TESTING AND MONITORING PLAN
40 CFR 146.90

Kern River Eastridge CCS

Facility Information

Facility name: Kern River Eastridge CCS
MC19001INJ, ANO9004INJ, MC19002INJ, ANO9005INJ

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35.4404°/-118.9983°; 35.4465°/-119.0012°; 35.4401°/-118.9981°;
35.4462°/-119.0010°

This Testing and Monitoring Plan describes how Chevron U.S.A. Inc. (Chevron) will monitor the Kern River Eastridge CCS Project (Project) site pursuant to 40 CFR 146.90. In addition to demonstrating that the wells are operating as planned, the carbon dioxide plume and pressure front are moving as predicted, and that there is no endangerment to underground sources of drinking water (USDWs), the monitoring data will be used to validate and adjust the geological models used to predict the distribution of the CO_2 within the storage zone to support Area of Review (AoR) reevaluations and a non-endangerment demonstration.

Results of the testing and monitoring activities described below may trigger action according to the Emergency and Remedial Response Plan.

Overall Strategy and Approach for Testing and Monitoring

Testing and Monitoring Plan Objectives

Chevron has created a comprehensive monitoring plan designed to assess (1) the location of the CO_2 front, (2) the region where the reservoir pressure is elevated beyond the critical pressure, and (3) the non-endangerment of USDW's. The technologies and techniques for this monitoring plan were selected based on site-specific focus areas as determined by the site characterization, reservoir modeling and simulation, and AoR sensitivity analysis. This plan will cover three main aspects: (1) well integrity, (2) operational parameters, and (3) geologic system changes. The combination of these aspects will provide the ability to assess the protection of groundwater resources.

Testing and Monitoring Plan Focus Areas

Chevron has determined seven (7), site-specific, focus areas for the testing and monitoring plan based on site characterization, reservoir modeling and simulation, and an AoR sensitivity analysis**.**

Site characterization identified the presence of multiple faults within the AoR that penetrate both the injection zone (i.e., reservoir) and the primary confining zone (i.e., top seal). A combination of fault seal analysis and reservoir simulation has determined that these faults are likely to act as sealing mechanisms, either slowing or permanently trapping CO_2. However, because these faults act as a trapping mechanism and extend vertically beyond the primary confining zone, the monitoring plan is designed to assess unexpected CO_2 migration as it pertains to faults, either vertically up the faults or laterally across faults at rates or volumes that are outside the range of simulated CO_2 movement and associated sensitivities. For more information on either the site characterization or CO_2 simulation, please see either the Project Narrative or the AoR and Corrective Action Plan.

Chevron has assessed wells within the AoR that penetrate the injection zone and/or the primary confining zone. Under current operational conditions, there are no integrity concerns for these wells. With proposed CO_2 injection, Chevron plans to conduct work to support proactive zonal isolation for three specific wells within the AoR (FEC0074, API# 040292411200; GWA0145, API# 040292697300; and OM_0044, API# 040290009800). With proposed CO_2 injection, Chevron also plans to abandon KA_0053X (API# 040296990300). Additionally, Chevron has robust drilling and completion procedures to provide vertical containment and isolation for Project wells (i.e., CO_2 injection, monitoring, and pressure management wells). The location of the CO_2 injection wells and other well penetrations informed the monitoring well locations. For more information on AoR well penetrations, please see the AoR and Corrective Action Plan

Chevron utilized reservoir simulation coupled with a sensitivity analysis to determine a range of outcomes for the location of the CO_2 front and the region where the reservoir pressure is elevated beyond the critical pressure. The sensitivity analysis included varying the (1) permeability, (2) porosity, (3) relative permeability, (4) injection strategy, (5) fault threshold pressure, and (6) fault transmissibility. While this sensitivity study provides a range of potential outcomes for the movement of CO_2 and region of elevated pressure, the possibility still exists that CO_2 could migrate at a rate or in a direction not predicted by the model, or in such a way as to produce a thin plume that is below seismic resolution (i.e., seismic detectability). Chevron has designed a monitoring well network and selected monitoring technologies to evaluate these possibilities.

As part of the site characterization for the Project, Chevron assessed the potential for induced seismicity related to injection from the Project. Results from this study, in general, conclude that southeast striking faults have a friction coefficient that approaches 0.4. Past operational information supports fault stability under injection. Chevron has injected over 50,000,000 barrels of water in the Vedder Sand over the past forty (40) years with no observed seismic response or pressure build up. To reduce the potential pressure build-up within the Vedder Sand related to CO_2 injection, Chevron plans to include a pressure management water production system that reduces reservoir pressure through the life of the injection. In addition to this pressure management system, Chevron plans to install a seismic monitoring system.

Overview of Monitoring Technologies and Techniques

Chevron plans to utilize a combination of monitoring techniques deployed on deep, injection zone monitoring wells (deep monitoring wells); shallow, groundwater monitoring wells (shallow monitoring wells); and the CO_2 injection wells. **Table 1** summarizes the different well types and the Monitoring Zones/Geologic Formations. **Figure 1** provides a schematic diagram of Chevron's monitoring plan, and **Table 2** provides a list of monitoring techniques and their frequency during the different stages of the project.

Table 1. Summary of monitoring wells.

Well Types	Well Name	Monitoring Zone	Formation	Top Zone Depth (ft TVDSS)	Quantity
Shallow Observation	IR_9001OB KER9001OB ANO9003OB GW_9001OB	Lowermost USDW	Santa Margarita	-810 to -1350	4
	ANO9001OB GW_9002OB	1st Permeable Zone	Olcese	-1840 to -2420	2
Deep Observation	HK_9001OB COR9001OB	1st Permeable & Injection Zone	Olcese & Vedder	-1840 to -2420 -3690 to -4230	2
	RCA9001OB DDA9001OB	Injection Zone	Vedder	-3690 to -4230	2
CO_2 Injection	ANO9004INJ MC19001INJ	Injection Zone	Vedder	-3690 to -4230	2

The deep monitoring wells are designed to monitor the location of the CO_2 front and the region where the reservoir pressure is elevated beyond the critical pressure using both direct and indirect methods. The wells will use a combination of direct cased hole pulsed neutron logs (PNLs) and indirect casing-conveyed distributed acoustic sensing fiber optics (DAS) vertical seismic profiles (VSPs) or equivalent technologies to monitor the location and thickness of the CO_2 plume. The deep monitoring wells will directly measure reservoir pressure in the injection zone via a casing-conveyed pressure sensor array or equivalent technology.

The shallow monitoring wells are designed to monitor the first permeable zone above the caprock (i.e., Olcese) for early detection of loss of containment and to monitor the lowermost USDW (i.e., Santa Margarita) to establish the non-endangerment of USDWs. The wells will be utilized to sample the groundwater using a U-tube tubing-conveyed sampling system or via a fluid sampling tool deployed on coil tubing or wireline or an equivalent technology while maintaining reservoir pressure of the sample. Chevron plans to have four (4) sampling locations for the Santa Margarita and four (4) sampling locations for the Olcese (**Figure 2**). For each zone,

one well is located downdip of the CO_2 injection wells, one well is located updip of the CO_2 injection wells, and two wells are located within the AoR near faults and well penetrations. All four (4) Santa Margita sampling locations will be in dedicated shallow monitoring wells (IR_9001OB, KER9001OB, ANO9003OB, and GW_9001OB). Two (2) Olcese sampling locations will be in dedicated shallow monitoring wells (ANO9001OB and GW_9002OB), and two (2) sampling locations will be in two (2) of the deep monitoring wells (HK_9001OB and COR9001OB). The deep monitoring wells will be cased through the injection zone (i.e., there will be no perforations across the injection zone), and the shallow perforated intervals will be isolated via packers. All wells will use the same sampling technologies as described above.

The CO_2 injection well monitoring equipment is designed to measure operational parameters (e.g., injection rate, volume, and pressure), monitor potential corrosion, verify external and internal mechanical integrity, and to monitor the location of the CO_2 front. Chevron plans to install and use continuous recording devices to monitor injection pressure, rate, and volume; the pressure on the annulus between the tubing and the long string casing; and the temperature of the CO_2 stream. To assess potential corrosion, Chevron plans to use corrosion loops or an equivalent technology. A pressure fall-off test is planned no less than every five (5) years on each operational CO_2 injection well. Oxygen activation logs will monitor external mechanical integrity.

In addition to the well-based monitoring technologies summarized above, Chevron plans to deploy and maintain a seismic monitoring system to determine the presence or absence of any induced micro-seismic activity associated with project injection. The seismic monitoring system will consist of surface and/or shallow borehole seismometers coupled with DAS fiber or equivalent technologies.

Chevron plans to monitor the CO_2 stream via an online analyzer, continuous emissions monitoring system (CEMS), or similar device.

The monitoring technologies and monitoring and reporting frequencies provided in this permit may change, pursuant to Environmental Protection Agency (EPA) approval, based on monitoring data and/or regulatory changes.

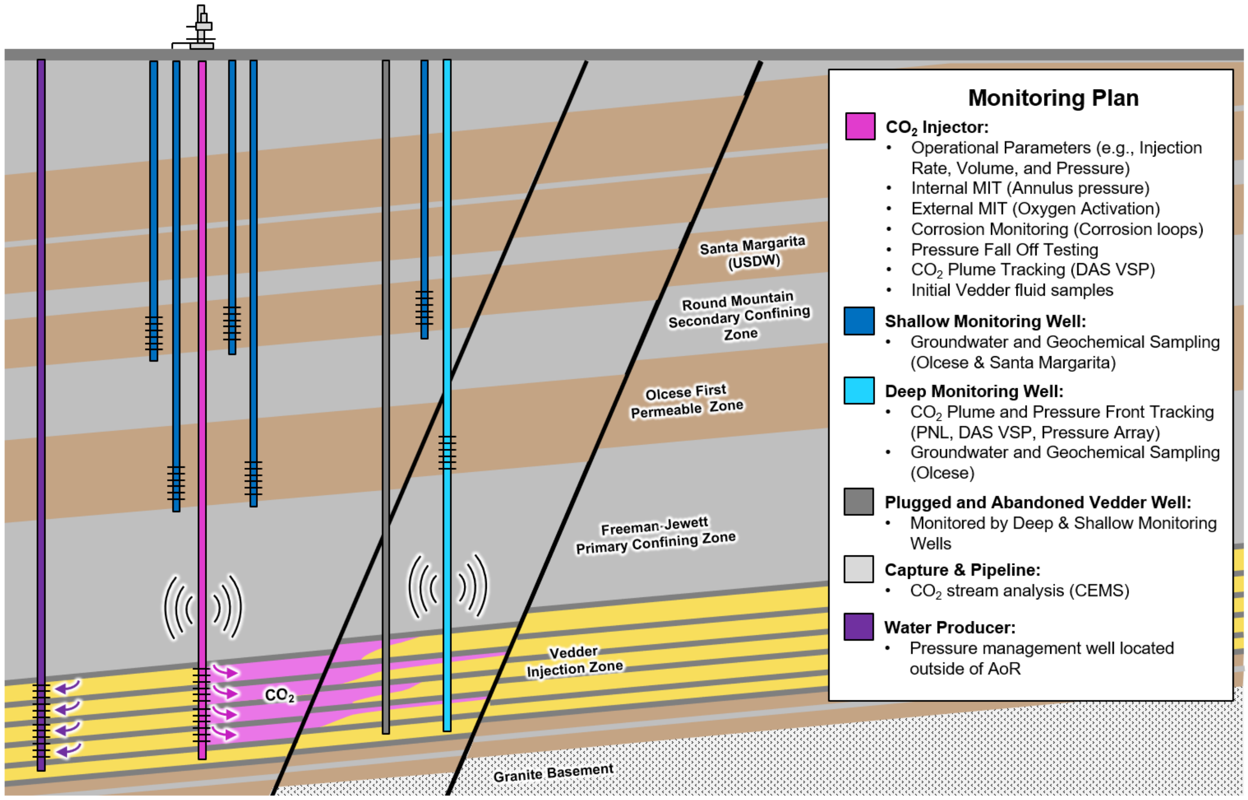

Figure 1. Schematic diagram of Chevron's monitoring plan.

Table 2. Monitoring methodologies and monitoring frequencies for baseline, injection, and post-injection phases

Monitoring Category	Monitoring Method		Baseline Frequency (1 year)	Injection Phase Frequency (20 years)*	Post-Injection Frequency (50 years)*
Monitoring Plan Update	Reviewed every 5 years. Updated as required		N/A	As required	As required
CO_2 Injection Stream Analysis	Continuous monitoring of injection stream composition		N/A	Continuous	N/A
CO_2 Injection Process Monitoring	Continuous monitoring of injection process (e.g., injection rate, pressure, and temperature; annulus pressure)		N/A	Continuous	N/A
Hydrogeologic Testing	Injection well pressure fall-off testing		1 Prior to injection	1 per every 5 years	N/A
Injection Well Mechanical Integrity Testing	*Internal*	Continuous annulus pressure monitoring of pressurized annulus	1 after well completion *(injectors)*	Continuous *(injectors)*	1 prior to abandonment
	External	Oxygen activation log	1 after well completion *(injectors)*	Annual *(injectors)*	1 prior to abandonment *(injectors)*
Corrosion Monitoring	Corrosion loop (well and pipeline materials)		N/A	Quarterly	N/A
Groundwater Quality and Geochemistry Monitoring (Above-Zone)	Above-zone & shallow groundwater fluid sampling		Quarterly, 1 yr. prior to injection	Quarterly	Annual
Direct Pressure Monitoring	Pressure array sensors in deep monitoring wells		1 yr. prior to injection	Monthly	1 per every 5 years
Direct & Indirect Plume Monitoring Techniques	*Wireline*	PNL	1 prior to injection	Annual	1 per every 5 years
	Seismic	Timelapse 3D DAS-VSP surveys	1 prior to injection	1 per every 5 years	10, 30, & 50 years post injection

*Monitoring technologies and monitoring and reporting frequencies provided in this permit may change, pursuant to EPA approval, based on monitoring data and/or regulatory changes.

Monitoring Network Design and Strategy

Chevron integrated the site-specific focus areas into both the technology selection for the monitoring plan **(Figure 1, Table 2)** and the location of the monitoring wells **(Figure 2)**. Deep monitoring well locations were determined using approximate illumination based on ray tracing of a modeled DAS VSP seismic shoot. The location of the deep monitoring wells and CO_2 injection wells with their associated illumination provides seismic imaging across the major faults within the AoR (e.g., Canfield, Omar Sterling Cortez South, Luck **[Figure 2]**) and well penetrations within the AoR. The wells are positioned to provide overlapping seismic imaging across the AoR with an additional well placed to the northwest of the Luck Fault. This arrangement of wells provides broad coverage inside and outside of the AoR to address the possibility that CO_2 could migrate at a rate or in a direction not predicted by the model. To address the possibility that the CO_2 plume could develop in such a way as to produce a thin plume that is below seismic resolution (i.e., seismic detectability), Chevron has added pulsed neutron logs to assess the location and thickness of the CO_2 plume. This method has a vertical resolution of less than one foot. To monitor potential induced seismicity associated with CO_2 injection, Chevron will deploy and maintain a seismic monitoring system, which consists of surface and/or shallow borehole seismometers coupled with DAS fiber on the deep monitoring wells and the CO_2 injection wells. The deep monitoring wells are positioned near faults that computation models indicate may interact with the CO_2 plume and the surface and/or shallow borehole seismometers will be positioned in such a way to triangulate the position of potential seismic events. Additionally, Chevron plans to use between 1 and 4 pressure management wells located outside of the AoR to manage any potential increase in pressure due to CO_2 injection. Simulation, described in detail in the AoR and Corrective Action Plan, indicates that these pressure management wells prevent pressure build up and therefore reduce the potential for induced seismicity. The locations of monitoring wells may change based on updated data or analysis, including data collected during the construction phase of the project. For more information on Chevron’s data collection strategy see the Pre-Operational Logging and Testing Plan. Additionally, Chevron has surface estate and/or physical access rights at the proposed monitoring well locations.

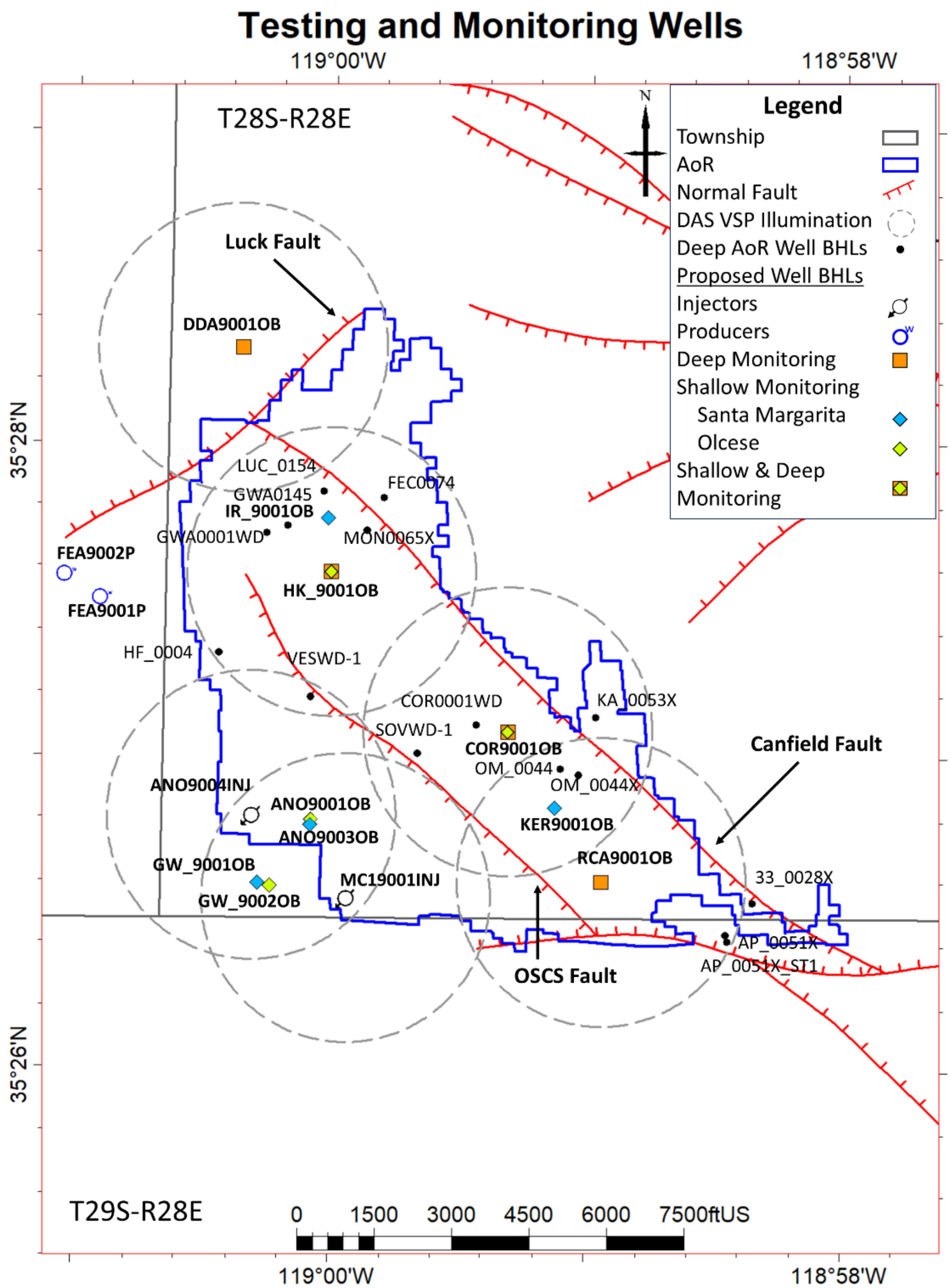

Figure 2. Location of the project wells including CO_2 injection wells (2), deep monitoring wells (4), shallow monitoring wells (4), and pressure management water production wells (2). Deep monitoring wells are located to provide overlapping seismic illumination from DAS VSPs of the AoR. The AoR for this project was calculated as the intersection of the CO_2 plume and the region where the reservoir pressure is elevated beyond the critical pressure. However, due to the use of pressure management wells, reservoir simulations indicate that there is no increase in pressure increase from to CO_2 injection. Therefore, the resulting AoR boundary is a function of the extent of the CO_2 plume.

Quality assurance procedures

A quality assurance and surveillance plan (QASP) for the testing and monitoring activities has been attached to this document pursuant to 146.90(k) in the Testing and Monitoring Plan.

Reporting procedures

Chevron will report the results of testing and monitoring activities to EPA in compliance with the requirements under 40 CFR 146.91.

Carbon Dioxide Stream Analysis [40 CFR 146.90(a)]

Chevron will analyze the CO_2 stream during the operation period to yield data representative of its chemical and physical characteristics and to meet the requirements of 40 CFR 146.90(a).

Sampling location and frequency

Chevron will monitor the CO_2 stream continuously via an online analyzer, continuous emissions monitoring system (CEMS), or similar device. The online analyzer will be placed after the CO_2 stream discharges from the compressor. No other equipment will act on the CO_2 stream at this point. Therefore, the analyzer will be exposed to the same CO_2 stream as the wellhead, any downhole equipment, and formation solids and fluids. Baseline laboratory samples will be collected quarterly during the first year of injection. The injectate composition is predicted to be approximately 95% CO_2 by volume with other minor components including H_2 (maximum 4% by volume), N_2 (maximum 4% by volume), H_20 (maximum 500 ppm), CO (maximum 35 ppm), Ar (maximum 4% by volume), O_2 (maximum 0.001% by volume), SO_2 (maximum 100 ppm), H_2S (maximum 0.01% by volume), CH_4 (maximum 4% by volume), NO_x (maximum 100 ppm), NH_3 (maximum 50 ppm), and C_2H_6 (maximum 1% by volume). The injectate composition will be refined based on specific sources and changes to the composition will be communicated to the EPA. Currently, there are no anticipated significant changes in the CO_2 stream throughout the injection period. A significant change is defined as the sum of the non-condensable gas components increasing to 4 vol% of the total stream. However, if significant changes are detected by monitoring equipment, Chevron would perform laboratory analysis on a sample of the CO_2 stream to verify the change and determine if operational adjustments are needed. Additionally, Chevron plans to continuously monitor physical characteristics of the injectate as described in the Continuous Recording of Operational Parameters section of this document.

Analytical parameters

Chevron will analyze the CO_2 stream both continuously and via laboratory samples. The parameters and methods for continuous monitoring are listed in **Table 3**. The parameters and methods for laboratory analysis are listed in **Table 4**.

Table 3. Summary of analytical parameters for continuous monitoring of the CO_2 stream.

Parameter	Analytical Method(s)
CO_2	Online Analyzer, Continuous Emission Monitoring System, or similar device
H_2O	Online Analyzer, Continuous Emission Monitoring System, or similar device

Table 4. Summary of analytical parameters for laboratory analysis of the CO_2 stream.

Parameter	Analytical Method(s)
CO_2	Gas Chromatography
O_2	Gas Chromatography
CH_4, C1-C5 hydrocarbon gasses	Gas Chromatography
$\delta^{13}C$ of CO_2	Isotope Ratio Mass Spectrometry
$\delta^{14}C$ of CO_2*	Accelerator Mass Spectrometry
N_2	Gas Chromatography
Ar	Gas Chromatography

*^{14}C of CO_2 will be measured in the first sampling event and if not present, will not be included in future sampling events.

Sampling methods

Continuous monitoring via an online analyzer (e.g., non-dispersive infrared analyzer) or similar device will occur on site at the sample collection point after the CO_2 stream discharges from the compressor. The online analyzer uses a small sample of the CO_2 steam to perform the analysis at the sample collection point. Laboratory samples will be taken from the same location as the online analyzer and stored in a gas cylinder or similar container. These samples will be sent to a laboratory with an established chain of custody (see chain of custody section below).

Laboratory to be used/chain of custody and analysis procedures

Chevron plans to collect laboratory samples via a gas cylinder or similar method and send them to a laboratory that has the technical capacity to measure the parameters listed in **Table 4** (e.g., Isotech/Stratum). A standardized form will be used to document chain-of-custody. An example of this form is displayed in the QASP. A copy of the form will be provided to the person or laboratory receiving the samples as well as the person or laboratory transferring the samples. These forms will allow simplified tracking of sample status and will be archived. For more information on laboratories, chain of custody, and analysis procedures see the CO_2 stream section of the QASP.

<u>Continuous Recording of Operational Parameters [40 CFR 146.88(e)(1), 146.89(b) and 146.90(b)]</u>

Chevron plans to install and use continuous recording devices to monitor injection pressure, rate, and volume; the pressure in the annulus between the tubing and the injection string casing; the annulus fluid volume added; and the temperature of the CO_2 stream, as required by 40 CFR 146.88(e)(1), 146.89(b), and 146.90(b).

Monitoring location and frequency

Chevron plans to perform the activities identified in **Table 5** to monitor operational parameters and verify internal mechanical integrity of the injection well. Monitoring will take place at the locations and frequencies shown in the table below.

Table 5. Sampling devices, locations, and frequencies for continuous monitoring.

Parameter	**Device(s)**	**Location**	**Min. Sampling Frequency[a]**	**Min. Recording Frequency[b]**
Injection Pressure	Pressure Gauge	Wellhead and downhole above packer	Continuous	Minute
Injection Rate	Coriolis Mass Flowmeter	Wellhead	Continuous	Minute
Injection Volume	Coriolis Mass Flowmeter	Wellhead	Continuous	Minute
Annular Pressure	Pressure Gauge	Wellhead and downhole above packer	Continuous	Minute
Annular Fluid Volume	N/A	Wellhead	As Required[c]	As Required[c]
CO_2 Stream Temperature	Temperature Gauge	Wellhead	Continuous	Minute

Notes:
[a]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.
[b]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.
[C]Fluid volumes added or removed to maintain annular pressure will be recorded and submitted as required.

Monitoring details

Injection pressure, annular pressure, and CO_2 stream temperature will be continuously monitored and recorded using pressure/temperature gauges. These downhole gauges will be placed above the packer. Injection pressure will also be measured with a gauge at the wellhead.

Coriolis mass flowmeters will be used to measure CO_2 mass flow rate, density, and volume at the wellhead at surface conditions. The calibration standards, precision, and tolerances for the instruments listed in **Table 5** will meet or exceed industry standards.

The data listed in **Table 5** will be stored in Chevron's Supervisory Control and Data Acquisition (SCADA) system. Once CO_2 injection commences, trends will be monitored on each well and compared to the average values so that deviations can be quickly recognized. Total injection volumes will be compared to total CO_2 supplied from the surface facilities. Rapid changes in annular pressure, volume of fluid added to the annulus, or any other unexpected trends in data, may provide cause for an investigation of mechanical integrity. Chevron will have automatic alarm and shutdown procedures if specified control parameters exceed their operating limits.

If a loss of mechanical integrity is discovered, Chevron will cease injection in the affected CO_2 injection well(s) and notify the Underground Injection (UIC) Program Director within 24 hours, as described in the "Well Integrity Failure" section of the Emergency and Remedial Response Plan.

Corrosion Monitoring [40 CFR 146.90(c)]

To meet the requirements of 40 CFR 146.90(c), Chevron will monitor well materials during the operational period for loss of mass, thickness, cracking, pitting, and other signs of corrosion to ensure that the well components meet the minimum standards for material strength and performance. Chevron will monitor corrosion using corrosion coupons installed in a corrosion loop and collect samples according to the description below.

Monitoring location and frequency

Coupon samples of the materials below will be installed on a corrosion loop downstream from the compressor but upstream of the wellhead at each injection well. No other equipment will act on the CO_2 at this point. Therefore, these coupons will be exposed to the same CO_2 stream properties as the wellhead and other downhole equipment.

Initial photographs and measurements will be taken of the corrosion coupons prior to injection. Once injection commences, monitoring of these coupons will occur quarterly.

Sample description

Samples representative of the downhole materials in **Table 6** will be used. Initial coupons will be measured, weighed, and photographed prior to installation. Coupons will be installed prior to injection.

Table 6. List of equipment with materials of construction.

Equipment Coupon	Material of Construction
Injection Casing	Carbon Alloy Steel from surface to packer, 25 Cr below packer
Injection Tubing	GRE Lined from surface to packer, 25Cr below packer
Wellhead/Tree	Flow wetted surfaces will be constructed of CRA material consistent with final design
Packer	Flow wetted surfaces will be constructed of CRA material consistent with final design

Monitoring details

The coupons will be photographed, visually inspected, weighed and measured. The data will be documented and changes in rates and trends will be noted. Based on these results, additional downhole casing inspection logs may be completed.

Above Confining Zone Monitoring [40 CFR 146.90(d)]

Chevron plans to monitor groundwater quality and geochemical changes above the confining zone during the operation period to meet the requirements of 40 CFR 146.90(d).

Monitoring location and frequency

Table 7 shows the planned monitoring methods, locations, and frequencies for groundwater quality and geochemical monitoring above the confining zone.

The shallow monitoring wells are designed to monitor the first permeable zone above the caprock (i.e., Olcese) for early detection of loss of containment and to monitor the lowermost USDW (i.e., Santa Margarita) to establish the non-endangerment of USDWs. The top of the Olcese is located at a depth of approximately -1840 to -2420 ft TVDSS and the top of the Santa Margarita is located at a depth of approximately -810 to -1350 ft TVDSS. Exact completion intervals of the monitoring wells will be based on geophysical logs which will be collected during drilling. Chevron plans to have four (4) sampling locations for the Santa Margarita and four (4) sampling locations for the Olcese (**Figure 2**). For each zone, one well is located downdip of the CO_2 injection wells, one well is located updip of the CO_2 injection wells, and two wells are located within the AoR near faults and well penetrations. All four (4) Santa Margarita sampling locations will be in dedicated shallow monitoring wells (IR_9001OB, KER9001OB, ANO9003OB, and GW_9001OB). Two (2) Olcese sampling locations will be in dedicated shallow monitoring wells (ANO9001OB and GW_9002OB), and two (2) sampling locations will be in two (2) of the four (4) deep monitoring wells (HK_9001OB and COR9001OB). The deep monitoring wells will be cased through the injection zone (i.e., there will be no perforations across the injection zone), and the shallow perforated intervals will be isolated via packers.

Additional monitoring wells may be added in the future based on CO_2 plume migration within the Vedder Sand injection zone.

Table 7. Monitoring of groundwater quality and geochemical changes above the confining zone.

Target Formation	Monitoring Activity	Monitoring Location(s)	Spatial Coverage	Frequency
Olcese -1840 to -2420 (ft TVDSS)	Fluid Sampling	ANO9001OB, GW_9002OB, HK_9001OB, COR9001OB	Updip & downdip of CO_2 injection wells; Near faults and well penetrations	Quarterly
Santa Margarita -810 to -1350 (ft TVDSS)	Fluid Sampling	IR_9001OB, KER9001OB, ANO9003OB, GW_9001OB	Updip & downdip of CO_2 injection wells; Near faults and well penetrations	Quarterly

Analytical parameters

Table 8 identifies the parameters to be monitored and the analytical methods Chevron will use.

An extensive suite of baseline groundwater parameters, which are listed in the "Baseline" section under **Table 8**, will be analyzed quarterly for one (1) year prior to injection to capture natural seasonal variability. This suite includes natural intrinsic tracers including ions, dissolved gases, and isotopes that can be used to determine whether a foreign brine or gas has invaded the aquifer.

After beginning injection, a reduced suite of groundwater parameters will be analyzed quarterly. An evaluation of the results from the baseline data collection will be used to inform which parameters will be included in this reduced suite. The reduced suite will likely include the parameters listed in the "During and Post-injection" section of **Table 8**.

The range of concentrations measured during the baseline period will be used to evaluate geochemical changes in the aquifer once injection begins. Geochemical measurements are influenced by a variety of factors including natural fluctuations in the aquifer as well as variability due to sampling and laboratory procedures. For these reasons, multiple lines of evidence are needed to evaluate whether a change has occurred.

Table 8. Summary of analytical and field parameters for groundwater samples

Parameters		Analytical Methods*
Baseline: Olcese and Santa Margarita		
Cations: Al, Ba, Mn, As, Cd, Cr, Cu, Pb, Sb, Se, Sr, Tl, Zn, Ca, Fe, K, Mg, Na, Si, B		ICP-MS, EPA Method 6020B, ICP, EPA Method 6010D
Anions: Br, Cl, F, NO_3, NO_2, SO_4, PO_4		Ion chromatography, EPA Method 300.0
Total Alkalinity		SM 2320B
Total dissolved solids		SM 2540C
Water density (lab)		Density Meter (ASTM D4052/D5002)
Water density (field)		Field instrument
pH (lab)		SM 4500 H+B
pH (field)		Field instrument
Specific conductance (lab)		EPA 120.1
Specific conductance (field)		Field instrument
Temperature (field)		Field instrument
Turbidity (lab)		U.S. EPA Method 180.1 (Same as APHA SM 2130B)
Turbidity (field)		Field instrument
Oxidation-Reduction Potential (field)		Field instrument
Dissolved Oxygen (field)		Field instrument
Dissolved Inorganic Carbon (DIC)		SM 5310B
$^{228}Ra/^{226}Ra$		EPA Method 901.1
$^{87}Sr/^{86}Sr$		ICP-MS
$\delta^{18}O$ and $\delta^{2}H$ of H_2O		Analyzed via CRDS (Cavity Ring Down Spectroscopy)
$\delta^{13}C$ of DIC		IRMS (Isotope Ratio Mass Spectrometry)
^{14}C of DIC**		AMS (Accelerator Mass Spectrometer)

Parameters		Analytical Methods*
Dissolved CO_2, N_2, Ar, O_2, He, C1-C6+, by headspace		Isotech/Stratum SOP, similar to RSK-175
$\delta^{13}C$ of CO_2		High precision (offline) analysis via Dual Inlet IRMS
$\delta^{13}C$ and $\delta^{2}H$ of Methane, Ethane, Propane		High precision (offline) analysis via Dual Inlet IRMS
Sulfide		EPA 9034
Dissolved Noble Gasses (He, Ne, Ar, Kr, Xe)		Noble Gas Mass Spectrometry
Total Petroleum Hydrocarbons		EPA 8015B with silica gel cleanup
Ammonium		EPA 350.1
Organic Acids (Acetate, Propionate, Butyrate)		APHA SM 5560B
<u>During and Post Injection: Olcese and Santa Margarita*</u>**		
pH (lab)		SM 4500 H+B
pH (field)		Field instrument
Specific conductance (lab)		EPA 120.1
Specific conductance (field)		Field instrument
Temperature (field)		Field instrument
Total Alkalinity		SM 2320B
Oxidation-Reduction Potential (field)		Field instrument
Total dissolved solids		SM 2540C
Cations: Al, Ba, Mn, As, Cr, Pb, Se, Sr, Tl, Zn, Ca, Fe, K, Mg, Na, Si, B		ICP-MS, EPA Method 6020B, ICP, EPA Method 6010D
Anions: Br, Cl, F, and SO_4		Ion chromatography, EPA Method 300.0

Parameters		Analytical Methods*
Alkalinity (total and bicarbonate)		SM 2320B
Dissolved Inorganic Carbon (DIC)		SM 5310B
$\delta^{13}C$ of DIC		IRMS
Water density (lab)		Density Meter (ASTM D4052/D5002)
Water density (field)		Field Instrument
Turbidity (lab)		U.S. EPA Method 180.1 (Same as APHA SM 2130B)
Turbidity (field)		Field Instrument
Sulfide (lab)		EPA 9034
* Analytical methods subject to change with approval from UIC director ** ^{14}C of CO_2 will be measured in the first sampling event and if not present, will not be included in future sampling events. ***Analyte list may change depending on results from baseline assessment		

Sampling methods

Sampling will be performed in accordance with the QASP. The groundwater wells will be purged to collect samples representative of aquifer conditions. Once conditions stabilize, groundwater samples will be lifted using a U-tube tubing conveyed sampling system or via a fluid sampling tool deployed on coil tubing or wireline. Both methods will ensure reservoir pressure is maintained. This is particularly important given the depths of the Santa Margarita and Olcese as a change in pressure can result in geochemical changes in the sample.

Field measurements will be taken for pH, temperature, conductance, and dissolved oxygen. Samples will be preserved and sent to the lab via the chain of custody procedures.

Laboratory to be used/chain of custody procedures.

Analyses will be performed by California or International Organization for Standardization (ISO) accredited laboratories with the capabilities to perform the analyses listed above. Several possible examples could include:

- Oilfield Environmental Compliance in Santa Maria for metals/cations/anions/alkalinity/TDS/density/pH
- Stratum (isotech) for dissolved gases/DIC/ water isotopes
- Lawrence Livermore National Laboratory for dissolved noble gas analysis
- Eurofins for organic acids
- Pace for Radium/Strontium Isotopes

Laboratories utilized for sample analysis may change based on accreditation and availability.

External Mechanical Integrity Testing [40 CFR 146.89(c), 146.90(e)]

During the injection phase of the Project, Chevron will periodically verify external mechanical integrity as required by 146.89(c) and 146.90(e) using the test in **Table 9** or an equivalent technology.

Testing location and frequency

During the injection phase, the external mechanical integrity (MIT) testing method in **Table 9** will be conducted annually on injection wells within 45 days of the respective anniversary date of the start of injection.

Table 9. External MIT Testing Method.

Test Description	Location
Oxygen Activation Log	Along wellbore using a wireline log

Testing details

An Oxygen Activation Log will monitor for external leaks along the long string of casing in the CO_2 injection wells. Log results will be interpreted and submitted to the UIC Program Director. The testing procedure is described below.

1. Move in and rig up wireline unit. Verify logging tools are calibrated per business partner specifications in the shop.
2. Make up logging tool string and run into the well.
3. Obtain baseline gamma ray (GR) and casing collar locator (CCL) log from the top of the injection zone to surface at a logging speed of ~10-30 ft/min with well static.
4. Perform oxygen activation (OA) logging run:
    a. Perform baseline logging run from the top of the injection zone to surface at a logging speed of ~1-30 ft/min with well static. Logging speed may vary depending on the rate of fluid migration to locate points of interest.
    b. Perform stationary OA log for a minimum of 5 minutes per station with the well static. Minimum required logging points:
        i. Approximately 100ft above the top of the injection zone (Vedder Sand)
        ii. Approximately 100ft below the top of the confining zone (Freeman-Jewett Silt)
        iii. Approximately 100ft above the base of the USDW (Santa Margarita)
    c. Based on the results from the initial logging run, perform stationary OA log at point(s) of interest for a minimum of 5 minutes per station with well static.
5. Rig down and move off wireline unit.

Pressure Fall-Off Testing [40 CFR 146.90(f)]

Chevron will perform pressure fall-off tests during the injection phase as described below to meet the requirements of 40 CFR 146.90(f).

Testing location and frequency

A pressure fall-off test is planned for no less than every 5 years on each operational injection well and at the end of the injection period. Results of the pressure fall-off tests will be submitted to the UIC Program Director electronically within 30 days of the test. The pressure fall-off testing procedure is described below.

Testing details

1. Hold injection rate constant while maintaining as stable operating conditions as possible prior to the fall-off test shut in period. Do not exceed the maximum operating pressure.
2. Shut in well at the wellhead, or as near to the wellhead as feasible. For offset injectors in the Vedder Sand that are operated by Chevron, maintain a constant injection rate and continuously record injection rates for the duration of the test.
3. Continuously measure pressure using downhole pressure gauges for the duration of the test. Conduct the test over a sufficient time period in which pressure is no longer influenced by wellbore storage or skin.

Carbon Dioxide Plume and Pressure Front Tracking [40 CFR 146.90(g)]

Chevron will employ direct and indirect methods to track the extent of the carbon dioxide plume and direct methods to track the presence or absence of elevated pressure during the operation period to meet the requirements of 40 CFR 146.90(g).

Plume monitoring location and frequency

Chevron will use four (4) deep monitoring wells along with the two (2) CO_2 injection wells to monitor the location of the CO_2 plume. Chevron has secured surface estate and/or physical access rights at the proposed monitoring well locations. For direct monitoring of the CO_2 plume, the deep monitoring wells will utilize cased-hole pulsed neutron logs (PNL) for quantitative measurements of gas saturation, which will be collected annually. Baseline PNL measurements will be collected prior to injection. For indirect monitoring of the CO_2 plume, the four (4) deep monitoring wells and the two (2) CO_2 injection wells will utilize distributed acoustic-sensing fiber optic vertical seismic profiles (DAS VSPs) to geophysically image the plume. The four (4) deep monitoring wells will be located updip from the two (2) CO_2 injectors to provide overlapping seismic illumination of the AoR based on site specific ray tracing of a potential VSP survey (**Figure 2**). Timelapse 3D DAS-VSP surveys will be conducted every five (5) years during the injection period with one baseline survey conducted prior to injection. Because Chevron expects DAS VSP survey analysis to take up to two (2) years, each survey will be collected two (2) years prior to the AoR reevaluation (e.g., a DAS VSP survey collected in year three (3) would be described in the year five (5) report). **Table 10** presents the methods that Chevron will use to monitor the position of the CO_2 plume, including the activities, locations, and frequencies that will be employed. The parameters to be analyzed as part of fluid sampling in the injection zone and associated analytical methods are presented in **Table 11**.

Quality assurance procedures for these methods are presented in the QASP.

Plume monitoring details

PNLs will be conducted for direct monitoring of the CO_2 plume (**Table 10**). PNLs will measure changes in gas saturation through time and vertically throughout the entire wellbore. Prior to injection Chevron will take baseline PNL measurements to calibrate changes observed in the subsurface. Overlapping DAS VSPs will be conducted for indirect monitoring (**Table 10**). Prior to injection Chevron will also take a baseline DAS VSP survey. Comparison of repeat DAS VSP surveys to the baseline survey will provide information on the position of the CO_2 plume.

In addition to the repeated methodologies listed above, Chevron plans to collect baseline fluid samples in the Vedder Sand injection zone once using an open hole sampling system. Analytical parameters for the Vedder Sand fluid sampling are included in **Table 11**.

Table 10. Plume monitoring activities

Target Formation	**Monitoring Activity**	**Monitoring Location(s)**	**Spatial Coverage**	**Frequency**
Vedder -3690 to -4230 (ft TVDSS)	PNL	RCA9001OB, COR9001OB, HK_9001OB, DDA9001OB	Updip of CO_2 injection wells near faults and well penetrations	Annual
	Timelapse 3D DAS-VSP Surveys	RCA9001OB, COR9001OB, HK_9001OB, DDA9001OB, ANO9002INJ, MC19001INJ	Overlapping illumination covering the AoR, faults and well penetrations	One (1) per every five (5) years

Table 11. Summary of analytical and field parameters for fluid sampling in the injection zone

Parameters	Analytical Methods
Total Alkalinity	SM 2320B
Organic Acids (Acetate, Propionate, Butyrate)	APHA SM 5560B
Dissolved sulfide	SM4500
lab pH (25°C)	SM 4500 H+B
Total Dissolved Solids	SM 2540C
Water Density	Density Meter (ASTM D4052/D5002)
Conductivity	U.S. EPA Method 120.1 (Same as APHA SM 2510B and ASTM D1125-95(A)).
Turbidity (lab)	U.S. EPA Method 180.1 (Same as APHA SM 2130B)
Temperature (field)	Field instrument
Dissolved Inorganic Carbon (DIC)*	Standard Method 5310B
d^{13}C Dissolved Inorganic Carbon	Gas Bench/CF-IRMS
dD & d^{18}O H_2O	Analyzed via CRDS
Hydrogen sulfide	ASTM D5623
Cations: Al, Ba, Mn, As, Cd, Cr, Cu, Pb, Sb, Se, Sr, Tl, Zn, Ca, Fe, K, Mg, Na, Si, B	ICP-MS, EPA Method 6020B, ICP, EPA Method 6010D
Anions: Br, Cl, F, NO_3, NO_2 , SO_4 and PO_4	Ion chromatography, EPA Method 300.0
δ^{13}C of dissolved Methane, Ethane, Propane, and CO_2, δ^2H of Methane	High precision (offline) analysis via Dual Inlet IRMS
Dissolved CO_2, N_2, Ar, He, O_2, C1 - C6+ by headspace	Lab in-house SOP, similar to RSK-175

Pressure-front monitoring location and frequency

Table 12 presents the methods that Chevron plans to use to monitor the position of the pressure front, including the activities, locations, and frequencies Chevron plans to employ.

Quality assurance procedures for these methods are presented in the QASP.

Chevron will use the deep monitoring wells to monitor the pressure front. Chevron has secured surface estate and/or physical access rights at the proposed monitoring well locations. For direct monitoring of the pressure front, the deep monitoring wells will utilize a casing conveyed pressure sensor array system. Prior to injection, Chevron will collect baseline pressure data via wireline logging and/or baseline pressure measurements from the pressure array sensors.

Pressure-front monitoring details

Casing conveyed pressure array sensors will provide direct measurement of the pressure front. Chevron will compare the pressure data to computational modeling results to validate the computational modeling.

Chevron evaluated a variety of indirect methods for pressure-front monitoring and determined that site-specific conditions preclude their use at the site. Seismic profiling is a geophysical method, which can be used to derive fluid pressure. This technique typically works by initiating the propagation of a seismic signal and measuring the reflection or transmission of that signal. Resulting data can be processed and interpolated to provide estimates of fluid pressure. Seismic profiling is not recommended for this site because the low anticipated pressure changes within the AoR are below the level of detectability for seismic profiling, which prevents use of this method as a reliable indirect method for pressure front tracking. Similarly, monitoring for low magnitude, microseismic events is expected to be ineffective as an indirect monitoring technique at the proposed injection rates due to the low anticipated pressure changes and the structurally stable subsurface conditions of the injection zone, resulting in insufficient information to provide adequate tracking of the of the pressure front. In addition to geophysical techniques, interferometric synthetic aperture radar (InSAR) can indicate changes in ground elevation associated with elevated pressure due to CO_2 injection. InSAR is expected to be ineffective for this project due to hydrocarbon production from stratigraphically shallower intervals in the Kern River Oil Field, and the associated signals related to this activity, which are expected to obscure any pressure response from CO_2 injection. In the absence of an effective indirect pressure front tracking method, Chevron has developed a robust network of monitoring wells to directly assess the location of the pressure front.

Table 12. Pressure-front monitoring activities.

Target Formation	Monitoring Activity	Monitoring Location(s)	Spatial Coverage	Frequency
Vedder -3690 to -4230 (ft TVDSS)	Pressure array sensors	RCA9001OB, COR9001OB, HK_9001OB, DDA9001OB	Updip of CO_2 injection wells near faults and well penetrations	Monthly

Induced Seismicity Monitoring

Chevron plans to use data collected from state and federal seismic networks (e.g., Southern California Seismic Network) for inducted seismicity monitoring. Additionally, during the injection period, Chevron will deploy and maintain a seismic monitoring system to determine the presence or absence of any seismic activity associated with CO_2 injection. The seismic monitoring system will consist of surface and/or shallow borehole seismometers coupled with DAS fiber. DAS fiber will be installed on the four (4) deep monitoring wells and the two (2) CO_2 injectors. Seismometer locations will be selected to enable triangulation of potential seismic events. Chevron plans to install the seismic monitoring system at least one (1) year prior to injection to collect background seismicity data.