6 INJECTION WELL OPERATIONS PLAN

40 CFR 146.82(a) (7), 40 CFR 146.88

TULARE COUNTY CARBON STORAGE PROJECT (TCCSP)

Facility Information

Facility (site) Name: Tulare County Carbon Storage Project (TCCSP)
Facility Operator: TCCSP, LLC.

Facility Contact: [redacted]

Project Location: [redacted], Tulare County, California

Injection Well Name and Coordinates:

Well Name	Latitude	Longitude
TCCSP_INJ-1	[redacted]	[redacted]
TCCSP_INJ-2	[redacted]	[redacted]

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List of Acronyms/Abbreviations

2D	2-Dimensional
3D	3-Dimensional
AoR	Area of Review
bbl/d	Barrels per day
BHP	Bottom Hole Pressure
CCS	Carbon capture, and storage
CO_2	Carbon dioxide

CMG	Computer Modelling Group
D_H	Hydraulic Diameter
DRM	Dynamic Reservoir Model
EoS	Equation of State
EPA	Environmental Protection Agency
f_D	Darcy's Friction Factor
ft	feet
g	Acceleration due to Gravity
GEM	General Equation of State
KB	Kelly Bushing
$k_{r,CO2}$	CO_2 Relative Permeability
kh	Permeability-Thickness Product
k_h	Absolute Horizontal Permeability
k_v	Absolute Vertical Permeability
$k_{r,w}$	Water Relative Permeability
mg/L	milligrams per liter
MIP	Mercury Intrusion Porosimetry
MMt	Millions of Metric tons
MMtpa	Millions of Metric tons per annum
MSL	Mean Sea Level
ΔP	Pressure Drop
ΔP_{TH}	Threshold Pressure
PISC	Post-Injection Site Care
P_{grid}	Grid Block Pressure
pH	Potential Hydrogen
ppm	Parts per Million
psi	Pounds per square inch
psia	Pounds per square inch, absolute
ρ	Fluid Density
ρ_i	Injection Zone Fluid Density
ρ_u	Underground Source for Drinking Water Fluid Density
RCA	Routine Core Analysis
R_e	Reynolds Number
SCA	Specialized Core Analysis
SEM	Static Earth Model
S_{grmax}	Maximum Residual Gas Saturation
SS	Subsea
S_{wconn}	Connate Water Saturation
S_{wirr}	Irreducible Water Saturation
TCCSP	Tulare County Carbon Storage Project
T_{grid}	Grid Block Temperature
TVD	True Vertical Depth
UIC	Underground Injection Control
USDW	Underground Source of Drinking Water
U.S. DOE	United States Department of Energy

U.S. EPA	United States Environmental Protection Agency
v	Fluid Velocity
z_i	Injection Zone Top Depth
zu	Underground Source for Drinking Water Bottom Depth

6.1 Class VI Injection Well Operations Plan Overview

Pursuant to the 40 CFR §146.82, TCCSP, LLC. prepared this document to describe the planned operation of the CO_2 injection wells for the Tulare County Carbon Storage Project (TCCSP). The locations for the injection wells TCCSP_INJ-1 and TCCSP_INJ-2 are displayed in **Figure 6-1**. The proposed construction procedures and specifications are detailed in this document.

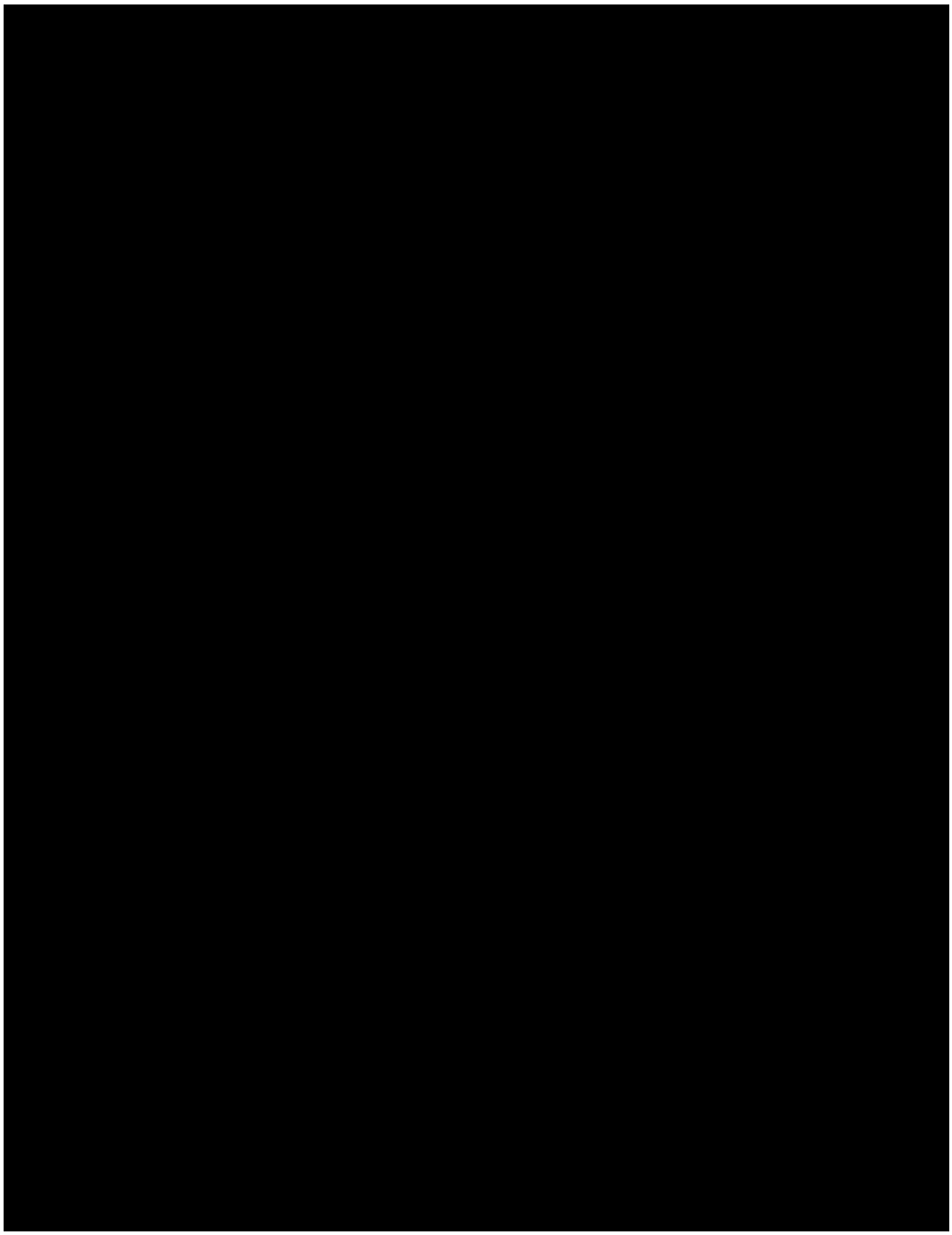

Figure 6-1. TCCSP_INJ-1 and TCCSP_INJ-2 well locations.

6.2 Injection Rates

The injection wells will be constructed as shown in the **Injection Well Construction Plan**. Injection will be facilitated through the tubing set in the long-string casing in a packer above the perforations in the [redacted] The operational values detailed in the following tables were obtained by constructing a hypothetical wellbore model that simulated multiphase fluid flow using [redacted], to conduct a nodal analysis presented in section **4.2** of the **Injection Well Construction Plan** which was used to determine the range of possible injection rates. Using the analysis, an average injection rate of [redacted] for TCCSP_INJ-1 and [redacted] for TCCSP_INJ-2. Both wells will have a maximum rate of [redacted] of CO_2 per well. The expected wellhead pressure during injection operations will likely be between [redacted]. **Table 6-1**, **Table 6-2,** and **Table 6-3** summarize the proposed operational parameters for the injection wells. Operational parameters are expected to remain constant throughout the duration of the injection period. The only possible changes to operational parameters may stem from variations in volume of the CO_2 source, which may lead to fluctuations in injection volumes.

Table 6-1. TCCSP_INJ-1 Injection Well Operational Parameters.

Parameters/Conditions	Limit or Permitted Value	Unit
	[redacted]	
Surface		psi
Downhole		psi
Surface		psi
Downhole		psi
Maximum Injection Rate		Metric tons/year
Average Injection Rate		Metric tons/year
Maximum Injection Volume and/or Mass ([redacted])		Metric tons
Average Injection Volume and/or Mass ([redacted])		Metric tons
Annulus Pressure		psi
Annular Fluid Weight		ppg
Annulus Pressure/Tubing Differential		psi

Table 6-2. TCCSP_INJ-2 [redacted] Injection Well Operational Parameters.

Parameters/Conditions	Limit or Permitted Value	Unit
	[redacted]	
Surface		psi
Downhole		psi
Surface		psi
Downhole		psi
Maximum Injection Rate		Metric tons/year
Average Injection Rate		Metric tons/year
Maximum Injection Volume and/or Mass ([redacted])		Metric tons
Average Injection Volume and/or Mass ([redacted])		Metric tons
Annulus Pressure		psi
Annular Fluid Weight		ppg
Annulus Pressure/Tubing Differential		psi

Table 6-3. TCCSP_INJ-2 [redacted]) Injection Well Operational Parameters.

Parameters/Conditions	Limit or Permitted Value	Unit
	[redacted]	
Surface		psi
Downhole		psi
Surface		psi
Downhole		psi
Maximum Injection Rate		Metric tons/year
Average Injection Rate		Metric tons/year
Maximum Injection Volume and/or Mass ([redacted])		Metric tons
Average Injection Volume and/or Mass ([redacted])		Metric tons
Annulus Pressure		psi
Annular Fluid Weight		ppg
Annulus Pressure/Tubing Differential		psi

The maximum allowable injection pressure was determined as the [redacted] value of the fracture pressure at the shallowest point in the injection zone and is in compliance with EPA's requirements set forth in 40 CFR 146.88(a)).

6.3 Specifications of CO_2 Stream

The CO_2 will come into the site meeting the specifications presented in section **7.3** of the **Testing and Monitoring Plan**. The CO_2 will enter a header and be piped to each injection well. Each well will inject continuously. The CO_2 will be in the supercritical phase as it enters the wellhead and will remain in a supercritical phase within the wellbore. The CO_2 will be sourced from [redacted] **Table 6-4** displays the chemical composition of the anticipated CO_2 stream. If the water content of the injectate or stream is higher than [redacted], then corrosion-resistant materials are suggested on all components of the injection well that would come into contact with the CO_2 stream [1]. Therefore, TCCSP_INJ-1 and TCCSP_INJ-2 will have corrosion resistant materials present where CO_2 will be present. At TCCSP_INJ-2, on average, the CO_2 stream will be at an average of [redacted] at the well head. After injection downhole into the reservoir zone, the CO_2 stream is anticipated to heat to near formation temperature with an average density of [redacted] Upon injection into the reservoir formation, the CO_2 will remain in supercritical phase which will allow for minimal interaction with the formation.

Table 6-4. Specifications of the Anticipated CO_2 Stream Composition.

Component	Specification	Unit
[redacted]	[redacted]	vol%, dry basis
		ppmv
		ppmv
		ppmv
		ppmv
		ppmv
		ppbv
		ppmv

6.4 Estimated Maximum Allowable Surface Pressure

The maximum allowable surface pressure (MASP) was estimated by using a [redacted] hypothetical wellbore model to calculate the wellhead pressure assuming the maximum allowed bottomhole pressure was attained bottomhole. This is likely possible when CO_2 is injected at the maximum single well injection rate ([redacted]). The bottomhole pressure was set to [redacted] of the estimated hydraulic fracture pressure at the top perf depth for TCCSP_INJ-1, TCCSP_INJ-2 ([redacted]), and TCCSP_INJ-2 ([redacted]) values of which were [redacted], respectively. The results estimate each MASP for TCCSP_INJ-1, TCCSP_INJ-2 ([redacted]), and TCCSP_INJ-2 ([redacted]) to be [redacted] respectively, as shown in **Figure 6-2**. TCCSP will ensure that the downhole pressures will not exceed [redacted] of the fracture pressure to maintain the integrity of the caprock.

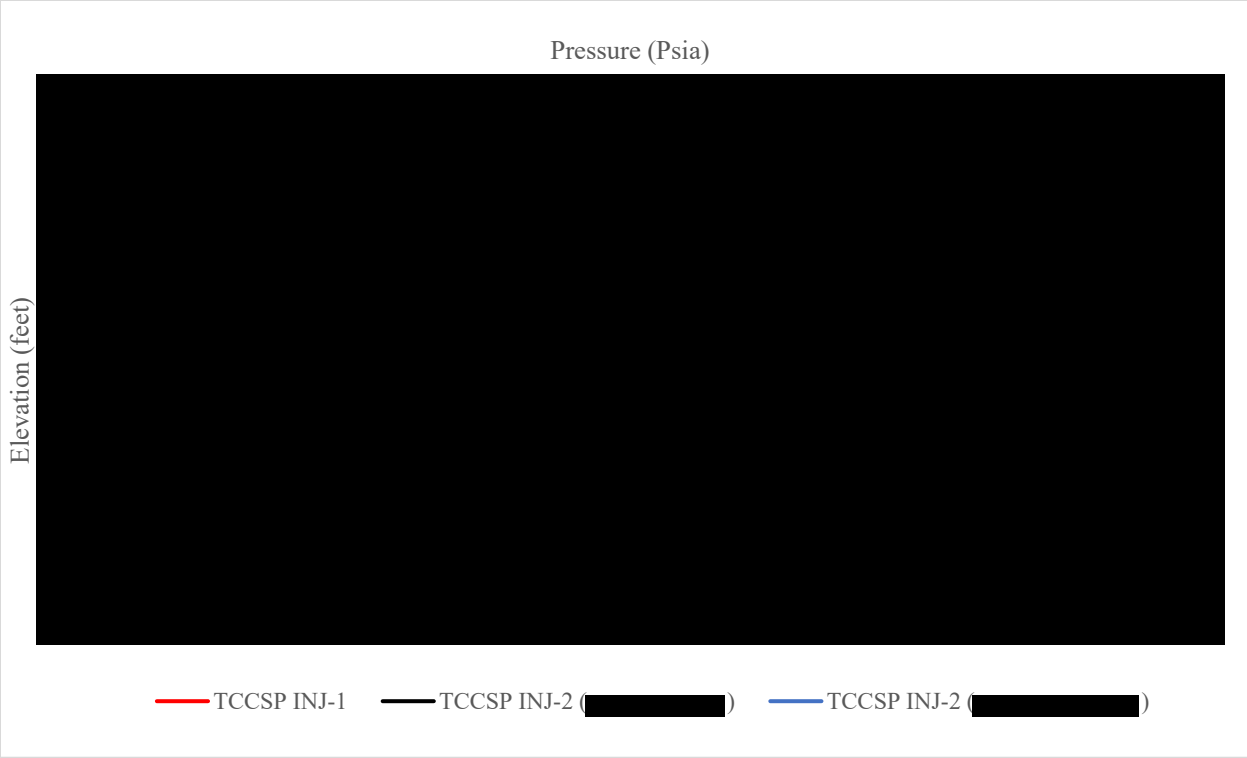

**Figure 6-2. Pressure versus depth profile at the maximum injection rate (
).**

6.5 Injection Well Operational Monitoring

Each injection well will be monitored to ensure safe operations. Safety monitoring includes monitoring the
. Each system is fully described in section **7.4** of the **Testing and Monitoring Plan**.

Each injection well will have a , both tied into the injection control system and set to trigger an alarm at the project control room and automatically shut down injection in the well if the MASP is reached. Injection parameters including pressure, rate, volume and/or mass, and temperature of the CO_2 stream will be continuously measured and recorded. The pressure and fluid volume of the annulus between the tubing and long-string casing will also be continuously measured by
. All automatic shutdowns will be investigated prior to bringing injection activities back online in the well to ensure that no integrity issues were the cause of the shutdown. If an un-remedied shutdown is triggered or a loss of mechanical integrity is discovered, TCCSP, LLC. will immediately investigate and identify as expeditiously as possible the cause of the shutdown. If the investigation determines that, the well appears to be lacking mechanical integrity, or if monitoring indicates that the well may be lacking mechanical integrity, TCCSP, LLC. will:

(1) Immediately cease injection in the affected well and in any other wells that may exacerbate the leakage risk of the affected well

(2) Take all steps reasonably necessary to determine whether there may have been a release of the injected CO_2 stream or formation fluids into any unauthorized zone

(3) Notify the Director in writing within 24 hours

(4) Restore and demonstrate mechanical integrity prior to resuming injection

(5) Notify the Director when injection can be expected to resume

The annular space between the tubing and long string casing of each injection well will be pressurized with a [redacted]. The annulus will be monitored continuously to ensure integrity of the well. The annulus will be filled with an [redacted]. The annular pressure differential held on the annulus at the wellhead will be [redacted], including times of shut-in. Additional pressure may be required on the annulus; if this is the case, the value will be set in conjunction with U.S. EPA Region 09. The [redacted] along the length of the casing. Rapid temperature changes or other excursions from a normal operating temperature profile will be investigated to ensure that there has been no breach of wellbore integrity.

6.6 Workover and Maintenance

TCCSP, LLC. will monitor and maintain the mechanical integrity of each injection well. Well maintenance and workovers will be part of normal operations to keep each injection well in a safe operating condition. Procedures for well maintenance will vary depending on the nature of the procedure, whether that is to pressure test the tubing or replace the packers and/or gauges. All maintenance and workover operations will be monitored to ensure there is no loss of mechanical integrity. Barriers such as BOPs and kill fluid will be used to ensure pressure is contained during the workovers. Each injection well is designed to allow the installation of a temporary plug in the tubing to allow the tubing to be removed and replaced as needed while keeping a barrier in place. The bottomhole [redacted] is set above the packer to allow for replacement, if needed, without removing the packer from the well.

6.7 Reporting Requirements

Table 6-5. Class VI Injection Well Reporting Requirements.

Activity	Reporting Requirements
[redacted]	

See section **7.2.5** of the **Testing and Monitoring Plan** to find more information regarding the Reporting Requirements.

6.8 References

[1] Meyer, J.P. 2007. API Summary of Carbon Dioxide Enhanced Oil Recovery Injection Well Technology. Prepared for API.