REGION 9
SAN FRANCISCO, CA 94105

May 24, 2024

William Chessum
California Resources Corporation (CRC)
27200 Tourney Road, Suite 200
Santa Clarita, CA 913558

Sent via email only

Dear William Chessum:

The United States Environmental Protection Agency, Region 9 has identified information or clarification needed for continued evaluation of the site characterization for the Carbon TerraVault V project. The comments are included in an Enclosure to this letter.

Please submit the information requested in the Site Characterization Enclosure by June 24, 2024. If you have any questions about this letter and the Enclosure, please contact me at (415) 972-3971, or Kaylee Glenney at (415) 972-3944.

Sincerely,

DAVID ALBRIGHT

Digitally signed by DAVID ALBRIGHT
Date: 2024.05.24 12:29:01 -07'00'

David Albright
Manager, Groundwater Protection Section

ENCLOSURE
1. Site Characterization Evaluation

cc (via email): Faisal Latif, Carbon Terra Vault Holdings LLC
Chris Jones, CalGEM Central District
Alex Olsen, Central Valley Regional Water Control Board
Janice Zinky, CA State Water Resources Control Board

ENCLOSURE
Request for Additional Information
Site Characterization Evaluation
Carbon TerraVault V
Underground Injection Control (UIC) Permit Application
Class VI Pre-Construction Permit Application No. R9UIC-CA6-FY23-6.1 to 6

This site characterization evaluation report for the proposed CTV V Class VI Sequestration Project summarizes the geologic evaluation and data submitted by Carbon TerraVault Holdings LLC (CTV) in their permit application narrative dated September 12, 2023 (Version 2), per 40 CFR 146.82(a). This Enclosure describes and evaluates the available data on which the UIC Class VI permit application is based and identifies uncertainties that EPA recommends be addressed via the pre-operational testing that will be performed before the applicant will receive an authorization to inject CO_2. Clarifying questions and requests for CTV are provided in blue in the text below. Additional objectives for pre-operational testing to address identified data gaps are identified at the end of the evaluation text.

Project Background

CTV plans to develop the CTV V CO_2 storage site in San Joaquin County, California. CTV proposes to construct and operate three (3) CO_2 injection wells to be completed in the Mokelumne River Formation (the upper injection zone) at a depth of approximately 6,100 feet true vertical depth subsea (TVDSS) and three (3) injection wells in the Starkey Formation (lower injection zone) at 7,200 feet TVDSS. The Capay comprises the upper confining zone, and the H&T Shale represents an impermeable internal barrier between the two injection zones. CTV is proposing to inject up to 0.41 million metric tons (MMT) of CO_2 annually into the upper injection zone for a period of 25 years and 0.43 MMT annually into the lower injection zone for a period of 15 years, for a total injection volume of 16.7 MMT at the project site. At the proposed injection site, the base of the lowermost underground source of drinking water (USDW) occurs at a depth of approximately 2,200 ft TVDSS. CTV is not requesting an injection depth waiver or aquifer exemption expansion for this project.

Site Characterization

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

Data Sources

CTV utilized literature review and available 2D and 3D seismic data, core data, well logs, and reservoir performance data to characterize the proposed injection site. Core and porosity data was available from 76 wells drilled within and near the Area of Review (AoR) as shown in Figure 2.2-1[1] and tabulated in Table 2.2-1. Regional wells with log and core data are identified in Figure 2.2-2. One type log was available from the well Piacentine_1 located in the center of the AoR (Figure 2.2-3). Core samples were available for the upper and lower injection zones from the wells Citizen Green 1 (located near the

[1] All references to Figures and Tables are those contained in the UIC Permit application which are not re-created in this document, unless otherwise noted.

center of the AoR) and Whiskey Slough 1A-E (located approximately 2 miles southwest of the AoR) and are provided in Tables 2.4-3 and 2.4-4.

Figure 2.2-4 displays the available seismic data and well ties used to create CTV's structural model of the AoR. Two overlapping 3D seismic surveys cover the AoR and span the Domengine Formation (above the upper confining zone) through the Forbes Formation (at the base of the Winters Formation, part of the lower confining zone); these surveys were merged in 2013. One 2D seismic line (crossing NW-SE across the northeastern corner of the AoR) and the type log from Figure 2.2-3 were used to constrain CTV's structural model.

Additional whole core data from within the AoR was available for the upper confining zone and upper injection zone from a 2014 UIC Class V Experimental Compressed Air Energy Storage (CAES) Test Injection/Withdrawal project (Permit No. R9UIC-CA5-FY13-1) conducted by Pacific Gas and Electric (PG&E). Data was available in DOE report DOE-PGE-00194-4 (the DOE report) from Medeiros, et al. (2018). One test well was permitted (PG&E TEST INJECTION WITHDRAWAL WELL 1) along with two observation wells (Piacentine 1-27 and Piacentine 2-27). These three wells are located near the center of the AoR in between the proposed injection wells (Figure 2.2-11). A CAES test and step-rate test were also conducted in the Mokelumne River upper injection zone as part of the project.

Site Geology

The CTV V storage site is located in the depleted King Island Gas Field, four miles northwest of Stockton, California within the southern Sacramento Basin, the northern asymmetric sub-basin of the larger Great Valley Forearc. Nearby gas fields include the Rio Vista Gas Field (nine miles to the east), East Islands Gas Field (to the north), and Rindge Tract Gas Field (to the south). Figure 2.1-1 shows the location of the proposed AoR in the context of the southern half of the Sacramento Basin. Figures 2.1-2 and 2.1-4 display the Sacramento Basin in map view and schematic cross section, respectively. Tectonic evolution of the Mendocino triple junction of the Gorda, North American and Pacific plates is shown in Figure 2.1-3. The sedimentary formations of the Great Valley Forearc range in age from Jurassic to Holocene, and the evolutionary stages are depicted in Figure 2.1-5.

The Sacramento Basin is constrained on the west by the Coast Range Thrust, on the north by the Klamath Mountains, on the east by the Cascade Range and Sierra Nevada Range, and on the south by the Stockton Arch Fault. Sedimentary infill consists of Cretaceous-Paleogene fluvial, deltaic, shelf, and slope sediments which thicken southward towards the Stockton Arch Fault due to the southern tilt of the basin. In the southern portion of the basin, the Mokelumne River and Starkey Formation injection zones are thick-bedded sandstones with interbedded shales. Local structure in this area is characterized as homoclinal, dipping gently about 2 degrees to the southwest. Figure 2.1-6 contains a schematic cross section of the Sacramento Basin.

Request for CTV:

1. *Please provide the citation for Figures 2.1-1 and 2.1-6.*
2. *For Figure 2.2-3, some of the permeability values don't match the values noted throughout the narrative. Please correct the figure or explain this discrepancy.*

Stratigraphy

Figure 2.2-5 is a schematic E-W cross section representing the local stratigraphy of the project area. The major stratigraphic intervals comprising the injection and confining zones are Late Cretaceous to Early Paleogene in age within the AoR.

While CTV does not name a lower confining zone, the Sacramento Shale and Winters Formation together appear to act as a lower confining unit based on site characterization data (see Injection and Confining Zone Details [40 CFR 146.82(a)(3)(iii)] below). The Starkey Formation overlies the Sacramento and Winters Formations, and its Peterson Sandstone member serves as the lower injection zone. The H&T Shale was overlain onto the Starkey and serves as an internal barrier between the two proposed injection zones. The Mokelumne River was deposited over the H&T Shale and serves as the upper injection zone. The Capay Shale unconformably overlies the Mokelumne River and serves as the primary upper confining zone. Above the Capay Shale upper confining zone lies the early-middle Eocene Domengine Formation pressure dissipation zone and the Nortonville Shale. The Nortonville will serve as an additional barrier unit between the injection zones and the lowermost USDW. Above the Nortonville Shale is an Oligocene-aged major unconformable surface, which separates the more deformed Mesozoic and lower Paleogene strata below from the less deformed uppermost Paleogene and Neogene strata above. The Paleogene and Neogene strata contain undifferentiated marine and non-marine sediments, within which is the base of the lowermost USDW.

Available data about geologic formations are summarized in Table 1 below. Further information is provided in Injection and Confining Zone Details [40 CFR 146.82(a)(3)(iii)] below. Average porosity and permeability values are based on local wells with well logs (Figure 2.2-2).

Table 1. Formation Summary.

Unit	Depth within the AoR (ft TVDSS)	Thickness Across the AoR (ft)	Total Dissolved Solids (mg/L)	Average Porosity (%)	Average Permeability (millidarcies, mD)
Base of Lowermost USDW	2,200	--	<10,000	--	--
Nortonville Shale (additional barrier unit)	~3,800	250	--	29.9 (Piacentine 1)	4 (Piacentine 1)
Domengine Formation (pressure dissipation zone)	~3,910	~700 to 1,300	--	35.5 (Piacentine 1)	528 (Piacentine 1)
Capay Shale (upper confining zone)	4,778	530	--	28.5	0.33
Mokelumne River Formation	5,433	963	14,000	32.2	216

Unit	Depth within the AoR (ft TVDSS)	Thickness Across the AoR (ft)	Total Dissolved Solids (mg/L)	Average Porosity (%)	Average Permeability (millidarcies, mD)
(upper injection zone)					
H&T Shale (internal barrier)	6,396	146	--	25.5	1.3
Starkey Formation (lower injection zone)	6,507	1,401	14,000	25.5	52

Request for CTV:

3. *In section 2.2.2.5 of the Narrative document, include a reference to Figure 2.4-4 which shows the thickness and structure maps for the Capay Shale.*
4. *Please explain why the Domengine Formation is referred to as a pressure dissipation zone.*

Maps and Cross Sections

Project Site Map [40 CFR 146.82(a)(2)]

Figure 2.2-11 satisfies the requirements of 40 CFR 146.82(a)(2) and includes a depiction of the AoR, the proposed injection wells, oil and gas wells, State- or EPA-approved subsurface cleanup sites, surface bodies of water, water wells, cities and communities, and roads. Faults within the AoR are depicted in Figure 2.3-1 (see Faults and Fractures [40 CFR 146.82(a)(3)(ii)] below) but are not included in Figure 2.2-11.

CTV notes that no known mines or quarries, springs, tribal lands, or surface faults are present within the delineated AoR boundary.

Depictions of the Area of Review [146.82(a)(3)(i)]

Pertinent surface features in the AoR are depicted in Figure 2.2-9, including surface and subsurface mines, quarries, surface bodies of water, and local boundaries. Surface bodies of water are also depicted in Figure 2.7-1. CTV obtained data on mines and quarries from the Conservation Division of Mine Reclamation (DMR) and the U.S. Geological Survey (USGS). Major surface water bodies located in and around the AoR include the San Joaquin River, Bear Creek River, and Calaveras River. State- or EPA-approved subsurface cleanup sites are depicted in Figure 2.2-10. CTV obtained cleanup site data from the State Water Resources Control Board's GeoTracker database, which contains records for sites that impact, or have the potential to impact, groundwater quality. Water wells are depicted in Figure 2.7-7, and location data were sourced from the California Division of Drinking Water (DWR) and Groundwater Ambient Monitoring and Assessment (GAMA) program.

Isopach maps for the H&T Shale internal barrier and Capay Shale upper confining zone are provided in Figures Figure 2.1-7a and b, respectively. Lower and upper injection zone structure and thickness maps are provided in Figures 2.2-6 and 2.2-8. Additional structure and thickness maps for these units are provided in Figures 2.4-4 and 2.4-5. See "Structural Information" below for a discussion of local structure.

Figure 2.2-5 is a SW-NE cross section showing the stratigraphy and lateral continuity of major formations across the AoR. Depicted on the figure is the base of the lowermost USDW where total dissolved solids (TDS) transitions to greater than 10,000 mg/L.

Request for CTV:

5. *For completeness and to satisfy the requirements of 40 CFR 146.82(a)(2), please add the faults shown on Figure 2.3-1 to Figure 2.2-11.*

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

CTV utilized 2D and 3D seismic data and public data from the California Geologic Survey (CGS) to identify faults within the AoR. Two faults are within the AoR and two outside of the AoR as depicted in Figure 2.3-1. CTV notes that these faults are normal with small offsets and are bound within the sedimentary section of the Sacramento Basin. The CGS fault map provided in Figure 2.3-4 does not show any faults near the AoR.

The two faults within the AoR are visualized in cross section in Figures 2.3-2 and 2.3-3. One is on the extreme western edge of the AoR, and one is to the east of the injection wells. Both faults transect the Capay Shale upper confining zone and H&T Shale internal barrier, but their offsets are minimal and range from approximately 50 to 100 feet. Neither fault is within the predicted extent of the CO_2 plume, but they are presumably within the extent of or influenced by the pressure front. Based on CTV's discussion of local seismicity (see Seismic History [40 CFR 146.82(a)(3)(v)] below), these faults appear to be inactive. However, no evidence of fault stability is provided by CTV to support whether reservoir pressure increases due to CO_2 injection activities will induce fault reactivation.

Questions/Requests for CTV:

6. *Based on Figure 2.3-1, 3D seismic coverage appears to be lacking on the eastern boundary of the AoR. EPA requests that CTV perform additional 3D seismic surveys as part of pre-operational testing to address this uncertainty.*
7. *Are the two faults within the AoR influenced by any increased pressure? If so, please include a discussion of the pressure increase at the locations of the faults, particularly the one to the east of the injectors.*
8. *What evidence is available to support assertions about the stability of the faults within and around the AoR, particularly in the context of the predicted pressure increases? Please discuss this in the context of faults and fractures and seismic mitigation.*

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

The available site-specific data provides relatively complete coverage of the AoR; however, there are fewer wells with data to the east of the injection wells. Figure 2.2-2 shows the locations of wells with core, porosity/permeability, and ductility data, where many data points are available from within the delineated AoR. One type log was available from the well Piacentine 1 in the center of the AoR, which describes average rock properties and established depths and thicknesses (Figure 2.2-3). Unit depths and thickness based on local well logs are also depicted in the structure and thickness maps in Figure

2.4-4 and 2.4-5. Areas where additional site-specific data are needed to confirm assumptions are noted below.

Quantitative mineralogy data was acquired from x-ray diffraction (XRD) and Fourier-transform infrared spectroscopy (FTIR) for the Capay Shale through the Sacramento Shale (Table 2.4-1). Mineralogy data for the upper and lower injection zones are available from the well Citizen Green 1 located in the center of the AoR; other data are from regional wells outside of, and within 15 miles of, the AoR as shown in Figure 2.2-2. CTV plans to fill site-specific data gaps for the remaining formations as part of pre-operational testing.

Wireline log data were acquired, including spontaneous potential (SP), natural gamma ray, borehole caliper, compressional sonic, resistivity, neutron porosity, and bulk density. CTV used these logs to determine unit depths and thickness (Table 2.4-5) and construct structure and isopach maps for the AoR. CTV acknowledges that log vintage variability affects the quality of some logs when identifying sandstones but asserts this had a minimal effect on unit mapping. Modern logs collected during pre-operational testing will need to confirm site-specific properties as determined by the historical logs.

Site-specific whole cores from the Mokelumne River upper injection zone and Capay Shale/Meganos Gorge from within the AoR was available from the PG&E King Island CAES Class V project. Additional whole cores for the upper and lower injection zones were available from Citizen Green 1 and Whiskey Slough 1A-E. For the remaining formations, cores collected during drilling will need to be analyzed to confirm site-specific properties, including porosity, permeability, capillary pressure, pore pressure, mineralogy, etc.

CTV determined formation porosities from bulk density using a matrix density of 2.65 g/cc as calibrated from core grain density and core porosity data, and from compressional sonic logs using 55.5 µsec/ft matrix slowness and the Wyllie time-average equation (Table 2.4-2). Formation clay volumes were determined by SP logs and calibrated to core data. CTV then estimated log permeability by applying a core-based permeability transform that utilizes capillary pressure, porosity, and permeability with clay values from XRD and/or FTIR. The permeability transform is based on 13 core data points from two wells, and an example transform for Sacramento Basin zones is provided in Figure 2.4-1. CTV notes that the permeability transform is consistent with both log permeability using the Timur-Coates method from a nuclear magnetic resonance (NMR) log and rotary sidewall cores in Citizen Green 1 as shown in Track 10 of the example log in Figure 2.4-2. Porosity and permeability data from wells across the AoR were used to find average values for each formation (Figure 2.4-3). There are no concerns with CTV's characterization of site-specific data, but data collected during pre-operational testing will be needed to confirm averaged values.

Capillary pressure data within the AoR is available from four sidewall core samples taken from Citizen Green 1. Two samples were collected from the upper injection zone and two from the lower injection zone and analyzed using mercury-injection capillary pressure (MICP). CTV provided the capillary pressure curve in Figure 3.11 of the Area of Review and Corrective Action Plan. Additionally, capillary pressure of the upper confining zone and internal barrier will need to be determined during pre-operational testing.

Injection Zone Properties

Mokelumne River Formation (Upper Injection Zone)

The Late Cretaceous Mokelumne River Formation upper injection zone was deposited as a fluvial-deltaic sequence prograding southwest into the basin. After deposition of the Mokelumne River and overlying Capay Shale Formation, the Late Paleocene/Early Eocene Meganos Gorge submarine canyon cut through and was infilled with fine-grained submarine fan deposits and transgressive deep-water shales. Due to downcutting by the Meganos, the Mokelumne River is locally thinned (see “Structural Information” below). Within the AoR, the thickness ranges from 18 to 1,902 ft and depth varies from 4,427 to 6,975 ft TVD (Table 2.4-5).

Six core samples with XRD data were available from Citizen Green 1, ranging in depth from 5,247 to 6,598 ft. Samples averaged 32% quartz, 21% plagioclase and potassium feldspar, and 18% total clay (kaolinite, chlorite and mixed layer illite/smectite). CTV notes that calcite and dolomite were not detected in any samples.

The average porosity is 32.2% based on porosity logs from 38 wells with 33,891 individual logging data points. The geometric average permeability is 216 mD based on 38 wells with porosity logs and 33,768 individual logging data points. This is consistent with the Citizen Green 1 NMR log permeability of 225 mD.

Table 2.4-3 shows 21 core data points from Citizen Green 1 and Whiskey Slough 1A-E which showed an average porosity of 32.5%, a horizontal permeability of 780 mD, and vertical to horizontal permeability (Kv/Kh) ratio of 0.74. Data from 162 core samples from Piacentine 2-27 generally agree with the Citizen Green 1 and Whiskey Slough 1A-E cores and showed an average porosity of 25%, a horizontal permeability of 807 mD, and an average Kv/Kh ratio of 0.8.

Starkey Formation (Lower Injection Zone)

The Starkey Formation lower injection zone was deposited as interbedded sands and shales in progradational deltaic complexes. Based on the structure and thickness maps in Figure 2.2-6, the formation dips and thickens southwest. Within the AoR, the thickness ranges from 760 to 2,660 ft and depth ranges from 5,399 to 7,286 ft TVD (Table 2.4-5).

Three samples with XRD data were available from Citizen Green 1, ranging in depth from 7,104 to 7,146 ft. Samples averaged 40% quartz, 9% plagioclase and potassium feldspar, and 14% total clay (kaolinite, chlorite and mixed layer illite/smectite). CTV notes that calcite and dolomite were not detected in any samples. Additional mineralogy data was available for the Peterson Sand unit of the Starkey Formation from 29 samples from the wells Emigh_15 and JA_Serpa_4 located approximately 15 miles west of the AoR. Samples averaged 54% quartz, 26% plagioclase and potassium feldspar, and 11% total clay (kaolinite, chlorite, and mixed-layer illite/smectite). Calcite cementation and dolomitization were noted in thin sections for some of these samples.

The average porosity is 25.5% based on porosity logs from 21 wells with 12,798 individual logging data points. The geometric average permeability is 52 mD based on 20 wells with porosity logs and 11,602 individual logging data points. This is consistent with the Citizen Green 1 NMR log permeability of 53 mD. Five core data points from Citizen Green 1 show an average porosity of 26.0% and horizontal permeability of 113 mD. Vertical permeability data was not presented for the Starkey.

Confining Zone Properties

Capay Shale (Upper Confining Zone)

The Eocene Capay Shale upper confining zone was deposited as a transgressive surface unconformably overlying the Mokelumne River and Meganos. Within the AoR, its thickness ranges from 72 to 1,361 ft and varies in depth from 4,154 to 5,670 ft TVD (Table 2.4-5).

Nine samples with mineralogy data were available from the wells RVGU_209, RVGU_248, and Wilcox_20 in the Rio Vista Gas Field (9 miles west of the AoR). RVGU_209 has FTIR data, while the other two wells have XRD data. Samples averaged 32% quartz, 39% plagioclase and potassium feldspar, 29% total clay (predominantly mixed-layer illite/smectite, with kaolinite and chlorite still prevalent), minimal pyrite, and less than 1% calcite and dolomite.

The average porosity is 28.5% based on 10 wells with porosity logs and 3,155 individual logging data points. Based on the Citizen Green 1 NMR log permeability, geometric average permeability is 0.33 mD. Core data from the well Piacentine 2-27 showed a vertical permeability between 0.04-0.06 mD.

Capillary pressure data was available from the DOE report for the upper confining zone, which found that no brine was produced at the highest delta pressure of 2,000 psi.

H&T Shale (Internal Barrier)

The H&T Shale is a regional seal that conformably overlies the Starkey Formation and will act as an impermeable internal barrier between the Starkey and Mokelumne Formation injection zones. Within the AoR, the thickness ranges from 58 to 269 ft and depth varies from 5,328 to 7,164 ft TVD (Table 2.4-5).

Nine samples with FTIR and XRD data were available from the well Speckman Decarli 1 located approximately 3 miles south of the AoR. Samples averaged 46% total clay (predominantly mixed layer illite/smectite, with kaolinite and chlorite still prevalent), 23% quartz, 29% plagioclase and potassium feldspar, 2% pyrite, and 1% calcite and dolomite.

The average porosity is 25.5% based on 23 wells with porosity logs and 9,854 individual logging data points. The geometric average permeability is 1.3 mD based on NMR logging in the Citizen Green 1 well.

Winters Formation (Lower Confining Unit)

The Winters Formation was deposited in a deep-sea fan system as an upward-fining sequence of Late Cretaceous sandstones and shales. In the Piacentine 1 type log, the Winters occurs at a depth of approximately 7,740 ft TVDSS.

Twenty-two samples with XRD data were available from the Lopes Transamerica 1 well in the Thornton Gas Field approximately 15 miles north of the AoR. Samples averaged 41% total clay (predominately chlorite, with illite/mica and smectite common), 25% quartz, 26% plagioclase and potassium feldspar, 2% pyrite, and less than 1% calcite and dolomite. Two samples are noted to show calcite cementation.

Porosity, permeability, and capillary pressure data were not provided.

Sacramento Shale (Lower Confining Unit)

The Sacramento Shale is the oldest in a series of transgressive Late Cretaceous shales in the southern Sacramento Basin. Ten samples with XRD data were available from the Lopes Transamerica 1 well in the Thornton Gas Field approximately 15 miles north of the AoR. Samples averaged 47% total clay (predominately chlorite, with illite/mica and smectite common), 22% quartz, 27% plagioclase and potassium feldspar, 1% pyrite, and less than 1% calcite and dolomite.

Porosity, permeability, and capillary pressure data were not provided.

Questions/Requests for CTV:

9. *Please update Attachment A to include the MICP test results from the Citizen Green 1 well.*
10. *Please clarify whether any pressure changes are expected above the Capay Shale, i.e., why is the Domengine characterized as a pressure dissipation zone?*
11. *Please edit Figure 2.2-3 to refer to the Nortonville Shale as an additional barrier unit rather than a secondary confining zone.*
12. *Please add the formation names, as used in the Stratigraphy section, to Figures 2.2-6, 2.2-7, and 2.2-8.*
13. *Update the narrative to use consistent convention when referring to depth (TVDSS). The text and the figures (i.e. Figures 2.2-6, 2.2-7, and 2.2-8) should be consistent.*
    a. *The structure and thickness values presented in Figure 2.2-8 don't match the values in the text of the Narrative document. Please clarify if this is due to differences in how depth is being reported and correct the issue.*
14. *For clarity, please revise the application to identify a lower confining zone.*
15. *Please provide any porosity, permeability, or capillary pressure data available for the Winters Formation or Sacramento Shale from any of the nearby fields.*
16. *Please add or reference Figure 3.6 from Attachment B in the narrative to clarify that RVGU 209 and 215 were used to create the permeability transform.*
17. *Several descriptions of mineralogy in this section don't add up to 100%. Please clarify why this is the case.*

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

CTV performed ductility and rock strength calculations based on the methodology and equations from Ingram & Urai (1999) and Ingram, et al. (1997) as described in subsection 2.5.1. Example calculations are provided in Figure 2.5-1 for the well Chevron 1 located on the western border of the maximum CO_2 plume extent near the center of the AoR. CTV calculated a brittleness index for the local formations by comparing the log-derived unconfined compressive strength (UCS) to an empirically derived UCS for a normally consolidated rock. Highlighted in red in the last track of Figure 2.5-1 are ductile intervals with brittleness index values below 2.0.

For the Capay Shale upper confining zone, CTV acquired data from 16 wells (shown as pink circles in Figure 2.2-2) comprising 8,863 individual logging data points within the AoR that had suitable compressional sonic and bulk density data to determine upper confining zone ductility. CTV also acquired data from the same 16 wells comprising 8,863 individual logging data points within the AoR that had suitable data to determine upper confining zone UCS. The Capay was calculated to have an average ductility of 1.34 and an average rock strength of 1,589 psi. The Nortonville Shale additional barrier unit was calculated to have an average ductility of 1.43 and UCS of 1,125 psi based on 15 well logs with 6,288 individual logging data points. The H&T Shale internal barrier unit was calculated to have an average ductility of 2.0 and UCS of 3,088 psi based on 15 wells with 6,288 individual logging data points. Each confining or barrier layer had intervals with brittleness index values below 2.0, indicating that confining intervals are unlikely to form brittle fractures and compromise CO_2 containment.

CTV states that the AoR has a strike-slip/reverse fault regime based on studies conducted within the Sacramento Basin. The maximum principal horizontal stress orientation is estimated to be N40°E±10° which is consistent with local data in Heidback et al. (2016) shown in Figure 2.5-3 and regional data in Lund-Snee and Zoback (2020) shown in Figure 2.6-2.

A step rate test (SRT) was performed in the well PG&E TEST_INJECTION_WITHDRAWAL_WELL_1, which identified a fracture gradient of 0.822 psi/ft in the Mokelumne River upper injection zone. No fracture gradient or pore pressure data currently exists for the lower injection zone or confining zones. CTV plans to conduct SRTs in the lower injection zone and confining zones as part of pre-operational testing. Some wells located 10 to 15 miles west of the AoR had formation integrity test (FIT) or leak-off test (LOT) data at depths ranging from 4,800 to 11,050 feet TVD, which showed an average fracture gradient of 0.82 psi/ft.

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

CTV researched historical seismic events spanning 1900 to present within the vicinity of the project site via the USGS earthquake catalog. Figure 2.6-1 shows the locations of events with a magnitude greater than 2.5, and Table 2.6-1 summarizes the events, including their date, depth, and magnitude. Seventeen events between 1909 and 2021 occurred within a 15-mile radius of the project site; every event occurred outside of the delineated AoR. The depth of the events ranged from 4.3 to 15.0 km (more than 2 km below the lower injection zone) and magnitudes ranged from 2.5 to 4.5. The historical events occurred outside of the AoR at greater depths than the proposed injection zones; as such, they appear unrelated to the minor faults identified within the AoR.

CTV asserts that those faults are not active or high-risk sources of seismicity due to their nature as small offset normal faults within sedimentary sections, the absence of major faults in the CGS map in Figure 2.3-4, and the lack of historical seismicity.

Section 2.6.2 describes how seismic hazards will be mitigated at the CTV V site (consistent with EPA recommendations). It describes how site geology is suitable to receiving and containing the volumes of CO_2 to be injected and that the site will be operated and monitored to limit risk of USDW endangerment due to seismic events or to detect and mitigate the effects of any seismic events that do occur. CTV's Attachment I: Pre-Operational Testing Plan (POTP) states that they will establish baseline seismicity to evaluate seismic risk prior to injection. CTV intends to monitor pressure changes and associated seismicity as part of Testing and Monitoring during operation.

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

CTV characterized the local hydrology and hydrogeology with data from the DWR and USGS. The CTV V project site is within the San Joaquin Valley Groundwater Basin, primarily in the Eastern San Joaquin Subbasin (ESJS) and partially in the Tracy Subbasin (Figure 2.7-1). Surface water features that run through the AoR include the San Joaquin River, Bear Creek River, Calaveras River, and sloughs and perennial stream tributaries. Section 2.7.1 includes further hydrologic information on each river.

CTV identifies both the base of fresh water (BFW) and the base of the lowermost USDW, defined as having a TDS less than 3,000 mg/L or 10,000 mg/L, respectively. Figures 2.7-2 and 2.7-3 are depth maps of the BFW from USGS and DWR, and Figure 2.7-4 depicts the BFW in cross section (line B-B' crosses E-W through the southern edge of the AoR). Figures 2.7-5 and 2.2-5 contain a depth map and cross sectional depiction of the lowermost USDW, which was determined based on a TDS calculated from salinity logs from across the AoR using the four-step process described in subsection 2.7.2.2. Based on Figure 2.7-5, the base of the lowermost USDW occurs from approximately 1,750 to 2,550 ft TVD. No fluid sampling was performed to determine the TDS of the lowermost USDW; the site-specific TDS will need to be determined during pre-operational testing.

The formations that comprise the principal local aquifers range in age from Holocene to Eocene and are the Younger Alluvium and Modesto/Riverbank formations, Turlock Lake, Laguna, Mehrten, Valley Springs, and Ione (Table 2.7-1). These formations are depicted in cross section in Figure 2.7-4. The principal aquifer is divided into the Shallow Aquifer Zone (Modesto, Riverbank, and Upper Turlock Lake), Intermediate Aquifer Zone (Lower Turlock Lake and Laguna), and Deep Aquifer Zone (Mehrten). The transition in salinity to the BFW occurs below the Deep Aquifer Zone within the Valley Springs and Ione Formations (Figure 2.7-4), and the base of the lowermost USDW occurs in the undifferentiated sediments below the principal aquifer formations at a depth of approximately 2,200 ft TVD in the center of the AoR (Figures 2.2-5 and 2.7-5).

The primary uses for groundwater from the principal aquifer are irrigated agriculture, public supply, and rural domestic. Local water supply wells from GAMA and DWR are depicted in Figure 2.7-7 and tabulated in Table 2.7-2. Over 2,000 water wells were identified within one mile of the AoR, including 1,539 producing wells. Water wells range in bottom depth from 18 to 880 feet below ground surface (ft BGS), averaging 143 ft BGS. Groundwater levels and flow for the ESJS are depicted in the groundwater contour map in Figure 2.7-6. Groundwater across the AoR typically flows east towards the center of the ESJS, following the gently east-dipping gradient of the local formations on the far western side of the subbasin (A-A' and B-B' in Figure 2.7-4).

CTV plans to collect groundwater samples during well drilling to establish the depth of the lowermost USDW within the AoR using analytes and testing methods described in the Testing and Monitoring Plan.

Questions/Requests for CTV:

18. *The last paragraph of subsection 2.7.2.2 describes the base of the lowermost USDW at 750 feet below ground surface. Please clarify that this is the BFW.*
19. *Please provide an estimation of the depth of the base of the lowermost USDW (TDS < 10,000 mg/L).*

20. Please clarify whether the lowermost USDW is within the Ione Formation.

Injection Zone Geochemistry [40 CFR 146.82(a)(6)]

Three wells with fluid samples from the upper and lower injection zones are depicted in Figure 2.8-1. Only the well Piacentine 2-27, from which the upper injection zone was sampled in 2013, is within the AoR. The water chemistry from this sample is provided in Figure 2.8-2; the TDS of the sample was 14,000 mg/L. One upper injection zone sample from 1980 from the Midland Fee Water Injection 1 well in the Rio Vista Gas Field (Figure 2.8-3) has a TDS of 13,889.4 mg/L. For the lower injection zone, one sample from 1990 was available from the well Trigueiro 4 (Figure 2.8-3), which had a measured TDS of 14,415 mg/L. Based on the salinity calculations described in subsection 2.7.2.2 for identifying USDWs, both the upper and lower injection zones have a log-based salinity ranging from 13,000 to 18,000 mg/L across the AoR. CTV states that a value of 14,000 mg/L was used in their computational modeling.

From the DOE report, a natural gas sample from Piacentine 1-27 indicated that formation gas in the upper injection zone is nearly 92% methane and 8% nitrogen, with trace amounts of ethane, propane, and CO_2. CTV states that no gas production is occurring within the lower injection zone within the AoR, so no hydrocarbon analysis is available.

CTV's geochemical modeling is described in "CO2 Stream Compatibility" below. CTV's POTP indicates that they will characterize the baseline geochemistry of the lowermost USDW and the upper and lower injection zones for all parameters and methods described in the Testing and Monitoring Plan to confirm the inputs to the geochemical modeling as well as establish a baseline for monitoring.

Site Suitability [40 CFR 146.83]

Facies Changes

Core data from wells within the AoR show relatively consistent mineralogy and porosity and permeability for the Mokelumne River Formation (upper injection zone) and Starkey Formation (lower injection zone). CTV's POTP states that cores and well logging will provide additional information on these formations' suitability for injection, including facies changes that could facilitate preferential flow. Particular attention to the Starkey may be necessary, where injection is targeted into the Peterson Sandstone member of the formation. While not necessary to the project, understanding the containment properties of interbedded shale layers in the Starkey would improve accuracy of the computational modeling.

Structural Information

CTV asserts that variability in the thickness and depth of the Capay Shale, Mokelumne River Formation sandstones, and Starkey Formation sandstones will not adversely affect CO_2 storage or confinement. CTV attributes structural and thickness variability in the Capay Shale and Mokelumne River to the Meganos submarine canyon erosional event. CTV describes the Meganos as a bounding feature for the Mokelumne River, asserting that it would contribute to CO_2 containment. However, provided cross sections and maps do not clearly identify the Meganos or demonstrate how it affects local stratigraphy. Confining zone properties are also not described for the Meganos canyon infill. Based on Table 2.4-5, the Capay Shale has a minimum thickness of 72 ft, and the Mokelumne River has a minimum thickness of 18 ft. The Mokelumne River experiences structural highs and greatest thickness in the center of the AoR, where CTV proposes to inject, above which the Capay is at its thinnest (< 250 ft; contour line resolution is too coarse to further define thickness at the injection site). It is unclear how these features are influenced by the Meganos.

CTV attributes structural and thickness variability within the Starkey Formation to deposition on the east flank of the Sacramento Basin, where structure dips and thickens west-southwest towards the basin axis. This appears fairly uniform in the Starkey as well as the overlying H&T Shale; there are no structural concerns in these units.

No other major structural features are present within the AoR.

CO_2 Stream Compatibility

CTV assessed the potential for reactions between minerals, formation fluids, and the CO_2 injectate for the upper and lower injection zones using PHREEQC software. A description of CTV's geochemical modeling is provided in Appendix 3. CTV's modeling approach applied available formation minerology and geochemical data and assumed two potential injectate chemical compositions (Table 7.2-2). Thermodynamic data for the prominent minerals within the injection zone and confining zone were obtained from the Lawrence Livermore National Laboratory because other applicable databases do not include data for the minerals characterized (i.e., quartz, feldspar, and various clay minerals). The calculation of saturation indices appears to be sufficient and consistent with EPA guidance recommendations, applying XRD data for the various minerals and assumptions for dissolution and precipitation reactions. The input parameters summarized in the associated tables (Tables 1 through 4) accurately reflect other information in the narrative, and the results summarized in Tables 5 through 10 are consistent with the modeling conclusions.

CTV explains that the upper and lower injection zones are predominantly quartz and feldspar with negligible carbonate minerals, so any dissolutions would only occur on grain surfaces. The modeling predicted a minimal net molar mass change of 0.2% to 0.5% in the upper injection zone and 0.3% to 0.4% in the lower injection zone. As identified in "Starkey Formation (Lower Injection Zone)" above, detected carbonates (calcite/dolomite) are localized to thin, tight streaks caused by calcite cementation. These are predicted to only reduce vertical permeability barriers if dissolved. Upper and lower injection zone fluid samples had minimal calcium and magnesium cations, so calcium mineralization is minimized; this will need to be confirmed with additional fluid sampling during pre-operational testing. The salinity being less than 30,000 mg/L will reduce the salting out effect seen in higher salinity brine under the presence of CO_2.

Fluid samples from the upper confining zone or internal barrier are unavailable to conduct stream compatibility tests; according to CTV, these zones will only produce fluid if stimulated. CTV does not anticipate any CO_2 compatibility issues with the formation fluids within these zones due to their low permeability and low carbonate content.

Significant reactions between the injectate and confining zone mineralogy that would affect containment were not noted from the geochemical modeling. Additional collection of site-specific core data from the upper confining zone during the pre-operating phase will be necessary to confirm assumptions of site parameters and reduce uncertainty in modeling inputs.

CTV describes in their POTP that, along with a baseline geochemical analysis of the upper and lower injection zones, the CO_2 stream will be evaluated to confirm that it will not react with the formation matrix. Anticipated testing includes injectate analysis, core testing, and geochemical modeling. Properties of the CO_2 stream will be analyzed for consistency with the AoR delineation model inputs and to confirm that the analytes for the injectate and ground water quality monitoring are appropriate based on the results of the geochemical modeling evaluation.

Storage Capacity

CTV estimates that the storage capacity of the project site is 16.7 MMT of CO_2 based on computational modeling to delineate the AoR. No additional information is provided in the narrative, although this is consistent with the CO_2 volumes used as model inputs (per Table 3.4 of the AoR and Corrective Action Plan). Additional site-specific data collection (e.g., porosity, pressure, and temperature) is needed to confirm the model inputs and the storage capacity of the injection zones.

Confining Zone Integrity

The Capay Shale upper confining zone is a regionally extensive unit; based on available log data, it ranges from 72 to 1,361 ft thick within the AoR. It is unclear where the Capay is the thinnest based on the application narrative. CTV's AoR delineation modeling predicts that the maximum vertical migration of the CO_2 plumes are still deeper than the base of the Capay Shale up to 100 years post-injection (Figure 2.10-1).

As described under "Faults and Fractures [40 CFR 146.82(a)(3)(ii)]," CTV utilized 2D and 3D seismic data and public data to identify faults within the AoR. Two faults transect the Capay Shale and H&T Shale near the AoR boundary and their offsets range from approximately 50 to 100 feet. They are outside the predicted extent of the CO_2 plume but are presumably within the extent of or influenced by the pressure front. As noted under "Faults and Fractures [40 CFR 146.82(a)(3)(ii)]" above, EPA requests that CTV provide evidence of fault stability to support a determination that potential fault reactivation will not adversely impact CO_2 storage.

As described under "Geomechanical and Petrophysical Information [40 CFR 146.82(a)(3)(iv)]" above, CTV characterized ductility and rock strength of the upper confining zone based on data from well Chevron 1 located near the center of the AoR. CTV also calculated a brittleness index below 2.0. CTV also acquired data from 16 wells within the AoR to determine upper confining zone UCS. CTV notes that the PG&E CAES test successfully pressurized and depressurized the upper injection zone without impacting the upper confining zone or Meganos. According to the POTP, CTV plans to confirm the fracture pressure of both the injection zone and the confining zone, via site-specific step rate tests in the project area.

Secondary Confinement

CTV asserts that identification of a secondary confining zone is not necessary due to the regional continuity, thickness, and low permeability of the upper confining zone. CTV's characterization of the Capay Shale upper confining zone supports this assertion, pending clarification of the Capay's minimum thickness at the locations of the proposed injection wells. CTV adds that the Nortonville Shale, a regionally widespread transgressive surface, will provide additional upper confinement. The Nortonville is included in CTV's AoR delineation modeling as an impermeable surface.

Questions/Requests for CTV:

21. *Please provide additional information on the structural variability of the Capay Shale and Mokelumne River in the center of the AoR. How are these intervals affected by the Meganos?*
22. *Please provide additional information and calculations regarding how CTV determined the storage capacity of the injection zone, and how site-specific properties of the injection zone from within the AoR and operational conditions were factored into this evaluation.*
23. *Approximately how thick is the Capay Shale at the location of each injection well? Please provide evidence that the thickness is sufficient to contain the total volume of CO_2 to be injected.*

Site Geomodel

CTV developed a static 3D representation of site geology in Schlumberger's Petrel software using well data and 3D seismic data rendered into a geo-cellular grid. Attachment B: Area of Review and Corrective Action Plan (AoR/CA) describes two static geomodels created for the AoR delineation – one for each proposed injection zone. CTV's geomodels appear to accurately represent the site characterization data as described in the narrative document, and there are no initial concerns with the methodologies used to construct the geomodels. All concerns regarding the geomodels reflect the concerns about uncertainties in the site characterization as described in this evaluation. Details of the geomodels are discussed below.

Model Domain

The model domains for the two injection zones are described in Table 3.1. Figures 3.3a and 3.3b display the geomodel boundary and geo-cellular grid used to define the CO_2 plume and pressure front extent and the delineated AoR. CTV rotated the models 40° to align with local structural and depositional trends; this decision appears appropriate given the site structural geology as described in the narrative. The upper injection zone has cells with an average grid size of 494 ft by 518 ft, and the lower injection zone has a uniform initial grid of 250 ft by 250 ft which was upscaled to a 426 by 487 ft grid. The static geomodel grid is displayed in cross section in Figure 3.4. Cells were modeled with heights of 19 ft to provide adequate vertical resolution for identification of sand vs. shale layers; this appears to accurately represent vertical facies distribution when compared to open hole log data from well Piacentine 1 (Figure 3.5).

Questions/Requests for CTV:

24. *As data are collected from within the AoR during pre-operational testing, the grid inputs should be revised as necessary to reflect any heterogeneities identified and reduce uncertainty in the model inputs.*

Porosity and Permeability

CTV used Sequential Gaussian simulation and Gaussian Random Function simulation to calculate porosity/permeability distributions for the upper and lower injection zone static geomodels, respectively. The porosity and permeability measurements and calculations are consistent with those described in "Injection and Confining Zone Details [40 CFR 146.82(a)(3)(iii)]" above. Histograms of the porosity/permeability distributions are provided in Figure 3.8, and the distributions of these properties are displayed in cross section view in Figure 3.9. The permeability transform used for these distribution calculations is consistent with the transform described in the narrative (Figure 3.7). As noted elsewhere, the geochemical modeling inputs will need to be updated with the results of site-specific core and fluid analyses to confirm these assumptions.

Reactive Transport

CTV references the results of geochemical modeling provided in Appendix 3: CTV II Geochemical Modeling (described in CO2 Stream Compatibility above) for potential geochemical reactions in the injection zone. CTV excluded reactive transport from the site geomodels, citing the IPCC Special Report on Carbon Dioxide Capture and Storage (2005), which shows that mineralization trapping has minor effects on the AoR, to assert that excluding reactive transport modeling will not adversely affect the computational modeling.

Boundary Conditions

CTV set open horizontal boundaries for the upper injection zone model by applying a large-volume modifier to the model edges. This is consistent with the characterization of the Mokelumne River Formation in the narrative, which is laterally continuous and lacks bounding features near the AoR. The upper vertical boundary, representing the Capay Shale upper confining zone, was set as a no-flow boundary due to its low permeability.

For the lower injection zone geomodel, CTV set three horizontal no-flow boundaries: the western boundary where the thickness of the formation sand interval decreases (note: this trend is best visualized with the permeability heat map in Figure 3.9), the southeastern boundary where the Starkey meets and is truncated by the Stockton Arch Fault (approximately 7 miles from the southeastern edge of the AoR), and the northwestern boundary where the Starkey meets the unnamed normal fault depicted in Figure 2.3-2 of the narrative. EPA recommends that CTV seek to determine whether the unnamed normal fault is sealing (see "Faults and Fractures [40 CFR 146.82(a)(3)(ii)]" above). Because the Stockton Arch Fault has influenced the regional structure of the area, EPA recommends that CTV update the narrative with information on the Stockton Arch Fault collected during pre-operational testing in CTV's other Class VI projects that use the fault as an AoR boundary. All other horizontal boundaries are open in the lower injection zone geomodel. The upper four layers of the lower injection zone geomodel represent the H&T Shale internal barrier, and the upper vertical boundary is set as a no-flow boundary due to the H&T's low permeability.

No lower boundary is defined in the geomodel, which is appropriate given the buoyant nature of the CO_2 plume.

Initial Conditions

Initial reservoir conditions for each geomodel are described in Table 3.3. Formation temperatures are based on bottomhole temperature data from logs in the area. Formation pressures are based on offset field production data; CTV notes that both the upper and lower injection zones are below hydrostatic pressure by 128 psi and 37 psi, respectively. Formation salinity is 14,000 mg/L for both injection zones, which is consistent with the measurements discussed in "Injection Zone Geochemistry [40 CFR 146.82(a)(6)]" above. CTV used a static distribution across the entire geomodel grids for these properties; site specific data collected during drilling will need to confirm actual property distribution across the AoR.

Fracture Pressure

CTV assumed a conservative fracture gradient of 0.76 psi/ft at the location of each proposed injection well for their computational modeling, based on the SRT performed in PG&E TEST_INJECTION_WITHDRAWAL_WELL_1 and FOT/FIT data from regional wells 10 to 15 miles from the AoR. CTV's discussion of fracture pressure is consistent with the narrative. CTV states that the overburden stress gradient in the injection and confining zones ranges from 0.87 to 0.94 psi/ft. CTV plans to confirm these values with SRTs during pre-operational testing.

Operating Details

Table 3.4 contains injection pressure details, including the estimated maximum allowable injection pressures at 90% of the assumed fracture pressure and elevations in each injection well corresponding to the maximum injection pressure. Table 3.4 details the modeled injection durations for each well, which were only summarized in the application narrative; each well in the model operated for a period of 10, 15, or 25 years. Modeled injection rates and total volumes injected are consistent with rates and volumes described for each well in Appendix 4: Operational Procedures.

Summarized Objectives for Pre-Operational Testing

Pre-operational testing on the six injection wells was described in the Narrative, Section 5.0 of each well's Construction and Plugging Plan (Attachment G1 through G6), and Attachment I: Pre-Operational Testing Plan. No pre-operational testing was described for the monitoring wells.

During drilling of the injection wells, open and cased hole logging and testing will include deviation checks, dual induction laterolog, spontaneous potential, gamma ray, caliper, compensated neutron, formation density, and mud logging.

Whole and sidewall cores will be obtained from the upper and lower injection zones, the internal barrier, and upper confining zone. No cores are planned to be taken in the lower confining zone. CTV also specifies that cores will be taken in one of the injection wells, but does not identify which well or the number of cores to be taken. Core analysis is proposed to include porosity, air permeability, saturations, grain density, gamma ray, core descriptions, capillary pressure (on select plugs), XRD, CO_2 to water relative permeability, geomechanical measurements, pore compressibility, and thin section/scanning electron microscopy.

EPA recommends that this full suite of analyses be done on a sufficient number of cores taken throughout the vertical extent of the injection and confining zones from at least one injection well in the northern CO_2 plume area and one or two injection wells in the southern CO_2 plume area. This would provide spatial representation across the AoR to help eliminate any uncertainties associated with localized heterogeneities or facies changes that could affect the storage or confinement of CO_2.

Groundwater samples will be collected to identify the lowermost USDW within the AoR. Formation fluid samples of the upper and lower injection zones will also be taken to confirm inputs to geochemical modeling and to establish a baseline for monitoring. The analytical parameter list and laboratory testing methods for the groundwater and formation fluid samples will be consistent with this in the Testing and Monitoring Plan.

A step rate test (SRT) will be conducted to determine site-specific fracture gradient of the injection zones, fracture pressure of the injection and confining zones, and confining zone pore pressure. CTV indicated that the SRT will collect information to fill data gaps and supplement formation characteristics available for the AoR. CTV indicates that a pressure fall-off test will also be performed to measure near-wellbore formation properties and any changes that could impact injectivity and/or increase pressure.

The logging and testing outlined in the Narrative, Construction and Plugging documents, and the POTP will help confirm site-specific structural, stratigraphic, physical, chemical, and geomechanical properties of the injection and confining zones that are needed to confirm assumptions that the applicant has made based on regional and local well field data and literature used for the application. This should reduce uncertainty about the geologic characterization of the site and ultimately support approval of the AoR delineation before CTV may be authorized to inject CO_2.

Requests for CTV:

25. *Please clarify the geomechanical measurements to be performed as part of the special core analysis program described in Section 6.2 of the Pre-Operational Testing Plan.*
26. *EPA recommends that the Pre-Operational Testing Plan include the collection of cores from at least one injection well in the northern CO_2 plume area and one or two injection wells in the southern CO_2 plume area.*
27. *EPA recommends that CTV describe the SRT procedures to avoid any potential delays associated with approving pre-operational testing procedures.*
28. *EPA requests the following revisions to the pre-operational testing plan to improve data collection:*
    - *Perform direct in-situ formation stress testing to confirm the minimum and maximum horizontal stress conditions that were referenced in Section 2.5.2 using published data.*
    - *Indicate in what intervals whole cores will be taken in the injection wells.*
    - *Describe any pre-operational testing that will be conducted during the drilling of the monitoring wells.*

CTV and EPA identified the following pre-operational testing objectives which should be fulfilled during the drilling of the injection and monitoring wells:

- Correlate available local and regional well data to the site and confirm assumptions and model inputs of the injection and confining zones.
- Characterize the geomechanical properties of the injection and confining zones, including ductility, rock strength, formation stress, brittleness, pore pressure, and capillary pressure based on cores collected throughout the vertical extent of each formation.
- Confirm the storage capacity of the Mokelumne River and Starkey formations based on updated site-specific data (e.g., porosity, pressure, and temperature) and planned operational data (CO_2 density).
- Characterize the baseline geochemistry of the injection zone and the USDWs to serve as a baseline for future monitoring.
- Perform geochemical modeling on site-specific cores to demonstrate compatibility of the formation fluids and rock of the injection and confining zones with the finalized CO_2 stream,

including how geochemical interactions may affect porosity, permeability, injectivity, and storage capacity due to mineralization, mineral precipitation, dissolution, or other processes.

- Validate pressure, salinity, and temperature initial conditions in the injection zones.
- Establish the depth of the lowermost USDW at the location of the injection and monitoring wells.
- Demonstrate the integrity and the suitability of the Capay Shale as the confining layer within the AoR.