Carbon TerraVault VI
Class VI Permit Application
Narrative Report

Submitted to:

U.S. Environmental Protection Agency Region 9
San Francisco, CA

Prepared by:

27200 Tourney Road, Suite 200
Santa Clarita, CA 91355
(888) 848-4754

ATTACHMENT A: NARRATIVE REPORT
[40 CFR 146.82(a)]
CTV VI

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Document Version History

Version	Revision Date	File Name	Description of Change
1	7/31/2024	Att A - CTV VI Narr.docx	Initial submission
2	8/26/2025	Att A - CTV VI Narr_v2.docx	Response to May 15, 2025 EPA Comments

1. Project Background and Contact Information

Carbon TerraVault Holdings, LLC (CTV), a wholly owned subsidiary of California Resources Corporation (CRC), proposes to construct and operate seven carbon dioxide (CO_2) geologic sequestration wells at the project area located in Fresno County, California. This application was prepared in accordance with the U.S. Environmental Protection Agency's (EPA's) Class VI regulations, in Title 40 of the Code of Federal Regulations (40 CFR 146.81). CTV is not requesting an injection depth waiver or aquifer exemption expansion.

CTV will obtain the required authorizations from applicable local and state agencies, including the associated environmental review process under the California Environmental Quality Act. **Appendix 1** outlines potential local, state and federal permits and authorizations. The project wells and facilities will not be located on Indian Lands. Federal act considerations and additional consultation, which includes the Endangered Species Act, the National Historic Preservation Act, and consultations with Tribes in the Area of Review (AoR), are presented in **Appendix 2**.

CTV forecasts the potential CO_2 stored in the Injection Zone Claimed as PBI [redacted] on average for Claimed as PBI [redacted] for a total of Claimed as PBI [redacted]

CTV is planning to construct a carbon capture and sequestration "hub" project (i.e., a project that collects CO_2 from multiple sources over time and injects the CO_2 stream(s) via Class VI UIC permitted injection wells). Therefore, CTV is currently considering multiple sources of anthropogenic CO_2 for the project. Potential sources include capture from existing and potential future industrial sources in the San Joaquin Basin area, as well as direct air capture (DAC).

The CTV VI storage site is located in the Claimed as PBI [redacted] The project is comprised of seven injection wells, surface facilities, and monitoring wells. This supporting documentation applies to each of the seven injection wells.

CTV will actively communicate project details and submitted regulatory documents to County and State agencies:

- Fresno County
  District 5 Supervisor –Nathan Magsig
  2281 Tulare St. Room #300
  Fresno, CA 93721
  (559) 600-5000

- Fresno County Department of Public Works and Planning
  Director – Steven E. White
  2220 Tulare Street, 6th Floor
  Fresno, CA 93721
  (559) 600-4537

- California Geologic Energy Management Division (CalGEM)
  Senior Oil and Gas Engineer – Erwin Sison

715 P Street, MS 1804
Sacramento, CA 95814
(916) 203-7734

- CA Assembly District 27
Assemblyman Esmeralda Soria
512 West 18th Street
Merced, CA 95340
(209) 726-5465
- CA Senate District 14
Senator Anna Caballero
512 West 18th Street
Merced, CA 95340
(209) 726-5465
- US Congressional District 13
Representative John S. Duarte
90 S. First Street
Turlock, CA 95380
(209) 226-6880
- United States Senator
Senator Laphonza Butler 2500 Tulare Street
Suite 4290
Fresno, CA 93721
(559) 485-7430
- United States Senator
Senator Alex Padilla 2500
Tulare Street
Suite 5290
Fresno, CA 93721
(559) 497-5109
- Region 9 Environmental Protection Agency
David Albright
75 Hawthorne Street
San Francisco, CA 94105
(415) 947-8000

2. Site Characterization

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

2.1.1 Geologic History

The CTV VI storage site is Claimed as PBI [redacted]

Claimed as PBI [redacted]

Claimed as PBI [redacted]

The CTV VI Injection Zone consists of Claimed as PBI [redacted]

The CTV VI AoR, shown as the red boundary Claimed as PBI [redacted] The project AoR was determined based on computational modeling as described in **Attachment B: AoR and Corrective Action Plan** (**Attachment B**).

2.1.2 Geology Overview

The CTV VI storage site lies within the northern San Joaquin Basin in central California (**Figure 2.1-2**). The San Joaquin Basin is the southern, asymmetric sub-basin of the larger, Great Valley Forearc.

2.1.2.1 Basin Structure

The Great Valley was developed during mid to late Mesozoic time. The advent of this development occurred under convergent-margin conditions via eastward, Farallon Plate subduction of oceanic crust beneath the western edge of North America (Beyer, 1988). The convergent continental margin that characterized central California during the Late Jurassic through Oligocene time was later replaced by a transform-margin tectonic system. This occurred as a result of the northward migration of the Mendocino Triple Junction (from Baja California to its present location off the coast of Oregon), located along California's coast (**Figure 2.1-3**). Following this migrational event, the progressive cessation of both subduction and arc volcanism occurred as the progradation of a transform fault system moved in as the primary tectonic environment (Graham, 1984). The major present day fault, the San Andreas, intersects most of the Franciscan subduction complex, which consists of the exterior region of the extinct convergent-margin system (Graham, 1984).

2.1.2.2 Basin Stratigraphy

The structural trough that developed subsequent to these tectonic events ("the Great Valley") became a depocenter for eroded sediment, and therefore currently contains a thick infilled sequence of sedimentary rocks. These sedimentary formations range in age from Jurassic to Holocene. The first deposits occurred as an ancient seaway that through time were built up by the erosion of the surrounding structures. The basin is constrained on the west by the Coast Range Thrust, on the north by the Stockton Arch, on the east by the Sierra Nevada, and on the south by the Wind Wolves Fault (**Figure 2.1-2**). To the west, the Coastal Range boundary was created by uplifted rocks of the Franciscan Assemblage (**Figure 2.1-4**). The Sierra Nevada, which make up the eastern boundary, are a result of a chain of ancient volcanos.

Basin development is broken out into evolutionary stages at the end of each time-period of the arc-trench system from Jurassic to Neogene in **Figure 2.1-5**. Sediment infill began as an ancient seaway and was later sourced from the erosion of the surrounding structures. Sedimentary infill consists of Cretaceous-Paleogene fluvial, deltaic, shelf and slope sediments. Due to the southward tilt of the basin, sedimentation Claimed as PBI [redacted] creating sequestration quality sandstones Claimed as PBI [redacted]

Claimed as PBI [redacted]

2.1.3 Geological Sequence

Claimed as PBI [redacted]

[redacted]

2.1.3.1 Basin Floor Fans

Eustatic sea level events and tectonics caused the northern San Joaquin Basin to undergo a series of shelf progradations and subsequent transgressions that resulted in a series of basin floor fan systems fed from erosive fan channel systems that dissected the shelf edge deltas. Claimed as [redacted]

[redacted]

Claimed as PBI [redacted]

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

2.2.1 Data

Claimed as PBI [redacted]

Well data are used in conjunction with two-dimensional (2D) and three-dimensional (3D) seismic to define the structure and stratigraphy of the injection zones and confining layers. **Figure 2.2-3** shows outlines of the seismic data used within the area of the model boundary. Also shown are the seismic well ties made to the 2D and 3D data, along with velocity data from wellbores with available checkshot surveys. Available 3D seismic data were used as the basis for phase- and time-matching the 2D seismic lines so that the surfaces were mapped on a consistent datum. The 2D and 3D data were mapped for the following surfaces:

- Claimed as PBI [redacted]
- Claimed as PBI [redacted]
- Claimed as PBI [redacted]
- Claimed as PBI [redacted]
- Claimed as PBI [redacted]
- Claimed as PBI [redacted]
- Claimed as PBI [redacted]

The interpretation of these layers began with a series of well ties at well locations shown in **Figure 2.2-3**. These well ties create an accurate relationship between wells which are in depth and the seismic which is in time. The well tie time-depth relationships are used in conjunction with available checkshot data to confirm the well picks relative to the seismic data. The layers listed above were mapped in time across the 2D and 3D seismic data and then gridded. Alongside this mapping was the interpretation of any faulting in the area, which is discussed further in the Faults and Fracture section of this document.

The gridded time maps are sampled to well pick tops across the model area to create time-depth pairs, which are used to calculate an average velocity. Average velocity maps are then created for each of the layers listed above to convert the gridded time maps into depth for input into the simulation model. Intermediate layers between the mapped seismic surfaces are developed using a framework using conformance relationships to create a series of depth grids that are controlled by formation well tops picked on well logs. The seismic mapped depth grids are used as structural control between these well tops to incorporate the detailed mapping of the seismic data. A separate 3D velocity model was created to depth convert any interpreted faults from the seismic data into the depth domain.

2.2.2 Stratigraphy

Claimed as PBI [redacted]

2.2.2.1 Claimed as PBI [redacted] Injection Zone)

The Claimed as PBI [redacted] represent Claimed as PBI [redacted]

2.2.2.2 Claimed as PBI [redacted] Injection Zone)

The Claimed as PBI [redacted]

2.2.2.3 Claimed as PBI [redacted] (Confining Zone)

The Claimed as PBI [redacted] It is composed of Claimed as PBI [redacted]

(Claimed as PBI [redacted]

2.2.2.4 Claimed as PBI [redacted] *(Monitoring Zone)*

Above the Claimed as PBI [redacted]

2.2.3 Maps of the Area of Review

As required by 40 CFR 146.82(a)(2), **Figure 2.2-6** is a summary map of the oil and gas wells, water wells, State- or EPA-approved subsurface cleanup sites, and surface features in the project area and the project AoR. AoR delineation is presented in **Attachment B**. **Tables 2.2-1 and 2.2-2** list water supply wells and the oil and gas wells present in the AoR. Water wells were identified using the California Department of Water Resources (DWR) Well Completion Report (WCR) and California State Water Resources Control Board Groundwater Ambient Monitoring Assessment Program (GAMA) databases and are shown in **Figure 2.2-6**.

Major surface water bodies Claimed as PBI [redacted]

The project AoR is in Fresno County. Claimed as PBI [redacted]

Claimed as PBI [redacted] This cleanup site information obtained from the State Water Resources Control Board (SWRCB) GeoTracker database contains records for sites that impact, or have the potential to impact, groundwater quality. Water wells within and adjacent to the AoR are discussed in Section 2.7 of this document.

40 CFR 146.82(a)(2) requires that the application includes a map showing the injection wells, the AoR, and the following list of items, and these are shown on the indicated maps where present:

- Existing injection wells, producing wells, abandoned wells, plugged wells or dry holes, deep stratigraphic boreholes (**Figures 2.2-1 and 2.2-6**).
- Surface bodies of water, springs, mines (surface and subsurface), quarries, State, Tribal, and Territory boundaries, roads and other pertinent surface features (**Figure 2.2-6**).
- State- or EPA-approved subsurface cleanup sites (**Figures 2.2-6 and 2.2-7**).
- Water wells (**Figure 2.2-6**; also see Section 2.7)
- **Figure 2.2-6** is a compilation of the above data including index numbers to well names. Referenced index numbers are listed in **Tables 2.2-1 and 2.2-2**.

Figure 2.2-8 displays the location of CTV VI project injection and monitoring wells and maximum CO_2 plume extent within each injection zone interval from modeling presented in **Attachment B**.

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

Claimed as PBI [redacted]

[redacted]

Claimed as PBI [redacted]

2.4 Injection and Confining Zone Details [40 CFR 146.82(a)(3)(iii)]

2.4.1 Mineralogy

No quantitative mineralogy information exists within the AoR boundary. Several wells outside the AoR have mineralogy over the formations of interest, and those data are presented below. The location of wells used for mineralogy are shown in **Figure 2.4-1**, and the mineralogy data are shown in **Table 2.4-1**. Additional mineralogy data from within the AoR will be collected during the pre-operational period as discussed in **Attachment I: Pre-operational Testing Plan**.

2.4.1.1 Monitoring Zone Claimed as PBI [redacted]

Mineralogy data are available for the Monitoring Zone in the form of semi-quantitative X-ray diffraction (XRD) data from one well Claimed as PBI [redacted] Two reservoir sand samples from this well contain on average 30 percent quartz, 50 percent plagioclase and potassium feldspar, and 20 percent total clay. The primary clay mineral is mixed layer illite/smectite. Calcite and dolomite were not detected in either of the samples. Additional mineralogy data from within the AoR will be collected during the pre-operational period as discussed in **Attachment I**.

2.4.1.2 Confining Zone Claimed as PBI [redacted]

Mineralogy data are available for the Confining Zone in the form of XRD data from two wells Claimed as PBI [redacted] A total of 10 shale samples from these wells average 19 percent quartz, 20 percent plagioclase and potassium feldspar, and 50 percent total clay. Additional minerals include on average 5 percent pyrite and Claimed as PBI [redacted] Opal-CT was detected with an average weight percent of 8 percent. The primary clay minerals are illite and mixed layer illite/smectite. Calcite and dolomite were detected in nominal amounts in the samples. This mineralogy is similar to outcrop samples of the Confining Zone from adjacent to the model boundary Claimed as PBI [redacted] Additional mineralogy data from within the AoR will be collected during the pre-operational period as discussed in **Attachment I**.

2.4.1.3 Claimed as PBI [redacted]

Mineralogy data are available for Claimed as PBI [redacted] The one sample in this well contains 43 percent quartz, 26 percent plagioclase and potassium feldspar, and 25 percent total clay. Additional minerals include 6 percent pyrite. The primary clay mineral is kaolinite. Calcite and dolomite were not detected in the sample.

Rough sand grain count mineralogy of Claimed as PBI [redacted] A total of 4 outcrop samples from Claimed as PBI [redacted] average 39 percent quartz and 60 percent plagioclase and potassium feldspar. No effort was made to determine clay mineralogy or content. Additional mineralogy data from within the AoR will be collected during the pre-operational period as discussed in **Attachment I**.

2.4.1.4 Claimed as PBI [redacted]

No mineralogy data are currently available for Claimed as PBI [redacted] used as an analog. Claimed as PBI [redacted]

Rough sand grain count mineralogy of Paleocene sandstone in the Claimed as PBI [redacted] A total of 14 outcrop samples from Claimed as PBI [redacted] average 44 percent quartz and 56 percent plagioclase and potassium feldspar. No effort was made to determine clay mineralogy or content. Additional mineralogy data from within the AoR will be collected during the pre-operational period as discussed in **Attachment I**.

2.4.1.5 Claimed as PBI [redacted]

No mineralogy data are available for Claimed as PBI [redacted] used as an analog. The Claimed as PBI [redacted] These samples average 35 percent quartz, 54 percent plagioclase and potassium feldspar, and 9 percent total clay. The primary clay minerals are kaolinite and illite. Calcite and dolomite were not detected in the samples. Additional mineralogy data from within the AoR will be collected during the pre-operational period as discussed in **Attachment I**.

2.4.1.6 Claimed as PBI [redacted]

No mineralogy data are available for Claimed as PBI [redacted] Therefore, data from Claimed as PBI [redacted] used as an analog. This mineralogic composition is described in Section 2.4.1.5. Additional mineralogy data from within the AoR will be collected during the pre-operational period as discussed in **Attachment I**.

2.4.2 Porosity and Permeability

Wireline log data were acquired with measurements that include but are not limited to spontaneous potential, natural gamma ray, borehole caliper, compressional sonic, resistivity, neutron porosity, and bulk density.

Formation porosity is determined one of two ways: from bulk density using 2.65 grams per cubic centimeter (g/cc) matrix density as calibrated from core grain density and core porosity data, or from compressional sonic using 55.5 microseconds per foot (µsec/ft) matrix slowness and the Wyllie time average equation. The compaction coefficient (Hilchie, 1978) was calculated using a depth dependent shale travel time.

Volume of clay is determined by spontaneous potential and is calibrated to core data.

Log-derived permeability is determined by applying a core-based transform that uses capillary pressure porosity and permeability along with clay values from XRD or FTIR. Core data from Claimed as PBI [redacted] were used to develop a permeability transform (**Figure 2.4-2**). The transform and core data is illustrated in **Figure 2.4-3.**

Comparison of log calculated porosity and the permeability transform to core permeability is shown in **Figure 2.4-4** Claimed as PBI [redacted] This well, while outside the AoR, has abundant core data across two of the main Injection Zones for comparison to the permeability transform. Both core porosity and permeability are matched well by the log calculated curves.

A log plot for Claimed as PBI [redacted] is included in **Figure 2.4-5**, showing the calculated model curves directly adjacent to the AoR.

2.4.2.1 Monitoring Zone

The average porosity of the Monitoring Zone is 32.1 percent, based on 39 wells with porosity logs and 10,424 individual logging data points. See **Figure 2.4-6** for the locations of wells used for porosity and permeability averaging. The geometric average permeability of the Monitoring Zone is 77 mD, based on 30 core data points from 3 wells (see **Figure 2.2-2(b)** for well locations). Core porosity was measured, and is in agreement with the log averages (see **Table 2.4-2**).

2.4.2.2 Confining Zone

The average porosity of the confining zone is 26.3 percent, based on 92 wells with porosity logs and 70,165 individual logging data points. The geometric average permeability of the confining zone is 1.62 nanodarcies (nD), based on core permeability measurements performed on 32 samples from Claimed as PBI [redacted] These samples were analyzed using the Gas Research Institute (GRI) crushed rock method, and the permeability reported is representative of the matrix permeability.

2.4.2.3 Claimed as PBI [redacted]

The average porosity of Claimed as PBI [redacted] is 30.6 percent, based on 90 wells with porosity logs and 70,766 individual logging data points. The geometric average permeability of Claimed as PBI [redacted] is 145 mD, based on 82 wells with porosity logs and 61,507 individual logging data points. A total of 11 core data points from 3 wells are from the

Claimed as PBI (see **Table 2.4-4**). The porosity and permeability measurements from core were used to calibrate log permeability and porosity.

2.4.2.4 Claimed as PBI

The average porosity of the Claimed as PBI is 29.4 percent, based on 80 wells with porosity logs and 55,954 individual logging data points. The geometric average permeability of the Claimed as PBI is 106 mD, based on 74 wells with porosity logs and 50,926 individual logging data points. A total of 42 core data points from 5 wells are from Claimed as PBI (see **Table 2.4-5)**. The porosity and permeability measurements from core were used to calibrate log permeability and porosity.

2.4.2.5 Claimed as PBI

The average porosity of Claimed as PBI is 26.4 percent, based on 86 wells with porosity logs and 59,117 individual logging data points. The geometric average permeability of the Claimed as PBI is 85 mD, based on 89 wells with porosity logs and 57,705 individual logging data points. A total of 375 core data points from 14 wells are from Claimed as PBI (see **Table 2.4-6**). The porosity and permeability measurements from core were used to calibrate log permeability and porosity.

2.4.2.6 Claimed as PBI

The average porosity of the Claimed as PBI is 22.7 percent, based on 34 wells with porosity logs and 24,170 individual logging data points. The geometric average permeability of the Claimed as PBI is 23 mD, based on 34 wells with porosity logs and 22,462 individual logging data points. A total of 181 core data points from the 7 wells are from the Claimed as PBI (see **Table 2.4-7**). The porosity and permeability measurements from core were used to calibrate log permeability and porosity.

2.4.3 Injection and Confining Zone Capillary Pressure

Capillary pressure is the difference across the interface of two immiscible fluids. Capillary entry pressure is the minimum pressure required for an injected phase to overcome capillary and interfacial forces and enter the pore space containing the wetting phase.

No capillary pressure data were available for the Confining Zone or any of the Injection Zones. These data will be acquired as part of pre-operational testing.

For computational modeling purposes, capillary pressure data obtained from the similar geologic age and setting Claimed as PBI and zone-specific data can be obtained as part of the pre-operational testing program (see **Figure 2.4-2** for well location). **Figure 2.4-7** shows the capillary pressure curve used for the computational modeling. In addition, sensitivity cases were run to gauge the effect of varying the capillary pressure curve on the CO_2 plume and reservoir pressure behavior and the effect was minimal (Attachment B).

Caprock threshold entry pressure tests were available for two of the internal shales, [redacted] A total of 12 samples from 2 wells [redacted] were tested; 5 of the samples showed no brine production at the highest delta pressure of 2,000 pounds per square inch (psi), 1 sample showed brine breakthrough at the last pressure tested of 2,000 psi, 1 sample showed brine breakthrough at 800 psi, 4 samples showed brine breakthrough at 600 psi, and 1 sample showed brine breakthrough at 400 psi. A comparison of measured air permeability on these samples versus threshold entry pressure is shown in **Figure 2.4-8**. Any sample with air permeability less than 0.1 mD showed no brine breakthrough even at the highest measured delta pressure of 2,000 psi. Because measured permeability on core samples from the Confining Zone are much lower than 0.1 mD (see Section 2.4.2), it can be assumed that the Confining Zone is an impermeable seal at reservoir conditions.

2.4.4 Depth and Thickness

Depth and thickness of the Confining Zone and Injection Zone (**Table 2.4-8**) are determined by structural and isopach maps based on well data (wireline logs) and seismic data. Structure maps of the Injection and Confining Zone, presented in **Figures 2.4-9(a)** through **2.4-9(d)** are provided to indicate a depth to formation adequate for supercritical-state injection.

Isopach maps of the Injection and Confining Zones are also presented in **Figures 2.4-9(a)** through **2.4-9(d)**. Spontaneous potential (SP) logs from surrounding [redacted] wells were used to identify sandstones. Negative millivolt (mV) deflections on these logs, relative to a baseline response in the enclosing shales, define the sandstones. These logs were shale baseline-shifted to 0 mV. Due to the log vintage variability, there is an effect on quality which creates a degree of subjectivity within the gross sand; however, this will not have a material impact on the maps.

Variability in the thickness and depth of the Confining Zone and the Injection Zone will not impact confinement. CTV will use the thicknesses and depths shown when determining operating parameters and assessing project geomechanics.

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

2.5.1 Caprock Ductility

Ductility and the unconfined compressive strength (*UCS*) of shale are two properties used to describe geomechanical behavior. Ductility refers to how much a rock can be distorted before it fractures, while the *UCS* is a reference to the resistance of a rock to distortion or fracture. Ductility generally decreases as compressive strength increases (IEAGHG, 2011).

Ductility and rock strength calculations were performed based on the methodology and equations from Ingram & Urai (1999) and Ingram et al. (1997). Brittleness is determined by comparing the log-derived *UCS* to an empirically derived *UCS* for a normally consolidated rock (UCS_{NC}).

$$\log UCS = -6.36 + 2.45\log(0.86V_p - 1172) \quad (1)$$

$$\sigma' = OB_{pres} - P_p \quad (2)$$

$$UCS_{NC} = 0.5\sigma' \quad (3)$$

$$BRI = \frac{UCS}{UCS_{NC}} \quad (4)$$

Units for the *UCS* equation are *UCS* in megapascals (MPa) and V_p (compressional velocity) in meters per second (m/s). OB_{pres} is overburden pressure, P_p is pore pressure, σ' is effective overburden stress, and *BRI* is brittleness index.

If the value of *BRI* is less than 2, empirical observation shows that the risk of embrittlement is lessened, and the confining zone is sufficiently ductile to accommodate large amounts of strain without undergoing brittle failure. However, if *BRI* is greater than 2, the "risk of development of an open fracture network cutting the whole seal depends on more factors than local seal strength, and therefore the *BRI* criterion is likely to be conservative, so that a seal classified as brittle may still retain hydrocarbons" (Ingram & Urai, 1999).

2.5.1.1 Confining Zone

Within the project area, 40 wells had compressional sonic and bulk density data over the confining zone to calculate ductility, comprising 31,800 individual logging data points (pink squares in **Figure 2.2-2(a)**). In addition, 87 wells were used to calculate *UCS*, comprising 67,692 individual logging data points. The average ductility of the confining zone based on the mean value is 0.95. The average rock strength of the confining zone, as determined by the log-derived *UCS* equation above, is 882 psi.

An example calculation for the Claimed as PBI [redacted] is shown in **Figure 2.5-1**. UCS_CCS_VP is the UCS based on the compressional velocity, UCS_NC is the UCS for a normally consolidated rock, and *BRI* is the calculated brittleness using this method. Brittleness less than 2 (representing ductile rock) is shaded red.

Within the Confining Zone, the brittleness calculation drops to a value less than 2. Additionally, almost all of the shales within and between the injection zones have BRI values of less than 2. Using this methodology, all of these caprocks would be classified as "Very Good" based on Kivior et al. (2002). As a result of the Confining Zone ductility, there are no fractures that will act as conduits for fluid migration from the Injection Zone.

2.5.2 Stress Field

The stress of a rock can be expressed as three principal stresses. Formation fracturing will occur when the pore pressure exceeds the least of the stresses. In this circumstance, fractures will propagate in the direction perpendicular to the least principal stress (**Figure 2.5-2**).

Stress orientations in Claimed as PBI [redacted] have been studied using both earthquake focal mechanisms and borehole breakouts (Hickman and Zoback, 2004; Townend and Zoback, 2004; Mount and Suppe, 1987, 1992). The general azimuth of maximum principal horizontal stress is that of Claimed as PBI [redacted] (Townend and Zoback, 2004; Zoback et al., 1987). Data from the World Stress Map 2016 release (Heidbach et al., 2016, 2018) shows an average S_{Hmax} azimuth of Claimed as PBI [redacted] once several S_{Hmax} indicators with very low-quality grades (D or less) are excluded (**Figure 2.5-3**). This is consistent with

Townend and Zoback (2004) (**Figure 2.5-4**). Mount and Suppe (1987) Claimed as PBI [redacted] (Lund Snee and Zoback, 2020).

There are no site-specific fracture gradient data for the injection or confining layers. A step-rate test (SRT) will be conducted per **Attachment I** in the Injection Zones. However, several wells in the project vicinity do have fracture gradient data either in the Injection Zones or in formations of similar age and depth. An SRT was performed Claimed as PBI [redacted] with a resultant fracture gradient of 0.82 pounds per square inch per foot (psi/ft). An additional seven wells in the vicinity have formation integrity tests (FITs) or leak-off tests (LOTs) performed at similar depth ranges to the project Injection and Confining Zones. A total of 11 tests from these wells average 0.825 psi/ft from tests in the depth range of 3,000 to 12,350 feet true vertical depth (TVD). See **Figure 2.5-5** for the locations of the wells. For the computational simulation modeling and well-performance modeling, a frac gradient of 0.8 psi/ft was assumed for now for all zones as a safety factor.

The overburden stress gradient in the confining and injection zones is 0.87 to 0.94 psi/ft. The method for calculating the overburden gradient was to integrate density logs using methodology laid out in Fjaer et al. (2008):

$$\sigma_v = \int_0^D \rho(z) g \, dz \qquad (5)$$

where ρ is the density of the sediments, g is the acceleration due to gravity, D is the depth of interest, z is the vertical depth interval, and σ_v is the vertical stress. This calculation was completed using the "Overburden Gradient Calculation" module in the software Interactive Petrophysics 5.1.0. **Figure 2.5-6** displays the overburden gradient calculation inputs and outputs from the software. The overburden gradient was calculated using 53 density logs. See **Table 2.5-1** for a list of the wells used for overburden stress gradient calculations.

No data currently exist for the pore pressure of the confining zone. This will be determined as part of the preoperational testing.

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

2.6.1 Recent Seismicity

As discussed in prior sections, 2D and 3D seismic along with well data were used to create depth surfaces within the model area and AoR. Claimed as PBI [redacted]

USGS (2024) provides an earthquake catalog tool that can be used to search for recent seismicity that could be associated with faults for movement. A search was made for earthquakes in the greater vicinity of the project area from 1850 to June 17, 2024 with events of a magnitude greater than 2.5. This threshold is used to account for "felt" seismicity across the catalog time record. **Figure 2.6-1** shows the results of this search.

Claimed as PBI [redacted]

Lund-Snee and Zoback (2020) published updated maps for crustal stress estimates across North America. **Figure 2.6-2** shows a modified image from Lundstern (2020) work highlighting the project area. This work agrees with previous estimates of maximum horizontal stress in the region of approximately Claimed as PBI [redacted] (see Section 2.5-2). **Attachment C: Testing and Monitoring Plan** (**Attachment C**) discusses the seismicity monitoring plan for this injection site.

2.6.2 Seismic Hazard Mitigation

Claimed as PBI [redacted]

The following is a summary of CTVs seismic hazard mitigation for CTV VI:

The project has a geologic system capable of receiving and containing the volumes of CO_2 proposed to be injected

- Claimed as PBI [redacted]
- There are no faults or fractures identified in the AoR that will impact the confinement of CO_2 injectate. Claimed as PBI [redacted]

Will be operated and monitored in a manner that will limit risk of endangerment to USDWs, including risks associated with induced seismic events

- Injection pressure will be lower than the fracture gradient of the sequestration reservoir with a safety factor (90 percent of the fracture gradient).
- Injection and monitoring well pressure monitoring will ensure that pressures are beneath the fracture pressure of the sequestration reservoir.

- A seismic monitoring program will be designed to detect events lower than seismic events that can be felt. This will ensure that operations can be modified with early warning events, before a felt seismic event.

Will be operated and monitored in a way that in the unlikely event of an induced event, risks will be quickly addressed and mitigated

- Via monitoring and surveillance practices (pressure and seismic monitoring program), CTV personnel will be notified of events that are considered an early warning sign. Early warning signs will be addressed to ensure that more significant events do not occur.
- CTV will establish a central control center to ensure that personnel have access to the continuous data being acquired during operations.

Minimizing potential for induced seismicity and separating any events from natural to induced

- Pressure will be monitored in each injector and sequestration monitoring well to ensure that pressure does not exceed the fracture pressure of the reservoir or Confining Zone.
- Seismic monitoring program will be installed pre-injection for a period to monitor for any baseline seismicity that is not being resolved by current monitoring programs.
- Average depth of prior seismic hazard in the region based on reviewed historical seismicity has been approximately 5.2 km. Significantly deeper than the proposed Injection Zones.

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

DWR has defined 515 groundwater basins and subbasins within California. Claimed as PBI [redacted]

Claimed as PBI [redacted]

2.7.1 Hydrologic Information

Claimed as PBI [redacted]

Claimed as PBI [redacted]

[redacted]

2.7.2 Base of Fresh Water and Base of USDWs

The owner or operator of a proposed Class VI injection must define the general vertical and lateral limits of all USDWs and their positions relative to the Injection and Confining Zones. The intent of this information is to demonstrate the relationship between the proposed injection formation and any USDWs, and it will support an understanding of the water resources near the proposed injection well. A USDW is defined as an aquifer or its portion that (a) (1) supplies any public water system or (2) contains a sufficient quantity of groundwater to supply a public water system and (i) currently supplies drinking water for human consumption or (ii) contains less than 10,000 milligrams per liter (mg/L) total dissolved solids (TDS) and (b) which is not an exempted aquifer. For the purpose of the California Sustainable Groundwater Management Act (SGMA), the bottom of the groundwater basin is defined as the base of fresh groundwater (BFW), which is approximately 2,000 to 3,000 mg/L TDS (Luhdorff & Scalmanini, 2022).

2.7.2.1 Base of Fresh Water

BFW helps define the aquifers that are used for public water supply and is by definition shallower than the base of the lowermost USDW. Local water agencies in the subbasins have participated in various studies to comply with SGMA. There is a significant thickness of sedimentary strata overlying basement bedrock. Therefore, it is appropriate to consider water quality when delineating the basin bottom.

USGS mapped the BFW based on measured specific conductance of less than 3,000 micromhos per centimeter (µmhos/cm), which is approximately 2,000 mg/L TDS (Page, 1971 and 1973). A similar dataset was presented by Kang (2020). Claimed as PBI [redacted]

2.7.2.2 Base of Lowermost USDW

Claimed as PBI [redacted]

Claimed as PBI [redacted]

The calculation of salinity from logs used by CRC is a four-step process:

1. Convert measured density or sonic to formation porosity, using the following equation:

$$POR = \frac{(Rhom - RHOB)}{(Rhom - Rhof)} \tag{6}$$

where POR = formation porosity
Rhom = formation matrix density, g/cc; 2.65 g/cc is used for sandstones
RHOB = calibrated bulk density taken from well log measurements (g/cc)
Rhof = fluid density (g/cc); 1.00 g/cc is used for water-filled porosity

The equation to convert measured sonic slowness to porosity is:

$$POR = -1\left(\frac{\Delta tma}{2\Delta tf} - 1\right) - \sqrt{\left(\frac{\Delta tma}{2\Delta tf} - 1\right)^2 + \frac{\Delta tma}{\Delta tlog} - 1} \tag{7}$$

where POR = formation porosity
Δtma = formation matrix slowness (µs/ft); 55.5 µs/ft is used for sandstones
Δtf = fluid slowness (µs/ft); 189 µs/ft is used for water-filled porosity
Δtlog = formation compressional slowness from well log measurements (µs/ft)

2. Calculate apparent water resistivity using the Archie equation:

$$Rwah = \frac{POR^m R_t}{a} \tag{8}$$

where Rwah = apparent water resistivity (ohm-m)
POR = formation porosity
m = the cementation factor; 2 is the standard value
R_t = deep reading resistivity taken from well log measurements (ohm-m)
a = the archie constant; 1 is the standard value

3. Correct apparent water resistivity to a standard temperature of 75°F:

$$Rwahc = Rwah\frac{TEMP + 6.77}{75 + 6.77} \tag{9}$$

where Rwahc = apparent water resistivity (ohm-m), corrected to surface temperature
TEMP = downhole temperature based on temperature gradient (°F)

4. Convert temperature-corrected apparent water resistivity to salinity (Davis 1988):

$$SAL\_a\_EPA = \frac{5500}{Rwahc} \tag{10}$$

where SAL_a_EPA = salinity from corrected Rwahc (parts per million [ppm])

2.7.3 Formations with USDWs

Claimed as PBI [redacted]

2.7.3.1 Shallow Alluvium

Groundwater encountered in the upper most part of the shallow aquifer, above the highest regionally extensive lacustrine clay layer where present, is locally named the “shallow zone,” and is defined by wells that are screened generally within the first 100 feet from ground surface. This area is not considered a principal aquifer or hydrologically connected to a principal aquifer. Groundwater in this zone is often degraded and locally may not meet USDW criteria (Kang, 2020).

2.7.3.2 Claimed as PBI [redacted] (Upper)

The terrestrial alluvial deposits overlying the uppermost Claimed as PBI [redacted]

Claimed as PBI [redacted]

2.7.3.3 Claimed as PBI [redacted]

The fine-grained Claimed as PBI [redacted]

2.7.3.4 [redacted] *(lower)*

[redacted] The basal deposits of the Lower Aquifer overlie and may interfinger with the uppermost [redacted]

2.7.3.5 [redacted]

The [redacted] records [redacted]

2.7.3.6 [redacted]

[redacted]

2.7.3.7 [redacted]

[redacted] potentially hosting an USDW in the project area, based on salinity logs of regional well bores. [redacted]

[redacted]

2.7.4 Geologic Cross Sections Illustrating Formations with USDWs

[redacted]

Claimed as PBI [redacted] The hydrogeological conceptual model for the site is depicted in **Figure 2.7-5,** and provides a clear illustration of the structure of the principal aquifer units, but does not provide a detailed stratigraphy or information regarding USDWs below the Lower Aquifer.

CTV has prepared a geologic cross section based on boreholes with wire-line geophysical logs within the project AoR. This cross section is provided in **Figure 2.7-6**. Features of the cross section include the following:

- The base of the Claimed as PBI [redacted] shown on Cross Section A-A' of Miller et al. (1971).
- Shallower units such as Claimed as PBI [redacted] are not depicted on the wireline logs.
- Log interpretation suggests Claimed as PBI [redacted]
- The top of Claimed as PBI [redacted] the lowest stratigraphic unit to potentially host a USDW.

The BFW in the project vicinity is roughly Claimed as PBI [redacted] and is also not depicted on the logs. Claimed as PBI [redacted]

2.7.5 Principal Aquifers

In the SGMA regulations, principal aquifers are defined as aquifers or aquifer systems that store, transmit, and yield significant or economic quantities of groundwater to wells, springs, or surface water systems. Claimed as PBI [redacted]

Claimed as PBI [redacted]

2.7.6 Groundwater Levels and Flow

Claimed as PBI [redacted]

Groundwater level data were obtained from several sources including Claimed as PBI [redacted]

2.7.6.1 Claimed as PBI [redacted]

Although considerable local variability is observed, many of the wells for which data are available displayed increasing groundwater levels prior to the early 2000s, followed by stable water levels in some wells after 2000. Data suggest that although temporal trends in groundwater levels tend to be similar at various depths within Claimed as PBI [redacted] pressure head variations can exist within Claimed as PBI [redacted] due to well construction details (i.e., screened intervals), local influences from groundwater pumping, and geological variability such as local confining layers or vertical head gradients. Recent groundwater level data (2008-2018) indicate a variable decline in groundwater elevation across the Subbasin, indicative of an extended period of drought coupled with temporary increases in groundwater pumping. This trend is most evident in deeper wells within Claimed as PBI [redacted]

A general trend of decreasing water levels toward Claimed as PBI [redacted] Although data in the project vicinity are sparse, Claimed as PBI [redacted]

2.7.6.2 Claimed as PBI [redacted]

Historically low groundwater levels within Claimed as PBI [redacted] occurred in the 1950s and 1960s, with a dramatic rise of water levels after completion of the Central Valley Project and delivery of surface water began in 1968. Groundwater levels remained relatively stable during the 1980s though early 2000s. Since 2010, however, groundwater levels in Claimed as PBI [redacted] declined significantly, with some wells Claimed as PBI [redacted] Water levels have continued to vary with seasonal and climatic conditions. Although the decline in groundwater elevations has been dramatic, note that this represents potentiometric surface changes in a confined aquifer, which may not be equivalent to elevation changes in an unconfined system in terms of change in aquifer storage.

Generally, groundwater elevation contours from 2015 show the lowest groundwater elevations along a north-south axis in the central portion of the Westside Subbasin, with the lowest groundwater levels at around 160 feet below sea level. Groundwater levels typically increase toward the western and eastern boundaries of the Westside Subbasin. Winter/spring contours of groundwater elevations from 2006/2007 and 2014/2015 indicate that groundwater in [redacted] flows eastward out of the subbasin during wet years and into the subbasin during extended drought periods. During the periods for which data are presented in Luhdorff & Scalmanini (2022), the groundwater flow direction in [redacted] in the project vicinity is generally southward. Although data in the project vicinity are sparse, [redacted]

2.7.7 Water Supply and Groundwater Monitoring Wells

The California State Water Resources Control Board GAMA, DWR, California Statewide Groundwater Elevation Monitoring (CASGEM), and other public databases were searched to identify any water supply and groundwater monitoring wells within the AoR. DWR's Water Data Library reports groundwater data collected from a variety of well types including irrigation, stock, domestic, and public supply wells. The State Water Board's GAMA Program was established in 2000 to create a comprehensive groundwater monitoring program throughout California and increase public availability and access to groundwater quality and contamination information (State Water Board, 2018).

A total of 136 wells were identified from DWR and GAMA databases within the AoR (**Figure 2.2-6** and **Table 2.2-1**); however, many of these are dedicated monitoring wells. A total of 29 known water supply wells were identified within the AoR. Data provided from public databases indicate that the wells identified are completed much shallower than the proposed injection zone.

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

2.8.1 Formation Geochemistry

All formation geochemistry information is presented in the mineralogy section (Section 2.4.1). However, almost all of the injection zones are lacking quantitative mineralogy data. For this reason, analogous data were used for the mineralogic inputs for the geochemical modeling as explained in Section 2.4.1.

2.8.2 Fluid Geochemistry

No water samples from the storage zones exist within the AoR, so samples from surrounding oil and gas fields in close proximity to the AoR have been used (see **Figure 2.8-1** for well locations).

2.8.2.1 Monitoring Zone

For the Monitoring Zone, a water sample was available from the nearby [redacted] The measurement of TDS for the sample is 41,835 mg/L. The complete water chemistry is shown in **Figure 2.8-2**.

2.8.2.2 Confining Zone

For the Confining Zone, a water sample was available from the nearby Claimed as PBI [redacted] The measurement of TDS for the sample is 31,200 mg/L. The complete water chemistry is shown in **Figure 2.8-3**.

2.8.2.3 Claimed as PBI [redacted]

No complete water chemistry for Claimed as PBI [redacted] was found. However, a partial analysis was available from Claimed as PBI [redacted] (**Figure 2.8-4**). The chloride content of this water (13,116 mg/L) is very similar to the chloride content of Claimed as PBI [redacted] was assumed to be analogous, with an assumed TDS of 20,700 mg/L, which is within the range for Claimed as PBI [redacted] based on data presented in Sullivan (1971).

2.8.2.4 Claimed as PBI [redacted]

No water samples were found for Claimed as PBI [redacted] For this reason, the water chemistry from the Claimed as PBI [redacted] was assumed to be analogous.

2.8.2.5 Claimed as PBI [redacted]

For the Claimed as PBI [redacted] a water sample was available from the nearby Claimed as PBI [redacted] The measurement of TDS for the sample is 20,700 mg/L. The complete water chemistry is shown in **Figure 2.8-5**.

2.8.2.6 Claimed as PBI [redacted]

For the Claimed as PBI [redacted] a water sample was available from the nearby Claimed as PBI [redacted] The measurement of TDS for the sample is 21,100 mg/L. The complete water chemistry is shown in **Figure 2.8-6**.

2.8.2.7 Geochemical Modeling

Using fluid geochemistry data for the Injection Zones and the available mineralogy data for the Injection Zones and Confining Zone, geochemical modeling was conducted using PHREEQC (ph-REdox-Equilibrium), the USGS geochemical modeling software, to evaluate the compatibility with formation rocks and fluid of the injectates being considered for the project.

The PHREEQC software was used to evaluate the behavior of minerals and changes in aqueous chemistry and mineralogy over the life of the project, and to identify major potential fluid/rock reactions that may affect injection or containment.

Based on the geochemical modeling, the injection of CO_2 at the CTV VI site does not cause significant reactions that will affect injection or containment. Detailed methodology and results are presented in **Appendix 3**.

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

No additional information necessary.

2.10 Site Suitability [40 CFR 146.83]

Sufficient data from both wells and seismic demonstrate the integrity through lateral continuity of the storage reservoirs as well as the Confining Zone. [redacted] Corrosion-resistant alloy (CRA) will be used for completion of the injection and monitoring wells, inhibiting any reaction between CO_2 and wellbores.

The [redacted] (Confining Zone) is regionally continuous, thick, and has low permeability, providing confinement for CO_2 storage and safely separating the Injection Zone from the Monitoring Zone and overlying USDWs.

CTV's estimated storage for the project is [redacted] MMT of CO_2. This mass was determined using the computational modeling presented in **Attachment B**. As discussed in **Attachment B,** a dynamic model was generated for the target Injection Zones with data from:

- The static model (structure, porosity, absolute permeability, net to gross ratio, facies)
- Special core analysis (relative permeability and capillary pressure)
- Pressure, volume, temperature (PVT) analysis (fluid PVT)
- Geochemical analysis (water salinity)

Injection well locations are based on geologic interpretation, petrophysical properties, and economic optimization. Injection rates were analyzed with flexibility to handle offset well failure during the project period. Injection wells were also designed with a maximum allowable injection pressure limit.

3. AoR and Corrective Action

Pursuant to 40 CFR 146.82(a)(4), 40 CFR 146.82(a)(13) and 146.84(b), and 40 CFR 146.84(c), **Attachment B** describes the process, software, and results to establish the AoR, and the wells that require corrective action.

AoR and Corrective Action GSDT Submissions
GSDT Module: AoR and Corrective Action ***Tab(s):*** All applicable tabs Please use the checkbox(es) to verify the following information was submitted to the GSDT: ☒ Tabulation of all wells within AoR that penetrate confining zone ***[40 CFR 146.82(a)(4)]*** ☒ AoR and Corrective Action Plan ***[40 CFR 146.82(a)(13) and 146.84(b)]***

☒ Computational modeling details ***[40 CFR 146.84(c)]***

4. Financial Responsibility

CTV's Financial Responsibility demonstration pursuant to 140 CFR 146.82(a)(14) and 40 CFR 146.85 (**Attachment H**) is met with a line of credit for Injection Well Plugging and Post-Injection Site Care and Site Closure and insurance to cover Emergency and Remedial Responses.

Financial Responsibility GSDT Submissions
GSDT Module: Financial Responsibility Demonstration ***Tab(s):*** Cost Estimate tab and all applicable financial instrument tabs Please use the checkbox(es) to verify the following information was submitted to the GSDT: ☒ Demonstration of financial responsibility ***[40 CFR 146.82(a)(14) and 146.85]***

5. Injection and Monitoring Well Construction

Appendix 5: Injection and Monitoring Well Schematics (Appendix 5) provides casing diagram figures for all injection and monitoring wells with construction specifications and anticipated completion details in graphical and/or tabular format.

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

There are no proposed stimulation programs currently.

5.2 Construction Procedures [40 CFR 146.82(a)(12)]

CTV has created Construction and Plugging documents for each project well pursuant to 40 CFR 146.82(a)(8). Each well-specific plan within **Attachment G: Well Construction and Plugging Plan (Attachment G)** document includes well construction information based on requirements defined within 40 CFR 146.82.

6. Pre-Operational Logging and Testing

CTV has indicated a proposed pre-operational logging and testing plan throughout the application documentation pursuant to 40 CFR 146.82(a)(8). Each **Attachment G** document (listed in Section 5.2) includes logging and testing plans for each individual project well based on requirements defined within 40 CFR 146.87. **Attachment I** summarizes pre-operational testing.

Pre-Operational Logging and Testing GSDT Submissions
GSDT Module: Pre-Operational Testing ***Tab(s):*** Welcome tab Please use the checkbox(es) to verify the following information was submitted to the GSDT: ☒ Proposed pre-operational testing program ***[40 CFR 146.82(a)(8) and 146.87]***

7. Well Operation

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

The Operational Procedures for all injectors associated with the project are detailed in **Appendix 4: Operational Procedures**.

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

CTV is planning to construct a carbon capture and sequestration "hub" project (i.e., a project that collects CO_2 from multiple sources over time. Therefore, CTV is currently considering multiple sources of anthropogenic CO_2 for the project. Potential sources include capture from existing and potential future industrial sources in the San Joaquin Basin area, as well as DAC. CTV would expect the CO_2 stream to be sampled at the transfer point from the source and between the final compression stage and the wellhead. Samples will be analyzed according to the analytical methods described in the Table 4 of **Appendix 10: QASP** (**Appendix 10**) and Table C-1 of **Attachment C**.

For the purposes of geochemical modeling, CO_2 plume modeling, AoR determination, and well design, two major types of injectate compositions were considered based on the source:

- Injectate 1: A potential injectate stream composition from DAC or a pre-combustion source (such as a blue hydrogen facility that produces hydrogen using steam methane reforming process) or a post-combustion source (such as a natural gas fired power plant or steam generator). The primary impurity in the injectate is nitrogen.
- Injectate 2: A potential injectate stream composition from a biofuel capture source (such as a biodiesel plant that produces biodiesel from a biologic source feedstock) or from an oil and gas refinery. The primary impurity in the injectate is light-end hydrocarbons (methane and ethane).

The compositions for these two injectates are shown in **Table 7.2-1** and are based on engineering design studies and literature.

For geochemical and plume modeling scenarios, these injectate compositions were simplified to a four-component system, shown in **Table 7.2-2**, and then normalized for use in the modeling. The four-component simplified compositions cover 99.9 percent by mass of Injectates 1 and 2 and cover particular impurities of concern (H_2S and SO_2). The estimated properties of the injectates at downhole conditions are specified in **Table 7.2-3**.

The anticipated injection temperature at the wellhead is 90 to 130°F.

No corrosion is expected in the absence of free-phase water provided that the entrained water is kept in solution with the CO_2. This is ensured by maintaining a Claimed as PBI [redacted] injectate specification limit, and this specification will be a condition of custody transfer at the capture facility. For transport through pipelines, which typically use standard alloy pipeline materials, this specification is critical to the mechanical integrity of the pipeline network, and out-of-specification product will be immediately rejected. Therefore, all product transported through pipeline to the injection wellhead is expected to be dry-phase CO_2 with no free-phase water present.

Injectate water solubility will vary with depth and time as temperature and pressures change. The water specification is conservative to ensure water solubility across supercritical operating ranges. CRA tubing will be used in the injection wells to mitigate any potential corrosion impact should free-phase water from the reservoir become present in the wellbore, such as during shut-in events when formation liquids, if present, could backflow into the wellbore. CTV may further optimize the maximum water content specification prior to injection based on technical analysis.

8. Testing and Monitoring

CTV's Testing and Monitoring Plan (**Attachment C**) pursuant to 40 CFR 146.82 (a) (15) and 40 CFR 146.90 describes the strategies for testing and monitoring to ensure protection of the USDW, injection well mechanical integrity, and plume monitoring.

Testing and Monitoring GSDT Submissions
GSDT Module: Project Plan Submissions ***Tab(s):*** Testing and Monitoring tab Please use the checkbox(es) to verify the following information was submitted to the GSDT: ☒ Testing and Monitoring Plan **[40 CFR 146.82(a)(15) and 146.90]**

9. Injection Well Plugging

CTV's Injection Well Plugging Plan pursuant to 40 CFR 146.92 (**Attachment D and Attachment G**) describes the process, materials and methodology for injection well plugging.

Injection Well Plugging GSDT Submissions
GSDT Module: Project Plan Submissions ***Tab(s):*** Injection Well Plugging tab Please use the checkbox(es) to verify the following information was submitted to the GSDT: ☒ Injection Well Plugging Plan **[40 CFR 146.82(a)(16) and 146.92(b)]**

10. Post-Injection Site Care (PISC) and Site Closure

CTV has developed **Attachment E: Post-Injection Site Care and Site Closure Plan (Attachment E)** pursuant to 40 CFR 146.93 (a) to define post-injection testing and monitoring.

CTV is proposing an alternative PISC time frame as described in **Attachment E**.

PISC and Site Closure GSDT Submissions
GSDT Module: Project Plan Submissions ***Tab(s):*** PISC and Site Closure tab Please use the checkbox(es) to verify the following information was submitted to the GSDT: ☒ PISC and Site Closure Plan **[40 CFR 146.82(a)(17) and 146.93(a)]**
GSDT Module: Alternative PISC Timeframe Demonstration ***Tab(s):*** All tabs (only if an alternative PISC timeframe is requested) Please use the checkbox(es) to verify the following information was submitted to the GSDT: ☒ Alternative PISC timeframe demonstration ***[40 CFR 146.82(a)(18) and 146.93(c)]***

11. Emergency and Remedial Response

Pursuant to 40 CFR 164.94, **Attachment F: Emergency and Remedial Response Plan** (**Attachment F**) describes the process and response to emergencies to ensure USDW protection.

Emergency and Remedial Response GSDT Submissions
GSDT Module: Project Plan Submissions ***Tab(s):*** Emergency and Remedial Response tab Please use the checkbox(es) to verify the following information was submitted to the GSDT: ☒ Emergency and Remedial Response Plan ***[40 CFR 146.82(a)(19) and 146.94(a)]***

12. Injection Depth Waiver and Aquifer Exemption Expansion

No depth waiver or aquifer exemption expansion is being requested as part of this application.

Injection Depth Waiver and Aquifer Exemption Expansion GSDT Submissions
GSDT Module: Injection Depth Waivers and Aquifer Exemption Expansions ***Tab(s):*** All applicable tabs Please use the checkbox(es) to verify the following information was submitted to the GSDT: ☐ Injection Depth Waiver supplemental report ***[40 CFR 146.82(d) and 146.95(a)]*** ☐ Aquifer exemption expansion request and data ***[40 CFR 146.4(d) and 144.7(d)]***

13. References

Claimed as PBI [redacted]

[redacted]

Claimed as PBI

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

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[redacted]

[redacted]

Claimed as PBI

[redacted]

Claimed as PBI [redacted]

Figures

Claimed as PBI

[redacted]

Figure 1-1. Location map of the project AoR in relation to the San Joaquin Basin. In the leftmost figure, city locations are labeled in red text. The city of Bakersfield is abbreviated with the letter B. Oil and Gas field locations are abbreviated in black text and are as follows: C, Coalinga; E, Edison; EH, Elk Hills; H, Harvester; KND, Kettleman North Dome; LH, Lost Hills; MS, Midway Sunset; MV, Mountain View; P, Paloma; SB, South Belridge; SJNW, San Joaquin Northwest; T, Trico; TNW, Trico Northwest; V, Vallecitos; Figure modified from (Scheirer, 2008).

Claimed as PBI

[redacted]

Figure 2.1-1. Surface Geologic Map of the San Joaquin Basin, California, showing the AoR. Figure modified from (Scheirer, 2008).

Claimed as PBI

[redacted]

Figure 2.1-2. Project location map of California modified from (Scheirer, 2008) Gas field outlines are shown in red and oil field boundaries are shown in green.

Claimed as PBI

[redacted]

Figure 2.1-3. Migrational position of the Mendocino triple junction (Connection point of the Gorda, North American and Pacific plates) on the west and migrational position of Sierran Arc volcanism in the east (Graham, 1984). The figure indicates space-time relations of major continental-margin tectonic events in California during the Miocene. San Joaquin Basin figure modified from (Scheirer, 2008).

Claimed as PBI

[redacted]

Figure 2.1-4. Schematic W-E cross-section of California, highlighting the Claimed as PBI as a continental margin during late Mesozoic. The oceanic Farallon plate was forced below the west coast of the North American continental plate. San Joaquin Basin figure modified from (Scheirer, 2008).

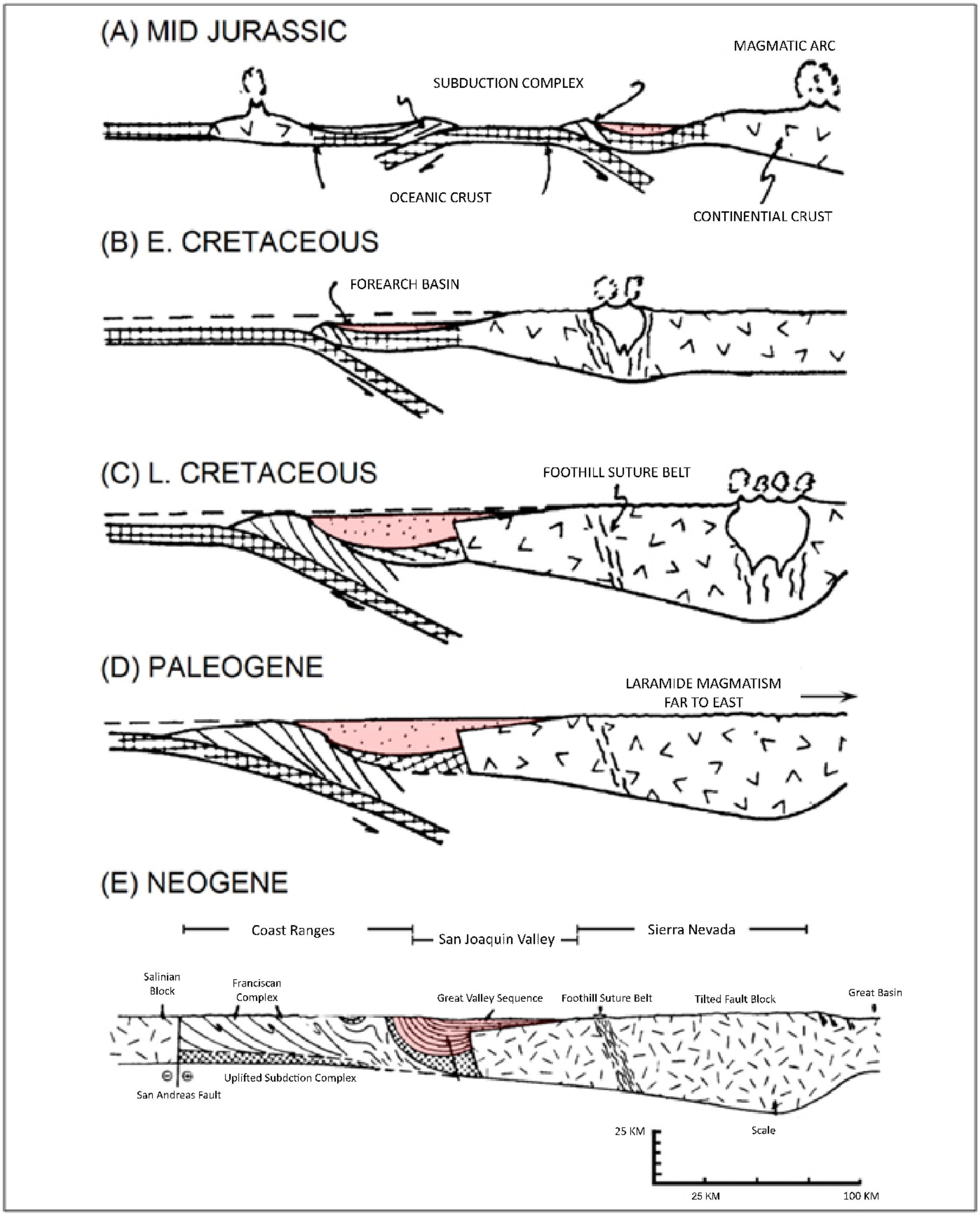

Figure 2.1-5. Evolutionary stages showing the history of the arc-trench system of California from Jurassic (A) to Neogene (E). Figure modified from (Beyer, 1988).

Claimed as PBI

Figure 2.1-6. Stratigraphic column of the Claimed as PBI (Scheirer, 2008). The stratigraphy associated with project area is outlined red.

Claimed as PBI

[redacted]

Figure 2.1-7. Detailed portion of the greater project area Stratigraphy. It also annotates the depositional age of the units. Figure modified from (Scheirer, 2008).

Claimed as PBI

Figure 2.1-8. Claimed as PBI isopach map for the greater project area. Wells shown as orange dots on the map penetrate the Claimed as PBI and have open-hole logs.

Claimed as PBI

[redacted]

Figure 2.2-1. Existing oil/gas wells and injector well locations in the AoR. There are two oil/gas wells in the AoR.

Claimed as PBI

[redacted]

Figure 2.2-2(a). Wells drilled in the project area with porosity data are shown in yellow and wells used for ductility calculation are shown in pink.

Claimed as PBI

[redacted]

Figure 2.2-2(b). Wells drilled in the project area with core.

Claimed as PBI

[redacted]

Figure 2.2-3. Summary map of seismic data used to build structural model within the model boundary. The 3D surveys were acquired between 2003 and 2007. The 2D seismic were acquired between 1979 and 1991.

Claimed as PBI

[redacted]

Figure 2.2-4. Type well showing average rock properties for the confining zones and injection zones within the project AoR.

Claimed as PBI

[redacted]

Figure 2.2-5. Cross section showing stratigraphy and lateral continuity of major formations across the AoR.

Claimed as PBI

[redacted]

Figure 2.2-6. Summary map of the AoR, oil or gas wells, water wells, State- or EPA-approved subsurface cleanup sites, and surface features in the project area. Water wells from California Division of Drinking Water (DWR) and Groundwater Ambient Monitoring and Assessment (GAMA) program. No Mines, quarries, springs or tribal lands are identified near the AoR.

Claimed as PBI

Figure 2.2-7. State- or EPA-approved subsurface cleanup sites. Source: California State Water Resources Control Board GeoTracker website.

Claimed as PBI

[redacted]

Figure 2.2-8. Locations of injection and monitoring wells

Claimed as PBI

[redacted]

Figure 2.3-1. Fault activity map from the California Geologic Survey which shows no mapped faults within the project AoR. (https://maps.conservation.ca.gov/cgs/fam/)

Claimed as PBI

[redacted]

Figure 2.3-2. Faults interpreted from seismic, well, and published data within the extended region of the model boundary.

Claimed as PBI

[redacted]

Figure 2.3-3. Schematic section from 2D seismic interpretation. Seismic surfaces are shown color matched with well picks from geophysical logs. Wells are projected in up to 3000ft into this line explaining some of the mismatch between surfaces and well picks. Claimed as PBI [redacted] The AoR boundary is delineated by the red striped vertical lines.

Claimed as PBI [redacted]

Figure 2.3-4. Schematic section from 2D seismic interpretation. Seismic surfaces are shown color matched with well picks from geophysical logs. Wells are projected in up to 900ft into this line explaining some of the mismatch between surfaces and well picks. Claimed as PBI [redacted] The AoR boundary is delineated by the red striped vertical lines.

Claimed as PBI

[redacted]

Figure 2.4-1. Map showing the location of wells with mineralogical data.

Claimed as PBI

[redacted]

Figure 2.4-2. Map showing the location of wells used in the permeability transform.

Claimed as PBI

[redacted]

Figure 2.4-3. Permeability transform for CTV VI Injection zones. Claimed as PBI [redacted] The black data points are core from a well specific to the CTV VI model area. Data shown is limited to those core data points representing sand, with a clay volume from XRD of less than 25% clay and exclude any percussion sidewall derived permeability values.

Claimed as PBI [redacted]

Figure 2.4-4. Example log from the Claimed as PBI [redacted] The last track shows a comparison of the permeability calculated from the transform (black) shown in **Figure 2.4-3** to core permeability (red dots). Track 1: Correlation and caliper logs. Track 2: Measured depth. Track 3: Zones. Track 4: Resistivity. Track 5: Compressional sonic, density, and neutron logs. Track 6: Volume of clay. Track 7: Porosity calculated from density and core porosity (red dots). Track 8: Permeability calculated using permeability transform and core permeability.

Claimed as PBI [redacted]

Figure 2.4-5. Log plot for well Claimed as PBI [redacted] showing the log curves used as inputs into calculations of clay volume, porosity and permeability, and their outputs. Track 1: Correlation and caliper logs. Track 2: Measured depth. Track 3: Zones. Track 4: Resistivity. Track 5: Compressional sonic, neutron, and density logs. Track 6: Volume of clay. Track 7: Porosity calculated from sonic (green) and density (red). Track 8: Permeability calculated using transform shown in **Figure 2.4-3.**

Claimed as PBI

[redacted]

Figure 2.4-6. Map of wells with porosity and permeability data.

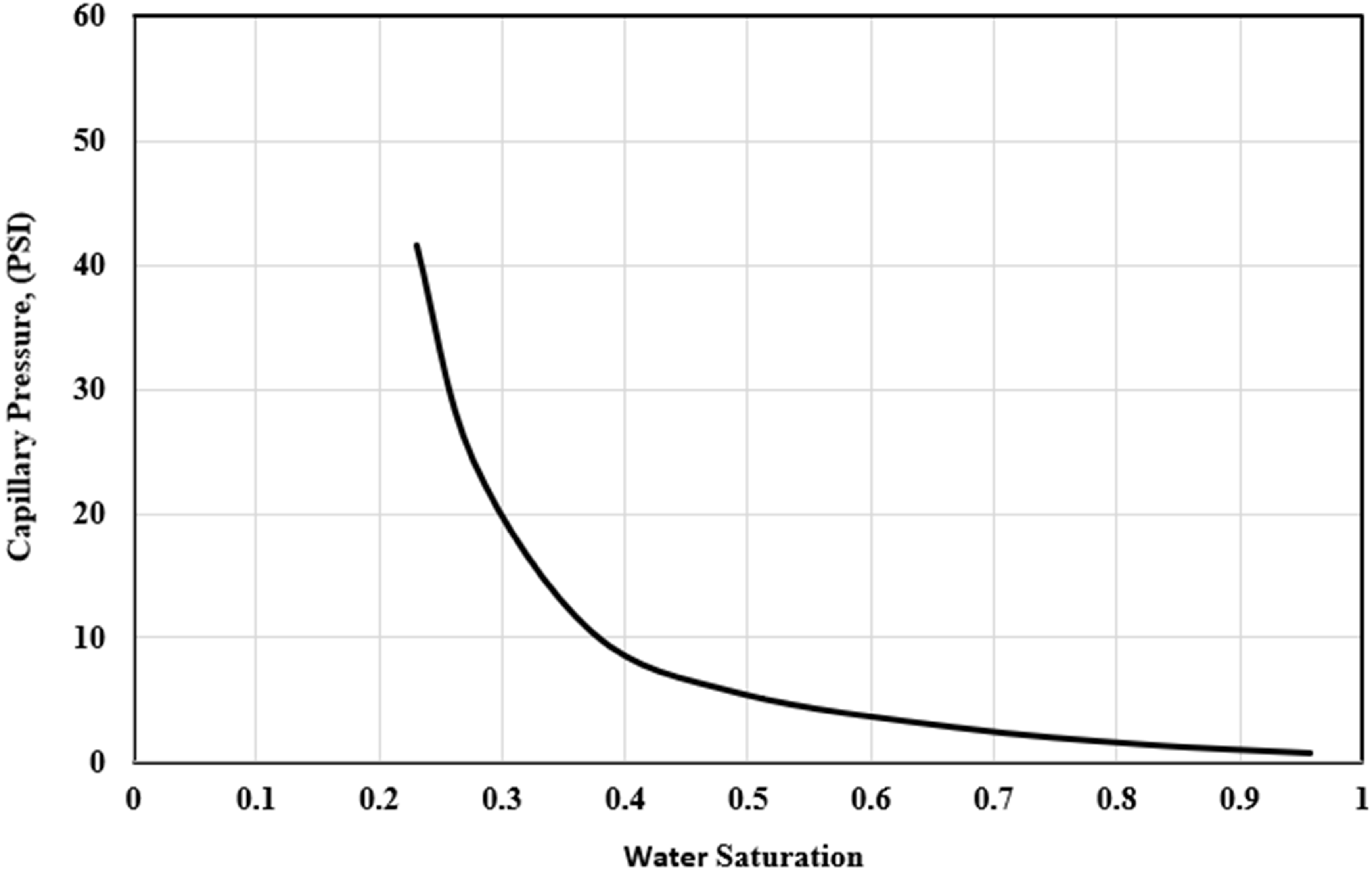

Figure 2.4-7. Injection zone capillary pressure curve used for computational modeling.

Claimed as PBI

[redacted]

Figure 2.4-8. Threshold entry pressure versus air permeability for samples from Claimed as PBI All the samples with less than 0.1 mD air permeability showed no brine breakthrough even at the maximum tested delta pressure of 2,000 psi.

Claimed as PBI

[redacted]

Figure 2.4-9(a). Thickness and structure map for the Confining Zone.

Claimed as PBI

[redacted]

Figure 2.4-9(b). Thickness and structure map for the Claimed as PBI [redacted] Injection Zone.

Claimed as PBI

[redacted]

Figure 2.4-9(c). Thickness and structure map for the Claimed as PBI [redacted] Injection Zone.

Claimed as PBI

[redacted]

Figure 2.4-9(d). Thickness and structure map for the [redacted] Injection Zone.

Claimed as PBI [redacted]

Figure 2.5-1. Unconfined compressive strength and ductility calculations for Claimed as PBI [redacted] The ductility is less than two for all of the upper confining zone as well as most of the internal shale layers. Track 1: Correlation logs. Track 2: Measured depth. Track 3: Zones. Track 4: Resistivity. Track 5: Density, neutron, and sonic logs. Track 6: Volume of clay. Track 7: Porosity calculated from density. Track 8: Permeability. Track 9: Caliper. Track 10: Overburden pressure, overburden pressure gradient, and hydrostatic pore pressure. Track 11: UCS and UCS_NC. Track 12: Brittleness.

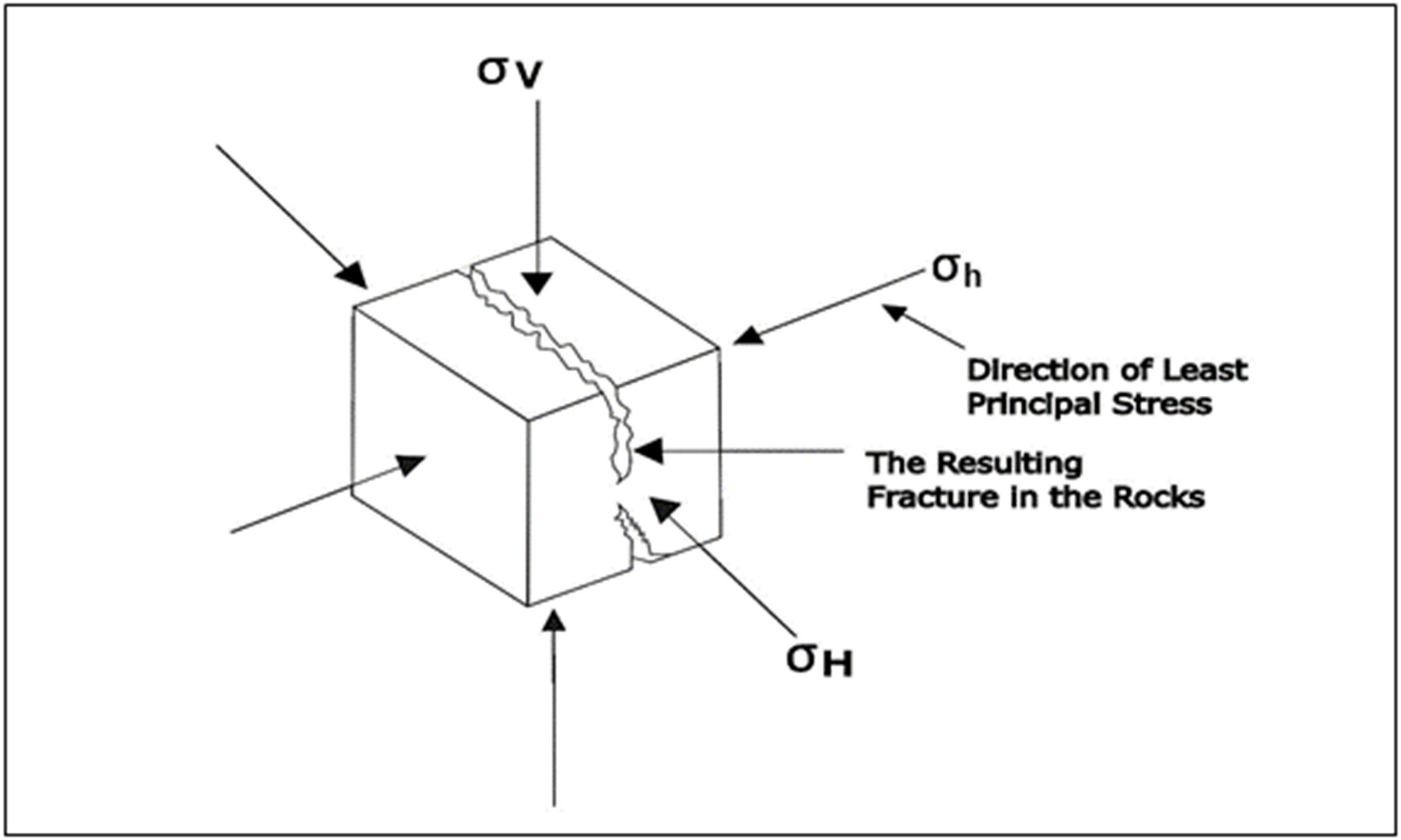

Figure 2.5-2. Stress diagram showing the three principal stresses and the fracturing that will occur perpendicular to the minimum principal stress.

Claimed as PBI

[redacted]

Figure 2.5-3. World Stress Map output showing S_{Hmax} azimuth indicators and earthquake faulting styles in the Sacramento Basin (Heidbach et al., 2016, 2018). In red is the outline of the project AoR. The background coloring represents topography.

Claimed as PBI

[redacted]

Figure 2.5-4. Figure from Townend & Zoback (2004) showing the location of the project AoR relative to major faults and stress indicators from the world stress map. The dashed lines show regional S_{Hmax} directions calculated from lithospheric buoyancy and plate interaction (Flesch et al., 2000).

Claimed as PBI

[redacted]

Figure 2.5-5. Map showing the location of wells with formation integrity tests (FIT).

Claimed as PBI [redacted]

Figure 2.5-6. Overburden gradient calculation for the Claimed as PBI [redacted]
Track 1: Correlation logs and caliper log. Track 2: Measured depth. Track 3: Vertical depth and vertical subsea depth. Track 4: Zones. Track 5: Resistivity. Track 6: Density, neutron, and compressional sonic logs. The black curve shows the merged density curve with the shallow density trend as determined from nearby shallow density logs that was used for the overburden calculation. Track 7: Overburden pressure (red) and overburden gradient (green).

Claimed as PBI

[redacted]

Figure 2.6-1. Historical earthquakes from the USGS catalog tool within the model boundary with magnitudes greater than or equal to 2.5. Events are sized by magnitude ranging from 2.5 to 4.84

Claimed as PBI

[redacted]

Figure 2.6-2. Image modified from Lundstern (2020) showing relative stress magnitudes across California.

Claimed as PBI

[redacted]

Figure 2.7-1. Map of the project AoR (black boundary) and groundwater subbasins. IRWM = Integrated Regional Water Management. Source: Luhdorff & Scalmanini, 2022.

Claimed as PBI

[redacted]

Figure 2.7-2. Map of the project AoR (black dashed boundary) and Claimed as PBI
Source: Luhdorff & Scalmanini, 2022.

Claimed as PBI

[redacted]

Figure 2.7-3. Base of fresh water map, SSTVD (Kang, 2020).

Claimed as PBI

[redacted]

Figure 2.7-4(a). Depth to lower-most USDW (base of Claimed as PBI [redacted], SSTVD

Claimed as PBI [redacted]

Figure 2.7-4(b). Thickness between the base of the lowermost USDW and the Claimed as PBI [redacted]

Claimed as PBI

[redacted]

Figure 2.7-5. Claimed as PBI [redacted] Hydrogeologic Conceptual Model. Source: Luhdorff & Scalmanini, 2022.

Claimed as PBI

[redacted]

Figure 2.7-6. Cross section of shallow stratigraphy in the project area showing formations containing USDWs.

Claimed as PBI

[redacted]

Figure 2.8-1. Map of wells with water samples

Claimed as PBI [redacted]

Figure 2.8-2. Water geochemistry for the Claimed as PBI [redacted] well.

Claimed as PBI [redacted]

Figure 2.8-3. Water geochemistry for the Claimed as PBI [redacted] well.

Claimed as PBI

Figure 2.8-4. Drilling history from the Claimed as PBI well showing the partial water geochemistry for the Claimed as PBI on February 1, 1984.

Claimed as PBI [redacted]

Figure 2.8-5. Water geochemistry for the Claimed as PBI [redacted] well.

Claimed as PBI [redacted]

Figure 2.8-6. Water geochemistry for the Claimed as PBI [redacted] well.

Tables

Table 2.2-1. Reference List of Water Supply Wells in the AoR

Claimed as PBI

[redacted]

Claimed as PBI

[redacted]

Claimed as PBI

[redacted]

Claimed as PBI

[redacted]

Table 2.2-2. Reference List of Oil and Gas Wells in the AoR

Claimed as PBI

Table 2.4-1. Formation Mineralogy from X-Ray Diffraction (XRD) in Five Wells

Claimed as PBI

[redacted]

Table 2.4-2. Core Samples from Three Wells in the Monitoring Zone

Claimed as PBI

[redacted]

Claimed as PBI

Table 2.4-3. Core Samples from Three Wells in the Confining Zone

Claimed as PBI

[redacted]

Claimed as PBI

[redacted]

Table 2.4-4. Core Samples from Three Wells in the Claimed as PBI

Claimed as PBI

Table 2.4-5. Core Samples from Five Wells in the Claimed as PBI [redacted]

Claimed as PBI

[redacted]

Claimed as PBI

[redacted]

Table 2.4-6. Core Samples from 14 Wells in the Claimed as PBI

Claimed as PBI

[redacted]

Claimed as PBI

[redacted]

Claimed as PBI

[redacted]

Claimed as PBI

[redacted]

Claimed as PBI

[redacted]

Claimed as PBI

[redacted]

Claimed as PBI

[redacted]

Claimed as PBI

[redacted]

Claimed as PBI

[redacted]

Claimed as PBI

[redacted]

Claimed as PBI

[redacted]

Claimed as PBI

[redacted]

Claimed as PBI

[redacted]

Claimed as PBI

[redacted]

Table 2.4-7. Core Samples from Seven Wells in the Claimed as PBI

Claimed as PBI

Claimed as PBI

[redacted]

Claimed as PBI

[redacted]

Claimed as PBI

[redacted]

Claimed as PBI

[redacted]

Claimed as PBI

[redacted]

Claimed as PBI

[redacted]

Table 2.4-8. Claimed as PBI Thickness and Depth within the AoR

Zone	Formation	Property	Low	High	Mean
Confining Zone	Claimed as PBI	[redacted]	[redacted]	[redacted]	[redacted]
		[redacted]	[redacted]	[redacted]	[redacted]
Injection Zone	Claimed as PBI	[redacted]	[redacted]	[redacted]	[redacted]
		[redacted]	[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
		[redacted]	[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
		[redacted]	[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
		[redacted]	[redacted]	[redacted]	[redacted]

Table 2.5-1. Wells Used for the Overburden Stress Gradient Calculation

Claimed as PBI

[redacted]

Claimed as PBI

[redacted]

Table 2.6-1. Data from USGS Earthquake Catalog for Historical Seismicity within the Model Boundary and a 7-mile Radius Around the Edge of the AoR

Claimed as PBI

[redacted]

Table A-15. Injectate Compositions

Component	Injectate 1 (Mass %)	Injectate 2 (Mass %)
CO_2	99.21%	99.88%
H_2	0.05%	0.01%
N_2	0.64%	0.00%
H_2O	0.02%	0.00%
CO	0.03%	0.00%
Ar	0.03%	0.00%
O_2	0.00%	0.00%
SO_2+SO_3	0.00%	0.00%
H_2S	0.00%	0.01%
CH_4	0.00%	0.04%
NOx	0.00%	0.00%
NH_3	0.00%	0.00%
C_2H_6	0.00%	0.05%
Ethylene	0.00%	0.00%
Total	100.00%	100.00%

Table 7.2-2. Simplified Four-Component Composition for Injectate 1 and Injectate 2

Injectate 1	
Component	Mass %
CO_2	99.213%
N_2	0.643%
SO_2+SO_3	0.003%
H_2S	0.001%

Injectate 2	
Component	Mass %
CO_2	99.884%
CH_4	0.039%
C_2H_6	0.053%
H_2S	0.014%

Table 7.2-3. Injectate Properties Range at Downhole Conditions for Injectate 1 and Injectate 2

Injectate property at downhole conditions	Injectate 1	Injectate 2
Viscosity, cp	0.05–0.06	0.05–0.06
Density, lb/ft^3	35.87–44.45	37.78–45.55
Compressibility factor, Z	0.43–0.68	0.41–0.67