Review of Project Plans for the CTV III Class VI Project

This evaluation report for the proposed CTV III Class VI Sequestration Project summarizes EPA's evaluation of several plans in the permit application submitted by Carbon TerraVault Holdings, LLC (CTV). The plans include operational procedures, corrective action plan, testing and monitoring plan, injection well plugging, post-injection site care and site closure plan, proposed emergency and remedial response plan, well construction plan, and pre-operational testing plan. Each plan evaluation is a self-contained report to facilitate separate requests for additional information. Questions and requests for CTV are provided below in *blue italics*.

Attachment A: Operational Procedures

This section of the evaluation report for the proposed CTV III Class VI Sequestration Project summarizes EPA's evaluation of the operational procedures that CTV proposes during injection into the Mokelumne River Formation. CTV submitted information regarding operational procedures in their Class VI permit application narrative dated October 2023 (Version 4).

Operational procedures for the six proposed injection wells are described in Tables 1 through 6 of Appendix: Operational Procedures of the application narrative and Table 3.3 of the Area of Review and Corrective Action (AoR/CA) Plan. Operating parameters and conditions for each well are summarized in Table 1 below:

Table 1. Operating Parameters and Conditions

Parameters/Conditions	Unit	C1	C2	E1	E2	W1	W2
Maximum Allowable Injection Pressure							
Surface	psig	2243	2539	2300	2254	2036	2272
Downhole	psig	4224	4919	4111	4774	4207	4802
Average (Target) Injection Rate	mmscfpd tonnes/day	52 2754	52 2754	13 688	13 688	13 688	26 1377
Average (Target) Injection Pressure							
Surface - Start / End / Average	psig	1240/ 1300/ 1270	1390/ 1450/ 1420	1060/ 1110/ 1085	1140/ 1180/ 1160	1080/ 1120/ 1100	1170/ 1240/ 1205
Downhole - Start / End / Average	psig	2934/ 3050/ 2992	3467/ 3566/ 3517	2760/ 2901/ 2831	3210/ 3363/ 3287	2856/ 2961/ 2909	3370/ 3504/ 3437
Maximum Injection Rate	mmscfpd tonnes/day	69 3654	69 3654	26 1376	26 1376	26 1376	52 2754
Injection Pressure at Maximum Rate							
Surface - Start / End / Average	psig	1440/ 1500/ 1470	1600/ 1660/ 1630	1200/ 1260/ 1230	1350/ 1400/ 1375	1280/ 1310/ 1295	1370/ 1490/ 1430
Downhole - Start / End / Average	psig	2983/ 3075/ 3029	3500/ 3589/ 3545	2784/ 2912/ 2848	3255/ 3396/ 3326	2916/ 2990/ 2953	3439/ 3547/ 3493

Parameters/Conditions	Unit	C1	C2	E1	E2	W1	W2
Proposed Injection Duration	years	28	28	10	14	5	14
Total Projected CO_2 Injected	MMT	28.2	28.2	2.5	3.5	1.3	7.0
Average Annulus Pressure							
Surface - Start / End	psig	100/ 525	100/ 1041	100/ 447	100/ 909	100/ 361	100/ 913
Downhole - Start / End	psig	2725/ 3150	2725/ 3666	2654/ 3001	2654/ 3463	2800/ 3061	2791/ 3604
Annulus – Tubing pressure differential at Packer	psig	>100	>100	>100	>100	>100	>100

Injection Pressure

The maximum allowable injection pressure (MAIP) calculated for each well incorporates a safety factor of 90% of the formation fracture pressure, where local fracture pressure is estimated by an assumed fracture gradient of 0.76 psi/ft. CTV chose this fracture gradient for their AoR modeling since formation integrity tests conducted in nearby wells in shallower formations showed gradients ranging from 0.75 to 0.76 psi/ft. Step rate tests will be conducted in the injection and primary upper confining zones to confirm the fracture gradient per CTV's Pre-Operational Testing Plan (POTP), but CTV's estimate is acceptable at this point in the review.

CTV estimated surface and bottomhole injection pressures using PROSPER, a multiphase well nodal analysis software, based on the results of their reservoir simulation. In these estimations, CTV assumed a 100% CO_2 injectate, though CTV notes that operating conditions will be updated as the injection stream and impurities are ascertained during the pre-injection phase.

Injection pressures will be automated during operation to never exceed the MAIPs. CTV plans to start injection at low pressures and increase pressure over the life of the project to maintain the target injection rates. Fracture gradient, MAIPs, and average injection rates and pressures are consistent between Appendix: Operational Parameters and Tables 3-3 and 3-4 in the AoR/CA Plan.

Annulus Pressure

CTV proposes to maintain a minimum annular pressure of 100 psi measured at the surface during injection in order to detect a loss of annular pressure via continuous surface monitoring as described in Attachment C: Testing and Monitoring (T&M) Plan. Downhole annular pressure will be held at a pressure differential between the tubing and tubing annulus of greater than 100 psi over the injection pressure. CTV asserts that the range of annular pressures described in Table 1 are suitable to the well designs and will not affect well integrity or induce formation fracture. CTV did not provide any evidence to support this statement; however, planned continuous monitoring would detect any leak that might occur. A comparison of the downhole annular pressure against the well material strength and burst ratings (specifically the long string casing, tubing, and packer) indicate that the

well material ratings are well above the anticipated annular injection pressures for each well. The range of potential annular pressures is consistent with the proposed injection pressure, which was calculated based on 90% of fracture pressure.

CTV intends to use 4% KCl completion fluid with corrosion inhibition and biocide as the annulus packer fluid. CTV states that this fluid is compatible with all well components and is not corrosive. CTV estimates the specific gravity of the packer fluid to be 1.024.

Questions/Request for CTV:

- *Please revise the annulus pressures in Table 1 to meet the requirements of 40 CFR 146.88(c) such that the annulus pressures would exceed the operating injection pressures anticipated for each injection well. Additionally, please describe the annulus pressure values, clarifying if they are average pressure values and their corresponding location (i.e. surface, bottomhole, above or below the packer).*
- *Please provide the proposed maximum annulus pressure for each injection well and explain how it is determined.*

Injection Rate and Volume

The average target injection rates and maximum injection rates corresponding to the MAIPs vary for each well and are shown in Table 1. CTV plans to implement a 10% safety threshold on the injection rate to account for daily rate and pressure fluctuations on top of the 90% safety factor used to calculate the maximum allowable injection pressure. Automatic shut-offs and alarms will be configured to trigger when either injection rate or pressure vary to within 10% below the expected maximum allowable injection rate or 10% below the maximum allowable injection pressure. In the event that an alarm is triggered, CTV states that the system will be reviewed to understand the issue, and the resolution to the alarm would depend on the type of alarm and systems installed to regulate the injection rate. CTV's Emergency and Remedial Response Plan addresses this scenario.

In the T&M Plan, CTV states that the volume of CO_2 injected into the Mokelumne River Formation will be calculated from the injection flow rate and CO_2 density using PVTP, a fluid thermodynamics package.

Automated Shutdown System

CTV states that downhole temperature and pressure and surface flow/mass movement, pressure, and temperature data will be monitored in real time. If an established operating threshold is reached or exceeded, the software will issue visual, audible, and digital alerts and/or begin with an unload procedure and initiate the shutdown process until it is understood why the thresholds were achieved and what corrective measures must be implemented.

CTV has not yet established the monitoring system that would trigger the automated shutdown system, and will share information about the monitoring system with EPA when

it is established. Attachment G (Version 3.1) indicates that the shutdown system will involve an automated surface shut-off valve.

The Emergency and Remedial Response Plan states that CTV will notify the UIC Program Director, pursuant to 40 CFR 146.91(c)(3), within 24 hours of any triggering of a surface or downhole shut-off system.

Stimulation

CTV states in Section 5.1 of the narrative that it does not plan to perform any stimulation activities. 40 CFR §146.88(a) requires that all stimulation programs be approved by the Director as part of the permit application and incorporated into the permit. If the initial permit does not include a stimulation program and the operator identifies a need for well stimulation later in the life of the project, a major permit modification would be necessary. EPA suggests that CTV prepare and include a proposed well stimulation program in the permit application. A generic stimulation program may be used for the pre-construction phase of the project.

Questions/Requests for CTV:

- *To avoid the need for a permit modification if stimulation were to become necessary in the future, EPA requests that CTV prepare a draft stimulation plan. EPA can provide some additional guidance about the content of the plan, but anticipates that the plan should describe:*
    - *The stimulation fluids to be used, including any additives (e.g., corrosion inhibitors, clay inhibitors, biocides, complexing agents, or surfactants) or diverting agents; and*
    - *Step-by-step procedures that would be employed during stimulation.*

Attachment B: Corrective Action Plan

This Corrective Action Plan evaluation report for the proposed CTV III Class VI Sequestration Project summarizes EPA's evaluation of CTV's assessment of wells/artificial penetrations within the Area of Review (AoR) and the corrective action they propose to address potential migration of injection fluids and impacts to USDWs. CTV submitted this information in Attachment B: AoR and Corrective Action (AoR/CA) Plan dated October 2023 (Version 3.1).

Tabulation/Assessment of Wells within the AoR

To identify wells within the AoR, CTV reviewed California Geologic Energy Management Division (CalGEM) data. Table 3.6 summarizes the number and type of wellbores found within the AoR and Appendix B-1 provides a detailed list of information for the wells including their location, type, depth, construction methods, and plugging and abandonment (P&A) methods (if applicable). This list also provides CTV's proposed determination for corrective action.

A total of 46 wellbores that penetrate the Capay Shale confining zone and the Mokelumne River Formation injection zone were identified. All of the wells (mainly dry holes associated with gas production) have been plugged. Figure 3.20 shows the locations of the wells within the AoR.

The depth of the Capay Shale confining zone at the location of each of the wells was determined through open-hole well logs using deviation surveys. CTV evaluated the following to assess the need for corrective action:

- Detailed casing diagrams for each wellbore.
- Perforations.
- Well design (casing depths, annular cement, etc.).
- Cement plug depths relative to key storage complex formation tops.

Of the 46 wellbores within the AoR, CTV proposed performing corrective action on the three wellbores within the predicted CO_2 plume: Salyer A 1, Borden 1, and Victoria Island Farms 1.

No information (including schematics) was provided for the remaining 43 wells that are located outside of the CO_2 plume area but within the project AoR.

In the three identified wellbores, the surface casing was set above the base of the lowermost USDW, and no production casing was installed. The P&A status is based on the placement of a cement plug at the top of the openhole section extending into the surface casing.

Planned Corrective Action

CTV's approach for plugging each wellbore will involve re-entering the wells, drilling out the existing plugs, and re-plugging the wellbores using Class G cement at specific depths targeting key areas within the wellbore as follows:

- Plug 1 will be placed across the top of the Mokelumne River Formation and base of the Capay Shale (potential brine conduit out of the injection zone through the confining layer).
- Plug 2 will be placed across the top of the Domengine Formation (potential exposure pathway through the dissipation zone).
- Plug 3 will be placed across the base of the lowermost USDW and into the bottom of surface casing (potential exposure of USDW).
- Plug 4, the surface plug, will be placed from 25 ft below grade to the ground surface.

Following the placement and curing of the surface plug, the surface casing will be cut to 5 ft below grade and the surface will be restored.

Attachment B-3 shows schematics of the current well configuration and proposed corrective action. The plugging details are provided on each proposed abandonment configuration schematic including the volume, depth, and method of placement. The plugs are consistent with the depths and target formations as proposed for corrective action.

The corrective action for the three wells identified within the CO_2 plume of the AoR appears to be sufficient. CTV indicates that corrective action will be adjusted for wells outside of the CO_2 plume, within the AoR, should data collected during pre-operational testing indicate a need for corrective action on any additional wells. However, they do not elaborate on how this would be determined, and no information beyond the tabulation in Table B-1 is provided for the 43 wells outside of the CO_2 plume within the AoR.

Plan for Site Access

CTV obtained surface access rights for the duration of the project.

Corrective Action Schedule

CTV indicated that all corrective action will be completed prior to commencing CO_2 injection into the reservoir. No corrective action schedule or timeline was provided.

Questions/Requests for CTV:

- *Did CTV perform any physical surveys (e.g., aerial surveys) to supplement the database searches?*
- *Please provide schematics or other information about the 43 wells outside the CO_2 plume and within the AoR to support the information on Table B-1 and elaborate on*

how CTV proposes to assess whether any of these wells need corrective action using data collected during pre-operational testing.

- *Please describe any materials (e.g., drilling mud or fluids) that will be placed in the annulus between the cement plugs.*
- *Please provide a schedule for corrective action activities.*

Attachment C: Testing and Monitoring Plan

This testing and monitoring evaluation report for the proposed CTV III Class VI Sequestration Project summarizes EPA's evaluation of the testing and monitoring that CTV proposes to conduct during injection operations into the Mokelumne River Formation. CTV submitted information regarding well testing and monitoring in their Class VI permit application in Attachment C: Testing and Monitoring (T&M) Plan dated October 2023 (Version 3).

CTV proposes to submit the results of all injection phase testing and monitoring activities to EPA semi-annually in compliance with the requirements under 40 CFR 146.91.

Carbon Dioxide Stream Analysis

To meet the requirements of 40 CFR 146.90(a), CTV plans to analyze the carbon dioxide (CO_2) stream quarterly for the constituents identified in Table 1 of the T&M Plan, which is replicated below:

Parameter	**Analytical Method(s)**
Oxygen, Argon, Hydrogen	ISBT 4.0 (GC/DID) GC/TCD
Nitrogen	ISBT 4.0 (GC/DID) GC/TCD
Carbon Monoxide	ISBT 5.0 (Colorimetric) ISBT 4.0 (GC/DID)
Total Hydrocarbons	ISBT 10.0 THA (FID)
Ammonia	ISBT 6.0 (DT)
Ethanol	ISBT 11.0 (GC/FID)
Oxides of Nitrogen	ISBT 7.0 Colorimetric
Methane, Ethane, Ethylene	ISBT 10.1 (FID)
Hydrogen Sulfide and Sulfur Dioxide	ISBT 14.0 (GC/SCD)
CO_2 purity	ISBT 2.0 Caustic absorption Zahm-Nagel ALI method SAM 4.1 subtraction method (GC/DID) GC/TCD
δ13C	Isotope ratio mass spectrometry

CTV will use analytical methods from the International Society of Beverage Technologists (ISBT) for injectate monitoring. These methods are accepted for CO_2 stream analysis in other Class VI projects. Table 4 in CTV's Quality Assurance Surveillance Plan (QASP) includes the testing methodology and is consistent with Table 1 in the T&M Plan. CO_2 will be sampled in the last compressor station prior to the CO_2 being sent to the injector. After

the initial sampling required prior to injection, sampling will begin three months after the start of injection and every three months thereafter.

Samples will be collected at sampling stations into containers and sent to Eurofins TestAmerica (Eurofins), a state-certified laboratory. CO_2 stream samples will be contained in one-liter tedlar bags for a maximum of 72 hours according to Table 16 of the QASP. Eurofins' chain of custody procedure is described in the T&M Plan and in subsection B.3.e of the QASP; the procedure includes recording sample date, sample description, sample type, relinquished by and received by signature, sampler name, and location information. CTV describes that sample transport and handling will be strictly controlled by the service provider field technician, and upon delivery to the laboratory, samples will be given unique laboratory sample numbers and recorded in a logbook indicating the client, well number, date, and time of delivery.

CTV will increase the sampling frequency if there is a significant change in the chemical or physical characteristics of the CO_2 injectate, a change in the CO_2 injectate source, or if the facility or injection well experiences a downtime over more than 30 days.

CTV states that CO_2 will be sourced from a blue hydrogen and ammonia plant to be located near the project site, direct air capture, and other CO_2 sources in the project area. Section 7.2 of the application narrative (October 2023) describes two sets of potential CO_2 stream constituents. Table 7.1 provides the compositions of both potential injectate sources by mass percent, and Table 7.2 presents simplified injectate compositions for both sets of potential constituents. The analytes described in the Testing and Monitoring Plan are similar to the anticipated injectate composition, with the exception of water, which is expected to be present in Injectate 1.

Note that, while multiple CO_2 sources can be permitted for injection, EPA requires that every source be clearly identified and characterized to be authorized in the permit. EPA will also require that a sample of every authorized fluid/source be analyzed prior to initiation of its injection to ensure that its physical/chemical properties are consistent with the pre-permitting characterization. Note that any change in the injection fluid would require advance notice and written approval from EPA. Addition of a new injection fluid (source) not authorized by the permit would also require a permit modification. The information provided is acceptable at this point of the permit application review; however, CTV will need to update Table 1 of the T&M Plan and Table 4 of the QASP once the specific CO_2 sources are identified.

Questions/Requests for CTV:

- *Please add H_2O as a CO_2 stream analyte on Table 1 to provide information about the potential presence of free phase water and to be consistent with the composition of Injectate 1 as described in the narrative.*
- *Tables 7.1 and 7.2 of the narrative indicate that sulfur trioxide (SO_3) may be a constituent of the CO_2 stream. Please update Table 1 of the Testing and Monitoring Plan with an appropriate analytical or alternative method for measuring SO_3 if it is determined to be a constituent of the final CO_2 stream.*

Continuous Recording of Operational Parameters

CTV proposes to use continuous recording devices in the six proposed injection wells to monitor injection pressure, rate, and volume; the pressure on the annulus between the tubing and the long 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).

Table 2 of Attachment C describes the operational recording devices, their locations, and minimum sampling and recording frequencies. The minimum sampling frequency for annulus fluid volume is 4 hours, and the minimum recording frequency is 24 hours. For all other parameters, minimum sampling frequency is 10 seconds and minimum recording frequency is 30 seconds. Table 6 of the QASP summarizes these measurement parameters for each type of field gauge and includes detection limits and ranges, typical measurement precision, and QC requirements. Instrument sensitivities are described in Tables 8 through 14 of the QASP.

CTV proposes to continuously monitor and record injection pressure, temperature, and annulus pressure from the CTV Central Command Facility using method ANSI Z540-1-1994. Injection pressure will be measured with surface and downhole pressure gauges that have a detection limit of 0.001 psi and range of 0 – 5,000 psi. Injectate temperature will be measured with surface and downhole temperature sensors with a detection limit of 0.001°F and range of 0 – 500 °F. The injection rate will be measured with a surface Coriolis flowmeter calibrated to be accurate to within 0.1%. Injection volume will be calculated from the injection flow rate and density of CO_2 (as calculated by the PVTP fluid thermodynamics package).

Annular pressure will be measured using a surface electronic pressure gauge with a detection limit of 0.001 psi and range of 0 – 5,000 psi. The annulus will be filled with a non-corrosive and incompressible aqueous packer fluid and be maintained with a 100-psi positive annular pressure at the surface. CTV notes that a SCADA alarm system will identify any decrease in pressure or annular fluid level. This is consistent with information in the Operations Plan and the monitoring approach appears to be sufficient to detect any triggers for responses specified in the Emergency and Remedial Response Plan. Data from

continuous monitoring of annular pressure will be provided in CTV's semi-annual report to demonstrate internal mechanical integrity.

Questions/Requests for CTV:

- *Please describe the device CTV will use to measure annular fluid level in the T&M Plan.*
- *Please describe the steps CTV would take to identify and investigate any unexpected pressure deviations, or reference that CTV would implement the procedures described under "Injection well or monitoring equipment failure" in the Emergency and Remedial Response Plan.*
- *Please indicate what threshold change will trigger the SCADA alarm system.*

Corrosion Monitoring

CTV will monitor corrosion of wellbore materials using corrosion coupons. Coupons will be installed in the pipeline that feeds CO_2 injectate to the injectors, between the compressor and wellhead. Corrosion monitoring will be conducted starting three months after injection begins and quarterly thereafter. A baseline assessment prior to exposing the materials to corrosive conditions is not described.

CTV will monitor well material coupon samples for loss of mass, change in thickness, cracking, pitting, and other signs of corrosion. The coupons (in the custody of Eurofins according to Table 1 of the QASP) will be photographed, measured, visually inspected, and weighed to a resolution of 0.1 milligram. If the corrosion rate is greater than 0.3 mils/year, CTV will consult with EPA. In addition, a casing inspection log may be run to assess the thickness and quality of the casing if the corrosion rate exceeds 0.3 mils/year. According to Table 5 of the QASP, CTV will use the analytical methods of NACE TM0169/ G31 and EPA 1110A SW846; the detection limit for these methods is 0.001 mg, and typical precisions are 10%.

Table 4 of the Testing and Monitoring Plan describes the compositions of the proposed coupons. There is some inconsistency between the materials described in the corrosion monitoring plan and the construction diagrams for each injection well in Appendix C-1 or the well construction plans (Attachment G), as shown in the table below.

Equipment	**Coupon Material (T&M, Table 4)**	**Construction Material (Appendix C1, Attachment G)**
Pipeline	Carbon Steel	Not listed
Casing	Chrome alloy	Per Appendix C-1: K55 (surface); N-80 (intermediate); L-80, CRA (long-string) Per Attach G: 13Cr L-80 or other corrosion resistant alloy
Tubing	Chrome alloy	13Cr L-80 or other corrosion resistant alloy

Equipment	Coupon Material (T&M, Table 4)	Construction Material (Appendix C1, Attachment G)
Packer	Not listed	Corrosion resistant alloy and hardened elastomer
Wellhead	Chrome alloy	Stainless steel or other corrosion resistant alloy

CTV states that construction materials will be reaffirmed post-construction and prior to injection as part of pre-operational testing, and corrosion coupons consistent with the final well construction materials will be used for corrosion monitoring. These will need to be incorporated into the final Testing and Monitoring Plan.

Questions/Requests for CTV:

- *Please include packer materials on Table 4.*
- *Please modify Table 4 to include coupons that reflect both the intermediate and long-string casing types listed in Attachment G/Appendix C-1 and the table above.*
- *Please indicate in the plan that CTV will record the baseline condition of the coupons to support future evaluations.*

Above Confining Zone Monitoring

CTV proposes to monitor groundwater quality and geochemical changes above the confining zone during the injection and post-injection phases through quarterly fluid sampling and continuous temperature and pressure monitoring to meet the requirements of 40 CFR 146.90(d). CTV will also acquire baseline water samples for analyses per the Pre-Operational Testing Plan (which EPA evaluated previously). Monitoring above the confining zone will be performed in two intervals:

- Two monitoring wells will be completed in the undifferentiated non-marine sediments, the lowermost underground source of drinking water (USDW).
- One monitoring well will be completed in the Domengine Formation.

Figure 1 in Attachment C shows the above confining zone monitoring well locations around the AoR. The lowermost USDW monitoring wells are located at the northeast and southwest portions of the predicted CO_2 plume. The Domengine Formation monitoring well is located very near the northeastern USDW monitoring well, and within the predicted plume. The well locations are appropriate given the modeled expansion of the CO_2 plume in the Area of Review and Corrective Action (AoR/CA Plan). Neither well is located in the portion of the AoR that is outside the plume but may be influenced by pressure increase. CTV states that surface access to the monitoring wells will be available for the life of the project. In the application narrative, CTV describes a normal fault in the boundary of the CO_2 plume, and EPA requested data to demonstrate it is sealing. Based on the replies,

additional monitoring wells may be appropriate to address uncertainties in the site characterization. Based on a comparison of Figure 2.3-1 of the narrative and Figure 1 of the Testing and Monitoring Plan, it does not appear that the above confining zone or USDW monitoring wells are located near the fault.

CTV notes that additional groundwater monitoring wells will be drilled to assess and monitor the lowermost USDW if the Domengine Formation monitoring well indicates pressure increases or if the undifferentiated non-marine sediments experience pressure or composition changes due to CO_2 injection.

Table 5 of Attachment C shows the planned monitoring activities, locations, depth intervals, and frequencies for geochemical monitoring above the confining zone. Fluid sampling will be conducted quarterly, and pressure and temperature will be continuously monitored. The depths of the monitoring wells on Table 5 are consistent with the depths of the perforations of those wells as shown in the well schematics in Appendix C-1.

Table 6 of Attachment C shows a summary of field parameters and analytical methods for fluid samples. Detection limit, ranges, typical precisions, and QC procedures are presented in Table 3 of the QASP. Table 6 of the Testing and Monitoring Plan, Table 3 of the QASP, and Table 2 of the PISC/SC Plan are consistent with each other. The analytical methods CTV proposes are EPA-approved, and both the lowermost USDW and Domengine Formation will be tested for the same analytical and field parameters. Fluid samples will be sent to Eurofins for analysis; the chain of custody procedure is the same as described above. Anticipated fluid sample containers, preservation techniques, and sample holding times for target cations, anions, dissolved CO_2, δ13C, and alkalinity samples are provided in Table 17 of the QASP.

Table 7 of the QASP describes actionable testing and monitoring outputs, where action will be taken if above-confining-zone pressure or water quality measurements deviate from the baseline analysis. However, Table 7 is qualitative and does not clarify values or ranges that would trigger action for any parameter.

Specific monitoring devices and instruments are not described; however, subsection B.4.b of the QASP states that service providers are expected to provide and use the equipment and instruments necessary to perform the required testing and analysis. CTV should provide this information in the updated Testing and Monitoring Plan submitted per 40 CFR 146.82(c).

Questions/Requests for CTV:

- *What threshold above or below baseline values for temperature, pressure, or water quality will trigger action? Please add this information to the Testing and Monitoring Plan.*
- *Please fix the typo in Table 6 referring to "aron" (instead of argon).*

- *EPA recommends that CTV document in the AoR reevaluation schedule (Section 3.4.1 of the AoR and Corrective Action Plan) that updates to the testing and monitoring plan may include additional USDW monitoring wells (e.g., if pressure increases are detected in the Domengine Formation or USDW) or additional plume and pressure front monitoring.*
- *On page 8, where CTV proposes that "Additional groundwater monitoring wells will be drilled...," please add a statement that, if CTV detects evidence of USDW endangerment, it will implement the Emergency and Remedial Response Plan (Attachment F of the permit). Please also add a statement that CTV would communicate with EPA first to determine appropriate types of monitoring to be performed, e.g., specific analytes, temperature/pressure monitoring.*

External Mechanical Integrity Testing

CTV will conduct external MITs on each injection and Mokelumne River Formation monitoring well at least once per year using an approved testing method per 40 CFR 146.89(c). (Internal MI will be monitored via the continuous monitoring described under "Continuous Recording of Operational Parameters.") CTV states that they may perform a temperature log or distributed temperature log (DTS), per Table 7, and describes the procedures for temperature logging and DTS. Table 9 of the QASP indicates the specifications of the logging tool.

While CTV may perform a DTS in addition to the temperature log, the Class VI Rule, at 40 CFR 146.89(c), requires an approved tracer survey such as an oxygen-activation log or a temperature or noise log be used to demonstrate external mechanical integrity.

Table 7 of the QASP states that temperature log results will be compared against a baseline to evaluate external mechanical integrity. The specific deviation that would trigger action is not provided.

Questions/Requests for CTV:

- *Please clarify that a temperature log will be performed on each injection well.*
- *What deviations in the temperature log would indicate a mechanical integrity issue?*

Pressure Fall-Off Testing

CTV will perform pressure fall-off tests (FOTs) every five years during the injection phase to meet the requirements of 40 CFR 146.90(f). CTV includes procedures for the FOTs and states that they will refer to EPA Region 9 UIC Pressure Fall-off Requirements for planning and conducting the testing as well as preparing and submitting the monitoring report. Though specific equipment is not described in the T&M Plan or the QASP, the procedures are consistent with the EPA Region 9 UIC Pressure Fall-Off Testing Requirements.

Questions/Requests For CTV:

- *Please clarify in the T&M Plan that a pressure fall-off test will be conducted prior to injection operations.*
- *Please edit the statement at the bottom of page 12 to refer to fall-off testing on all six injectors (not two).*

Carbon Dioxide Plume and Pressure Front Tracking

CTV proposed direct and indirect methods to track the extent of the CO_2 plume and the pressure front during the injection and post-injection phases to meet the requirements of 40 CFR 146.90(g). Three monitoring wells (M-1, M-2, and Sonol Securities 2) will monitor the injection zone. Wells M-1 and M-2 are located at the extreme southwestern and northeastern edge of the predicted extent of the plume, Sonol Securities 2 is located outside the AoR on the same side of the Stockton Arch Fault as the AoR. Monitoring well locations are shown in Figures 2 and 3 (which shows the wells and the modeled plume).

The position of these wells within the AoR appears appropriate to detect any unplanned plume movement to validate predictions from the AoR delineation modeling. The perforations of each well per the well schematics are at the appropriate depths, consistent with the narrative. However, data coverage is missing to the east and west of the CO_2 plume, where no injection zone monitoring wells are proposed. Also, no wells are located outside the CO_2 plume in the larger AoR.

CO_2 Plume Tracking

Plume monitoring activities CTV proposed during the injection phase are summarized in Table 8 of Attachment C. Direct monitoring activities include quarterly fluid sampling in wells M-1 and M-2 and continuous pressure and temperature monitoring in all 3 monitoring wells. (This pressure and temperature monitoring is also described as a plume tracking method.) CTV states that DTS will provide continuous temperature measurements from the packer to the surface. Fluid sampling analytes and methods are presented in Table 9 of Attachment C, and the analytical methods are consistent with above-confining zone monitoring in Table 6 of Attachment C. Based on AoR modeling, CTV expects to observe minor changes to pH, dissolved CO_2, and water density in fluid samples. Data collection, analysis, and QA procedures appear to be the same as that of above-confining-zone monitoring for fluid sampling, pressure monitoring, and temperature monitoring. Table 2 of the QASP indicates that downhole gauges, DTS, and direct sampling will be utilized for direct monitoring. Anticipated fluid sample containers, preservation techniques, and sample holding times for the fluid analytes are provided in Table 17 of the QASP.

The only indirect plume tracking activity CTV proposes on Table 8 of Attachment C is pulsed neutron logging to measure CO_2 saturation changes over time. CTV proposes to perform the logs once before injection as a baseline and every two years following the start of injection.

Tables 8 and 9 of the T&M Plan are also consistent with Tables 4 and 5 of the PISC/SC Plan.

Pressure Front Tracking

Table 10 of Attachment C presents the direct and indirect methods that CTV proposes to monitor the position of the pressure front, including the activities, locations, and frequencies CTV will employ. This is consistent with Table 6 of the PISC/SC Plan, which describes post-injection phase pressure front monitoring. Direct monitoring will include continuous pressure and temperature monitoring in all three injection zone monitoring wells. The monitoring wells will be equipped with pressure gauges to measure the pressure increase, which CTV will use to validate computational modeling results and identify operational discrepancies.

CTV also plans to use passive seismic monitoring through a network of surface and shallow borehole seismometers across the AoR for indirect pressure front tracking. Per the QASP, CTV will partner with a third-party for data processing (this partner is not identified in the T&M Plan or QASP). CTV will also monitor the Northern California Earthquake Data Center (NCEDC) network for seismic events.

The plan refers to comparing seismic data to baseline seismicity, but does not describe the extent or duration of a baseline seismic study. EPA recommends that, to the extent possible, CTV provide EPA with information about the sensors before they are installed and collect as much seismic data as possible from them during baseline analysis. CTV should provide information about the location and depth of the installed seismometers in the updated Testing and Monitoring Plan submitted per 40 CFR 146.82(c).

Questions/Request for CTV:

- *How will data collected in the planned monitoring wells validate the predicted east-west expansion of the CO_2 plume?*
- *How does CTV plan to gather data on pressure increases beyond the area of the CO_2 plume?*
- *Please describe the pulsed neutron logging procedures for plume monitoring.*
- *Please include the sampling and recording frequencies for continuous pressure monitoring (i.e., to be consistent with Table 3 of the PISC/SC Plan).*
- *Pressure and temperature monitoring in the Mokelumne River Formation are described as both a plume and pressure front tracking method in the injection phase, but only as a pressure front tracking method in the post-injection phase. Please update either Table 8 of Attachment C or Table 4 of Attachment E to make these consistent.*
- *Please expand the discussion of seismic monitoring in the Testing and Monitoring Plan to discuss:*
    - *The sensitivity of the seismometers, and how they will be sufficient to detect events in the Emergency and Remedial Response Plan.*

    - *How CTV plans to collect and evaluate seismic data.*
    - *How CTV will establish baseline seismicity, including the duration of the monitoring.*
    - *Any preliminary information about the location of the seismometers to demonstrate coverage throughout the AoR.*
- *Please explain how the combination of pulsed neutron logging, pressure/temperature monitoring, and seismic monitoring via geophones at the planned locations will provide a complete description of the plume and pressure front movement throughout the AoR that meets the goals of 40 CFR 146.90(g).*
- *On pages 13-14, where CTV proposes that, "if the plume development is not consistent with computation modeling results, CTV will assess whether additional monitoring of the plume is necessary," please add a statement that, if CTV detects evidence of USDW endangerment, it will implement the Emergency and Remedial Response Plan (Attachment F of the permit).*

Surface Air and/or Soil Gas Monitoring

No surface air and/or soil gas data were submitted with the permit application. However, we could request surface air and/or soil gas monitoring, per 40 CFR 146.90(h), as we continue with the permitting process (e.g., during further technical review, in response to public comments, or as noted below).

Considerations based on the results of Pre-Operational Testing/Modeling Updates:

- *If, based on the results of planned pre-operational testing, uncertainties about the geologic setting are identified, the need for surface air and/or soil gas monitoring will be reconsidered.*

Quality Assurance Procedures

All monitoring and testing activities proposed in the T&M and PISC/SC Plans are addressed in CTV's QASP, and that information is represented consistently between the submittals (except as noted below).

The QASP describes sampling methods; sample handling and custody; analytical methods; quality control; instrument/equipment testing, inspection, and maintenance; data management; and data review, verification, and validation procedures. CTV plans to rely on third-party service providers for data collection and interpretation; as such, the QASP does not list specific instruments or equipment and associated procedures. CTV does plan to maintain data storage internally.

Questions/Requests for CTV:

- *Please include H_2O in Table 4 of the QASP.*
- *Please add Zn and Tl to Table 17 of the QASP for consistency with the analytes in the Testing and Monitoring Plan; please also delete Ti (which appears to be a typo).*

Attachment D: Injection Well Plugging Plan

This Well Plugging Plan evaluation report for the proposed CTV III Class VI Sequestration Project summarizes EPA's evaluation of CTV's proposed well plugging procedures for the injection and monitoring wells intended to be used at the CTV III CO_2 sequestration project. CTV submitted information regarding well plugging with the Injection Well Plugging Plan (Attachment D, October 2023) and Injection and Monitoring Well Plugging Schematics (Appendix C-1) as required in 40 CFR 146.92.

Prior to plugging each well, CTV will determine the pressure needed to properly squeeze the cement into the perforations based on bottom hole pressure monitoring. The cement slurry will be overbalanced to ensure a proper seal of the perforations such that no reservoir fluids will enter the wellbore during plugging. Also prior to plugging, CTV will perform a temperature log to demonstrate external mechanical integrity.

Plug details for the injection wells, including depth, volume, type, and emplacement method are summarized on the abandonment schematic of each well in Appendix C-1. The Narrative Description of Plugging Procedures section of Attachment D provides detailed procedures for plugging the wells. The plugs for the injection wells will target specific depths as follows:

- Plug 1 - Bottomhole plug targeting the perforations that will extend up through the Mokelumne River Formation and into the Capay Shale just before the top of the Capay.
- Plug 2 – Plug across the base of the Domengine Formation or top of the Mokelumne River Formation.
- Plug 3 – Base of the lowermost USDW; placement will cross over and into the base of the intermediate casing.
- Plug 4 – Surface plug from a depth of 14 to 39 ft.

CTV proposes to use cement plugs consisting of a blend that is "equivalent to Class G cement," but does not specify the formulation to be used.

Prior to emplacing cement plugs, a kill fluid will be pumped into the well to buffer and flush the wellbore and ensure reservoir fluid does not flow back into the well. The cement plugs will be emplaced into the wells using a coil tubing unit or cement retainer. The schematics show what appears to be abandonment mud placed in between the cement plugs but it is not identified. CTV will notify EPA at least 60 days prior to implementing well plugging activities as required by 40 CFR 146.92(c).

Plugging schematics for the monitoring wells (including depth, volume, type, and emplacement method) are summarized on each well plugging schematic provided in Appendix C-1.

The injection zone monitoring wells (M-1 and M-2) will be abandoned in a similar manner as the injection wells (i.e., Class G cement, four plug system), targeting the same depths and formations.

The above confining zone monitoring well (D-1) will be plugged with three plugs that will cover the perforation zones up through the base of the Nortonville Shale (top of the Domengine Formation), the lowermost USDW up into the intermediate casing, and a surface plug.

USDW monitoring wells (US-1 and US-2) will be plugged using two plugs, including a bottom plug that will cover the perforation zone and a surface plug.

Question/Request for CTV:

- *For clarity, please describe the specific formulation of the cement CTV will use to plug the injection wells.*
- *Please describe any materials (e.g., drilling mud or brine fluid) that will be placed in between the cement plugs.*

Attachment E: Post-Injection Site Care/Site Closure Plan

This evaluation report for the proposed CTV III Class VI Sequestration Project summarizes EPA's evaluation of the post-injection site care and site closure (PISC/SC) procedures that CTV proposes. CTV submitted information regarding PISC/SC procedures in their Class VI permit application in a Post-Injection Site Care and Site Closure Plan dated October 2023. CTV clarifies that they have obtained surface access rights for the duration of the project.

CTV is not proposing an alternative PISC timeframe for the CTV III project and plans to monitor groundwater quality and track the position of the carbon dioxide (CO_2) plume and pressure front for the default 50-year post-injection timeframe. CTV states that they will not cease post-injection monitoring until a demonstration of non-endangerment of underground sources of drinking water (USDWs) has been approved by the UIC Program Director pursuant to 40 CFR 146.93(b)(3). Following approval for site closure, CTV will plug all monitoring wells, restore the site to its original condition, and submit a site closure report and associated documentation.

Pre- and Post-Injection Pressure Differential

CTV states that current pressure in the injection zone near the injection site is approximately 2,860 psi. Based on computational modeling, CTV predicts the pressure will peak 14 years into injection, with a pressure of 3,184 psi predicted to occur at the monitoring well location M-2. Once injection ceases, the pressure is predicted to drop fairly rapidly to below 2,950 psi within 10 years of the end of injection. 50 years after the end of injection, the pressure in the reservoir is expected to return to approximately initial conditions.

Figure 1 of Attachment E shows the modeled pressure at monitoring well M-2 during the injection period and 100 years post injection.

Predicted Position of the CO_2 Plume and Associated Pressure Front at Site Closure

The PISC and Site Closure Plan describes Figure 2 of Attachment E as the predicted maximum extent of the plume and pressure front during the PISC timeframe. However, the map only shows the modeled extent of the CO_2 plume. In general, it appears that the application depicts the extent of a relatively small area within the larger AoR, which is bounded by three faults. While it is presumed that there is at least some pressure influence of injection throughout the AoR, the pressure front and the magnitude of pressure increase are not defined or described within the application.

Figures 3 and 4 of Attachment E show the development of the CO_2 plume during the injection period, at years 1, 4, 6, 10, 16, 20, 28 (cessation of injection), and post-injection at years 52 and 100.

Questions/Requests for CTV:

- *Please indicate the extent of the pressure front on Figure 2 of Attachment E , in accordance with 40 CFR 146.93(a)(2)(ii).*
- *For clarity, EPA recommends CTV provide a pressure front map similar to Figure 3 of Attachment E.*

Post-Injection Monitoring Plan

CTV will conduct post-injection monitoring to meet the requirements of 40 CFR 146.93(b)(1), and submit monitoring data and results to EPA in annual reports within 90 days following the anniversary date on which injection ceases. The reports will contain information and data generated during the reporting period; i.e., well-based monitoring data, sample analysis, and the results from updated site models.

The proposed post-injection monitoring activities are consistent with Attachment C: Testing and Monitoring (T&M) Plan and the Quality Assurance and Surveillance Procedures (QASP).

Tables 1 through 3 of Attachment E describe above-confining zone monitoring, where CTV proposes to perform annual fluid sampling and continuous pressure and temperature monitoring throughout the post-injection phase:

- Table 1 presents above-confining zone monitoring methods, devices, locations, depths covered, and frequencies. Table 1 is consistent with Table 5 of the T&M Plan.
- Table 2 summarizes fluid sample parameters and analytical methods and is identical to Table 6 of the T&M Plan. All of the proposed analytical methods are appropriate for use in Class VI projects.
- Table 3 presents sampling and recording frequencies for continuous monitoring in the USDW monitoring well. During the post-injection phase, the sampling and recording frequencies for continuous monitoring will be reduced relative to injection-phase monitoring from 5 hours to 12 hours. It appears that Table 3 only applies to the pressure gauge and not the temperature monitoring devices. It is unclear whether CTV plans similar monitoring and recording frequencies in the Domengine Formation monitoring wells intended for pressure monitoring or to the Mokelumne River Formation monitoring wells for pressure front tracking.

The injection zone monitoring wells and CO_2 plume boundary, as predicted in the AoR delineation modeling, are depicted in map view in Figure 3 and in cross-section in Figure 4. Tables 4 through 6 describe injection zone monitoring, where CTV will use direct and indirect methods to track the CO_2 plume and pressure front:

- Table 4 presents the direct and indirect CO_2 plume tracking activities in the Mokelumne River Formation, including locations and frequencies. CTV proposes annual fluid sampling (direct monitoring) and pulsed neutron logging every 5 years

(indirect monitoring). Table 4 is consistent with Table 8 in the T&M Plan except that the frequency of pulsed neutron logging will be reduced during post-injection from every 2 years to every 5 years.

- Table 5 summarizes fluid sample parameters and analytical methods and is identical to Table 9 in the T&M Plan. CTV proposes to reduce the frequency of injection zone fluid sampling from quarterly (during the injection phase) to annually in the post-injection phase. This is consistent with recommendations in EPA's UIC Class VI Well Plugging, Post-Injection Site Care, and Site Closure Guidance.
- Table 6 describes the direct and indirect pressure front tracking activities and includes locations and frequencies. Similar to the injection phase, CTV proposes continuous pressure and temperature monitoring in wells M-1, M-2, and Sonol Securities 2. CTV will indirectly monitor the pressure front by monitoring seismicity with a seismic monitoring network with coverage across the entire AoR. Table 6 is consistent with Table 10 in the T&M Plan.

Questions/Requests for CTV:

- *Please add temperature sampling and recording frequencies to Table 3.*
- *Please add fluid sampling depths to Table 4.*
- *To provide continuity between injection and post-injection phase monitoring, please modify the fluid sampling frequency to be quarterly for at least the first 5 years after cessation of injection (i.e., to coincide with AoR reevaluation) to establish that injection zone chemistry is not changing.*
- *Do the sampling and recording frequencies described in Table 3 also apply to continuous monitoring in the Domengine and Mokelumne River Formations? If so, please update Table 3 accordingly.*

Non-Endangerment Demonstration Criteria

CTV will provide a report demonstrating non-endangerment of USDWs to the Director prior to authorization of site closure per 40 CFR 143.93(b)(3). CTV proposes that the non-endangerment demonstration report include the following:

- A summary of monitoring data from the injection and post-injection phases, computational modeling results of the CO_2 plume and pressure front, and evaluations of reservoir pressure, potential conduits, and seismic monitoring.
- A narrative that explains the monitoring activities, dates of all monitoring events, changes to the monitoring program over time, an explanation of all monitoring information collected at the site, and how the monitoring data from injection and PISC phases have varied from the baseline data collected during site characterization. The narrative will also describe any emergencies that occurred, how they were resolved, and demonstrate that there is no endangerment to USDWs.

- Calibration of computational modeling results with monitoring data to demonstrate the lack of CO_2 leakage over the project timeframe, the accuracy of the original model to predict and represent the storage reservoir, and that the computational model adequately defined the AoR.
- Evaluation of reservoir pressure to demonstrate that plume migration is minimal and reservoir pressure changes are less than 10 psi/year. CTV will support this demonstration with the calibrated computational model.
- Review of wells that either required or will require corrective action (including injection and monitoring wells) to demonstrate that natural or artificial conduits will not allow fluid migration from the storage reservoir.
- Seismic monitoring data to demonstrate plume stabilization, negligible pressure change, and seal integrity.

CTV's description of the non-endangerment demonstration report is consistent with EPA's recommendations, appears adequate to support the demonstration of plume stability and negligible year over year pressure changes, and will support a common understanding with EPA about the criteria that will be used for the non-endangerment demonstration.

Site Closure Plan

CTV will notify EPA of its intent to close the site at least 120 days prior to site closure pursuant to 40 CFR 146.93(d). After approval to close the site, CTV will plug the injection and monitoring wells, restore the site, and submit a site closure plan to EPA. Appendix C-1 provides proposed abandonment schematics for all of the monitoring wells. The proposed activities appear to be adequate to protect USDWs, with plugs across the perforations within the injection zone, the base of the Domengine Formation, the base of the lowermost USDW, and a surface plug.

CTV plans to submit the site closure report within 90 days following site closure pursuant to 40 CFR 146.93(f). The report will include verification of injection and monitoring well plugging, notifications to state and local authorities per 40 CFR 146.93 (f)(2), composition and volume of the injected CO_2, and post-injection monitoring records.

CTV will also record a notation to the property's deed that the property was used for CO_2 sequestration, the period of injection and the volume of CO_2 injected, the formation that the fluid was injected, and the name of the local agency to which a plat of survey with injection well locations was submitted.

Question/Requests for CTV:

- *Please indicate in the PISC and Site Closure Plan that the monitoring wells will be plugged as described in the Proposed Abandonment Schematics in Appendix C-1.*
- *Please state that CTV will retain the site closure report and records collected during the post-injection site care period for 10 years following site closure pursuant to 40 CFR 146.93(f) and 40 CFR 146.93(h).*

Attachment F: Proposed Emergency and Remedial Response Plan

EPA reviewed the proposed Emergency and Remedial Response Plan for CTV's proposed CTV III Class VI geologic sequestration (GS) project (Attachment F, submitted to the GSDT on October 24, 2023). While the evaluation of certain response scenarios is pending other reviews, the plan appears to be complete. EPA's questions and recommendations for the applicant are provided below.

Introduction

EPA recommends that CTV add a statement to the Emergency and Remedial Response Plan that responses would be implemented in response to events detected via testing and monitoring as described in the Testing and Monitoring Plan, including exceedances of actionable testing and monitoring outputs as described in the QASP.

EPA recommends that CTV identify the following under local resources and infrastructure to be consistent with the site characterization narrative:

- The major water bodies in the area, e.g., Discovery Bay, Clifton Court Forebay, Victoria Canals, Grant Line Canal, and the Indian Slough.
- The subsurface cleanup sites on Figure 2.2-8 of the narrative.

Potential Risk Scenarios

There is no description of responses to the "CO_2 leakage to USDW or land surface" scenario. However, this appears to be addressed in the "Potential Brine or CO_2 Leakage to a USDW" scenario. EPA recommends combining these in the list of Risk Scenarios for clarity and consistency.

Emergency Identification and Response Actions

EPA recommends some revisions to the descriptions and response actions for the scenarios identified in the Emergency and Remedial Response Plan. These are presented in the table below:

Event/Scenario	**EPA Comment/Recommendation**
1. Well Integrity Failure	a) A mechanical integrity failure can also occur in the post-injection phase; please update the "timing of the event" accordingly. b) There is a typo, "*Preform* a well log/MIT to detect CO_2 movement outside of the casing" under Major and Minor emergencies (pages 4 and 5). Please revise.
2. Injection Well Monitoring Equipment Failure	a) Please revise the title of this scenario to read "Injection Well or Monitoring Equipment Failure" to reflect the list of scenarios.

Event/Scenario	EPA Comment/Recommendation
3. Potential Brine or CO_2 Leakage to USDW	a) Please describe how CO_2 leakage would be identified (e.g., via elevated concentrations of indicator parameters in groundwater samples or other evidence of fluid/brine or CO_2 leakage into a USDW), including specific triggers (e.g., pressure increase or pH changes). b) EPA recommends that the introduction to this scenario be broadened to encompass any evidence of CO_2 or fluid movement out of the injection zone (i.e., not necessarily to a USDW) to address events associated with unanticipated fluid movement pathways, any potential USDW endangerment/unacceptable changes in water quality, and CO_2 leakage to the surface. This would also more directly address the identified "potential risk scenarios." c) Under detection methods, please identify specific triggers (e.g., pressure gauge detection limits). d) Please refer to shutting the injection wells (plural) rather than "the injection well" throughout the responses since there are multiple wells at the site.
4. Natural Disaster	a) Please move the sentence "If a natural disaster occurs that affects normal operation of the injection well, CTV will perform the following" to immediately precede the listed response actions. b) Please refer to shutting the injection wells (plural) rather than "the injection well" throughout the responses since there are multiple wells at the site.

Event/Scenario	EPA Comment/Recommendation
5. Induced or Natural Seismic Event	a) Under timing, please edit the sentence to read, "An induced seismic event ~~will~~ would occur when the reservoir stresses are altered…" since this is a conditional statement. b) Please make the following revisions to the response activities in Table 2: • Refer to shutting the injection wells (plural) rather than "the injection well" throughout the table since there are multiple wells at the site. • Edit, "Report findings to the UIC Program Director and ~~issue~~ perform corrective actions" in item # 5 under the orange operating state, and # 11 in the magenta and red operating states. • Edit #1 in the magenta operating state to refer to the "gradual shutdown plan" (instead of a rate reduction plan) to be consistent with other text in the E&RR Plan. • Edit items #9 under the magenta and red operating states to read, "If USDW contamination is detected, endangerment ~~and~~ or CO_2 leaked" (so the response applies to either situation). • In #10 in the red operating state, delete the text as written, since it duplicates # 7. Replace it with: "Assess monitoring plans and where necessary intensify the monitoring plan to ensure containment." • On the magenta and red operating states, please add a step: "Perform a fall-off test to identify whether any changes to formation pressure or injectivity occurred" to address concerns about the effects of seismic events on the subsurface. c) How will California Geological Survey staff participate in response actions?

Attachment G: Well Construction Plan

This well construction evaluation report for the proposed CTV III Class VI Sequestration Project summarizes EPA's evaluation of CTV's proposed well construction design details for the injection wells to be used for the sequestration of carbon dioxide (CO_2) in the Mokelumne River Formation at the project site. CTV submitted information regarding well construction with the Well Construction and Testing Plan (Attachment G, V 3.1, October 2023) and Injection and Monitoring Well Construction Schematics (Appendix C-1) as required in 40 CFR 146.86.

Injection Well Construction

CTV intends to install six new injection wells C-1, C-2, E-1, E-2, W-1, and W-2. The locations of the wells are presented in Figure 1. Well schematics for each well are provided in Appendix C-1. The casing, tubing, and packer details are presented on the schematics.

CTV states in the Well Construction and Testing Plan that no corrosion is anticipated as the injectate will consist of dry phase CO_2 with no free phase water component. However, the narrative describes a potential Injectate #1 that contains water. The well schematics show the depths of the temperature and pressure gauges and the wellhead surface equipment. The materials CTV proposes to use for well construction will adhere to various API and industry safety specifications, and were selected to withstand the anticipated pressures, temperatures, and axial loads of the formation depths.

Based on the well schematics, the injection wells will consist of the following components:

- Conductor casing from 14 to 54 ft.
- Surface casing consisting of K-55 grade steel, installed from 14 to 600 ft.
- Intermediate casing consisting of N-80 grade steel, installed from 14 to 2,550 ft.
- Long string casing is installed in 2 sections, one (L-80 grade steel) from 14 to 5,850 ft and the other (L-80 corrosion resistant alloy, CRA) from 5,850 to 7,960 ft. The first section will consist of L-80 grade steel; the deeper casing will consist of L-80 corrosion resistant alloy (CRA) material.

There is a discrepancy in the descriptions of the casing materials between Appendix C-1 and Attachment G, which describes the casing construction as 13Cr L-80 or other corrosion resistant alloy.

Intermediate casing will be set at approximately 13 to 30 ft below the lowermost USDW, but the surface casing is shallow and does not cover the lowermost USDW, as required per 40 CFR 146.86(b)(2).

The tubing specifications are provided on the well schematics and will consist of either L-80 CRA or 13Cr-L80 corrosion resistant materials. Although not shown in the schematics, the packer will consist of a CRA and hardened elastomer according to the Well

Construction and Testing Plan. The packer will be set at 6,070 ft, which is near the base of the tubing and above the perforations. Based on the specifications, no liner will be installed, as these are newly constructed injection wells.

The well annulus will be filled with a 4% potassium chloride completion fluid treated with corrosion inhibitor and biocide to be protective of the long string casing and tubing.

Class G Portland cement will be used to cement the casings in place. The Class G Portland cement will be enhanced with additives to increase flow properties and thickening time. The tail cement slurry for the intermediate casing will also contain CO_2 resistant additives. CTV indicates that other additives (anti-foam, fluid loss additives, lost circulation material, dispersants, silica flour, and extenders) may also be considered to ensure effective placement of cement.

Monitoring Well Construction

Two monitoring wells (M-1 and M-2) will be installed for injection zone monitoring, and well D-1 will be installed as an above-confining zone monitoring well. Two monitoring wells (US-1 and US-2) will be installed to monitor water quality in the lowermost USDW.

Injection zone monitoring wells M-1 and M-2 will be installed using similar materials, depths, and specifications as the injection wells. CTV notes that the perforation depths are "to be determined" and informed based on the injection well installations. Similar to the injection wells, the surface casing in these wells does not extend below the base of the lowermost USDW; however, the intermediate casing does extend just below the base of the lowermost USDW.

Above zone monitoring well D1 will also be constructed using similar materials, depths, and specifications, except the depth of the long string casing will be 5,700 ft; this depth is consistent with the depth of the Domengine Formation above the Capay Shale confining layer. The perforations will be from 5,240 to 5,360 ft and the well will be completed at the top of the Capay Shale formation. Additionally, no CRA casing materials are specified as this well is not expected to be in contact with CO_2.

USDW monitoring wells US-1 and US-2 will consist of the following components:

- Conductor casing consisting of H-40 grade steel from 14 to 54 ft.
- Intermediate casing consisting of J-55 grade steel, installed from 14 to 2,550 ft.

CTV also proposes that the wells be constructed with J-55 grade steel tubing from 14 to 2,480 ft and a low carbon, alloy steel packer set at 2,460 ft.

Class G Portland cement will be used to cement the casings in place. The perforations for US-1 and US-2 will be set at 2,500 to 2,520 ft. The pressure and temperature gauge will be set at 2,450 ft and is shown on the well schematics.

Corrosion of Well Construction Materials

Factors impacting the corrosivity of an environment containing CO_2 are complex and include pressure, temperature, and impurities (Cl^-, O_2, SO_2, NO_x, H_2S, etc.) that are frequently found to be present in sequestration injectate and/or formation fluids. Selection of appropriate well construction materials is therefore project-specific and depends, among other things, on the composition of formation fluids and the CO_2 stream.

Due to the acidic conditions generated by the mixing of CO_2 and water, alloys that may come into contact with water should be able to withstand pH values below 2.5. Examples of acceptable alloys may include Cr-25 steel and Hastelloy C-22. Some materials commonly used in less corrosive environments, such as Portland cement and Cr-13, are likely not appropriate for the corrosive conditions that occur where both water and CO_2 are present, either from aqueous formation fluids mixing with CO_2 or water present in the CO_2 stream itself. Also, monitoring wells located in the injection zone that contact the CO_2 plume will need to be adequately corrosion-resistant to tolerate the acidic conditions that can be generated by mixing of CO_2 streams and formation fluids in order to prevent endangerment of underground sources of drinking water.

Applicants proposing to use less corrosion resistant materials should demonstrate the adequacy of their planned materials including, but not limited to, through performing corrosion modeling over the timescale of their project. Any corrosion modeling used to validate well materials should take into account site specific chemistry, including the CO_2 stream and the formation fluids, and consider possible stress cases, in addition to normal operations, among other relevant factors.

Also see the email entitled “UIC Class VI Well Materials - CTV III UIC Permit Application” from David Albright, manager of the EPA R9 Groundwater Protection Section, to Faisal Latif, storage development manager of the Carbon TerraVault Holdings LLC. dated September 3, 2024.

Questions/Requests for CTV:

- *Please revise the planned construction of injection wells C-1, C-2, E-1, E-2, W-1, and W-2 to include surface casing that is cemented below the lowermost USDW, per 40 CFR 146.86(b)(2).*
- *Please also similarly revise the construction for monitoring wells M-1, M-2, and D-1.*
- *Please include the packer on the injection well schematics.*
- *Please clarify the discrepancy in the casing materials as described in Appendix C-1 and Attachment G. Please note that these should be consistent with the coupons to be used for corrosion monitoring in the Testing and Monitoring Plan. EPA recommends using the materials described in Appendix C-1, particularly for the*

monitoring wells as there has been evidence of corrosion of 13Cr in wet environments or if the injectate from any anticipated source will contain water.

- *Please describe how and when CTV will notify the EPA if additional additives will be used in the cement slurry.*
- *Please submit a demonstration that must include, at a minimum, corrosion modeling over the timescale of the project in addition to the provision of site-specific information required by 40 CFR 146.82. Any corrosion modeling must consider the site-specific chemistry, including the CO_2 stream and formation fluids, as well as consider possible stress cases in addition to normal operations and any other relevant factors.*

Pre-Operational Testing Plan

This pre-operational testing evaluation report for the proposed CTV III Class VI Sequestration Project summarizes EPA's evaluation of the pre-operational well construction and mechanical integrity testing that will be performed on the newly drilled injection wells. CTV provided pre-operational testing information in their Well Construction and Testing document (Attachment G, V 3.1, October 2023). EPA previously evaluated CTV's planned pre-operational formation testing program as part of the site characterization evaluation.

CTV plans to drill six new injection wells (C-1, C-2, E-1, E-2, W-1, and W-2) and perform a variety of open hole and cased wireline logging including dual induction laterolog, spontaneous potential, gamma ray, caliper, compensated neutron, formation density, mud log, and acoustic cement bond log. Deviation checks will be completed in the uncased borehole at 120 ft intervals. Logging will be performed during drilling, before the installation of each casing string (surface, intermediate, and long string), and after casing installation. Mechanical integrity testing (MIT) will consist of a standard annulus pressure test (SAPT) for internal MI and a temperature log for external MI.

CTV provided procedures for the MITs in Attachment G. Injection well SAPT will be performed using a fluid to fill the well annulus to stabilize the temperature. The well will then be pressurized to a surface pressure of "no less equal to or greater than [sic]" the highest annular pressure specified in the Operating Procedures document. The annulus will be isolated for no less than 60 minutes, with pressure measurements conducted at 10-minute intervals. CTV intends to submit an SAPT plan prior to conducting the test.

For monitoring wells M-1 and M-2, CTV proposes to perform wireline logging including dual induction laterolog, spontaneous potential, gamma ray, caliper, compensated neutron, formation density, and acoustic cement bond log. Similar to the injection wells, deviation checks will be completed in the uncased borehole every 120 ft. CTV indicates that an SAPT will be performed to demonstrate mechanical integrity. The testing will be similar to that

performed on the injection wells, but the plan specifies a pressurization to a surface pressure of no less than 500 psi for the well annulus.

Similar pre-operational testing will be conducted on the USDW monitoring wells US-1 and US-2, including dual induction laterolog, spontaneous potential, gamma ray, caliper, compensated neutron, formation density, and acoustic cement bond log. CTV states that the USDW monitoring well casings will be pressure tested, but does not refer to this as an SAPT.

Questions/Requests for CTV:

- *Please edit step 3 of the annulus pressure test procedures to clarify that the annular pressurization in injection well SAPTs will be "no less than the highest annular pressure specified in the Operating Procedures document," or revise as appropriate.*
- *Please describe pre-operational testing and any MITs that will be performed on above-zone monitoring well D-1.*
- *The plan alludes to multiple tests to be performed on M-1 and M-2 for mechanical integrity; however, only an SAPT is specified. Please describe what additional tests (if any) will be performed on these wells.*
- *Please clarify that SAPTs will be conducted on the USDW monitoring wells.*