CLASS VI PERMIT APPLICATION NARRATIVE
40 CFR 146.82(a)

Sutter Decarbonization Project, Northern California

1.0 Facility Information

Facility name: Sutter Energy Center
CCS 1 Well
CCS 2 Well
CCS 3 Well

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2.0 Project Background and Contact Information

2.1 Project goals

The Sutter Energy Center (SEC) is a 525 megawatt (MW) natural gas combined cycle powerplant that produces up to 2.0 million tons of CO_2/year. The SEC is located approximately 17 miles southwest of Yuba City in Sutter County, California.

The Sutter Decarbonization Project ("Project") will geologically store the carbon dioxide (CO_2) captured from the SEC, in strata of the Late Cretaceous Starkey sandstones of the Sacramento Basin (Storage Facility) The proposed Storage Facility is located in Sutter County, approximately 15 miles from the SEC.

This application is for three UIC Class VI CO_2 injection wells (CCS1, CCS2, and CCS3) associated with the Project.

Using a conservative estimate of the total available pore space acreage, the proposed Storage Facility has the capability of storing over 50-million metric tons (MMt) of CO_2. The current Project is designed to inject over a 12-year period. Based in part on the results of the Sutter Decarbonization Project, additional field development work may be considered. CO_2 captured by the Project will be delivered to the Storage Facility via a regulated pipeline extending approximately 15.7 miles from the SEC to the Storage Site.

The Project construction schedule is currently pending, but the Commercial Operation Date anticipates the Project will be completed and operational in 2027.

In the early stages of project development, Sutter CCUS will apply for necessary and applicable permits for federally regulated and state regulated activities as necessary. These permits will cover activities related to transport, storage, and construction for the project.

2.2 Ownership

Sutter CCUS, LLC will hold the permits and authorizations necessary for the SEC carbon capture facility and the pipeline. Calpine California CCUS Holdings, LLC, a parent company of Sutter CCUS, is the applicant for the UIC Class VI CO_2 injection well, CCS1. 1PointFive Sequestration Hub, LLC (1PointFive) will own and operate the proposed Storage Facility.

Contact for the Applicant is:

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The documentation included in this UIC Class VI Permit application was prepared in accordance with the U.S. Environmental Protection Agency's (US EPA's) *UIC Control Program for Carbon Dioxide Geologic Sequestration Wells* (The Geological Sequestration [GS] Rule, codified in Title 40 of the Code of Federal Regulations [40 CFR 146.81 et seq.]).

Neither an injection depth waiver nor an aquifer exemption expansion is being requested.

There are no federally recognized Native American tribal lands or territories within the proposed Area of Review (AoR). The proposed area of review (AoR) has no known critical cultural sites or sites of archaeological significance. There is one known place of worship and one known cemetery within a 1-mile buffer zone surrounding the AoR. There are no known schools, hospitals, or nursing homes within the AoR or buffer zone surrounding the AoR.

2.3 Applicable permits

[The information is Confidential Business Information per 5 U.S.C. § 552 (b)(4) and (b)(9).]

GSDT Submission - Project Background and Contact Information
GSDT Module: Project Information Tracking ***Tab(s):*** General Information tab; Facility Information and Owner/Operator Information tab Please use the checkbox(es) to verify the following information was submitted to the GSDT: ☐ Required project and facility details ***[40 CFR 146.82(a)(1)]***

3.0 Site Characterization

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

3.1.1 Starkey Storage Complex

The term "subsurface storage complex" refers to the geologic storage site that is targeted to safely and permanently store injected CO_2 underground within a storage formation with at least one, or usually multiple, regionally continuous sealing formations called caprocks or seals (NETL 2023). The Sutter Decarbonization Project is proposing storage into the Starkey Storage Complex consisting of the Winters Formation and the Sacramento Shale, a base restrictive interval for CO_2 injection, the injection reservoir, the Starkey Formation, which rests unconformably beneath the Capay Formation, a prominent regional stratigraphic marker and upper the seal of the Starkey Storage Complex. The complex consists of a basal confining interval, an injection reservoir, and an upper seal. The stratigraphic relation of these formations is shown in **Error! Reference source not found.**.

A well cross-section located one township north of the project area (**Error! Reference source not found.**) illustrates the project area, located on the downthrown side of the Willows Fault, and the lateral continuity of the Starkey Storage Complex and the underlying Kione Storage Complex, which is without a lateral seal. The Cretaceous Kione Storage Complex, a potential future target for injection operations, (**Error! Reference source not found.**) consists of the basal Forbes Formation, a shale with interbedded sandstone lenses, the overlying Kione Sandstone injection zone, and the upper Sacramento Shale, a regional shale and primary upper seal.

Regional mapping and computational modeling outputs have projected the stratigraphic tops for the Starkey Storage Complex at the proposed stratigraphic test location, shown in **Error! Reference source not found.**. The projected stratigraphic tops for the stratigraphic test well are presented below in Table 1.

3.2 Regional characterization

3.2.1 Injection reservoir

The Starkey Formation occurs throughout much of the southern Sacramento Basin, angular unconformities truncate the formation in the subsurface to the north, east, and west (Downey 2010). The Starkey Formation consists of a series of fluvial-deltaic sediments sourced from the Sierra Nevada during the late Cretaceous. The delta depositional system prograded basin wards directed from the East and Northeast towards the South and Southwest. In the literature, three distinct facies are identified: (1) delta front, (2) lower delta plain, and (3) upper delta plain/fluvial. Formation heterogeneity may reduce reservoir quality but improve the likelihood of vertical and lateral trapping of CO_2. The Richter #8-4 well situated west of the Willows Fault zone, identified with a red circle on the west end of the C-C' cross section, (**Error! Reference source not found.**a) has a log signature in the Starkey Formation consistent with a coarsening-upward channel facies (**Error! Reference source not found.**b) in a progradational setting of the delta front. **Error! Reference source not found.** is a compilation of the stratigraphic tops for the Starkey Storage Complex within the Richter #8-4.

The Starkey Formation is separated into the upper Starkey and the Starkey Clean Sand (shown in the Richter #8-4 geophysical log traces and reflected in stratigraphic tops). The upper Starkey Formation (**Error! Reference source not found.**) has been inferred to be a distributary channel environment with overbank thin sands and shales (Edmondson, 1977).

The Starkey Clean Sand (**Error! Reference source not found.**) or Starkey sand occurs as shallow as 1,000 feet in southern Sutter County, and dips basin ward to over 11,000 feet deep in south-central Solano County; porosities of 25 – 35% are typical in the Starkey Clean Sand shallower than 9,000 feet (Downey, 2010). The Starkey Clean Sand is a sequence of deltaic sands and intertonguing shales that conformably overly, and prograde westward over the underlying formations. The Starkey Formation and Winters Formation are different facies of the same depositional system and were contemporaneously deposited (Johnson, 1990).

The Starkey Formation is located below 2,600 ft (800 m) on the downthrown side of the Willows fault zone, which implies that CO_2 should be in the required super-critical dense phase.

3.2.2 Confining zones

The Sacramento Shale (**Error! Reference source not found.**) is a regional shale below the Winters Formation. On petrophysical logs, the Sacramento Shale is characterized by low density and slow velocities on the sonic log. The Sacramento Shale is also a source rock in the Delta depocenter to the south of the project area (Magoon, 1995). The Sacramento Shale outcrops in the southern Coast Ranges south of the Rumsey-Capay Hills and in the northeastern Diablo Range (Nilsen, 1990).

The Winters Formation (**Error! Reference source not found.**) is mostly shale in the project area, it was deposited in a silt and shale-rich slope environment often referred to as the "Delta Shale" (Nilsen, 1990). The Delta Shale is nearly all clays and fine clastics, most of the coarse clastics from the shelf were distributed through channels to the basin floor (Drummond, 1976); the Winters sand deposition starts in the southwest of the study area. The Delta shale is continuous with the Winters shale in areas where the Winters sand was not deposited (Johnson, 1990). The maximum thickness of the Winters Formation occurs along the axis of the basin. The Winters Formation and Sacramento Shale may appear as one thick shale on geophysical logs; however, these are two separate shales, identified with low density/slow velocity in the Sacramento Shale, which the Winters Shale lacks. The Winters acts as a base seal for CO_2 injection into the overlying Starkey Clean Sand.

The Capay Formation (**Error! Reference source not found.**) is the upper sealing unit to the Starkey Storage Complex. The Capay Formation is a prominent regional stratigraphic marker due in part to abundant fossil assemblages that are indicative of deposition in the early Eocene. Micropaleontologic data indicate that the lower portion of the Capay was deposited in an outer-neritic environment whereas the upper portion was deposited in an inner-neritic to brackish-water environment (Johnson, 1990). This shale deposition represents the last major transgression in the Lower Eocene; the Capay Formation rests unconformably on top of the Starkey Formation.

3.3 General Geologic History of the Region

The Sacramento Basin represents the northern extent of the Great Valley forearc basin of California. The forearc basin existed for 80 million years of the Mesozoic (Williams and Graham, 2013) between magmatic arc rocks of the Sierra Nevada and Klamath Range to the east and the Franciscan accretionary prism complex of the California Coast Ranges to the west (**Error! Reference source not found.**) (Ingersoll, 1979). Siliciclastic fill of this elongate, asymmetric basin is comprised of the Upper Jurassic or Lower Cretaceous (Surpless et al., 2006) to Paleogene Great Valley Group. The Great Valley Group was deposited on the Jurassic age Coast Range Ophiolite in the west and to the east on igneous and metamorphic rocks of accreted Paleozoic terranes (Dickinson and Seely, 1979). The Great Valley Group consists of predominately deep-marine sediments sourced from continental magmatic arc rocks to the east and north (Figure 9). Subduction related tectonism is interpreted to control tilting and subsidence of the basin, which subsequently influenced submarine canyons, channels and associated turbidite-dominated sediments in the forearc basin (Williams and Graham, 2013).

Conversion of the California plate margin from convergent to transform during the Cenozoic allowed for preservation of the forearc basin strata (Dickinson and Seely, 1979). Subsequent uplift and deformation of the basin along its western margin is represented by homoclinal folding, uplift, and erosion of the Mesozoic forearc basin fill. Cenozoic deformation of the forearc basin strata is attributed to lateral convergence, transpression, across the San Andreas fault system (Dickinson, 1979; Harwood and Helley, 1987).

The late Cenozoic structural setting of the Sacramento Basin represents a distinct tectonic regime between the Coast Ranges province to the west and the Basin and Range province to the east. Late Cenozoic deformation in the Sacramento Basin has occurred in a stress regime with the maximum component of compressive stress oriented roughly east-west and the minimum compressive stress oriented north-south (Harwood and Helley, 1987). This stress regime has resulted in strain patterns that have developed high-angle reverse faults and folds that trend north-northwest through the Sacramento Basin. This style of deformation is in direct contrast to east-west oriented thrust faults, northwest trending folds and pull-apart basins related to right-lateral displacement along the San Andreas fault system to the west and pervasive east-west extension and volcanism of the Basin and Range province to the east.

Major Geologic Features

Major geologic and structural features include the following:

- The Sutter Buttes
- Willows-Corning fault zone
- Coast Ranges-Sierran Block Boundary Zone (CRSBZ)
- Sierra Nevada Frontal fault system

The Sutter Buttes represent a late Cenozoic volcanic center that is located over the tectonic boundary between oceanic basement rocks comprised of Jurassic ophiolites to the west against metamorphic and plutonic rocks of the Sierran basement (**Error! Reference source not found.**). This tectonic boundary between basement terranes is interpreted to roughly coincide with the location of the Willows fault zone to the southeast of Sutter Buttes (Harwood, 1984; Harwood and Helley, 1987). Volcanism occurred between 2.4 and 1.4 Ma and uplifted and deformed the surrounding sedimentary rocks into a dome 8 miles across (Williams and Curtis, 1977).

The Willows-Corning fault zone is part of a N-NW-trending, W-vergent, high-angle basement-involved reverse fault system that is penetrated by wells and imaged on seismic reflection data (**Error! Reference source not found.-Error! Reference source not found.** and **Error! Reference source not found.-Error! Reference source not found.**) (Harwood and Helley, 1987, Williams and Graham, 2013). The Willows fault zone extends from the NW corner of the Sacramento Basin, west of Red Bluff, for ~135 miles to the S-SE edge of the basin south of the town of Rosemont (**Error! Reference source not found.**). Displacement along the Willows fault and related folding postdates deposition of Upper Cretaceous forearc sediments and precede deposition of the Capay Formation, occurring between 60 and 53 Ma (Harwood and Helley, 1987). Williams and Graham (2013) interpret a component of dextral strike-slip displacement along the Willows-Corning fault zone in addition to previously documented reverse displacement. The Willows-Corning fault zone is not thought to have any Pliocene to Quaternary deformation associated with it and is discussed further in the Faults and Fractures section.

The western margin of the Sacramento Basin is marked by the Coast Ranges-Sierran Block Boundary Zone (CRSBZ), a zone of compressional reverse/thrust and strike slip faulting between the Coast Ranges and the Sierran Block (**Error! Reference source not found.**). This zone is characterized by seismically active blind thrusts associated with tectonic wedging. One such structure is interpreted beneath the Dunnigan Hills region directly to the west of the AoR and is discussed in further detail in the historical seismicity section (**Error! Reference source not found.**).

The Sacramento Basin is bordered to the east by the Sierra Nevada foothills (**Error! Reference source not found.**). The Sierra Nevada Frontal fault system, or Foothills fault system, separates Paleozoic and Mesozoic metamorphosed volcanic and sedimentary rocks that have been intruded by granitic plutons of Jurassic to Cretaceous age from the Great Valley sequence of the forearc basin (Clark, 1960, Wong, 1992). The Foothills fault system is characterized by Clark (1960) as steeply east-dipping to near vertical faults that are complex zones of sheared, cataclastic rocks that tectonically separate Paleozoic and Mesozoic rocks of the Sierra Nevada to the east from forearc sediments of the Sacramento Valley.

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

The Sutter Decarbonization Project AoR contains a total of 150 water wells and 53 oil and Gas wells (**Error! Reference source not found.**, **Error! Reference source not found.**, Table). Of these wells, 47 penetrate the Starkey Storage Complex.

The upper confining unit, the Capay Formation, is laterally continuous across the AoR in both North-South and West-East directions and there are no indications from the geophysical well sections (**Error! Reference source not found.** and **Error! Reference source not found.**) of lateral pinch-outs. The Capay Formation is thinnest in the northern section of the AoR and thickens to the south. This relationship will be confirmed upon the interpretation of the 3D seismic acquisition as part of the PhaseII Carbon Safe stratigraphic test well evaluation. The Capay Formation marks the base of the lowest USDW and is an average of 145 feet in the modeled area.

The full injection complex, the Starkey Formation, has been separated into two distinct intervals: the upper Starkey, which has a higher volume of shale in the interval and more variability in the facies and petrophysical parameters. The upper Starkey interval is continuous throughout the AoR and has a fairly consistent thickness (250 feet). The target injection zone is the Starkey Clean Sand, it is laterally continuous with little variability in facies or thickness throughout the AoR (392 feet). The petrophysical properties of the Starkey Clean Sand are also consistently better than the upper Starkey interval. Both Starkey Formation intervals follow the regional trend of thickening to the south.
Further discussion of the regional geology, primary seal thicknesses, and lateral extent, injection zone thickness, and other site-specific geologic characteristics is discussed in the Regional Geology and the Injection and Confining Zone Details sections of this document. Information concerning the faults and fractures and their spatial relation to the injection wells is further discussed in the Faults and Fractures section of this document.

4.1 Regional Cross Sections

4.1.1 East-West Cross Section

[The information is Confidential Business Information per 5 U.S.C. § 552 (b)(4) and (b)(9).]

4.1.2 North-South Cross Section

[The information is Confidential Business Information per 5 U.S.C. § 552 (b)(4) and (b)(9).]

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

4.2.1 Willows-Corning Fault Zone

The Willows-Corning fault zone extends from the NW corner of the Sacramento basin for ~135 mi to the SE corner of the basin, passing through the NE corner of the AoR (**Error! Reference source not found.**). The fault zone is imaged by seismic reflection data and observed on well cross-sections. In the northern portion of the Sacramento Basin the fault zone splays into several disparate fault strands, including the Corning fault, whereas it is delineated as a single fault strand through the central and southern portions of the basin (**Error! Reference source not found.**). The Willows-Corning fault zone is a basement involved structure that displays reverse offset and was active throughout the Paleogene and Neogene (Harwood and Helley, 1987). Based on stratigraphic relationships reminiscent of structural inversion in the northern Sacramento Basin, Williams and Graham (2013) infer a component of dextral strike-slip displacement on the Willows-Corning fault system in addition to previously documented reverse displacement.

The Willows-Corning fault zone transects the confining zone intervals of the lower Maastrichtian to upper Campanian Starkey Formation and the lower Campanian Kione Formation. North of the AoR the main strand of the Willows fault zone displaces ophiolitic basement rocks by ~550 ft and the Eocene Capay formation by ~330 ft with eastside up reverse motion (**Error! Reference source not found.**)(Harwood and Helley, 1987). South of the AoR the Willows fault zone displaces the Capay Formation by ~100 ft, the Starkey Formation by ~150 ft, and ophiolitic basement rocks by ~500 ft (**Error! Reference source not found.**)(Harwood and Helley, 1987).

Further delineation and characterization of the Willows-Corning fault zone is required to address uncertainty around the fault system's stability and sealing capacity. 3D seismic reflection data as part of the CarbonSAFE PhaseII program will help to better understand stratigraphic and structural relationships both across and along the fault zone. The proposed seismic program will additionally allow for characterization of any additional faults and related structures in the AOR. The stratigraphic test well and associated coring program proposed as part of the CarbonSAFE PhaseII project will provide critical rock property, pore pressure, and geomechanical data that will allow for fault zone stability and fluid flow properties to be analyzed. The stratigraphic test well will additionally provide the data necessary to determine fracture presence, density, and orientation within the AoR.

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

4.3.1 Depth, areal extent, and thickness of the injection and confining zones

Geophysical logs from 22 wells, well tests, and data collected from published literature were used to characterize the injection and confining zones for this project. Additionally, sidewall core analyses from an analog field 50 miles south of the AoR were used to support the conclusions from well and published data. Further data collection in the AoR including the Phase II CarbonSAFE stratigraphic test well and associated tests summarized in the Pre-Operational Testing section will be used to better constrain subsurface uncertainties. Isopachs and a Stratigraphic Column for the Starkey Storage Complex are in the Regional Geology, Hydro, and Local Structure section of this Permit (**Error! Reference source not found.** and **Error! Reference source not found.-Error! Reference source not found.**).

4.3.2 Starkey Formation

The Upper Cretaceous Starkey Formation is a part of a series of deltas sourced from the Sierran arc that prograded to the west and southwest (Cherven, 1983; Downey, 2005; Garcia, 1981). These delta cycles provided sand-rich submarine fan, slope, and basin plain sediment to the shelf edge feeding the Lathrop, Winters, Blewett, and Tracy Formations (Downey, 2005; Garcia, 1981). The cyclical nature of the Starkey delta system and its evolution from a cuspate wave-dominated system with upward coarsening delta facies to a highly lobate system with moderately developed delta plain facies resulted in a high degree of variability to both the lateral and interbedded depositional facies of the Starkey Formation (Cherven, 1983).

Regionally, sandstones of the Starkey Formation can range from a few feet to a few hundreds of feet in thickness with maximum thicknesses upwards of 1500 feet. Porosities for sandstones at the depths below 2900 feet (ft), deeper than the required depth to retain injected CO_2 in the supercritical phase (2600 ft), range from 14–17%, while shallower sandstones can have average porosities of 30%. There is a single study of permeability data for sandstones in the Starkey Formation in the Sacramento Basin, where values of 50–100 md were reported (California Department of Conservation, 1983).
Geophysical logs show that the Starkey Formation has two distinct zones in the AoR. They have been separated as the Starkey (upper) and the Starkey Clean Sand (lower). The Starkey (upper) is on average 250 feet thick in the AoR and the Starkey Clean Sand averages 392 feet in thickness. Porosity and permeability data for each zone is discussed below. The Starkey Clean Sand is located below 2600 feet of depth on the downthrown side of the Willows fault, which suggests that CO_2 can be stored in the super-critical dense phase.

4.3.3 Capay Formation

The Capay Formation, which lies unconformably above the Starkey Formation, is the uppermost sealing unit and a prominent regional stratigraphic marker in well logs. South of the AoR at Bunker Gas Field, Solano County, CA, the Capay shale is described as claystone, interbedded with shale and siltstone (Shariff, 1983). North of the AoR in the Sutter Buttes area, the Capay Formation is described as greenish-gray shale and claystone with buff-colored sandstone interbeds and ranges from 250 to 400 feet in thickness (Hausback and Nilsen, 1999). Forams and ostrocods from the Capay Formation indicate deposition in a shallow marine environment and are of Early Eocene Age (Hausback and Nilsen, 1999). Within the AoR, the Capay Formation ranges from 111 feet to 236 feet thick, averaging 145 feet, and generally thickening to the southwest. This episode of shale deposition represents the last major transgression in the lower Eocene within the Sacramento Basin (Safonov, 1968). The Capay Formation is the top seal of the Starkey Storage Complex and is the barrier between the proposed CO_2 injection zone and the base of the lowest USDW.

4.3.4 Winters Formation

The Winters Formation rests conformably below the Starkey Formation. The Winters Formation is described as a shale dominated lithofacies within the AoR and is described as shale-rich slope deposits that are fed from a prograding Starkey deltaic system (Downey, 2005; Garcia, 1981; Nilsen, 1990). Distal to the slope shale facies, the Winters Formation is characterized as a turbiditic system down dip of the Starkey Deltas and is noted as a possible source rock to gas accumulations in the area (Garcia, 1981; Magoon, 1995). At the Union Island gas field, lithofacies within the Winters Formation are highly variable and include thick basal sandstone, interbedded sandstones and shales, and laminated shales (Williamson and Hill, 1981). For this reason, the Winters Formation acts as the primary base seal for proposed CO_2 injection into the overlying Starkey Clean Sand.

4.3.5 Sacramento Shale

The Upper Cretaceous Sacramento Shale is a regional shale below the Winters Formation and acts as a secondary base seal for CO_2 injection into the Starkey Clean Sand. It was deposited during a late Campanian transgression in the Sacramento Basin (Cherven, 1983; Downey, 2005). The Sacramento Shale has historically been identified as a regional seal for hydrocarbon exploration and as a source rock in the deltaic depocenter to the south of the AoR (Magoon, 1995; Scheirer, 2007). Regionally, the Sacramento Shale has been noted to be upwards of 300ft thick and in the area of interest, it averages 390 feet (ft) thick. On petrophysical logs, the Sacramento shale is characterized by a low density and slow velocity signature on the sonic log. Mudlogs describe the Sacramento Shale as soft, slightly soluble, with hydrated lumpy organic material (which may cause the low-density log signature). Acquiring rotary sidewall cores may be difficult due to the materials softness.

4.3.6 AoR thickness variability of the injection and confining zone

Petrophysical logs indicate that all zones are present in the AoR, and generally thicken to the south-southwest. The total thickness of the Starkey Storage Complex, including the Capay Formation top seal, the Starkey Formation injection zone, and the Winters Formation and Sacramento Shale base seals, ranges from 997 feet to 2329 feet thick, with an average thickness of 1574 feet. The cross sections shown in **Error! Reference source not found.** and **Error! Reference source not found.** of the Maps and Cross Sections of the AoR section show the lateral continuity of each of the zones of interest across the AoR. 3D seismic data acquisition and interpretation, planned for Phase II of this CarbonSAFE project, will be used to confirm the lateral continuity and stratigraphic relationships of the confining zones prior to well construction and injection.

4.3.7 Mineralogy of the injection and confining zones

No direct mineralogy data was available within the AoR for analysis at the time of this report. Provenance studies of the Capay Formation (N=9) by Baker (1975) and the Great Valley Sequence - K.P Helmhold data (N=15) (Dickinson et al, 1982; Mertz and Nilsen, 1990) provide the framework mineralogy and source terrane interpretation for the late Cretaceous and Eocene stratigraphic intervals. Mineralogy for the Sacramento Shale was not available.

In both the Capay and the Starkey/Winters/Kione/Forbes Formations, the framework mineralogy classifies the intervals as Lithic Arkose (Q-F-R) and is identified as having a dissected arc provenance (Q-F-L), falling within the Circum-Pacific Volcanic-Plutonic suites of the Qm-P-K diagram (**Error! Reference source not found.**), (Dickinson, 1985). These classifications are further supported by paleo current data from Baker (1975), which indicate provenance from the N-NE, with lithics being dominated by plutonic and volcaniclastic detritus (Baker, 1975; Cherven, 1983; Dickinson, 1985; Ingersoll, 1983; Mertz and Nilsen, 1990, Mertz, 1990).

Additionally, XRD data of the Starkey Formation is available from the analog WESTCARB study 50 miles to south of the AoR (Citizen Green #1 well (API07720688) and further support the framework mineralogical classifications of the Upper Cretaceous Starkey Formation. XRD data averaged 41% Quartz, 7.6% Potassium Feldspars, 33% Andesine, 6% detrital Mica, and approximately 12% authigenic minerals and clays (Ajo-Franklin et al., 2022). These mineral constituents are consistent with derivation from a Sierran arc/Klamath source and subsequent framework mineralogy studies (Barth, 2011; Dickinson, 1985; Hotz,1971; Ingersoll, 1983).

4.3.8 Injection and confining zone geochemical sensitivity

Given the arkosic nature of the Starkey Formation Clean Sand, it is possible that reactions similar to those observed in the Mt. Simon sandstone, which include dissolution of feldspars leading to increased porosity and permeability, and changes to the rock's mechanical strength, may be possible (Harbert et al, 2020). These geochemical changes, however, cannot be modeled accurately without information on the formation fluids and detailed mineralogic data for the injection and confining zones. Geochemical modelling to address these questions is proposed as part of the Stratigraphic test well for the PhaseII CarbonSAFE Project. The proposed CO_2 stream will be greater than 95% pure prior to injection after dehydration and compression. Expected geochemical reactions with brine and injection/confining zone rocks are discussed in the Geochemistry section.

4.3.8.1 Porosities and permeabilities

Porosities and permeabilities from geophysical logs of 22 wells were used to characterize the pore space of the injection and confining zones in the AoR and surrounding area. These data were used to inform the storage capacity estimates discussed below and the simulation model discussed in the AoR and Corrective Action Plan. Effective porosity for each of the intervals was derived from historical wireline logs within the model area (**Error! Reference source not found.**). The calculation for this measurement was:
XPORE = PHIT – VSH*SHPHI
where PHIT was the total porosity, and VSH*SHPHI was representative of volume of clay-bound water in the shale. Notably, because XPORE accounted for clay-bound water, the addition of a net to gross cutoff was not necessary with the given dataset.
Permeabilities were calculated using a modified Timur equation (Timur, 1968); which links permeability with the porosity and irreducible water saturation in sandstones. These data were then constrained by the reported values in the literature by ensuring that the P50 calculated average permeabilities by well were less than 100mD (California Department of Conservation, 1983). **Error! Reference source not found.** in the Geomechanical and Petrophysical Information section gives the average values for the thicknesses and petrophysical properties calculated for the wells.
For the simulation model, the porosities and permeabilities at the 22 wells in the model area were averaged over each of the layers in each of the zones. **Error! Reference source not found.**a and **Error! Reference source not found.**b show the distribution of the well logs within the modeling domain. The model contained two zones: the Starkey upper and the Starkey Clean Sand.

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4.3.9 Storage capacity and injectivity

The estimated storage capacity of the proposed injection zone assumes CO_2 injection into the sandstone dominated facies of the Starkey Formation and is based on nearby rock formation data that demonstrates a net sandstone thickness of 286.5 ft and a total porosity value of 24.8%.

Single well CO_2 injectivity into the sandstones of the Starkey Formation are modeled using the EasiTool from University of Texas GCCC - Gulf Coast Carbon Center. Assumptions for single well injectivity include the following (**Error! Reference source not found.**):

- Injection over 30 years.
- A fracture gradient of 0.65 psi/ft.
- Maximum injection pressure is 80% of the fracture gradient.
- Injection into clean sandstone of the Starkey Formation.

Limited data are currently available to assess the integrity of the Capay Formation confining zone, which lies above the Starkey Formation storage target. The 3D seismic program of the CarbonSAFE PhaseII project will help to delineate the lateral extent and thickness of the Capay Formation as well as map the presence and amount of displacement due to late Cenozoic faulting (see discussion in Faults and Fractures section). Critical rock property and capillary pressure measurements will be made available through the proposed stratigraphic test well and associated logging and coring programs of the CarbonSAFE PhaseII project. Data from the stratigraphic test well will allow for the collection of rock property information and geomechanical studies within the AoR necessary to address the integrity of the confining zone.

4.3.9.1 Uncertainties and further testing
Injection and confining zone characterization within the AoR will be further studied with the collection of data at the Phase II CarbonSAFE stratigraphic well and the data outlined in the Pre-Operational Testing

section of this permit. Wireline logs, in-situ fluid and pressure testing, rotary sidewall cores, and whole cores will be collected at the injection well site during construction. 3D seismic data will be acquired to determine the lateral extent, depth, thickness, and structural integrity of the injection and confining zones and integrated with core and wireline logs. Core collected from the Starkey Clean Sand injection interval and the Capay Formation top seal and Winters/Sacramento bottom seal will be run through a suite of laboratory measurements to better address the uncertainties outlined herein. Please refer to the Pre-Injection Operational Testing section for the summary of data to be collected pre-injection.

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

5.1 Petrophysics

Petrophysical calculation methods from geophysical wells for the injection and confining zone are discussed in the Injection and Confining Zone Characteristics section and are summarized in **Error! Reference source not found.**. Petrophysical well log sections can be found in the Maps and Cross sections of the AoR section of the report.

5.2 Geomechanics

A geomechanical study, as proposed by the CarbonSAFE PhaseII project, is required to address key questions regarding the confining zone interval. Cores collected from the stratigraphic test well proposed for this program will provide measurements of rock strength and ductility for the confining zone. The stratigraphic test well will also allow for detailed fracture analysis (see discussion in Faults and Fractures section). Pore pressure of the confining zone and in situ stress measurements will also be made available with the proposed stratigraphic test well and will allow for analysis of the stability of nearby faults (see discussion of the Willows-Corning fault zone in the Faults and Fractures section).
Regional observations of the in situ stress field orientation and mode are available from the World Stress Map. Borehole breakout measurements approximately 20 miles south of the AoR, and from depths between 3,166 to 5,768 feet, show a maximum compressive stress (SHmax) azimuth of 47° (B quality, to within ±20°), the mode is undefined (**Error! Reference source not found.**) (Heidbach et al., 2018). Focal mechanism analysis from within the Sacramento Basin place the basin in the thrust faulting (TF) regime and show SHmax azimuth orientations 99-105° (D quality, to within ±40°) or roughly east-west (**Error! Reference source not found.**) (Heidbach et al., 2018). None of the available in situ stress observations are within the AoR of the project.
Observations from the World Stress Map that place the orientation of SHmax at roughly northeast-southwest to east-west in a thrust fault regime suggest that the northwest-southeast trending Willows-Corning fault zone (see discussion in Faults and Fractures section) may be optimally orientated for possible reactivation. Detailed geomechanical analysis of the in situ pore pressure and the critical pressure threshold for reactivation of this fault system is required to understand the stability of this fault system and any others that are identified from subsequent seismic surveys as part of the CarbonSAFE PhaseII project.

[The information is Confidential Business Information per 5 U.S.C. § 552 (b)(9).]

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

6.1 Regional Seismicity

The USGS ANSS (Advanced National Seismic System) Comprehensive Earthquake Catalog, which includes the CGS (California Geologic Society) network is used to provide the historical seismicity record for the AoR locally and regionally (USGS, 2017). Regional historical seismicity was considered for a 100 mi radius around the approximate center of the AoR for a 40-year time period (extending from May 2023 to May 1983) with a magnitude greater than M2.5 (**Error! Reference source not found.**) and M4.0 (**Error! Reference source not found.**) (USGS, 2023).
Regional seismicity is broadly distributed throughout the Sacramento Valley with increasing density and frequency towards the basin margins, this includes the Coast Ranges along the southwestern border of the basin and the Sierra Nevada to the northeast (**Error! Reference source not found.**). During the 40-year interval from May 2023 to May 1983 there have been 7169 earthquakes of magnitude 2.5 or greater (**Error! Reference source not found.**), of these, 25 earthquakes have been of magnitude 4.0 or greater (**Error! Reference source not found.**). None of the magnitude 4.0 or greater earthquakes have occurred within the Sacramento Basin as these earthquakes represent deformation in tectonic regimes separate from that observed in the Sacramento Basin (see Regional Geology for further discussion). This relationship of a relatively seismically stable basin surrounded by regions of active deformation and seismicity is also demonstrated on the USGS Geologic Hazard Map for California (**Error! Reference source not found.**) (USGS, 2014).

The Coast Ranges-Sierran Block Boundary Zone (CRSBZ; Wong and Ely, 1983) is the most proximal zone of notable seismicity to the AoR and is located along the western margin of the Great Valley (Unruh, et al., 2019). The CRSBZ is also referred to as the Great Valley thrust fault system by the Working Group of Northern California Earthquake Potential (WGNCEP, 1996) and is used by Uniform California Earthquake Rupture Forecast 2 (UCERF2; WGCEP, 2007, Wills et al., 2008) and 3 (UCERF3; Dawson, 2013) statewide models. Deformation along the CRSBZ in the Southern Sacramento Valley area is expressed by en echelon west-dipping blind thrust faults (O'Connell et al., 2001) and locally by growth anticlines in the Rumsey and Dunnigan Hills area (Unruh and Morres, 1992).
In the Dunnigan Hills area, discrete clusters of small earthquakes occur below ~ 23,000 ft (7 km) on what are interpreted as basement faults beneath imaged thrust faults and tectonic wedging of the eastern CRSBZ (**Error! Reference source not found.**, nDUNH) (Unruh, et al., 2019). These structures represent the most proximal sources of Quaternary deformation to the proposed storage AoR.

6.2 Local Seismicity

Over the 40-year period from May 2023 to May 1983 a total of 19 earthquakes have occurred within 10 miles of the AOR, with a magnitude greater than 0 (**Error! Reference source not found.** and **Error! Reference source not found.**). Of these 19 earthquakes only two of them are greater than magnitude 2.5, both of these earthquakes, one of M 2.56 and the other of M 2.93, occurred in 1995 at significant depth in basement rocks (Table 1). Most of the 19 earthquakes have occurred deep within the Sacramento Basin or in basement rocks, only two shallower earthquakes were recorded, one a M 1.52 at 3,297' and one a M 1.6 at 6,998' (**Error! Reference source not found.**).

Overall, the historical seismicity record suggests that the proposed storage location is not in a seismically hazardous location. Fault stability and induced-seismicity potential are discussed in the Geomechanics section.

[The information is Confidential Business Information per 5 U.S.C. § 552 (b)(9).]

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

7.1 Hydrogeologic Description

The following discussion about the local freshwater aquifers, which comprise the Underground Sources of Drinking Water (USDW) is described from youngest to oldest (shallowest to deepest). This section describes a generalized stratigraphic section to the top of the bottom of the Ione Formation/ top of Capay Formation, considered the base of freshwater and the deepest point of any USDWs. The definition of a base of fresh water for the State of California differs from what is Federally considered a base of fresh water, which in this permit application is the deepest source of USDWs. The limit for freshwater in California is 3,000 µMhos (equivalent to 3,000 µS/cm), which is about 1,923 ppm of total dissolved solids (TDS). The federal USDW limit is 10,000 ppm TDS. TDS data within the AoR were from wells that were relatively shallow and therefore not near the USDW limit, or from significantly deeper oil and gas wells, beyond the depth at which the USDWs are no longer present. The depth of the top of the Capay Formation in the AoR is about 2,610 feet below ground surface or about -2,590 feet above mean sea level. Formation water salinities below the Capay, in the Starkey Storage Complex are approximately 14,000 ppm based on log calculations (See the Geochemistry section). The proposed project, therefore, will protect all water above the top of the Capay Formation as a USDW.

7.1.1 Holocene Alluvium

The uppermost geologic unit in the Sutter County area of the Sacramento Basin is the Holocene Alluvium, composed of unconsolidated sediments deposited during the Holocene epoch. These fluvially deposited sediments include silt, sand, and gravel, with occasional clay layers, and were deposited primarily from the Feather and the Sacramento rivers (Helley and Harwood, 1985). The Holocene alluvium is a source of shallow groundwater. The following description is from the 2016 Sutter Subbasin Alternative Plan:
"Deposits further from the riverbeds thin in thickness and also become finer gained. These sediments are highly permeable and provide areas where groundwater can be recharged and wells can yield from 2,000 to 4,000 gpm (DWR, Bulletin 118 – 2006 Update)."

7.1.2 Late Pleistocene Alluvium

Underlying the Holocene Alluvium is the Late Pleistocene Alluvium (Older Alluvium), which consists of alluvial deposits from the last glacial period. Similar to the Holocene Alluvium, these sediments are also composed of unconsolidated silt, sand, and gravel with occasional clay layers (Helley and Harwood, 1985). The Late Pleistocene Alluvium is generally more compact and less permeable than the overlying Holocene Alluvium but still contributes to the overall groundwater system in the region. The following description is from the 2016 Sutter Subbasin Alternative Plan:
"The Older Alluvium consists of the Modesto and Riverbank Formations, and the Victor Formation. These sediments are fairly similar and grouped together in the cross sections.
In the study area, the Modesto Formation is characterized mostly by gravels, cobbles, and sand with some silt and clay. It was encountered from the ground surface to about 70 to 120 feet bgs just to the west of Yuba City near SEWD Well #1. The formation is thicker to the south and thins to the north, with beds that are generally flat-lying (GEI, 2008).
In the study area, the Riverbank Formation underlies the Modesto Formation, and is also sedimentary in origin, and is composed of silts and clays with 10- to 20-foot thick sand and gravel layers. The sand and

gravel beds of the Riverbank Formation are thinner and less laterally extensive than those of the overlying Modesto Formation and are therefore more difficult to predict where they may occur. Similar to the Modesto Formation, the Riverbank Formation is thicker to the south, and thins closer to the Sutter Buttes, with beds that are generally flat-lying (GEI, 2008).

The Victor Formation is approximately 100 feet of Sierran alluvial fan deposits consisting of loosely compacted silt, sand, and gravel with lesser amounts of clay deposits. The deposit thins with distance to the west of the Yuba River and the foothills and wells can yield up to 1,000 gpm."

7.1.3 Laguna Formation

Below the Late Pleistocene Alluvium is the Laguna Formation, which was deposited in the Pliocene epoch. This unit is characterized by marine and non-marine sedimentary deposits, including sandstone, siltstone, claystone, and conglomerate (Bartow, 1984). The sediments within the Laguna Formation are primarily derived from the erosion of the Sierra Nevada and are associated with a fluctuating sea level during the Pliocene. The Laguna Formation typically has lower permeability than the overlying alluvial units, which results in a less significant contribution to groundwater resources. The following description is from the 2016 Sutter Subbasin Alternative Plan:

"The formation occurs above the Sutter Buttes Rampart and is unconformably overlain by the Riverbank Formation. The formation consists of two alluvial units and the Nomlaki Tuff Member which is a regional tuff that is a time correlative marker. The Nomlaki Tuff is also present in the Tuscan Formation which is part of the Sutter formation in the study area. Each of the two units create fining upward packages with basal gravels fining up through sand, silt and clay (Busacca, others. 1989). The Laguna Formation in the study area is thinner to the north and thickens to the south with the thickness ranging from about 80-feet in the north to almost 700-feet to the south."

7.1.4 Sutter formation

The Sutter formation is an informal stratigraphic designation for several regionally extensive units. These units are highly spatially variable and have different facies depending on the proximity to their sources. From Springhorn, 2008:

"Transportation of these sediments from their source areas, largely by fluvial processes has produced a large thickness of reworked volcaniclastic and epiclastic strata in the subsurface of the Central Sacramento Valley. This overlap and mixture of formal and informal stratigraphic units, has created complications and confusion in subsurface studies due to the lack of distinguishing characteristics of these deposits. To avoid further confusion, the various nomenclatures of these units have been grouped together as a single informal stratigraphic unit in this study for the purpose of subsurface correlation."

The following description is from the 2016 Sutter Subbasin Alternative Plan:

"The Sutter formation is generally characterized by black, blue, gray and greenish gray, angular to sub-rounded sand gravel. The Sutter formation is an informal unit and consists of sediments interpreted to be the distal portion of the upper Princeton Valley Fill, Mehrten Formation, Nomlaki Tuff, and Tuscan Formation (Springhorn, 2008). The presence of either of these units varies with the relative location of the Sutter Formation with the Sutter Buttes.

The upper Princeton Valley Fill is in the lower portion of the Sutter Formation and lies unconformably above the Lovejoy Basalt (Williams and Curtis, 1977). It consists of fluvially derived sands, conglomerates, and shales up to 1,400 feet thick (Redwine, 1972). The Valley Springs Formation of the Sierra Nevada, located greater than 2,000 feet deep in the Sacramento Valley or found shallower near the eastern margin of the valley, consists of tan, white, and green rhyolitic fragments and is the equivalent to the Princeton Valley Fill (Springhorn, 2008).

The Mehrten Formation consists of fluvial deposits, cobble tuff breccia deposits, tuff deposits, and tuff breccia deposits from the Sierra Nevada (Moses, 1985). The deposits primarily consist of clastic and

pyroclastic andesitic fragments that have been deposited as sandstone, siltstone, conglomerate, and tuff breccia.
The Nomlaki Tuff, found in the lower to middle portion of the Sutter formation, consists of white to light gray dacitic pumice tuff dated at 3.4 Ma (Harwood, 1981). The Nomlaki Tuff is near the bottom of the Tuscan Formation.
The Tuscan Formation, a primary aquifer in the northeastern Sacramento Valley, is composed of volcanic sediments derived from Mount Yana located south of Lassen Peak (Lydon, 1968). The Tuscan Formation is subdivided into Unit A through Unit D and mostly consists of interbedded lahars, volcanic conglomerate, volcanic sandstone, and siltstone with slightly varying mineral compositions and a couple notable tuff members (Harwood, 1981).”

7.1.5 Ione Formation

The Ione Formation is Eocene in age and comprised of non-marine sedimentary deposits. The primary constituents of the Ione Formation include claystone, siltstone, sandstone, and locally developed conglomerate layers, which were deposited in lacustrine and fluvial environments (Bartow and McDougall, 1984).
The sediments in the Ione Formation are largely derived from the weathering and erosion of the Sierra Nevada. The unit records a time of significant tectonic activity, with associated changes in regional drainage patterns and sediment supply (Bartow and McDougall, 1984). The Ione Formation generally has moderate to low permeability, depending on the lithology and degree of cementation. This often limits its contribution to groundwater resources, although more permeable sandstone layers can locally provide water-bearing potential. The Ione overlies the Capay Formation, which is considered the base of freshwater, within which no USDW is present, and the caprock for the storage reservoir, which is described in the regional geology portion of this application.

7.2 Groundwater Flow Direction in Principal Aquifer Zones:

The following **Error! Reference source not found.** shows the general groundwater surface elevation contours and flow direction for the Aquifer Zone-1 (AZ-1) as defined in the Sutter Subbasin Water Year 2022 Annual Report. The general flow direction is from northwest to southeast. The general flow direction for AZ-2 and AZ-3 is also from northwest to southeast. The aquifer zones in the subbasin are defined as follows:

- Shallow Aquifer Zone, up to 50 feet bgs
- AZ-1 between 50 and 150 feet bgs and includes the Modesto Formation and Riverbank Formation
- AZ-2, between 150 and 400 feet bgs and includes the Sutter Buttes Rampart and Laguna Formation
- AZ-3, deeper than 400 feet bgs includes the Laguna Formation, Sutter Buttes Rampart and Sutter Formation. Each of these aquifer zones is identified as a principal aquifer within the Sutter Subbasin. These are the primary zones where USDW is produced.

7.2.1 Drinking Water Wells within AoR

There were about 100 well completion reports located in the California Department of Water Resources Well Completion Report database. The wells ranged from a 19-foot deep well drilled in 1942 (WCR1942-000117) to a 1,000-foot deep exploratory borehole that was completed into a 360-foot deep well (WCR2012-004355) in 2012.

7.2.2 Water Quality in Principal Aquifer Zones

The Sutter Subbasin Groundwater Sustainability Plan (GSP **- Error! Reference source not found.**) has a representative monitoring network for groundwater quality in the aquifers that are used for drinking water and agricultural uses. The network consists of wells distributed both spatially throughout the subbasin and vertically through the different aquifer zones (Shallow, AZ-1, AZ-2 and AZ-3). The following figure shows the location of the groundwater quality wells and the tables provide the well construction details along with the aquifers monitored and the water quality results. The GSP was completed in 2022 and the water quality data presented in the tables below from the GSP are the most recent water quality data for the subbasins monitoring well network and are from 2009 to 2012. In 2024 the annual report update will provide water quality data from 2023.

[The information is Confidential Business Information per 5 U.S.C. § 552 (b)(9).]

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

[The information is Confidential Business Information per 5 U.S.C. § 552 (b)(9).]

8.0 Site Suitability [40 CFR 146.83]

8.1 Existing well penetrations in the Injection Zone

[The information is Confidential Business Information per 5 U.S.C. § 552 (b)(9).]
A full hydrogeological assessment to characterize and catalogue all water wells within the AoR and surrounding area was completed.
A review of all artificial penetrations within the AoR was completed and wells identified that may require corrective action in the future were identified as described in the AoR and Correction Action Plan submitted separately.

8.2 Model assumptions and conclusions

[The information is Confidential Business Information per 5 U.S.C. § 552 (b)(4) and (b)(9).]

8.3 Check list of requirements

Analysis of the regional and local geology near the Sutter Decarbonization Project demonstrates that the subsurface system is suitable for injection. The Starkey Clean Sand provide effective injection reservoirs in terms of mineralogical composition and petrophysical characteristics according to available information. Further characterization is planned during the CarbonSAFE Phase II project associated with the Sutter Decarbonization Project. Shales of the overlying Capay Formation appear to possess the necessary characteristics to serve as an effective confining zone.

[The information is Confidential Business Information per 5 U.S.C. § 552 (b)(4) and (b)(9).]

9.0 Description of AoR and Corrective Action Plan

9.1 Description of the files submitted for the AoR and the Corrective Action Plan

The Sutter Decarbonization Project has submitted the AoR and Corrective Action Plan to satisfy the rule requirements of 40 CFR 146.82(a)(13) and 40 CFR 146.84(b) in Confidential Business Information form. Detailed documentation regarding the computational modeling (40 CFR 146.84(c)) has been submitted into the GSDT AoR and Corrective Action Module. All tabs that require input data within the module have also been completed and submitted via the GSDT.
The report covers in detail the computation modelling approach to the AoR delineation, the Corrective Action Plan relating to existing well penetrations within the AoR and the Re-evaluation Schedule for AoR delineation once operations commence.

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

10.0 Description of Financial Responsibility

10.1 Description of the files submitted for the financial responsibility

The financial responsibility plan was completed and submitted to the GSDT in Confidential Business Information form. The plan includes a description of potential financial mechanisms for each phase as required by 40 CFR 146.82(a)(14) and 40 CFR 146.85 and will satisfy these rule requirements. All tabs that require input data within the module have been completed and submitted via the GSDT.

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

11.0 Description of Well Construction Plan

11.1 Well Construction Overview

The injection wells will be constructed new to meet the requirements of 40 CFR 146.82.a.12 and 40 CFR 146.86. Proposed specifications and procedures for injection wells CCS1, CCS2, and CCS3 are detailed in the corresponding documents for Injection Well Design Plan for the Sutter Decarbonization Project [CONSTRUCTION DETAILS (40 CFR 146.86(a))].

Each I Injection Well Design Plan document provides details on:

- Injection Well Operating Conditions
- Formation Conditions
- Open Hole Parameters
- Casing and Completion Tubing Specifications
- Minimum Logging Specifications for Well Construction
- Cement Specifications
- Wellhead Design Parameters
- Proposed Stimulation Program [40 CFR 146.82(a)(9)]

[The information is Confidential Business Information per 5 U.S.C. § 552 (b)(4) and (b)(9).]

12.0 Description of Pre-Operational Logging and Testing

12.1 Description of documents submitted to the GSDT

The Pre-Operational Logging and Testing Plan has been developed to meet the testing requirements of 40 CFR 146.87 and well construction requirements of 40 CFR 146.86 and submitted in Confidential Business Information form. All tabs that require input data within the module have also been completed and submitted via the GSDT.

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

13.0 Description of Well Operation

The injection operations will be implemented by Sutter CCUS, LLC, the permit OWNER. Under the permit, the OWNER will develop the Sutter Decarbonization Project.

Upon issuance of the UIC permits, the OWNER will begin the process of installing three injection wells and other project infrastructure as described in the permit application. Injection operations will begin once US EPA authorizes permission to operate, and the CO_2 delivery system is commissioned. The project intends to inject approximately 2 million tonnes of CO_2 annually. Injection will be distributed across the three permitted injection wells, in accordance with the permit operating conditions for each respective well. The project intends to store a total of up to 22 million tonnes of CO_2, injected over a period of approximately 12 years. Well operations, and a description of the proposed CO_2 injectate and its properties (Table 1) are described below.

13.1 Volume of Injection Fluid Generated Daily and Annually

The proposed injection rate for the project is 1690 tonnes/day in each of three injection wells with lateral completions. Injection rates in each well are to be determined based on pre-operational testing results. Planned annual CO_2 injection for all wells could be up to 600,000 tonnes/year. At full operating capacity, the expected daily injection, per well will ramp up to 1,690 tonnes/day depending on site geology and injectivity at each well location, and CO_2 availability. A flow meter will be installed to produce a direct reading of the total volume per time of CO_2 being injected. Location will be after compression, but prior to the well head.

13.2 Injection Operations and Procedures

The Sutter Decarbonization Project proposed injection procedures for the project injection wells incorporates maintenance and inspection of the wells and surface equipment that the waste contacts, along with long-term monitoring and contingency planning for safe, responsible operations. The Sutter Decarbonization Project is committed to operating the wells to meet all applicable United States Environmental Protection Agency (US EPA) regulations for CO_2 injection wells. A detailed review of the monitoring program for the wells and surface equipment is provided in the Testing and Monitoring Plan. The operation of all site wells includes recording of various parameters such as the injection flow rate, pressure, and annulus pressure, which are continuously monitored and recorded on digital drives and/or backup charts. Since the injection facility will operate 24 hours per day, seven days a week, it will be continuously manned by trained operators in injection well operations.

A maximum wellhead pressure of 2,000 psi was used for the well design. The maximum surface injection pressure will be based on actual site conditions but will not exceed 90% of the fracture pressure.

A mechanical integrity testing program for each injection well will be implemented in accordance with the Testing and Monitoring Plan.

13.3 Operational Constraints – Maximum Allowable Surface Pressure

The primary operational constraint would be imposed by potential limitation of permitted injection volumes and maximum allowable injection pressure. Once each injection well is drilled and pre-operational testing is complete, this upper bound to injectivity for that well will be established. However, the maximum (surface) injection pressure will not exceed 90% of the fracture pressure. Table 2 includes a summary of proposed operational constraints.

13.4 Operational Contingency Plans

Contingency plans will be in place to identify situations where potential plant and/or process upset conditions may occur and take appropriate measures that are protective to the local area and the environment by shutting in the wells and monitoring their pressure falloff. Operational contingency plans for all the Sutter Decarbonization Project injection wells include potential downtime periods when annual injection well testing, maintenance, well service, and stimulation occur. These plans include the following:

- Annual testing
- Monitoring downhole and on surface

With three permitted injection wells, two wells would normally be operational while one well is tested or serviced for maintenance.

The availability of multiple wells and adhering to proper operations practices, including regular well maintenance and service, will reduce most injection well down-time and should eliminate the unlikely occurrence of one or more wells being simultaneously unavailable for use. In the unlikely event that all wells are temporarily unavailable or are out of commission, CO_2 may be vented to the atmosphere for that limited period until operations and injectivity is re-established. Additional detailed monitoring, and other contingency planning for potential events that may occur during well injection operations are provided in the Testing and Monitoring Plan and in the Emergency and Remedial Response Plan.

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

[The information is Confidential Business Information per 5 U.S.C. § 552 (b)(4) and (b)(9).]

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

13.6.1 Injection Well and Reporting Conditions

Injection well operating conditions are described in more detail in the Narrative section “Well Operation.” Reports will be provided as described in the Testing and Monitoring Plan and other Plans (e.g., Emergency and Remedial Response Plan)

The maximum injection pressure, which serves to prevent confining-formation fracturing, was determined: using the local fracture gradient of 0.65 multiplied by 0.9, per 40 CFR 146.88(a). The fracture gradient for the Sutter Decarbonization Project will be determined via step rate testing during the pre-operational testing program.

13.7 Routine Shutdown Procedure

For injection shutdowns occurring under routine conditions (e.g., for well workovers), the permittee will reduce CO_2 injection rates in coordination with the compression and pipeline operator. The purpose is to ensure protection of health, safety, and the environment, and prevent sudden changes in the injection system. For routine shutdowns, the normal injection rate will be reduced by 25% and then allowed to stabilize for a minimum of one hour. This will be followed by similar reductions of 50%, 75%, and then 100% of normal injection. (Procedures that address immediately shutting in the well are in the Emergency and Remedial Response Plan of this permit.)

14.0 Description of Testing and Monitoring Plan

14.1 Description of documents submitted to the GSDT

This Testing and Monitoring Plan describes how Sutter CCUS, LLC will monitor the Sutter Decarbonization Project pursuant to 40 CFR 146.90. The Testing and Monitoring Plan has been submitted vis the GSDT in Confidential Business Information form. All tabs that require input data within the module have been completed and submitted via the GSDT in addition to the Confidential Business Information version, which has been submitted to Region IX of EPA.
This report covers in detail the overall strategy and approach for testing and monitoring, CO2 stream analysis, continuous recording of operational parameters, corrosion monitoring, CO2 plume and pressure front tracking, environmental monitoring at the surface, and sampling/analytical procedures.
The Testing and Monitoring plan satisfies the rule requirements of 40 CFR 146.82(a)(15) and 146.90.

Testing and Monitoring GSDT Submissions

GSDT Module: Project Plan Submissions
Tab(s): Testing and Monitoring tab

Please use the checkbox(es) to verify the following information was submitted to the GSDT:
☐ Testing and Monitoring Plan ***[40 CFR 146.82(a)(15) and 146.90]***

15.0 Description of Injection Well Plugging Plan

15.1 Description of the documents that are submitted to the GSDT

The Injection Well Plugging Plan includes schematics and describes how the Sutter Decarbonization Project will plug the injection wells in accordance with the requirements of 40 CFR 146.92. The Post-Injection Site Care and Site Closure (PISC) has been submitted vis the GSDT in Confidential Business Information form. All tabs that require input data within the module have been completed and submitted via the GSDT in addition to the Confidential Business Information version, which has been submitted to Region IX of EPA.
This report covers in detail the planned tests and measurement to determine the bottom hole injection zone pressure, planned External Mechanical Integrity test, information of plugs, methods used for volume calculations, notifications, permits and inspections required, plugging procedures and contingency procedures/measures.
The Injection and Well Plugging Plan satisfies the rule requirements of 40 CFR 146.82(a)(16) and 146.92(b).

Injection Well Plugging GSDT Submissions

GSDT Module: Project Plan Submissions
Tab(s): Injection Well Plugging tab

Please use the checkbox(es) to verify the following information was submitted to the GSDT:
☐ Injection Well Plugging Plan ***[40 CFR 146.82(a)(16) and 146.92(b)]***

16.0 Description of Post-Injection Site Care (PISC) and Site Closure

16.1 Description of the documents submitted to the GSDT

This Post-Injection Site Care and Site Closure (PISC) has been submitted vis the GSDT in Confidential Business Information form. All tabs that require input data within the module have been completed and submitted via the GSDT in addition to the Confidential Business Information version, which has been submitted to Region IX of EPA.
The plan describes the activities that the Sutter Decarbonization Project will utilize to meet the requirements of 40 CFR 146.93. The report covers in detail the pre and post injection pressure differential, post-injection monitoring plan, non-endangerment demonstration criteria, site closure plan, and QASP.
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No alternative PISC time frame is requested at this time.

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

17.0 Emergency and Remedial Response

17.1 Description of the documents that are submitted to the GSDT

The Emergency and Remedial Response Plan has been submitted via the GSDT in the Confidential Business Information form. All tabs that require input data within the module have been completed and submitted via the GSDT in addition to the Confidential Business Information version, which has been submitted to Region IX of EPA.
The report covers in detail the local resources and infrastructure, potential risk scenarios, response personnel and equipment, emergency communications plan, plan review, and staff training procedures.

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

18.0 Injection Depth Waiver and Aquifer Exemption Expansion

No injection depth waivers or aquifer exception expansions will be requested in relation to the Sutter Decarbonization Project.

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

19.0 Optional Additional Project Information [40 CFR 144.4]

At present, none of the following impact development of the Sutter Decarbonization Project. The project OWNER, Sutter CCUS
, LLC will follow California requirements for environmental monitoring as described above in the Narrative section "*Other Information (Including Surface Air and/or Soil Gas Data, if Applicable)*".

- The Wild and Scenic Rivers Act, 16 U.S.C. 1273 et seq. Identify any national wild and scenic river that may be impacted by the activities associated with the proposed project.
- The National Historic Preservation Act of 1966, 16 U.S.C. 470 et seq. Identify properties listed or eligible for listing in the National Register of Historic Places that may be affected by the activities associated with the proposed project. If previous historic and cultural resource survey(s) have been conducted, provide the results of the survey(s).
- The Endangered Species Act, 16 U.S.C. 1531 et seq. Identify any endangered or threatened species that may be affected by the activities associated with the proposed project. If a previous endangered or threatened species survey has been conducted, provide the results of the survey.
- The Coastal Zone Management Act, 16 U.S.C. 1451 et seq. Identify any coastal zones that may be affected by the activities associated with the proposed project.]

19.1 Other Information

No other information is included in the permit application at this time.
However, the OWNER will provide any other information requested by the UIC Program Director, or new or updated information that is not specifically requested/required but may be useful for the permit application. This section fulfills the requirement at 40 CFR 146.82(a)(21).

20.0 References

[The information is Confidential Business Information per 5 U.S.C. § 552 (b)(4) and (b)(9).]