this project are listed in **Table 1-1**.

Name	**Role**
White Energy Carbon Solutions, LLC	Owner
White Energy Carbon Solutions, LLC	Storage Operator
White Energy Carbon Solutions, LLC	CO_2 Capture Operator

Table 1-1: Key project partners and collaborators.

1.1.3 Overview of the Project Timeframe

The overall timeframe of the project, including well drilling, CO_2 injection, monitoring, and closure, is anticipated to be approximately 77 years (**Table 1-2**). This includes:

- 1 year for permit approval
- 1 year for construction
- [redacted] years of CO_2 injection and monitoring
- 1 year for closure
- 50 years of post-injection site care (PISC) and monitoring

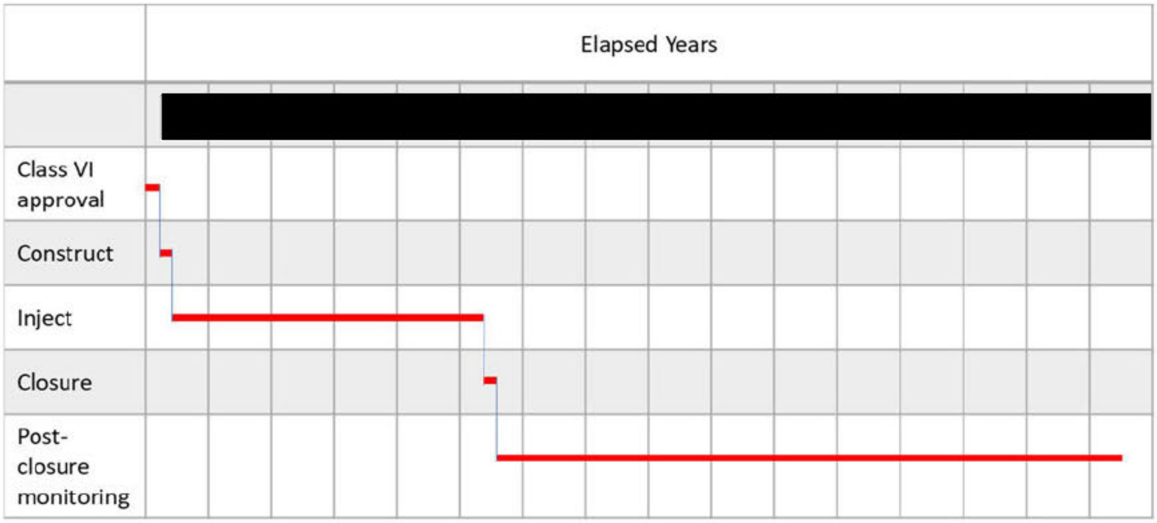


Table 1-2: Project Gantt Chart

1.1.4 Proposed Injection Mass/Volume and CO_2 Source

The average annual injection rate is [redacted] MMmt/Yr. Prior to injection, the chemical and physical characteristics of the injectant will be confirmed using appropriate analytical methods and will be shown in **Table 1-3**.

Component	Quantity
CO_2	TBD
Oxygen	TBD
Nitrogen	TBD
TEG	TBD
Water Vapor	TBD
Hydrogen sulfide (H_2S)	TBD

Table 1-3: CO_2 stream composition injected at the Texas Carbon Storage I project

1.1.5 Injection Depth Waiver or Aquifer Exemption Requested

No injection depth waiver or aquifer exemption is being sought as part of this permit application.

1.1.6 Other Administrative Information

Table 1-4 provides the administrative information for this Class VI injection well permit application as required by 40 CFR 144.31(e)(1 through 6).

Injection Well Information	
Well Name and Number	[redacted] #1
County	[redacted], Texas
Latitude and Longitude	[redacted]
Applicant Information	
Name	White Energy Carbon Solutions, LLC
Address and Phone Number	[redacted]
Project point of contact	Kim Do Director of Financial Planning and Analysis
Ownership Status	Private
Status as federal, state, private, public, or other entity	Private
The injection well and the sequestration site are not located on Indian land.	

Table 1-4: General Class VI CO_2 injection well permit application information.

1.2 Site Characterization

1.2.1 Regional Geology, Hydrogeology, and Local Structural Geology [40 CFR 146.82(a)(3)(vi)]

The White Energy [redacted] located [redacted] Texas. The facility sits within the [redacted] basin in the [redacted] (**Figure 1-2**). This region has favorable geology for carbon storage in porous and permeable deep saline formations interstratified with low porosity and low permeability confining zones. The present-day [redacted], and [redacted] basins were part of a broad passive margin on the edge of the North American craton (Merrill et al., 2015). The Ancestral Rocky Mountains orogeny established the current structural configuration of the [redacted] basin, which includes the northwest-trending Amarillo Mountains uplift (Merrill et al., 2015). Additional structural features such as faults generally trend northwest-southeast, and trend west along the Matador uplift (Merrill et al., 2015). Local structural features near the site area, include a small basement uplift named the Arney positive (See Section 1.2.3 Faults and Fractures; **Figure 1-6**) (Budnik, 1989), extending northward into the southeast corner of [redacted] County and extending southeastward [redacted] and [redacted] Counties. Budnik (1989) suggests this feature is bounded by basement faults on the southeast and northwest sides. Basement offset in [redacted] is not observed or present in licensed 2D seismic data near the site area, however a low magnitude fold is visible within Precambrian through Permian Wichita sections. The Castro trough sits southeast of the Arney positive along the synclinal axis of the [redacted] (Budnik, 1989). Further information regarding detailed discussion of nearby faults can be found in Section 1.2.3 Faults and Fractures and **Figure 1-6**. The Precambrian basement in the [redacted] basin reaches depths of 10,000 ft below the surface and has two axes in the basin, an east-west basin axis in the eastern part of the basin and a northwest-southeast axis in the western part of the basin (Merrill et al., 2015). The sedimentary rocks of the [redacted] basin are primarily Paleozoic in age (Merrill et al., 2015).

The [redacted] basin has favorable geology for carbon storage in various formations. The focus of this permit is the clastic rocks of the [redacted]. This formation is composed of arkosic detrital [redacted] sediment, primarily sand-sized quartz and feldspar in lithology. The depth to the top of the storage formation, [redacted], at the site location is [redacted] ft true vertical depth (TVD) subsurface, which exceeds the depth criteria required to sustain a supercritical phase of the injected CO_2 at the site. The primary confining zones for the storage formation are composed of low permeability carbonates present in the [redacted]. The stratigraphic column in **Figure 1-3** shows the study area's stratigraphic succession, highlighting the storage formation and confining zone.

[redacted]

Figure 1-2: Structural Elements of the Palo Duro Basin; [redacted]

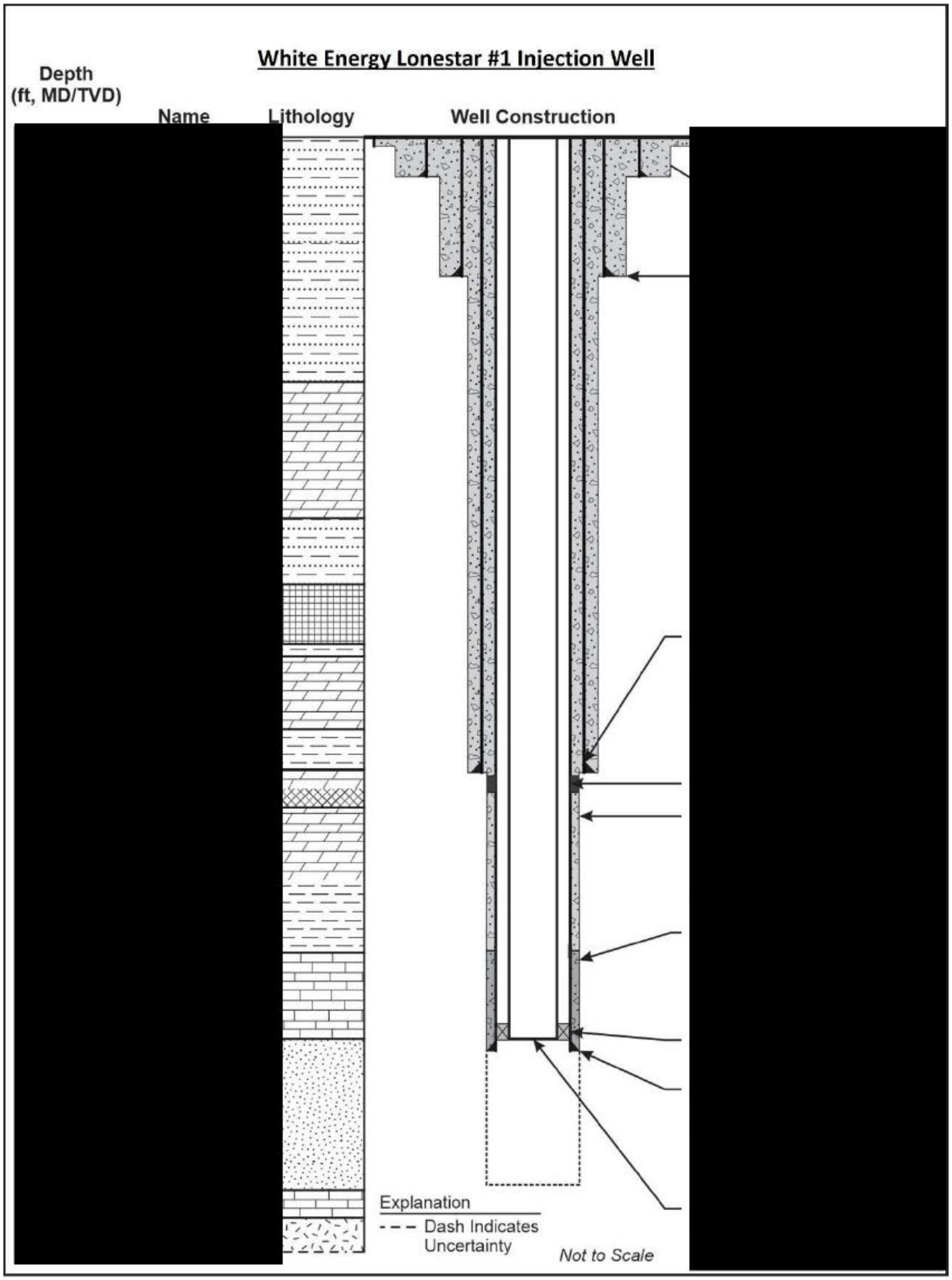


Figure 1-3: Stratigraphic column with lithology for the [redacted] site (left). Estimated depths are based on structural model surfaces at the location of the [redacted] #1 injection well. [redacted] #1 injection well schematic based on current information from [redacted] #1 (right).

1.2.2 Maps and Cross Sections of the AoR [40 CFR 146.82(a)(2), 146.82(a)(3)(i)]

The formations found in the subsurface of the [redacted] site are locally correlative and laterally extensive across the region, and none of the data reviewed suggests any formation pinch-outs within the area. This was evaluated and confirmed through regional reports, regional and local cross sections and maps, well correlations, and 2D seismic interpretation throughout the immediate site location and surrounding area. Regional structure and thickness maps for these units and further detail on data types used can be found in Section 1.2.4. Major geologic units and their stratigraphic relationships are depicted in the local cross section shown in **Figure 1-4**.

The deepest USDW at the site location is the [redacted]. This aquifer is composed of sandstones, conglomerates, and siltstones and is overlain by the [redacted]. At the [redacted] site project, the base of the [redacted] above mean sea level, which is equivalent to [redacted] (**Figure 1-4; Figure 1-5**). In some areas, portions of the [redacted] are in hydraulic communication with the [redacted] and can be considered as part of the [redacted]). At the site location, the storage formation is found at [redacted] true vertical depth sub-sea (TVDss), which is equivalent to [redacted] TVD. There are various secondary confining zones between the CO_2 storage formation and the base of the [redacted] such as the [redacted] evaporitic formations. Near the [redacted] #1 well, the [redacted] are expected to fall at approximately 65-200 ft and 460-1,060 ft TVD, respectively (See Section 2.4.1 and **Table 2-8**). The exact spatial relationship between the lowermost USDW and the injection and confining zones will be confirmed prior to start of injection.

[redacted]

Figure 1-4: Geologic cross section from northwest to southeast featuring the structural configuration of subsurface strata that contain the storage formation and confining zones, as well as the deepest USDW and additional confining zones. Well log tracks from left to right: Measured Depth (MD), Sub-Sea True Vertical Depth (SSTVD), Gamma Ray (XGR), and Deep Resistivity (XRDEEP).

[redacted]

Figure 1-5: Structural contours of the base of the [redacted] Site location denoted with yellow star (modified from Bradley and Kalaswad, 2003).

A map of the AoR, including existing wells within the AoR and the proposed injection well is shown in **Figure 1-1**. The AoR for the [redacted] site location has a total of 85 known wellbores; 84 documented shallow groundwater wells registered with the Texas Water Development Board and the High Plains Water Conservation District, and the deep [redacted] #1 test well (future deep monitoring well). The groundwater wells within the AoR vary in depth from 92 to 952 ft and are mostly used for irrigation or domestic use. Of these 84 registered groundwater wells, 10 are plugged and the remainder are currently active. More information on the wells within the AoR can be found in Section 2.4.1 of the AoR and Corrective Action Plan document 40 CFR 146.84(b).

1.2.3 Faults and Fractures [40 CFR 146.82(a)(3)(ii)]

Regional tectonic faulting within the [redacted] basin has been previously studied by a variety of authors including but not limited to Dutton et al. (1982) and Budnik (1989) (**Figure 1-6**). Budnik (1989) documented a basement fault northeast of the AoR (**Figure 1-6**) on the southwest side of the Arney positive though no evidence of offset has been found by our study. The literature-documented fault sits outside the AoR and lies [redacted] from the nearest CO_2 plume extent. 2D seismic data was licensed within the AoR and extends across the literature-documented fault. The seismic data was tied to the [redacted] #1 well to ensure subsurface horizons were appropriately picked in time (**Figure 1-7**). Two seismic lines with sufficient data quality, Lines EE and CC, cross the area associated with the literature-documented fault and do not show offset of time horizons (**Figure 1-8**). Line AA, east of the [redacted] #1 well, also crosses the literature-documented fault but is of poor data quality and was not used for interpretation (**Figure 1-9**; **Table 1-5**. The presence of a fold was observed in the formations of interest (above Precambrian basement) including the Permian Wichita through the Pennsylvanian sections at the location of the literature-documented fault (**Figure 1-8**). No offset is observed in seismic lines crossing the literature-documented fault at the storage formation intervals (**Figure 1-8**). For this reason, no faults are expected to impact the integrity of the confining zone and the containment of injected CO_2 at the site location. Additionally, the [redacted] #1 well collected image logs over the [redacted] intervals which were interpreted by Baker Hughes. Over the [redacted] confining zone and [redacted] storage formation, drilling induced tensile fractures were observed. Single and sporadic natural fractures were interpreted, however no prolific fracture zones were observed in these intervals. Single fractures did not extend up through the confining zone and are not anticipated to impact the integrity of the confining zone. Additional data to be collected at the [redacted] #1 well include additional image logs and whole core samples to confirm the absence of fractures in the confining zone.

[redacted]

Figure 1-6: Basement fault map [redacted]. The proposed injection well, [redacted] #1 is denoted with a black dot (modified from [redacted]).

[redacted]

Figure 1-7: 2D PSTM seismic Line DD with [redacted] #1 (blue dot) seismic-to-well tie and associated horizon interpretation (data courtesy of [redacted]). Inset map shows the proposed [redacted] #1 injection well (black dot), [redacted] #1 well with velocity data (red dot), and Line DD (highlighted in orange).

[redacted]

Figure 1-8: 2D PSTM seismic Line CC with associated horizon interpretation and fold feature (data courtesy of [redacted]). Fold does not show fault offset in the intervals of interest. The inset map shows the proposed [redacted] #1 injection well (black dot), [redacted] #1 well with velocity data (red dot), and Line CC (highlighted in orange). Fold outline highlighted in blue dashed area.

1.2.4 Storage Formation and Confining Zone Details [40 CFR 146.82(a)(3)(iii)]

Much of the subsurface data analyzed in this study are derived from regional wells where modern wireline log data exists, as well as historical log data from wells in proximity to the site (**Figure 1-9**). Well logs from 35 wells across the region were obtained, which provided multiple log types of interest and adequate spatial and depth coverage. These were used to develop structural surfaces throughout the area. Of these wells, nine had sufficient log data to provide regional and local measurements of in-situ physical rock properties, such as porosity, at depths that captured the entirety of the target storage formation and confining zone formations. Additionally, the [redacted] #1 well was drilled within the AoR in [redacted] 2023 to confirm storage formation presence and evaluate local storage formation quality. This well collected modern wireline log data as well as multiple sidewall cores that provided near-site storage formation information such as the expected formation depth and thickness, as well as porosity and permeability values. Further information regarding the data collected in this well is discussed in Section 1.2.5 Geomechanical and Petrophysical Information [40 CFR 146.82(a)(3)(iv)]. These datasets enabled the project to interpret crucial subsurface information regarding the lithology and quality of the storage formation and confining zone and calculate rock properties. In addition, various 2D seismic lines were licensed to further evaluate the subsurface of the site location (**Figure 1-9**). This data includes six partial 2D seismic lines totaling 39.1-line miles. Of the six seismic lines, three were of good seismic quality, two fair and one poor (**Table 1-5**). The poor-quality seismic line was not used in any analyses. The [redacted] #1 well was used for a seismic-to-well tie to Line DD leveraging check shot (time/depth) information from the nearby [redacted] #1 well, as a check shot was not acquired in [redacted] #1 (**Figure 1-7**). Seismic interpretation was completed for key horizons (**Figure 1-7**; **Figure 1-8**) resulting in time surface grids. Time data was converted to depth and integrated with formation tops from nearby wells to create final depth grids.

[redacted]

Figure 1-9: Map of the wells and 2D seismic data used for subsurface interpretation at the [redacted] site location. The proposed injection well is denoted with a black dot.

Vendor	**2D/3D**	**Survey Name**	**Yr Acq / Yr Last Processing**	**Licensed Line Mileage**	**Quality Rating**
[redacted]	2D	AA	1968/2014	6.0	Poor
[redacted]	2D	BB	1968/2014	6.5	Fair
[redacted]	2D	CC	1981/2014	7.8	Good
[redacted]	2D	DD	1981/2014	4.7	Good
[redacted]	2D	EE	1981/2014	9.1	Good
[redacted]	2D	FF	1980/2016	5.0	Fair

Table 1-5: Summary of licensed 2D seismic data from [redacted] within the AoR.

Confining Zone: [redacted]

The confining zone at the site location is the regional and laterally extensive [redacted], which sit atop the [redacted] interval and below the [redacted] strata. Near the site location, the top of the [redacted] shelf carbonate is anticipated at depths of -[redacted] TVDss, which is equivalent to [redacted] TVD and with a gross thickness [redacted]. Depth and thickness across the AoR were determined by picking formation tops from digital well log data proximal to the site. These were gridded using a convergent interpolation algorithm from Schlumberger's Petrel® and contoured in TVDss. All surface maps were quality control checked using the 2D seismic lines. Maps of the top structural surface and the thickness of the Pennsylvanian Carbonates are presented in **Figure 1-10**.

Storage formation: [redacted]

The storage formation at the site location is principally the [redacted]. The top of the [redacted] storage formation is found at [redacted] TVDss, which is equivalent to [redacted] TVD, with a gross thickness of approximately [redacted]. Maps of the top structural surface and the thickness of the [redacted] are presented in **Figure 1-11**. At these depths, pressure and temperature conditions are high enough to sustain a supercritical phase of the injected CO_2 at the site. The modest variation in thickness demonstrates no evidence of local formation pinch out or faulting that would affect CO_2 storage. All surface maps were quality control checked using the 2D seismic lines.

[redacted]

Figure 1-10: Structural map showing True Vertical Depth Sub-Sea (ft) from the surface to the top of the [redacted] (left) and formation thickness map (right) at the [redacted] project location. Contour intervals are 200 ft and 50 ft, respectively. The black box indicates the Static Earth Model area, and the white dashed line indicates the Dynamic Reservoir Model boundary.

[redacted]

Figure 1-11: Structural map showing True Vertical Depth Sub-Sea (ft) from the surface to the top of the [redacted] (left) and formation thickness map (right) at the [redacted] project location. Contour intervals are 200 ft and 50 ft, respectively. The black box indicates the Static Earth Model area, and the white dashed line indicates the Dynamic Reservoir Model boundary.

During early [redacted] time, the [redacted] basin was composed of shallow seas that, as the basin deepened, created isolated carbonate buildups around the topographic highs of the [redacted] shelf (Handford and Dutton, 1980). These buildups coalesced and formed large shelf margins of several hundred feet in height (Handford and Dutton, 1980). During [redacted] time, the main carbonate organisms that created these buildups were sponge-phylloid algal bioherms, crinoids, fusinilids, bryozoans, and brachiopods (Handford and Dutton, 1980). Sediments of the [redacted] shelf carbonates consist mostly of limestone and dolomite. Rotary sidewall cores collected at the [redacted] #1 well have a bulk grain density of 2.62 g/cm^3 which corresponds to limestone. An example of the samples collected at the [redacted] #1 well can be seen in **Figure 1-12**. Data and rock samples collected from the proposed injector, [redacted] #1, will be used to confirm that the mineral composition of the [redacted] shelf carbonates is conducive to confining CO_2.

[redacted]

Figure 1-12: Sidewall core of the [redacted] carbonates interval in the [redacted] #1 well. Fractures are drilling-induced tensile fractures based on Baker Hughes image log analyses and interpretation. Based on same image log, they are not pervasive in the confining zone.

The [redacted] formation is a heterogeneous formation composed mainly of terrigenous sediments with some interbedded limestones (Handford and Dutton, 1980). The main source of sediments for the [redacted] at the site location was the Bravo Dome, which is part of the Wichita Igneous province, composed of mainly granite and granodiorite (Dutton, 1984). Cores analyzed from [redacted] in [redacted] basin have medium grained sandstones as well as conglomerates (Handford and Dutton, 1980). The mineralogical composition of these sandstones was 60-80% quartz, 20-30% feldspar, and 10% lithic rock fragments (Handford and Dutton, 1980).

Based on these components and Folks (1974) classification scheme for sandstones, the [redacted] is classified as arkose, lithic arkose, and subarkose (**Figure 1-13**). Additionally, feldspar and quartz overgrowths as well as ankerite, kaolinite, and calcite cements are present ([redacted]) (**Table 1-6**). The sidewall cores of the [redacted] collected at the [redacted] #1 well can be seen in **Figure 1-14**. These samples show a wide variation in grain size, possibly related to the environment of deposition within the Fan Delta system. Abundant lithic fragments are present as well as quartz and feldspar grains. Additionally, regional well data from the [redacted] well northwest of the AoR has [redacted] sediments composed of granular, very coarse sandstone to sandy pebble conglomerates with poor to moderate sorting of subangular grains (Dutton, 1984).

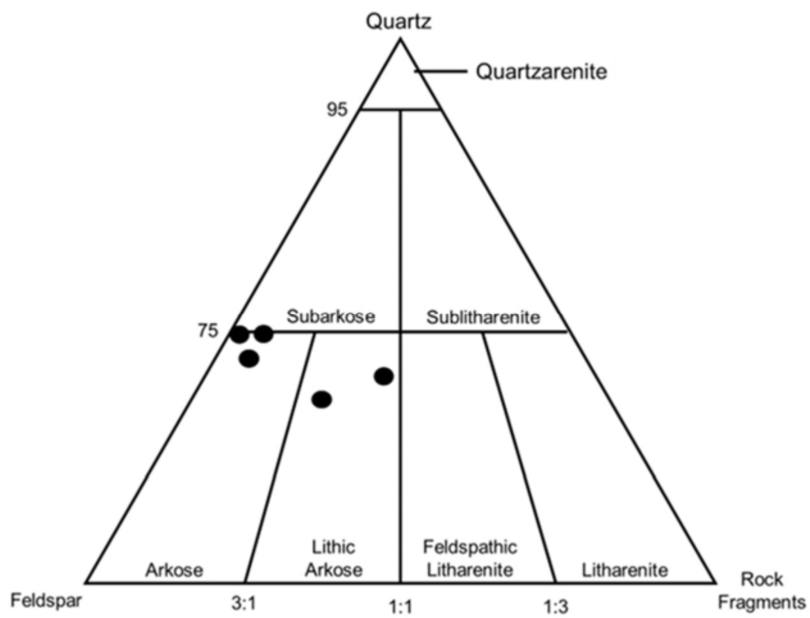


Figure 1-13: Ternary diagram displaying the compositional make up of rock samples collected from the [redacted], Texas (modified from [redacted]).

[redacted] Mineralogy	
Major Minerals	Quartz
	Feldspar
	Lithic Fragments
Minor Minerals	Ankerite
	Kaolinite
	Calcite

Table 1-6: Summary of the mineralogical make-up of the [redacted]

[redacted]

Figure 1-14: Sidewall cores of the [redacted] interval in the [redacted] #1 well.

Various rotary side-wall cores were collected in the [redacted] carbonates and [redacted] intervals at the [redacted] #1 well to confirm reservoir quality. Routine core analysis was conducted on these rotary sidewall core samples by Premier CoreX and can be seen in **Table 1-7**.

Depth Range (ft)	Formation	Grain Density (g/cm^3)	Porosity (%)	K_{air} (mD)
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Table 1-7: Routine core analysis of rotary side-wall cores of the [redacted] Carbonates and [redacted] formations collected at [redacted] #1.

Porosimeter measured porosity in [redacted] County [redacted] samples range from 16.1% to [redacted] (Dutton, 1984). These ranges are similar to the values obtained from the [redacted] #1 sidewall core data and indicate good reservoir quality for CO_2 sequestration. Core plug permeability to air measurements ranged up to 2,000 mD, while drill stem tests from nearby wells reported effective permeability ranges from 40 to [redacted] ([redacted]).

Based on the Department of Energy (DOE)-National Energy Technology Laboratory (NETL) methods for static volumetric calculations (Peck et. al, 2014), the estimated storage capacity for the [redacted] within the AoR is approximately [redacted] of CO_2 per square mile. Inputs for thickness and porosity were determined by calculating the average net thickness and effective porosity values from the [redacted] #1 well for the [redacted] section (221 ft and 11%, respectively). The input for the density of CO_2 was calculated using the same temperature and pressure gradients as the reservoir model, which were applied to the midpoint depth for the [redacted] in the center of the AoR (approximately [redacted] ft below ground surface). Finally, a storage efficiency factor of 21% was applied based on the formation's depositional environment (Haeri, 2022).

The [redacted] interval has a low range of porosity and permeability values of 0.3% to 5.2% and 0.001 to 0.037 mD, respectively. Values are from sidewall core collected in the [redacted] #1 well. The tight, impermeable nature and the lack of faults and natural fractures in this formation indicate that it will serve as an adequate confining zone.

Current interpretations of the storage formation and confining zone at the site will be confirmed by routine and advanced datasets acquired from the next STW, [redacted] #1 injector, as detailed in the Pre-operational Testing Plan (Section 1.6 Permit Section 5.0: Pre-operational Logging and Testing). Site-specific geologic core and special core analysis will confirm porosity and permeability, mineralogy, capillary pressure, and relative permeability as specified by EPA (2012) [40 CFR 146.82(a)(3)(iii)]. Additionally, geomechanical data in the storage formation will confirm the maximum injection pressure, rock strength, and in-situ fluid pressure as specified by EPA (2012) [40 CFR 146.82(a)(3)(iv)].

1.2.5 Geomechanical and Petrophysical Information [40 CFR 146.82(a)(3)(iv)]

Petrophysical analysis was conducted to integrate available log data in the study area, generate porosity log curves used to populate the static earth model (SEM), and determine the storage reservoir properties of porosity and permeability **(Figure 1-15)**. The [redacted] #1 (existing test well and planned deep monitoring well), was drilled within the AoR and acquired wireline logs and 29 rotary sidewall cores across the proposed storage formation and confining zone (**Figure 1-12; Figure 1-14**; **Table 1-7**). The wireline logs collected include gamma ray, resistivity, neutron porosity, bulk density, dipole sonic, formation micro-imager (FMI) and nuclear magnetic resonance (NMR) (**Figure 1-15**). Analysis on the rotary sidewall cores includes routine properties such as porosity, permeability, and grain density. In addition to the [redacted] #1 well, regional well log data was compiled as part of the data collection effort, as detailed in Section 1.2.4. These logs were edited and normalized as part of the quality control procedure to eliminate erroneous data points, correct for varying signal intensities, and establish consistent readings between wells. A lithologic log representing the fraction of clay with depth (V_{clay}) was generated and integrated with core data and routine porosity logs to calculate refined porosity curves (**Figure 1-15**). NMR-based permeability was validated with lab-measured permeability on the sidewall cores and used to create a porosity-permeability transform function (**Figure 1-15**).

Additional geomechanical and petrophysical properties will be evaluated and confirmed through well tests, wireline logs, and laboratory analyses of core samples from the proposed STW, [redacted] #1 injector. Geomechanical properties of the target and confining zone will be confirmed from minifrac test analysis and dipole sonic logs. The geomechanical integrity of the confining zone is confirmed if its fracture pressure exceeds that of the target zone. Data will be collected in the [redacted] #1 using wireline logging tools such as the dipole sonic to determine elastic rock properties such as Young's modulus, stresses, and Poisson's ratio, which will be used as an accuracy check for the minifrac data in case of any operational issues during testing.

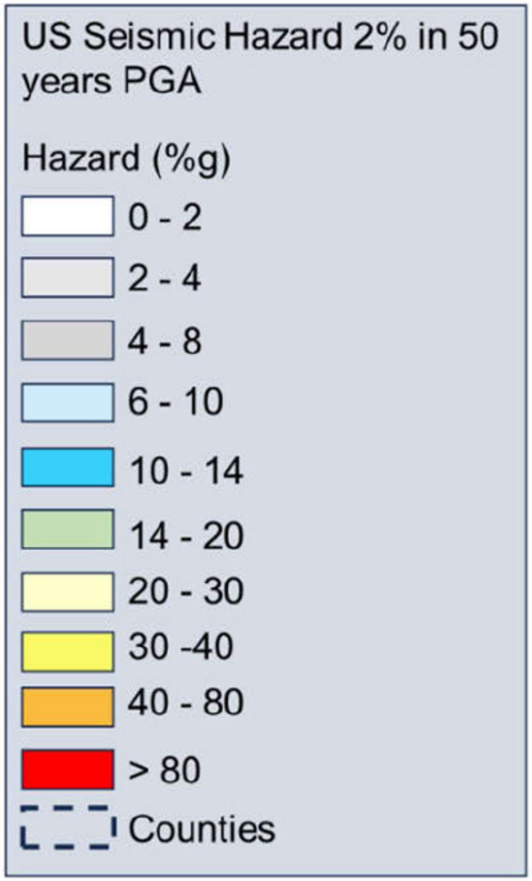
[redacted]

Figure 1-15: Log plot of the [redacted] #1 well showing (left to right) stratigraphic zone, gamma ray, depth with caliper, resistivity, porosity, dipole sonic, NMR permeability, NMR porosity. Core-based porosity and permeability measurements are plotted in the NMR permeability and NMR porosity tracks in magenta points.

1.2.6 Seismic History [40 CFR 146.82(a)(3)(v)]

The seismic history for the area was characterized using publicly available data from the United States Geological Survey (USGS) and the TexNet Earthquake Catalog from the Bureau of Economic Geology (BEG). Texas is a largely inactive state for natural seismicity and earthquakes have historically occurred with low frequency and magnitude. The [redacted] has relatively low faulting. The faults in the [redacted] are primarily growth faults associated with sediment loading and are not seismically active. For more information on local structures and faults refer to Section 1.2.3.

The absence of recorded naturally occurring earthquakes near the [redacted] project site is consistent with the regional seismic hazard map published by the USGS (2014), which designates the area as a relatively low-risk area for seismic activity. There is a 6-10% chance of a naturally occurring seismic event happening over the next 50 years near the [redacted] site location (**Figure 1-16**). According to the USGS, seismic events (Jan. 1950 - Sept. 2023) have been recorded and mapped as shown in **Figure 1-17.** Recent seismic activity (2017-2023) within 100 miles of the project are recorded in **Table 1-8**.



[redacted]

Figure 1-16: 2014 regional seismic hazard map for Texas showing peak ground accelerations (PGA) having a 2% probability of being exceeded in 50 years, for a firm rock site; %g denotes percent of acceleration due to gravity (USGS, 2014).

[redacted]

Figure 1-17: Map of recent seismic events (Jan. 1950 - Sept. 2023) in the [redacted] Site location and nearby area (data from TexNet Earthquake Catalog). The [redacted] site location is denoted with a yellow star.

Date and Time	Magnitude	Magnitude Type	County Name	Latitude	Longitude	Depth in Km (MSL)	Depth in Km (Surface)	Depth Uncertainty
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Date and Time	Magnitude	Magnitude Type	County Name	Latitude	Longitude	Depth in Km (MSL)	Depth in Km (Surface)	Depth Uncertainty
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Date and Time	Magnitude	Magnitude Type	County Name	Latitude	Longitude	Depth in Km (MSL)	Depth in Km (Surface)	Depth Uncertainty
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Table 1-8: Recent seismic events (2017 - 2023) in the [redacted] Site location and 100 mi surrounding area (data from TexNet Earthquake Catalog).

1.2.7 Hydrologic and Hydrogeologic Information [40 CFR 146.82(a)(3)(vi), 146.82(a)(5)]

To further understand the subsurface underlying the [redacted] site location, an assessment of the local hydraulic and hydrogeologic conditions was completed. This included a review of the hydrostratigraphy, groundwater flow direction, and salinity of shallow and deep aquifers in the [redacted] basin area.

The major USDW within the AoR is the [redacted] of the High Plains Aquifer System (**Figure 1-18** aerial extent). This aquifer is composed primarily of sand, gravel, clay, and silt and reaches a maximum thickness of 800 ft (Bruun et al., 2016). On average, 95 ft of thickness is saturated with freshwater but increases in several paleovalleys that were eroded into the Permian- to Cretaceous-aged surfaces prior to [redacted] deposition (Bruun et al., 2016). This aquifer has experienced a large amount of pumping for irrigation which has diminished its baseflow from aquifer discharge and springs. Average annual baseflow for the [redacted] in [redacted] County is 3.1 cubic feet per second (Bruun et al., 2016). Increased salinity to the south (1,000 mg/L) may be associated with evaporative concentration of groundwater in saline playa lakes in the southern portion of the aquifer and up flow of additional saline water from the underlying [redacted] and other sources (Bruun et al., 2016).

[redacted]

Figure 1-18: Regional extent of the [redacted] Texas. The [redacted] site location is denoted with the yellow star (modified from Bruun et al., 2016).

The deepest USDW at the White Energy [redacted] site is the [redacted] (**Figure 1-19** structure map and **Figure 1-20** extent). This aquifer is composed of Triassic sediments of alternating sandstones and shales (Bradley and Kalaswad, 2003). Most of the freshwater of this aquifer is found in the porous sandstone and conglomerate beds of the sedimentary sequence, and fine-grained sediments create low permeability aquitards (Bradley and Kalaswad, 2003). This aquifer is overlain by, and may be hydraulically connected to, the [redacted]. It is found at a depth of 2,600 ft above sea level, which is equivalent to ~1,200 ft TVD (true vertical depth) (Bruun et al., 2016) (**Figure 1-21**). The base of the [redacted] is marked by the Santa Rosa formation which unconformably overlies Upper Permian red beds (Bradley and Kalaswad, 2003).

[redacted]

Figure 1-19: Structure map on top of [redacted] (modified from Bradley and Kalaswad, 2003). The [redacted] site location is denoted with a yellow star.

[redacted]

Figure 1-20: Aerial extent of the [redacted] in the AoR. The [redacted] site location is denoted with the yellow star (modified from Bruun et al., 2016).

[redacted]

Figure 1-21: NW-SE cross section illustrating the presence and thickness of the USDWs at the site location. The [redacted] site location is denoted with the yellow star (modified from Bradley and Kalaswad, 2003).

Overall, groundwater in the [redacted] flows to the southeast or east-southeast (Bruun et al., 2016). Local variations in this trend occur towards large rivers such as the Brazos, Canadian, and Colorado River drainage basins and local springs (Bruun et al., 2016). Natural springs of this aquifer can be found where the sediments intersect the water table and have been reported along the Pecos River Valley in southwestern Texas (Bruun et al., 2016). Water quality in the [redacted] is generally poor and very hard, with a TDS content of 1,000 to 3,000 mg/L at the [redacted] site (**Figure 1-22**). Brine is common in the western portions of the aquifer in the subsurface (Bruun et al., 2016).

[redacted]

Figure 1-22: Total Dissolved Solids concentrations for the [redacted]. The [redacted] site location is denoted with the black star (modified from Bruun et al., 2016).

In addition to reviewing shallow subsurface freshwater aquifers, it was also necessary to review the salinity levels of the potential saline storage formation. Pickett plots are a graphical solution to Archie's water saturation equation and are a cross-plot of deep resistivity versus porosity on a log-log scale (**Figure 1-23**). Formation water resistivity is a function of salinity and temperature. Where the formation is fully saturated, the Pickett plot, also known as the resistivity-porosity method, can be used to determine formation salinity (U.S. EPA, 1988; Pickett, 1973). The red and blue lines represent lines of equal water saturation, with the red line drawn through the fully water-saturated reservoir log derived data. The red line is extrapolated to Total Porosity = 1 and the intercept indicates a resistivity of the water in the formation (Rw) at in-situ formation temperature. The Rw is converted to salinity in parts per million (ppm) using an industry standard chart within the petrophysical software (U.S. EPA, 1988). The slope of these lines is the m-exponent. The n-exponent and a-factor are standard inputs into the Archie equation. These Pickett-plot-derived salinity values should be considered a minimum salinity. The Pickett plot using log data from the [redacted] #1 well show a salinity of 150,000 ppm in the [redacted] (**Figure 1-23**), which is significantly greater than the regulatory lower limit of 10,000 ppm.

[redacted]

	m exponent: 2.31	a factor: 1
Rw at Formation Temperature: 0.031	n exponent: 2	Rw Salinity parts per million (ppm): 150,000

Figure 1-23: Calculated log salinity of the [redacted] intervals for the [redacted] #1. The [redacted] salinity is calculated to be 150,000 ppm.

A map of the AoR, known wells within the AoR, and proposed injection wells is shown in **Figure 1-1**. There are a total of 84 documented shallow groundwater wells within the AoR, and one deep well, the [redacted] #1. The groundwater wells vary in depth from 100 to 1,000 ft. The [redacted] #1 was drilled to a depth of [redacted] ft as a test well and will be used as a deep monitoring well.

1.2.8 Geochemistry [40 CFR 146.82(a)(6)]

Regional geochemical data and well log analysis provide insights into the storage formation water salinity (TDS) of the [redacted] Formation. However, site-specific geochemistry data are not currently available due to a lack of subsurface water samples. The acquisition of this data will be completed either during the installation of an onsite STW; the [redacted] #1 injector or in an independent deep groundwater well that may be drilled if it provides a more efficient sampling procedure. Water samples will be collected for aqueous and solid-phase geochemical data through analysis of major cations and anions, trace metals, and general geochemical properties (i.e., pH, TDS, alkalinity, etc.). These analyses will be used to determine:

- The deepest USDW at the project site
- Baseline geochemical data for the project site to evaluate any migration of CO_2 and brine waters at the site
- Baseline geochemical equilibrium conditions to evaluate the saturation relationship between the dissolved and solid-phase minerals at the site
- Geochemical reactions that may occur from the injection of CO_2

The analysis of onsite geochemical properties in the subsurface reservoirs above and within the storage formation will confirm the intervals identified for CO_2 storage meet the criteria outlined for Class VI permit approval.

1.2.9 Other Information (Including Surface Air and/or Soil Gas Data, if Applicable)

No surface air and/or soil gas data were collected at the [redacted] site location.

1.2.10 Site Suitability [40 CFR 146.83]

An extensive set of subsurface data has been analyzed at the [redacted] Site location to support the evaluation of site suitability. The integration of well logs, 2D seismic, and regional maps and cross sections confirm the lateral extent of the storage formation and confining zones, as well as the absence of faulting at the site location and surrounding area that would impact the integrity of the storage formation and confining zones. Therefore, the containment risk is low, and although multiple secondary confinements zones are present, none are necessary for USDW protection. With the exception of [redacted] #1 there are no deep wellbore penetrations into the confining zone above the storage formation (refer to section 2.4.2 Wells Penetrating the Confining Zone). Additional well and rock data to be collected from [redacted] #1 will provide further geomechanical data to support the integrity of the storage formation and confining zones.

The [redacted] site location is suitable for CO_2 sequestration due to the favorable lithologies of the storage and confining formations. The storage formation, the [redacted], is mostly composed of medium grained arkose, lithic arkose, and subarkose sandstones intermixed with conglomerates with [redacted] measured porosity ([redacted]). The most common mineral in the sandstones of this formation is quartz followed by feldspar and lithic rock fragments. Additionally, quartz overgrowth cements are seen in this formation ([redacted]). The prevalence of quartz cement has positive implications for CO_2 injection because quartz-cemented rocks are naturally resistant to the potentially corrosive effects of long-term exposure to injected CO_2. Furthermore, although neither the CO_2 stream nor formation waters are expected to be highly corrosive, the injection well materials that come in contact with the CO_2 stream and/or reservoir brines will be constructed of corrosion-resistant materials, such as ^{13}CR steel, or similar. For example, the casing string across the [redacted] formation, the packer, and deep portions of the tubing with be constructed with corrosion-resistant materials or coatings. The thickness and porosity of the [redacted] storage formation make the [redacted] site location optimal for CO_2 sequestration with a large CO_2 storage capacity. Based on the DOE-NETL methods for static volumetric calculations, the estimated storage capacity for the [redacted] within the AoR is approximately 3.2 MMmt of CO_2 per mi^2. With a total AoR area of 6 mi^2, the [redacted] provides more than enough storage capacity to accommodate the target injection volumes.

The [redacted] was deposited in a fan-delta system. The resulting geometries are influenced by the orientation of the main sediment source during deposition, which ultimately has some influence on the direction of plume migration for the injected CO_2. The main sediment source at the [redacted] site location during the [redacted] was the Bravo Dome (Handford and Dutton, 1980). This had a north-northwest orientation that shed granite washes in a southeasterly direction (**Figure 1-24**). These geometries were integrated into the SEM to provide depositionally informed anisotropy, which resulted in local north and northwest trending fan delta systems.

[redacted]

Figure 1-24: Inferred sediment dispersal routes and geometries of the [redacted] Dispersal routes denoted with black arrows (modified from [redacted]).

1.3 Permit Section 2.0: AoR and Corrective Action

The AoR and Corrective Action Plan are submitted to meet the requirements of Plan 40 CFR 146.82(a)(13), 146.84(b) and 40 CFR 146.84(c).

The plan describes the computational modeling approach and results. The objective of the computational modeling is to track the CO_2 plume size and shape, area of pressure buildup, and determine an AoR for CO_2 injection at the Texas Carbon Storage I project site. The SEM is a three-dimensional (3D) geocellular model that represents the porosity and permeability of different stratigraphic formations, most notably, the intended CO_2 storage formation and overlying confining zone. This type of model was selected as it offers the best options for quantifying, representing, and visualizing the subsurface geologic interpretations for the site. The purpose of this model is to represent available pore volume and enable the estimation of CO_2 storage capacity. Primarily, this geologic model serves as the framework (in terms of delineating zones, surfaces, permeability, and porosity) for dynamic computational modeling of CO_2 injection within the SEM.

Computational modeling to simulate CO_2 injection into the saline aquifer was performed using a 3D multiphase flow simulator CMG-GEM (Computer Modelling Group, 2022). In addition to the geological framework imported from the SEM, additional parameters, such as relative permeability data, initial conditions, phase behavior model, and well/perforation parameters, were added to the computational model to complete the dynamic modeling. A site-specific test well, [redacted] #1, has been drilled within the AoR (**Figure 1-1**). An extensive suite of wireline logs and sidewall cores were acquired and incorporated into the computational model. An additional STW will be drilled, the [redacted] #1 injector upon completion, to further characterize the subsurface within the AoR. Extensive wireline logging, coring, fluid sampling, and formation hydrogeologic testing will be performed in this STW well. The data will be incorporated into the SEM and DRM.

CMG-GEM is an equation-of-state based compositional simulator that models the phase behavior of brine and CO_2 saturations (at high concentrations defined as a plume) during the injection and post-injection phases of a project. Multiple phases were accounted for in the computational model including aqueous, gas, and supercritical phases.

Modeling multiphase flow processes in porous media, with all components as described above, enables:

- Estimation of pressure buildup in the storage formation – confining layer system
- Characterization of CO_2 phase behavior at storage reservoir conditions
- Estimation of CO_2 saturation (plume extent) in the storage formation ([redacted])
- Understanding of confining layer parameters to ensure seal integrity over the project life

The processes bulleted above are modeled throughout the entire project life (injection and post-injection).

The estimated CO_2 saturation map and pressure buildup from modeling multiphase flow processes predicts CO_2 movement during the injection and post injection periods and helps define the AoR. **Figure 1-25** shows the CO_2 saturation map at the end of the [redacted]-year injection period and the AoR.

[redacted]

Figure 1-25: CO_2 Saturation after [redacted] injection (plan view left, cross section right).

1.4 Permit Section 3.0: Financial Responsibility

The Financial Responsibility Plan is submitted as Section 3.0 to meet the requirements of 40 CFR 146.82(a)(14) and 146.85.

1.5 Permit Section 4.0: Injection Well Construction

1.5.1 Proposed Stimulation Program [40 CFR 146.82(a)(9)]

No completion stimulation is planned at this time because the reservoir quality is expected to be adequate for the planned injection volumes. A typical acid wash will be used to clean any drilling mud, cement invasion and debris in the near-wellbore region that may be generated during drilling operations.

1.5.2 Construction Procedures [40 CFR 146.2(a)(12)]

A newly drilled injection well ([redacted] #1) will be constructed at the Texas Carbon Storage I, to meet the requirements of 40 CFR 146.86.

1.5.3 Casing and Cementing

The injection well ([redacted] #1) will be vertical from surface to total depth (TD). The injection well construction plan is designed to prevent the movement of fluids into or between USDWs or into any unauthorized zones, and to permit the use of appropriate testing and monitoring devices, as well as workover tools. The design also accommodates continuous monitoring of the annular space between the injection tubing and long string casing ((146.86 (a)(1,2,3)). The proposed injection well diagram is shown in **Figure 1-3**. The injection well will initially be drilled as a Stratigraphic Test Well (STW) and a comprehensive suite of wireline logs, core, fluid samples and reservoir testing will be acquired.

Table 1-9 summarizes the casing program for the injection well and **Table 1-10** summarizes the cement program. All casing strings will be cemented to the surface and any changes to the final well design will be discussed with the UIC Director or representative. The deepest USDW will be confirmed from the planned fluid sampling program. Surface casing will be set through the deepest USDW; the intermediate string and the production string casings will provide additional layers of protection to the USDW.

Casing String Name	Open Hole Size (in.)	Outside Diameter (in.)	Setting Depth (ft rGL)	Weight (lb/ft)	Wall Thickness (in.)	Grade	Connection
Conductor	36”	30”	120	118	0.375		Welded
Surface	26”	20”	[redacted]	94	0.4375	J-55	STC / Round Thread
Surface	17-1/2”	13-3/8”	[redacted]	54.5	0.38	J-55	BTC
Intermediate	12-1/4”	9-5/8”	[redacted]	40	0.352	J-55	LTC / Round Thread
Long String	8-3/4”	7”	[redacted]	26	.375	L-80	LTC / Round Thread
Long String	8-3/4”	7”	[redacted]	26	.375	13Cr80	JFE Bear
Injection Tubing	N/A	4-1/2”	[redacted]	11.6	0.25 Plus 0.125 lining-0.375	L-80 Lined	LTC/ Round Thread

Table 1-9: Casing details.

Casing String	Appx. Depth Range (MDKB ft)	Cement Type
Surface	[redacted]	Class C
Surface	[redacted]	Class C
Intermediate	[redacted]	Class C
Production	[redacted]	Lead: Class C Poz slurry Tail: CO_2-Resistant slurry

Table 1-10: Cement program for the CO_2 injection well.

The tubing-casing annular fluid will be a dilute salt solution such as potassium chloride (KCl), sodium chloride (NaCl), or similar. The fluid will be mixed on site from dry salt and good quality (clean) fresh water, or it will be acquired pre-mixed. The fluid will also be filtered to ensure that solids do not interfere with the packer or other components of the annular protection system. The likely density of the annular fluid will be approximately 9.2 ppg. The final choice of the type of fluid will depend on availability and wellbore conditions.

1.6 Permit Section 5.0: Pre-Operational Logging and Testing

The Pre-Operational Logging and Testing Plan is submitted to meet the requirements of 40 CFR 146.82(a)(8) and 40 CFR 146.87.

This plan describes the pre-operational formation testing program implemented to characterize the chemical and physical features of the storage formation and confining zone at the Texas Carbon Storage I project and will supplement the site-specific test well already obtained from the [redacted] #1 test well completion (**Figure 1-1**).

An additional STW will be drilled at the site which will be completed as the injection well ([redacted] #1). Data will be collected in the STW during drilling to further characterize the subsurface at the injection location within the Area of Review (AoR) at the Texas Carbon Storage I project. Extensive wireline logging, coring, fluid sampling, and formation hydrogeologic testing will be performed in the STW. These data will be incorporated into the site static earth and dynamic models (Permit Section 2.0) from which the AoR is derived.

1.7 Permit Section 6.0: Well Operations

1.7.1 Operational Procedures [40 CFR 146.82(a)(10)]

This section describes the source of the CO_2 that will be delivered to the storage site, its chemical and physical properties, flow rate, and the anticipated pressure and temperature of the CO_2 at the pipeline outlet. In addition, this section provides the monitoring that will be performed on the injection well to confirm that it does not provide a conduit for CO_2 and/or brine from the storage formation up past the confining zone and into USDWs or the surface.

The design basis of this project is to capture and inject the CO_2 produced at Texas Carbon Storage I project. The average annual injection rate is [redacted] MMmt/Yr. and the planned injection phase of this project is [redacted] years.

Monitoring of the injection well parameters will be performed to ensure proper operation and compliance with 40 CFR 146.90(b). The wellhead injection pressure will be used to confirm that storage formation pressures remain below the regulated limit while the storage formation pressure will be measured with downhole pressure sensors. The mass injection rate will be continuously monitored to ensure the rate remains below the regulated limit. The annular pressure and temperature will be measured continuously to maintain compliance with the EPA Class VI permit and to monitor the internal mechanical integrity of the well. All monitoring will take place at the locations and frequencies shown in **Table 1-11**. The operational monitoring data will be connected to the main facility (CO_2 emission source's control room) through a supervisory control and data acquisition (SCADA) system.

In addition to the annular monitoring system that will evaluate the internal mechanical integrity of the well, a mechanical integrity test will be performed on the well after the tubing has been placed in the well and the packer has been set. External mechanical integrity will be monitored on an annual basis via external temperature measurements over the entire depth of the well in an attempt to identify any vertical fluid movement above the storage reservoir.

Parameter	Device(s)	Location	Min. Sampling Frequency	Min. Recording Frequency
CO_2 stream pressure (wellhead)	Pressure Gauge	Injection wellsite	Every 1 min.	Hourly
Mass injection rate	Coriolis Meter	Injection wellsite	Every 10 sec.	Hourly
Annular pressure	Pressure Gauge	Injection wellsite	Every 1 min.	Hourly
Annulus fluid volume	Volume	Injection wellsite	Every 1 min.	Hourly
CO_2 stream temperature	Thermocouple	Injection wellsite	Every 1 min.	Hourly

Notes:

- Sampling frequency refers to how often the monitoring device obtains data from the well for a particular parameter. For example, a recording device might sample a pressure transducer monitoring injection pressure once every two seconds and save this value in memory.
- Recording frequency refers to how often the sampled information gets recorded to digital format (such as a computer hard drive). For example, the data from the injection pressure transducer might be recorded to a hard drive once every minute.

Table 1-11: Sampling devices, locations, and frequencies for continuous monitoring.

1.7.2 Proposed Carbon Dioxide Stream [40 CFR 146.82(a)(7)(iii) and (iv)]

The injection stream will be monitored during the baseline and operational phases of the project (Permit Section 7.2). Prior to the start of the injection phase, the CO_2 stream will be sampled for analysis during regular plant operations to obtain representative CO_2 samples that will serve as a baseline dataset.

1.8 Permit Section 7.0: Testing and Monitoring

The Testing and Monitoring Plan describes how White Energy will monitor the site pursuant to 40 CFR 146.82(a)(15) and 146.90.

The Testing and Monitoring Plan has been developed in conjunction with the project risk assessment to reduce the risks associated with carbon dioxide (CO_2) injection into the subsurface at this site. Goals of the monitoring strategy include:

- Meeting the regulatory requirements of 40 CFR 146.90
- Protecting underground sources of drinking water (USDWs)
- Ensuring that the injection well is operating as planned
- Providing data to validate and calibrate the geological and dynamic models used to predict the distribution of CO_2 within the injection zone
- Support Area of Review (AoR) re-evaluations over the course of the project

The Testing and Monitoring Plan will be adaptive over time; the plan can be adjusted to respond:

- As project risks evolve over the course of the project
- If significant differences between the monitoring data and predicted dynamic modeling results are identified
- If key monitoring techniques indicate anomalous results related to well integrity or the loss of containment

Error! Reference source not found. illustrates the AoR at the end of the PISC period, the proposed location of the deep monitor well ([redacted] #1) and the conceptual location of the above confining zone monitoring well, the anticipated location of the injector ([redacted] #1) and the conceptual distribution of seismicity stations.

The Testing and Monitoring Plan will outline several proposed direct and indirect technologies used throughout the injection and PISC phases of the project selected to appropriately monitor:

- Daily activities of the injection operations
- Development of the CO_2 and pressure plumes in the storage formation over time
- Well integrity
- CO_2 or brine containment within the injection reservoir
- Groundwater quality in multiple aquifers, including the USDWs and the deepest water-bearing formation above the caprock

Monitoring injection operations will be through a range of continuous, daily, and quarterly techniques as detailed in the Well Operations Plan (Permit Section 6.0). **Table 1-12** summarizes the proposed testing and monitoring plan for the project. Plume monitoring and USDW sampling will include pre injection baseline monitoring for comparison with injection and post injection results.

Monitoring Activity	Baseline Data Frequency	Injection Phase Frequency	Location	Formation top / Depth Range (ft, MD)
Assurance Monitoring:				
USDW Sampling	Quarterly	Quarterly	AoR Groundwater well network[1]	Producing zone
USDW Isotope Analysis	Biannually	Annually	AoR Groundwater well network[1]	0 – TD
Operational Monitoring:				
CO_2 Stream Analysis	N/A	Quarterly	CO_2 Delivery Pipeline	NA
Corrosion Coupon Analysis	N/A	Quarterly	CO_2 Delivery Pipeline	NA
Injection Pressure	N/A	Continuous	Injection Wellhead	Surface
Mass Injection Rate	N/A	Continuous	Injection Wellhead	Surface
Injection Volume (Calculated)	N/A	Continuous	Storage Formation	Surface
Annular Pressure	N/A	Continuous	Injection Well	Surface
Annular Fluid Volume	N/A	Continuous	Injection Well	Surface
Temperature Measurement (DTS)	Continuous	Continuous	Injection Well	0 – TD
PFO Tests	Once	Every 5 years	Injection Well	Surface

Monitoring Activity	Baseline Data Frequency	Injection Phase Frequency*	Location	Formation top / Depth Range (ft, MD)
Verification Monitoring:				
Fluid Sampling				
Deepest USDW	Twice	Annually	ACZ well or independent groundwater well	TBD
Top confining zone	Twice	Annually	ACZ well	TBD
Injection zone	Twice	Annually	Deep monitor well[2]	TBD
Isotope Analysis	Twice	Annually	ACZ Well	All samples
Pressure Sensors	Prior to injection			
Deepest USDW	Continuous	Continuous	ACZ Well or independent groundwater well	TBD
Top confining zone	Continuous	Continuous	ACZ Well	TBD
Injection zone	Continuous	Continuous	Deep monitor well	TBD
Temperature Sensors (DTS)	Prior to injection			
Deepest USDW	Continuous	Continuous	ACZ Well	TBD
Top confining zone	Continuous	Continuous	ACZ Well	TBD
Injection zone	Continuous	Continuous	Deep monitor well	TBD
PNC Logging				
Deepest USDW	Once	Annually	ACZ Well	TBD
Top confining zone	Once	Annually	ACZ Well	TBD
Injection zone	Once	Annually	Deep Monitor well	TBD
Microseismic Monitoring	Prior to injection	Continuous	Surface stations	TBD
Time-lapse Borehole Seismic VSP Data	Once	Every 5 years and as required	Surface	

[1] Groundwater well network incorporating selected wells from existing network and additional, new groundwater wells, as warranted to provide coverage across AoR

[2] In-zone fluid sampling will be discontinued once CO_2 breakthrough occurs at the well

Table 1-12: General schedule and spatial extent for the testing and monitoring activities for CCS project.

1.9 Permit Section 8.0: Injection Well Plugging

The Injection Well Plugging Plan describes how White Energy will plug the injection well pursuant to 40 CFR 146.82(a)(16) and 146.92.

A Notice of Intent to plug the well will be submitted to the EPA at least 60 days prior to the plugging operations (40 CFR 146.92 (c)). After the project has verified that there are no external well integrity issues, the well will be flushed with buffer fluid to remove any fluids or particulates that may be present in the well. The injection well casing will be plugged with cement to ensure that it does not provide a conduit outside the injection zone. **Table 1-13** shows the intervals that will be plugged as well as the materials and methods that will be used to plug the intervals.

Description	Cemented Interval (ft, MD)	Formation	Plugging Method	Plug Description	
				Type	Quantity
Open Hole Interval	[redacted]	[redacted]	Retainer	CO_2-Resistant	300 sacks
On cement retainer	[redacted]		Balance	CO_2-Resistant	26 sacks
At cement stage tool	[redacted]		Balance	CO_2-Resistant	26 sacks
Intermediate Casing Shoe	[redacted]		Balance	Class C	22 sacks
Surface Casing Shoe	[redacted]		Balance	Class C	22 sacks
Surface	[redacted]		Balance	Class C	110 sacks

Table 1-13: Intervals to be plugged and materials/methods used (40 CFR 146.92 (b)(2 – 4)).

The cement volume required for each plug was calculated using the inside diameter of the deep casing string, the length of the zone to be plugged, and the yield of the cement slurry (1.18 ft^3/sack for Class A or G or H and 1.07 ft^3/sack for the CO_2-resistant cement). The storage formation will be plugged using CO_2-resistant cement with a retainer/squeeze method or other method approved by the UIC Director. A cement retainer will be set in the injection casing 100 ft above the top perforation. These depths will be re-evaluated after the injection well has been drilled and precise formation depths have been established. CO_2-resistant cement will be used to plug the storage formation; this will include a 20% excess volume to be squeezed into the injection formation. It requires approximately 0.2 sack of cement to seal one foot of hole, and this value may be used to estimate the amount of cement needed for different perforation scenarios. For more information on the Well Plugging Plan, refer to Permit Section 8.0.

1.10 Permit Section 9.0: Post-Injection Site Care (PISC) and Site Closure

The PISC and Site Closure Plan describes the activities that White Energy will perform to meet the requirements of 40 CFR 146.82(a)(18) and 146.93(c).

White Energy will monitor groundwater quality and track the position of the CO_2 plume and pressure front for 50 years after the cessation of injection. Additional information on the projected post-injection pressure decline and differentials is presented in the Post-Injection Site Care and Site Closure Plan (Permit Section 9.0).

1.11 Permit Section 10.0: Emergency and Remedial Response

The Emergency and Remedial Response Plan (ERRP) is submitted to meet the requirements of Plan 40 CFR 146.82(a)(19) and 146.94(a).

The ERRP provides actions that White Energy will take in the event of an emergency and to address movement of CO_2 or formation fluid that may endanger a USDW during the construction, operation, or PISC periods.

If evidence indicates that the injected CO_2 stream, formation fluids, and/or associated pressure front may cause an endangerment to a USDW, the following actions must be performed:

1. Initiate shutdown plan for the injection well
2. Take all steps reasonably necessary to identify and characterize any release
3. Notify the permitting agency/UIC Program Director (UIC Director) of the emergency event within 24 hours
4. Implement applicable portions of the ERRP

If an emergency shutdown should occur, CO_2 injection will only resume with the consent of the UIC Director. If White Energy can demonstrate that the injection operation will not endanger USDWs, the UIC Director may allow the resumption of injection prior to remediation.

If a non-emergency shutdown of the CO_2 injection system is required, the operator will complete the shutdown in a stepwise approach to prevent over-pressure situations and/or damage to the equipment. Efforts will also be made to maintain the CO_2 in the injection stream in a supercritical phase to prevent special operations during the restart of the system.

1.12 Injection Depth Waiver and Aquifer Exemption Expansion

White Energy is not applying for a depth waiver or an aquifer exemption.

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