REGION 9
SAN FRANCISCO, CA 94105

April 3, 2024

Jim Levine
Montezuma Carbon LLC
2000 Powell Street
Suite 920
Emeryville, CA 94608

Sent electronically only

Dear Jim Levine:

The United States Environmental Protection Agency, Region 9 (EPA) has identified information or clarification needed for continued evaluation of the site characterization and area of review (AoR) delineation modeling for the Montezuma NorCal Carbon Sequestration Hub Project. The comments are included in two (2) enclosures to this letter (one on AoR modeling and one on site characterization). In addition to the information requested in these enclosures, we reviewed the information provided for Endangered Species Act (ESA) and National Historic Preservation Act (NHPA) compliance and determined additional information is needed, as noted in the attached Endangered Species Act and National Historic Preservation Act enclosure.

Please submit the information requested in the Area of Review and Modelling Enclosure and the Site Characterization Enclosure by May 3, 2024, along with an update on ESA and NHPA compliance progress. If you have any questions about this letter and the Enclosures, please contact me at (415) 972-3971, or Kaylee Glenney at (415) 972-3944.

Sincerely,

DAVID ALBRIGHT
Digitally signed by DAVID ALBRIGHT
Date: 2024.04.03 17:04:25 -07'00'

David Albright
Manager, Groundwater Protection Section

ENCLOSURES
1. Area of Review and Modelling Evaluation
2. Site Characterization Evaluation
3. Endangered Species Act and National Historic Preservation Act

cc (via email): Erwin Sison, CalGEM Northern District
Alex Olsen, Central Valley Regional Water Quality Control Board
Janice Zinky, CA State Water Resources Control Board

ENCLOSURE
Request for Additional Information
<u>AoR Delineation Modeling Evaluation</u>
Montezuma NorCal Carbon Sequestration Hub
Underground Injection Control (UIC) Permit Application
Class VI Pre-Construction Permit Application No. R9UIC-CA6-FY23-4

This Computational and Static Modelling Evaluation for the proposed Montezuma Carbon Class VI geologic sequestration project summarizes EPA's review of the computational modeling as described in the Area of Review and Corrective Action Plan (AoR CAP) (Section B, submitted August 28, 2023) of the permit application.

Model Suitability

1. The application does not explicitly address dispersion. In the absence of this discussion, we assume that this is also the case in the dynamic simulation performed for this application. Please clarify how dispersion is treated in the dynamic model.
2. Even though Montezuma Carbon has presented a Thermal-hydrological-mechanical model (Section B, page 11), they have not conducted a fully coupled simulation of fluid flow and geomechanics. Instead, the applicant has used a simplified approach (page 17 of Section B) "ignoring potential shear/tensile failure." More robust coupled modeling and improvements to parameter representations should be pursued as additional site-specific data and information become available.

Model Design

3. The model assumes a closed boundary on all four sides and a top boundary open to the atmosphere at constant-pressure and constant-temperature. The lateral boundaries are established based on geological features, including the Kirby Hills Fault, Sherman Island Fault, and termination of the Anderson Formation, supported by local information on closed pressures across faults. Lateral boundaries are based on the approximate size of the fault-bounded area of interest. However, Montezuma Carbon should consider the sensitivity of the no-flow boundary assumption on the south side of the modeled domain since they note "uncertainty about the nature of the Antioch and Davis faults south of the project and on the other side of the Sacramento River." Please clarify why assuming a no flow boundary to the south is reasonable and conservative or consider the impacts on pressure and saturation response (and corresponding AoR) by varying the "openness" of the southern lateral boundary.

Incorporation of Site-Specific Conditions

4. The relative permeability model was assigned based on generic values for the van Genuchten-Corey model. Please provide the reference for this.
5. Please specify what parameters have been included in the geomechanical analysis. Our understanding is that rock tensile strength does not factor into the calculation, but this was not initially clear since estimated tensile strength for different formations are reported. It is not necessary to modify the geomechanical analysis to include this - just to clarify that these values, while reported, were not used for anything.

6. In Attachment B, the applicant provided a simple schedule for injecting CO_2 into the Anderson formation using a single well at 1 MMt/year for a duration of 40 years (for the 20 mD case) and 30 years (for the 200 mD case). The operational information for the 40-year injection case is shown in Table B-3. Although not specifically stated by the applicant, we assume the total modelled volume of CO_2 to be 40 MMt and 30 MMt, respectively. Please clarify if this is correct.

Model Presentation

7. The applicant provided results showing the cross-section and reservoir-top CO_2 plume and associated pressure fronts at 1, 20, 40, and 100 years only for the 20 mD case. Please also provide the results for the 200 mD case.
8. The applicant did not explicitly specify the total planned injection volume. Nevertheless, their 20 mD simulation model suggests a calculated storage capacity of 40 MMtonnes for the scenario being considered in this application. The application states that it's possible the storage potential is more than 80 MMtonnes, with sustainable injection rates over 2 MMtonnes per year and maximum storage of 250 MMtonnes (page 15, Section A). Supporting justification was not provided for this claim. It is our understanding that this maximum storage volume is not related to this permit application. Please clarify.

Model Calibration and Sensitivity Analyses

9. The applicant seemingly performed sensitivity analysis only on reservoir permeability (20 mD vs. 200 mD) but no results were provided for comparison. The only comparison provided is pressure increases at the Kirby Hills Fault after 40 years injection. Sensitivity to the southern boundary condition assumption (noted to be uncertain) was not included. There was no sensitivity analysis to grid block size or mesh refinement reported (or justification for not performing one provided). A more thorough sensitivity analysis is needed for this project.
10. The model used a finite-difference method, however the applicant does not discuss the choices of finite-difference methods or forecast sensitivity to those choices. Please include a discussion on this.

ENCLOSURE
Request for Additional Information
Site Characterization Evaluation
Montezuma NorCal Carbon Sequestration Hub
Underground Injection Control (UIC) Permit Application
Class VI Pre-Construction Permit Application No. R9UIC-CA6-FY23-4

This site characterization evaluation report for the proposed Montezuma Carbon Class VI Sequestration Project summarizes the geologic evaluation and data submitted by Montezuma Carbon, LLC (MC) in the site characterization document (Section A.1) submitted with their Class VI permit application per 40 CFR 146.82(a). This report 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. Clarifying questions for MC 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

MC plans to develop the Montezuma Norcal Carbon Sequestration Hub in the Montezuma Hills in Solano County, California. MC proposes to construct and operate one CO_2 injection well to be completed in the Anderson Sandstone (the injection zone) at a depth of approximately 11,300 feet below ground surface (ft bgs). The Meganos Shale and Upper Martinez Shale together comprise the primary upper confining zone, and the Lower Martinez Shale comprises the lower confining zone.

MC plans to inject 1 million metric tons (MMtonnes) of CO_2 annually for a period of 40 years, for a total injection volume of 40 MMtonnes. At the proposed injection site, the base of the lowermost underground source of drinking water (USDW) is contained within the Tehama Formation at a depth of approximately 2,000 ft bgs. MC is not requesting an injection depth waiver or aquifer exemption expansion for this project.

Site Characterization

MC's site characterization is based on regional oil and gas well data, existing data from a US DOE-supported pilot CO_2 injection project conducted by Shell and Lawrence Berkeley National Laboratory (LBNL) to evaluate CO_2 storage potential in the Montezuma Hills, and available references and literature sources. Thus, the data provided in the permit application are mainly regional and not specific to MC's proposed injection site. To address site-specific data gaps, MC plans to conduct a 3D seismic survey across the project Area of Review (AoR), then construct a stratigraphic test well to collect site-specific data prior to injection. MC states that this stratigraphic test well may be converted into the proposed injection well IW-A1 or monitoring well IZMW-A1. See Summarized Objectives for Pre-Operational Testing below for further discussion of MC's Pre-Operational Testing Plan (POTP).

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

The proposed injection site is in the Montezuma Hills in the central part of the early Tertiary Rio Vista Basin, a north-south trending extensional sub-basin. The project site is within a sub-basin composed of an asymmetric south-southeast-plunging syncline and formed by two extensional fault zones: the

Midland fault zone to the east and the Kirby Hills fault zone to the west. See Faults and Fractures below for further discussion of these structural features.

Stratigraphic units of interest for the Montezuma project span the Nortonville Shale to the Lower Martinez Shale (Figure A.I-5). MC proposes to inject CO_2 into the Anderson Sandstone, the thickest sandstone interval in the stratigraphic column based on MacKevett (1992) and as shown on the 2D seismic cross section (3 miles north of the AoR) in Figure A.I-3. This unit is confined above by the combined Meganos Shale and Upper Martinez Shale and below by the Lower Martinez Shale. MC's Class VI permit application (and this evaluation) only address proposed injection operations via injection well IW-A1 in the Anderson Sandstone. MC identifies the Hamilton and Domengine units as potential intervals for future injection activities (that are not the subject of the current permit application); these units are confined by the Nortonville, Capay, and Meganos / Upper Martinez shales. Available data about relevant geologic formations (collected at gas fields in the project area) at the project site are summarized in Table 1 below.

Table 1. Formation Summary.

Unit	Depth within the AoR (ft bgs)	Thickness Across the AoR (ft)	Total Dissolved Solids (ppm)	Average Porosity (%)	Average Permeability (millidarcies, mD)
Tehama Formation (Base of Lowermost USDW)	2,000	--	< 10,000	--	--
Nortonville Shale (Potential Confining Unit)	7,850	300	--	--	--
Domengine Sandstone (Potential future Injection Zone)	8,150	400	11,000	20	40
Capay Shale (Potential Confining Unit)	8,550	650	--	--	--
Hamilton Sandstone (Potential future Injection Zone)	9,200	700	12,000	18	30
Meganos / Upper Martinez Shale (Primary Confining Zone)	9,900	1,400	--	--	--
Anderson Sandstone (Injection Zone)	11,300	1,300	17,000	20	200

Unit	Depth within the AoR (ft bgs)	Thickness Across the AoR (ft)	Total Dissolved Solids (ppm)	Average Porosity (%)	Average Permeability (millidarcies, mD)
Lower Martinez Shale (Lower Confining Zone)	12,600	1,300	--	--	--

Questions/Comments:

- *Please provide more information on the erosive nature of the Anderson sand contact with Hamilton sands and how far from the AoR it has been encountered?*
- *Please provide a more complete and organized description of the displacement evolution of the presented faults, especially the Midland and Kirby faults.*
- *Please provide the API numbers for the relevant wells within the Brazos Oil and Gas "Concord Gun Club", Hershey Oil "McDougal" and McCulloch Oil "GP 1-7" and "Anderson 5" oil fields. Mark them on Figure A.I-1 or display them on a separate figure.*
- *What is the source of the TDS data from the Brazos Oil and Gas "Concord Gun Club"?*

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

Figure A-3 in the narrative document depicts the proposed injection well IW-A1; the delineated AoR; legacy oil and gas wells (tabulated in Appendix B-1); EPA cleanup and Superfund sites, all located outside of the project AoR; surface bodies of water including the Montezuma Slough, an un-named slough, the Sacramento River; local wetlands; surface sand mining operations; water wells (tabulated in Appendix B-1); and areas with structures intended for human occupancy.

MC notes that no Class I through V injection wells, subsurface cleanup sites, springs, subsurface mines, or quarries are present within the AoR. Several faults and fractures, the previously identified surface bodies of water, public roads, and county boundaries are stated to be located within the AoR; however, these features are either not depicted or not labeled on Figure A-3.

Figure A.I-1 contains a map of regional surface faults around the study area for the project. A cross section of the region is provided in Figure A.I-2. A structure map of the Anderson Sandstone injection zone is provided in Figure A.I-3. A 2D seismic image from approximately 3 miles north of the AoR is provided in Figure A.I-4. Figure A.I-5 contains a generalized stratigraphic column for the project area. Figure A.I-7 is a seismic history map of the Kirby Hills Fault Area. No hydrologic maps are provided in the site characterization document.

Questions/Comments:

- *Please update Figure A-3 to include traces of the faults depicted in Figure A.I-3; also, please label all of the surface bodies of water, roads, and county boundaries mentioned in the narrative.*
- *For clarity, please update Figures A.I-1 and A.I-7 to show the project AoR.*

- *Please provide a map of the study area from Hymes (2010) that demonstrates the relationship of the Shell/LBNL study area to the Montezuma AoR.*
- *What is the source data for Figures A.I-2 and A.I-3?*
- *Please include the approximate location of the planned Injection Well (IW) on Figure A.1-2.*
- *Explain the lack of continuation of the Midland fault through the Neogene Undifferentiated section as depicted in Figure A.I-2.*
- *Clarify what units are being used on the vertical scale for Figure A.I-2. Throughout the document, including the figures, there is inconsistency regarding units being used. Please use units consistently throughout the application.*
- *The labels on Figure A.I-3 are not legible. Please improve the quality of the labels on the figure and include a label for the fault to the right of the Sherman Island Fault. In addition, please include a horizontal scale.*
- *Please provide the source(s) for the stratigraphic column in Figure A.1-4 (the API # of the wells with adequate logs and/or citations for the work that resulted in creation of the illustrated column).*
- *Please provide the isopach maps for the proposed injection formation and all confining formations across the AoR.*

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

Regional surface faults are depicted in Figure A.I-1. The Rio Vista Basin is formed by the Midland fault zone to the east and the Kirby Hills fault zone to the west. Within these fault zones, the pressure front that defines the delineated AoR is confined by the Kirby Hills Fault to the west and the Sherman Island Fault to the east and north (Figures A.I-2 and A.I-3). The Antioch Fault bounds the regional synclinal structure to the south but does not provide pressure confinement.

- The Kirby Hills Fault is a normal fault that dips steeply east and forms the western boundary of the AoR. MC notes that the Kirby Hills Fault is an active fault and shows evidence of Holocene-aged deformation (see
- Seismic History [40 CFR 146.82(a)(3)(v)] below).
- The Sherman Island Fault is a secondary antithetic fault to the Midland Fault, running west of and subparallel to it. The Sherman Island Fault dips moderately to steeply east. MC asserts that the Sherman Island Fault terminates within the Kirby Hills fault zone north of the AoR, forming the northern boundary of the delineated AoR (Figure A.I-4). However, MC notes that available seismic data does not confirm this intersection, which is an objective for the 3D seismic survey planned for pre-operational testing.

MC asserts that that the Kirby Hills and Sherman Island faults will be sealing for formation pressure increases from injection based on regional observations that these faults trap gas in several gas fields in the project area, and MC predicts that the proposed injection zone is not in communication with other reservoirs. MC states that at the Kirby Hills gas field (located about 6 miles north of IW-A1), the Kirby Hills Fault juxtaposes Upper Cretaceous shales against the reservoir zones, trapping gas in the reservoir. MC should provide site-specific evidence to demonstrate that the Kirby Hills and Sherman Island faults will provide pressure confinement within the AoR. For example, direct evidence of pressure compartmentalization may be provided from pressure measurements across the faults within and just outside the AoR or interpreted seismic velocity data. Other lines of evidence include describing how the faults juxtapose the proposed injection zone against impermeable shales within the project AoR, developing Allan charts, providing evidence of catalysis or diagenesis, or calculating shale gauge ratio, as described in the Class VI Site Characterization Guidance.

MC states that no faults or fractures were identified within the AoR as defined by the Kirby Hills and Sherman faults. The 2D seismic image in Figure A.I-4 demonstrates an absence of faulting 3 miles north of IW-A1. MC plans to confirm these assumptions with a 3D seismic survey to be conducted during the siting process for IW-A1.

Questions/Comments:

- *Is any evidence available from within the AoR to support the assertion that the Kirby Hills and Sherman Island faults are pressure-sealing at the anticipated pressures due to injection? Possible lines of evidence include evidence of pressure compartmentalization, descriptions of how the faults juxtapose the injection zone against shales, Allan charts, or demonstration of catalysis or diagenetic sealing. See Section 3.5.2 of EPA's Class VI Site Characterization Guidance for further information.*
- *What evidence is there that the Kirby Hills and Sherman Island faults will contain the CO_2 plume?*
- *Please add the proposed 3D seismic survey to the Pre-Operational Testing Plan. What is the planned extent of the 3D survey area?*
- *Figure A.I-1 illustrates surface and subsurface faults in the vicinity of the AoR, but not all faults mentioned in the text are presented (Kirker fault). Please update the map to include all faults.*

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

Information about the injection and confining zones in the site characterization document is based on a log from the Rio Vista gas field, located approximately 5 miles east of the AoR, as described in Johnson (1992); data from the Sherman Island gas field, approximately 6 miles east of the injection site (MacKevett, 1992); and information in the literature. Because no data are available from within the AoR, pre-operational testing data will be needed to confirm assumptions about the representativeness of this data and reduce uncertainty about the site and the AoR modeling that will be needed for final approval/authorization to inject.

Injection Zone Properties

The middle Paleocene Anderson Sandstone is described as a light gray, fine to medium grained, micaceous quartz sand occurring at a depth of approximately 11,300 ft bgs with an estimated thickness of approximately 1,300 ft (MacKevett, 1992). The structure map for the Anderson Sandstone provided in Figure A.I-3 demonstrates that the injection zone is continuous across the AoR and thickens south-southeast towards the axis of the syncline.

MC notes that, based on logs from gas fields in the area, the Anderson Sandstone is composed of 910 ± 182 feet of sand layers. Based on MacKevett (1992), the average permeability is approximately 200 mD, and ranges from 20 to 400 mD. MacKevett (1992) reports an average sand porosity of 20%, ranging from 16 to 28%. The porosity of the Anderson is listed as 20% on field data sheets from the Kirby Hill gas field. Based on data from the Sherman Island gas field, the Anderson Sandstone's porosity is 29 to 32%. No mineralogy nor capillary pressure data for the injection zone were provided in the site characterization document.

Confining Zone Properties

Meganos / Upper Martinez Shale (Primary Confining Zone)

The lower Eocene Meganos Shale and upper Paleocene Upper Martinez Shale together comprise the primary confining zone. A type log in Johnson (1992) from the Rio Vista gas field (located approximately 5 miles east of the AoR) describes the Meganos as a light to medium gray to black shale, soft, and clayey, and the Upper Martinez as a medium to dark brown, firm, hard, occasionally massive siltstone with light to medium gray claystone. These shales directly overlay the proposed injection zone at a depth of approximately 9,900 ft bgs. They have a combined thickness of approximately 1,400 ft at the proposed project site. Mineralogy, porosity, permeability, and capillary pressure data were not provided in the site characterization document.

Lower Martinez Shale (Lower Confining Zone)

The lower Paleocene Lower Martinez Shale directly underlies the injection zone in the AoR. The type log in Johnson (1992) describes the Lower Martinez as a medium-dark brown, firm, hard siltstone, occasionally massive, with light-medium gray claystone. The unit occurs at a depth of approximately 12,600 ft bgs and is 1,300 ft thick. MC notes that the base of the Lower Martinez is a sand layer, but MC asserts that the overall thickness of the unit should provide suitable confinement. This assertion is acceptable given that MC does not request an injection depth waiver, though an annotated type log would confirm that the thickness of impermeable shale is sufficient to demonstrate the Lower Martinez's effectiveness as a confining layer. Mineralogy, porosity, permeability, and capillary pressure data were not provided in the site characterization document.

Questions/Comments:

- *From where were the porosity and permeability measurements for the Anderson Sandstone taken?*
- *Please explain why data from the Rio Vista and Sherman Island gas fields is considered to be representative of the properties of the injection and confining zones within the AoR.*
- *Are any mineralogy, porosity, permeability, and/or capillary pressure data available for the upper and lower confining zones? If none, please confirm this data will be collected from the stratigraphic test well.*
- *If possible, please provide the logs/cross sections used to identify formation depths and thicknesses.*

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

MC presented limited geomechanical and petrophysical information in the site characterization document. The information provided included formation pore pressures and ranges from mud weights from the Rio Vista and Suisun Bay natural gas fields. The pore pressure data tends to show a consistent increase up until around 10,000 ft depth, at which point the high range of pressure shows a more rapid increase. The range around the depth of the Anderson Sandstone is 6,006 to 7,436 psig as shown on Figure A.I-6. MC established an in-situ stress direction of N35E ± 12 based on regional earthquake focal mechanisms and Rio Vista field borehole breakout data.

The geomechanical and petrophysical data used for modeling as described in the Area of Review and Corrective Action Plan (AoR/CA), are based on regional gas field data and literature. A fracture gradient of 0.71 psi/ft was chosen based on "local information." Table B-4 of the AoR/CA summarized the geomechanical properties of each formation from the Capay Shale down to the Martinez Shale. These properties were calculated using generic values/estimates for the formation type (shale, sandstone).

MC plans to collect site-specific geomechanical and petrophysical data through open hole logging, formation fluid sampling, and coring and analysis. Testing for this data is outlined in the POTP and will include gathering data on properties such as density, compressional and shear measurements, fracture pressure, rock mechanics, and pore pressure. The POTP indicates that data collection to characterize geomechanical properties includes mini-frac and micro-frac stress testing. This pre-operational testing data will be needed for a full geomechanical characterization of the injection and confining zones and to confirm assumptions in the AoR modeling that will be needed for final approval/authorization to inject.

Questions/Comments:

- *Please clarify that the soil coring described in Section A.I.5 refers to rock coring.*
- *Please describe the "mud weights" that are the source of pore pressure data. Provide the list of the wells with mud weights used for Figure A.I-6 as well as the distribution of these wells in relation to AoR.*
- *What is the source of the fracture gradient of 0.71 psi/ft cited in the AoR and Corrective Action Plan? What is the "local information" that serves as the basis for the fracture pressure?*
- *Typically mud weight is measured in pounds per gallon (lb/gal) (ppg) or pound cubic feet (pcf) but they are being reported in ppm in the Formation Pressure section. Please clarify the values and/or units of the mud weights from the Anderson UMC "GP" #1-7 and "Anderson" #1-5.*

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

Seismicity data were obtained from various USGS sources and literature review. The project site area, being bounded by the Sherman Island Fault to the east and Kirby Hills Fault to the west, has an extensive history of seismicity. Figure A.I-7 shows the depth and magnitude of seismic events between 1969 and 2019. A majority of these events occurred at depths ranging from 15 to 20 kilometers (km) within the AoR. Several events also occurred within the northern portion of the AoR at 20 to 60 km depth. Although not as abundant, there are a number of events that did occur within the 0 to 5 km depth. The majority of the seismic events are shown to have a magnitude of <3.0, although there are events of magnitude 4.0 or above with the AoR. The highest magnitude earthquake occurred approximately 8 miles southeast of the AoR in 1889 near Antioch with an estimated magnitude of M 6.0. There appears to be some ambiguity regarding the source of the deeper (>20 km) earthquakes, whether they originate from the San Andreas fault system or the Kirby Hills fault zone.

MC discusses the potential for induced seismicity through pressure diffusion and poro-elastic mechanisms. MC asserts that the project site would not be at risk for induced seismicity based on the following:

- A vertical distance of over 8 miles between the seismic source and the injection interval.
- Vertical separation between the injection zone and the basement rock.
- Impermeable nature of major faults based on historical oil and gas production.
- Lack of induced seismicity, or pressure changes, observed within surrounding fields during years of significant gas extraction (>4 trillion cubic feet).

MC asserts that seismic events that produce fault slips will not compromise the confining shales or the injection wells based on historical research data (Pratt, et. al., 1978), and any slip within the region would be less than the thickness of the confining shales. MC indicated that any faults encountered during drilling of the injection or monitoring wells would result in that well being sidetracked. However, because there is no site-specific geomechanical data, pre-operational testing (as described in Summarized Objectives for Pre-Operational Testing below) is needed to confirm the statements on which the applicant's assertions of low seismic risk are based.

Questions/Comments:

- *Please provide a tabulation of the seismic events in the vicinity of the AoR including their locations, hypocenters, and magnitudes.*
- *Please comment on seismic risk to any partial artificial penetrations within the AoR.*
- *On Figure A.1-7, mark the Sherman Island fault, as referenced in the text.*

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

MC cited data from references/literature to characterize regional aquifers near the project site, including the Sacramento Valley aquifer. The water table depth in the Montezuma Hills is up to 30 m (100 ft) beneath the highest ridges in the central portion of the hills. Based on an average hydraulic conductivity of the Sacramento Valley aquifer of 0.9 m/day, a maximum gradient of 0.01, and an estimated effective porosity of 25%, the site characterization document estimates an estimated maximum linear groundwater velocity of 15 m/yr. Water pressures are hydrostatic from the water table down to the Cretaceous Delta Shale.

The deepest USDW within the region is identified as the Tehama Formation which extends from approximately 2,000 to 3,000 ft bgs. The Tehama is a gravel rich sedimentary formation consisting of marine and non-marine sandstones, siltstones, shales, and conglomerates. This unit is approximately 2,000 ft thick within the project area and has a hydraulic gradient of approximately 0.01. No information was provided regarding the total dissolved solids (TDS) content or direction of groundwater flow in the site characterization document. MC references the Tehama Formation being separated from the proposed injection zones by clay-rich volcanoclastic sandstones, in addition to the primary confining units.

Water wells identified within the AoR are shown on Figure B-17 and listed in Appendix B-2 of the AoR/CA. A total of 60 water wells were identified, including 46 domestic wells, 13 industrial/agricultural wells, and 1 public supply well. The total depths of these wells range from 28 to 773 ft bgs; none of these wells penetrate any confining units.

Questions/Comments:

- *Are any data available about the TDS concentration of the Tehama Formation? On what basis does MC consider this to be the lowermost USDW?*
- *Is the Sacramento Valley aquifer the drinking water supply in the project area? If not, please identify and describe the local source(s) of drinking water.*
- *Please provide potentiometric maps, isopach maps, and cross-sections showing the vertical and lateral limits of the drinking water supply aquifers and USDWs at the project site.*

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

MC described geochemistry data collected from the Anderson Sandstone at the Kirby Hills and Sherman Island gas fields. Field data sheets from the Kirby Hills gas field recorded a salinity of 14,723 ppm at a depth of 5,400 ft, and data sheets from the Sherman Island gas field recorded a salinity greater than 10,000 at a depth of 6,100 ft. MacKevett (1992) cites average TDS content of the Anderson Sandstone of 17,000 ppm and ranging from 13,000-25,000 ppm. The locations of these measurements are not described in the site characterization document. Other geochemical and mineralogical data are not provided in the site characterization document for the injection or confining zones beyond log/core descriptions (see

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

The Site Characterization document does not describe any geochemical modeling but does indicate that MC intends to fill in any data gaps and confirm literature information used for geochemical site characterization. This will be completed as proposed in MC's pre-operational testing. Collection of this site-specific data during pre-operational testing will be important to eliminate uncertainties about CO_2-rock-fluid compatibility. Geochemical modeling is further described within Section B.3.2 of the AoR/CA. The results of the modeling show that the greatest stress changes are within the plume center with some lateral increases towards the east and west boundaries. The vertical stress changes are confined to the plume region and are similar in shape to the plume outline. MC will update this model as additional data becomes available from site-specific site characterization.

Site Suitability [40 CFR 146.83]

Facies Changes

MC states that the Anderson Sandstone injection zone is composed of two main sand packages separated by a shaley interval, based on log interpretation (though these logs are not provided). Facies changes are shown on cross section figures generated from 2D seismic data collected 3 miles outside of the AoR and depicted in the regional stratigraphic cross sections on Figures A.I-2 and B-2. These sections include the MC study area and the bounding Kirby Hills and Midland Faults. The various formation changes are also shown on the stratigraphic column in Figure A.I-5. Because no lithology data for the injection or confining zone are available from within the AoR, collection and evaluation of site-specific data from within the AoR is necessary to identify whether any localized heterogeneities or facies changes have the potential to affect the storage or confinement of CO_2.

Structural Information

Based on regional study information and available seismic data, the proposed project site is situated within a fault bounded asymmetric south-southeast plunging syncline structure (Figures A.I-2 and A.I-3). The major faults that bound the AoR to the east and west are asserted to be sealing faults that provide structural trapping based on trapping observed at regional gas fields. The Anderson Sandstone injection zone is thickest along the axis of the syncline, as it is eroded west of the Kirby Hills Fault by an unconformity and thins out to the east towards the Midland Fault.

CO_2 Stream Compatibility

No discussion of CO_2 compatibility with the injection or confining zone was provided in the site characterization document. However, no site-specific mineralogical data were presented for this formation, including a discussion of any secondary clay minerals, carbonates, or magnesium/calcium-bearing silicates, so solids and fluid geochemistry of the injection zone will need to be collected from within the AoR to confirm assertions of CO_2 stream compatibility at the project site location. Collection of this data is included in MC's POTP; however, benchtop tests to confirm compatibility are not described.

Storage Capacity

Based on MC's plume and pressure front simulation model, the Anderson Sandstone at the project site can store a volume of one MMtonnes per year for 40 years over a predicted plume extent of a 1.3 km radius. These capacities are based on the studies conducted as part of the Shell/LBNL study.

Confining Zone Integrity

Based on the reported regional characteristics of the primary confining zone, as interpreted by data from the Shell/LBNL study and seismic data, the Meganos / Upper Martinez shales consist of thick (~1,400 ft), clay rich shale and are laterally continuous across the AoR. The Lower Martinez Shale provides lower confinement and appears to be laterally continuous. Although the major faults identified in the area transect the upper and lower confining zones, they occur along the boundaries of the AoR and are considered to be sealing faults that act as structural traps (as evidenced by historical gas field data). Since there is no site-specific evidence that the Kirby Hills and Sherman Island faults will provide pressure confinement within the AoR, further data is requested to demonstrate that these faults are sealing (see

Faults and Fractures [40 CFR 146.82(a)(3)(ii)] above). The results of planned pre-operational testing to determine the geomechanical properties of the confining zone will be needed to confirm assertions about the integrity of the Meganos / Upper Martinez and Lower Martinez shales.

Secondary Confinement

Site-specific data on the primary confining zone are limited, but there are no indications that, if pre-operational testing confirms assertions about the confining zone, identification of a secondary confining zone would be required. MC identified the Capay and Nortonville shales as additional confining units intended to contain potential future injection into the Domengine and Hamilton sands.

These units are hundreds of feet thick and are also present throughout the project site area, with the exception of the Capay along the western edge of the AoR where it is shown to be eroded by the Kirby Hills fault zone.

Questions/Comments:

- *What wells provided data to determine stratigraphic formation extent and vertical facies changes, and where are they located? Are any located within the AoR?*
- *Please describe any geochemical modeling or benchtop laboratory experiments performed to evaluate the compatibility of the CO_2 injectate with formation solids and fluids. If none have been performed, please add this analysis to the POTP.*

Site Geomodel

For the Montezuma project, MC contracted UC Berkeley and LBNL to develop a 3D continuum finite-element model of the site geology using TReactMech (V4.213) geomechanical simulator software and model the CO_2 plume and pressure propagation using the equation of state TOUGH reservoir simulation package ECO2N V2.0. The AoR/CA describes the site geomodel MC created for the AoR delineation. MC's geomodel appears to accurately represent the site characterization data as described in the site characterization document, and there are no initial concerns with the methodologies used to construct the geomodel. However, MC does not specifically describe what data was used, i.e., whether it was from wireline logging, seismic, and/or core data from available wells located near the proposed facility. MC references data from the Shell/LBNL CO_2 injection pilot study, and the data appears to be from gas fields. Details of the geomodel are discussed below:

- MC used a variety of methods to model two-phase water/gas behavior, including the TOUGH EOS (Pan, Pruess, and Spycher), Henry's solubility model, brine viscosity correlation (Kestin, Khalifa, and Correia), Rowe-Chou correlation, and Land's correlation. These methods were used to calculate phase properties, including brine density due to CO_2 dissolution, brine solubility, and hysteresis CO_2 trapping. However, they are not based on site-specific geochemical measurements. MC elected to not incorporate geochemical reactions into the simulations, instead applying non-isothermal conditions to all multiphase simulations.
- MC used a rectangular cartesian grid system with a 146 x 146 x 148 grid cell layout totaling 3,154,768 grid points. The model area is 6 (east to west) by 18 (north to south) kilometers, measuring a total of 41.7 square miles and extending beyond the AoR boundary. The Anderson injection zone was subdivided into 16 layers, each 24.77 meters thick. Figure B.3 illustrates an example of the 3-D reservoir model grid and formation permeabilities, each with the superimposed CO_2 plume at 30 and 40 years. The model accounted for the overlying Meganos / Upper Martinez shales and underlying Martinez Shale Formations, in addition to the potential future Hamilton Sandstone injection zone and overlying Capay Shale. This appears to accurately represent the vertical facies distribution when compared to data on known stratigraphy for the project area (Figure A.I-5). As site-specific data are collected from within the AoR during pre-operational testing, the grid inputs should be revised as necessary to reflect any heterogeneities identified.

- MC describes the five formations modeled (which are summarized on Table B-2), which include the Capay, Hamilton, Meganos / Upper Martinez, Anderson, and Lower Martinez formations. Table B-2 provides the hydrological and thermal properties for each formation used in the 3-D reservoir model.
- MC designed the model as a no-flow boundary system based on the bounding fault systems to the west (Kirby Hills), the north and east (Sherman Island Fault), and the thinning out of the Anderson Formation to the south.
- Injection zone porosity and permeability conditions in the model are summarized in Table B-2. These values for the injection and confining zones are consistent with values reported in the site characterization document (though these are assumed values based on regional studies). Shale permeability data used in the model ranged between 10 to 100 nanodarcies (nD) based on the estimated values for each layer in Unruh et al. (2016). This range has no analog in the site characterization document.
- Table B-3 presents the planned injection pressures at well IW-A1. The injection pressure of 2,291 is based on a fracture gradient of 0.71 psi/ft and is equal to 90% of the assumed fracture pressure minus the reservoir initial pressure based on estimates from local information. MC does not clarify the source of this information.
- Initial reservoir pressure and temperature conditions are based on generic values for sandstones and shale, and local information. The reservoir pressure within the Anderson injection zone is 4,905 psi at a depth of 11,341 ft, based on a pressure gradient of 0.433 psia/ft. The reservoir temperature of 96.46°C is based on a geothermal gradient of 22.7 °C/km. Based on MC's reported pressure and fracture gradients, these values are inconsistent with those reported in the site characterization document from the Sherman Island Gas Field (approximately 6 miles updip and east of the injection site), where the reservoir pressure for the Anderson was 3,122 psi with a temperature of 152°F at a depth of 6,100 ft.
- Initial injection zone salinity is assumed to be 16,658 mg/L. This was based on local literature values and is generally consistent with data reported in MacKevett (1992) as described under
- Injection Zone Geochemistry [40 CFR 146.82(a)(6)].

The data inputs to the site geomodel appear to be generic values or based on regional information, and are generally consistent with the data collected and described in the site characterization document, except as noted above. The data used for the model should be confirmed with the collection of site-specific data from within the AoR during pre-operational testing to affirm their appropriateness as modeling inputs (or the model revised) to generate a final approvable AoR.

Summarized Objectives for Pre-Operational Testing

Per the site characterization document, the geologic characterization of the proposed site is based on data collected at the US DOE Shell/LBNL CO_2 injection pilot study. As described in their POTP and in Section A.I-5 of the site characterization report, MC plans to collect site-specific information during the drilling and construction of the injection well IW-A1 and monitoring well IZMW-A1 (of which, one may be used as a stratigraphic test well). According to the Testing and Monitoring Plan, IZMW-A1 will be located approximately 1,400 ft southwest of IW-A1 (Figure E.3 of the T&M plan). Open hole and cased hole logging will be performed to collect in-situ structural, stratigraphic, petrophysical, chemical, and geomechanical data for the injection and confining zones (e.g., density, compressional and shear measurements, fracture, rock mechanics, and pore pressure). Geophysical logging will be conducted during the drilling and completion of the injection well including gamma ray, neutron porosity, resistivity, spontaneous potential, formation micro image, pulsed neutron spectroscopy, high-definition nuclear magnetic resonance, and wireline formation testing.

Whole core rock samples will be collected from the injection and confining zones (including lower confinement) at IZMW-A1 for laboratory analysis of formation properties and for mineralogical analysis. Whole cores will be collected from the potential injection zones only at IW-A1. Additionally, sidewall core samples will be collected, and the depth of the samples will be determined during logging. Analysis of the cores will include core description, fracture analysis, fluid saturation, permeability, porosity, grain density, x-ray diffraction and fluorescence, mercury injection capillary pressure, mechanical properties testing, and fracture pressure.

Fluid samples will be collected from each potential injection and confining zone formation during drilling or following well completion. Laboratory analysis and testing parameters were not specified within the POTP, but Table E-12 in the Testing and Monitoring Plan summarizes analytical and field parameters for fluid sampling.

MC will perform a pressure fall-off test, an injectivity test, and a step rate test to determine reservoir properties and hydrogeologic characteristics of the injection zone and validate assumptions about formation fracture pressure. Step rate testing will be performed to determine in situ formation stress and analyze the stress field within the injection and confining zones. The POTP also indicates that data collection to characterize geomechanical properties includes mini-frac and micro-frac stress testing.

The logging and tests outlined in the POTP will characterize site-specific structural, stratigraphy, physical, chemical, and geomechanical properties of the injection and confining zones that is needed to confirm assumptions that the applicant has made based on injection studies, literature, and available regional well data used for the application. This should reduce uncertainty about the geologic characterization of the site and ultimately support approval of the AoR delineation before MC may be authorized to inject CO_2.

Question/Comments:

- *Please describe the analytical methods and parameters for fluid analysis in the injection and confining zones. EPA recommends that they be consistent with those described in the Testing and Monitoring Plan.*

Based on the permit application and EPA's evaluation, the following pre-operational testing objectives should be fulfilled during the drilling of the injection and monitoring wells:

- Correlate available research and regional 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.

- Verify that any localized heterogeneities or facies changes in the injection or confining zones will not affect the storage or confinement of CO_2.
- Confirm the storage capacity of the Anderson Sandstone formation based on site-specific data (e.g., porosity, pressure, and temperature) and planned operational data (CO_2 density).
- Characterize the baseline geochemistry of the injection zone, the Meganos / Upper Martinez, the Tehama Formation, and the shallow and deep aquifers to provide a baseline for future monitoring.
- Perform geochemical modeling or benchtop laboratory experiments to demonstrate compatibility of the formation fluids and rock of the injection and confining zones with injected CO_2, including how geochemical interactions may affect porosity, permeability, injectivity, and storage capacity due to mineralization, mineral precipitation, dissolution, or other processes.
- Establish site-specific pressure, salinity, and temperature initial conditions in the Anderson Formation.
- Establish the TDS of the Tehama Formation and confirm the depth of the lowermost USDW.
- Demonstrate the integrity and the viability of the Meganos / Upper Martinez shale formations as confining layers in the AoR.

While the Nortonville Shale, Domengine Sandstone, Capay Shale, and Hamilton Sandstone, which are identified as future potential injection and confining zones, are not the subject of this evaluation, EPA recommends that MC perform similar testing of those formations to facilitate future permitting efforts.

ENCLOSURE
Request for Additional Information
Endangered Species Act and National Historic Preservation Act
Montezuma NorCal Carbon Sequestration Hub
Underground Injection Control (UIC) Permit Application
Class VI Pre-Construction Permit Application No. R9UIC-CA6-FY23-4

In addition to the information requested in the other enclosures, we reviewed the information provided for Endangered Species Act (ESA) and National Historic Preservation Act (NHPA) compliance and determined additional information is needed. Please note that delays in providing the requested information could result in delays processing the permit.

Endangered Species Act

The ESA requires EPA to ensure, in consultation with the U.S. Fish and Wildlife Service (FWS), that any action authorized by EPA is not likely to jeopardize the continued existence of any endangered or threatened species or adversely affect its critical habitat. In accordance with the 50 CFR Section 402.12, EPA must make a determination, based on the best available information, whether there are any potential effects from the proposed project/permit to endangered, threatened species or critical habitat that may be found in the action area. Montezuma Carbon provided EPA with a Memorandum of Preliminary Assessment of Biological Resources for the Montezuma Carbon LLC NorCal Sequestration Hub Project. While the memo provided an initial review of the resources present at the site, we request the applicant provide a draft Biological Evaluation to assist with our ESA determination. The draft BE should:

- Describe all activities that are likely to occur as a result of the federal action (i.e. issuing the permit), including construction and operation of the facility. Refer to 50 CFR Section 402.17(a).
- Clearly define the action area. The action area shall include all areas that will be affected directly or indirectly by the federal action, and not merely the immediate area involved in the action.
- Identify the listed species and critical habitats that may occur in the action area. For the species under the U.S. Fish and Wildlife Service (FWS) jurisdiction, you can obtain a current report from the Information for Planning and Consultation database (IPaC), https://ecos.fws.gov/ipac/. If the action area includes areas where species are under National Marine Fisheries Service (NOAA Fisheries) jurisdiction, you will also need a species list from NOAA Fisheries.
- Describe each species and critical habitat that may occur in the defined action area. See the FWS Environmental Conservation Online system for resources related to this item: https://ecos.fws.gov/ecp
- Describe the potential effects to each species and critical habitat that are likely to occur as a result of the federal action and projects. Given the number of listed species and the presence of critical habitat identified in the resource assessment provided, we believe it is appropriate to seek technical assistance from the FWS and/or the NOAA Fisheries to understand the potential effects to each species and critical habitat. In addition, you may need to hire a consultant or

biologist familiar with the ESA to assist with analysis of potential effects to each species and critical habitat.

- Recommend effects determinations for each of the species and critical habitats. EPA must determine whether the action may affect each species and critical habitat, and for those species and critical habitats that may be affected, whether adverse effects are likely. EPA will consider recommendations supported by the analysis in your document when making our determinations.

National Historic Preservation Act

The National Historic Preservation Act (NHPA) §106 requires a federal agency to take certain steps before it commits to any "undertaking" including the issuance of a permit or license, that has the potential to adversely affect property that is listed, or eligible for listing, in the National Register for Historic Places. The NHPA requires EPA, before issuing a permit, to adopt measures when feasible to mitigate potential adverse effects of the permitted activity and properties listed or eligible for listing in the National Register of Historic Places. The Act's requirements are to be implemented in cooperation with State Historic Preservation Officers and upon notice to, and when appropriate, in consultation with the Advisory Council on Historic Preservation.

Montezuma Carbon provided EPA with a Cultural Resources Report from the 2001 Montezuma Wetlands Project. To facilitate EPA's consideration of NHPA compliance for the Montezuma Carbon proposed project, we request that you provide an updated report with an appropriately defined Area of Potential Effect (APE) for this project. In the updated report, you should identify the Historic Places designated in the National Register for Historic Places (https://www.nps.gov/subjects/nationalregister/database-research.htm) in close proximity to the project site and please provide a list of the historic places near the site. Based on the results of your review of the National Register of Historic Places listings in Solano County, you may need to hire an archaeologist to provide additional analysis or otherwise show how your project will not adversely affect the identified historic places located near the project site. When you submit this information to EPA, please include any comments or reports made by an archaeologist, if applicable.