ATTACHMENT E: POST-INJECTION SITE CARE AND SITE CLOSURE PLAN [40 CFR 146.93(a)] CTV III

Document Version History

Version	Revision Date	File Name	Description of Change
1	5/03/2022	Att E - CTV III PISC	Original submission
2	2/14/2025	Att E - CTV III PISC_V2_RtC	Response to October 31, 2024 EPA Comments
3	8/20/2025	Att E - CTV III PISC_V3_RtC	Response to May 19, 2025 EPA Comments

Facility Information

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This Post-Injection Site Care and Site Closure (PISC) plan describes the activities that Carbon TerraVault Holdings, LLC (CTV) will perform to meet the requirements of 40 CFR 146.93. CTV will monitor ground water quality and track the position of the carbon dioxide plume and pressure front for 20 years post injection. CTV will not cease post-injection monitoring until a demonstration of non-endangerment of 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 [40 CFR 146.93(a)(2)(i)]

Based on the computational modeling, pressure in the injection area is expected to stabilize approximately 50 years after injection ceases. Injection limits will be based on the fracture pressure of the Mokelumne River Formation. Additional information on the projected post-injection pressure declines and differentials is presented in the permit application, and the AoR and Corrective Action Plan.

Discussion

The storage reservoir will be operated such that the bottom hole injection pressures will not exceed the fracture pressure of the reservoir with a 10% safety factor.

The pressure near the injection site is approximately 2860 psi prior to the start of injection. As shown in **Figure E-1** the pressure at the injection site peaks 14 years into injection with 3118 psi modeled to be seen at the monitoring well location M2. Once injection ceases, the pressure is expected to drop fairly rapidly, with pressure dropping down to 2993 psi at the monitoring well M2 within 10 years of the end of injection. 50 years after the end of injection the pressure in the reservoir is expected be back approximately to initial conditions.

Predicted Position of the CO_2 Plume and Associated Pressure Front at Site Closure [40 CFR 146.93(a)(2)(ii)]

Figure E-2 shows the predicted maximum extent of the plume during the PISC timeframe. This map is based on the final AoR delineation modeling results submitted pursuant to 40 CFR 146.84. **Figures E-3** and **E-4** show the development of the CO2 plume during the injection period and after the cessation of injection. 52 years after the cessation of injection, the CO2 plume has largely stabilized, and no further movement is expected. **Figure E-5** shows initial, peak, and delta reservoir pressure across the project area.

Post-Injection Monitoring Plan [40 CFR 146.93(b)(1)]

Monitoring during the post-injection phase will include a combination of groundwater pressure, fluid composition and storage zone pressure as described in the following sections and will meet the requirements of 40 CFR 146.93(b)(1). The results of all post-injection phase testing and monitoring will be submitted annually, within 90 days, as described under "Schedule for Submitting Post-Injection Monitoring Results," below.

A quality assurance and surveillance plan (QASP) for all testing and monitoring activities during the injection and post injection phases is provided as **Appendix 11: QASP (Appendix 11)**.

Post-injection monitoring will include a combination of groundwater monitoring, and storage zone pressure monitoring. Pressure monitoring of the Mokelumne River Formation storage reservoir will monitor for pressure stabilization. This is the best method to confirm confinement of the reservoir. If pressure in the reservoir trends lower post injection and is inconsistent when compared to computational modeling results, CTV will assess for potential leakage.

Throughout the AoR there are USDWs. As such, ongoing groundwater monitoring of the USDWs will assess potential impacts. Groundwater samples will be analyzed quarterly for the first year after injection cessation, and then annually thereafter for indicators of CO2 movement into the USDWs.

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

Monitoring Above the Confining Zone

Table E-1 presents the monitoring methods, locations, and frequencies for monitoring above the confining zone. **Table E-2** identifies the parameters to be monitored and the analytical methods CTV will employ. **Table E-3** displays the sampling and recording frequencies for continuous monitoring during active injection and post injection.

Carbon Dioxide Plume and Pressure Front Tracking [40 CFR 146.93(a)(2)(iii)]

CTV will employ direct and indirect methods to track the extent of the carbon dioxide plume and the presence or absence of elevated pressure.

Table E-4 presents the direct and indirect methods that CTV will use to monitor the CO_2 plume, including the activities, locations, and frequencies CTV will employ. The parameters to be analyzed as part of fluid sampling in the Mokelumne River Formation (and associated analytical methods) are presented in **Table E-5**.

Table E-6 presents the direct and indirect methods that CTV will use to monitor the pressure front, including the activities, locations, and frequencies CTV will employ.

Fluid sampling will be performed as described in B.1. of **Appendix 11**; sample handling and custody will be performed as described in B.3. of **Appendix 11**; and quality control will be ensured using the methods described in B.5. of **Appendix 11**.

CTV will employ indirect and direct methods to monitor the pressure front (**Table E-6**). Direct monitoring will include pressure gauges to monitor the pressure of the CO2 plume in the three Mokelumne River Formation monitoring wells. Additionally, seismic monitoring via installed surface and/or shallow borehole seismometers well will be utilized to detect micro seismic events. **Figure E-3** shows the location of the monitoring wells and the predicted extent of the CO2 plume in plan view.

Schedule for Submitting Post-Injection Monitoring Results [40 CFR 146.93(a)(2)(iv)]

All post-injection site care monitoring data and monitoring results collected using the methods described above will be submitted to EPA in annual reports submitted 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.

Non-Endangerment Demonstration Criteria

Prior to authorization of site closure, CTV will submit a demonstration of non-endangerment of USDWs to the Director as per 40 CFR 143.93(b)(2) or (3).

CTV will provide a report to the Director that demonstrated USDW non-endangerment based on the evaluation of site monitoring data. The report will detail how the non-endangerment determination is based on site-specific conditions, supported with the computational model. All relevant monitoring data and interpretations will be provided.

Summary of Monitoring Data

A summary of the site monitoring data, pursuant to the Testing and Monitoring Plan and this PISC and Site Closure Plan, including data collected during the injection and PISC phases of the project. Data submission will be in a format acceptable to the Director and will include:

1. A narrative that explains the monitoring activities,
2. Dates of all monitoring events,
3. Changes to the monitoring program over time,
4. An explanation of all monitoring information that has existed at the site,
5. Explanation of how the monitoring data from injection and PISC has varied from the baseline data during site characterization, and
6. Summary of any emergencies that occurred during the injection and post-injection phases of the project. Included will be a description of how any issues have been resolved and that there is no endangerment to the USDW.

Evaluation of the CO_2 Plume and the AoR

Computational modeling results calibrated with monitoring data (e.g., pressure) will be used to support that the plume has stabilized and that the pressure change is negligible (less than 10 psi per year) and poses no risk for potential vertical migration. Computational modeling results calibrated with monitoring data from storage reservoir, USDW and above zone will be used to demonstrate:

1. the lack of CO_2 leakage over the project timeframe,
2. the accuracy of the model to predict and represent the storage reservoir, and
3. the computational model adequately defined the AoR.

Evaluation of Reservoir Pressure

Monitoring data will be reviewed to ensure that the CO_2 plume has stabilized post-injection and that the reservoir pressure change is negligible (less than 10 psi per year). This demonstration will be supported by the computational model that has been calibrated with the most recent monitoring data. The plume is trapped by structure and pinch-out of the reservoir sands. Plume migration is minimal, as such pressure stabilization will be used for non-endangerment assessment.

Evaluation of Potential Conduits for Fluid Movement

Wells that require corrective action will be reviewed and assessed prior to PISC and Site Closure, this includes monitoring wells, injection wells and other wells that penetrate within the AoR and the confining layer. Final demonstration will be made that natural and artificial conduits will not allow fluid migration from the storage reservoir.

Evaluation of Seismicity Monitoring

Demonstration will be made that the plume has stabilized and the pressure change is negligible (less than 10 psi per year), minimizing the risk for induced seismicity after site closure. Final review will be made with the seismicity monitoring to demonstrate seal integrity and that there is no further endangerment to the USDW.

Site Closure Plan

CTV will conduct site closure activities to meet the requirements of 40 CFR 146.93(e), with notification to the permitting agencies at least 120 days prior to its intent to close the site. Upon approval of the permitting agencies, CTV will plug the injection and monitoring wells as shown in the proposed abandonment schematics presented in **Appendix 5: Injection and Monitoring Well Schematics**, restore the site and submit a site closure plan to the EPA.

A site closure report will be prepared and submitted within 90 days following site closure supported by the following:

- Verification of injector and monitoring well plugging,
- Notifications to state and local authorities as per 40 CFR 146.93 (f)(2),
- Composition and volume of the injected CO_2, and
- Post-injection monitoring records

CTV will record a notation to the property's deed that will indicate:

- 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.

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).

Alternative Post-Injection Site Care Timeframe

An alternative PISC time frame of 20 years (compared to the default of 50 years) is appropriate based on the results of the detailed geologic analyses and numerical plume and pressure-front modeling presented in **Attachment A: Narrative Report (Attachment A)** and **Attachment B: AoR and Corrective Action Plan (Attachment B)**.

Injection well and monitoring well construction are presented in **Attachment G: Well Construction and Testing (Attachment G)**, and wells will be constructed and plugged for the case of the injection wells to maintain integrity and prevent fluid leakage.

Computational Modeling Results

AoR delineation modeling information, including methods, results, and sensitivity analyses, is presented in **Attachment B**. These results are used for discussion of plume and pressure front migration in the following subsections.

Predicted Time Frame for Pressure Decline

Figure E-1 displays modeled pressure at injection-zone monitoring well M2. The pressure near the injection site is approximately 2860 psi prior to the start of injection. Pressure peaks 14 years into injection with 3118 psi modeled to be seen at the monitoring well location M2. Once injection ceases, the pressure is expected to drop fairly rapidly, with pressure dropping down to 2993 psi at the monitoring well M2 within 10 years of the end of injection. Figure B-17 in **Attachment B** displays reservoir pressures near each injector through time. In all cases, pressure declines from a peak at the end of injection (2054), with the rate of decline reaching an asymptotic trend by 20 years after the end of injection (2074).

Predicted Rate of Plume Migration

Figure E-3 displays the location of the simulated injection zone CO_2 plumes at various times (outermost extent of CO_2 plume within each formation). The CO_2 plume is predicted to show essentially no horizontal movement after the injection period, with a similar plume outline at the end of injection (28-year CO_2 boundary), and 50- and 100-years post-injection.

EPA Class VI Well Plugging, PISC and Site Closure Guidance states that when the plume is migrating at a negligible rate compared to the location of sensitive receptors, the plume migration rate may be considered sufficiently minor so as to not pose an endangerment to USDWs. Figure B-30 in **Attachment B** shows the locations of plugged wells. At the end of injection (28 years after the beginning of injection), the CO_2 plume has already spread to cover the location of the wells designated for corrective action within the AoR. The rate of movement predicted for the CTV III storage project and lack of interface with sensitive receptors (plugged wells) after 20 years after the end of injection supports a PISC time frame of 20 years.

Site-Specific Trapping Processes

At the CTV III site, simulations indicate that trapping occurs primarily by capillary trapping and CO_2 dissolution in the brine. Equilibrium geochemical modeling presented in **Appendix 3: Geochemical Modeling (Appendix 3)** indicates minor CO_2 mineralization. **Attachment B** includes a detailed discussion of simulated CO_2 fate after injection (see Figure B-20 of **Attachment B**). Most of the CO_2 is trapped as separate-phase CO_2 ("capillary trapping"), consistent with scientific understanding of key storage processes in saline reservoirs (e.g., Krevor et al., 2015). The fraction of CO_2 predicted to be stored via capillary trapping in pore space remains relatively constant in the post-injection period, supporting a reduced PISC time frame.

Confining Zone Characterization

Attachment A includes a detailed evaluation of the Capay Shale, a regionally continuous sealing facies present. The Capay ranges from 94 to 364 feet thick throughout the AoR (Table A-7 of **Attachment A**). The geometric average permeability of the upper confining zone (Capay Shale) is 0.34 millidarcys (mD), based on the Citizen_Green_1 well NMR permeability from the Timur-Coates method. Geochemical modeling indicates that the Capay Shale will not be significantly reactive with CO_2 (**Appendix 3**). These attributes indicate that the Confining Zone will restrict upward fluid movement and support a reduced PISC time frame.

Assessment of Fluid Movement Potential

Attachment B presents information on abandoned wells within the AoR. There are three wells within the CO_2 plume that penetrate the Confining Zone and Injection Zone. CTV will implement corrective actions before injection (see Figure B-30 of **Attachment B**) for the three identified wells. Decisions regarding corrective measures for the remaining wells in the AoR will be made in consultation with the EPA, based on reservoir pressure response and phased monitoring results.

Location of USDWs

Delineation of the depth to the top of the Injection Zone and the depth of the lowermost USDW are discussed in **Attachment A**. Figure 1 of Report 2 in **Appendix B-4: Leakage Risk Analysis Reports** presents a map of the thickness between the Injection Zone and the lowermost USDW. Minimum distance between the Injection Zone and the lowermost USDW within the AoR is approximately 2,575 feet. There is significant thickness that exists between the Injection Zone and lowermost USDW, which, as described in **Attachment A**, consists of the Capay Shale, Domengine Sand, Nortonville Shale and Lower Markley Formation. Along with the other analyses described above, the significant thickness and presence of the Domengine dissipation zone between the Injection Zone and lowermost USDW is another assurance of the limited risk to USDWs and supports a shorter PISC time frame.

References

Krevor, S., Blunt, M. J., Benson, S. M., Pentland, C. H., Reynolds, C., Al-Menhali A., Niu, B., 2015, Capillary trapping for geologic carbon dioxide storage - From pore scale physics to field scale implications: International Journal of Greenhouse Gas Control, v.40, P. 221-237. https://doi.org/10.1016/j.ijggc.2015.04.006

Figures

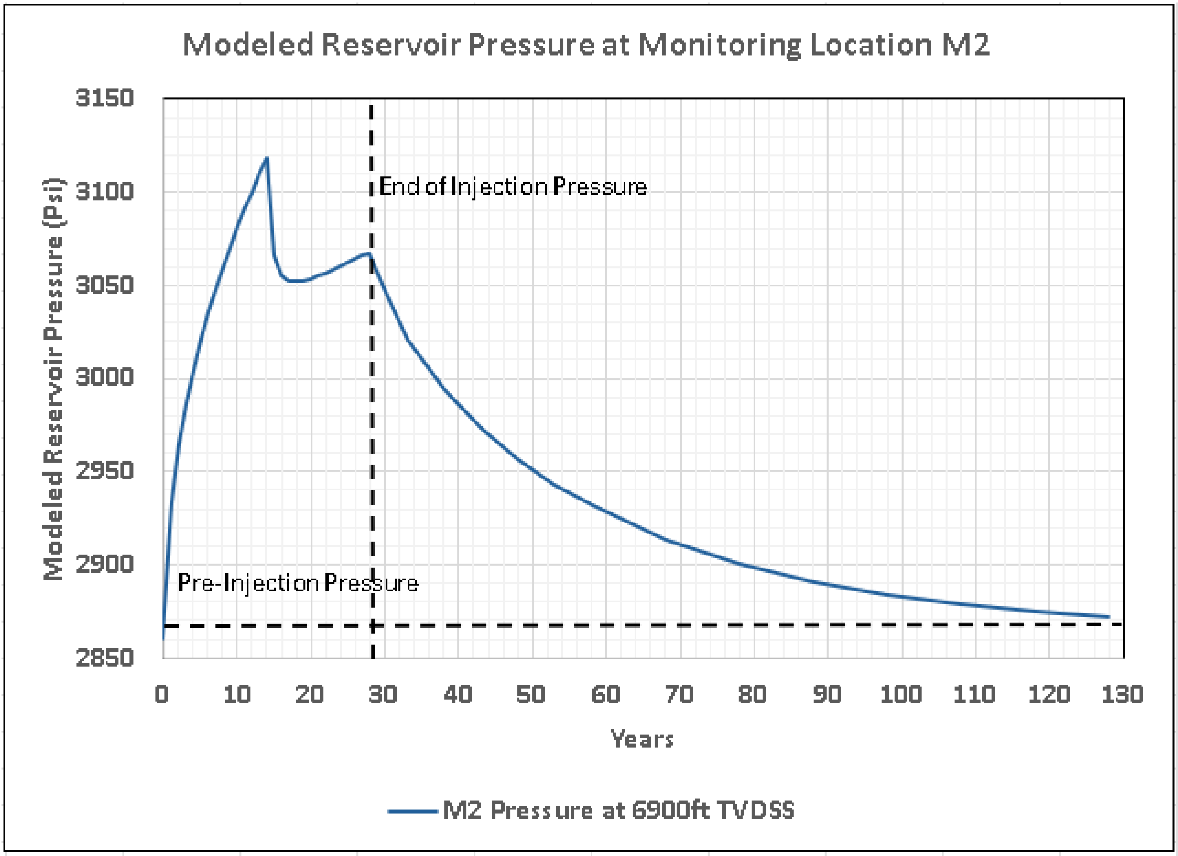

Figure E-1: Modeled pressure at Monitoring well location M2 at 6,900 TVDSS during the injection period and 100 years post injection.

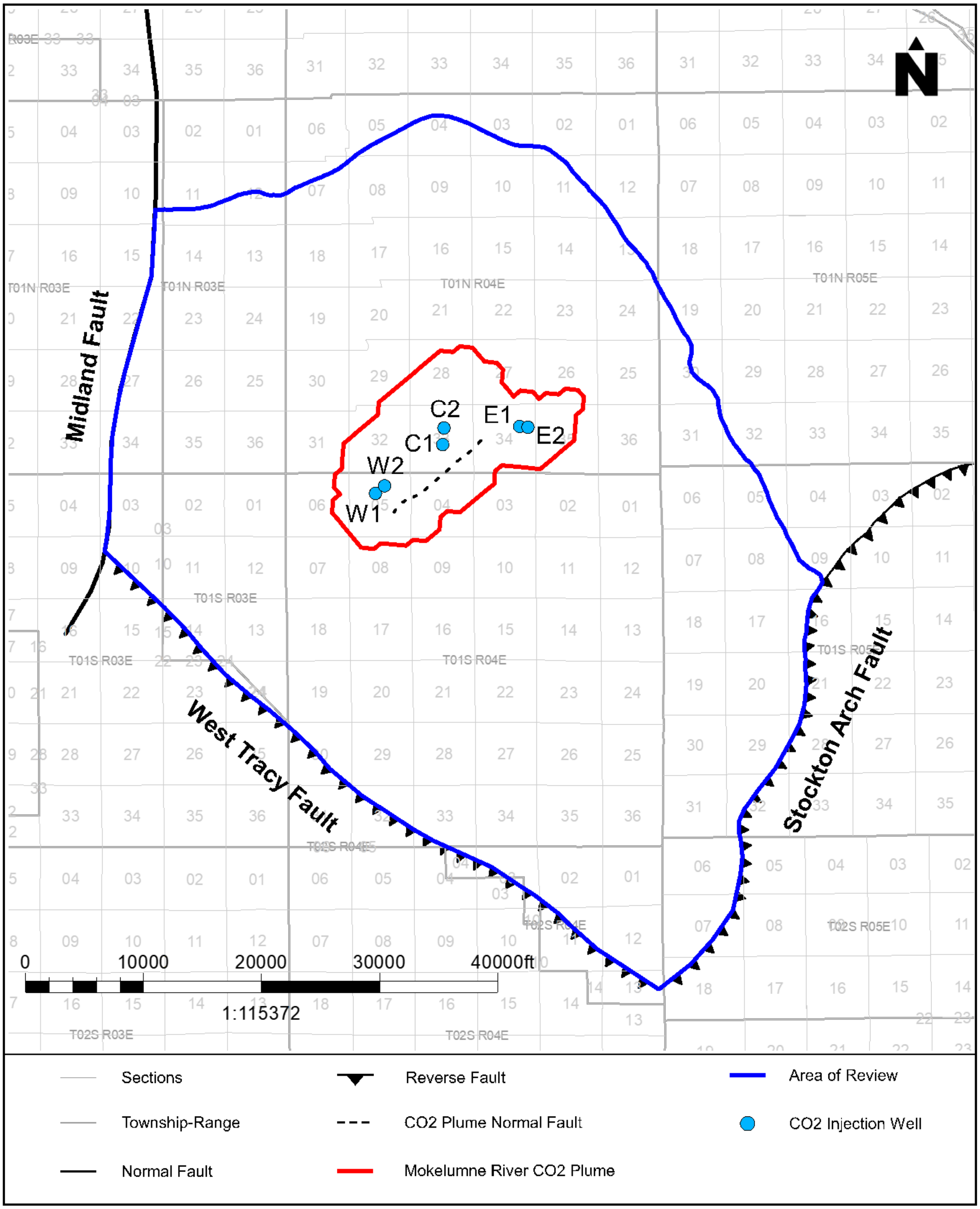

Figure E-2: Map of the predicted extent of the CO_2 plume at site closure.

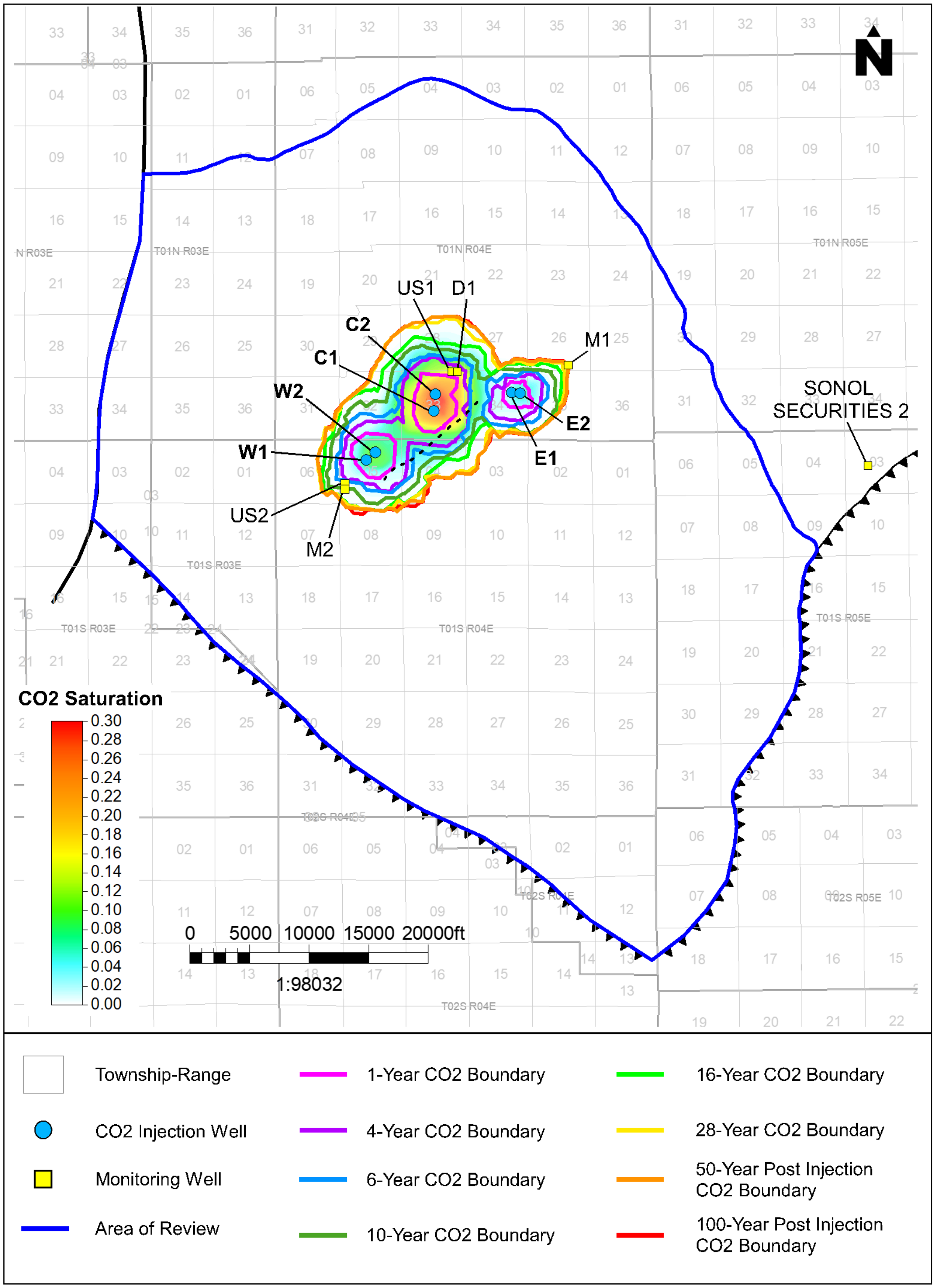

Figure E-3: Map showing the location of monitoring wells and plume development through time from the computational model. Monitoring wells M1, M2, and Sonol Securities 2 monitor the injection interval, D1 monitors the dissipation zone, and US1 and US2 monitor the USDW.

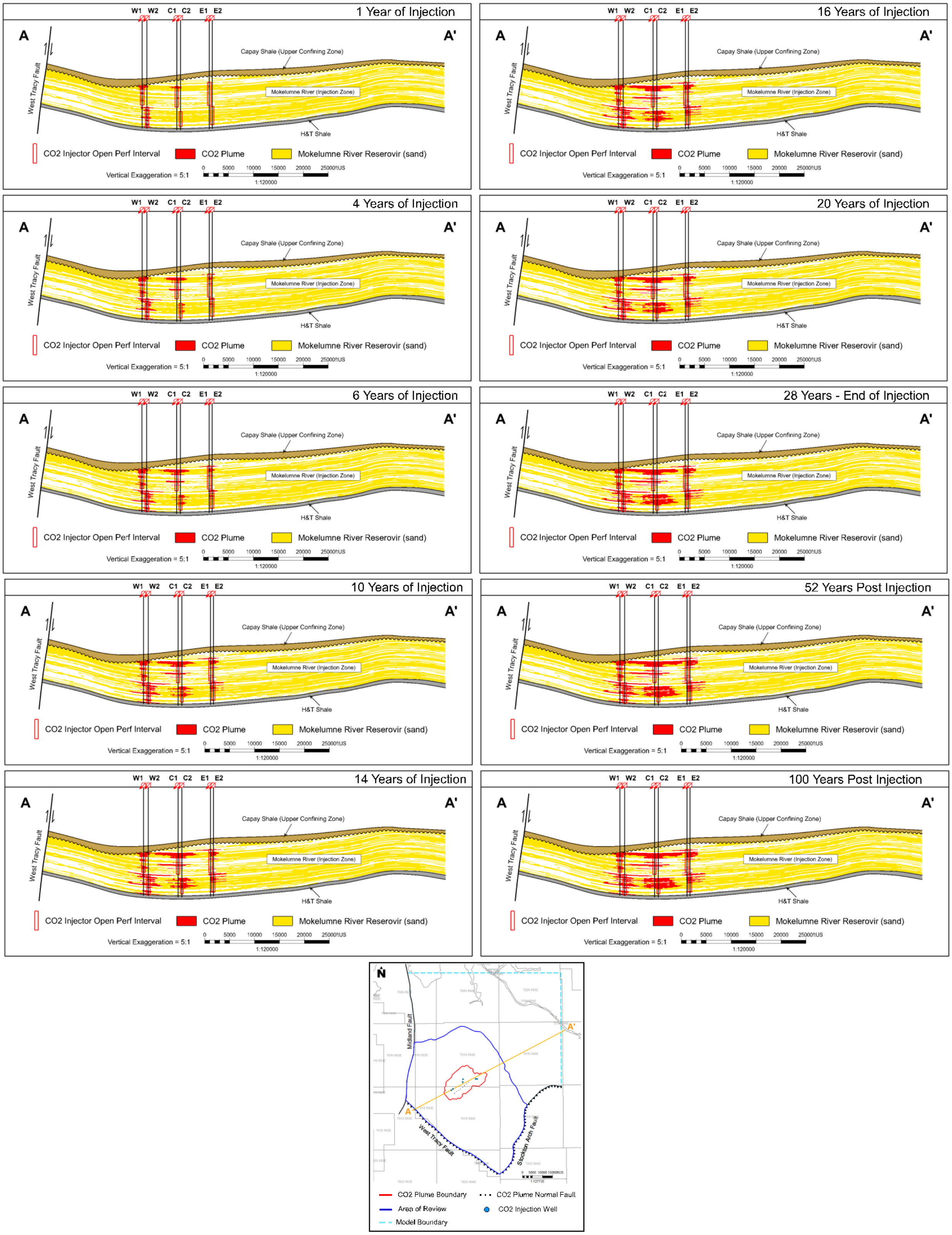

Figure E-4: Cross sections showing plume development at varying time steps through the project.

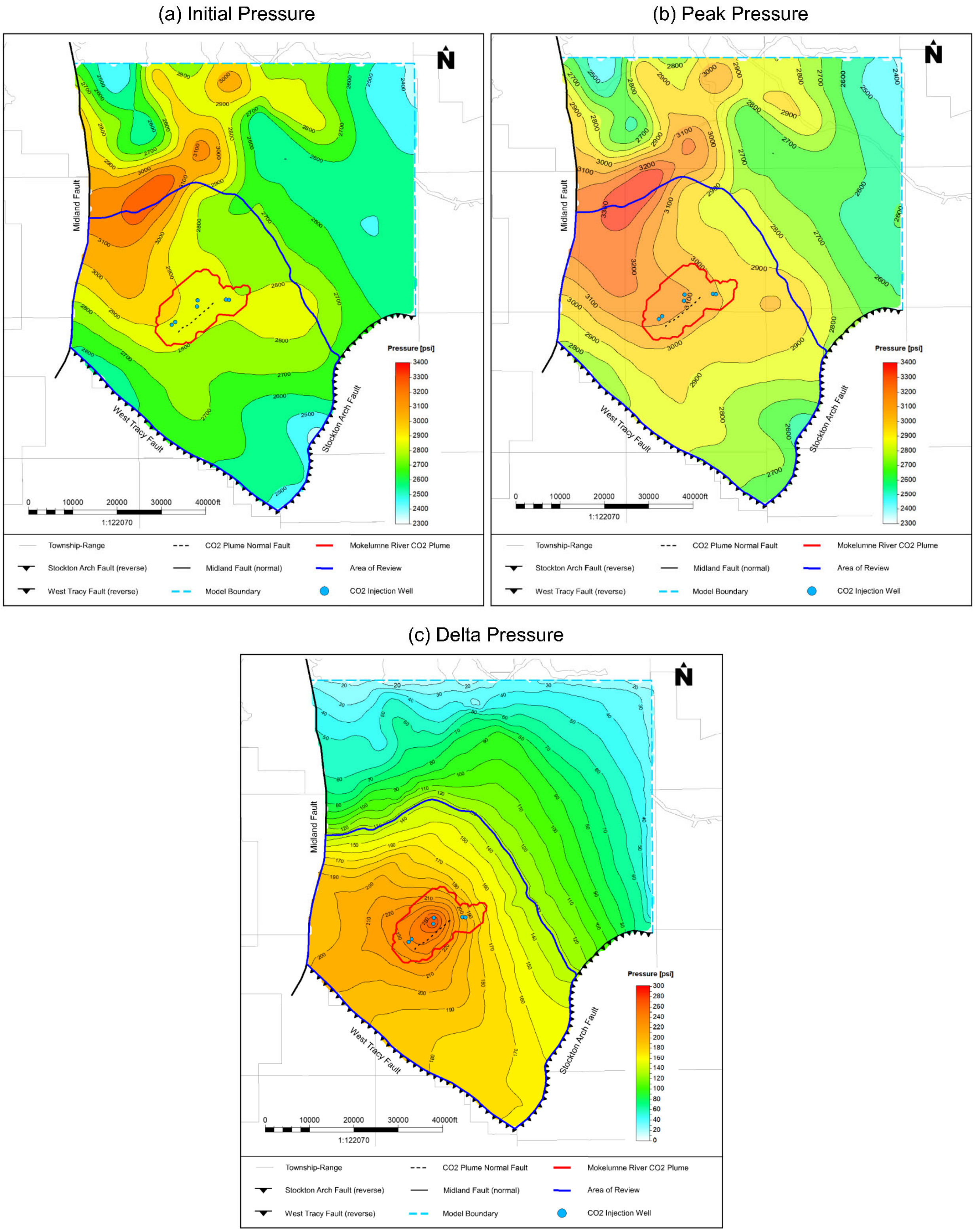

Figure E-5: (a) Initial pressure across the model boundary, (b) Peak pressure across the model boundary, (c) Delta pressure across the model boundary.

Tables

Table E-1. Monitoring of groundwater quality and geochemical changes above the confining zone.

Target Formation	Monitoring Activity	Monitoring Location(s)	Spatial Coverage or Depth (feet MD/TVD)	Frequency (Post Injection Phase)
Undifferentiated non-marine sediments.	Fluid sampling	USDW Monitoring Wells: US1 US2	2,500 – 2,520	Quarterly for first year, Annually thereafter
	Pressure	USDW Monitoring Wells: US1 US2	5,080	Continuous
	Temperature	USDW Monitoring Wells: US1 US2	0 – 5,080	Continuous
Domengine Formation	Fluid sampling	D1	5,123 – 5,646	Quarterly for first year, Annually thereafter
	Pressure	D1	5,080	Continuous
	Temperature	D1	0 – 5,080	Continuous

Table E-2. Summary of analytical and field parameters for ground water samples.

Parameters	Analytical Methods
USDW and Domengine Formation	
Cations (Al, Ba, Mn, As, Cd, Cr, Cu, Pb, Se, Zn, Tl)	ICP-MS EPA Method 6020
Cations (Ca, Fe, K, Mg, Na, Si)	ICP-OES EPA Method 6010B
Anions (Br, Cl, F, NO3, SO4)	Ion Chromatography, EPA Method 300.0
Dissolved CO2	Coulometric titration ASTM D513-11
δ13C	Isotope ratio mass spectrometry
Hydrogen Sulfide	ISBT 14.0 (GC/SCD)
Oxygen, Argon and Hydrogen	ISBT 4.0 (GC/DID) GC/TCD
Total Dissolved Solids	Gravimetry; Method 2540 C
Alkalinity	Method 2320B
pH (field)	EPA 150.1
Specific Conductance (field)	SM 2510 B
Temperature (field)	Thermocouple

Table E-3. Sampling and recording frequencies for continuous monitoring.

Parameter	Device(s)	Target Formation	Location	Min. Sampling Frequency	Min. Recording Frequency
During active injection	Pressure Gauge/ Temperature Sensor	Undifferentiated non-marine	USDW Monitoring wells: US1 US2	5 hours	5 hours
		Domengine Formation	Above Confining Zone Monitoring well: D1	5 hours	5 hours
		Mokelumne River Formation	Injection Zone Monitoring Well: M1 M2 SONOL SECURITIES 2	5 hours	5 hours
Post injection	Pressure Gauge/ Temperature Sensor	Undifferentiated non-marine	USDW Monitoring wells: US1 US2	12 hours	12 hours
		Domengine Formation	Above Confining Zone Monitoring well: D1	12 hours	12 hours
		Mokelumne River Formation	Injection Zone Monitoring Well: M1 M2 SONOL SECURITIES 2	12 hours	12 hours

Notes:

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

Table E-4. Post-injection phase plume monitoring.

Monitoring Category and Class VI Rule Citation	Target Formation	Monitoring Activity	Data Collection Location(s)	Spatial Coverage or Depth (feet MD)	Frequency (Post Injection Phase)
Plume Monitoring [40 CFR 146.90(g)] DIRECT MONITORING	Mokelumne River Formation	Fluid Sampling	M1	5,744 – 7,668	Quarterly for first year, Annually thereafter
		Pressure		5,680	Continuous
		Temperature		0 - 5,680	Continuous
	Mokelumne River Formation	Fluid Sampling	M2	6,157 – 7,703	Quarterly for first year, Annually thereafter
		Pressure		6,110	Continuous
		Temperature		0 – 6,110	Continuous
	Mokelumne River Formation	Fluid Sampling	SONOL SECURITIES 2	5,731 – 5,792	Quarterly for first year, Annually thereafter
		Pressure		5,690	Continuous
		Temperature		0 – 5,690	Continuous
Plume Monitoring [40 CFR 146.90(g)] INDIRECT MONITORING	Mokelumne River Formation	Pulse neutron logging	M1	5,744 – 7,668	Every 5 years
			M2	6,157 – 7,703	

Table E-5. Summary of analytical and field parameters for fluid sampling in the injection zone.

Parameters	Analytical Methods
Mokelumne Formation	
Cations (Al, Ba, Mn, As, Cd, Cr, Cu, Pb, Se, Zn, Tl)	ICP-MS EPA Method 6020
Cations (Ca, Fe, K, Mg, Na, Si)	ICP-OES EPA Method 6010B
Anions (Br, Cl, F, NO3, SO4)	Ion Chromatography, EPA Method 300.0
Dissolved CO_2	Coulometric titration ASTM D513-11
δ13C	Isotope ratio mass spectrometry
Hydrogen Sulfide	ISBT 14.0 (GC/SCD)
Oxygen, Argon and Hydrogen	ISBT 4.0 (GC/DID) GC/TCD
Total Dissolved Solids	Gravimetry; Method 2540 C
Alkalinity	Method 2320B
pH (field)	EPA 150.1
Specific Conductance (field)	SM 2510 B
Temperature (field)	Thermocouple

Table E-6. Post-injection phase pressure-front monitoring.

Monitoring Category and Class VI Rule Citation	Target Formation	Monitoring Activity	Data Collection Location(s)	Spatial Coverage or Depth (feet MD)	Frequency (Post Injection)
Pressure-Front Monitoring [40 CFR 146.90(g)] DIRECT MONITORING	Mokelumne River Formation	Pressure	M1	5744 – 7668	Continuous
		Temperature			Continuous
	Mokelumne River Formation	Pressure	M2	6160 - 7700	Continuous
		Temperature			Continuous
	Mokelumne River Formation	Pressure	SONOL SECURITIES 2	5731 - 5792	Continuous
		Temperature			Continuous
Pressure-Front Monitoring [40 CFR 146.90(g)] INDIRECT MONITORING	All strata	Seismicity	Seismic Monitoring Network	Two-mile radius from injector well	Continuous