UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

OFFICE OF
AIR AND RADIATION

January 12, 2021

Mr. William Calhoun
OXY USA WTP LP
100 NW 7th Street
Seminole, Texas 79360

Re: Monitoring, Reporting and Verification (MRV) Plan for West Seminole San Andres Unit

Dear Mr. Calhoun:

The United States Environmental Protection Agency (EPA) has reviewed the Monitoring, Reporting and Verification (MRV) Plan submitted for the West Seminole San Andres Unit as required by 40 CFR Part 98, Subpart RR of the Greenhouse Gas Reporting Program. The EPA is approving the MRV Plan submitted by OXY USA WTP LP for the West Seminole San Andres Unit as the final MRV plan. The MRV Plan Approval Number is 1013793-1. This decision is effective January 17, 2021 and appealable to EPA's Environmental Appeals Board under 40 CFR Part 78.

If you have any questions regarding this determination, please write to ghgreporting@epa.gov and a member of the Greenhouse Gas Reporting Program will respond.

Sincerely,

Julius Banks, Chief
Greenhouse Gas Reporting Branch

Technical Review of Subpart RR MRV Plan for West Seminole San Andres Unit

January 2021

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This document summarizes the U.S. Environmental Protection Agency's (EPA's) technical evaluation of the Greenhouse Gas Reporting Program (GHGRP) Subpart RR Monitoring, Reporting, and Verification (MRV) Plan submitted by OXY USA WTP LP, a subsidiary of Occidental (Oxy), for the carbon dioxide (CO_2) - enhanced oil recovery (EOR) project in the West Seminole San Andres Unit (WSSAU).

1 Overview of Project

Oxy states in the MRV plan that it operates a CO_2-EOR project in the West Seminole San Andres Unit (WSSAU). This MRV plan was developed in accordance with 40 CFR §98.440-449 (Subpart RR) to provide for the monitoring, reporting and verification of the quantity of CO_2 sequestered at the WSSAU during a Specified Period of injection. Oxy submitted its MRV plan related to EOR operations within the WSSAU, located in the northeastern portion of the Central Basin Platform in West Texas. The WSSAU was discovered in 1944 and first produced in 1948. The WSSAU was first unitized in 1961. Operators in the WSSAU began waterflooding in 1969 and CO_2 flooding in 2013.

The MRV plan states there are 227 wells in the WSSAU field area. Of those 227 wells, there are 141 active wells, 2 dry and abandoned wells, 11 inactive wells, 43 plugged and abandoned wells, 4 shut-in wells, and 26 temporarily abandoned wells in the WSSAU. The Oil and Gas Division of the Texas Railroad Commission (TRRC) regulates oil and gas activity in Texas. All wells in the WSSAU (including production, injection, and monitoring wells) are permitted by TRRC through Texas Administrative Code (TAC) Title 16 Chapter 3. TRRC has primacy to implement the Underground Injection Control (UIC) Class II program in the state for injection wells. All EOR injection wells in the WSSAU are currently classified as UIC Class II wells. The MRV plan states that all wells are in material compliance with the TRRC rules.

The WSSAU produces oil from a Permian (Guadalupian) aged reservoir comprised of the San Andres formation dolostone. The dolomites that compose the producing reservoir were deposited in a shallow marine environment approximately 250-300 million years ago. The total thickness of the geologic unit is approximately 1,500 feet thick. The primary reservoir within the middle of the San Andres formation is approximately 600 feet thick. The carbon dioxide sequestration zone is also the oil pay completion interval, and ranges on average between 4,925-5,640 feet below the ground surface.

The main confining system is approximately 300 feet thick and is comprised of nonporous anhydrite sequences. This nonporous anhydrite serves as a stratigraphic seal. The depth interval for the confining system ranges from the top of the San Andres formation to the top of the pay zone (4,545-5,194 feet) with a typical range of 4,660-4,925 feet below ground surface. There are numerous relatively thin layers that provide additional secondary containment between the sequestration zone and freshwater aquifers. These secondary containment layers are comprised of siltstones, shales, salts, and anhydrite sequences with little to no porosity or permeability. Refer to Figure 3-3 in the MRV plan for a geologic column that contains more detailed information on the stratigraphy of the WSSAU.

There are no significant geologic faults or fractures identified that intersect the carbon dioxide storage complex. The WSSAU is a domal structure that includes the highest structural elevations within the area. The elevated area forms a natural trap for oil and gas that migrated from below over millions of years. In the case of the WSSAU, this oil and gas have been trapped in the reservoir for 50 to 100 million years. Over time, buoyant fluids, including CO_2, rise vertically until reaching the ceiling of the dome and then migrate to the highest elevation of the structure. At the time of its discovery, natural gas was trapped at the structural high points of the WSSAU, forming a “gas cap.” Oxy asserts that the presence of an oil deposit and a gas cap is evidence of the effectiveness of the seal formed by the anhydrite sequences in the upper San Andres. If the gas could escape the WSSAU through faults or fractures, then it would have escaped over millennia.

The MRV plan states approximately 20 million tons of CO_2 will be injected into the reservoir over the lifetime of the project. Once the CO_2 flood is complete and injection ceases, the remaining mobile CO_2 will rise slowly upward, driven by buoyancy forces. Oxy asserts that the amount of CO_2 injected will not exceed the reservoir’s secure storage capacity and, consequently, the risk that CO_2 could migrate to other reservoirs in the Central Basin Platform is negligible. The volume of CO_2 storage is based on the estimated total pore space within the WSSAU. The total pore space within the WSSAU, from the top of the reservoir down to the base of the oil zone, is calculated to be 1,512 million reservoir barrels (RB). This is the volume of rock multiplied by porosity. Table 3-1 in the MRV plan shows the conversion of pore space into an estimated maximum volume of approximately 1,770 BCF (96 million tons) of CO_2 storage in the reservoir. Oxy forecasts that CO_2 stored at the end of EOR operations will fill approximately 20% of the total calculated storage capacity. Oxy states they have confidence that stored CO_2 will be contained securely within the WSSAU reservoir due to the reservoir’s large storage capacity and evidence of a competent confining zone through experience with previous and current CO_2 injection operations.

Figure 3-5 in the MRV plan shows a simplified process flow diagram of the project facilities and equipment in the WSSAU. CO_2 is delivered to the WSSAU via the Permian Basin CO_2 pipeline network. Specified amounts of CO_2 are drawn from the Bravo pipeline based on contractual arrangements among suppliers of CO_2, purchasers of CO_2, and the pipeline operator. Once CO_2 enters the WSSAU there are three main processes involved in EOR operations: CO_2 distribution and injection, produced fluids handling and water treatment, and injection.

Section 3.3 of the MRV plan describes how the mass of CO_2 received at the WSSAU via CO_2 pipeline is metered and calculated at the pipeline delivery point. The CO_2 received is combined with recycled CO_2 and a mix of hydrocarbon gases from the recompression facility (RCF). The output of the RCF is then distributed to the water alternating gas (WAG) headers for injection into the injection wells. Each well pattern alternates between water and CO_2 injection according to the pre-programmed injection plan. The reservoir pressure must be maintained above the minimum miscibility pressure during an EOR project. Therefore, injection pressure must be sufficiently high to allow injectants to enter the reservoir, but below formation parting pressure (FPP). The FPP is the pressure at which the induced stress from the injection of fluids causes brittle fractures, which results in discontinuous and non-recoverable deformation to the formation.

Produced fluids from the production wells are a mixture of oil, hydrocarbon gas, water, CO_2, and trace amounts of other constituents in the field including nitrogen and H_2S. Produced fluids are gathered and sent to satellite test stations (SATs) for separation into a gas/CO_2 mix and a produced fluids mix of water, oil, gas, and CO_2. The produced gas, which is composed primarily of hydrocarbons and CO_2, is sent to the RCF for dehydration and recompression before reinjection into the reservoir. An operations meter at the RCF is used to determine the total volume of produced gas that is reinjected. The separated oil is metered at the central tank battery and sold into a pipeline. Water is recovered for reuse and forwarded to the water injection station for treatment and reinjection or disposal.

The MRV plan states that a history matched reservoir model of the current and forecasted CO_2 injection within the WSSAU has been made. The model was created to demonstrate that the storage complex has the capacity to contain the planned volume of purchased CO_2; track injected CO_2; identify how and where CO_2 is trapped in the WSSAU; and monitor sequestration volumes and distribution. The reservoir model utilizes four types of data: site characteristics as described in the WSSAU geomodel, initial reservoir conditions and fluid property data, capillary pressure data and well data. The geomodel used as the foundation for the reservoir model used data from 232 wells in the WSSAU. The model is a four-component model consisting of water, oil, reservoir gas, and injected CO_2. The WSSAU reservoir model was used to evaluate the plume of CO_2 using a set of injection, production, and facilities constraints that describe the injection plan. The history match indicates that the model is robust and that there is little chance that uncertainty about any specific variable will have a meaningful impact on the reservoir CO_2 storage performance. The model forecasts that CO_2 is contained in the reservoir within the boundaries of WSSAU.

The description of the project is determined to be acceptable and provides the necessary information to comply with 40 CFR 98.448(a)(6).

2 Evaluation of the Delineation of the Maximum Monitoring Area (MMA) and Active Monitoring Area (AMA)

As part of the MRV Plan, the reporter must identify both the maximum monitoring area (MMA) and active monitoring area (AMA), pursuant to 40 CFR 98.448(a)(1). Subpart RR defines maximum monitoring area as “the area that must be monitored under this regulation and is defined as equal to or greater than the area expected to contain the free phase CO_2 plume until the CO_2 plume has stabilized plus an all-around buffer zone of at least one-half mile.” Subpart RR defines active monitoring area as “the area that will be monitored over a specific time interval from the first year of the period (n) to the last year in the period (t). The boundary of the active monitoring area is established by superimposing two areas: (1) the area projected to contain the free phase CO_2 plume at the end of year t, plus an all-around buffer zone of one-half mile or greater if known leakage pathways extend laterally more than one-half mile; (2) the area projected to contain the free phase CO_2 plume at the end of year t + 5.” See 40 CFR 98.449.

Oxy has defined the AMA as the boundary of the WSSAU plus the required 0.5-mile radius buffer. Oxy has also defined the MMA as the boundary of the WSSAU plus the required 0.5-mile buffer as required by 40 CFR §98.440-449 (subpart RR). Factors considered include: the extent of free-phase CO_2 within the WSSAU, the operational strategies to retain injected CO_2 within the unit, and the geological structure of the unit. The MRV states the primary purpose for injecting CO_2 is to produce oil that would otherwise remain trapped in the reservoir and not, as in UIC Class VI, "specifically for the purpose of geologic storage".

The MRV plan states there will be a subsidiary purpose of establishing the long-term containment of CO_2 in the WSSAU during the Specified Period. The Specified Period will be shorter than the period of production from the WSSAU. At the conclusion of the Specified Period, a request for discontinuation of reporting will be submitted. This request will be submitted with a demonstration that current monitoring and model(s) show that the cumulative mass of CO_2 reported as sequestered during the Specified Period is not expected to migrate in the future in a manner likely to result in surface leakage. It is expected that it will be possible to make this demonstration almost immediately after the Specified Period ends based upon predictive modeling supported by monitoring data.

The reservoir pressure in the WSSAU is collected for use in reservoir modeling and operations management. Reservoir pressure is not forecast to change appreciably since the injection to withdrawal ratio (IWR) will be maintained at approximately 1.0. The reservoir model shows that by the end of CO_2 injection, average reservoir pressure will be approximately 2,360 psi. Once injection ceases, reservoir pressure is predicted to stabilize within one year. Over time, reservoir pressure is expected to drop by approximately 10 psi. The trend of the reservoir pressure decline will be one of the bases of a request to discontinue monitoring and reporting.

The MMA, as it is defined in the MRV plan, is consistent with subpart RR requirements because the defined MMA accounts for the expected free phase CO_2 plume, based on modeling results, and incorporates the additional 0.5-mile or greater buffer area. The rationale used to delineate the MMA, as described in Oxy's MRV plan, accounts for the existing operational and subsurface conditions at the site along with any potential changes in future operations. Therefore, the designation of the AMA as the WSSAU, plus the required 0.5-mile buffer and the designation of the MMA as the WSSAU, plus the required 0.5-mile buffer, is an acceptable approach.

The delineations of the MMA and AMA were determined to be acceptable and in compliance with 40 CFR 98.448(a)(1). The MMA and AMA described in the MRV plan are clearly and explicitly delineated and are consistent with the definitions in 40 CFR 98.449.

3 Identification of Potential Surface Leakage Pathways

As part of the MRV Plan, the reporter must identify potential surface leakage pathways for CO_2 in the MMA and the likelihood, magnitude, and timing of surface leakage of CO_2 through these pathways pursuant to 40 CFR 98.448(a)(2). Oxy identified the following as potential leakage pathways in their MRV plan that required consideration:

- Existing well bores;
- Faults and fractures;
- Natural and induced seismic activity;
- Previous operations;
- Pipeline and surface equipment;
- Lateral migration outside the WSSAU;
- Drilling through the CO_2 area; and
- Diffuse leakage through the seal.

3.1 Leakage through Existing Well Bores

As part of the TRRC requirement to initiate CO_2 flooding, all WSSAU penetrations were reviewed to determine the need for corrective action. The review determined that all penetrations have either been adequately plugged and abandoned, or if in use, do not require corrective action. The MRV plan states that all wells in the WSSAU were constructed and are operated in compliance with TRRC rules.

Oxy's routine risk management efforts identified and evaluated the following wells based on their potential risk of leakage: i) CO_2 flood beam wells; ii) electrical submersible pump (ESP) producer wells; and iii) CO_2 WAG injector wells. The risk assessment classified all risks associated with the subsurface as low risk, i.e., less than 1% likelihood to occur and having a consequence that is insubstantial. The risks were classified as low risk because, the WSSAU geology is well suited to CO_2 sequestration with an extensive confining zone that is free of fractures and faults that could be potential conduits for CO_2 migration. Further, the MRV plan states that Oxy will mitigate risks through: i) adhering to regulatory requirements for well drilling and testing; ii) implementing best practices that Oxy has developed through its extensive operating experience; iii) monitoring injection/production performance, wellbores, and the surface; and iv) maintaining surface equipment.

Section 5.1 of the MRV plan describes how Oxy plans to detect leaks or other potential well problems through continual and routine monitoring of well bores and site operations. Pressure monitors on the injection wells are programmed to flag whenever statistically significant pressure deviations from the targeted ranges in the plan are identified. Leakage on the inside or outside of the injection wellbore would affect pressure and be detected through this approach. If such events occur, they will be investigated and addressed.

The performance of production wells is also routinely monitored through a production well test process that is conducted when produced fluids are gathered and sent to a SAT. Each SAT has a routing testing cycle, which occurs approximately once every two months. During this cycle, each production well is diverted to the well test equipment for a period of time, as determined by Oxy, to be sufficient to measure and sample produced fluids (generally 8-12 hours). These tests are used as the basis for allocating a portion of the produced fluids measured at the SAT to each production well, assessing the composition of produced fluids by location and assessing the performance of each well. Performance data are reviewed on a routine basis to ensure that CO_2 flooding efficiency is optimized. The MRV plan states that leakage to the outside of production wells is not considered a major risk because the reduced pressure in the casing would be detected. If production deviates from the plan, it is investigated, and any identified issues addressed. Additionally, because H_2S leakage can be a proxy for CO_2 leakage, the presence of personal H_2S monitors allows for the detection of leaked fluids around production wells during routine well inspections.

Routine field inspections are conducted by field personnel. Section 5.1 of the MRV plan describes how leaking CO_2 leads to the formation of bright white clouds and ice that are easily spotted at the surface. All field personnel are trained to identify leaking CO_2 and other potential problems at wellbores and in the field. Any CO_2 leakage detected will be documented, reported, and quantified.

Thus, the MRV plan provides an acceptable characterization of the likelihood of CO_2 leakage that could be expected from existing well bores.

3.2 Leakage through Faults and Fractures

According to section 5.2 of the MRV plan, there is no risk of leakage due to fractures or faults because there are no known faults or fractures that transect the San Andres reservoir in the project area. There is one identified reverse fault in the Devonian interval approximately one mile below the sequestration zone. The base of sequestration zone is approximately 2,175 feet subsea depth, while the top of fault offset is interpreted to end at approximately 7,500 feet subsea depth. Fault displacement within the Devonian is approximately 200 feet. The fault is linear, subvertical, and dips toward the northeast. Section 3.2 of the MRV plan asserts that the presence of a gas cap is evidence of the effectiveness of the seal formed by the upper San Andres.

Oxy routinely updates measurements to determine FPP and reservoir pressure so that the injection pressure does not exceed the FPP. An IWR is maintained at or near 1.0. IWR is the ratio of the volume of fluids injected to the volume of fluids produced. Volumes are measured under reservoir conditions for all fluids. By keeping IWR close to 1.0, reservoir pressure is held constant, neither increasing nor decreasing. To maintain the IWR, fluid injection and production are monitored and managed to ensure that reservoir pressure does not increase to a level that would compromise the reservoir seal or otherwise damage the integrity of the oil field. As a safeguard, Oxy also continuously monitors WAG skids and has them set with automatic shutoff controls if injection pressures exceed programmed levels. WAG skids are remotely operated and can inject either CO_2 or water at various rates and injection pressures as specified in the injection plans.

Thus, the MRV plan provides an acceptable characterization of the likelihood of CO_2 leakage that could be expected through faults and fractures.

3.3 Leakage through Natural and Induced Seismicity

The MRV plan concludes that there is no direct evidence that natural seismic activity poses a significant risk for loss of CO_2 to the surface in the Permian Basin, specifically in the WSSAU. This conclusion is supported by Oxy's review of historical seismic activity in the Permian Basin, in addition to their operating experience in the region. Section 5.3 of the MRV plan states that there are no recorded earthquakes with a magnitude greater than 3.0 on the Richter scale in the West Seminole Field. The closest earthquake took place in 1992 approximately 35 miles away from the field. The plan indicates that if induced seismicity resulted in a pathway for material amounts of CO_2 to migrate from the injection zone, other reservoir fluid monitoring provisions would detect the migration and lead to further investigation. Oxy also indicates that they participate in the TexNet seismic monitoring network and will continue to monitor for seismic signals that may indicate the creation of potential leakage pathways in the WSSAU.

Thus, the MRV plan provides an acceptable characterization of the likelihood of CO_2 leakage that could be expected through natural and induced seismicity.

3.4 Leakage as a Result of Previous Operations

Before CO_2 flooding was initiated in the WSSAU in 2013, Oxy evaluated the area of review (AOR) around all CO_2 injector wells to determine if there were any unknown penetrations and to assess if corrective action was required at any wells. Oxy reviewed the penetrations necessary to obtain permits for CO_2 flooding and determined that no additional corrective action was needed. The MRV plan states that Oxy has a standard practice for drilling new wells that includes a rigorous review of nearby wells to ensure that drilling will not cause damage to or interfere with existing wells. As discussed in section 5.1 of the MRV plan, all penetrations have been identified to be adequately plugged and abandoned, or, if in use, do not require corrective action. The plan indicates these practices are created to make sure that there are no unknown wells within the WSSAU and that the risk of migration from older wells has been sufficiently mitigated.

Thus, the MRV plan provides an acceptable characterization of the likelihood of CO_2 leakage that could be expected as a result of previous operations.

3.5 Leakage from Pipeline and Surface Equipment

As part of routine risk management practices, Oxy identified and evaluated the risk of leakage associated with the production satellite, the central tank battery and facility pipelines. The MRV plan classifies these potential leakage pathways as low risk because the WSSAU is operated in a manner that maintains, monitors and documents the integrity of the reservoir. Oxy states that they mitigate this risk by: i) adhering to the regulatory requirements for well drilling and testing; implementing best practices that have been developed through extensive operating experience; monitoring injection/production performance, wellbores and the surface; and iv) maintaining surface equipment.

Field personnel continuously monitor the pipeline system using a supervisory control and data acquisition (SCADA) system to detect and mitigate pipeline leaks. The MRV plan states that risks will be prevented, when possible, by relying on the use of prevailing design and construction practices and maintaining compliance with applicable regulations. The facilities and pipelines currently utilize and will continue to utilize construction materials and control processes that are standard for CO_2-EOR projects in the oil and gas industry. Oxy asserts that their operating and maintenance practices and CO_2 delivery via the Permian Basin CO_2 pipeline system will continue to follow industry standards and regulations. Routine visual inspections of surface facilities provide an additional way to detect leaks and support the efforts to detect and remedy any leaks in a timely manner. If leakage is detected from pipeline or surface equipment, Oxy plans to quantify the volume of CO_2 released by following the requirements of subpart W of the GHGRP.

Thus, the MRV plan provides an acceptable characterization of the likelihood of CO_2 leakage that could be expected from pipelines and other surface equipment.

3.6 Leakage from Lateral Migration

The plan states that it is highly unlikely that injected CO_2 will migrate downdip and laterally outside the WSSAU because of the nature of the reservoir's geology and the approach used for injection. The WSSAU reservoir model, as described in section 3.4 of the MRV plan, forecast that CO_2 is contained in the reservoir within the boundaries of the WSSAU. Over time, CO_2 will tend to rise vertically towards the Upper San Andres and continue to the WSSAU because it is the highest local elevation within the San Andres. The planned injection approach involves active fluid management during injection operations, which the plan states will prevent CO_2 from migrating laterally out of the structure. As discussed in Section 3.1, injection pressure is monitored on a continual basis and any deviations are investigated and addressed. Oxy states that there have been no incidents of fluid migration out of the intended zone at the WSSAU. Lastly, section 5.5 of the MRV plan explains that the total volume of fluids contained in the WSSAU will stay relatively constant, meaning the reservoir pressure is expected to remain stable.

Thus, the MRV plan provides an acceptable characterization of the likelihood of CO_2 leakage that could be expected from lateral migration outside of the WSSAU.

3.7 Leakage from Drilling Operations

The TRRC regulates well drilling activity in Texas, and thus in the WSSAU. Pursuant to TRRC rules, the plan recognizes that well casings shall be securely anchored in the hole in order to effectively control the well at all times, all usable quality water zones shall be isolated and sealed off to effectively prevent contamination or harm, and all productive zones, potential flow zones, and zones with corrosive formation fluids shall be isolated and sealed off to prevent vertical migration of fluids, including gases, behind the casing. Where rules do not specify the methods to achieve objectives, operators are expected to make every effort to follow the intent of the relevant section by using good engineering practices and the best currently available technology. Applications and approvals must be submitted to the TRRC before a well is drilled, re-completed, or re-entered. The MRV plan asserts that well drilling activity at the WSSAU is conducted in accordance with TRRC rules.

Oxy states that their visual inspection process, including routine site visits, will identify unapproved drilling activity in the WSSAU. Additionally, Oxy makes note of their intention to operate the WSSAU for several more decades. The plan indicates that it is in the best interests of Oxy to be vigilant about protecting the integrity of its assets and maximizing the potential of its resources, including oil, gas, and CO_2. Consequently, the plan concludes that the risks associated with third parties penetrating the WSSAU are negligible.

Thus, the MRV plan provides an acceptable characterization of the likelihood of CO_2 leakage that could be expected from drilling operations.

3.8 Leakage through the Formation Seal

The WSSAU is a domal structure that forms a natural trap for oil and gas that has migrated from source rocks over millions of years. Figure 3-3 of the MRV plan illustrates that there are five non-permeable seals that overlay the San Andres formation dolostone storage complex: the upper San Andres, Seven Rivers, Tansill, Salado and Rustler formations. The main confining system is roughly 300 feet thick and is comprised of nonporous anhydrite sequences. There are numerous relatively thin layers comprised of siltstones, shales, salts and anhydrite sequences with little to no porosity or permeability that are stated to provide additional secondary containment between the sequestration zone and freshwater aquifers. As noted, the plan asserts that the presence of an oil deposit and a gas cap is evidence of the effectiveness of the seal formed by the upper San Andres.

The MRV plan states that injection pattern monitoring assures that no breach of the seal will be created. Wellbores that penetrate the seal make use of cement and steel construction that is closely regulated to ensure that no leakage takes place. The plan goes on to state that injection pressure is continuously monitored and unexplained changes in injection pressure that might indicate leakage would trigger investigation as to the cause.

Thus, the MRV plan provides an acceptable characterization of the likelihood of CO_2 leakage that could be expected through the formation seal.

3.9 Leakage Detection, Verification and Quantification

Section 5.8 of the MRV plan contains a table (Table 2) that includes a response plan in the event of CO_2 leakage. Oxy plans to determine the most appropriate methods for quantifying the volume of leaked CO_2 on a case by case basis and will report it as required by subpart RR. The plan goes on further to state that any volume of CO_2 detected leaking to surface will be quantified using acceptable emission factors such as those found in 40 CFR Part 98 subpart W or engineering estimates of leak amounts based on measurements in the subsurface, field experience, and other factors such as the frequency of inspection. The plan also states that leaks will be documented, evaluated, and addressed in a timely manner.

The characterization of leakage risks and their associated monitoring and response plans provide an acceptable strategy for detection, verification and quantification of CO_2 leakage that could be expected from the CO_2-EOR project in the WSSAU.

4 Strategy for Detection and Quantifying Surface Leakage of CO_2 and for Establishing Expected Baselines for Monitoring

Section 5 of the MRV plan outlines Oxy's strategy for detecting and verifying potential surface leakage. Oxy's approach primarily includes monitoring of injection wells, well maintenance, monitoring of surface infrastructure, and field inspections (visual inspections and H_2S detection by personnel and in-field monitoring equipment). Oxy's approach to these activities is described in sections 4, 5 and 6 of the MRV plan and is summarized in Table 2 of the MRV plan, which is reproduced below.

Risk	Monitoring Plan	Response Plan
Tubing Leak	Monitor changes in tubing and annulus pressure; MIT for injectors	Wellbore is shut in and workover crews respond within days
Casing Leak	Routine Field inspection; Monitor changes in annulus pressure, MIT for injectors; extra attention to high risk wells	Wellbore is shut in and workover crews respond within days
Wellhead Leak	Routine Field inspection, SCADA system monitors wellhead pressure	Wellbore is shut in and workover crews respond within days
Loss of Bottom-hole pressure control	Blowout during well operations	Maintain well kill procedures
Unplanned wells drilled through San Andres	Routine Field inspection to prevent unapproved drilling; compliance with TRRC permitting for planned wells.	Assure compliance with TRRC regulations
Loss of seal in abandoned wells	Reservoir pressure in WAG headers; high pressure found in new wells	Re-enter and reseal abandoned wells
Pumps, valves, etc.	Routine Field inspection, SCADA	Workover crews respond within days
Overfill beyond spill points	Reservoir pressure in WAG headers; high pressure found in new wells	Fluid management along lease lines
Leakage through induced fractures	Reservoir pressure in WAG headers; high pressure found in new wells	Comply with rules for keeping pressures below parting pressure
Leakage due to seismic event	Reservoir pressure in WAG headers; high pressure found in new wells	Shut in injectors near seismic event

40 CFR 98.448(a)(3) requires that an MRV Plan contain a strategy for detecting and quantifying any surface leakage of CO_2, and 40 CFR 98.448(a)(4) requires that an MRV Plan include a strategy for establishing the expected baselines for monitoring CO_2 surface leakage. Sections 6 and 7 of the MRV plan provide Oxy's strategy for detecting and verifying potential subsurface leakage and describe a strategy for establishing baselines against which monitoring results are compared. The MRV plan describes an acceptable strategy for detecting and quantifying any surface leakage of CO_2 based on the identification of potential leakage risks.

Oxy follows industry standard metering protocols for custody transfers to accurately measure mass flow. CO_2 is supplied by several different sources via the Permian Basin CO_2 pipeline network. Specified amounts are drawn from the Bravo pipeline based on contractual arrangements among suppliers of CO_2, purchasers of CO_2, and the pipeline operator. Another metered input/output site is the RCF, which is used to determine the total volume of produced gas that is reinjected.

Oxy's monitoring approach includes the collection of flow, pressure, temperature, and gas composition data from wells and facilities in the WSSAU, which is then stored in centralized data management systems as part of ongoing operations. The automatic data systems will be used to identify and investigate deviations from expected performance that could indicate CO_2 leakage. The plan notes that data systems are used primarily for operational control and monitoring and as such are set to capture more information than is necessary for reporting in the annual subpart RR report.

Fluid composition will be determined quarterly to be consistent with subpart RR specifications in section 98.447(a). The MRV plan states that all meter and composition data are documented, and records will be retained for at least three years.

Oxy has a multi-layered, risk-based monitoring program for event-driven incident that is designed to: 1) detect problems before CO_2 leaks to the surface; and 2) detect and quantify any leaks that do occur.

4.1 Injection/Production Zone Leakage

In addition to the measures discussed in section 5.9 of the MRV plan, the plan states that both injection into and production from the reservoir will be monitored as a means of early identification of potential anomalies that could indicate leakage from the subsurface. Oxy describes that if injection pressure or rate measurements are outside the specified set points determined as part of each pattern injection plan, a data flag is automatically triggered, and field personnel will investigate and resolve the problem. These excursions will be reviewed by well management personnel to determine if CO_2 leakage may be occurring. According to the plan, excursions are not necessarily indicators of leaks; they simply indicate that injection rates and pressures are not conforming to the pattern injection plan. If an issue is not readily resolved, a work order would be developed in the work order management system. This system allows for the tracking of progress on investigating potential leaks and, if a leak has occurred, the quantification of its magnitude.

Similarly, Oxy plans to develop a forecast of the rate and composition of produced fluid to confirm that production is at the level forecasted. Well management personnel will investigate if there is significant deviation from the forecast. As in the case of the injection pattern monitoring, if the investigation leads to a work order in the work order management system, this record will provide the basis for tracking the outcome of the investigation and if a leak has occurred, recording the quantity leaked to the surface.

In the event of a subsurface leak, Oxy indicates in the plan that they would determine the appropriate approach for tracking subsurface leakage to determine and quantify leakage to the surface. To quantify leakage, the relevant parameters (e.g., the rate, concentration, and duration of leakage) would be estimated to quantify the leak volume. Depending on specific circumstances, these determinations may rely on engineering estimates.

The plan concludes that in the event leakage from the subsurface occurred diffusely through the seals, the leaked gas would include H_2S, which would trigger the alarm on the personal monitors worn by field personnel. Such a diffuse leak from the subsurface has not occurred in the WSSAU. In the event such a leak was detected, personnel would determine how to address the problem. The personnel might use modeling, engineering estimates, and direct measurements to assess, address and quantify the leakage.

4.2 Wellbore Leakage

Section 6.1.5 of the MRV plan describes how wellbores in the WSSAU are monitored through continual, automated pressure monitoring of the injection zone, monitoring of the annular pressure in wellheads, and routine maintenance and inspection. Oxy plans to detect leaks from wellbores through the follow-up investigation of pressure anomalies, visual inspection, or the use of personal H_2S monitors.

The plan states that anomalies in injection zone pressure may not indicate a leak, as discussed in the previous section. However, if an investigation leads to a work order, field personnel would inspect the equipment in question and determine the nature of the problem. If it is a simple matter, the repair would be made, and the volume of leaked CO_2 would be calculated using 40 CFR Part 98 Subpart W. If more extensive repair were needed, the appropriate approach for quantifying leaked CO_2 using the relevant parameters (e.g., the rate, concentration, and duration of leakage) would be determined. The work order serves as the basis for tracking the event for GHG reporting. Any anomalies in annular pressure or other issues detected during routine maintenance inspections would be treated the same way. The MRV plan indicates that if extensive repairs were needed, the well would be shut in.

Visual inspection by field personnel is a method employed to detect unexpected releases of CO_2 from wellbores. As discussed in the plan, this is because leaking CO_2 at the surface is very cold and leads to the formation of bright white clouds and ice that are easily spotted. Field personnel visit the surface facilities on a routine basis where their inspections may include tank levels, equipment status, lube oil levels, pressure and flow rates in the facility and valves. Field personnel also check that injectors are on the proper WAG schedule and observe the facility for visible CO_2 or fluid line leaks.

4.3 H_2S Detection

Oxy states that the same visual inspection process and H_2S monitoring system will be used to detect other potential leakage at the surface as it does for leakage from wellbores. Inspections are run on a routine basis. In addition to visual inspections, the plan indicates that the data collected by H_2S monitors, which are always worn by all field personnel, are used as a method to detect leakage from wellbores. The H_2S monitors detect concentrations of H_2S up to 500 parts per million (ppm) in 0.1 ppm increments and will sound an alarm if the concentration exceeds the detection limit of 10 ppm. If an H_2S alarm is triggered, the first response is to protect the safety of the personnel, and the next step is to safely investigate the source of the alarm. Oxy considers H_2S a proxy for potential CO_2 leaks in the field. The plan notes that a gas compositional analysis showed that H_2S is approximately 1% of total injected fluid stream. Thus, any detected H_2S leaks are investigated to determine and, if needed, quantify potential CO_2 leakage.

4.4 Equipment Leaks and Vented Emissions of CO_2

The plan states that Oxy evaluates and estimates leaks from equipment, the CO_2 content of produced oil and vented CO_2, as required under 40 CFR Part 98 subpart W. Missing data estimation procedures will be used for any values associated with CO_2 emissions from equipment leaks and vented emissions of CO_2 from surface equipment at the facility that are reported in this subpart, as specified in subpart W of 40 CFR Part 98. Section 11 of the MRV plan indicates that records will be retained for information used to calculate the CO_2 emitted from equipment leaks and vented emissions of CO_2 from equipment located on the surface between the flow meter used to measure injection quantity and the injection wellhead, as well as between the production wellhead and the flow meter used to measure production quantity.

4.5 Determination of Baselines for Monitoring CO_2 Surface Leakage

Pressure monitoring of injection wells, along with the operational and monitoring data used to determine the baseline, is an established way to detect leaks in the injection wells. High and low set points are established in the monitoring program and operators are alerted if a parameter is outside the allowable window. Based on the described strategy, if results of the monitoring activities fall outside their normal predicted ranges, Oxy will initiate an investigation to determine if a leak has occurred. If investigation of an event identifies a CO_2 leak, it will be reported and documented alongside the development of a plan to correct the issue.

The strategy for detecting and quantifying surface leakage of CO_2 and for establishing expected baselines for monitoring is determined to comply with 40 CFR 98.448(a)(3) and 40 CFR 98.448(a)(4). The strategies described in the MRV plan are clearly and explicitly delineated and are consistent with subpart RR requirements.

5 Considerations Used to Calculate Site-Specific Variables for the Mass Balance Equation

5.1 Calculation of Mass of CO_2 Received

Oxy proposes to use equation RR-2 per 40 CFR 98.443(a)(2) to calculate the amount of CO_2 received. The equation is:

$$CO_{2T,r} = \sum_{p=1}^{4} (Q_{p,r} - S_{r,p}) * D * C_{CO2,r,p}$$

Where:

$CO_{2T,r}$ = Net annual mass of CO_2 received through flow meter r (metric tons).

$Q_{r,p}$ = Quarterly volumetric flow through a receiving flow meter r in quarter p at standard conditions (standard cubic meters).

$S_{r,p}$ = Quarterly volumetric flow through a receiving flow meter r that is redelivered to another facility without being injected into your well in quarter p (standard cubic meters).

D = Density of CO_2 at standard conditions (metric tons per standard cubic meter): 0.0018682.

$C_{CO2,p,r}$ = Quarterly CO_2 concentration measurement in flow for flow meter r in quarter p (vol. percent CO_2, expressed as a decimal fraction).

p = Quarter of the year.

r = Receiving flow meter.

Oxy provides an acceptable approach to calculating each of these variables in section 8.1 of the MRV Plan.

5.2 Calculation of Total Annual Mass of CO_2 Injected

Mass of CO_2 Injected into the Subsurface at the WSSAU will be calculated using the receiving custody transfer flow meter from the Permian Basin CO_2 pipeline delivery system and the flow meter located at the output of the RCF. This approach is consistent with Equation RR-5 (which allows use of a volumetric flow meter) and Equation RR-6 (which allows aggregating injection data for all wells by summing the mass of all CO_2 injected through all injection wells). Oxy explains in the MRV Plan that using data at each injection well would give an inaccurate estimate of total injection volume due to the large number of wells and the potential for propagation of error due to allowable calibration ranges for each meter.

Oxy's proposed approach for calculating the total annual mass injected is acceptable for the subpart RR requirements.

5.3 Calculation of Total Annual Mass of CO_2 Produced

Oxy will use Equation RR-8 from 40 CFR 98.443 to calculate the total mass of CO_2 produced from all production wells and Equation RR-9 to calculate CO_2 produced from all production wells in addition to the mass of CO_2 entrained in oil in the reporting year. The MRV plan states that Oxy will calculate the mass of CO_2 produced at the WSSAU using measurements from the flow meters at the inlet to RCF and the custody transfer meter for oil sales rather than the metered data from each production well. As noted in the previous section, using the data at each production well would give an inaccurate estimate of total production due to the large number of wells and the potential for propagation of error due to allowable calibration ranges for each meter.

The MRV plan states in equation RR-9 that the mass of the CO_2 entrained in oil in the reporting year will be measured utilizing commercial meters and electronic flow measurement devices at each point of custody transfer, with such mass of CO_2 calculated by multiplying the total volumetric rate by the CO_2 concentration.

Oxy's proposed approach for calculating the total annual mass produced is acceptable for the subpart RR requirements.

5.4 Calculation of Total Annual Mass of CO_2 Emitted by Surface Leakage

For reporting of the total annual CO_2 mass sequestered under subpart RR, potential surface leaks must be accounted for in the mass balance equation. Pursuant to 40 CFR 98.448(a)(2), an MRV Plan must describe the likelihood, magnitude, and timing of surface leakage of CO_2 through potential pathways. Subpart RR also requires that the MRV plan identify a strategy for establishing a baseline for monitoring CO_2 surface leakage, pursuant to 40 CFR 98.448(a)(4).

Equation RR-10 would be used to calculate and report the mass of CO_2 emitted by surface leakage. The plan states that the total annual Mass of CO_2 emitted by Surface Leakage will be calculated and reported using an approach that is tailored to specific leakage events and relies on 40 CFR Part 98 Subpart W reports of equipment leakage. Oxy states that they are prepared to address the potential for leakage in a variety of settings. The plan notes that their estimates will be dependent on several site-specific factors including measurements, engineering estimates, and emission factors, depending on the source and nature of the leakage. The plan's approach, using techniques from subpart W of the GHGRP, is acceptable for estimating potential emissions from surface leakage given the likelihood, magnitude and timing of surface leakage as described in the MRV plan.

5.5 Calculation of Mass of CO_2 Sequestered

Oxy will use equation RR-11 to calculate the mass of CO_2 sequestered in subsurface geologic formations in the reporting year at the WSSAU. Oxy will sum the total annual volumes for the cumulative mass of CO_2 sequestered. Oxy proposes an acceptable approach for calculating mass of CO_2 sequestered.

6 Summary of Findings

The subpart RR MRV plan for the West Seminole San Andres Unit facility meets the requirements of 40 CFR 98.238. The regulatory provisions of 40 CFR 98.238(a), which specifies the requirements for MRV plans, are summarized below along with a summary of relevant provisions in the WSSAU MRV Plan.

Subpart RR MRV Plan Requirement	**WSSAU MRV Plan**
40 CFR 98.448(a)(1): Delineation of the maximum monitoring area (MMA) and the active monitoring areas (AMA).	Section 4 of the MRV Plan describes the MMA and AMA. The MMA is delineated as equal to the boundary of the WSSAU, plus an all-around buffer zone of at least one-half mile and the AMA is defined as the boundary of the WSSAU plus an all-around buffer zone of at least one-half mile. The MMA and AMA delineations consider site characterization and reservoir modeling along with prior operating experience.
40 CFR 98.448(a)(2): Identification of potential surface leakage pathways for CO_2 in the MMA and the likelihood, magnitude, and timing, of surface leakage of CO_2 through these pathways.	Section 5 of the MRV Plan identifies and evaluates potential surface leakage pathways. The MRV Plan identifies the following potential pathways: well bores, faults and fractures, natural and induced seismicity, prior operations, pipeline and surface equipment, lateral migration, drilling operations, and the reservoir seal. The MRV Plan analyzes the likelihood, magnitude and timing of surface leakage through these pathways. Oxy determined that these leakage pathways are highly improbable to minimal at the WSSAU facility and it is very unlikely that potential leakage conduits would result in significant loss of CO_2 to the atmosphere.
40 CFR 98.448(a)(3): A strategy for detecting and quantifying any surface leakage of CO_2.	Section 6 of the MRV Plan describes how the facility would detect CO_2 leakage to the surface, such as monitoring of existing wells, field inspections and pressure monitoring. Sections 6 and 8 of the MRV Plan describe how surface leakage would be quantified.

40 CFR 98.448(a)(4): A strategy for establishing the expected baselines for monitoring CO_2 surface leakage.	Section 7 of the MRV Plan describes the strategy for establishing baselines against which monitoring results will be compared to assess potential surface leakage.
40 CFR 98.448(a)(5): A summary of the considerations you intend to use to calculate site-specific variables for the mass balance equation.	Section 8 of the MRV Plan describes Oxy's approach to determining the amount of CO_2 sequestered using the subpart RR mass balance equation, including as related to calculation of total annual mass emitted as equipment leakage.
40 CFR 98.448(a)(6): For each injection well, report the well identification number used for the UIC permit (or the permit application) and the UIC permit class.	Section 12.1 in the MRV Plan provides well identification numbers for each injection well. The MRV Plan specifies that all EOR injection wells in the WSSAU are classified as UIC Class II wells.
40 CFR 98.448(a)(7): Proposed date to begin collecting data for calculating total amount sequestered according to equation RR-11 or RR-12 of this subpart.	The MRV Plan states that the facility will begin implementation of this MRV plan starting in January 2021 or within 90 days of EPA approval.

Appendix A: Final MRV Plan

Oxy West Seminole San Andres Unit Subpart RR Monitoring, Reporting and Verification (MRV) Plan

December 11, 2020

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1. Introduction

OXY USA WTP LP, a subsidiary of Occidental (Oxy) operates a CO_2-EOR project in the West Seminole San Andres Unit (WSSAU). This MRV plan was developed in accordance with 40 CFR §98.440-449 (Subpart RR) to provide for the monitoring, reporting and verification of the quantity of CO_2 sequestered at the WSSAU during a specified period of injection.

2. Facility Information

2.1. Reporter Number

575401 – West Seminole San Andres Unit

2.2. UIC Permit Class

The Oil and Gas Division of the Texas Railroad Commission (TRRC) regulates oil and gas activity in Texas. All wells in the WSSAU (including production, injection and monitoring wells) are permitted by TRRC through Texas Administrative Code (TAC) Title 16 Chapter 3. TRRC has primacy to implement the Underground Injection Control (UIC) Class II program in the state for injection wells. All EOR injection wells in the WSSAU are currently classified as UIC Class II wells.

2.3. Existing Wells

Wells in the WSSAU are identified by name and number, API number, type and status. The list of wells as of September 2020 is included in Section 12.1. Any changes in wells will be indicated in the annual report.

3. Project Description

This project takes place in the West Seminole San Andres Unit (WSSAU), an oil field located in West Texas that was first produced more than 70 years ago. CO_2 flooding was initiated in 2013 and the injection plan calls for a total of approximately 20 million tonnes of CO_2 over the lifetime of the project. The field is well characterized and is suitable for secure geologic storage. Oxy uses a water alternating with gas (WAG) injection process and maintains an injection to withdrawal ratio (IWR) of at or near 1.0. A history matched reservoir simulation of the injection at WSSAU has been constructed.

3.1. Project Characteristics

The West Seminole San Andres field was discovered in 1944 and started producing in 1948. The field was unitized in 1961 and waterflood was initiated in 1969. CO_2 flooding was initiated in 2013. A long-term forecast for WSSAU was developed using the reservoir modeling approaches described in Section 3.4 that includes injection of a total of approximately 20 million tonnes of CO_2 over the life of the project. Figure 3-1 shows actual and projected CO_2 injection, production, and stored volumes in WSSAU.

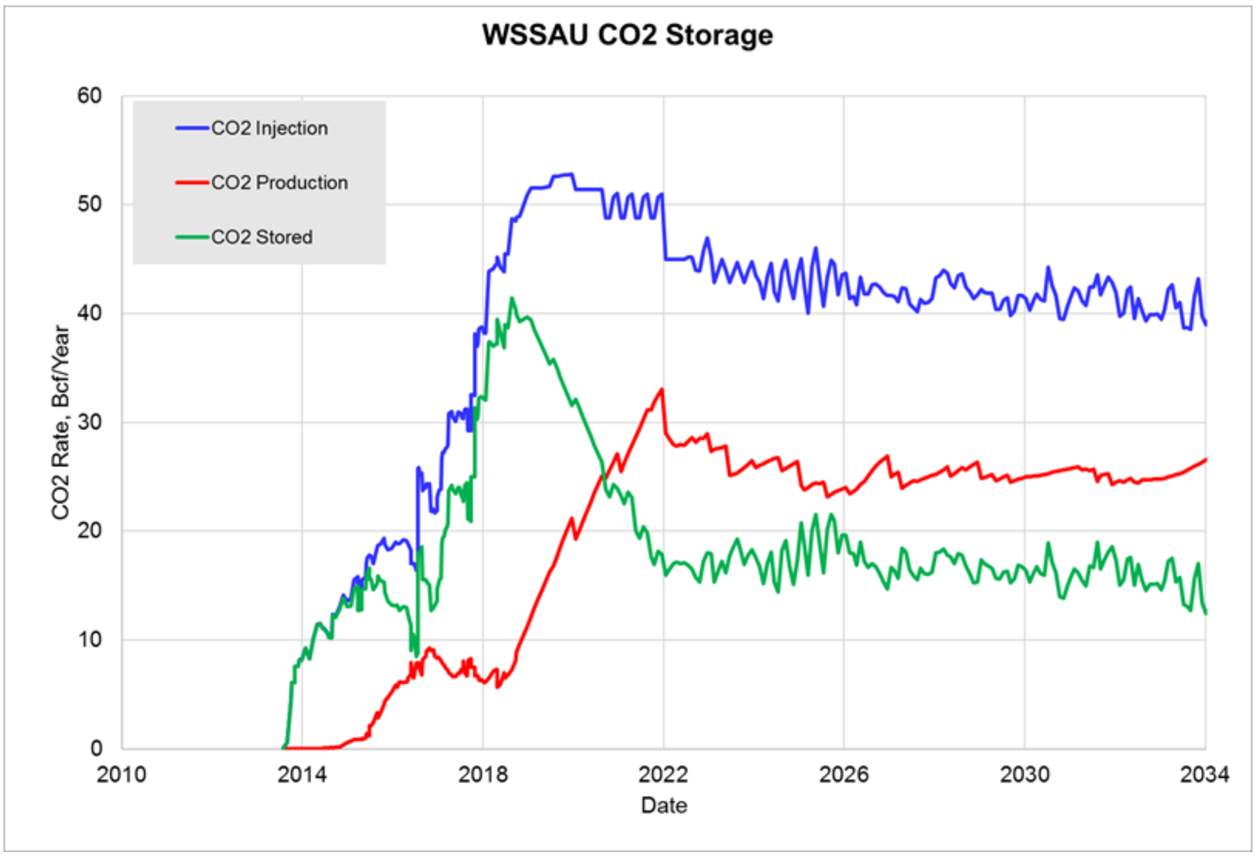

Figure 3-1 WSSAU Historic and Forecast CO_2 Injection, Production, and Storage

3.2. Environmental Setting

The WSSAU is located in the NE portion of the Central Basin Platform in West Texas (See Figure 3-2).

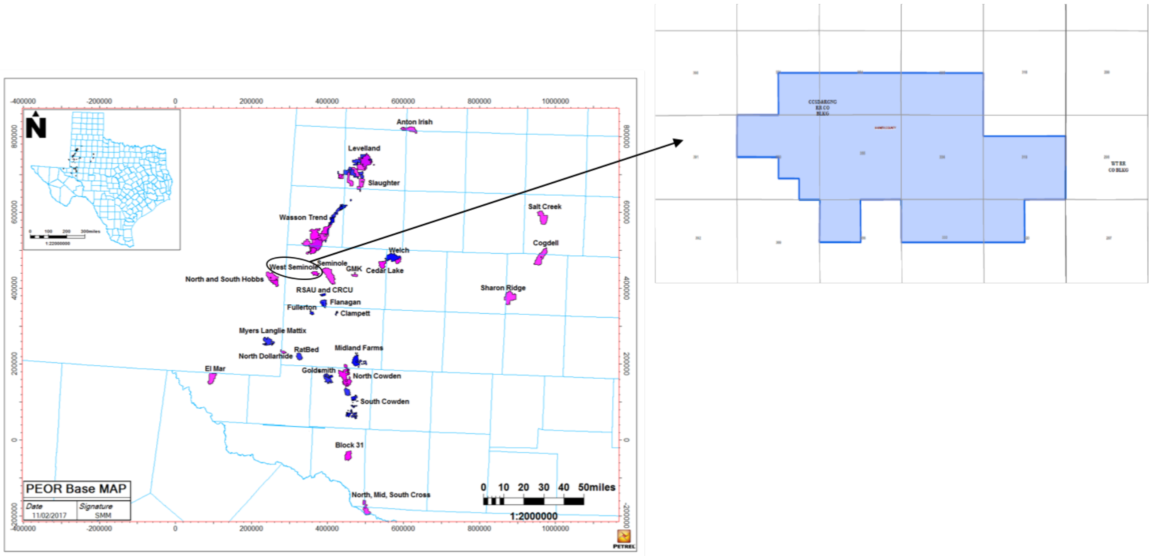

Figure 3-2 Location of WSSAU in West Texas

WSSAU produces oil from the Permian (Guadalupian) aged reservoir comprised of San Andres formation dolostone. Total thickness of the geologic unit is approximately 1500 feet, with the main reservoir within the middle 600 feet. The sequestration zone is also the oil pay completion interval, and ranges on average between 4925-5640 feet below the ground surface. See the WSSAU geologic column in Figure 3-3. The productive interval, or reservoir, is composed of layers of permeable dolomites that were deposited in a shallow marine environment during the Permian Era, some 250 to 300 million years ago.

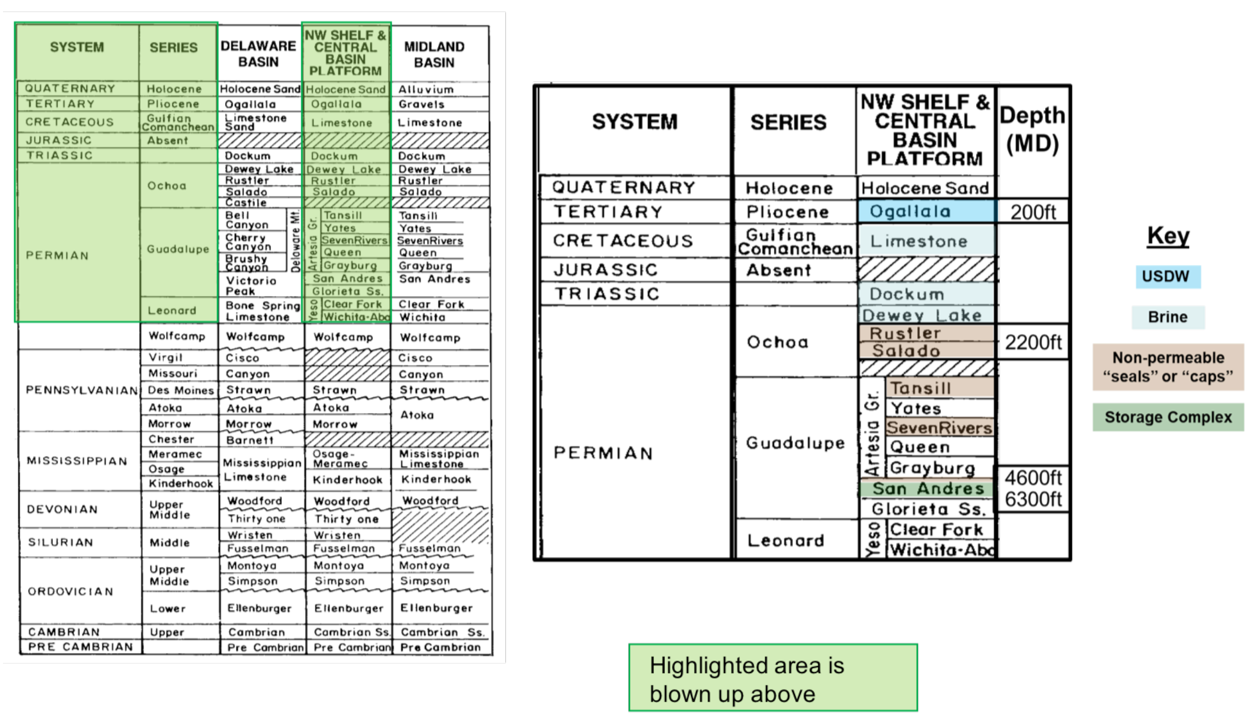

Figure 3-3 WSSAU Geologic Column

The main confining system is ~300 feet thick and is comprised of nonporous anhydrite sequences. The depth interval for the confining system ranges from top San Andres Formation to Top Pay (4545-5194 feet) with a typical range of 4660-4925 feet below ground surface. There are numerous relatively thin layers that provide additional secondary containment between the sequestration zone and freshwater aquifers. These layers are comprised of siltstones, shales, salts, and anhydrite sequences with little to no porosity or permeability.

There are no significant geologic faults or fractures identified that intersect the storage complex. There is one identified reverse fault in the Devonian interval approximately one mile below the sequestration zone. The base of sequestration zone is approximately 2175 ft. subsea depth, while the top of fault offset is interpreted to end at approximately 7500 ft. subsea depth. Fault displacement within the Devonian is approximately 200 ft. The fault is linear, subvertical, and dips toward the northeast. The presence of a gas cap is evidence of the effectiveness of the seal formed by the upper San Andres.

WSSAU is a domal structure that includes the highest elevations within the area. The elevated area forms a natural trap for oil and gas that migrated from below over millions of years. Once trapped in these high points, the oil and gas has remained in place. In the case of the WSSAU, this oil and gas has been trapped in the reservoir for 50 to 100 million years. Over time, buoyant fluids, including CO_2, rise vertically until reaching the ceiling of the dome and then migrate to the highest elevation of the structure. Figure 3-4, shows the Top San Andres pay interval structure. The colors in the structure map in Figure 3-4 indicate the subsurface elevation, with red being higher, (a shallower level) and purple being lower (a deeper level).

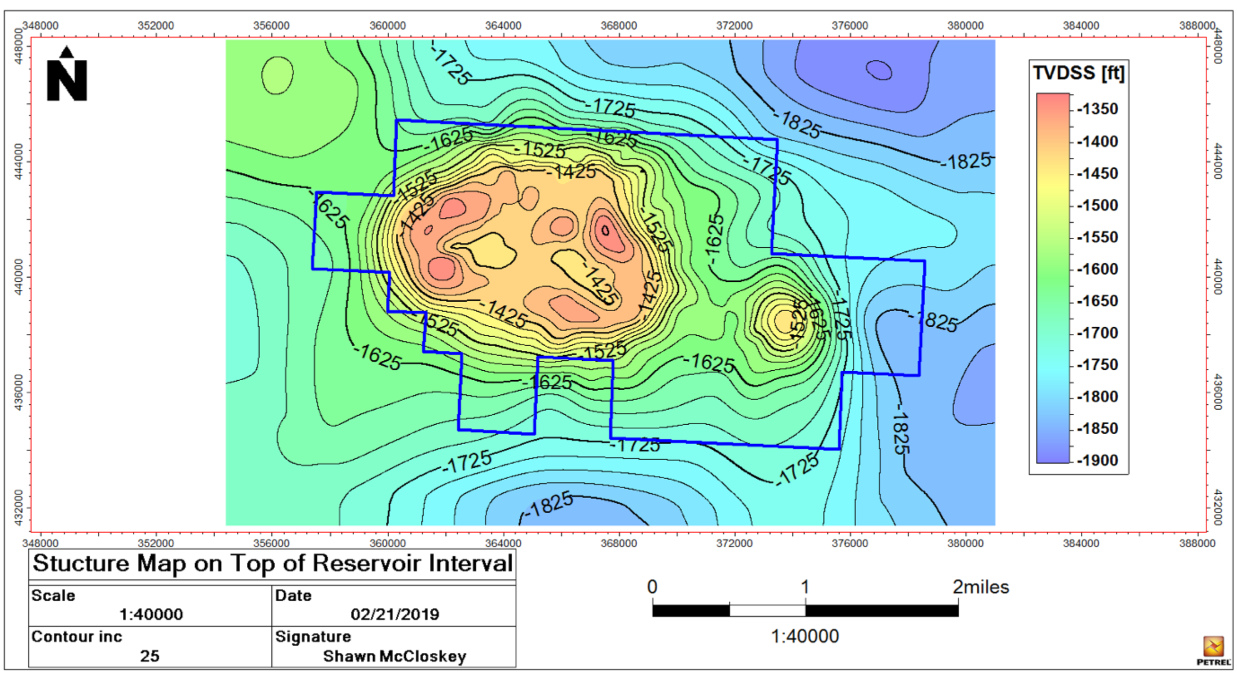

Figure 3-4 Local Area Structure on Top of San Andres

Buoyancy dominates where oil and gas are found in a reservoir. Gas, being lightest, rises to the top and water, being heavier, moves downward. Oil, being heavier than gas but lighter than water, lies in between. At the time of its discovery, natural gas was trapped at the structural high points of WSSAU, forming a "gas cap." The presence of an oil deposit and a gas cap is evidence of the effectiveness of the seal formed by the upper San Andres. Gas is buoyant and highly mobile. If it could escape WSSAU naturally, through faults or fractures, it would have done so over the millennia. Below the gas cap is an oil accumulation, the oil zone, and below that there are no distillable hydrocarbons.

Once the CO_2 flood is complete and injection ceases, the remaining mobile CO_2 will rise slowly upward, driven by buoyancy forces. There is more than enough pore space to sequester the planned CO_2 injection. The amount of CO_2 injected will not exceed the reservoir's secure storage capacity and, consequently, the risk that CO_2 could migrate to other reservoirs in the Central Basin Platform is negligible. The volume of CO_2 storage is based on the estimated total pore space within WSSAU. The total pore space within WSSAU, from the top of the reservoir down to the base of the oil zone, is calculated to be 1,512 million reservoir barrels (RB). This is the volume of rock multiplied by porosity. Table 3-1 below shows the conversion of this amount of pore space into an estimated maximum volume of approximately 1,770 Bcf (96 million tonnes) of CO_2 storage in the reservoir. It is forecasted that at the end of EOR operations stored CO_2 will fill approximately 20% of total calculated storage capacity.

Table 3-1 Calculation of Maximum Volume of CO_2 Storage Capacity at WSSAU

Top of Pay to Free Water Level (2175 ft subsea)	
Variables	WSSAU Outline
Pore Volume (**RB**)	1,511,810,594
$\mathbf{B}_{CO2}$	0.45
$\mathbf{S}_{wirr}$	0.2
$\mathbf{S}_{orCO2(volume\ weighted)}$	0.273
Max CO_2 (MCF)	1,770,498,185
Max CO_2 (BCF)	1,770

$$\mathbf{M}ax\ CO_2 = Volume\ (\mathbf{RB}) * (1 - \mathbf{S}_{wirr} - \mathbf{S}_{orCO2}) / \mathbf{B}_{CO2}$$

Where:
$CO_2(max)$ = the maximum amount of storage capacity
Pore Volume (RB) = the volume in Reservoir Barrels of the rock formation
B_{CO2} = the formation volume factor for CO_2
S_{wirr} = the irreducible water saturation
S_{orCO2} = the irreducible oil saturation

Given that WSSAU is located at the highest subsurface elevations in the area, that the confining zone has proved competent over both millions of years and current CO_2 flooding, and that the WSSAU has ample storage capacity, there is confidence that stored CO_2 will be contained securely within the reservoir.

3.3. Description of CO_2-EOR Project Facilities and the Injection Process

Figure 3-5 shows a simplified process flow diagram of the project facilities and equipment in the WSSAU. CO_2 is delivered to the WSSAU via the Permian Basin CO_2 pipeline network. The CO_2 is supplied by a number of different sources. Specified amounts are drawn from the Bravo pipeline based on contractual arrangements among suppliers of CO_2, purchasers of CO_2, and the pipeline operator.

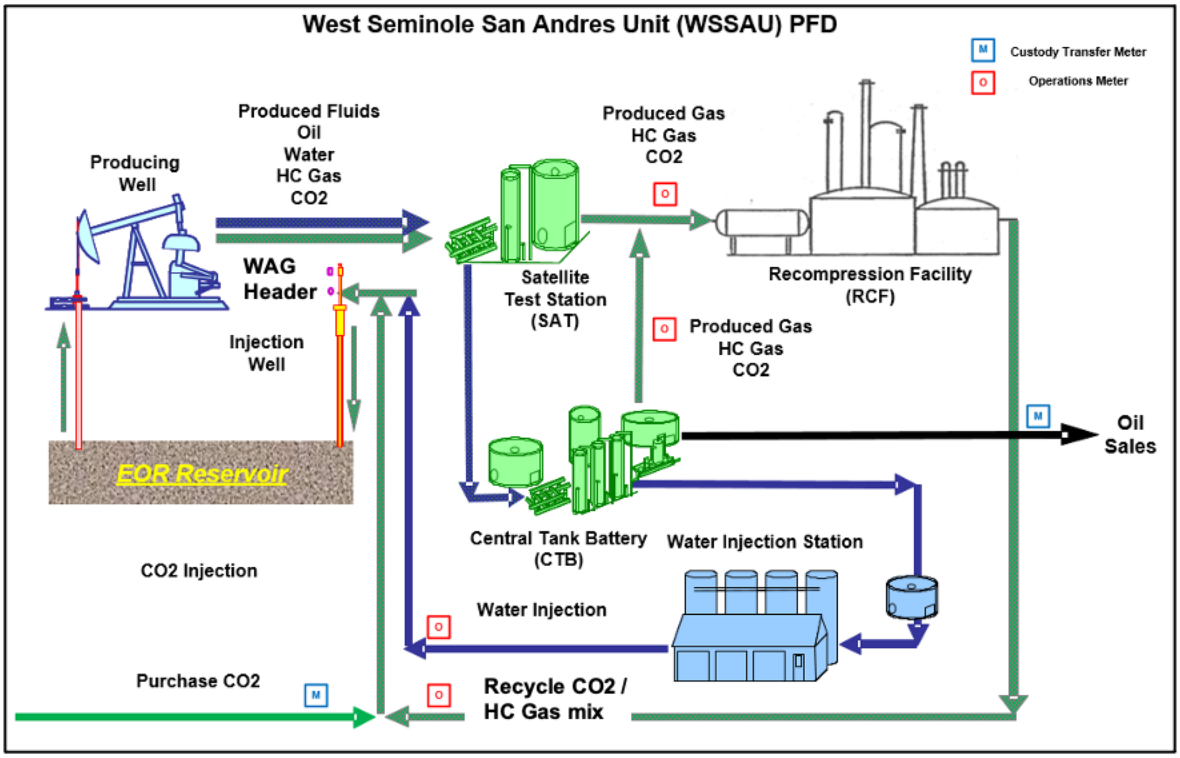

Figure 3-5 WSSAU Process Flow Diagram

Once CO_2 enters WSSAU there are three main processes involved in EOR operations:

i. CO_2 Distribution and Injection. The mass of CO_2 received at WSSAU is metered and calculated through the Custody Transfer Meter located at the pipeline delivery point as indicated in the bottom left of Figure 3-5. The mass of CO_2 received is combined with recycled CO_2 / hydrocarbon gas mix from the recompression facility (RCF) and distributed to the WAG headers for injection into the injection wells according to the pre-programmed injection plan for each well pattern which alternates between water and CO_2 injection. WAG headers are remotely operated and can inject either CO_2 or water at various rates and injection pressures as specified in the injection plans. This is an EOR project and reservoir pressure must be maintained above minimum miscibility pressure. Therefore, injection pressure must be sufficiently high to allow injectants to enter the reservoir, but below formation parting pressure (FPP).

ii. Produced Fluids Handling. Produced fluids from the production wells are a mixture of oil, hydrocarbon gas, water, CO_2 and trace amounts of other constituents in the field including nitrogen and H_2S as discussed in Section 7. They are gathered and sent to satellite test stations (SAT) for separation into a gas/CO_2 mix and a produced fluids mix of water, oil, gas, and CO_2.

The produced gas, which is composed primarily of hydrocarbons and CO_2, is sent to the recompression facility (RCF) for dehydration and recompression before reinjection into the reservoir. An operations meter at the RCF is used to determine the total volume of produced gas that is reinjected. The separated oil is metered through the Custody Transfer Meter located at the central tank battery and sold into a pipeline.

iii. Water Treatment and Injection. Water is recovered for reuse and forwarded to the water injection station for treatment and reinjection or disposal.

3.3.1. Wells in the WSSAU

The Texas Railroad Commission (TRRC) has broad authority over oil and gas operations including primacy to implement UIC Class II wells. The rules are found in Texas Administrative Code Title 16, Part 1, Chapter 3 and are also explained in a TRRC Injection/Disposal Well Permitting, Testing and Monitoring Manual (See Appendix 12-3). TRRC rules govern well siting, construction, operation, maintenance, and closure for all wells in oilfields. Briefly, TRRC rules include the following requirements:

- Fluids must be constrained in the strata in which they are encountered;
- Activities cannot result in the pollution of subsurface or surface water;
- Wells must adhere to specified casing, cementing, drilling well control, and completion requirements designed to prevent fluids from moving from the strata they are encountered into other strata with oil and gas, or into subsurface and surface waters;
- Completion report for each well including basic electric log (e.g., a density, sonic, or resistivity (except dip meter) log run over the entire wellbore) must be prepared;
- Operators must follow plugging procedures that require advance approval from the TRRC Director and allow consideration of the suitability of the cement based on the use of the well, the location and setting of plugs; and,
- Injection well operators must identify an Area of Review (AoR), use compatible materials and equipment, test, and maintain well records.

Table 2 provides a well count by type and status. All these wells are in material compliance with TRRC rules.

Table 1 WSSAU Well Penetrations by Type and Status

TYPE	ACTIVE	Dry & Abandoned	INACTIVE	P & A*	SHUT-IN	TA**	Total
DISP_H2O	2			2			**4**
INJ_GAS					1		**1**
INJ_H2O	23		7	25	3	5	**63**
INJ_WAG	35						**35**
OBSERVATION	1					1	**2**
PROD_GAS						3	**3**
PROD_OIL	80	2	4	16		16	**118**
SUP_H2O						1	**1**
TOTAL	**141**	**2**	**11**	**43**	**4**	**26**	**227**

*P&A = Plugged and Abandoned
**TA = Temporarily Abandoned

As indicated in Figure 3-6, wells are distributed across the WSSAU. The well patterns currently undergoing CO_2 flooding are outlined in the black box and CO_2 will be injected across the entire unit over the project life.

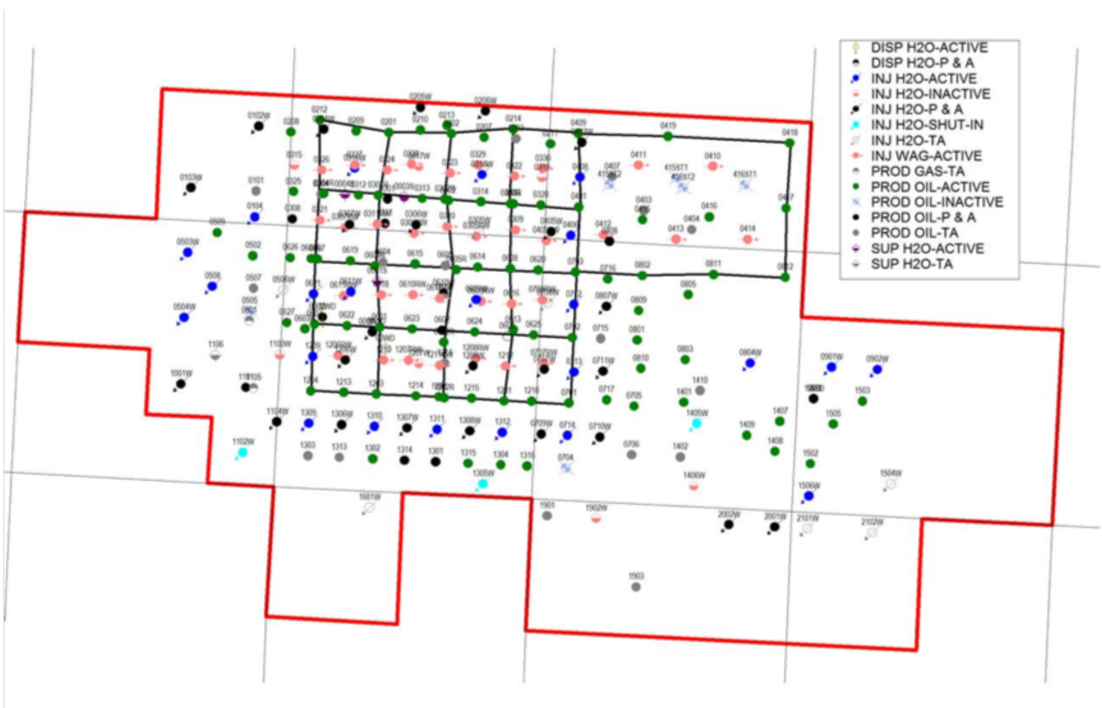

Figure 3-6 WSSAU Wells and Injection Patterns

WSSAU CO_2 EOR operations are designed to avoid conditions which could damage the reservoir and cause a potential leakage pathway. Reservoir pressure in the WSSAU is managed

by maintaining an injection to withdrawal ratio (IWR)[1] of approximately 1.0. To maintain the IWR, fluid injection and production are monitored and managed to ensure that reservoir pressure does not increase to a level that would compromise the reservoir seal or otherwise damage the integrity of the oil field.

Injection pressure is also maintained below the FPP, which is measured using step-rate tests.

3.4. Reservoir modeling

A history matched reservoir model of the current and forecast WSSAU CO_2 injection has been made. The model was constructed using Eclipse software which is a commercially available reservoir simulation code. The model simulates the recovery mechanism in which CO_2 is miscible with the hydrocarbon in the reservoir.

The model was created to:

i. Demonstrate that the storage complex has, at the minimum, the capacity to contain the planned volume of purchased CO_2.
ii. Track injected CO_2, identify how and where CO_2 is trapped in the WSSAU, and to monitor sequestration volumes and distribution.

The reservoir model utilizes four types of data:

i. Site Characteristics as described in the WSSAU Geomodel,
ii. Initial reservoir conditions and fluid property data
iii. Capillary pressure data, and
iv. Well data

The geomodel used as the foundation for the reservoir model used data from 232 wells in the area of interest that includes WSSAU. These wells have digital open- or cased-hole logs that were used for correlation of formation tops. A sequence stratigraphic framework was developed based upon core descriptions and outcrop analogs, this correlation framework was then extrapolated to well logs. The sequence stratigraphic correlations are picked at the base of mud-dominated flooding surfaces mapped out in core and extrapolated to well logs throughout the rest of the field.

The model is a four-component model consisting of water, oil, reservoir gas and injected CO_2. It is an extension of the black oil model that enables the modeling of recovery mechanisms in which the injected CO_2 is miscible with reservoir oil. This is a reasonable assumption since the reservoir under study is above minimum miscibility pressure (MMP). The total hydrocarbon and solvent (CO_2) saturation is used to calculate relative permeability to water. The solvent and oil relative permeability are then calculated using multipliers from a look-up table. The Todd-

[1] Injection to withdrawal ratio (IWR) is the ratio of the volume of fluids injected to the volume of fluids produced (withdrawn). Volumes are measured under reservoir conditions for all fluids. By keeping IWR close to 1.0, reservoir pressure is held constant, neither increasing nor decreasing.

Longstaff[2] model is used to calculate the effective viscosity and density of the hydrocarbon and solvent phases.

History matching is the process of adjusting input parameters within the range of data uncertainties until the actual reservoir performance is closely reproduced in the model. A 70-year history match was obtained. All three-phase rates (oil, gas, and water) are included in the history record. The model uses liquid rate control (combination of oil and water) for the history match.

The graphs in Figure 3-7 present the history match results of oil rate, gas rates, water rates, and water cut and show that the reservoir model provides an excellent match to actual historic data. Figure 3-8 shows the match of water and CO_2 injection.

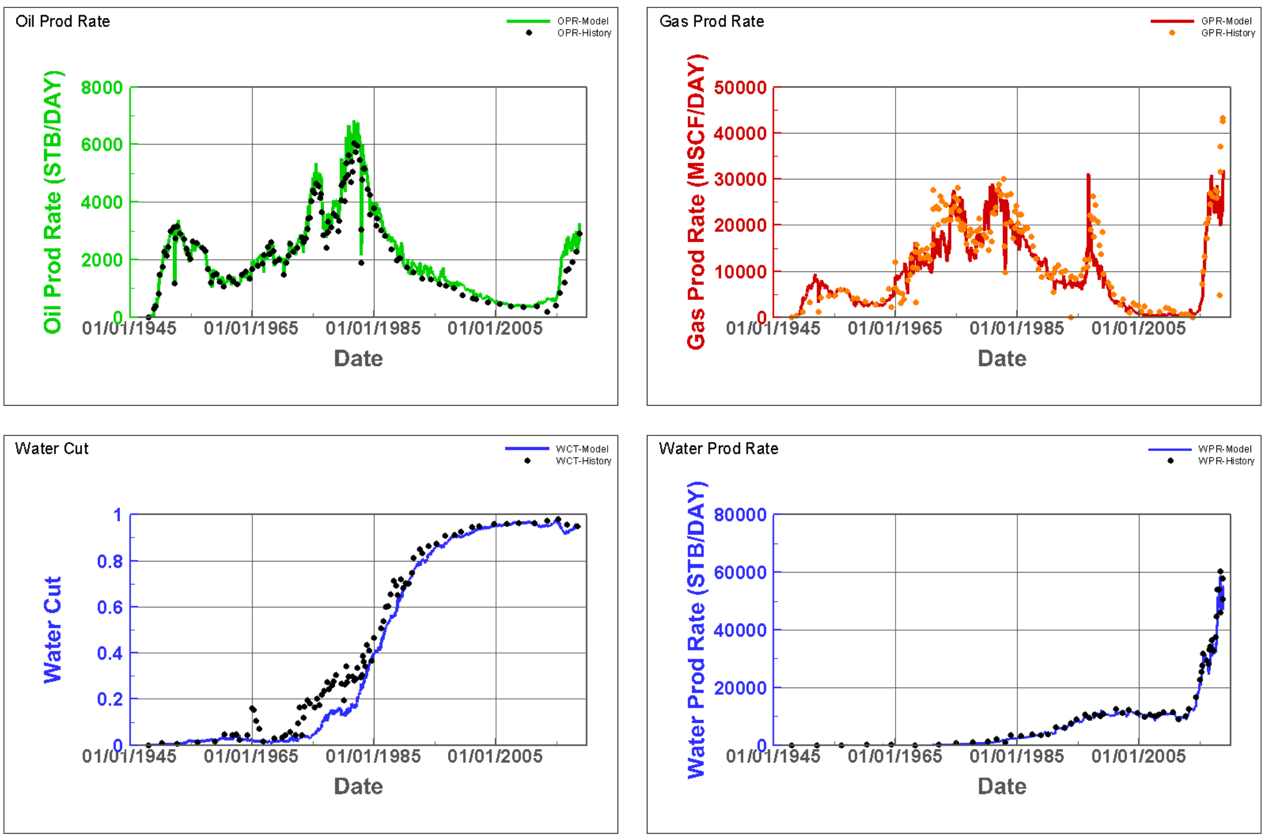

Figure 3-7 Four Parameters of History-Matched Modeling in the WSSAU Reservoir Model

[2] Todd, M.R., Longstaff, W.J.: The development, testing and application of a numerical simulator for predicting miscible flood performance. J. Petrol. Tech. 24(7), 874–882 (1972)

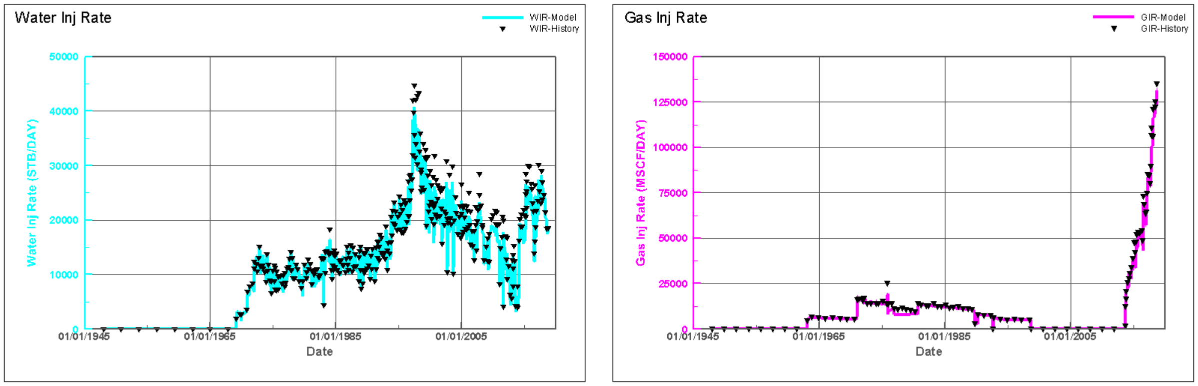

Figure 3-8 Plots of Injection History Match in the WSSAU Reservoir Model

The WSSAU reservoir model was used to evaluate the plume of CO_2 using a set of injection, production, and facilities constraints that describe the injection plan. The history match indicates that the model is robust and that there is little chance that uncertainty about any specific variable will have a meaningful impact on the reservoir CO_2 storage performance. The model forecast showed that CO_2 is contained in the reservoir within the boundaries of WSSAU.

4. Delineation of Monitoring Area and Timeframes

4.1. Active Monitoring Area

The Active Monitoring Area (AMA) is defined by the boundary of the WSSAU plus the required ½ mile buffer.

4.2. Maximum Monitoring Area

The Maximum Monitoring Area (MMA) is defined by the boundary of the WSSAU plus the required ½ mile buffer as required by 40 CFR §98.440-449 (Subpart RR).

4.3. Monitoring Timeframes

The primary purpose for injecting CO_2 is to produce oil that would otherwise remain trapped in the reservoir and not, as in UIC Class VI, "specifically for the purpose of geologic storage."[3] During a Specified Period, there will be a subsidiary purpose of establishing the long-term containment of CO_2 in the WSSAU. The Specified Period will be shorter than the period of production from the WSSAU.

At the conclusion of the Specified Period, a request for discontinuation of reporting will be submitted. This request will be submitted with a demonstration that current monitoring and model(s) show that the cumulative mass of CO_2 reported as sequestered during the Specified Period is not expected to migrate in the future in a manner likely to result in surface leakage. It is expected that it will be possible to make this demonstration almost immediately after the Specified Period ends based upon predictive modeling supported by monitoring data.

The reservoir pressure in the WSSAU is collected for use reservoir modeling and operations management. Reservoir pressure is not forecast to change appreciably since the IWR will be maintained at approximately 1.0. The reservoir model shows that by the end of CO_2 injection, average reservoir pressure will be approximately 2,360 psi. Once injection ceases, reservoir pressure is predicted to stabilize within one year. Over time, reservoir pressure is expected to drop by approximately 10 psi. The trend of the reservoir pressure decline will be one of the bases of a request to discontinue monitoring and reporting.

[3] EPA UIC Class VI rule, EPA 75 FR 77291, December 10, 2010, section 146.81(b).

5. Evaluation of Potential Pathways for Leakage to the Surface, Leakage Detection, Verification, and Quantification

In the roughly 70 years since the oil field of the WSSAU was discovered, the reservoir has been studied and documented extensively. Based on the knowledge gained from that experience, this section assesses the potential pathways for leakage of stored CO_2 to the surface including:

i. Existing Well Bores
ii. Faults and Fractures
iii. Natural and Induced Seismic Activity
iv. Previous Operations
v. Pipeline/Surface Equipment
vi. Lateral Migration Outside the WSSAU
vii. Drilling Through the CO_2 Area
viii. Diffuse Leakage Through the Seal

This analysis shows that leakage through wellbores and surface equipment pose the only meaningful potential leakage pathways. The monitoring program to detect and quantify leakage is based on this assessment as discussed below.

5.1. Existing Wellbores

As part of the TRRC requirement to initiate CO_2 flooding, an extensive review of all WSSAU penetrations was completed to determine the need for corrective action. That analysis showed that all penetrations have either been adequately plugged and abandoned or, if in use, do not require corrective action. All wells in the WSSAU were constructed and are operated in compliance with TRRC rules.

As part of routine risk management, the potential risk of leakage associated with the following were identified and evaluated:

i. CO_2 flood beam wells
ii. Electrical submersible pump (ESP) producer wells, and
iii. CO_2 WAG injector wells.

The risk assessment classified all risks associated with subsurface as low risk, i.e., less than 1% likelihood to occur and having a consequence that is insubstantial. The risks were classified as low risk because, the WSSAU geology is well suited to CO_2 sequestration with an extensive confining zone that is free of fractures and faults that could be potential conduits for CO_2 migration. The low risk is supported by the results of the reservoir model which shows that stored CO_2 is not predicted to leave the WSSAU boundary. Any risks are further mitigated because the WSSAU is operated in a manner that maintains, monitors, and documents the integrity of the reservoir.

The risk of well leakage is mitigated through:

i. Adhering to regulatory requirements for well drilling and testing;
ii. implementing best practices that Oxy has developed through its extensive operating experience;

iii. monitoring injection/production performance, wellbores, and the surface; and,
iv. maintaining surface equipment.

Continual and routine monitoring of the wellbores and site operations will be used to detect leaks or other potential well problems, as follows:

- Pressure in injection wells is monitored on a continual basis. The injection plans for each pattern are programmed into the injection WAG satellite to govern the rate, pressure, and duration of either water or CO_2 injection. Pressure monitors on the injection wells are programmed to flag whenever statistically significant pressure deviations from the targeted ranges in the plan are identified. Leakage on the inside or outside of the injection wellbore would affect pressure and be detected through this approach. If such events occur, they are investigated and addressed. Oxy's experience, from over 40 years of operating CO_2 EOR projects, is that such leakage is very rare and there have been no incidents of fluid migration out of the intended zone at WSSAU.

- Production well performance is monitored using the production well test process conducted when produced fluids are gathered and sent to an SAT. There is a routine well testing cycle for each SAT, with each well being tested approximately once every two months. During this cycle, each production well is diverted to the well test equipment for a period of time sufficient to measure and sample produced fluids (generally 8-12 hours). These tests are the basis for allocating a portion of the produced fluids measured at the SAT to each production well, assessing the composition of produced fluids by location, and assessing the performance of each well. Performance data are reviewed on a routine basis to ensure that CO_2 flooding efficiency is optimized. If production is off the plan, it is investigated and any identified issues addressed. Leakage to the outside of production wells is not considered a major risk because of the reduced pressure in the casing. Further, the personal H_2S monitors are designed to detect leaked fluids around production wells during well inspections.

- Field inspections are conducted on a routine basis by field personnel. Leaking CO_2 is very cold and leads to formation of bright white clouds and ice that are easily spotted. All field personnel are trained to identify leaking CO_2 and other potential problems at wellbores and in the field. Any CO_2 leakage detected will be documented and reported and quantified.

Based on ongoing monitoring activities and review of the potential leakage risks posed by well bores, it is concluded that the risk of CO_2 leakage through well bores is being mitigated by detecting problems as they arise and quantifying any leakage that does occur.

5.2. Faults and Fractures

After reviewing geologic, seismic, operating, and other evidence, it has been concluded that there are no known faults or fractures that transect the San Andres reservoir in the project area. As a result, there is no risk of leakage due to fractures or faults.

Measurements to determine FPP and reservoir pressure are routinely updated. This information is used to manage injection patterns so that the injection pressure will not exceed FPP. An IWR at or near 1 is also maintained. Both of these measures mitigate the potential for inducing faults or fractures. As a safeguard, WAG skids are continuously monitored and set with automatic shutoff controls if injection pressures exceed programmed levels.

5.3. Natural or Induced Seismicity

After reviewing the literature and actual operating experience, it is concluded that there is no direct evidence that natural seismic activity poses a significant risk for loss of CO_2 to the surface in the Permian Basin, and specifically in the WSSAU.

To evaluate this potential risk at WSSAU, Oxy has reviewed the nature and location of seismic events in West Texas. Some of the recorded earthquakes in West Texas are far removed from any injection operation. These are judged to be from natural causes. Others are near oil fields or water disposal wells and are placed in the category of "quakes in close association with human enterprise."[4] A review of the USGS database of recorded earthquakes at M3.0 or greater in the Permian Basin indicates that none have occurred in the West Seminole Field; the closest took place in 1992 approximately 35 miles away. The concern about induced seismicity is that it could lead to fractures in the seal providing a pathway for CO_2 leakage to the surface. Oxy is not aware of any reported loss of injectant (brine water or CO_2) to the surface associated with any seismic activity. There is no direct evidence to suggest that natural seismic activity poses a significant risk for loss of CO_2 to the surface in the Permian Basin, and specifically in the WSSAU. If induced seismicity resulted in a pathway for material amounts of CO_2 to migrate from the injection zone, other reservoir fluid monitoring provisions (e.g., reservoir pressure, well pressure, and pattern monitoring) would detect the migration and lead to further investigation. Oxy also participates in the TexNet seismic monitoring network[5] and will continue to monitor for seismic signals that could indicate the creation of potential leakage pathways in WSSAU.

5.4. Previous Operations

CO_2 flooding was initiated in WSSAU in 2013. To obtain permits for CO_2 flooding, the AoR around all CO_2 injector wells was evaluated to determine if there were any unknown penetrations and to assess if corrective action was required at any wells. As indicated in Section 5.1, this evaluation reviewed the identified penetrations and determined that no additional corrective action was needed. Further, Oxy's standard practice for drilling new wells includes a rigorous review of nearby wells to ensure that drilling will not cause damage to or interfere with existing wells. And, requirements to construct wells with materials that are designed for CO_2 injection are adhered to at WSSAU. These practices ensure that that there are no unknown wells within WSSAU and that the risk of migration from older wells has been sufficiently mitigated. The successful experience with CO_2 flooding in WSSAU demonstrates that the confining zone has not been impaired by previous operations.

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[4] Frohlich, Cliff (2012) "Induced or Triggered Earthquakes in Texas: Assessment of Current Knowledge and Suggestions for Future Research", Final Technical Report, Institute for Geophysics, University of Texas at Austin, Office of Sponsored Research.
[5] https://www.beg.utexas.edu/texnet-cisr/texnet

5.5. Pipelines and Surface Equipment

As part of routine risk management described in Section 5, the potential risk of leakage associated with the following are identified and evaluated:

i. The production satellite
ii. The Central Tank Battery; and
iii. Facility pipelines.

As described in Section 5.1, the risk assessment classified all subsurface risks as low risk, i.e., less than 1% likelihood to occur and having a consequence that is insubstantial. The risks associated with pipelines and surface equipment were classified as low risk because, the WSSAU is operated in a manner that maintains, monitors, and documents the integrity of the reservoir.

The risk of well leakage is mitigated through:

i. Adhering to regulatory requirements for well drilling and testing;
ii. implementing best practices that Oxy has developed through its extensive operating experience;
iii. monitoring injection/production performance, wellbores, and the surface; and,
iv. maintaining surface equipment.

Personnel continuously monitor the pipeline system using the SCADA system and are able to detect and mitigate pipeline leaks expeditiously. Such risks will be prevented, to the extent possible, by relying on the use of prevailing design and construction practices and maintaining compliance with applicable regulations. The facilities and pipelines currently utilize and will continue to utilize materials of construction and control processes that are standard for CO_2 EOR projects in the oil and gas industry. Operating and maintenance practices currently follow and will continue to follow demonstrated industry standards. CO_2 delivery via the Permian Basin CO_2 pipeline system will continue to comply with all applicable regulations. Finally, routine visual inspection of surface facilities by field staff will provide an additional way to detect leaks and further support the efforts to detect and remedy any leaks in a timely manner. Should leakage be detected from pipeline or surface equipment, the volume of released CO_2 will be quantified following the requirements of Subpart W of EPA's GHGRP.

5.6. Lateral Migration Outside the WSSAU

It is highly unlikely that injected CO_2 will migrate downdip and laterally outside the WSSAU because of the nature of the geology and the approach used for injection. First, WSSAU is situated in the highest local elevations within the San Andres. This means that over long periods of time, injected CO_2 will tend to rise vertically towards the Upper San Andres and continue towards the point in the WSSAU with the highest elevation. Second, the planned injection volumes and active fluid management during injection operations will prevent CO_2 from migrating laterally out of the structure. Finally, the total volume of fluids contained in the WSSAU will stay relatively constant. Based on site characterization and planned and projected operations it is estimated that the total volume of stored CO_2 will be considerably less than calculated capacity.

5.7. Drilling in the WSSAU

The TRRC regulates well drilling activity in Texas. Pursuant to TRRC rules, wells casing shall be securely anchored in the hole in order to effectively control the well at all times, all usable-quality water zones shall be isolated and sealed off to effectively prevent contamination or harm, and all productive zones, potential flow zones, and zones with corrosive formation fluids shall be isolated and sealed off to prevent vertical migration of fluids, including gases, behind the casing. Where TRRC rules do not detail specific methods to achieve these objectives, operators shall make every effort to follow the intent of the section, using good engineering practices and the best currently available technology. The TRRC requires applications and approvals before a well is drilled, recompleted, or reentered. Well drilling activity at WSSAU is conducted in accordance with TRRC rules. Oxy's visual inspection process, including routine site visits, will identify unapproved drilling activity in the WSSAU.

In addition, Oxy intends to operate WSSAU for several more decades and will continue to be vigilant about protecting the integrity of its assets and maximizing the potential of its resources, including oil, gas and CO_2. Consequently, the risks associated with third parties penetrating the WSSAU are negligible.

5.8. Diffuse Leakage Through the Seal

Diffuse leakage through the seal formed by the upper San Andres is highly unlikely. The presence of a gas cap trapped over millions of years confirms that the seal has been secure. Injection pattern monitoring assures that no breach of the seal will be created. Wellbores that penetrate the seal make use of cement and steel construction that is closely regulated to ensure that no leakage takes place. Injection pressure is continuously monitored and unexplained changes in injection pressure that might indicate leakage would trigger investigation as to the cause.

5.9. Leakage Detection, Verification, and Quantification

As discussed above, the potential sources of leakage include issues, such as problems with surface equipment (pumps, valves, etc.) or subsurface equipment (well bores), and unique events such as induced fractures. An event-driven process to assess, address, track, and if applicable quantify potential CO_2 leakage is used. Table 3 summarizes some of these potential leakage scenarios, the monitoring activities designed to detect those leaks, the standard response, and other applicable regulatory programs requiring similar reporting.

Given the uncertainty concerning the nature and characteristics of any leaks that may be encountered, the most appropriate methods for quantifying the volume of leaked CO_2 will be determined on a case by case basis. In the event leakage occurs, the most appropriate methods for quantifying the volume leaked will be determined and it will be reported as required as part of the annual Subpart RR submission.

Any volume of CO_2 detected leaking to surface will be quantified using acceptable emission factors such as those found in 40 CFR Part 98 Subpart W or engineering estimates of leak amounts based on measurements in the subsurface, field experience, and other factors such as the frequency of inspection. Leaks will be documented, evaluated and addressed in a timely manner.

Records of leakage events will be retained in the electronic environmental documentation and reporting system. Repairs requiring a work order will be documented in the electronic equipment maintenance system.

Table 2 Response Plan for CO_2 Loss

Risk	Monitoring Plan	Response Plan
Tubing Leak	Monitor changes in tubing and annulus pressure; MIT for injectors	Wellbore is shut in and workover crews respond within days
Casing Leak	Routine Field inspection; Monitor changes in annulus pressure, MIT for injectors; extra attention to high risk wells	Well is shut in and workover crews respond within days
Wellhead Leak	Routine Field inspection, SCADA system monitors wellhead pressure	Well is shut in and workover crews respond within days
Loss of Bottom-hole pressure control	Blowout during well operations	Maintain well kill procedures
Unplanned wells drilled through San Andres	Routine Field inspection to prevent unapproved drilling; compliance with TRRC permitting for planned wells.	Assure compliance with TRRC regulations
Loss of seal in abandoned wells	Reservoir pressure in WAG headers; high pressure found in new wells	Re-enter and reseal abandoned wells
Pumps, valves, etc.	Routine Field inspection, SCADA	Workover crews respond within days
Overfill beyond spill points	Reservoir pressure in WAG headers; high pressure found in new wells	Fluid management along lease lines
Leakage through induced fractures	Reservoir pressure in WAG headers; high pressure found in new wells	Comply with rules for keeping pressures below parting pressure
Leakage due to seismic event	Reservoir pressure in WAG headers; high pressure found in new wells	Shut in injectors near seismic event

5.10. Summary

The structure and stratigraphy of the San Andres reservoir in the WSSAU is ideally suited for the injection and storage of CO_2. The stratigraphy within the CO_2 injection zones is porous, permeable and thick, providing ample capacity for long-term CO_2 storage. The reservoir is overlain by several intervals of impermeable geologic zones that form effective seals or "caps" to fluids in the reservoir. After assessing potential risk of release from the subsurface and steps that have been taken to prevent leaks, it has been determined that the potential threat of leakage is extremely low.

In summary, based on a careful assessment of the potential risk of release of CO_2 from the subsurface, it has been determined that there are no leakage pathways at the WSSAU that are likely to result in significant loss of CO_2 to the atmosphere. Further, given the detailed knowledge of the field and its operating protocols, it is concluded that any CO_2 leakage to the surface that could arise through either identified or unexpected leakage pathways would be detected and quantified.

6. Monitoring and Considerations for Calculating Site Specific Variables

Monitoring will also be used to determine the quantities in the mass balance equation and to make the demonstration that the CO_2 plume will not migrate to the surface after the time of discontinuation.

6.1. For the Mass Balance Equation

6.1.1. General Monitoring Procedures

Flow rate, pressure, and gas composition data are monitored and collected from the WSSAU in centralized data management systems as part of ongoing operations. These data are monitored by qualified technicians who follow response and reporting protocols when the systems deliver notifications that data exceed statistically acceptable boundaries.

Metering protocols used at WSSAU follow the prevailing industry standard(s) for custody transfer as currently promulgated by the API, the American Gas Association (AGA), and the Gas Processors Association (GPA), as appropriate. This approach is consistent with EPA GHGRP's Subpart RR, section 98.444(e)(3). These meters will be maintained routinely, operated continually, and will feed data directly to the centralized data collection systems. The meters meet the industry standard for custody transfer meter accuracy and calibration frequency.

6.1.2. CO_2 Received

As indicated in Figure 3-5, the volume of received CO_2 is measured using a commercial custody transfer meter at the point at which custody of the CO_2 from the Permian Basin CO_2 pipeline delivery system is transferred to the WSSAU. This meter measures flow rate continually. The transfer is a commercial transaction that is documented. CO_2 composition is governed by contract and the gas is routinely sampled. Fluid composition will be determined, at a minimum, quarterly, consistent with EPA GHGRP's Subpart RR, section 98.447(a). All meter and composition data are documented, and records will be retained for at least three years. No CO_2 is received in containers.

6.1.3. CO_2 Injected in the Subsurface

Injected CO_2 will be calculated using the flow meter volumes at the operations meter at the outlet of the RCF and the custody transfer meter at the CO_2 off-take point from the Permian Basin CO_2 pipeline delivery system

6.1.4. CO_2 Produced, Entrained in Products, and Recycled

The following measurements are used for the mass balance equations in Section 7:

CO_2 produced in the gaseous stage is calculated using the volumetric flow meters at the inlet to the RCF.

CO_2 that is entrained in produced oil, as indicated in Figure 3-5, is calculated using volumetric flow through the custody transfer meter.

Recycled CO_2 is calculated using the volumetric flow meter at the outlet of the RCF, which is an operations meter.

6.1.5. CO_2 Emitted by Surface Leakage

Oxy uses 40 CFR Part 98 Subpart W to estimate surface leaks from equipment at the WSSAU. Subpart W uses a factor-driven approach to estimate equipment leakage. In addition, an event-driven process to assess, address, track, and if applicable quantify potential CO_2 leakage to the surface is used. The Subpart W report and results from any event-driven quantification will be reconciled to assure that surface leaks are not double counted.

The multi-layered, risk-based monitoring program for event-driven incidents has been designed to meet two objectives: 1) to detect problems before CO_2 leaks to the surface; and 2) to detect and quantify any leaks that do occur. This section discusses how this monitoring will be conducted and used to quantify the volumes of CO_2 leaked to the surface.

Monitoring for potential Leakage from the Injection/Production Zone:

In addition to the measures discussed in Section 5.9, both injection into and production from the reservoir will be monitored as a means of early identification of potential anomalies that could indicate leakage from the subsurface.

Reservoir simulation modeling, based on extensive history-matched data, is used to develop injection plans (fluid rate, pressure, volume) that are programmed into each WAG satellite. If injection pressure or rate measurements are outside the specified set points determined as part of each pattern injection plan, a data flag is automatically triggered and field personnel will investigate and resolve the problem. These excursions will be reviewed by well management personnel to determine if CO_2 leakage may be occurring. Excursions are not necessarily indicators of leaks; they simply indicate that injection rates and pressures are not conforming to the pattern injection plan. In many cases, problems are straightforward to fix (e.g., a meter needs to be recalibrated or some other minor action is required), and there is no threat of CO_2 leakage. In the case of issues that are not readily resolved, more detailed investigation and response would be initiated, and support staff would provide additional assistance and evaluation. Such issues would lead to the development of a work order in the work order management system. This record enables the tracking of progress on investigating potential leaks and, if a leak has occurred, to quantify its magnitude.

Likewise, a forecast of the rate and composition of produced fluids is developed. Each producer well is assigned to a specific SAT and is isolated during each cycle for a well production test. This data is reviewed on a periodic basis to confirm that production is at the level forecasted. If there is a significant deviation from the plan, well management personnel investigate. If the issue cannot be resolved quickly, more detailed investigation and response would be initiated. As in the case of the injection pattern monitoring, if the investigation leads to a work order in the work order management system, this record will provide the basis for tracking the outcome of the investigation and if a leak has occurred, recording the quantity leaked to the surface. If leakage in the flood zone were detected, an appropriate method would be used to quantify the involved volume of CO_2. This might include use of material balance equations based on known

injected quantities and monitored pressures in the injection zone to estimate the volume of CO_2 involved.

A subsurface leak might not lead to a surface leak. In the event of a subsurface leak, Oxy would determine the appropriate approach for tracking subsurface leakage to determine and quantify leakage to the surface. To quantify leakage, the relevant parameters (e.g., the rate, concentration, and duration of leakage) would be estimated to quantify the leak volume. Depending on specific circumstances, these determinations may rely on engineering estimates.

In the event leakage from the subsurface occurred diffusely through the seals, the leaked gas would include H_2S, which would trigger the alarm on the personal monitors worn by field personnel. Such a diffuse leak from the subsurface has not occurred in the WSSAU. In the event such a leak was detected, personnel would determine how to address the problem. The personnel might use modeling, engineering estimates, and direct measurements to assess, address, and quantify the leakage.

Monitoring of Wellbores:
WSSAU wells are monitored through continual, automated pressure monitoring of the injection zone, monitoring of the annular pressure in wellheads, and routine maintenance and inspection.

Leaks from wellbores would be detected through the follow-up investigation of pressure anomalies, visual inspection, or the use of personal H_2S monitors.

Anomalies in injection zone pressure may not indicate a leak, as discussed above. However, if an investigation leads to a work order, field personnel would inspect the equipment in question and determine the nature of the problem. If it is a simple matter, the repair would be made and the volume of leaked CO_2 would be included in the 40 CFR Part 98 Subpart W report for the WSSAU. If more extensive repair were needed, the appropriate approach for quantifying leaked CO_2 using the relevant parameters (e.g., the rate, concentration, and duration of leakage) would be determined. The work order would serve as the basis for tracking the event for GHG reporting.

Anomalies in annular pressure or other issues detected during routine maintenance inspections would be treated in the same way. Field personnel would inspect the equipment in question and determine the nature of the problem. For simple matters the repair would be made at the time of inspection and the volume of leaked CO_2 would be included in the 40 CFR Part 98 Subpart W report for the WSSAU. If more extensive repairs were needed, the well would be shut in, a work order would be generated and the appropriate approach for quantifying leaked CO_2 using the relevant parameters (e.g., the rate, concentration, and duration of leakage) would be determined. The work order would serve as the basis for tracking the event for GHG reporting.

Because leaking CO_2 at the surface is very cold and leads to formation of bright white clouds and ice that are easily spotted, a visual inspection process in the area of the WSSAU is employed to detect unexpected releases from wellbores. Field personnel visit the surface facilities on a routine basis. Inspections may include tank levels, equipment status, lube oil levels, pressures and flow rates in the facility, and valves. Field personnel also check that injectors are on the proper WAG schedule and observe the facility for visible CO_2 or fluid line leaks.

Finally, the data collected by the H_2S monitors, which are worn by all field personnel at all times, is used as a last method to detect leakage from wellbores. The H_2S monitors detection limit is 10 ppm; if an H_2S alarm is triggered, the first response is to protect the safety of the personnel, and the next step is to safely investigate the source of the alarm. As noted previously, H_2S is considered a proxy for potential CO_2 leaks in the field. Thus, detected H_2S leaks will be investigated to determine and, if needed, quantify potential CO_2 leakage. If the incident results in a work order, this will serve as the basis for tracking the event for GHG reporting.

Other Potential Leakage at the Surface:

The same visual inspection process and H_2S monitoring system will be used to detect other potential leakage at the surface as it does for leakage from wellbores. Routine visual inspections are used to detect significant loss of CO_2 to the surface. Field personnel routinely visit surface facilities to conduct a visual inspection. Inspections may include review of tank level, equipment status, lube oil levels, pressures and flow rates in the facility, valves, ensuring that injectors are on the proper WAG schedule, and also conducting a general observation of the facility for visible CO_2 or fluid line leaks. If problems are detected, field personnel would investigate, and, if maintenance is required, generate a work order in the maintenance system, which is tracked through completion. In addition to these visual inspections, the results of the personal H_2S monitors worn by field personnel will be used as a supplement for smaller leaks that may escape visual detection.

If CO_2 leakage to the surface is detected, it will be reported to surface operations personnel who will review the reports and conduct a site investigation. If maintenance is required, steps are taken to prevent further leaks, a work order will be generated in the work order management system. The work order will describe the appropriate corrective action and be used to track completion of the maintenance action. The work order will also serve as the basis for tracking the event for GHG reporting and quantifying any CO_2 emissions.

6.1.6. CO_2 emitted from equipment leaks and vented emissions of CO_2 from surface equipment located between the injection flow meter and the injection wellhead

Oxy evaluates and estimates leaks from equipment, the CO_2 content of produced oil, and vented CO_2, as required under 40 CFR Part 98 Subpart W.

6.1.7. CO_2 emitted from equipment leaks and vented emissions of CO_2 from surface equipment located between the production flow meter and the production wellhead

Oxy evaluates and estimates leaks from equipment, the CO_2 content of produced oil, and vented CO_2, as required under 40 CFR Part 98 Subpart W.

6.2. To Demonstrate that Injected CO_2 is not Expected to Migrate to the Surface

At the end of the Specified Period, injecting CO_2 for the subsidiary purpose of establishing the long-term storage of CO_2 in the WSSAU will cease. Some time after the end of the Specified

Period, a request to discontinue monitoring and reporting will be submitted. The request will demonstrate that the amount of CO_2 reported under 40 CFR §98.440-449 (Subpart RR) is not expected to migrate in the future in a manner likely to result in surface leakage. At that time, the request will be supported with years of data collected during the Specified Period as well as two to three (or more, if needed) years of data collected after the end of the Specified Period. This demonstration will provide the information necessary for the EPA Administrator to approve the request to discontinue monitoring and reporting and may include, but is not limited to:

i. Data comparing actual performance to predicted performance (purchase, injection, production) over the monitoring period;
ii. An assessment of the CO_2 leakage detected, including discussion of the estimated amount of CO_2 leaked and the distribution of emissions by leakage pathway;
iii. A demonstration that future operations will not release the volume of stored CO_2 to the surface;
iv. A demonstration that there has been no significant leakage of CO_2; and,
v. An evaluation of reservoir pressure that demonstrates that injected fluids are not expected to migrate in a manner to create a potential leakage pathway.

7. Determination of Baselines

Existing automatic data systems will be utilized to identify and investigate excursions from expected performance that could indicate CO_2 leakage. Data systems are used primarily for operational control and monitoring and as such are set to capture more information than is necessary for reporting in the Annual Subpart RR Report. The necessary system guidelines to capture the information that is relevant to identify possible CO_2 leakage will be developed. The following describes the approach to collecting this information.

Visual Inspections

As field personnel conduct routine inspections, work orders are generated in the electronic system for maintenance activities that cannot be addressed on the spot. Methods to capture work orders that involve activities that could potentially involve CO_2 leakage will be developed, if not currently in place. Examples include occurrences of well workover or repair, as well as visual identification of vapor clouds or ice formations. Each incident will be flagged for review by the person responsible for MRV documentation (the responsible party will be provided in the monitoring plan, as required under Subpart A, 98.3(g)).The Annual Subpart RR Report will include an estimate of the amount of CO_2 leaked. Records of information used to calculate emissions will be maintained on file for a minimum of three years.

Personal H_2S Monitors

Oxy's injection gas compositional analysis indicates H_2S is approximately 1% of total injected fluid stream.

H_2S monitors are worn by all field personnel. The H_2S monitors detect concentrations of H_2S up to 500 ppm in 0.1 ppm increments and will sound an alarm if the detection limit exceeds 10ppm. If an H_2S alarm is triggered, the immediate response is to protect the safety of the personnel, and the next step is to safely investigate the source of persistent alarms. Oxy considers H_2S to be a proxy for potential CO_2 leaks in the field. The person responsible for MRV documentation will receive notice of all incidents where H_2S is confirmed to be present. If the incident results in a work order, this will serve as the basis for tracking the event for GHG reporting. The Annual Subpart RR Report will provide an estimate the amount of CO_2 emitted from any such incidents. Records of information to calculate emissions will be maintained on file for a minimum of three years.

Injection Rates, Pressures and Volumes

Target injection rate and pressure for each injector are developed within the permitted limits based on the results of ongoing pattern modeling. The injection targets are programmed into the WAG satellite controllers. High and low set points are also programmed into the controllers, and flags whenever statistically significant deviations from the targeted ranges are identified. The set points are designed to be conservative, because it is preferable to have too many flags rather than too few. As a result, flags can occur frequently and are often found to be insignificant. For purposes of Subpart RR reporting, flags (or excursions) will be screened to determine if they could also lead to CO_2 leakage to the surface. The person responsible for the MRV documentation will receive notice of excursions and related work orders that could potentially involve CO_2 leakage. The Annual Subpart RR Report will provide an estimate of CO_2 emissions. Records of information to calculate emissions will be maintained on file for a minimum of three years.

Production Volumes and Compositions

A general forecast of production volumes and composition is developed which is used to periodically evaluate performance and refine current and projected injection plans and the forecast. This information is used to make operational decisions but is not recorded in an automated data system. Sometimes, this review may result in the generation of a work order in the maintenance system. The MRV plan implementation lead will review such work orders and identify those that could result in CO_2 leakage. Should such events occur, leakage volumes would be calculated following the approaches described in Sections 5 and 6. Impact to Subpart RR reporting will be addressed, if deemed necessary.

8. Determination of Sequestration Volumes Using Mass Balance Equations

To account for the potential propagation of error that would result if volume data from flow meters at each injection and production well were utilized, it is proposed to use the data from custody and operations meters on the main system pipelines to determine injection and production volumes used in the mass balance. This issue arises because while each meter has a small but acceptable margin of error, this error would become significant if data were taken from all of the well head meters within the WSSAU.

The following sections describe how each element of the mass-balance equation (Equation RR-11) will be calculated.

8.1. Mass of CO_2 Received

Equation RR-2 will be used as indicated in Subpart RR §98.443 to calculate the mass of CO_2 at the receiving custody transfer meter from the Permian Basin CO_2 pipeline delivery system. The volumetric flow at standard conditions will be multiplied by the CO_2 concentration and the density of CO_2 at standard conditions to determine mass.

$$CO_{2T,r} = \sum_{p=1}^{4} (Q_{p,r} - S_{r,p}) * D * C_{CO2,r,p} \qquad \text{(Eq. RR-2)}$$

where:

$CO_{2T,\,r}$ = Net annual mass of CO_2 received through flow meter r (metric tons).

$Q_{r,p}$ = Quarterly volumetric flow through a receiving flow meter r in quarter p at standard conditions (standard cubic meters).

$S_{r,p}$ = Quarterly volumetric flow through a receiving flow meter r that is redelivered to another facility without being injected into a site well in quarter p (standard cubic meters).

D = Density of CO_2 at standard conditions (metric tons per standard cubic meter): 0.0018682.

$C_{CO2,r,r}$ = Quarterly CO_2 concentration measurement in flow for flow meter r in quarter p (vol. percent CO_2, expressed as a decimal fraction).

p = Quarter of the year.

r = Receiving flow meters.

Given WSSAU's method of receiving CO_2 and requirements at Subpart RR §98.444(a):

- All delivery to the WSSAU is used within the unit so no quarterly flow redelivered, and $S_{r,p}$ will be zero ("0").
- Quarterly CO_2 concentration will be taken from the gas measurement database

8.2. Mass of CO_2 Injected into the Subsurface

The equation for calculating the Mass of CO_2 Injected into the Subsurface at the WSSAU is equal to the sum of the Mass of CO_2 Received as calculated in RR-2 of §98.443 (section 8.1 above) and the Mass of CO_2 Recycled calculated using measurements taken from the flow meter located at the output of the RCF (see Figure 3-5). As previously explained, using data at each injection well would give an inaccurate estimate of total injection volume due to the large number of wells and the potential for propagation of error due to allowable calibration ranges for each meter.

The Mass of CO_2 Recycled will be determined using equations RR-5 as follows:

$$CO_{2u} = \sum_{p=1}^{4} Q_{p,u} * D * C_{CO2,p,u} \qquad \text{(Eq. RR-5)}$$

where:

CO_{2u} = Annual CO_2 mass recycled (metric tons) as measured by flow meter u.

$Q_{p,u}$ = Quarterly volumetric flow rate measurement for flow meter u in quarter p at standard conditions (standard cubic meters per quarter).

D = Density of CO_2 at standard conditions (metric tons per standard cubic meter): 0.0018682.

$C_{CO2,p,u}$ = CO_2 concentration measurement in flow for flow meter u in quarter p (vol. percent CO_2, expressed as a decimal fraction).

p = Quarter of the year.

u = Flow meter.

The total Mass of CO_2 Injected will be the sum of the Mass of CO_2 Received (RR-3) and Mass of CO_2 Recycled (modified RR-5).

$$CO_{2I} = CO_2 + CO_{2u}$$

8.3. Mass of CO_2 Produced

The Mass of CO_2 Produced at the WSSAU will be calculated using the measurements from the flow meters at the inlet to RCF and the custody transfer meter for oil sales rather than the metered data from each production well. Again, using the data at each production well would give an inaccurate estimate of total injection due to the large number of wells and the potential for propagation of error due to allowable calibration ranges for each meter.

Equation RR-8 in §98.443 will be used to calculate the Mass of CO_2 Produced from all production wells as follows:

$$CO_{2w} = \sum_{p=1}^{4} Q_{p,w} * D * C_{CO2,p,w} \qquad \text{(Eq. RR-8)}$$

Where:

CO_{2W} = Annual CO_2 mass produced (metric tons) .

$Q_{P,W}$ = Volumetric gas flow rate measurement for meter w in quarter p at standard conditions (standard cubic meters).

D = Density of CO_2 at standard conditions (metric tons per standard cubic meter): 0.0018682.

$C_{CO2,P,W}$ = CO_2 concentration measurement in flow for meter w in quarter p (vol. percent CO_2, expressed as a decimal fraction).

p = Quarter of the year.

w = inlet meter to RCF.

For Equation RR-9 in §98.443 the variable X_{oil} will be measured as follows:

$$CO2_p = \sum_{w=1}^{w} CO2_w + X_{oil} \qquad \text{(Eq. RR-9)}$$

Where:

CO_{2P} = Total annual CO_2 mass produced (metric tons) through all meters in the reporting year.

CO_{2w} = Annual CO_2 mass produced (metric tons) through meter w in the reporting year.

X_{oil} = Mass of entrained CO_2 in oil in the reporting year measured utilizing commercial meters and electronic flow-measurement devices at each point of custody transfer. The mass of CO_2 will be calculated by multiplying the total volumetric rate by the CO_2 concentration.

8.4. Mass of CO_2 Emitted by Surface Leakage

The total annual Mass of CO_2 emitted by Surface Leakage will be calculated and reported using an approach that is tailored to specific leakage events and relies on 40 CFR Part 98 Subpart W reports of equipment leakage. Oxy is prepared to address the potential for leakage in a variety of settings. Estimates of the amount of CO_2 leaked to the surface will depend on a number of site-specific factors including measurements, engineering estimates, and emission factors, depending on the source and nature of the leakage.

The process for quantifying leakage will entail using best engineering principles or emission factors. While it is not possible to predict in advance the types of leaks that will occur, some approaches for quantification are described in Sections 5.9 and 6. In the event leakage to the surface occurs, leakage amounts would be quantified and reported, and records that describe the methods used to estimate or measure the volume leaked as reported in the Annual Subpart RR Report would be retained. Further, the Subpart W report and results from any event-driven quantification will be reconciled to assure that surface leaks are not double counted.

Equation RR-10 in 48.433 will be used to calculate and report the Mass of CO_2 emitted by Surface Leakage:

$$CO_{2E} = \sum_{x=1}^{x} CO_{2x} \qquad \text{(Eq. RR-10)}$$

where:

CO_{2E} = Total annual CO_2 mass emitted by surface leakage (metric tons) in the reporting year.

CO_{2x} = Annual CO_2 mass emitted (metric tons) at leakage pathway x in the reporting year.

x = Leakage pathway.

8.5. Mass of CO_2 Sequestered in Subsurface Geologic Formation

Equation RR-11 in 98.443 will be used to calculate the Mass of CO_2 Sequestered in Subsurface Geologic Formations in the Reporting Year as follows:

$$CO_2 = CO_{2I} - CO_{2P} - CO_{2E} - CO_{2FI} - CO_{2FP} \qquad \text{(Eq. RR-11)}$$

where:

CO_2 = Total annual CO_2 mass sequestered in subsurface geologic formations (metric tons) at the facility in the reporting year.

CO_{2I} = Total annual CO_2 mass injected (metric tons) in the well or group of wells covered by this source category in the reporting year.

CO_{2P} = Total annual CO_2 mass produced (metric tons) net of CO_2 entrained in oil in the reporting year.

CO_{2E} = Total annual CO_2 mass emitted (metric tons) by surface leakage in the reporting year.

CO_{2FI} = Total annual CO_2 mass emitted (metric tons) from equipment leaks and vented emissions of CO_2 from equipment located on the surface between the flow meter used to measure injection quantity and the injection wellhead, for which a calculation procedure is provided in subpart W of this part.

CO_{2FP} = Total annual CO_2 mass emitted (metric tons) from equipment leaks and vented emissions of CO_2 from equipment located on the surface between the production wellhead and the flow meter used to measure production quantity, for which a calculation procedure is provided in subpart W of this part.

8.6. Cumulative Mass of CO_2 Reported as Sequestered in Subsurface Geologic Formation

The total annual volumes obtained using equation RR-11 in 98.443 will be summed to arrive at the Cumulative Mass of CO_2 Sequestered in Subsurface Geologic Formations.

9. MRV Plan Implementation Schedule

This MRV plan will be implemented starting January 2021 or within 90 days of EPA approval, whichever occurs later. Other GHG reports are filed on March 31 of the year after the reporting year and it is anticipated that the Annual Subpart RR Report will be filed at the same time. It is anticipated that the MRV program will be in effect during the Specified Period, during which time the WSSAU will be operated with the subsidiary purpose of establishing long-term containment of a measurable quantity of CO_2 in subsurface geological formations at the WSSAU. It is anticipated to establish that a measurable amount of CO_2 injected during the Specified Period will be stored in a manner not expected to migrate resulting in future surface leakage. At such time, a demonstration supporting the long-term containment determination will be prepared and a request to discontinue monitoring and reporting under this MRV plan will be submitted. *See* 40 C.F.R. § 98.441(b)(2)(ii).

10. Quality Assurance Program

10.1. Monitoring QA/QC

The requirements of §98.444 (a) – (d) have been incorporated in the discussion of mass balance equations. These include the following provisions.

CO_2 Received and Injected

- The quarterly flow rate of CO_2 received by pipeline is measured at the receiving custody transfer meters.
- The quarterly CO_2 flow rate for recycled CO_2 is measured at the flow meter located at the RCF outlet.

CO_2 Produced

- The point of measurement for the quantity of CO_2 produced from oil or other fluid production wells is a flow meter directly downstream of each separator that sends a stream of gas into a recycle or end use system.
- The produced gas stream is sampled at least once per quarter immediately downstream of the flow meter used to measure flow rate of that gas stream and measure the CO_2 concentration of the sample.
- The quarterly flow rate of the produced gas is measured at the flow meters located at the RCF inlet.

CO_2 emissions from equipment leaks and vented emissions of CO_2

These volumes are measured in conformance with the monitoring and QA/QC requirements specified in subpart W of 40 CFR Part 98.

Flow meter provisions

The flow meters used to generate date for the mass balance equations are:

- Operated continuously except as necessary for maintenance and calibration.
- Operated using the calibration and accuracy requirements in 40 CFR §98.3(i).
- Operated in conformance with American Petroleum Institute (API) standards.
- National Institute of Standards and Technology (NIST) traceable.

Concentration of CO_2

CO_2 concentration is measured using an appropriate standard method. Further, all measured volumes of CO_2 have been converted to standard cubic meters at a temperature of 60 degrees Fahrenheit and at an absolute pressure of 1 atmosphere, including those used in Equations RR-2, RR-5 and RR-8 in Section 8.

10.2. Missing Data Procedures

In the event data needed for the mass balance calculations cannot be collected, procedures for estimating missing data in §98.445 will be used as follows:

- A quarterly flow rate of CO_2 received that is missing would be estimated using invoices or using a representative flow rate value from the nearest previous time period.

- A quarterly CO_2 concentration of a CO_2 stream received that is missing would be estimated using invoices or using a representative concentration value from the nearest previous time period.
- A quarterly quantity of CO_2 injected that is missing would be estimated using a representative quantity of CO_2 injected from the nearest previous period of time at a similar injection pressure.
- For any values associated with CO_2 emissions from equipment leaks and vented emissions of CO_2 from surface equipment at the facility that are reported in this subpart, missing data estimation procedures specified in subpart W of 40 CFR Part 98 would be followed.
- The quarterly quantity of CO_2 produced from subsurface geologic formations that is missing would be estimated using a representative quantity of CO_2 produced from the nearest previous period of time.

10.3. MRV Plan Revisions

In the event there is a material change to the monitoring and/or operational parameters of the CO_2 EOR operations in the WSSAU that is not anticipated in this MRV plan, the MRV plan will be revised and submitted to the EPA Administrator within 180 days as required in §98.448(d).

11. Records Retention

The record retention requirements specified by §98.3(g) will be followed. In addition, the requirements in Subpart RR §98.447 will be met by maintaining the following records for at least three years:

- Quarterly records of CO_2 received at standard conditions and operating conditions, operating temperature and pressure, and concentration of these streams.
- Quarterly records of produced CO_2, including volumetric flow at standard conditions and operating conditions, operating temperature and pressure, and concentration of these streams.
- Quarterly records of injected CO_2 including volumetric flow at standard conditions and operating conditions, operating temperature and pressure, and concentration of these streams.
- Annual records of information used to calculate the CO_2 emitted by surface leakage from leakage pathways.
- Annual records of information used to calculate the CO_2 emitted from equipment leaks and vented emissions of CO_2 from equipment located on the surface between the flow meter used to measure injection quantity and the injection wellhead.
- Annual records of information used to calculate the CO_2 emitted from equipment leaks and vented emissions of CO_2 from equipment located on the surface between the production wellhead and the flow meter used to measure production quantity.

These data will be collected as generated and aggregated as required for reporting purposes.

12. Appendix

12.1 Well Identification Numbers

The following table presents the well name and number, API number, type, and status for active wells in WSSAU as of September 2020. The table is subject to change over time as new wells are drilled, existing wells change status, or existing wells are repurposed. The following terms are used:

- Well Status
  - ACTIVE refers to active wells
  - DRILL refers to wells under construction
  - TA refers to wells that have been temporarily abandoned
  - SHUT_IN refers to wells that have been temporarily idled or shut-in
  - INACTIVE refers to wells that have been completed but are not in use
- Well Type
  - DISP_H2O refers to wells for water disposal
  - INJ_GAS refers to wells that inject CO_2 Gas
  - INJ_WAG refers to wells that inject water and CO_2 Gas
  - INJ_H2O refers to wells that inject water
  - OBSERVATION refers to observation or monitoring wells
  - PROD_GAS refers to wells that produce natural gas
  - PROD_OIL refers to wells that produce oil
  - SUP_H2O refers to wells that supply water

• Well Name & Number	API Number	Well Type	Well Status as of September 2020
WSSAU-0002WD	4216500675	DISP_H2O	ACTIVE
WSSAU-0101	4216501591	PROD_OIL	TA
WSSAU-0104	4216532613	INJ_H2O	ACTIVE
WSSAU-0201	4216500642	PROD_OIL	ACTIVE
WSSAU-0202	4216500643	PROD_OIL	ACTIVE
WSSAU-0203	4216500645	PROD_OIL	TA
WSSAU-0207	4216534204	PROD_OIL	ACTIVE
WSSAU-0208	4216537800	PROD_OIL	ACTIVE
WSSAU-0209	4216537801	PROD_OIL	ACTIVE
WSSAU-0210	4216537802	PROD_OIL	ACTIVE
WSSAU-0211	4216537803	PROD_OIL	ACTIVE
WSSAU-0212	4216538559	PROD_OIL	ACTIVE
WSSAU-0213	4216538558	PROD_OIL	ACTIVE
WSSAU-0214	4216538557	PROD_OIL	ACTIVE
WSSAU-0301R	4216538445	PROD_OIL	ACTIVE
WSSAU-0302R	4216538446	PROD_OIL	ACTIVE

WSSAU-0303	4216500644	PROD_OIL	ACTIVE
WSSAU-0303R	4216538447	PROD_OIL	ACTIVE
WSSAU-0304R	4216538448	PROD_OIL	ACTIVE
WSSAU-0305RW	4216538449	INJ_WAG	ACTIVE
WSSAU-0305W	4216530388	INJ_H2O	TA
WSSAU-0306RW	4216538450	INJ_WAG	ACTIVE
WSSAU-0307RW	4216538451	INJ_WAG	ACTIVE
WSSAU-0309	4216531624	INJ_WAG	ACTIVE
WSSAU-0310	4216531626	INJ_WAG	ACTIVE
WSSAU-0311RW	4216537493	INJ_WAG	ACTIVE
WSSAU-0312	4216531743	PROD_OIL	ACTIVE
WSSAU-0313	4216531744	PROD_OIL	ACTIVE
WSSAU-0314	4216531745	PROD_OIL	ACTIVE
WSSAU-0315	4216531787	INJ_H2O	INACTIVE
WSSAU-0316W	4216531786	INJ_H2O	ACTIVE
WSSAU-0317W	4216531790	INJ_H2O	INACTIVE
WSSAU-0318W	4216531788	INJ_H2O	ACTIVE
WSSAU-0319	4216531789	INJ_H2O	INACTIVE
WSSAU-0320	4216531838	PROD_OIL	ACTIVE
WSSAU-0321	4216531837	INJ_WAG	ACTIVE
WSSAU-0322	4216532404	INJ_WAG	ACTIVE
WSSAU-0323	4216532405	INJ_WAG	ACTIVE
WSSAU-0324	4216532566	INJ_WAG	ACTIVE
WSSAU-0325	4216534144	PROD_OIL	ACTIVE
WSSAU-0326	4216534203	INJ_WAG	ACTIVE
WSSAU-0327	4216538560	INJ_WAG	ACTIVE
WSSAU-0328	4216538561	INJ_WAG	ACTIVE
WSSAU-0329	4216538562	INJ_WAG	ACTIVE
WSSAU-0330	4216538563	INJ_WAG	ACTIVE
WSSAU-03WD	4216538439	DISP_H2O	ACTIVE
WSSAU-0401	4216501587	PROD_OIL	ACTIVE
WSSAU-0404	4216501590	PROD_OIL	TA
WSSAU-0405RW	4216538452	INJ_WAG	ACTIVE
WSSAU-0406	4216531978	INJ_H2O	ACTIVE
WSSAU-0407	4216531979	PROD_OIL	TA
WSSAU-0408	4216534205	INJ_H2O	ACTIVE
WSSAU-0409	4216538556	PROD_OIL	ACTIVE
WSSAU-0410	4216538550	INJ_WAG	ACTIVE

WSSAU-0411	4216538571	INJ_WAG	ACTIVE
WSSAU-0412	4216538583	INJ_WAG	ACTIVE
WSSAU-0413	4216538572	INJ_WAG	ACTIVE
WSSAU-0414	4216538573	INJ_WAG	ACTIVE
WSSAU-0415	4216538585	PROD_OIL	ACTIVE
WSSAU-0416	4216538586	PROD_OIL	ACTIVE
WSSAU-0417	4216538574	PROD_OIL	ACTIVE
WSSAU-0418	4216538580	PROD_OIL	ACTIVE
WSSAU-0419	4216538582	PROD_OIL	ACTIVE
WSSAU-0501	4216500657	PROD_GAS	TA
WSSAU-0502	4216500610	PROD_OIL	ACTIVE
WSSAU-0503W	4216500604	INJ_H2O	ACTIVE
WSSAU-0504W	4216500625	INJ_H2O	ACTIVE
WSSAU-0505	4216581090	PROD_OIL	ACTIVE
WSSAU-0507	4216532609	PROD_OIL	TA
WSSAU-0508	4216534225	INJ_H2O	ACTIVE
WSSAU-0509	4216537203	PROD_OIL	ACTIVE
WSSAU-0601	4216500663	PROD_OIL	ACTIVE
WSSAU-0602R	4216538300	PROD_OIL	ACTIVE
WSSAU-0603	4216500665	PROD_OIL	ACTIVE
WSSAU-0603R	4216538404	PROD_OIL	ACTIVE
WSSAU-0604	4216500666	PROD_OIL	TA
WSSAU-0604R	4216538299	PROD_OIL	ACTIVE
WSSAU-0605	4216500667	PROD_OIL	TA
WSSAU-0605R	4216538298	PROD_OIL	ACTIVE
WSSAU-0606	4216500629	INJ_GAS	SHUT-IN
WSSAU-0607	4216500630	PROD_OIL	ACTIVE
WSSAU-0607R	4216538405	PROD_OIL	ACTIVE
WSSAU-0608	4216500631	PROD_OIL	ACTIVE
WSSAU-0609RW	4216538403	INJ_WAG	ACTIVE
WSSAU-0609W	4216530214	INJ_H2O	ACTIVE
WSSAU-0610RW	4216538402	INJ_WAG	ACTIVE
WSSAU-0611RW	4216538401	INJ_WAG	ACTIVE
WSSAU-0611W	4216530279	INJ_H2O	ACTIVE
WSSAU-0613	4216530531	PROD_OIL	ACTIVE
WSSAU-0614	4216531632	PROD_OIL	ACTIVE
WSSAU-0615	4216531630	PROD_OIL	ACTIVE
WSSAU-0616	4216531627	INJ_WAG	ACTIVE

WSSAU-0617	4216531629	PROD_GAS	TA
WSSAU-0617RW	4216537492	INJ_WAG	ACTIVE
WSSAU-0618	4216531628	INJ_WAG	ACTIVE
WSSAU-0619	4216531836	PROD_OIL	ACTIVE
WSSAU-0620	4216531835	PROD_OIL	ACTIVE
WSSAU-0621	4216531834	INJ_H2O	ACTIVE
WSSAU-0622	4216531833	PROD_OIL	ACTIVE
WSSAU-0623	4216531832	PROD_OIL	ACTIVE
WSSAU-0624	4216531831	PROD_OIL	ACTIVE
WSSAU-0625	4216531980	PROD_OIL	ACTIVE
WSSAU-0626	4216532403	PROD_OIL	ACTIVE
WSSAU-0627	4216532402	PROD_OIL	ACTIVE
WSSAU-0701	4216500633	PROD_OIL	ACTIVE
WSSAU-0702	4216500635	PROD_OIL	ACTIVE
WSSAU-0703	4216500637	PROD_OIL	ACTIVE
WSSAU-0704	4216500613	PROD_OIL	ACTIVE
WSSAU-0705	4216500612	PROD_OIL	ACTIVE
WSSAU-0706	4216500641	PROD_OIL	TA
WSSAU-0707RW	4216538453	INJ_WAG	ACTIVE
WSSAU-0708RW	4216538454	INJ_WAG	ACTIVE
WSSAU-0708W	4216530392	INJ_H2O	ACTIVE
WSSAU-0712	4216531981	INJ_H2O	ACTIVE
WSSAU-0713	4216531982	INJ_H2O	ACTIVE
WSSAU-0714	4216532299	INJ_H2O	ACTIVE
WSSAU-0715	4216532406	PROD_OIL	TA
WSSAU-0716	4216532567	PROD_OIL	ACTIVE
WSSAU-0717	4216534023	PROD_OIL	ACTIVE
WSSAU-0801	4216500634	PROD_OIL	TA
WSSAU-0802	4216500636	PROD_OIL	ACTIVE
WSSAU-0803	4216500638	PROD_OIL	ACTIVE
WSSAU-0804W	4216500639	INJ_H2O	ACTIVE
WSSAU-0805	4216500640	PROD_OIL	ACTIVE
WSSAU-0809	4216532595	PROD_OIL	ACTIVE
WSSAU-0810	4216532612	PROD_OIL	ACTIVE
WSSAU-0811	4216538581	PROD_OIL	ACTIVE
WSSAU-0812	4216538587	PROD_OIL	ACTIVE
WSSAU-0901W	4216500498	INJ_H2O	ACTIVE
WSSAU-0902W	4216500500	INJ_H2O	ACTIVE

WSSAU-1102W	4216500632	INJ_H2O	SHUT-IN
WSSAU-1103W	4216530285	INJ_H2O	INACTIVE
WSSAU-1105	4216531401	PROD_GAS	TA
WSSAU-1106	4216537204	SUP_H2O	TA
WSSAU-1201	4216502768	PROD_OIL	ACTIVE
WSSAU-1202R	4216538406	PROD_OIL	ACTIVE
WSSAU-1203	4216502750	PROD_OIL	ACTIVE
WSSAU-1204	4216502771	PROD_OIL	ACTIVE
WSSAU-1206RW	4216538400	INJ_WAG	ACTIVE
WSSAU-1207RW	4216538399	INJ_WAG	ACTIVE
WSSAU-1207W	4216530291	INJ_H2O	INACTIVE
WSSAU-1208RW	4216538398	INJ_WAG	ACTIVE
WSSAU-1209	4216531977	INJ_H2O	ACTIVE
WSSAU-1210	4216531976	INJ_WAG	ACTIVE
WSSAU-1211	4216531983	PROD_OIL	TA
WSSAU-1211RW	4216537491	INJ_WAG	ACTIVE
WSSAU-1212	4216531985	INJ_WAG	ACTIVE
WSSAU-1213	4216531984	PROD_OIL	ACTIVE
WSSAU-1214	4216531974	PROD_OIL	ACTIVE
WSSAU-1215	4216531975	PROD_OIL	ACTIVE
WSSAU-1216	4216531986	PROD_OIL	ACTIVE
WSSAU-1302	4216500661	PROD_OIL	SHUT-IN
WSSAU-1303	4216500626	PROD_OIL	TA
WSSAU-1304	4216500627	PROD_OIL	ACTIVE
WSSAU-1305W	4216530090	INJ_H2O	SHUT-IN
WSSAU-1309	4216532298	INJ_H2O	ACTIVE
WSSAU-1310	4216532297	INJ_H2O	ACTIVE
WSSAU-1311	4216532303	INJ_H2O	ACTIVE
WSSAU-1312	4216532302	INJ_H2O	ACTIVE
WSSAU-1313	4216532301	PROD_OIL	TA
WSSAU-1315	4216532304	PROD_OIL	ACTIVE
WSSAU-1316	4216532305	PROD_OIL	ACTIVE
WSSAU-1401	4216581121	PROD_OIL	SHUT-IN
WSSAU-1402	4216500504	PROD_OIL	TA
WSSAU-1403	4216581123	PROD_OIL	ACTIVE
WSSAU-1405W	4216530401	INJ_H2O	SHUT-IN
WSSAU-1406W	4216530400	INJ_H2O	INACTIVE
WSSAU-1407	4216530508	PROD_OIL	ACTIVE

WSSAU-1408	4216530552	PROD_OIL	ACTIVE
WSSAU-1409	4216534022	PROD_OIL	ACTIVE
WSSAU-1410	4216534145	PROD_OIL	TA
WSSAU-1502	4216501300	PROD_OIL	ACTIVE
WSSAU-1503	4216500497	PROD_OIL	ACTIVE
WSSAU-1504W	4216500499	INJ_H2O	SHUT-IN
WSSAU-1505	4216530550	PROD_OIL	ACTIVE
WSSAU-1506W	4216534146	INJ_H2O	ACTIVE
WSSAU-1601W	4216501392	INJ_H2O	SHUT-IN
WSSAU-1901	4216501464	PROD_OIL	TA
WSSAU-1902W	4216501466	INJ_H2O	INACTIVE
WSSAU-1903	4216538549	PROD_OIL	TA
WSSAU-2101W	4216502546	INJ_H2O	TA
WSSAU-2102W	4216502544	INJ_H2O	TA

12.2 Regulatory References

Regulations cited in this plan:

i. Texas Administrative Code Title 16 Part 1 Chapter 3 Oil & Gas Division - https://texreg.sos.state.tx.us/public/readtac$ext.ViewTAC?tac_view=4&ti=16&pt=1&ch=3&rl=Y

ii. TRRC Injection/Disposal Well Permitting, Testing and Monitoring Manual - https://www.rrc.state.tx.us/oil-gas/publications-and-notices/manuals/injectiondisposal-well-manual/

Appendix B: Submissions and Responses to Request for Additional Information

Oxy West Seminole San Andres Unit Subpart RR Monitoring, Reporting and Verification (MRV) Plan

December 11, 2020

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1. Introduction

OXY USA WTP LP, a subsidiary of Occidental (Oxy) operates a CO_2-EOR project in the West Seminole San Andres Unit (WSSAU). This MRV plan was developed in accordance with 40 CFR §98.440-449 (Subpart RR) to provide for the monitoring, reporting and verification of the quantity of CO_2 sequestered at the WSSAU during a specified period of injection.

2. Facility Information

2.1. Reporter Number

575401 – West Seminole San Andres Unit

2.2. UIC Permit Class

The Oil and Gas Division of the Texas Railroad Commission (TRRC) regulates oil and gas activity in Texas. All wells in the WSSAU (including production, injection and monitoring wells) are permitted by TRRC through Texas Administrative Code (TAC) Title 16 Chapter 3. TRRC has primacy to implement the Underground Injection Control (UIC) Class II program in the state for injection wells. All EOR injection wells in the WSSAU are currently classified as UIC Class II wells.

2.3. Existing Wells

Wells in the WSSAU are identified by name and number, API number, type and status. The list of wells as of September 2020 is included in Section 12.1. Any changes in wells will be indicated in the annual report.

3. Project Description

This project takes place in the West Seminole San Andres Unit (WSSAU), an oil field located in West Texas that was first produced more than 70 years ago. CO_2 flooding was initiated in 2013 and the injection plan calls for a total of approximately 20 million tonnes of CO_2 over the lifetime of the project. The field is well characterized and is suitable for secure geologic storage. Oxy uses a water alternating with gas (WAG) injection process and maintains an injection to withdrawal ratio (IWR) of at or near 1.0. A history matched reservoir simulation of the injection at WSSAU has been constructed.

3.1. Project Characteristics

The West Seminole San Andres field was discovered in 1944 and started producing in 1948. The field was unitized in 1961 and waterflood was initiated in 1969. CO_2 flooding was initiated in 2013. A long-term forecast for WSSAU was developed using the reservoir modeling approaches described in Section 3.4 that includes injection of a total of approximately 20 million tonnes of CO_2 over the life of the project. Figure 3-1 shows actual and projected CO_2 injection, production, and stored volumes in WSSAU.

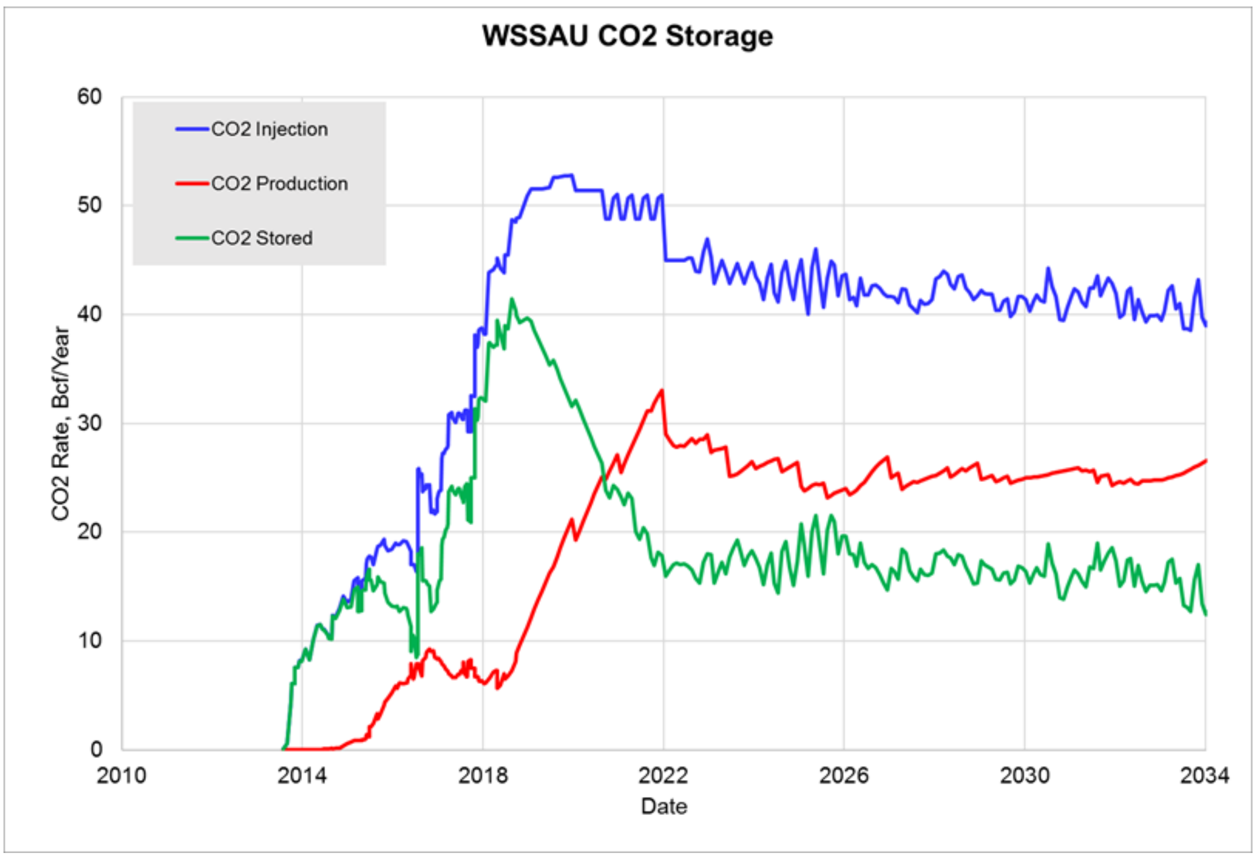

Figure 3-1 WSSAU Historic and Forecast CO_2 Injection, Production, and Storage

3.2. Environmental Setting

The WSSAU is located in the NE portion of the Central Basin Platform in West Texas (See Figure 3-2).

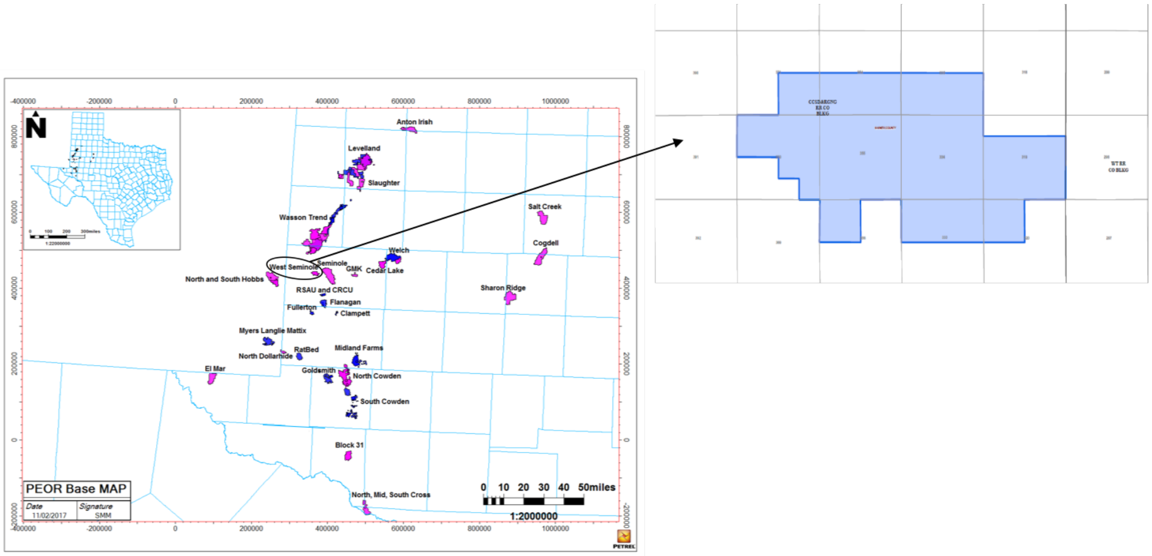

Figure 3-2 Location of WSSAU in West Texas

WSSAU produces oil from the Permian (Guadalupian) aged reservoir comprised of San Andres formation dolostone. Total thickness of the geologic unit is approximately 1500 feet, with the main reservoir within the middle 600 feet. The sequestration zone is also the oil pay completion interval, and ranges on average between 4925-5640 feet below the ground surface. See the WSSAU geologic column in Figure 3-3. The productive interval, or reservoir, is composed of layers of permeable dolomites that were deposited in a shallow marine environment during the Permian Era, some 250 to 300 million years ago.

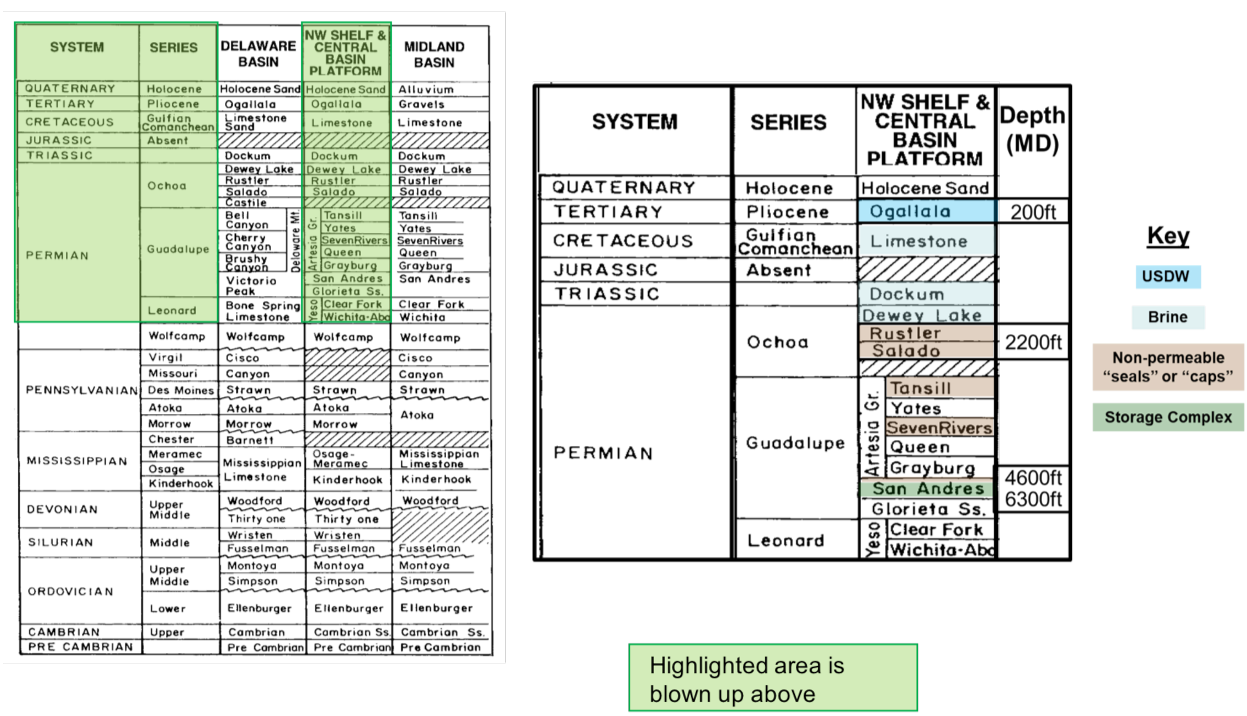

Figure 3-3 WSSAU Geologic Column

The main confining system is ~300 feet thick and is comprised of nonporous anhydrite sequences. The depth interval for the confining system ranges from top San Andres Formation to Top Pay (4545-5194 feet) with a typical range of 4660-4925 feet below ground surface. There are numerous relatively thin layers that provide additional secondary containment between the sequestration zone and freshwater aquifers. These layers are comprised of siltstones, shales, salts, and anhydrite sequences with little to no porosity or permeability.

There are no significant geologic faults or fractures identified that intersect the storage complex. There is one identified reverse fault in the Devonian interval approximately one mile below the sequestration zone. The base of sequestration zone is approximately 2175 ft. subsea depth, while the top of fault offset is interpreted to end at approximately 7500 ft. subsea depth. Fault displacement within the Devonian is approximately 200 ft. The fault is linear, subvertical, and dips toward the northeast. The presence of a gas cap is evidence of the effectiveness of the seal formed by the upper San Andres.

WSSAU is a domal structure that includes the highest elevations within the area. The elevated area forms a natural trap for oil and gas that migrated from below over millions of years. Once trapped in these high points, the oil and gas has remained in place. In the case of the WSSAU, this oil and gas has been trapped in the reservoir for 50 to 100 million years. Over time, buoyant fluids, including CO_2, rise vertically until reaching the ceiling of the dome and then migrate to the highest elevation of the structure. Figure 3-4, shows the Top San Andres pay interval structure. The colors in the structure map in Figure 3-4 indicate the subsurface elevation, with red being higher, (a shallower level) and purple being lower (a deeper level).

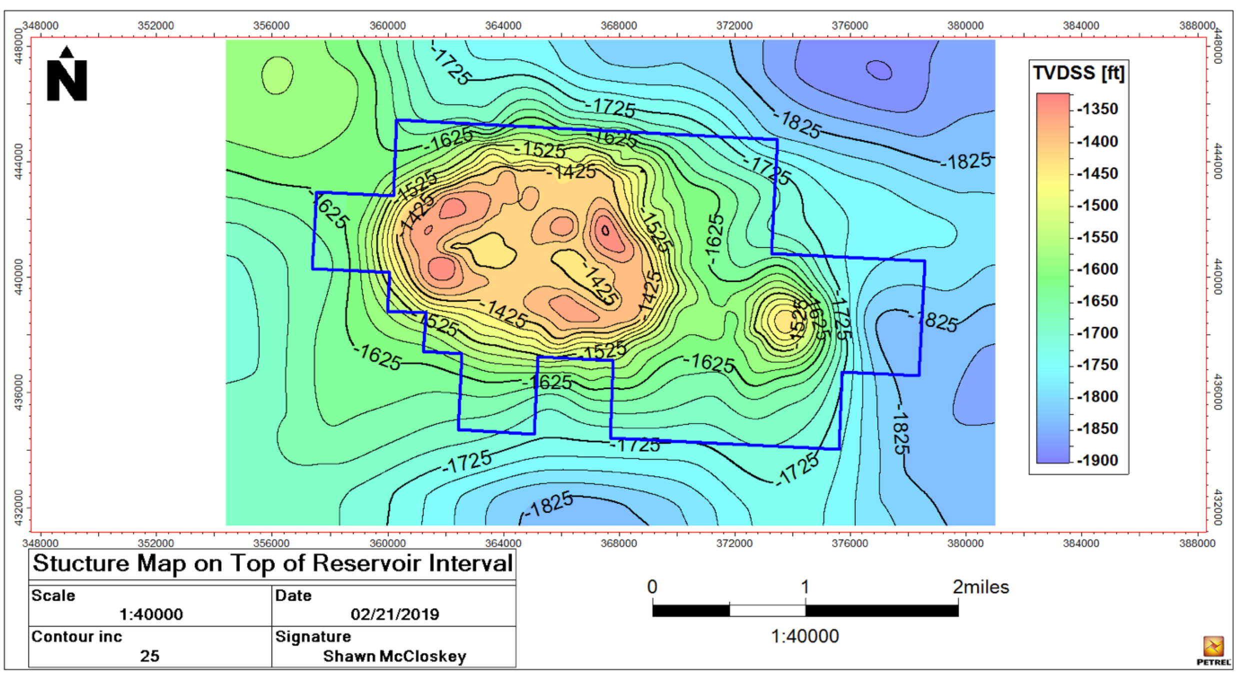

Figure 3-4 Local Area Structure on Top of San Andres

Buoyancy dominates where oil and gas are found in a reservoir. Gas, being lightest, rises to the top and water, being heavier, moves downward. Oil, being heavier than gas but lighter than water, lies in between. At the time of its discovery, natural gas was trapped at the structural high points of WSSAU, forming a "gas cap." The presence of an oil deposit and a gas cap is evidence of the effectiveness of the seal formed by the upper San Andres. Gas is buoyant and highly mobile. If it could escape WSSAU naturally, through faults or fractures, it would have done so over the millennia. Below the gas cap is an oil accumulation, the oil zone, and below that there are no distillable hydrocarbons.

Once the CO_2 flood is complete and injection ceases, the remaining mobile CO_2 will rise slowly upward, driven by buoyancy forces. There is more than enough pore space to sequester the planned CO_2 injection. The amount of CO_2 injected will not exceed the reservoir's secure storage capacity and, consequently, the risk that CO_2 could migrate to other reservoirs in the Central Basin Platform is negligible. The volume of CO_2 storage is based on the estimated total pore space within WSSAU. The total pore space within WSSAU, from the top of the reservoir down to the base of the oil zone, is calculated to be 1,512 million reservoir barrels (RB). This is the volume of rock multiplied by porosity. Table 3-1 below shows the conversion of this amount of pore space into an estimated maximum volume of approximately 1,770 Bcf (96 million tonnes) of CO_2 storage in the reservoir. It is forecasted that at the end of EOR operations stored CO_2 will fill approximately 20% of total calculated storage capacity.

Table 3-1 Calculation of Maximum Volume of CO_2 Storage Capacity at WSSAU

Top of Pay to Free Water Level (2175 ft subsea)	
Variables	WSSAU Outline
Pore Volume (**RB**)	1,511,810,594
$\mathbf{B}_{CO2}$	0.45
$\mathbf{S}_{wirr}$	0.2
$\mathbf{S}_{orCO2(volume\ weighted)}$	0.273
Max CO_2 (MCF)	1,770,498,185
Max CO_2 (BCF)	1,770

Max CO_2 = Volume (**RB**) * $(1 - \mathbf{S}_{wirr} - \mathbf{S}_{orCO2}) / \mathbf{B}_{CO2}$

Where:
$CO_2(max)$ = the maximum amount of storage capacity
Pore Volume (RB) = the volume in Reservoir Barrels of the rock formation
B_{CO2} = the formation volume factor for CO_2
S_{wirr} = the irreducible water saturation
S_{orCO2} = the irreducible oil saturation

Given that WSSAU is located at the highest subsurface elevations in the area, that the confining zone has proved competent over both millions of years and current CO_2 flooding, and that the WSSAU has ample storage capacity, there is confidence that stored CO_2 will be contained securely within the reservoir.

3.3. Description of CO_2-EOR Project Facilities and the Injection Process

Figure 3-5 shows a simplified process flow diagram of the project facilities and equipment in the WSSAU. CO_2 is delivered to the WSSAU via the Permian Basin CO_2 pipeline network. The CO_2 is supplied by a number of different sources. Specified amounts are drawn from the Bravo pipeline based on contractual arrangements among suppliers of CO_2, purchasers of CO_2, and the pipeline operator.

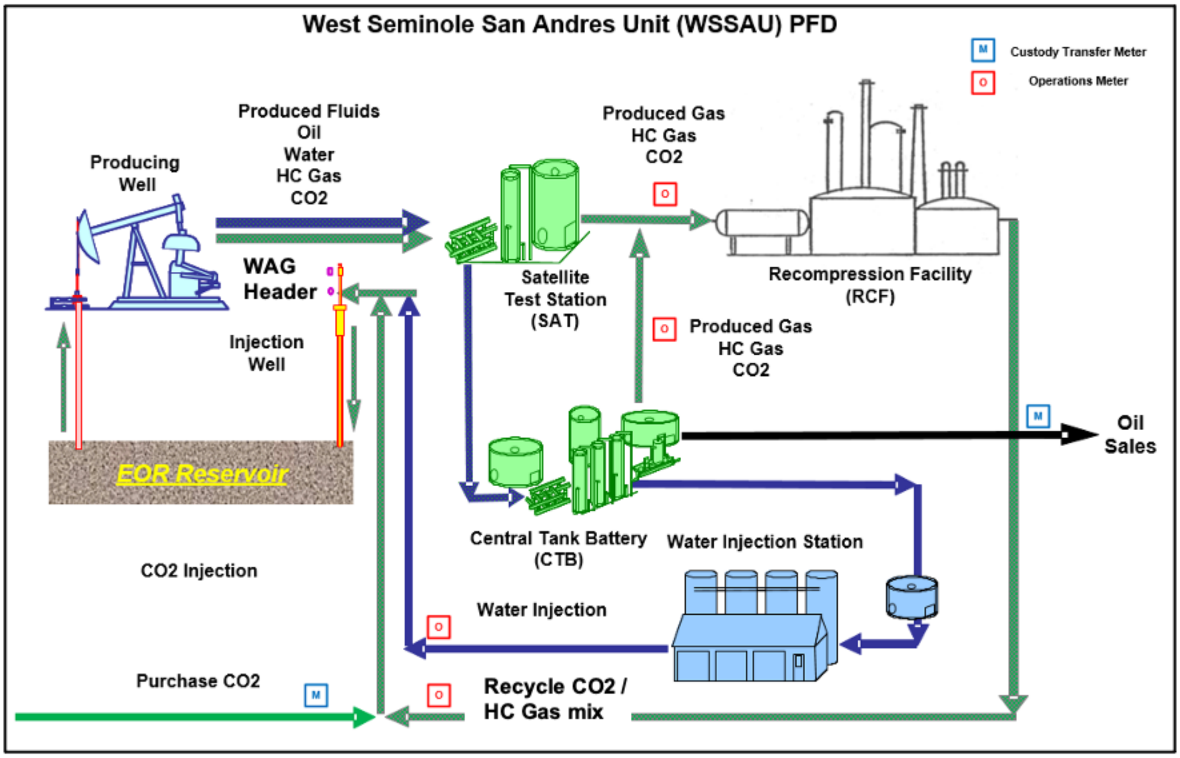

Figure 3-5 WSSAU Process Flow Diagram

Once CO_2 enters WSSAU there are three main processes involved in EOR operations:

i. CO_2 Distribution and Injection. The mass of CO_2 received at WSSAU is metered and calculated through the Custody Transfer Meter located at the pipeline delivery point as indicated in the bottom left of Figure 3-5. The mass of CO_2 received is combined with recycled CO_2 / hydrocarbon gas mix from the recompression facility (RCF) and distributed to the WAG headers for injection into the injection wells according to the pre-programmed injection plan for each well pattern which alternates between water and CO_2 injection. WAG headers are remotely operated and can inject either CO_2 or water at various rates and injection pressures as specified in the injection plans. This is an EOR project and reservoir pressure must be maintained above minimum miscibility pressure. Therefore, injection pressure must be sufficiently high to allow injectants to enter the reservoir, but below formation parting pressure (FPP).

ii. Produced Fluids Handling. Produced fluids from the production wells are a mixture of oil, hydrocarbon gas, water, CO_2 and trace amounts of other constituents in the field including nitrogen and H_2S as discussed in Section 7. They are gathered and sent to satellite test stations (SAT) for separation into a gas/CO_2 mix and a produced fluids mix of water, oil, gas, and CO_2.

The produced gas, which is composed primarily of hydrocarbons and CO_2, is sent to the recompression facility (RCF) for dehydration and recompression before reinjection into the reservoir. An operations meter at the RCF is used to determine the total volume of produced gas that is reinjected. The separated oil is metered through the Custody Transfer Meter located at the central tank battery and sold into a pipeline.

iii. Water Treatment and Injection. Water is recovered for reuse and forwarded to the water injection station for treatment and reinjection or disposal.

3.3.1. Wells in the WSSAU

The Texas Railroad Commission (TRRC) has broad authority over oil and gas operations including primacy to implement UIC Class II wells. The rules are found in Texas Administrative Code Title 16, Part 1, Chapter 3 and are also explained in a TRRC Injection/Disposal Well Permitting, Testing and Monitoring Manual (See Appendix 12-3). TRRC rules govern well siting, construction, operation, maintenance, and closure for all wells in oilfields. Briefly, TRRC rules include the following requirements:

- Fluids must be constrained in the strata in which they are encountered;
- Activities cannot result in the pollution of subsurface or surface water;
- Wells must adhere to specified casing, cementing, drilling well control, and completion requirements designed to prevent fluids from moving from the strata they are encountered into other strata with oil and gas, or into subsurface and surface waters;
- Completion report for each well including basic electric log (e.g., a density, sonic, or resistivity (except dip meter) log run over the entire wellbore) must be prepared;
- Operators must follow plugging procedures that require advance approval from the TRRC Director and allow consideration of the suitability of the cement based on the use of the well, the location and setting of plugs; and,
- Injection well operators must identify an Area of Review (AoR), use compatible materials and equipment, test, and maintain well records.

Table 2 provides a well count by type and status. All these wells are in material compliance with TRRC rules.

Table 1 WSSAU Well Penetrations by Type and Status

TYPE	ACTIVE	Dry & Abandoned	INACTIVE	P & A*	SHUT-IN	TA**	Total
DISP_H2O	2			2			**4**
INJ_GAS					1		**1**
INJ_H2O	23		7	25	3	5	**63**
INJ_WAG	35						**35**
OBSERVATION	1					1	**2**
PROD_GAS						3	**3**
PROD_OIL	80	2	4	16		16	**118**
SUP_H2O						1	**1**
TOTAL	**141**	**2**	**11**	**43**	**4**	**26**	**227**

*P&A = Plugged and Abandoned
**TA = Temporarily Abandoned

As indicated in Figure 3-6, wells are distributed across the WSSAU. The well patterns currently undergoing CO_2 flooding are outlined in the black box and CO_2 will be injected across the entire unit over the project life.

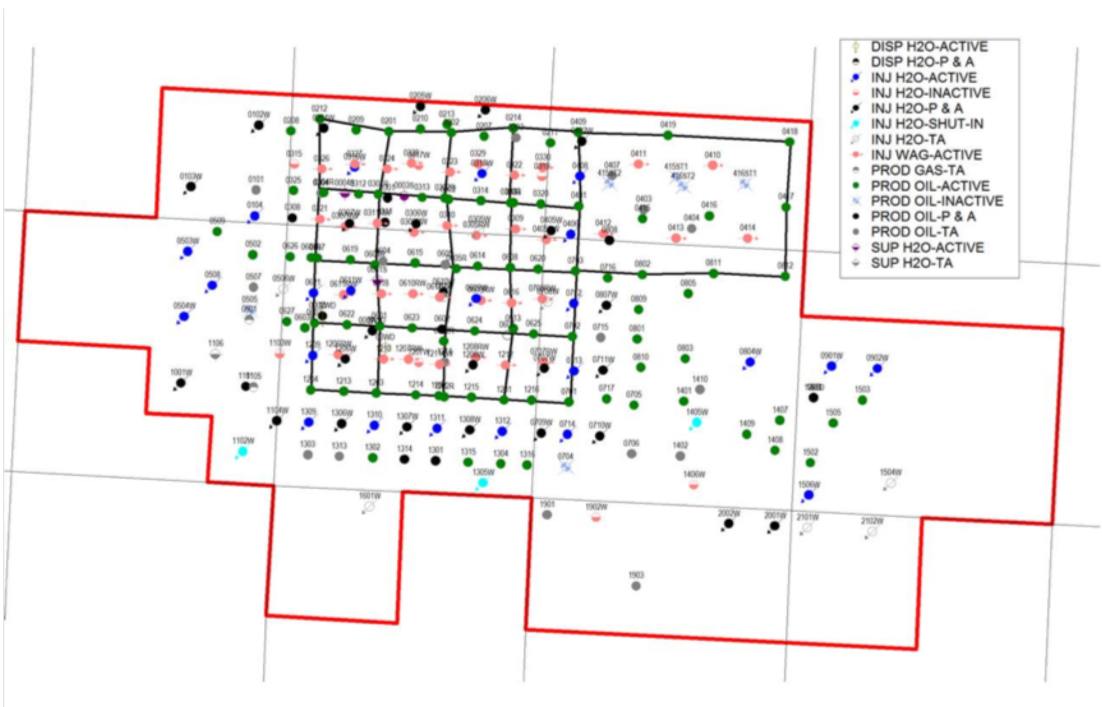

Figure 3-6 WSSAU Wells and Injection Patterns

WSSAU CO_2 EOR operations are designed to avoid conditions which could damage the reservoir and cause a potential leakage pathway. Reservoir pressure in the WSSAU is managed

by maintaining an injection to withdrawal ratio (IWR)[1] of approximately 1.0. To maintain the IWR, fluid injection and production are monitored and managed to ensure that reservoir pressure does not increase to a level that would compromise the reservoir seal or otherwise damage the integrity of the oil field.

Injection pressure is also maintained below the FPP, which is measured using step-rate tests.

3.4. Reservoir modeling

A history matched reservoir model of the current and forecast WSSAU CO_2 injection has been made. The model was constructed using Eclipse software which is a commercially available reservoir simulation code. The model simulates the recovery mechanism in which CO_2 is miscible with the hydrocarbon in the reservoir.

The model was created to:

i. Demonstrate that the storage complex has, at the minimum, the capacity to contain the planned volume of purchased CO_2.
ii. Track injected CO_2, identify how and where CO_2 is trapped in the WSSAU, and to monitor sequestration volumes and distribution.

The reservoir model utilizes four types of data:

i. Site Characteristics as described in the WSSAU Geomodel,
ii. Initial reservoir conditions and fluid property data
iii. Capillary pressure data, and
iv. Well data

The geomodel used as the foundation for the reservoir model used data from 232 wells in the area of interest that includes WSSAU. These wells have digital open- or cased-hole logs that were used for correlation of formation tops. A sequence stratigraphic framework was developed based upon core descriptions and outcrop analogs, this correlation framework was then extrapolated to well logs. The sequence stratigraphic correlations are picked at the base of mud-dominated flooding surfaces mapped out in core and extrapolated to well logs throughout the rest of the field.

The model is a four-component model consisting of water, oil, reservoir gas and injected CO_2. It is an extension of the black oil model that enables the modeling of recovery mechanisms in which the injected CO_2 is miscible with reservoir oil. This is a reasonable assumption since the reservoir under study is above minimum miscibility pressure (MMP). The total hydrocarbon and solvent (CO_2) saturation is used to calculate relative permeability to water. The solvent and oil relative permeability are then calculated using multipliers from a look-up table. The Todd-

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[1] Injection to withdrawal ratio (IWR) is the ratio of the volume of fluids injected to the volume of fluids produced (withdrawn). Volumes are measured under reservoir conditions for all fluids. By keeping IWR close to 1.0, reservoir pressure is held constant, neither increasing nor decreasing.

Longstaff[2] model is used to calculate the effective viscosity and density of the hydrocarbon and solvent phases.

History matching is the process of adjusting input parameters within the range of data uncertainties until the actual reservoir performance is closely reproduced in the model. A 70-year history match was obtained. All three-phase rates (oil, gas, and water) are included in the history record. The model uses liquid rate control (combination of oil and water) for the history match.

The graphs in Figure 3-7 present the history match results of oil rate, gas rates, water rates, and water cut and show that the reservoir model provides an excellent match to actual historic data. Figure 3-8 shows the match of water and CO_2 injection.

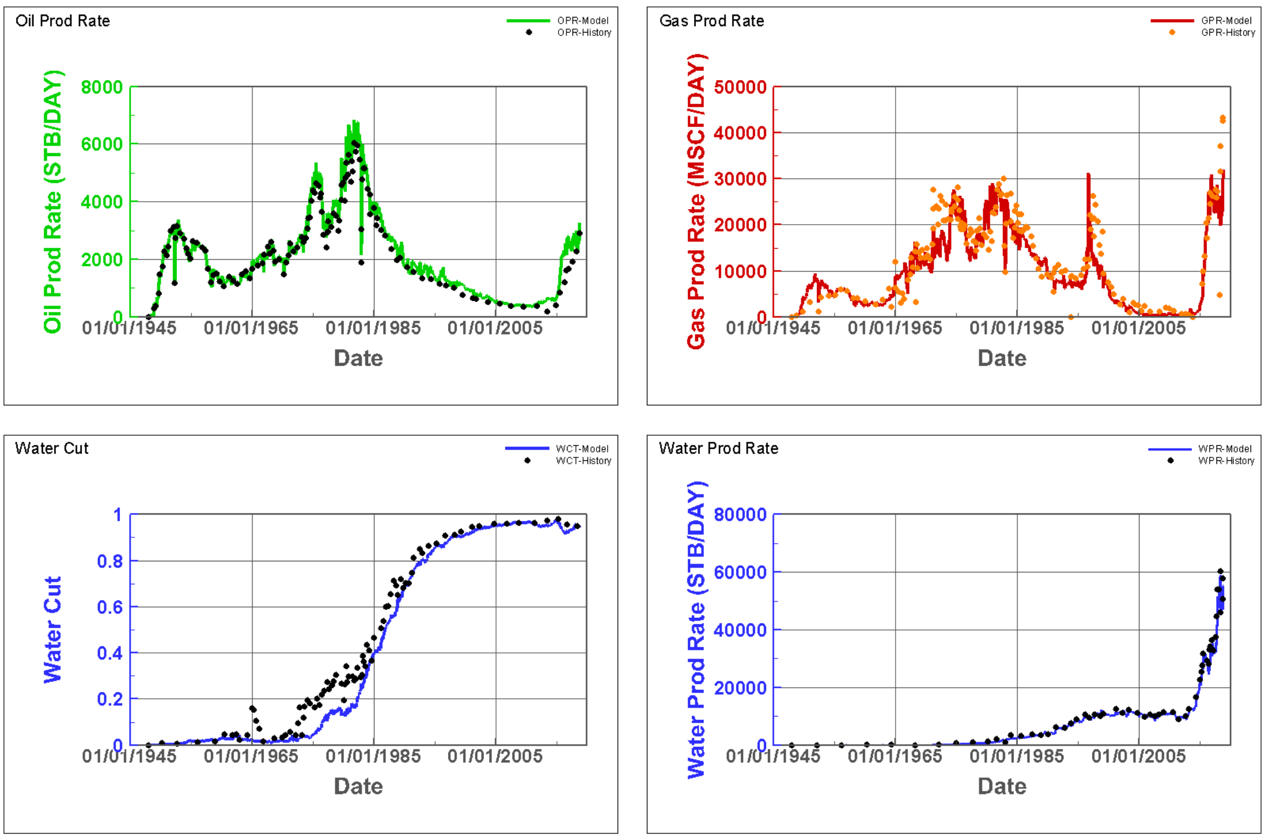

Figure 3-7 Four Parameters of History-Matched Modeling in the WSSAU Reservoir Model

[2] Todd, M.R., Longstaff, W.J.: The development, testing and application of a numerical simulator for predicting miscible flood performance. J. Petrol. Tech. 24(7), 874–882 (1972)

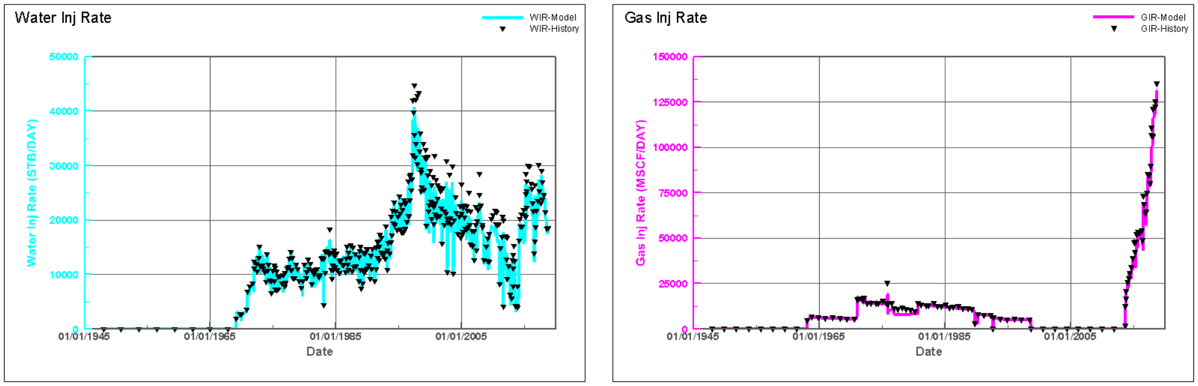

Figure 3-8 Plots of Injection History Match in the WSSAU Reservoir Model

The WSSAU reservoir model was used to evaluate the plume of CO_2 using a set of injection, production, and facilities constraints that describe the injection plan. The history match indicates that the model is robust and that there is little chance that uncertainty about any specific variable will have a meaningful impact on the reservoir CO_2 storage performance. The model forecast showed that CO_2 is contained in the reservoir within the boundaries of WSSAU.

4. Delineation of Monitoring Area and Timeframes

4.1. Active Monitoring Area

The Active Monitoring Area (AMA) is defined by the boundary of the WSSAU plus the required ½ mile buffer.

4.2. Maximum Monitoring Area

The Maximum Monitoring Area (MMA) is defined by the boundary of the WSSAU plus the required ½ mile buffer as required by 40 CFR §98.440-449 (Subpart RR).

4.3. Monitoring Timeframes

The primary purpose for injecting CO_2 is to produce oil that would otherwise remain trapped in the reservoir and not, as in UIC Class VI, "specifically for the purpose of geologic storage."[3] During a Specified Period, there will be a subsidiary purpose of establishing the long-term containment of CO_2 in the WSSAU. The Specified Period will be shorter than the period of production from the WSSAU.

At the conclusion of the Specified Period, a request for discontinuation of reporting will be submitted. This request will be submitted with a demonstration that current monitoring and model(s) show that the cumulative mass of CO_2 reported as sequestered during the Specified Period is not expected to migrate in the future in a manner likely to result in surface leakage. It is expected that it will be possible to make this demonstration almost immediately after the Specified Period ends based upon predictive modeling supported by monitoring data.

The reservoir pressure in the WSSAU is collected for use reservoir modeling and operations management. Reservoir pressure is not forecast to change appreciably since the IWR will be maintained at approximately 1.0. The reservoir model shows that by the end of CO_2 injection, average reservoir pressure will be approximately 2,360 psi. Once injection ceases, reservoir pressure is predicted to stabilize within one year. Over time, reservoir pressure is expected to drop by approximately 10 psi. The trend of the reservoir pressure decline will be one of the bases of a request to discontinue monitoring and reporting.

[3] EPA UIC Class VI rule, EPA 75 FR 77291, December 10, 2010, section 146.81(b).

5. Evaluation of Potential Pathways for Leakage to the Surface, Leakage Detection, Verification, and Quantification

In the roughly 70 years since the oil field of the WSSAU was discovered, the reservoir has been studied and documented extensively. Based on the knowledge gained from that experience, this section assesses the potential pathways for leakage of stored CO_2 to the surface including:

i. Existing Well Bores
ii. Faults and Fractures
iii. Natural and Induced Seismic Activity
iv. Previous Operations
v. Pipeline/Surface Equipment
vi. Lateral Migration Outside the WSSAU
vii. Drilling Through the CO_2 Area
viii. Diffuse Leakage Through the Seal

This analysis shows that leakage through wellbores and surface equipment pose the only meaningful potential leakage pathways. The monitoring program to detect and quantify leakage is based on this assessment as discussed below.

5.1. Existing Wellbores

As part of the TRRC requirement to initiate CO_2 flooding, an extensive review of all WSSAU penetrations was completed to determine the need for corrective action. That analysis showed that all penetrations have either been adequately plugged and abandoned or, if in use, do not require corrective action. All wells in the WSSAU were constructed and are operated in compliance with TRRC rules.

As part of routine risk management, the potential risk of leakage associated with the following were identified and evaluated:

i. CO_2 flood beam wells
ii. Electrical submersible pump (ESP) producer wells, and
iii. CO_2 WAG injector wells.

The risk assessment classified all risks associated with subsurface as low risk, i.e., less than 1% likelihood to occur and having a consequence that is insubstantial. The risks were classified as low risk because, the WSSAU geology is well suited to CO_2 sequestration with an extensive confining zone that is free of fractures and faults that could be potential conduits for CO_2 migration. The low risk is supported by the results of the reservoir model which shows that stored CO_2 is not predicted to leave the WSSAU boundary. Any risks are further mitigated because the WSSAU is operated in a manner that maintains, monitors, and documents the integrity of the reservoir.

The risk of well leakage is mitigated through:

i. Adhering to regulatory requirements for well drilling and testing;
ii. implementing best practices that Oxy has developed through its extensive operating experience;

iii. monitoring injection/production performance, wellbores, and the surface; and,
iv. maintaining surface equipment.

Continual and routine monitoring of the wellbores and site operations will be used to detect leaks or other potential well problems, as follows:

- Pressure in injection wells is monitored on a continual basis. The injection plans for each pattern are programmed into the injection WAG satellite to govern the rate, pressure, and duration of either water or CO_2 injection. Pressure monitors on the injection wells are programmed to flag whenever statistically significant pressure deviations from the targeted ranges in the plan are identified. Leakage on the inside or outside of the injection wellbore would affect pressure and be detected through this approach. If such events occur, they are investigated and addressed. Oxy's experience, from over 40 years of operating CO_2 EOR projects, is that such leakage is very rare and there have been no incidents of fluid migration out of the intended zone at WSSAU.

- Production well performance is monitored using the production well test process conducted when produced fluids are gathered and sent to an SAT. There is a routine well testing cycle for each SAT, with each well being tested approximately once every two months. During this cycle, each production well is diverted to the well test equipment for a period of time sufficient to measure and sample produced fluids (generally 8-12 hours). These tests are the basis for allocating a portion of the produced fluids measured at the SAT to each production well, assessing the composition of produced fluids by location, and assessing the performance of each well. Performance data are reviewed on a routine basis to ensure that CO_2 flooding efficiency is optimized. If production is off the plan, it is investigated and any identified issues addressed. Leakage to the outside of production wells is not considered a major risk because of the reduced pressure in the casing. Further, the personal H_2S monitors are designed to detect leaked fluids around production wells during well inspections.

- Field inspections are conducted on a routine basis by field personnel. Leaking CO_2 is very cold and leads to formation of bright white clouds and ice that are easily spotted. All field personnel are trained to identify leaking CO_2 and other potential problems at wellbores and in the field. Any CO_2 leakage detected will be documented and reported and quantified.

Based on ongoing monitoring activities and review of the potential leakage risks posed by well bores, it is concluded that the risk of CO_2 leakage through well bores is being mitigated by detecting problems as they arise and quantifying any leakage that does occur.

5.2. Faults and Fractures

After reviewing geologic, seismic, operating, and other evidence, it has been concluded that there are no known faults or fractures that transect the San Andres reservoir in the project area. As a result, there is no risk of leakage due to fractures or faults.

Measurements to determine FPP and reservoir pressure are routinely updated. This information is used to manage injection patterns so that the injection pressure will not exceed FPP. An IWR at or near 1 is also maintained. Both of these measures mitigate the potential for inducing faults or fractures. As a safeguard, WAG skids are continuously monitored and set with automatic shutoff controls if injection pressures exceed programmed levels.

5.3. Natural or Induced Seismicity

After reviewing the literature and actual operating experience, it is concluded that there is no direct evidence that natural seismic activity poses a significant risk for loss of CO_2 to the surface in the Permian Basin, and specifically in the WSSAU.

To evaluate this potential risk at WSSAU, Oxy has reviewed the nature and location of seismic events in West Texas. Some of the recorded earthquakes in West Texas are far removed from any injection operation. These are judged to be from natural causes. Others are near oil fields or water disposal wells and are placed in the category of "quakes in close association with human enterprise."[4] A review of the USGS database of recorded earthquakes at M3.0 or greater in the Permian Basin indicates that none have occurred in the West Seminole Field; the closest took place in 1992 approximately 35 miles away. The concern about induced seismicity is that it could lead to fractures in the seal providing a pathway for CO_2 leakage to the surface. Oxy is not aware of any reported loss of injectant (brine water or CO_2) to the surface associated with any seismic activity. There is no direct evidence to suggest that natural seismic activity poses a significant risk for loss of CO_2 to the surface in the Permian Basin, and specifically in the WSSAU. If induced seismicity resulted in a pathway for material amounts of CO_2 to migrate from the injection zone, other reservoir fluid monitoring provisions (e.g., reservoir pressure, well pressure, and pattern monitoring) would detect the migration and lead to further investigation. Oxy also participates in the TexNet seismic monitoring network[5] and will continue to monitor for seismic signals that could indicate the creation of potential leakage pathways in WSSAU.

5.4. Previous Operations

CO_2 flooding was initiated in WSSAU in 2013. To obtain permits for CO_2 flooding, the AoR around all CO_2 injector wells was evaluated to determine if there were any unknown penetrations and to assess if corrective action was required at any wells. As indicated in Section 5.1, this evaluation reviewed the identified penetrations and determined that no additional corrective action was needed. Further, Oxy's standard practice for drilling new wells includes a rigorous review of nearby wells to ensure that drilling will not cause damage to or interfere with existing wells. And, requirements to construct wells with materials that are designed for CO_2 injection are adhered to at WSSAU. These practices ensure that that there are no unknown wells within WSSAU and that the risk of migration from older wells has been sufficiently mitigated. The successful experience with CO_2 flooding in WSSAU demonstrates that the confining zone has not been impaired by previous operations.

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[4] Frohlich, Cliff (2012) "Induced or Triggered Earthquakes in Texas: Assessment of Current Knowledge and Suggestions for Future Research", Final Technical Report, Institute for Geophysics, University of Texas at Austin, Office of Sponsored Research.

[5] https://www.beg.utexas.edu/texnet-cisr/texnet

5.5. Pipelines and Surface Equipment

As part of routine risk management described in Section 5, the potential risk of leakage associated with the following are identified and evaluated:

i. The production satellite
ii. The Central Tank Battery; and
iii. Facility pipelines.

As described in Section 5.1, the risk assessment classified all subsurface risks as low risk, i.e., less than 1% likelihood to occur and having a consequence that is insubstantial. The risks associated with pipelines and surface equipment were classified as low risk because, the WSSAU is operated in a manner that maintains, monitors, and documents the integrity of the reservoir.

The risk of well leakage is mitigated through:

i. Adhering to regulatory requirements for well drilling and testing;
ii. implementing best practices that Oxy has developed through its extensive operating experience;
iii. monitoring injection/production performance, wellbores, and the surface; and,
iv. maintaining surface equipment.

Personnel continuously monitor the pipeline system using the SCADA system and are able to detect and mitigate pipeline leaks expeditiously. Such risks will be prevented, to the extent possible, by relying on the use of prevailing design and construction practices and maintaining compliance with applicable regulations. The facilities and pipelines currently utilize and will continue to utilize materials of construction and control processes that are standard for CO_2 EOR projects in the oil and gas industry. Operating and maintenance practices currently follow and will continue to follow demonstrated industry standards. CO_2 delivery via the Permian Basin CO_2 pipeline system will continue to comply with all applicable regulations. Finally, routine visual inspection of surface facilities by field staff will provide an additional way to detect leaks and further support the efforts to detect and remedy any leaks in a timely manner. Should leakage be detected from pipeline or surface equipment, the volume of released CO_2 will be quantified following the requirements of Subpart W of EPA's GHGRP.

5.6. Lateral Migration Outside the WSSAU

It is highly unlikely that injected CO_2 will migrate downdip and laterally outside the WSSAU because of the nature of the geology and the approach used for injection. First, WSSAU is situated in the highest local elevations within the San Andres. This means that over long periods of time, injected CO_2 will tend to rise vertically towards the Upper San Andres and continue towards the point in the WSSAU with the highest elevation. Second, the planned injection volumes and active fluid management during injection operations will prevent CO_2 from migrating laterally out of the structure. Finally, the total volume of fluids contained in the WSSAU will stay relatively constant. Based on site characterization and planned and projected operations it is estimated that the total volume of stored CO_2 will be considerably less than calculated capacity.

5.7. Drilling in the WSSAU

The TRRC regulates well drilling activity in Texas. Pursuant to TRRC rules, wells casing shall be securely anchored in the hole in order to effectively control the well at all times, all usable-quality water zones shall be isolated and sealed off to effectively prevent contamination or harm, and all productive zones, potential flow zones, and zones with corrosive formation fluids shall be isolated and sealed off to prevent vertical migration of fluids, including gases, behind the casing. Where TRRC rules do not detail specific methods to achieve these objectives, operators shall make every effort to follow the intent of the section, using good engineering practices and the best currently available technology. The TRRC requires applications and approvals before a well is drilled, recompleted, or reentered. Well drilling activity at WSSAU is conducted in accordance with TRRC rules. Oxy's visual inspection process, including routine site visits, will identify unapproved drilling activity in the WSSAU.

In addition, Oxy intends to operate WSSAU for several more decades and will continue to be vigilant about protecting the integrity of its assets and maximizing the potential of its resources, including oil, gas and CO_2. Consequently, the risks associated with third parties penetrating the WSSAU are negligible.

5.8. Diffuse Leakage Through the Seal

Diffuse leakage through the seal formed by the upper San Andres is highly unlikely. The presence of a gas cap trapped over millions of years confirms that the seal has been secure. Injection pattern monitoring assures that no breach of the seal will be created. Wellbores that penetrate the seal make use of cement and steel construction that is closely regulated to ensure that no leakage takes place. Injection pressure is continuously monitored and unexplained changes in injection pressure that might indicate leakage would trigger investigation as to the cause.

5.9. Leakage Detection, Verification, and Quantification

As discussed above, the potential sources of leakage include issues, such as problems with surface equipment (pumps, valves, etc.) or subsurface equipment (well bores), and unique events such as induced fractures. An event-driven process to assess, address, track, and if applicable quantify potential CO_2 leakage is used. Table 3 summarizes some of these potential leakage scenarios, the monitoring activities designed to detect those leaks, the standard response, and other applicable regulatory programs requiring similar reporting.

Given the uncertainty concerning the nature and characteristics of any leaks that may be encountered, the most appropriate methods for quantifying the volume of leaked CO_2 will be determined on a case by case basis. In the event leakage occurs, the most appropriate methods for quantifying the volume leaked will be determined and it will be reported as required as part of the annual Subpart RR submission.

Any volume of CO_2 detected leaking to surface will be quantified using acceptable emission factors such as those found in 40 CFR Part 98 Subpart W or engineering estimates of leak amounts based on measurements in the subsurface, field experience, and other factors such as the frequency of inspection. Leaks will be documented, evaluated and addressed in a timely manner.

Records of leakage events will be retained in the electronic environmental documentation and reporting system. Repairs requiring a work order will be documented in the electronic equipment maintenance system.

Table 2 Response Plan for CO_2 Loss

Risk	Monitoring Plan	Response Plan
Tubing Leak	Monitor changes in tubing and annulus pressure; MIT for injectors	Wellbore is shut in and workover crews respond within days
Casing Leak	Routine Field inspection; Monitor changes in annulus pressure, MIT for injectors; extra attention to high risk wells	Well is shut in and workover crews respond within days
Wellhead Leak	Routine Field inspection, SCADA system monitors wellhead pressure	Well is shut in and workover crews respond within days
Loss of Bottom-hole pressure control	Blowout during well operations	Maintain well kill procedures
Unplanned wells drilled through San Andres	Routine Field inspection to prevent unapproved drilling; compliance with TRRC permitting for planned wells.	Assure compliance with TRRC regulations
Loss of seal in abandoned wells	Reservoir pressure in WAG headers; high pressure found in new wells	Re-enter and reseal abandoned wells
Pumps, valves, etc.	Routine Field inspection, SCADA	Workover crews respond within days
Overfill beyond spill points	Reservoir pressure in WAG headers; high pressure found in new wells	Fluid management along lease lines
Leakage through induced fractures	Reservoir pressure in WAG headers; high pressure found in new wells	Comply with rules for keeping pressures below parting pressure
Leakage due to seismic event	Reservoir pressure in WAG headers; high pressure found in new wells	Shut in injectors near seismic event

5.10. Summary

The structure and stratigraphy of the San Andres reservoir in the WSSAU is ideally suited for the injection and storage of CO_2. The stratigraphy within the CO_2 injection zones is porous, permeable and thick, providing ample capacity for long-term CO_2 storage. The reservoir is overlain by several intervals of impermeable geologic zones that form effective seals or "caps" to fluids in the reservoir. After assessing potential risk of release from the subsurface and steps that have been taken to prevent leaks, it has been determined that the potential threat of leakage is extremely low.

In summary, based on a careful assessment of the potential risk of release of CO_2 from the subsurface, it has been determined that there are no leakage pathways at the WSSAU that are likely to result in significant loss of CO_2 to the atmosphere. Further, given the detailed knowledge of the field and its operating protocols, it is concluded that any CO_2 leakage to the surface that could arise through either identified or unexpected leakage pathways would be detected and quantified.

6. Monitoring and Considerations for Calculating Site Specific Variables

Monitoring will also be used to determine the quantities in the mass balance equation and to make the demonstration that the CO_2 plume will not migrate to the surface after the time of discontinuation.

6.1. For the Mass Balance Equation

6.1.1. General Monitoring Procedures

Flow rate, pressure, and gas composition data are monitored and collected from the WSSAU in centralized data management systems as part of ongoing operations. These data are monitored by qualified technicians who follow response and reporting protocols when the systems deliver notifications that data exceed statistically acceptable boundaries.

Metering protocols used at WSSAU follow the prevailing industry standard(s) for custody transfer as currently promulgated by the API, the American Gas Association (AGA), and the Gas Processors Association (GPA), as appropriate. This approach is consistent with EPA GHGRP's Subpart RR, section 98.444(e)(3). These meters will be maintained routinely, operated continually, and will feed data directly to the centralized data collection systems. The meters meet the industry standard for custody transfer meter accuracy and calibration frequency.

6.1.2. CO_2 Received

As indicated in Figure 3-5, the volume of received CO_2 is measured using a commercial custody transfer meter at the point at which custody of the CO_2 from the Permian Basin CO_2 pipeline delivery system is transferred to the WSSAU. This meter measures flow rate continually. The transfer is a commercial transaction that is documented. CO_2 composition is governed by contract and the gas is routinely sampled. Fluid composition will be determined, at a minimum, quarterly, consistent with EPA GHGRP's Subpart RR, section 98.447(a). All meter and composition data are documented, and records will be retained for at least three years. No CO_2 is received in containers.

6.1.3. CO_2 Injected in the Subsurface

Injected CO_2 will be calculated using the flow meter volumes at the operations meter at the outlet of the RCF and the custody transfer meter at the CO_2 off-take point from the Permian Basin CO_2 pipeline delivery system

6.1.4. CO_2 Produced, Entrained in Products, and Recycled

The following measurements are used for the mass balance equations in Section 7:

CO_2 produced in the gaseous stage is calculated using the volumetric flow meters at the inlet to the RCF.

CO_2 that is entrained in produced oil, as indicated in Figure 3-5, is calculated using volumetric flow through the custody transfer meter.

Recycled CO_2 is calculated using the volumetric flow meter at the outlet of the RCF, which is an operations meter.

6.1.5. CO_2 Emitted by Surface Leakage

Oxy uses 40 CFR Part 98 Subpart W to estimate surface leaks from equipment at the WSSAU. Subpart W uses a factor-driven approach to estimate equipment leakage. In addition, an event-driven process to assess, address, track, and if applicable quantify potential CO_2 leakage to the surface is used. The Subpart W report and results from any event-driven quantification will be reconciled to assure that surface leaks are not double counted.

The multi-layered, risk-based monitoring program for event-driven incidents has been designed to meet two objectives: 1) to detect problems before CO_2 leaks to the surface; and 2) to detect and quantify any leaks that do occur. This section discusses how this monitoring will be conducted and used to quantify the volumes of CO_2 leaked to the surface.

Monitoring for potential Leakage from the Injection/Production Zone:
In addition to the measures discussed in Section 5.9, both injection into and production from the reservoir will be monitored as a means of early identification of potential anomalies that could indicate leakage from the subsurface.

Reservoir simulation modeling, based on extensive history-matched data, is used to develop injection plans (fluid rate, pressure, volume) that are programmed into each WAG satellite. If injection pressure or rate measurements are outside the specified set points determined as part of each pattern injection plan, a data flag is automatically triggered and field personnel will investigate and resolve the problem. These excursions will be reviewed by well management personnel to determine if CO_2 leakage may be occurring. Excursions are not necessarily indicators of leaks; they simply indicate that injection rates and pressures are not conforming to the pattern injection plan. In many cases, problems are straightforward to fix (e.g., a meter needs to be recalibrated or some other minor action is required), and there is no threat of CO_2 leakage. In the case of issues that are not readily resolved, more detailed investigation and response would be initiated, and support staff would provide additional assistance and evaluation. Such issues would lead to the development of a work order in the work order management system. This record enables the tracking of progress on investigating potential leaks and, if a leak has occurred, to quantify its magnitude.

Likewise, a forecast of the rate and composition of produced fluids is developed. Each producer well is assigned to a specific SAT and is isolated during each cycle for a well production test. This data is reviewed on a periodic basis to confirm that production is at the level forecasted. If there is a significant deviation from the plan, well management personnel investigate. If the issue cannot be resolved quickly, more detailed investigation and response would be initiated. As in the case of the injection pattern monitoring, if the investigation leads to a work order in the work order management system, this record will provide the basis for tracking the outcome of the investigation and if a leak has occurred, recording the quantity leaked to the surface. If leakage in the flood zone were detected, an appropriate method would be used to quantify the involved volume of CO_2. This might include use of material balance equations based on known

injected quantities and monitored pressures in the injection zone to estimate the volume of CO_2 involved.

A subsurface leak might not lead to a surface leak. In the event of a subsurface leak, Oxy would determine the appropriate approach for tracking subsurface leakage to determine and quantify leakage to the surface. To quantify leakage, the relevant parameters (e.g., the rate, concentration, and duration of leakage) would be estimated to quantify the leak volume. Depending on specific circumstances, these determinations may rely on engineering estimates.

In the event leakage from the subsurface occurred diffusely through the seals, the leaked gas would include H_2S, which would trigger the alarm on the personal monitors worn by field personnel. Such a diffuse leak from the subsurface has not occurred in the WSSAU. In the event such a leak was detected, personnel would determine how to address the problem. The personnel might use modeling, engineering estimates, and direct measurements to assess, address, and quantify the leakage.

Monitoring of Wellbores:
WSSAU wells are monitored through continual, automated pressure monitoring of the injection zone, monitoring of the annular pressure in wellheads, and routine maintenance and inspection.

Leaks from wellbores would be detected through the follow-up investigation of pressure anomalies, visual inspection, or the use of personal H_2S monitors.

Anomalies in injection zone pressure may not indicate a leak, as discussed above. However, if an investigation leads to a work order, field personnel would inspect the equipment in question and determine the nature of the problem. If it is a simple matter, the repair would be made and the volume of leaked CO_2 would be included in the 40 CFR Part 98 Subpart W report for the WSSAU. If more extensive repair were needed, the appropriate approach for quantifying leaked CO_2 using the relevant parameters (e.g., the rate, concentration, and duration of leakage) would be determined. The work order would serve as the basis for tracking the event for GHG reporting.

Anomalies in annular pressure or other issues detected during routine maintenance inspections would be treated in the same way. Field personnel would inspect the equipment in question and determine the nature of the problem. For simple matters the repair would be made at the time of inspection and the volume of leaked CO_2 would be included in the 40 CFR Part 98 Subpart W report for the WSSAU. If more extensive repairs were needed, the well would be shut in, a work order would be generated and the appropriate approach for quantifying leaked CO_2 using the relevant parameters (e.g., the rate, concentration, and duration of leakage) would be determined. The work order would serve as the basis for tracking the event for GHG reporting.

Because leaking CO_2 at the surface is very cold and leads to formation of bright white clouds and ice that are easily spotted, a visual inspection process in the area of the WSSAU is employed to detect unexpected releases from wellbores. Field personnel visit the surface facilities on a routine basis. Inspections may include tank levels, equipment status, lube oil levels, pressures and flow rates in the facility, and valves. Field personnel also check that injectors are on the proper WAG schedule and observe the facility for visible CO_2 or fluid line leaks.

Finally, the data collected by the H_2S monitors, which are worn by all field personnel at all times, is used as a last method to detect leakage from wellbores. The H_2S monitors detection limit is 10 ppm; if an H_2S alarm is triggered, the first response is to protect the safety of the personnel, and the next step is to safely investigate the source of the alarm. As noted previously, H_2S is considered a proxy for potential CO_2 leaks in the field. Thus, detected H_2S leaks will be investigated to determine and, if needed, quantify potential CO_2 leakage. If the incident results in a work order, this will serve as the basis for tracking the event for GHG reporting.

<u>Other Potential Leakage at the Surface:</u>
The same visual inspection process and H_2S monitoring system will be used to detect other potential leakage at the surface as it does for leakage from wellbores. Routine visual inspections are used to detect significant loss of CO_2 to the surface. Field personnel routinely visit surface facilities to conduct a visual inspection. Inspections may include review of tank level, equipment status, lube oil levels, pressures and flow rates in the facility, valves, ensuring that injectors are on the proper WAG schedule, and also conducting a general observation of the facility for visible CO_2 or fluid line leaks. If problems are detected, field personnel would investigate, and, if maintenance is required, generate a work order in the maintenance system, which is tracked through completion. In addition to these visual inspections, the results of the personal H_2S monitors worn by field personnel will be used as a supplement for smaller leaks that may escape visual detection.

If CO_2 leakage to the surface is detected, it will be reported to surface operations personnel who will review the reports and conduct a site investigation. If maintenance is required, steps are taken to prevent further leaks, a work order will be generated in the work order management system. The work order will describe the appropriate corrective action and be used to track completion of the maintenance action. The work order will also serve as the basis for tracking the event for GHG reporting and quantifying any CO_2 emissions.

6.1.6. CO_2 emitted from equipment leaks and vented emissions of CO_2 from surface equipment located between the injection flow meter and the injection wellhead

Oxy evaluates and estimates leaks from equipment, the CO_2 content of produced oil, and vented CO_2, as required under 40 CFR Part 98 Subpart W.

6.1.7. CO_2 emitted from equipment leaks and vented emissions of CO_2 from surface equipment located between the production flow meter and the production wellhead

Oxy evaluates and estimates leaks from equipment, the CO_2 content of produced oil, and vented CO_2, as required under 40 CFR Part 98 Subpart W.

6.2. To Demonstrate that Injected CO_2 is not Expected to Migrate to the Surface

At the end of the Specified Period, injecting CO_2 for the subsidiary purpose of establishing the long-term storage of CO_2 in the WSSAU will cease. Some time after the end of the Specified

Period, a request to discontinue monitoring and reporting will be submitted. The request will demonstrate that the amount of CO_2 reported under 40 CFR §98.440-449 (Subpart RR) is not expected to migrate in the future in a manner likely to result in surface leakage. At that time, the request will be supported with years of data collected during the Specified Period as well as two to three (or more, if needed) years of data collected after the end of the Specified Period. This demonstration will provide the information necessary for the EPA Administrator to approve the request to discontinue monitoring and reporting and may include, but is not limited to:

i. Data comparing actual performance to predicted performance (purchase, injection, production) over the monitoring period;
ii. An assessment of the CO_2 leakage detected, including discussion of the estimated amount of CO_2 leaked and the distribution of emissions by leakage pathway;
iii. A demonstration that future operations will not release the volume of stored CO_2 to the surface;
iv. A demonstration that there has been no significant leakage of CO_2; and,
v. An evaluation of reservoir pressure that demonstrates that injected fluids are not expected to migrate in a manner to create a potential leakage pathway.

7. Determination of Baselines

Existing automatic data systems will be utilized to identify and investigate excursions from expected performance that could indicate CO_2 leakage. Data systems are used primarily for operational control and monitoring and as such are set to capture more information than is necessary for reporting in the Annual Subpart RR Report. The necessary system guidelines to capture the information that is relevant to identify possible CO_2 leakage will be developed. The following describes the approach to collecting this information.

Visual Inspections

As field personnel conduct routine inspections, work orders are generated in the electronic system for maintenance activities that cannot be addressed on the spot. Methods to capture work orders that involve activities that could potentially involve CO_2 leakage will be developed, if not currently in place. Examples include occurrences of well workover or repair, as well as visual identification of vapor clouds or ice formations. Each incident will be flagged for review by the person responsible for MRV documentation (the responsible party will be provided in the monitoring plan, as required under Subpart A, 98.3(g)).The Annual Subpart RR Report will include an estimate of the amount of CO_2 leaked. Records of information used to calculate emissions will be maintained on file for a minimum of three years.

Personal H_2S Monitors

Oxy's injection gas compositional analysis indicates H_2S is approximately 1% of total injected fluid stream.

H_2S monitors are worn by all field personnel. The H_2S monitors detect concentrations of H_2S up to 500 ppm in 0.1 ppm increments and will sound an alarm if the detection limit exceeds 10ppm. If an H_2S alarm is triggered, the immediate response is to protect the safety of the personnel, and the next step is to safely investigate the source of persistent alarms. Oxy considers H_2S to be a proxy for potential CO_2 leaks in the field. The person responsible for MRV documentation will receive notice of all incidents where H_2S is confirmed to be present. If the incident results in a work order, this will serve as the basis for tracking the event for GHG reporting. The Annual Subpart RR Report will provide an estimate the amount of CO_2 emitted from any such incidents. Records of information to calculate emissions will be maintained on file for a minimum of three years.

Injection Rates, Pressures and Volumes

Target injection rate and pressure for each injector are developed within the permitted limits based on the results of ongoing pattern modeling. The injection targets are programmed into the WAG satellite controllers. High and low set points are also programmed into the controllers, and flags whenever statistically significant deviations from the targeted ranges are identified. The set points are designed to be conservative, because it is preferable to have too many flags rather than too few. As a result, flags can occur frequently and are often found to be insignificant. For purposes of Subpart RR reporting, flags (or excursions) will be screened to determine if they could also lead to CO_2 leakage to the surface. The person responsible for the MRV documentation will receive notice of excursions and related work orders that could potentially involve CO_2 leakage. The Annual Subpart RR Report will provide an estimate of CO_2 emissions. Records of information to calculate emissions will be maintained on file for a minimum of three years.

Production Volumes and Compositions

A general forecast of production volumes and composition is developed which is used to periodically evaluate performance and refine current and projected injection plans and the forecast. This information is used to make operational decisions but is not recorded in an automated data system. Sometimes, this review may result in the generation of a work order in the maintenance system. The MRV plan implementation lead will review such work orders and identify those that could result in CO_2 leakage. Should such events occur, leakage volumes would be calculated following the approaches described in Sections 5 and 6. Impact to Subpart RR reporting will be addressed, if deemed necessary.

8. Determination of Sequestration Volumes Using Mass Balance Equations

To account for the potential propagation of error that would result if volume data from flow meters at each injection and production well were utilized, it is proposed to use the data from custody and operations meters on the main system pipelines to determine injection and production volumes used in the mass balance. This issue arises because while each meter has a small but acceptable margin of error, this error would become significant if data were taken from all of the well head meters within the WSSAU.

The following sections describe how each element of the mass-balance equation (Equation RR-11) will be calculated.

8.1. Mass of CO_2 Received

Equation RR-2 will be used as indicated in Subpart RR §98.443 to calculate the mass of CO_2 at the receiving custody transfer meter from the Permian Basin CO_2 pipeline delivery system. The volumetric flow at standard conditions will be multiplied by the CO_2 concentration and the density of CO_2 at standard conditions to determine mass.

$$CO_{2T,r} = \sum_{p=1}^{4} (Q_{p,r} - Sr,_{p}) * D * C_{CO2,r,p} \qquad \text{(Eq. RR-2)}$$

where:

$CO_{2T,\,r}$ = Net annual mass of CO_2 received through flow meter r (metric tons).

$Q_{r,p}$ = Quarterly volumetric flow through a receiving flow meter r in quarter p at standard conditions (standard cubic meters).

$S_{r,p}$ = Quarterly volumetric flow through a receiving flow meter r that is redelivered to another facility without being injected into a site well in quarter p (standard cubic meters).

D = Density of CO_2 at standard conditions (metric tons per standard cubic meter): 0.0018682.

$C_{CO2,r,r}$ = Quarterly CO_2 concentration measurement in flow for flow meter r in quarter p (vol. percent CO_2, expressed as a decimal fraction).

p = Quarter of the year.

r = Receiving flow meters.

Given WSSAU's method of receiving CO_2 and requirements at Subpart RR §98.444(a):

- All delivery to the WSSAU is used within the unit so no quarterly flow redelivered, and $S_{r,p}$ will be zero ("0").
- Quarterly CO_2 concentration will be taken from the gas measurement database

8.2. Mass of CO_2 Injected into the Subsurface

The equation for calculating the Mass of CO_2 Injected into the Subsurface at the WSSAU is equal to the sum of the Mass of CO_2 Received as calculated in RR-2 of §98.443 (section 8.1 above) and the Mass of CO_2 Recycled calculated using measurements taken from the flow meter located at the output of the RCF (see Figure 3-5). As previously explained, using data at each injection well would give an inaccurate estimate of total injection volume due to the large number of wells and the potential for propagation of error due to allowable calibration ranges for each meter.

The Mass of CO_2 Recycled will be determined using equations RR-5 as follows:

$$CO_{2u} = \sum_{p=1}^{4} Q_{p,u} * D * C_{CO2,p,u} \qquad \text{(Eq. RR-5)}$$

where:

CO_{2u} = Annual CO_2 mass recycled (metric tons) as measured by flow meter u.

$Q_{p,u}$ = Quarterly volumetric flow rate measurement for flow meter u in quarter p at standard conditions (standard cubic meters per quarter).

D = Density of CO_2 at standard conditions (metric tons per standard cubic meter): 0.0018682.

$C_{CO2,p,u}$ = CO_2 concentration measurement in flow for flow meter u in quarter p (vol. percent CO_2, expressed as a decimal fraction).

p = Quarter of the year.

u = Flow meter.

The total Mass of CO_2 Injected will be the sum of the Mass of CO_2 Received (RR-3) and Mass of CO_2 Recycled (modified RR-5).

$$CO_{2I} = CO_2 + CO_{2u}$$

8.3. Mass of CO_2 Produced

The Mass of CO_2 Produced at the WSSAU will be calculated using the measurements from the flow meters at the inlet to RCF and the custody transfer meter for oil sales rather than the metered data from each production well. Again, using the data at each production well would give an inaccurate estimate of total injection due to the large number of wells and the potential for propagation of error due to allowable calibration ranges for each meter.

Equation RR-8 in §98.443 will be used to calculate the Mass of CO_2 Produced from all production wells as follows:

$$CO_{2w} = \sum_{p=1}^{4} Q_{p,w} * D * C_{CO2,p,w} \qquad \text{(Eq. RR-8)}$$

Where:

CO_{2W} = Annual CO_2 mass produced (metric tons) .

$Q_{P,W}$ = Volumetric gas flow rate measurement for meter w in quarter p at standard conditions (standard cubic meters).

D = Density of CO_2 at standard conditions (metric tons per standard cubic meter): 0.0018682.

$C_{CO2,P,W}$ = CO_2 concentration measurement in flow for meter w in quarter p (vol. percent CO_2, expressed as a decimal fraction).

p = Quarter of the year.

w = inlet meter to RCF.

For Equation RR-9 in §98.443 the variable X_{oil} will be measured as follows:

$$CO2_p = \sum_{w=1}^{W} CO2_w + X_{oil} \qquad \text{(Eq. RR-9)}$$

Where:

CO_{2P} = Total annual CO_2 mass produced (metric tons) through all meters in the reporting year.

CO_{2w} = Annual CO_2 mass produced (metric tons) through meter w in the reporting year.

X_{oil} = Mass of entrained CO_2 in oil in the reporting year measured utilizing commercial meters and electronic flow-measurement devices at each point of custody transfer. The mass of CO_2 will be calculated by multiplying the total volumetric rate by the CO_2 concentration.

8.4. Mass of CO_2 Emitted by Surface Leakage

The total annual Mass of CO_2 emitted by Surface Leakage will be calculated and reported using an approach that is tailored to specific leakage events and relies on 40 CFR Part 98 Subpart W reports of equipment leakage. Oxy is prepared to address the potential for leakage in a variety of settings. Estimates of the amount of CO_2 leaked to the surface will depend on a number of site-specific factors including measurements, engineering estimates, and emission factors, depending on the source and nature of the leakage.

The process for quantifying leakage will entail using best engineering principles or emission factors. While it is not possible to predict in advance the types of leaks that will occur, some approaches for quantification are described in Sections 5.9 and 6. In the event leakage to the surface occurs, leakage amounts would be quantified and reported, and records that describe the methods used to estimate or measure the volume leaked as reported in the Annual Subpart RR Report would be retained. Further, the Subpart W report and results from any event-driven quantification will be reconciled to assure that surface leaks are not double counted.

Equation RR-10 in 48.433 will be used to calculate and report the Mass of CO_2 emitted by Surface Leakage:

$$CO_{2E} = \sum_{x=1}^{x} CO_{2x} \qquad \text{(Eq. RR-10)}$$

where:

CO_{2E} = Total annual CO_2 mass emitted by surface leakage (metric tons) in the reporting year.

CO_{2x} = Annual CO_2 mass emitted (metric tons) at leakage pathway x in the reporting year.

x = Leakage pathway.

8.5. Mass of CO_2 Sequestered in Subsurface Geologic Formation

Equation RR-11 in 98.443 will be used to calculate the Mass of CO_2 Sequestered in Subsurface Geologic Formations in the Reporting Year as follows:

$$CO_2 = CO_{2I} - CO_{2P} - CO_{2E} - CO_{2FI} - CO_{2FP} \qquad \text{(Eq. RR-11)}$$

where:

CO_2 = Total annual CO_2 mass sequestered in subsurface geologic formations (metric tons) at the facility in the reporting year.

CO_{2I} = Total annual CO_2 mass injected (metric tons) in the well or group of wells covered by this source category in the reporting year.

CO_{2P} = Total annual CO_2 mass produced (metric tons) net of CO_2 entrained in oil in the reporting year.

CO_{2E} = Total annual CO_2 mass emitted (metric tons) by surface leakage in the reporting year.

CO_{2FI} = Total annual CO_2 mass emitted (metric tons) from equipment leaks and vented emissions of CO_2 from equipment located on the surface between the flow meter used to measure injection quantity and the injection wellhead, for which a calculation procedure is provided in subpart W of this part.

CO_{2FP} = Total annual CO_2 mass emitted (metric tons) from equipment leaks and vented emissions of CO_2 from equipment located on the surface between the production wellhead and the flow meter used to measure production quantity, for which a calculation procedure is provided in subpart W of this part.

8.6. Cumulative Mass of CO_2 Reported as Sequestered in Subsurface Geologic Formation

The total annual volumes obtained using equation RR-11 in 98.443 will be summed to arrive at the Cumulative Mass of CO_2 Sequestered in Subsurface Geologic Formations.

9. MRV Plan Implementation Schedule

This MRV plan will be implemented starting January 2021 or within 90 days of EPA approval, whichever occurs later. Other GHG reports are filed on March 31 of the year after the reporting year and it is anticipated that the Annual Subpart RR Report will be filed at the same time. It is anticipated that the MRV program will be in effect during the Specified Period, during which time the WSSAU will be operated with the subsidiary purpose of establishing long-term containment of a measurable quantity of CO_2 in subsurface geological formations at the WSSAU. It is anticipated to establish that a measurable amount of CO_2 injected during the Specified Period will be stored in a manner not expected to migrate resulting in future surface leakage. At such time, a demonstration supporting the long-term containment determination will be prepared and a request to discontinue monitoring and reporting under this MRV plan will be submitted. *See* 40 C.F.R. § 98.441(b)(2)(ii).

10. Quality Assurance Program

10.1. Monitoring QA/QC

The requirements of §98.444 (a) – (d) have been incorporated in the discussion of mass balance equations. These include the following provisions.

CO_2 Received and Injected

- The quarterly flow rate of CO_2 received by pipeline is measured at the receiving custody transfer meters.
- The quarterly CO_2 flow rate for recycled CO_2 is measured at the flow meter located at the RCF outlet.

CO_2 Produced

- The point of measurement for the quantity of CO_2 produced from oil or other fluid production wells is a flow meter directly downstream of each separator that sends a stream of gas into a recycle or end use system.
- The produced gas stream is sampled at least once per quarter immediately downstream of the flow meter used to measure flow rate of that gas stream and measure the CO_2 concentration of the sample.
- The quarterly flow rate of the produced gas is measured at the flow meters located at the RCF inlet.

CO_2 emissions from equipment leaks and vented emissions of CO_2

These volumes are measured in conformance with the monitoring and QA/QC requirements specified in subpart W of 40 CFR Part 98.

Flow meter provisions

The flow meters used to generate date for the mass balance equations are:

- Operated continuously except as necessary for maintenance and calibration.
- Operated using the calibration and accuracy requirements in 40 CFR §98.3(i).
- Operated in conformance with American Petroleum Institute (API) standards.
- National Institute of Standards and Technology (NIST) traceable.

Concentration of CO_2

CO_2 concentration is measured using an appropriate standard method. Further, all measured volumes of CO_2 have been converted to standard cubic meters at a temperature of 60 degrees Fahrenheit and at an absolute pressure of 1 atmosphere, including those used in Equations RR-2, RR-5 and RR-8 in Section 8.

10.2. Missing Data Procedures

In the event data needed for the mass balance calculations cannot be collected, procedures for estimating missing data in §98.445 will be used as follows:

- A quarterly flow rate of CO_2 received that is missing would be estimated using invoices or using a representative flow rate value from the nearest previous time period.

- A quarterly CO_2 concentration of a CO_2 stream received that is missing would be estimated using invoices or using a representative concentration value from the nearest previous time period.
- A quarterly quantity of CO_2 injected that is missing would be estimated using a representative quantity of CO_2 injected from the nearest previous period of time at a similar injection pressure.
- For any values associated with CO_2 emissions from equipment leaks and vented emissions of CO_2 from surface equipment at the facility that are reported in this subpart, missing data estimation procedures specified in subpart W of 40 CFR Part 98 would be followed.
- The quarterly quantity of CO_2 produced from subsurface geologic formations that is missing would be estimated using a representative quantity of CO_2 produced from the nearest previous period of time.

10.3. MRV Plan Revisions

In the event there is a material change to the monitoring and/or operational parameters of the CO_2 EOR operations in the WSSAU that is not anticipated in this MRV plan, the MRV plan will be revised and submitted to the EPA Administrator within 180 days as required in §98.448(d).

11. Records Retention

The record retention requirements specified by §98.3(g) will be followed. In addition, the requirements in Subpart RR §98.447 will be met by maintaining the following records for at least three years:

- Quarterly records of CO_2 received at standard conditions and operating conditions, operating temperature and pressure, and concentration of these streams.
- Quarterly records of produced CO_2, including volumetric flow at standard conditions and operating conditions, operating temperature and pressure, and concentration of these streams.
- Quarterly records of injected CO_2 including volumetric flow at standard conditions and operating conditions, operating temperature and pressure, and concentration of these streams.
- Annual records of information used to calculate the CO_2 emitted by surface leakage from leakage pathways.
- Annual records of information used to calculate the CO_2 emitted from equipment leaks and vented emissions of CO_2 from equipment located on the surface between the flow meter used to measure injection quantity and the injection wellhead.
- Annual records of information used to calculate the CO_2 emitted from equipment leaks and vented emissions of CO_2 from equipment located on the surface between the production wellhead and the flow meter used to measure production quantity.

These data will be collected as generated and aggregated as required for reporting purposes.

12. Appendix

12.1 Well Identification Numbers

The following table presents the well name and number, API number, type, and status for active wells in WSSAU as of September 2020. The table is subject to change over time as new wells are drilled, existing wells change status, or existing wells are repurposed. The following terms are used:

- Well Status
  - ACTIVE refers to active wells
  - DRILL refers to wells under construction
  - TA refers to wells that have been temporarily abandoned
  - SHUT_IN refers to wells that have been temporarily idled or shut-in
  - INACTIVE refers to wells that have been completed but are not in use
- Well Type
  - DISP_H2O refers to wells for water disposal
  - INJ_GAS refers to wells that inject CO_2 Gas
  - INJ_WAG refers to wells that inject water and CO_2 Gas
  - INJ_H2O refers to wells that inject water
  - OBSERVATION refers to observation or monitoring wells
  - PROD_GAS refers to wells that produce natural gas
  - PROD_OIL refers to wells that produce oil
  - SUP_H2O refers to wells that supply water

• Well Name & Number	API Number	Well Type	Well Status as of September 2020
WSSAU-0002WD	4216500675	DISP_H2O	ACTIVE
WSSAU-0101	4216501591	PROD_OIL	TA
WSSAU-0104	4216532613	INJ_H2O	ACTIVE
WSSAU-0201	4216500642	PROD_OIL	ACTIVE
WSSAU-0202	4216500643	PROD_OIL	ACTIVE
WSSAU-0203	4216500645	PROD_OIL	TA
WSSAU-0207	4216534204	PROD_OIL	ACTIVE
WSSAU-0208	4216537800	PROD_OIL	ACTIVE
WSSAU-0209	4216537801	PROD_OIL	ACTIVE
WSSAU-0210	4216537802	PROD_OIL	ACTIVE
WSSAU-0211	4216537803	PROD_OIL	ACTIVE
WSSAU-0212	4216538559	PROD_OIL	ACTIVE
WSSAU-0213	4216538558	PROD_OIL	ACTIVE
WSSAU-0214	4216538557	PROD_OIL	ACTIVE
WSSAU-0301R	4216538445	PROD_OIL	ACTIVE
WSSAU-0302R	4216538446	PROD_OIL	ACTIVE

WSSAU-0303	4216500644	PROD_OIL	ACTIVE
WSSAU-0303R	4216538447	PROD_OIL	ACTIVE
WSSAU-0304R	4216538448	PROD_OIL	ACTIVE
WSSAU-0305RW	4216538449	INJ_WAG	ACTIVE
WSSAU-0305W	4216530388	INJ_H2O	TA
WSSAU-0306RW	4216538450	INJ_WAG	ACTIVE
WSSAU-0307RW	4216538451	INJ_WAG	ACTIVE
WSSAU-0309	4216531624	INJ_WAG	ACTIVE
WSSAU-0310	4216531626	INJ_WAG	ACTIVE
WSSAU-0311RW	4216537493	INJ_WAG	ACTIVE
WSSAU-0312	4216531743	PROD_OIL	ACTIVE
WSSAU-0313	4216531744	PROD_OIL	ACTIVE
WSSAU-0314	4216531745	PROD_OIL	ACTIVE
WSSAU-0315	4216531787	INJ_H2O	INACTIVE
WSSAU-0316W	4216531786	INJ_H2O	ACTIVE
WSSAU-0317W	4216531790	INJ_H2O	INACTIVE
WSSAU-0318W	4216531788	INJ_H2O	ACTIVE
WSSAU-0319	4216531789	INJ_H2O	INACTIVE
WSSAU-0320	4216531838	PROD_OIL	ACTIVE
WSSAU-0321	4216531837	INJ_WAG	ACTIVE
WSSAU-0322	4216532404	INJ_WAG	ACTIVE
WSSAU-0323	4216532405	INJ_WAG	ACTIVE
WSSAU-0324	4216532566	INJ_WAG	ACTIVE
WSSAU-0325	4216534144	PROD_OIL	ACTIVE
WSSAU-0326	4216534203	INJ_WAG	ACTIVE
WSSAU-0327	4216538560	INJ_WAG	ACTIVE
WSSAU-0328	4216538561	INJ_WAG	ACTIVE
WSSAU-0329	4216538562	INJ_WAG	ACTIVE
WSSAU-0330	4216538563	INJ_WAG	ACTIVE
WSSAU-03WD	4216538439	DISP_H2O	ACTIVE
WSSAU-0401	4216501587	PROD_OIL	ACTIVE
WSSAU-0404	4216501590	PROD_OIL	TA
WSSAU-0405RW	4216538452	INJ_WAG	ACTIVE
WSSAU-0406	4216531978	INJ_H2O	ACTIVE
WSSAU-0407	4216531979	PROD_OIL	TA
WSSAU-0408	4216534205	INJ_H2O	ACTIVE
WSSAU-0409	4216538556	PROD_OIL	ACTIVE
WSSAU-0410	4216538550	INJ_WAG	ACTIVE

WSSAU-0411	4216538571	INJ_WAG	ACTIVE
WSSAU-0412	4216538583	INJ_WAG	ACTIVE
WSSAU-0413	4216538572	INJ_WAG	ACTIVE
WSSAU-0414	4216538573	INJ_WAG	ACTIVE
WSSAU-0415	4216538585	PROD_OIL	ACTIVE
WSSAU-0416	4216538586	PROD_OIL	ACTIVE
WSSAU-0417	4216538574	PROD_OIL	ACTIVE
WSSAU-0418	4216538580	PROD_OIL	ACTIVE
WSSAU-0419	4216538582	PROD_OIL	ACTIVE
WSSAU-0501	4216500657	PROD_GAS	TA
WSSAU-0502	4216500610	PROD_OIL	ACTIVE
WSSAU-0503W	4216500604	INJ_H2O	ACTIVE
WSSAU-0504W	4216500625	INJ_H2O	ACTIVE
WSSAU-0505	4216581090	PROD_OIL	ACTIVE
WSSAU-0507	4216532609	PROD_OIL	TA
WSSAU-0508	4216534225	INJ_H2O	ACTIVE
WSSAU-0509	4216537203	PROD_OIL	ACTIVE
WSSAU-0601	4216500663	PROD_OIL	ACTIVE
WSSAU-0602R	4216538300	PROD_OIL	ACTIVE
WSSAU-0603	4216500665	PROD_OIL	ACTIVE
WSSAU-0603R	4216538404	PROD_OIL	ACTIVE
WSSAU-0604	4216500666	PROD_OIL	TA
WSSAU-0604R	4216538299	PROD_OIL	ACTIVE
WSSAU-0605	4216500667	PROD_OIL	TA
WSSAU-0605R	4216538298	PROD_OIL	ACTIVE
WSSAU-0606	4216500629	INJ_GAS	SHUT-IN
WSSAU-0607	4216500630	PROD_OIL	ACTIVE
WSSAU-0607R	4216538405	PROD_OIL	ACTIVE
WSSAU-0608	4216500631	PROD_OIL	ACTIVE
WSSAU-0609RW	4216538403	INJ_WAG	ACTIVE
WSSAU-0609W	4216530214	INJ_H2O	ACTIVE
WSSAU-0610RW	4216538402	INJ_WAG	ACTIVE
WSSAU-0611RW	4216538401	INJ_WAG	ACTIVE
WSSAU-0611W	4216530279	INJ_H2O	ACTIVE
WSSAU-0613	4216530531	PROD_OIL	ACTIVE
WSSAU-0614	4216531632	PROD_OIL	ACTIVE
WSSAU-0615	4216531630	PROD_OIL	ACTIVE
WSSAU-0616	4216531627	INJ_WAG	ACTIVE

WSSAU-0617	4216531629	PROD_GAS	TA
WSSAU-0617RW	4216537492	INJ_WAG	ACTIVE
WSSAU-0618	4216531628	INJ_WAG	ACTIVE
WSSAU-0619	4216531836	PROD_OIL	ACTIVE
WSSAU-0620	4216531835	PROD_OIL	ACTIVE
WSSAU-0621	4216531834	INJ_H2O	ACTIVE
WSSAU-0622	4216531833	PROD_OIL	ACTIVE
WSSAU-0623	4216531832	PROD_OIL	ACTIVE
WSSAU-0624	4216531831	PROD_OIL	ACTIVE
WSSAU-0625	4216531980	PROD_OIL	ACTIVE
WSSAU-0626	4216532403	PROD_OIL	ACTIVE
WSSAU-0627	4216532402	PROD_OIL	ACTIVE
WSSAU-0701	4216500633	PROD_OIL	ACTIVE
WSSAU-0702	4216500635	PROD_OIL	ACTIVE
WSSAU-0703	4216500637	PROD_OIL	ACTIVE
WSSAU-0704	4216500613	PROD_OIL	ACTIVE
WSSAU-0705	4216500612	PROD_OIL	ACTIVE
WSSAU-0706	4216500641	PROD_OIL	TA
WSSAU-0707RW	4216538453	INJ_WAG	ACTIVE
WSSAU-0708RW	4216538454	INJ_WAG	ACTIVE
WSSAU-0708W	4216530392	INJ_H2O	ACTIVE
WSSAU-0712	4216531981	INJ_H2O	ACTIVE
WSSAU-0713	4216531982	INJ_H2O	ACTIVE
WSSAU-0714	4216532299	INJ_H2O	ACTIVE
WSSAU-0715	4216532406	PROD_OIL	TA
WSSAU-0716	4216532567	PROD_OIL	ACTIVE
WSSAU-0717	4216534023	PROD_OIL	ACTIVE
WSSAU-0801	4216500634	PROD_OIL	TA
WSSAU-0802	4216500636	PROD_OIL	ACTIVE
WSSAU-0803	4216500638	PROD_OIL	ACTIVE
WSSAU-0804W	4216500639	INJ_H2O	ACTIVE
WSSAU-0805	4216500640	PROD_OIL	ACTIVE
WSSAU-0809	4216532595	PROD_OIL	ACTIVE
WSSAU-0810	4216532612	PROD_OIL	ACTIVE
WSSAU-0811	4216538581	PROD_OIL	ACTIVE
WSSAU-0812	4216538587	PROD_OIL	ACTIVE
WSSAU-0901W	4216500498	INJ_H2O	ACTIVE
WSSAU-0902W	4216500500	INJ_H2O	ACTIVE

WSSAU-1102W	4216500632	INJ_H2O	SHUT-IN
WSSAU-1103W	4216530285	INJ_H2O	INACTIVE
WSSAU-1105	4216531401	PROD_GAS	TA
WSSAU-1106	4216537204	SUP_H2O	TA
WSSAU-1201	4216502768	PROD_OIL	ACTIVE
WSSAU-1202R	4216538406	PROD_OIL	ACTIVE
WSSAU-1203	4216502750	PROD_OIL	ACTIVE
WSSAU-1204	4216502771	PROD_OIL	ACTIVE
WSSAU-1206RW	4216538400	INJ_WAG	ACTIVE
WSSAU-1207RW	4216538399	INJ_WAG	ACTIVE
WSSAU-1207W	4216530291	INJ_H2O	INACTIVE
WSSAU-1208RW	4216538398	INJ_WAG	ACTIVE
WSSAU-1209	4216531977	INJ_H2O	ACTIVE
WSSAU-1210	4216531976	INJ_WAG	ACTIVE
WSSAU-1211	4216531983	PROD_OIL	TA
WSSAU-1211RW	4216537491	INJ_WAG	ACTIVE
WSSAU-1212	4216531985	INJ_WAG	ACTIVE
WSSAU-1213	4216531984	PROD_OIL	ACTIVE
WSSAU-1214	4216531974	PROD_OIL	ACTIVE
WSSAU-1215	4216531975	PROD_OIL	ACTIVE
WSSAU-1216	4216531986	PROD_OIL	ACTIVE
WSSAU-1302	4216500661	PROD_OIL	SHUT-IN
WSSAU-1303	4216500626	PROD_OIL	TA
WSSAU-1304	4216500627	PROD_OIL	ACTIVE
WSSAU-1305W	4216530090	INJ_H2O	SHUT-IN
WSSAU-1309	4216532298	INJ_H2O	ACTIVE
WSSAU-1310	4216532297	INJ_H2O	ACTIVE
WSSAU-1311	4216532303	INJ_H2O	ACTIVE
WSSAU-1312	4216532302	INJ_H2O	ACTIVE
WSSAU-1313	4216532301	PROD_OIL	TA
WSSAU-1315	4216532304	PROD_OIL	ACTIVE
WSSAU-1316	4216532305	PROD_OIL	ACTIVE
WSSAU-1401	4216581121	PROD_OIL	SHUT-IN
WSSAU-1402	4216500504	PROD_OIL	TA
WSSAU-1403	4216581123	PROD_OIL	ACTIVE
WSSAU-1405W	4216530401	INJ_H2O	SHUT-IN
WSSAU-1406W	4216530400	INJ_H2O	INACTIVE
WSSAU-1407	4216530508	PROD_OIL	ACTIVE

WSSAU-1408	4216530552	PROD_OIL	ACTIVE
WSSAU-1409	4216534022	PROD_OIL	ACTIVE
WSSAU-1410	4216534145	PROD_OIL	TA
WSSAU-1502	4216501300	PROD_OIL	ACTIVE
WSSAU-1503	4216500497	PROD_OIL	ACTIVE
WSSAU-1504W	4216500499	INJ_H2O	SHUT-IN
WSSAU-1505	4216530550	PROD_OIL	ACTIVE
WSSAU-1506W	4216534146	INJ_H2O	ACTIVE
WSSAU-1601W	4216501392	INJ_H2O	SHUT-IN
WSSAU-1901	4216501464	PROD_OIL	TA
WSSAU-1902W	4216501466	INJ_H2O	INACTIVE
WSSAU-1903	4216538549	PROD_OIL	TA
WSSAU-2101W	4216502546	INJ_H2O	TA
WSSAU-2102W	4216502544	INJ_H2O	TA

12.2 Regulatory References

Regulations cited in this plan:

i. Texas Administrative Code Title 16 Part 1 Chapter 3 Oil & Gas Division - https://texreg.sos.state.tx.us/public/readtac$ext.ViewTAC?tac_view=4&ti=16&pt=1&ch=3&rl=Y

ii. TRRC Injection/Disposal Well Permitting, Testing and Monitoring Manual - https://www.rrc.state.tx.us/oil-gas/publications-and-notices/manuals/injectiondisposal-well-manual/

Request for Additional Information: West Seminole San Andres Unit (WSSAU)
December 9, 2020

Instructions: Please enter responses into this table. Any long responses, references, or supplemental information may be attached to the end of the table as an appendix. Supplemental information may also be provided in a resubmitted MRV plan.

No.	MRV Plan		EPA Questions	Responses
	Section	Page		
1.	5.3	19	"Oxy also participates in the TexNet seismic monitoring network and will continue to monitor for seismic signals that could indicate the creation of potential leakage pathways in WSSAU.Previous Operations" Is the text "Previous Operations" unintentionally included in section 5.3? The initial MRV submission included a separate section (Section 5.4) for potential leakage through Previous Operations.	The term "Previous Operations" was intended as the header for Section 5.4 and the formatting code was mistakenly removed. That would add another subsection to Section 5. This has been corrected in the text and in the table of contents.
2.	Multiple	24,32	There are a number of inaccurate references to section 5.9, which appears to have been changed to section 5.8 in the latest submission. It appears that addressing Request for Additional Information No. 1 (fixing the "Previous Operations" header) would also correct this issue.	As indicated in the response to #1 above, a section number was missing. By adding it back in, the references to Section 5.9 are now correct and have not been changed.
3.	8.2	30	"The equation for calculating the Mass of CO2 Injected into the Subsurface at the WSSAU is equal to the sum of the Mass of CO2 Received as calculated in RR-3 of §98.443 (section 8.1 above)" Equation RR-3 is not included in section 8.1. Please reword the sentence or include the equation so that all the variables in the equation in section 8.2 are accounted for.	The reference in Section 8.2 has been corrected to refer to Equation RR-2 because there is only one delivery point RR-3 is not needed.
4.	8.3	31	"Equation RR-8 in §98.443 will be used to calculate the Mass of CO2 Produced from all <u>injection</u> wells as follows:" (emphasis added) Is it the intent to use equation RR-8 to calculate Mass of CO2 Produced from production wells or injection wells?	The intent is to calculate the mass from production wells and the typographical error has been corrected.

Oxy West Seminole San Andres Unit Subpart RR Monitoring, Reporting and Verification (MRV) Plan

November 6, 2020

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1. Introduction

OXY USA WTP LP, a subsidiary of Occidental (Oxy) operates a CO_2-EOR project in the West Seminole San Andres Unit (WSSAU). This MRV plan was developed in accordance with 40 CFR §98.440-449 (Subpart RR) to provide for the monitoring, reporting and verification of the quantity of CO_2 sequestered at the WSSAU during a specified period of injection.

2. Facility Information

2.1. Reporter Number

575401 – West Seminole San Andres Unit

2.2. UIC Permit Class

The Oil and Gas Division of the Texas Railroad Commission (TRRC) regulates oil and gas activity in Texas. All wells in the WSSAU (including production, injection and monitoring wells) are permitted by TRRC through Texas Administrative Code (TAC) Title 16 Chapter 3. TRRC has primacy to implement the Underground Injection Control (UIC) Class II program in the state for injection wells. All EOR injection wells in the WSSAU are currently classified as UIC Class II wells.

2.3. Existing Wells

Wells in the WSSAU are identified by name and number, API number, type and status. The list of wells as of September 2020 is included in Section 12.1. Any changes in wells will be indicated in the annual report.

3. Project Description

This project takes place in the West Seminole San Andres Unit (WSSAU), an oil field located in West Texas that was first produced more than 70 years ago. CO2 flooding was initiated in 2013 and the injection plan calls for a total of approximately 20 million tonnes of CO2 over the lifetime of the project. The field is well characterized and is suitable for secure geologic storage. Oxy uses a water alternating with gas (WAG) injection process and maintains an injection to withdrawal ratio (IWR) of at or near 1.0. A history matched reservoir simulation of the injection at WSSAU has been constructed.

3.1. Project Characteristics

The West Seminole San Andres field was discovered in 1944 and started producing in 1948. The field was unitized in 1961 and waterflood was initiated in 1969. CO2 flooding was initiated in 2013. A long-term forecast for WSSAU was developed using the reservoir modeling approaches described in Section 3.4 that includes injection of a total of approximately 20 million tonnes of CO2 over the life of the project. Figure 3-1 shows actual and projected CO2 injection, production, and stored volumes in WSSAU.

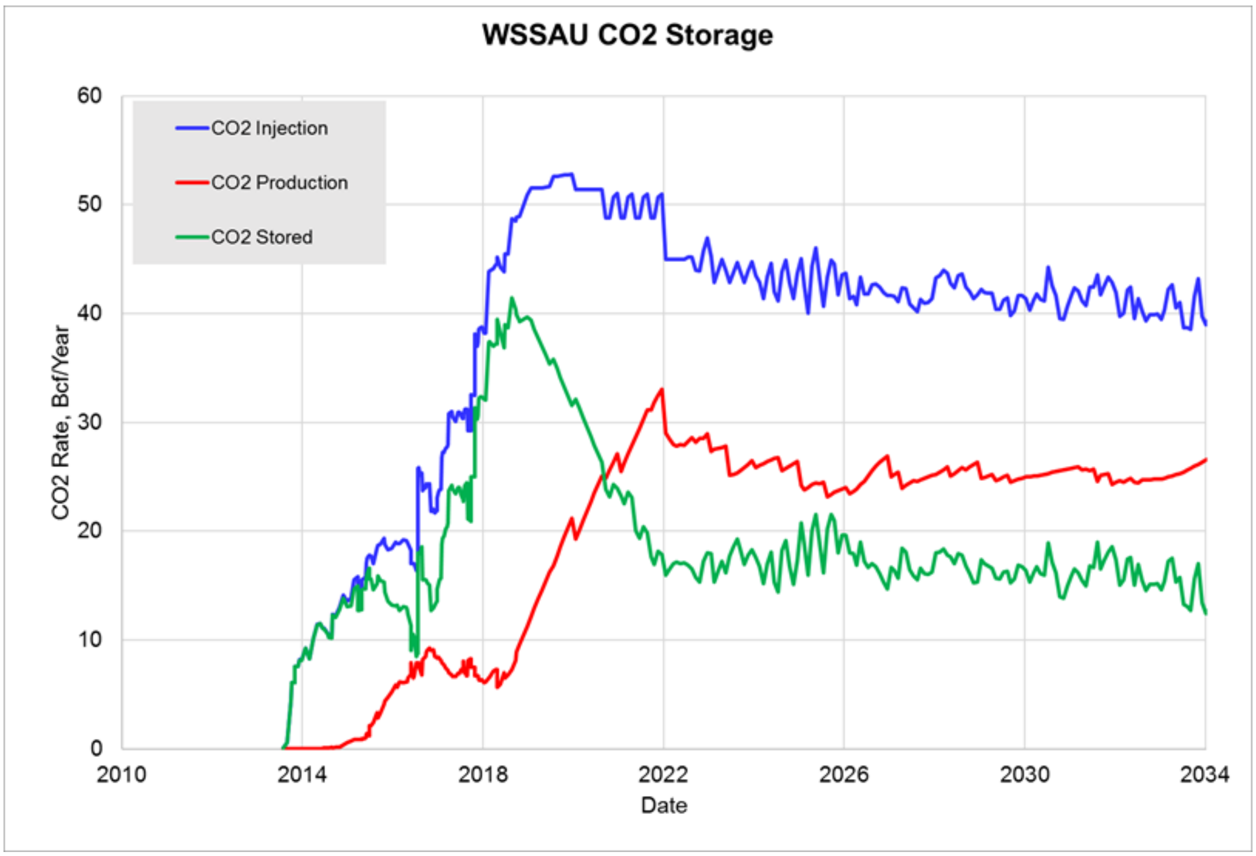

Figure 3-1 WSSAU Historic and Forecast CO2 Injection, Production, and Storage

3.2. Environmental Setting

The WSSAU is located in the NE portion of the Central Basin Platform in West Texas (See Figure 3-2).

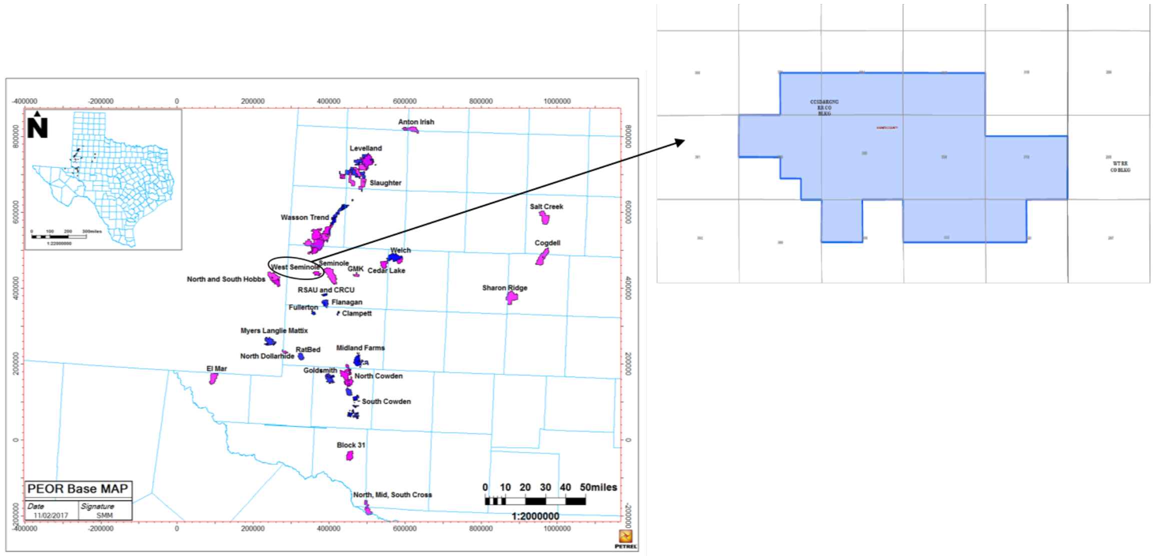

Figure 3-2 Location of WSSAU in West Texas

WSSAU produces oil from the Permian (Guadalupian) aged reservoir comprised of San Andres formation dolostone. Total thickness of the geologic unit is approximately 1500 feet, with the main reservoir within the middle 600 feet. The sequestration zone is also the oil pay completion interval, and ranges on average between 4925-5640 feet below the ground surface. See the WSSAU geologic column in Figure 3-3. The productive interval, or reservoir, is composed of layers of permeable dolomites that were deposited in a shallow marine environment during the Permian Era, some 250 to 300 million years ago.

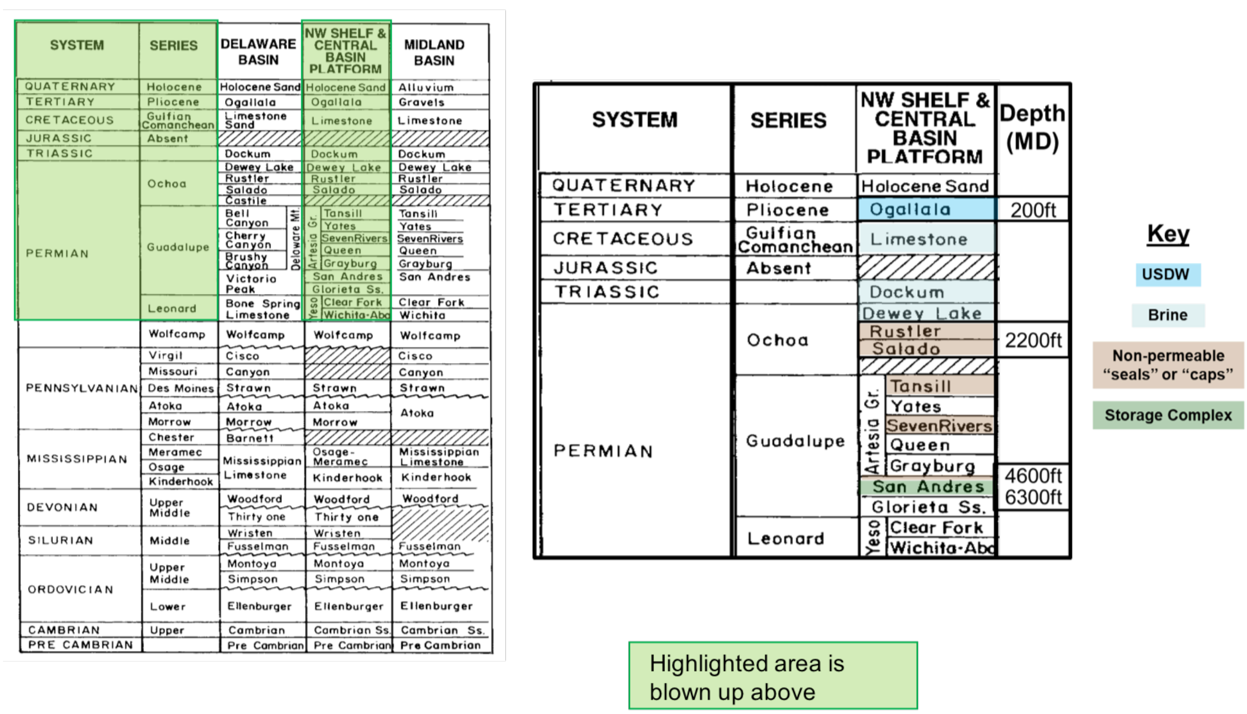

Figure 3-3 WSSAU Geologic Column

The main confining system is ~300 feet thick and is comprised of nonporous anhydrite sequences. The depth interval for the confining system ranges from top San Andres Formation to Top Pay (4545-5194 feet) with a typical range of 4660-4925 feet below ground surface. There are numerous relatively thin layers that provide additional secondary containment between the sequestration zone and freshwater aquifers. These layers are comprised of siltstones, shales, salts, and anhydrite sequences with little to no porosity or permeability.

There are no significant geologic faults or fractures identified that intersect the storage complex. There is one identified reverse fault in the Devonian interval approximately one mile below the sequestration zone. The base of sequestration zone is approximately 2175 ft. subsea depth, while the top of fault offset is interpreted to end at approximately 7500 ft. subsea depth. Fault displacement within the Devonian is approximately 200 ft. The fault is linear, subvertical, and dips toward the northeast. The presence of a gas cap is evidence of the effectiveness of the seal formed by the upper San Andres.

WSSAU is a domal structure that includes the highest elevations within the area. The elevated area forms a natural trap for oil and gas that migrated from below over millions of years. Once trapped in these high points, the oil and gas has remained in place. In the case of the WSSAU, this oil and gas has been trapped in the reservoir for 50 to 100 million years. Over time, buoyant fluids, including CO_2, rise vertically until reaching the ceiling of the dome and then migrate to the highest elevation of the structure. Figure 3-4, shows the Top San Andres pay interval structure. The colors in the structure map in Figure 3-4 indicate the subsurface elevation, with red being higher, (a shallower level) and purple being lower (a deeper level).

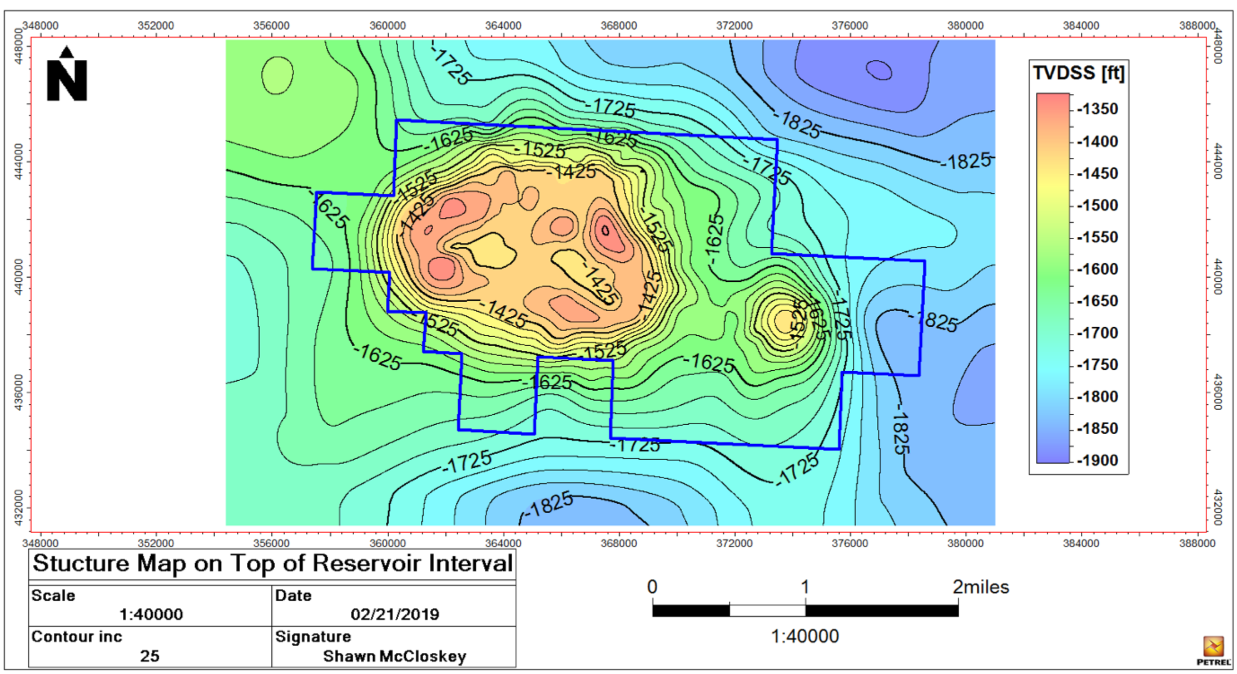

Figure 3-4 Local Area Structure on Top of San Andres

Buoyancy dominates where oil and gas are found in a reservoir. Gas, being lightest, rises to the top and water, being heavier, moves downward. Oil, being heavier than gas but lighter than water, lies in between. At the time of its discovery, natural gas was trapped at the structural high points of WSSAU, forming a "gas cap." The presence of an oil deposit and a gas cap is evidence of the effectiveness of the seal formed by the upper San Andres. Gas is buoyant and highly mobile. If it could escape WSSAU naturally, through faults or fractures, it would have done so over the millennia. Below the gas cap is an oil accumulation, the oil zone, and below that there are no distillable hydrocarbons.

Once the CO2 flood is complete and injection ceases, the remaining mobile CO2 will rise slowly upward, driven by buoyancy forces. There is more than enough pore space to sequester the planned CO2 injection. The amount of CO2 injected will not exceed the reservoir's secure storage capacity and, consequently, the risk that CO2 could migrate to other reservoirs in the Central Basin Platform is negligible. The volume of CO2 storage is based on the estimated total pore space within WSSAU. The total pore space within WSSAU, from the top of the reservoir down to the base of the oil zone, is calculated to be 1,512 million reservoir barrels (RB). This is the volume of rock multiplied by porosity. Table 3-1 below shows the conversion of this amount of pore space into an estimated maximum volume of approximately 1,770 Bcf (96 million tonnes) of CO2 storage in the reservoir. It is forecasted that at the end of EOR operations stored CO2 will fill approximately 20% of total calculated storage capacity.

Table 3-1 Calculation of Maximum Volume of CO2 Storage Capacity at WSSAU

Top of Pay to Free Water Level (2175 ft subsea)	
Variables	WSSAU Outline
Pore Volume (**RB**)	1,511,810,594
$\mathbf{B}_{CO2}$	0.45
$\mathbf{S}_{wirr}$	0.2
$\mathbf{S}_{orCO2(volume\ weighted)}$	0.273
Max CO2 (MCF)	1,770,498,185
Max CO2 (BCF)	1,770

Max CO2 = Volume (**RB**) * $(1 - \mathbf{S}_{wirr} - \mathbf{S}_{orCO2}) / \mathbf{B}_{CO2}$

Where:
CO2(max) = the maximum amount of storage capacity
Pore Volume (RB) = the volume in Reservoir Barrels of the rock formation
B_{CO2} = the formation volume factor for CO2
S_{wirr} = the irreducible water saturation
S_{orCO2} = the irreducible oil saturation

Given that WSSAU is located at the highest subsurface elevations in the area, that the confining zone has proved competent over both millions of years and current CO2 flooding, and that the WSSAU has ample storage capacity, there is confidence that stored CO2 will be contained securely within the reservoir.

3.3. Description of CO2-EOR Project Facilities and the Injection Process

Figure 3-5 shows a simplified process flow diagram of the project facilities and equipment in the WSSAU. CO2 is delivered to the WSSAU via the Permian Basin CO2 pipeline network. The CO2 is supplied by a number of different sources. Specified amounts are drawn from the Bravo pipeline based on contractual arrangements among suppliers of CO2, purchasers of CO2, and the pipeline operator.

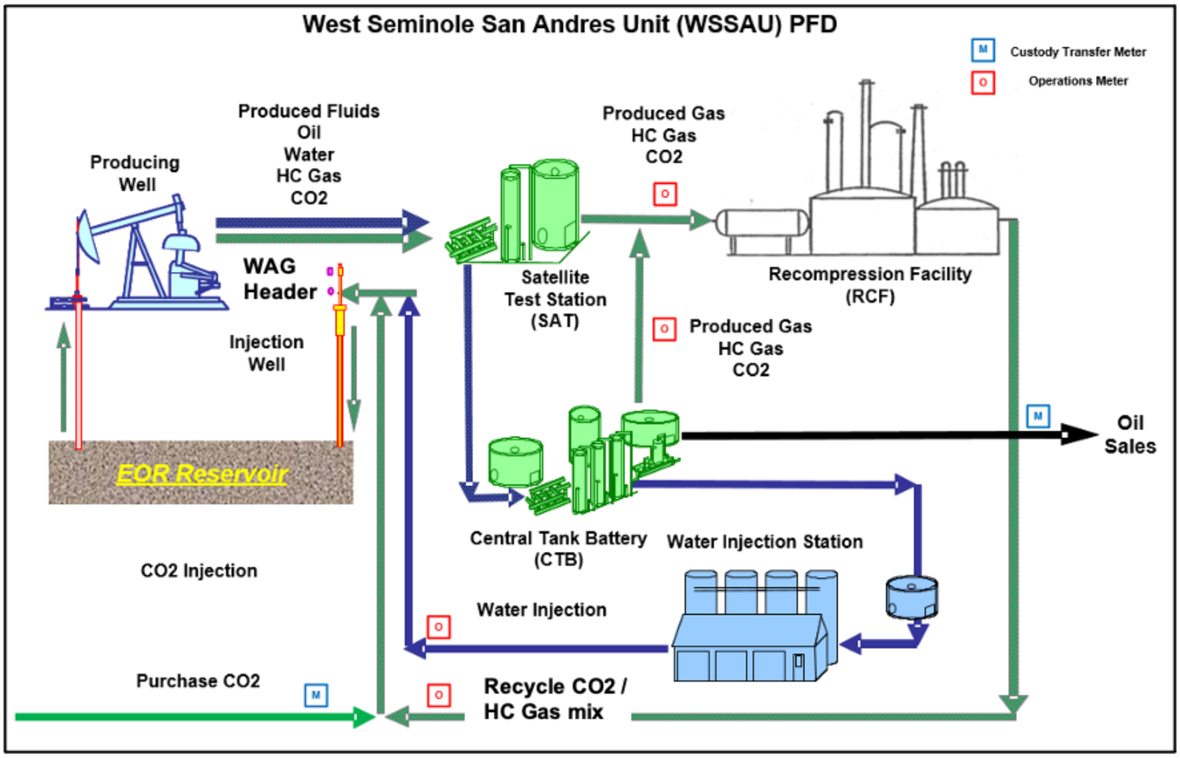

Figure 3-5 WSSAU Process Flow Diagram

Once CO2 enters WSSAU there are three main processes involved in EOR operations:

i. CO2 Distribution and Injection. The mass of CO2 received at WSSAU is metered and calculated through the Custody Transfer Meter located at the pipeline delivery point as indicated in the bottom left of Figure 3-5. The mass of CO2 received is combined with recycled CO2 / hydrocarbon gas mix from the recompression facility (RCF) and distributed to the WAG headers for injection into the injection wells according to the pre-programmed injection plan for each well pattern which alternates between water and CO2 injection. WAG headers are remotely operated and can inject either CO2 or water at various rates and injection pressures as specified in the injection plans. This is an EOR project and reservoir pressure must be maintained above minimum miscibility pressure. Therefore, injection pressure must be sufficiently high to allow injectants to enter the reservoir, but below formation parting pressure (FPP).

ii. Produced Fluids Handling. Produced fluids from the production wells are a mixture of oil, hydrocarbon gas, water, CO2 and trace amounts of other constituents in the field including nitrogen and H2S as discussed in Section 7. They are gathered and sent to satellite test stations (SAT) for separation into a gas/CO2 mix and a produced fluids mix of water, oil, gas, and CO2.

The produced gas, which is composed primarily of hydrocarbons and CO_2, is sent to the recompression facility (RCF) for dehydration and recompression before reinjection into the reservoir. An operations meter at the RCF is used to determine the total volume of produced gas that is reinjected. The separated oil is metered through the Custody Transfer Meter located at the central tank battery and sold into a pipeline.

iii. Water Treatment and Injection. Water is recovered for reuse and forwarded to the water injection station for treatment and reinjection or disposal.

3.3.1. Wells in the WSSAU

The Texas Railroad Commission (TRRC) has broad authority over oil and gas operations including primacy to implement UIC Class II wells. The rules are found in Texas Administrative Code Title 16, Part 1, Chapter 3 and are also explained in a TRRC Injection/Disposal Well Permitting, Testing and Monitoring Manual (See Appendix 12-3). TRRC rules govern well siting, construction, operation, maintenance, and closure for all wells in oilfields. Briefly, TRRC rules include the following requirements:

- Fluids must be constrained in the strata in which they are encountered;
- Activities cannot result in the pollution of subsurface or surface water;
- Wells must adhere to specified casing, cementing, drilling well control, and completion requirements designed to prevent fluids from moving from the strata they are encountered into other strata with oil and gas, or into subsurface and surface waters;
- Completion report for each well including basic electric log (e.g., a density, sonic, or resistivity (except dip meter) log run over the entire wellbore) must be prepared;
- Operators must follow plugging procedures that require advance approval from the TRRC Director and allow consideration of the suitability of the cement based on the use of the well, the location and setting of plugs; and,
- Injection well operators must identify an Area of Review (AoR), use compatible materials and equipment, test, and maintain well records.

Table 2 provides a well count by type and status. All these wells are in material compliance with TRRC rules.

Table 1 WSSAU Well Penetrations by Type and Status

TYPE	ACTIVE	Dry & Abandoned	INACTIVE	P & A*	SHUT-IN	TA**	Total
DISP_H2O	2			2			**4**
INJ_GAS					1		**1**
INJ_H2O	23		7	25	3	5	**63**
INJ_WAG	35						**35**
OBSERVATION	1					1	**2**
PROD_GAS						3	**3**
PROD_OIL	80	2	4	16		16	**118**
SUP_H2O						1	**1**
TOTAL	**141**	**2**	**11**	**43**	**4**	**26**	**227**

*P&A = Plugged and Abandoned
**TA = Temporarily Abandoned

As indicated in Figure 3-6, wells are distributed across the WSSAU. The well patterns currently undergoing CO_2 flooding are outlined in the black box and CO_2 will be injected across the entire unit over the project life.

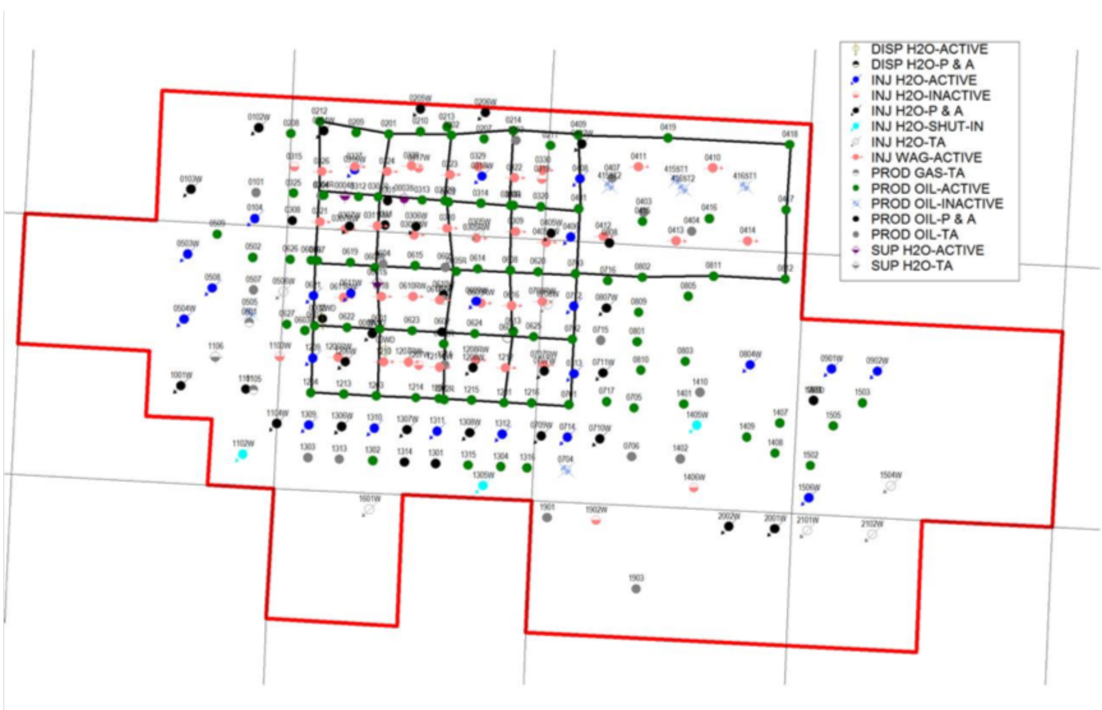

Figure 3-6 WSSAU Wells and Injection Patterns

WSSAU CO_2 EOR operations are designed to avoid conditions which could damage the reservoir and cause a potential leakage pathway. Reservoir pressure in the WSSAU is managed

by maintaining an injection to withdrawal ratio (IWR)[1] of approximately 1.0. To maintain the IWR, fluid injection and production are monitored and managed to ensure that reservoir pressure does not increase to a level that would compromise the reservoir seal or otherwise damage the integrity of the oil field.

Injection pressure is also maintained below the FPP, which is measured using step-rate tests.

3.4. Reservoir modeling

A history matched reservoir model of the current and forecast WSSAU CO2 injection has been made. The model was constructed using Eclipse software which is a commercially available reservoir simulation code. The model simulates the recovery mechanism in which CO2 is miscible with the hydrocarbon in the reservoir.

The model was created to:

i. Demonstrate that the storage complex has, at the minimum, the capacity to contain the planned volume of purchased CO2.
ii. Track injected CO2, identify how and where CO2 is trapped in the WSSAU, and to monitor sequestration volumes and distribution.

The reservoir model utilizes four types of data:

i. Site Characteristics as described in the WSSAU Geomodel,
ii. Initial reservoir conditions and fluid property data
iii. Capillary pressure data, and
iv. Well data

The geomodel used as the foundation for the reservoir model used data from 232 wells in the area of interest that includes WSSAU. These wells have digital open- or cased-hole logs that were used for correlation of formation tops. A sequence stratigraphic framework was developed based upon core descriptions and outcrop analogs, this correlation framework was then extrapolated to well logs. The sequence stratigraphic correlations are picked at the base of mud-dominated flooding surfaces mapped out in core and extrapolated to well logs throughout the rest of the field.

The model is a four-component model consisting of water, oil, reservoir gas and injected CO2. It is an extension of the black oil model that enables the modeling of recovery mechanisms in which the injected CO2 is miscible with reservoir oil. This is a reasonable assumption since the reservoir under study is above minimum miscibility pressure (MMP). The total hydrocarbon and solvent (CO2) saturation is used to calculate relative permeability to water. The solvent and oil relative permeability are then calculated using multipliers from a look-up table. The Todd-

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[1] Injection to withdrawal ratio (IWR) is the ratio of the volume of fluids injected to the volume of fluids produced (withdrawn). Volumes are measured under reservoir conditions for all fluids. By keeping IWR close to 1.0, reservoir pressure is held constant, neither increasing nor decreasing.

Longstaff[2] model is used to calculate the effective viscosity and density of the hydrocarbon and solvent phases.

History matching is the process of adjusting input parameters within the range of data uncertainties until the actual reservoir performance is closely reproduced in the model. A 70-year history match was obtained. All three-phase rates (oil, gas, and water) are included in the history record. The model uses liquid rate control (combination of oil and water) for the history match.

The graphs in Figure 3-7 present the history match results of oil rate, gas rates, water rates, and water cut and show that the reservoir model provides an excellent match to actual historic data. Figure 3-8 shows the match of water and CO2 injection.

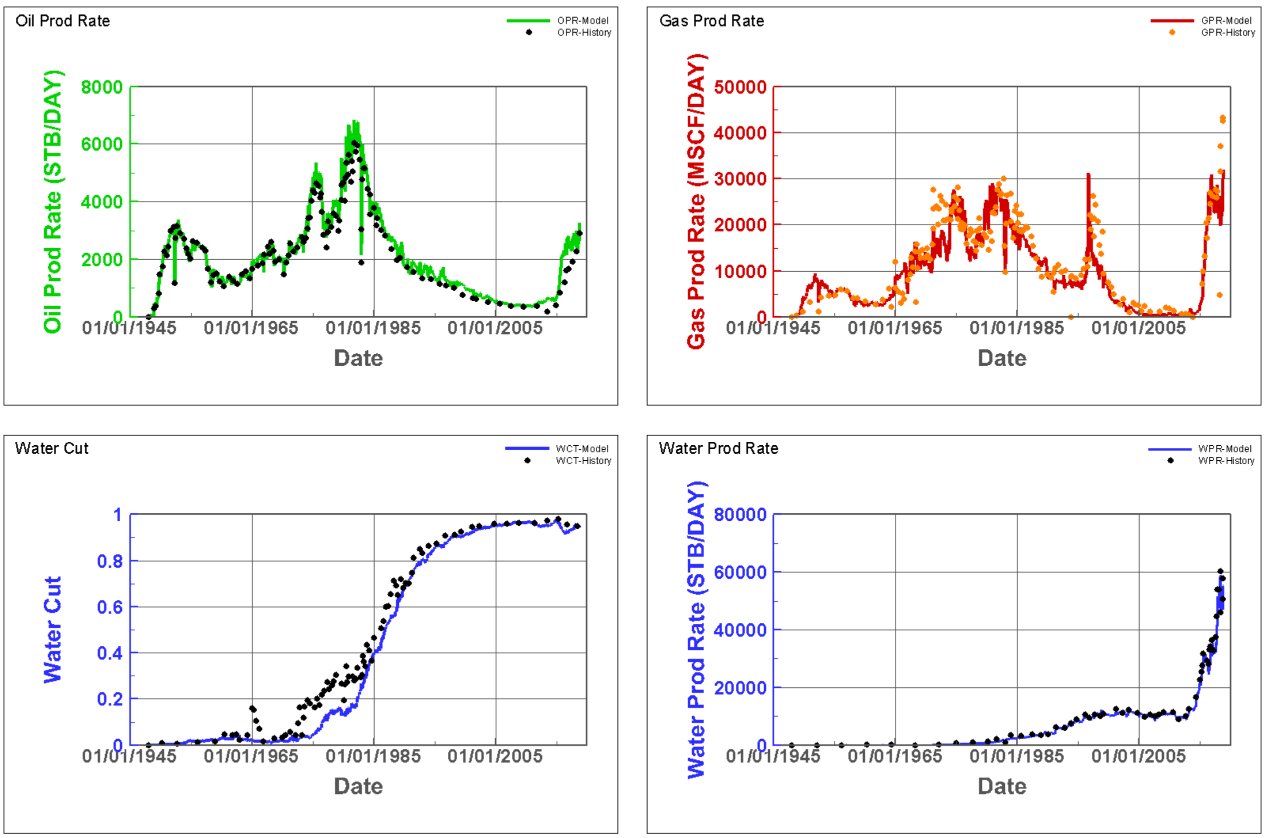

Figure 3-7 Four Parameters of History-Matched Modeling in the WSSAU Reservoir Model

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[2] Todd, M.R., Longstaff, W.J.: The development, testing and application of a numerical simulator for predicting miscible flood performance. J. Petrol. Tech. 24(7), 874–882 (1972)

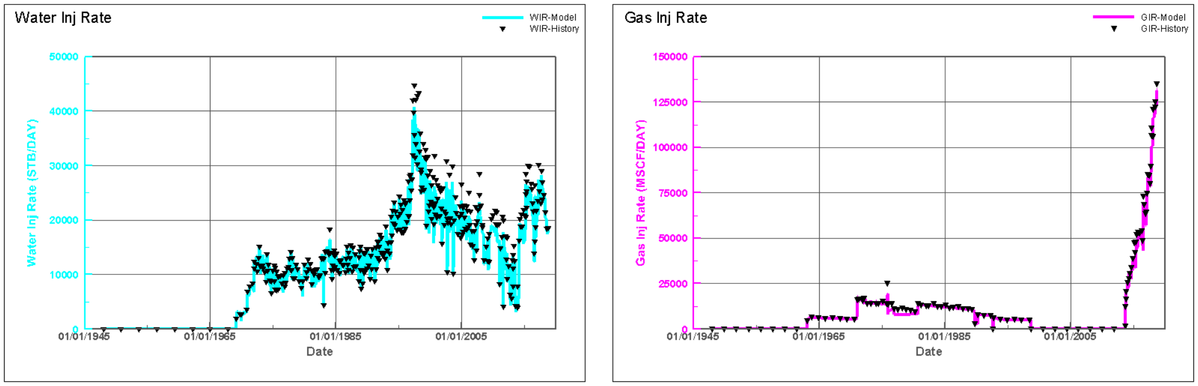

Figure 3-8 Plots of Injection History Match in the WSSAU Reservoir Model

The WSSAU reservoir model was used to evaluate the plume of CO2 using a set of injection, production, and facilities constraints that describe the injection plan. The history match indicates that the model is robust and that there is little chance that uncertainty about any specific variable will have a meaningful impact on the reservoir CO2 storage performance. The model forecast showed that CO2 is contained in the reservoir within the boundaries of WSSAU.

4. Delineation of Monitoring Area and Timeframes

4.1. Active Monitoring Area

The Active Monitoring Area (AMA) is defined by the boundary of the WSSAU plus the required ½ mile buffer.

4.2. Maximum Monitoring Area

The Maximum Monitoring Area (MMA) is defined by the boundary of the WSSAU plus the required ½ mile buffer as required by 40 CFR §98.440-449 (Subpart RR).

4.3. Monitoring Timeframes

The primary purpose for injecting CO2 is to produce oil that would otherwise remain trapped in the reservoir and not, as in UIC Class VI, "specifically for the purpose of geologic storage."[3] During a Specified Period, there will be a subsidiary purpose of establishing the long-term containment of CO2 in the WSSAU. The Specified Period will be shorter than the period of production from the WSSAU.

At the conclusion of the Specified Period, a request for discontinuation of reporting will be submitted. This request will be submitted with a demonstration that current monitoring and model(s) show that the cumulative mass of CO2 reported as sequestered during the Specified Period is not expected to migrate in the future in a manner likely to result in surface leakage. It is expected that it will be possible to make this demonstration almost immediately after the Specified Period ends based upon predictive modeling supported by monitoring data.

The reservoir pressure in the WSSAU is collected for use reservoir modeling and operations management. Reservoir pressure is not forecast to change appreciably since the IWR will be maintained at approximately 1.0. The reservoir model shows that by the end of CO2 injection, average reservoir pressure will be approximately 2,360 psi. Once injection ceases, reservoir pressure is predicted to stabilize within one year. Over time, reservoir pressure is expected to drop by approximately 10 psi. The trend of the reservoir pressure decline will be one of the bases of a request to discontinue monitoring and reporting.

[3] EPA UIC Class VI rule, EPA 75 FR 77291, December 10, 2010, section 146.81(b).

5. Evaluation of Potential Pathways for Leakage to the Surface, Leakage Detection, Verification, and Quantification

In the roughly 70 years since the oil field of the WSSAU was discovered, the reservoir has been studied and documented extensively. Based on the knowledge gained from that experience, this section assesses the potential pathways for leakage of stored CO2 to the surface including:

i. Existing Well Bores
ii. Faults and Fractures
iii. Natural and Induced Seismic Activity
iv. Previous Operations
v. Pipeline/Surface Equipment
vi. Lateral Migration Outside the WSSAU
vii. Drilling Through the CO2 Area
viii. Diffuse Leakage Through the Seal

This analysis shows that leakage through wellbores and surface equipment pose the only meaningful potential leakage pathways. The monitoring program to detect and quantify leakage is based on this assessment as discussed below.

5.1. Existing Wellbores

As part of the TRRC requirement to initiate CO2 flooding, an extensive review of all WSSAU penetrations was completed to determine the need for corrective action. That analysis showed that all penetrations have either been adequately plugged and abandoned or, if in use, do not require corrective action. All wells in the WSSAU were constructed and are operated in compliance with TRRC rules.

As part of routine risk management, the potential risk of leakage associated with the following were identified and evaluated:

i. CO2 flood beam wells
ii. Electrical submersible pump (ESP) producer wells, and
iii. CO2 WAG injector wells.

The risk assessment classified all risks associated with subsurface as low risk, i.e., less than 1% likelihood to occur and having a consequence that is insubstantial. The risks were classified as low risk because, the WSSAU geology is well suited to CO2 sequestration with an extensive confining zone that is free of fractures and faults that could be potential conduits for CO2 migration. The low risk is supported by the results of the reservoir model which shows that stored CO2 is not predicted to leave the WSSAU boundary. Any risks are further mitigated because the WSSAU is operated in a manner that maintains, monitors, and documents the integrity of the reservoir.

The risk of well leakage is mitigated through:

i. Adhering to regulatory requirements for well drilling and testing;
ii. implementing best practices that Oxy has developed through its extensive operating experience;

iii. monitoring injection/production performance, wellbores, and the surface; and,
iv. maintaining surface equipment.

Continual and routine monitoring of the wellbores and site operations will be used to detect leaks or other potential well problems, as follows:

- Pressure in injection wells is monitored on a continual basis. The injection plans for each pattern are programmed into the injection WAG satellite to govern the rate, pressure, and duration of either water or CO2 injection. Pressure monitors on the injection wells are programmed to flag whenever statistically significant pressure deviations from the targeted ranges in the plan are identified. Leakage on the inside or outside of the injection wellbore would affect pressure and be detected through this approach. If such events occur, they are investigated and addressed. Oxy's experience, from over 40 years of operating CO2 EOR projects, is that such leakage is very rare and there have been no incidents of fluid migration out of the intended zone at WSSAU.

- Production well performance is monitored using the production well test process conducted when produced fluids are gathered and sent to an SAT. There is a routine well testing cycle for each SAT, with each well being tested approximately once every two months. During this cycle, each production well is diverted to the well test equipment for a period of time sufficient to measure and sample produced fluids (generally 8-12 hours). These tests are the basis for allocating a portion of the produced fluids measured at the SAT to each production well, assessing the composition of produced fluids by location, and assessing the performance of each well. Performance data are reviewed on a routine basis to ensure that CO2 flooding efficiency is optimized. If production is off the plan, it is investigated and any identified issues addressed. Leakage to the outside of production wells is not considered a major risk because of the reduced pressure in the casing. Further, the personal H2S monitors are designed to detect leaked fluids around production wells during well inspections.

- Field inspections are conducted on a routine basis by field personnel. Leaking CO2 is very cold and leads to formation of bright white clouds and ice that are easily spotted. All field personnel are trained to identify leaking CO2 and other potential problems at wellbores and in the field. Any CO2 leakage detected will be documented and reported and quantified.

Based on ongoing monitoring activities and review of the potential leakage risks posed by well bores, it is concluded that the risk of CO2 leakage through well bores is being mitigated by detecting problems as they arise and quantifying any leakage that does occur.

5.2. Faults and Fractures

After reviewing geologic, seismic, operating, and other evidence, it has been concluded that there are no known faults or fractures that transect the San Andres reservoir in the project area. As a result, there is no risk of leakage due to fractures or faults.

Measurements to determine FPP and reservoir pressure are routinely updated. This information is used to manage injection patterns so that the injection pressure will not exceed FPP. An IWR at or near 1 is also maintained. Both of these measures mitigate the potential for inducing faults or fractures. As a safeguard, WAG skids are continuously monitored and set with automatic shutoff controls if injection pressures exceed programmed levels.

5.3. Natural or Induced Seismicity

After reviewing the literature and actual operating experience, it is concluded that there is no direct evidence that natural seismic activity poses a significant risk for loss of CO2 to the surface in the Permian Basin, and specifically in the WSSAU.

To evaluate this potential risk at WSSAU, Oxy has reviewed the nature and location of seismic events in West Texas. Some of the recorded earthquakes in West Texas are far removed from any injection operation. These are judged to be from natural causes. Others are near oil fields or water disposal wells and are placed in the category of "quakes in close association with human enterprise."[4] A review of the USGS database of recorded earthquakes at M3.0 or greater in the Permian Basin indicates that none have occurred in the West Seminole Field; the closest took place in 1992 approximately 35 miles away. The concern about induced seismicity is that it could lead to fractures in the seal providing a pathway for CO2 leakage to the surface. Oxy is not aware of any reported loss of injectant (brine water or CO2) to the surface associated with any seismic activity. There is no direct evidence to suggest that natural seismic activity poses a significant risk for loss of CO2 to the surface in the Permian Basin, and specifically in the WSSAU. If induced seismicity resulted in a pathway for material amounts of CO2 to migrate from the injection zone, other reservoir fluid monitoring provisions (e.g., reservoir pressure, well pressure, and pattern monitoring) would detect the migration and lead to further investigation. Oxy also participates in the TexNet seismic monitoring network[5] and will continue to monitor for seismic signals that could indicate the creation of potential leakage pathways in WSSAU.Previous Operations

CO2 flooding was initiated in WSSAU in 2013. To obtain permits for CO2 flooding, the AoR around all CO2 injector wells was evaluated to determine if there were any unknown penetrations and to assess if corrective action was required at any wells. As indicated in Section 5.1, this evaluation reviewed the identified penetrations and determined that no additional corrective action was needed. Further, Oxy's standard practice for drilling new wells includes a rigorous review of nearby wells to ensure that drilling will not cause damage to or interfere with existing wells. And, requirements to construct wells with materials that are designed for CO2 injection are adhered to at WSSAU. These practices ensure that that there are no unknown wells within WSSAU and that the risk of migration from older wells has been sufficiently mitigated. The successful experience with CO2 flooding in WSSAU demonstrates that the confining zone has not been impaired by previous operations.

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[4] Frohlich, Cliff (2012) "Induced or Triggered Earthquakes in Texas: Assessment of Current Knowledge and Suggestions for Future Research", Final Technical Report, Institute for Geophysics, University of Texas at Austin, Office of Sponsored Research.

[5] https://www.beg.utexas.edu/texnet-cisr/texnet

5.4. Pipelines and Surface Equipment

As part of routine risk management described in Section 5, the potential risk of leakage associated with the following are identified and evaluated:

i. The production satellite
ii. The Central Tank Battery; and
iii. Facility pipelines.

As described in Section 5.1, the risk assessment classified all subsurface risks as low risk, i.e., less than 1% likelihood to occur and having a consequence that is insubstantial. The risks associated with pipelines and surface equipment were classified as low risk because, the WSSAU is operated in a manner that maintains, monitors, and documents the integrity of the reservoir.

The risk of well leakage is mitigated through:

i. Adhering to regulatory requirements for well drilling and testing;
ii. implementing best practices that Oxy has developed through its extensive operating experience;
iii. monitoring injection/production performance, wellbores, and the surface; and,
iv. maintaining surface equipment.

Personnel continuously monitor the pipeline system using the SCADA system and are able to detect and mitigate pipeline leaks expeditiously. Such risks will be prevented, to the extent possible, by relying on the use of prevailing design and construction practices and maintaining compliance with applicable regulations. The facilities and pipelines currently utilize and will continue to utilize materials of construction and control processes that are standard for CO2 EOR projects in the oil and gas industry. Operating and maintenance practices currently follow and will continue to follow demonstrated industry standards. CO2 delivery via the Permian Basin CO2 pipeline system will continue to comply with all applicable regulations. Finally, routine visual inspection of surface facilities by field staff will provide an additional way to detect leaks and further support the efforts to detect and remedy any leaks in a timely manner. Should leakage be detected from pipeline or surface equipment, the volume of released CO2 will be quantified following the requirements of Subpart W of EPA's GHGRP.

5.5. Lateral Migration Outside the WSSAU

It is highly unlikely that injected CO2 will migrate downdip and laterally outside the WSSAU because of the nature of the geology and the approach used for injection. First, WSSAU is situated in the highest local elevations within the San Andres. This means that over long periods of time, injected CO2 will tend to rise vertically towards the Upper San Andres and continue towards the point in the WSSAU with the highest elevation. Second, the planned injection volumes and active fluid management during injection operations will prevent CO2 from migrating laterally out of the structure. Finally, the total volume of fluids contained in the WSSAU will stay relatively constant. Based on site characterization and planned and projected operations it is estimated that the total volume of stored CO2 will be considerably less than calculated capacity.

5.6. Drilling in the WSSAU

The TRRC regulates well drilling activity in Texas. Pursuant to TRRC rules, wells casing shall be securely anchored in the hole in order to effectively control the well at all times, all usable-quality water zones shall be isolated and sealed off to effectively prevent contamination or harm, and all productive zones, potential flow zones, and zones with corrosive formation fluids shall be isolated and sealed off to prevent vertical migration of fluids, including gases, behind the casing. Where TRRC rules do not detail specific methods to achieve these objectives, operators shall make every effort to follow the intent of the section, using good engineering practices and the best currently available technology. The TRRC requires applications and approvals before a well is drilled, recompleted, or reentered. Well drilling activity at WSSAU is conducted in accordance with TRRC rules. Oxy's visual inspection process, including routine site visits, will identify unapproved drilling activity in the WSSAU.

In addition, Oxy intends to operate WSSAU for several more decades and will continue to be vigilant about protecting the integrity of its assets and maximizing the potential of its resources, including oil, gas and CO2. Consequently, the risks associated with third parties penetrating the WSSAU are negligible.

5.7. Diffuse Leakage Through the Seal

Diffuse leakage through the seal formed by the upper San Andres is highly unlikely. The presence of a gas cap trapped over millions of years confirms that the seal has been secure. Injection pattern monitoring assures that no breach of the seal will be created. Wellbores that penetrate the seal make use of cement and steel construction that is closely regulated to ensure that no leakage takes place. Injection pressure is continuously monitored and unexplained changes in injection pressure that might indicate leakage would trigger investigation as to the cause.

5.8. Leakage Detection, Verification, and Quantification

As discussed above, the potential sources of leakage include issues, such as problems with surface equipment (pumps, valves, etc.) or subsurface equipment (well bores), and unique events such as induced fractures. An event-driven process to assess, address, track, and if applicable quantify potential CO2 leakage is used. Table 3 summarizes some of these potential leakage scenarios, the monitoring activities designed to detect those leaks, the standard response, and other applicable regulatory programs requiring similar reporting.

Given the uncertainty concerning the nature and characteristics of any leaks that may be encountered, the most appropriate methods for quantifying the volume of leaked CO2 will be determined on a case by case basis. In the event leakage occurs, the most appropriate methods for quantifying the volume leaked will be determined and it will be reported as required as part of the annual Subpart RR submission.

Any volume of CO2 detected leaking to surface will be quantified using acceptable emission factors such as those found in 40 CFR Part 98 Subpart W or engineering estimates of leak amounts based on measurements in the subsurface, field experience, and other factors such as the frequency of inspection. Leaks will be documented, evaluated and addressed in a timely manner.

Records of leakage events will be retained in the electronic environmental documentation and reporting system. Repairs requiring a work order will be documented in the electronic equipment maintenance system.

Table 2 Response Plan for CO2 Loss

Risk	Monitoring Plan	Response Plan
Tubing Leak	Monitor changes in tubing and annulus pressure; MIT for injectors	Wellbore is shut in and workover crews respond within days
Casing Leak	Routine Field inspection; Monitor changes in annulus pressure, MIT for injectors; extra attention to high risk wells	Well is shut in and workover crews respond within days
Wellhead Leak	Routine Field inspection, SCADA system monitors wellhead pressure	Well is shut in and workover crews respond within days
Loss of Bottom-hole pressure control	Blowout during well operations	Maintain well kill procedures
Unplanned wells drilled through San Andres	Routine Field inspection to prevent unapproved drilling; compliance with TRRC permitting for planned wells.	Assure compliance with TRRC regulations
Loss of seal in abandoned wells	Reservoir pressure in WAG headers; high pressure found in new wells	Re-enter and reseal abandoned wells
Pumps, valves, etc.	Routine Field inspection, SCADA	Workover crews respond within days
Overfill beyond spill points	Reservoir pressure in WAG headers; high pressure found in new wells	Fluid management along lease lines
Leakage through induced fractures	Reservoir pressure in WAG headers; high pressure found in new wells	Comply with rules for keeping pressures below parting pressure
Leakage due to seismic event	Reservoir pressure in WAG headers; high pressure found in new wells	Shut in injectors near seismic event

5.9. Summary

The structure and stratigraphy of the San Andres reservoir in the WSSAU is ideally suited for the injection and storage of CO2. The stratigraphy within the CO2 injection zones is porous, permeable and thick, providing ample capacity for long-term CO2 storage. The reservoir is overlain by several intervals of impermeable geologic zones that form effective seals or "caps" to fluids in the reservoir. After assessing potential risk of release from the subsurface and steps that have been taken to prevent leaks, it has been determined that the potential threat of leakage is extremely low.

In summary, based on a careful assessment of the potential risk of release of CO2 from the subsurface, it has been determined that there are no leakage pathways at the WSSAU that are likely to result in significant loss of CO2 to the atmosphere. Further, given the detailed knowledge of the field and its operating protocols, it is concluded that any CO2 leakage to the surface that could arise through either identified or unexpected leakage pathways would be detected and quantified.

6. Monitoring and Considerations for Calculating Site Specific Variables

Monitoring will also be used to determine the quantities in the mass balance equation and to make the demonstration that the CO2 plume will not migrate to the surface after the time of discontinuation.

6.1. For the Mass Balance Equation

6.1.1. General Monitoring Procedures

Flow rate, pressure, and gas composition data are monitored and collected from the WSSAU in centralized data management systems as part of ongoing operations. These data are monitored by qualified technicians who follow response and reporting protocols when the systems deliver notifications that data exceed statistically acceptable boundaries.

Metering protocols used at WSSAU follow the prevailing industry standard(s) for custody transfer as currently promulgated by the API, the American Gas Association (AGA), and the Gas Processors Association (GPA), as appropriate. This approach is consistent with EPA GHGRP's Subpart RR, section 98.444(e)(3). These meters will be maintained routinely, operated continually, and will feed data directly to the centralized data collection systems. The meters meet the industry standard for custody transfer meter accuracy and calibration frequency.

6.1.2. CO2 Received

As indicated in Figure 3-5, the volume of received CO2 is measured using a commercial custody transfer meter at the point at which custody of the CO2 from the Permian Basin CO2 pipeline delivery system is transferred to the WSSAU. This meter measures flow rate continually. The transfer is a commercial transaction that is documented. CO2 composition is governed by contract and the gas is routinely sampled. Fluid composition will be determined, at a minimum, quarterly, consistent with EPA GHGRP's Subpart RR, section 98.447(a). All meter and composition data are documented, and records will be retained for at least three years. No CO2 is received in containers.

6.1.3. CO2 Injected in the Subsurface

Injected CO2 will be calculated using the flow meter volumes at the operations meter at the outlet of the RCF and the custody transfer meter at the CO2 off-take point from the Permian Basin CO2 pipeline delivery system

6.1.4. CO2 Produced, Entrained in Products, and Recycled

The following measurements are used for the mass balance equations in Section 7:

CO2 produced in the gaseous stage is calculated using the volumetric flow meters at the inlet to the RCF.

CO2 that is entrained in produced oil, as indicated in Figure 3-5, is calculated using volumetric flow through the custody transfer meter.

Recycled CO_2 is calculated using the volumetric flow meter at the outlet of the RCF, which is an operations meter.

6.1.5. CO_2 Emitted by Surface Leakage

Oxy uses 40 CFR Part 98 Subpart W to estimate surface leaks from equipment at the WSSAU. Subpart W uses a factor-driven approach to estimate equipment leakage. In addition, an event-driven process to assess, address, track, and if applicable quantify potential CO_2 leakage to the surface is used. The Subpart W report and results from any event-driven quantification will be reconciled to assure that surface leaks are not double counted.

The multi-layered, risk-based monitoring program for event-driven incidents has been designed to meet two objectives: 1) to detect problems before CO_2 leaks to the surface; and 2) to detect and quantify any leaks that do occur. This section discusses how this monitoring will be conducted and used to quantify the volumes of CO_2 leaked to the surface.

Monitoring for potential Leakage from the Injection/Production Zone:
In addition to the measures discussed in Section 5.9, both injection into and production from the reservoir will be monitored as a means of early identification of potential anomalies that could indicate leakage from the subsurface.

Reservoir simulation modeling, based on extensive history-matched data, is used to develop injection plans (fluid rate, pressure, volume) that are programmed into each WAG satellite. If injection pressure or rate measurements are outside the specified set points determined as part of each pattern injection plan, a data flag is automatically triggered and field personnel will investigate and resolve the problem. These excursions will be reviewed by well management personnel to determine if CO_2 leakage may be occurring. Excursions are not necessarily indicators of leaks; they simply indicate that injection rates and pressures are not conforming to the pattern injection plan. In many cases, problems are straightforward to fix (e.g., a meter needs to be recalibrated or some other minor action is required), and there is no threat of CO_2 leakage. In the case of issues that are not readily resolved, more detailed investigation and response would be initiated, and support staff would provide additional assistance and evaluation. Such issues would lead to the development of a work order in the work order management system. This record enables the tracking of progress on investigating potential leaks and, if a leak has occurred, to quantify its magnitude.

Likewise, a forecast of the rate and composition of produced fluids is developed. Each producer well is assigned to a specific SAT and is isolated during each cycle for a well production test. This data is reviewed on a periodic basis to confirm that production is at the level forecasted. If there is a significant deviation from the plan, well management personnel investigate. If the issue cannot be resolved quickly, more detailed investigation and response would be initiated. As in the case of the injection pattern monitoring, if the investigation leads to a work order in the work order management system, this record will provide the basis for tracking the outcome of the investigation and if a leak has occurred, recording the quantity leaked to the surface. If leakage in the flood zone were detected, an appropriate method would be used to quantify the involved volume of CO_2. This might include use of material balance equations based on known

injected quantities and monitored pressures in the injection zone to estimate the volume of CO2 involved.

A subsurface leak might not lead to a surface leak. In the event of a subsurface leak, Oxy would determine the appropriate approach for tracking subsurface leakage to determine and quantify leakage to the surface. To quantify leakage, the relevant parameters (e.g., the rate, concentration, and duration of leakage) would be estimated to quantify the leak volume. Depending on specific circumstances, these determinations may rely on engineering estimates.

In the event leakage from the subsurface occurred diffusely through the seals, the leaked gas would include H2S, which would trigger the alarm on the personal monitors worn by field personnel. Such a diffuse leak from the subsurface has not occurred in the WSSAU. In the event such a leak was detected, personnel would determine how to address the problem. The personnel might use modeling, engineering estimates, and direct measurements to assess, address, and quantify the leakage.

Monitoring of Wellbores:
WSSAU wells are monitored through continual, automated pressure monitoring of the injection zone, monitoring of the annular pressure in wellheads, and routine maintenance and inspection.

Leaks from wellbores would be detected through the follow-up investigation of pressure anomalies, visual inspection, or the use of personal H2S monitors.

Anomalies in injection zone pressure may not indicate a leak, as discussed above. However, if an investigation leads to a work order, field personnel would inspect the equipment in question and determine the nature of the problem. If it is a simple matter, the repair would be made and the volume of leaked CO2 would be included in the 40 CFR Part 98 Subpart W report for the WSSAU. If more extensive repair were needed, the appropriate approach for quantifying leaked CO2 using the relevant parameters (e.g., the rate, concentration, and duration of leakage) would be determined. The work order would serve as the basis for tracking the event for GHG reporting.

Anomalies in annular pressure or other issues detected during routine maintenance inspections would be treated in the same way. Field personnel would inspect the equipment in question and determine the nature of the problem. For simple matters the repair would be made at the time of inspection and the volume of leaked CO2 would be included in the 40 CFR Part 98 Subpart W report for the WSSAU. If more extensive repairs were needed, the well would be shut in, a work order would be generated and the appropriate approach for quantifying leaked CO2 using the relevant parameters (e.g., the rate, concentration, and duration of leakage) would be determined. The work order would serve as the basis for tracking the event for GHG reporting.

Because leaking CO2 at the surface is very cold and leads to formation of bright white clouds and ice that are easily spotted, a visual inspection process in the area of the WSSAU is employed to detect unexpected releases from wellbores. Field personnel visit the surface facilities on a routine basis. Inspections may include tank levels, equipment status, lube oil levels, pressures and flow rates in the facility, and valves. Field personnel also check that injectors are on the proper WAG schedule and observe the facility for visible CO2 or fluid line leaks.

Finally, the data collected by the H2S monitors, which are worn by all field personnel at all times, is used as a last method to detect leakage from wellbores. The H2S monitors detection limit is 10 ppm; if an H2S alarm is triggered, the first response is to protect the safety of the personnel, and the next step is to safely investigate the source of the alarm. As noted previously, H2S is considered a proxy for potential CO2 leaks in the field. Thus, detected H_2S leaks will be investigated to determine and, if needed, quantify potential CO2 leakage. If the incident results in a work order, this will serve as the basis for tracking the event for GHG reporting.

Other Potential Leakage at the Surface:

The same visual inspection process and H2S monitoring system will be used to detect other potential leakage at the surface as it does for leakage from wellbores. Routine visual inspections are used to detect significant loss of CO2 to the surface. Field personnel routinely visit surface facilities to conduct a visual inspection. Inspections may include review of tank level, equipment status, lube oil levels, pressures and flow rates in the facility, valves, ensuring that injectors are on the proper WAG schedule, and also conducting a general observation of the facility for visible CO2 or fluid line leaks. If problems are detected, field personnel would investigate, and, if maintenance is required, generate a work order in the maintenance system, which is tracked through completion. In addition to these visual inspections, the results of the personal H2S monitors worn by field personnel will be used as a supplement for smaller leaks that may escape visual detection.

If CO2 leakage to the surface is detected, it will be reported to surface operations personnel who will review the reports and conduct a site investigation. If maintenance is required, steps are taken to prevent further leaks, a work order will be generated in the work order management system. The work order will describe the appropriate corrective action and be used to track completion of the maintenance action. The work order will also serve as the basis for tracking the event for GHG reporting and quantifying any CO2 emissions.

6.1.6. CO2 emitted from equipment leaks and vented emissions of CO2 from surface equipment located between the injection flow meter and the injection wellhead

Oxy evaluates and estimates leaks from equipment, the CO2 content of produced oil, and vented CO2, as required under 40 CFR Part 98 Subpart W.

6.1.7. CO2 emitted from equipment leaks and vented emissions of CO2 from surface equipment located between the production flow meter and the production wellhead

Oxy evaluates and estimates leaks from equipment, the CO2 content of produced oil, and vented CO2, as required under 40 CFR Part 98 Subpart W.

6.2. To Demonstrate that Injected CO2 is not Expected to Migrate to the Surface

At the end of the Specified Period, injecting CO2 for the subsidiary purpose of establishing the long-term storage of CO2 in the WSSAU will cease. Some time after the end of the Specified

Period, a request to discontinue monitoring and reporting will be submitted. The request will demonstrate that the amount of CO_2 reported under 40 CFR §98.440-449 (Subpart RR) is not expected to migrate in the future in a manner likely to result in surface leakage. At that time, the request will be supported with years of data collected during the Specified Period as well as two to three (or more, if needed) years of data collected after the end of the Specified Period. This demonstration will provide the information necessary for the EPA Administrator to approve the request to discontinue monitoring and reporting and may include, but is not limited to:

i. Data comparing actual performance to predicted performance (purchase, injection, production) over the monitoring period;
ii. An assessment of the CO_2 leakage detected, including discussion of the estimated amount of CO_2 leaked and the distribution of emissions by leakage pathway;
iii. A demonstration that future operations will not release the volume of stored CO_2 to the surface;
iv. A demonstration that there has been no significant leakage of CO_2; and,
v. An evaluation of reservoir pressure that demonstrates that injected fluids are not expected to migrate in a manner to create a potential leakage pathway.

7. Determination of Baselines

Existing automatic data systems will be utilized to identify and investigate excursions from expected performance that could indicate CO_2 leakage. Data systems are used primarily for operational control and monitoring and as such are set to capture more information than is necessary for reporting in the Annual Subpart RR Report. The necessary system guidelines to capture the information that is relevant to identify possible CO_2 leakage will be developed. The following describes the approach to collecting this information.

<u>Visual Inspections</u>

As field personnel conduct routine inspections, work orders are generated in the electronic system for maintenance activities that cannot be addressed on the spot. Methods to capture work orders that involve activities that could potentially involve CO_2 leakage will be developed, if not currently in place. Examples include occurrences of well workover or repair, as well as visual identification of vapor clouds or ice formations. Each incident will be flagged for review by the person responsible for MRV documentation (the responsible party will be provided in the monitoring plan, as required under Subpart A, 98.3(g)).The Annual Subpart RR Report will include an estimate of the amount of CO_2 leaked. Records of information used to calculate emissions will be maintained on file for a minimum of three years.

<u>Personal H2S Monitors</u>

Oxy's injection gas compositional analysis indicates H_2S is approximately 1% of total injected fluid stream.

H_2S monitors are worn by all field personnel. The H_2S monitors detect concentrations of H_2S up to 500 ppm in 0.1 ppm increments and will sound an alarm if the detection limit exceeds 10ppm. If an H_2S alarm is triggered, the immediate response is to protect the safety of the personnel, and the next step is to safely investigate the source of persistent alarms. Oxy considers H_2S to be a proxy for potential CO_2 leaks in the field. The person responsible for MRV documentation will receive notice of all incidents where H_2S is confirmed to be present. If the incident results in a work order, this will serve as the basis for tracking the event for GHG reporting. The Annual Subpart RR Report will provide an estimate the amount of CO_2 emitted from any such incidents. Records of information to calculate emissions will be maintained on file for a minimum of three years.

<u>Injection Rates, Pressures and Volumes</u>

Target injection rate and pressure for each injector are developed within the permitted limits based on the results of ongoing pattern modeling. The injection targets are programmed into the WAG satellite controllers. High and low set points are also programmed into the controllers, and flags whenever statistically significant deviations from the targeted ranges are identified. The set points are designed to be conservative, because it is preferable to have too many flags rather than too few. As a result, flags can occur frequently and are often found to be insignificant. For purposes of Subpart RR reporting, flags (or excursions) will be screened to determine if they could also lead to CO_2 leakage to the surface. The person responsible for the MRV documentation will receive notice of excursions and related work orders that could potentially involve CO_2 leakage. The Annual Subpart RR Report will provide an estimate of CO_2 emissions. Records of information to calculate emissions will be maintained on file for a minimum of three years.

Production Volumes and Compositions

A general forecast of production volumes and composition is developed which is used to periodically evaluate performance and refine current and projected injection plans and the forecast. This information is used to make operational decisions but is not recorded in an automated data system. Sometimes, this review may result in the generation of a work order in the maintenance system. The MRV plan implementation lead will review such work orders and identify those that could result in CO_2 leakage. Should such events occur, leakage volumes would be calculated following the approaches described in Sections 5 and 6. Impact to Subpart RR reporting will be addressed, if deemed necessary.

8. Determination of Sequestration Volumes Using Mass Balance Equations

To account for the potential propagation of error that would result if volume data from flow meters at each injection and production well were utilized, it is proposed to use the data from custody and operations meters on the main system pipelines to determine injection and production volumes used in the mass balance. This issue arises because while each meter has a small but acceptable margin of error, this error would become significant if data were taken from all of the well head meters within the WSSAU.

The following sections describe how each element of the mass-balance equation (Equation RR-11) will be calculated.

8.1. Mass of CO2 Received

Equation RR-2 will be used as indicated in Subpart RR §98.443 to calculate the mass of CO2 at the receiving custody transfer meter from the Permian Basin CO2 pipeline delivery system. The volumetric flow at standard conditions will be multiplied by the CO2 concentration and the density of CO2 at standard conditions to determine mass.

$$CO2_{T,r} = \sum_{p=1}^{4} (Q_{p,r} - Sr_{,p}) * D * C_{CO2,r,p} \qquad \text{(Eq. RR-2)}$$

where:

$CO2_{T,r}$ = Net annual mass of CO2 received through flow meter r (metric tons).

$Q_{r,p}$ = Quarterly volumetric flow through a receiving flow meter r in quarter p at standard conditions (standard cubic meters).

$S_{r,p}$ = Quarterly volumetric flow through a receiving flow meter r that is redelivered to another facility without being injected into a site well in quarter p (standard cubic meters).

D = Density of CO2 at standard conditions (metric tons per standard cubic meter): 0.0018682.

$C_{CO2,r,r}$ = Quarterly CO2 concentration measurement in flow for flow meter r in quarter p (vol. percent CO2, expressed as a decimal fraction).

p = Quarter of the year.

r = Receiving flow meters.

Given WSSAU's method of receiving CO2 and requirements at Subpart RR §98.444(a):

- All delivery to the WSSAU is used within the unit so no quarterly flow redelivered, and $S_{r,p}$ will be zero ("0").
- Quarterly CO2 concentration will be taken from the gas measurement database

8.2. Mass of CO2 Injected into the Subsurface

The equation for calculating the Mass of CO2 Injected into the Subsurface at the WSSAU is equal to the sum of the Mass of CO2 Received as calculated in RR-3 of §98.443 (section 8.1 above) and the Mass of CO2 Recycled calculated using measurements taken from the flow meter located at the output of the RCF (see Figure 3-5). As previously explained, using data at each injection well would give an inaccurate estimate of total injection volume due to the large number of wells and the potential for propagation of error due to allowable calibration ranges for each meter.

The Mass of CO2 Recycled will be determined using equations RR-5 as follows:

$$CO2_u = \sum_{p=1}^{4} Q_{p,u} * D * C_{CO2,p,u} \qquad \text{(Eq. RR-5)}$$

where:

$CO2_u$ = Annual CO2 mass recycled (metric tons) as measured by flow meter u.

$Q_{p,u}$ = Quarterly volumetric flow rate measurement for flow meter u in quarter p at standard conditions (standard cubic meters per quarter).

D = Density of CO2 at standard conditions (metric tons per standard cubic meter): 0.0018682.

$C_{CO2,p,u}$ = CO2 concentration measurement in flow for flow meter u in quarter p (vol. percent CO2, expressed as a decimal fraction).

p = Quarter of the year.

u = Flow meter.

The total Mass of CO2 Injected will be the sum of the Mass of CO2 Received (RR-3) and Mass of CO2 Recycled (modified RR-5).

$$CO2_I = CO2 + CO2_u$$

8.3. Mass of CO2 Produced

The Mass of CO2 Produced at the WSSAU will be calculated using the measurements from the flow meters at the inlet to RCF and the custody transfer meter for oil sales rather than the metered data from each production well. Again, using the data at each production well would give an inaccurate estimate of total injection due to the large number of wells and the potential for propagation of error due to allowable calibration ranges for each meter.

Equation RR-8 in §98.443 will be used to calculate the Mass of CO2 Produced from all injection wells as follows:

$$CO2_w = \sum_{p=1}^{4} Q_{p,w} * D * C_{CO2,p,w} \qquad \text{(Eq. RR-8)}$$

Where:

$CO2_W$ = Annual CO2 mass produced (metric tons) .

$Q_{P,W}$ = Volumetric gas flow rate measurement for meter w in quarter p at standard conditions (standard cubic meters).

D = Density of CO_2 at standard conditions (metric tons per standard cubic meter): 0.0018682.

$C_{CO2,P,W}$ = CO_2 concentration measurement in flow for meter w in quarter p (vol. percent CO_2, expressed as a decimal fraction).

p = Quarter of the year.

w = inlet meter to RCF.

For Equation RR-9 in §98.443 the variable X_{oil} will be measured as follows:

$$CO2_p = \sum_{w=1}^{W} CO2_w + X_{oil} \qquad \text{(Eq. RR-9)}$$

Where:

$CO2_P$ = Total annual CO_2 mass produced (metric tons) through all meters in the reporting year.

$CO2_w$ = Annual CO_2 mass produced (metric tons) through meter w in the reporting year.

X_{oil} = Mass of entrained CO_2 in oil in the reporting year measured utilizing commercial meters and electronic flow-measurement devices at each point of custody transfer. The mass of CO_2 will be calculated by multiplying the total volumetric rate by the CO_2 concentration.

8.4. Mass of CO2 Emitted by Surface Leakage

The total annual Mass of CO2 emitted by Surface Leakage will be calculated and reported using an approach that is tailored to specific leakage events and relies on 40 CFR Part 98 Subpart W reports of equipment leakage. Oxy is prepared to address the potential for leakage in a variety of settings. Estimates of the amount of CO2 leaked to the surface will depend on a number of site-specific factors including measurements, engineering estimates, and emission factors, depending on the source and nature of the leakage.

The process for quantifying leakage will entail using best engineering principles or emission factors. While it is not possible to predict in advance the types of leaks that will occur, some approaches for quantification are described in Sections 5.9 and 6. In the event leakage to the surface occurs, leakage amounts would be quantified and reported, and records that describe the methods used to estimate or measure the volume leaked as reported in the Annual Subpart RR Report would be retained. Further, the Subpart W report and results from any event-driven quantification will be reconciled to assure that surface leaks are not double counted.

Equation RR-10 in 48.433 will be used to calculate and report the Mass of CO2 emitted by Surface Leakage:

$$CO2_E = \sum_{x=1}^{x} CO2_x \qquad \text{(Eq. RR-10)}$$

where:

$CO2_E$ = Total annual CO2 mass emitted by surface leakage (metric tons) in the reporting year.

$CO2_x$ = Annual CO2 mass emitted (metric tons) at leakage pathway x in the reporting year.

x = Leakage pathway.

8.5. Mass of CO2 Sequestered in Subsurface Geologic Formation

Equation RR-11 in 98.443 will be used to calculate the Mass of CO2 Sequestered in Subsurface Geologic Formations in the Reporting Year as follows:

$$CO2 = CO2_I - CO2_P - CO2_E - CO2_{FI} - CO2_{FP} \qquad \text{(Eq. RR-11)}$$

where:

CO2 = Total annual CO2 mass sequestered in subsurface geologic formations (metric tons) at the facility in the reporting year.

$CO2_I$ = Total annual CO2 mass injected (metric tons) in the well or group of wells covered by this source category in the reporting year.

$CO2_P$ = Total annual CO2 mass produced (metric tons) net of CO2 entrained in oil in the reporting year.

$CO2_E$ = Total annual CO2 mass emitted (metric tons) by surface leakage in the reporting year.

$CO2_{FI}$ = Total annual CO2 mass emitted (metric tons) from equipment leaks and vented emissions of CO2 from equipment located on the surface between the flow meter used to measure injection quantity and the injection wellhead, for which a calculation procedure is provided in subpart W of this part.

$CO2_{FP}$ = Total annual CO2 mass emitted (metric tons) from equipment leaks and vented emissions of CO2 from equipment located on the surface between the production wellhead and the flow meter used to measure production quantity, for which a calculation procedure is provided in subpart W of this part.

8.6. Cumulative Mass of CO2 Reported as Sequestered in Subsurface Geologic Formation

The total annual volumes obtained using equation RR-11 in 98.443 will be summed to arrive at the Cumulative Mass of CO2 Sequestered in Subsurface Geologic Formations.

9. MRV Plan Implementation Schedule

This MRV plan will be implemented starting January 2021 or within 90 days of EPA approval, whichever occurs later. Other GHG reports are filed on March 31 of the year after the reporting year and it is anticipated that the Annual Subpart RR Report will be filed at the same time. It is anticipated that the MRV program will be in effect during the Specified Period, during which time the WSSAU will be operated with the subsidiary purpose of establishing long-term containment of a measurable quantity of CO_2 in subsurface geological formations at the WSSAU. It is anticipated to establish that a measurable amount of CO_2 injected during the Specified Period will be stored in a manner not expected to migrate resulting in future surface leakage. At such time, a demonstration supporting the long-term containment determination will be prepared and a request to discontinue monitoring and reporting under this MRV plan will be submitted. *See* 40 C.F.R. § 98.441(b)(2)(ii).

10. Quality Assurance Program

10.1. Monitoring QA/QC

The requirements of §98.444 (a) – (d) have been incorporated in the discussion of mass balance equations. These include the following provisions.

CO2 Received and Injected

- The quarterly flow rate of CO2 received by pipeline is measured at the receiving custody transfer meters.
- The quarterly CO2 flow rate for recycled CO2 is measured at the flow meter located at the RCF outlet.

CO2 Produced

- The point of measurement for the quantity of CO2 produced from oil or other fluid production wells is a flow meter directly downstream of each separator that sends a stream of gas into a recycle or end use system.
- The produced gas stream is sampled at least once per quarter immediately downstream of the flow meter used to measure flow rate of that gas stream and measure the CO2 concentration of the sample.
- The quarterly flow rate of the produced gas is measured at the flow meters located at the RCF inlet.

CO2 emissions from equipment leaks and vented emissions of CO2

These volumes are measured in conformance with the monitoring and QA/QC requirements specified in subpart W of 40 CFR Part 98.

Flow meter provisions

The flow meters used to generate date for the mass balance equations are:

- Operated continuously except as necessary for maintenance and calibration.
- Operated using the calibration and accuracy requirements in 40 CFR §98.3(i).
- Operated in conformance with American Petroleum Institute (API) standards.
- National Institute of Standards and Technology (NIST) traceable.

Concentration of CO2

CO2 concentration is measured using an appropriate standard method. Further, all measured volumes of CO2 have been converted to standard cubic meters at a temperature of 60 degrees Fahrenheit and at an absolute pressure of 1 atmosphere, including those used in Equations RR-2, RR-5 and RR-8 in Section 8.

10.2. Missing Data Procedures

In the event data needed for the mass balance calculations cannot be collected, procedures for estimating missing data in §98.445 will be used as follows:

- A quarterly flow rate of CO_2 received that is missing would be estimated using invoices or using a representative flow rate value from the nearest previous time period.
- A quarterly CO_2 concentration of a CO_2 stream received that is missing would be estimated using invoices or using a representative concentration value from the nearest previous time period.
- A quarterly quantity of CO_2 injected that is missing would be estimated using a representative quantity of CO_2 injected from the nearest previous period of time at a similar injection pressure.
- For any values associated with CO_2 emissions from equipment leaks and vented emissions of CO_2 from surface equipment at the facility that are reported in this subpart, missing data estimation procedures specified in subpart W of 40 CFR Part 98 would be followed.
- The quarterly quantity of CO_2 produced from subsurface geologic formations that is missing would be estimated using a representative quantity of CO_2 produced from the nearest previous period of time.

10.3. MRV Plan Revisions

In the event there is a material change to the monitoring and/or operational parameters of the CO_2 EOR operations in the WSSAU that is not anticipated in this MRV plan, the MRV plan will be revised and submitted to the EPA Administrator within 180 days as required in §98.448(d).

11. Records Retention

The record retention requirements specified by §98.3(g) will be followed. In addition, the requirements in Subpart RR §98.447 will be met by maintaining the following records for at least three years:

- Quarterly records of CO2 received at standard conditions and operating conditions, operating temperature and pressure, and concentration of these streams.
- Quarterly records of produced CO2, including volumetric flow at standard conditions and operating conditions, operating temperature and pressure, and concentration of these streams.
- Quarterly records of injected CO2 including volumetric flow at standard conditions and operating conditions, operating temperature and pressure, and concentration of these streams.
- Annual records of information used to calculate the CO2 emitted by surface leakage from leakage pathways.
- Annual records of information used to calculate the CO2 emitted from equipment leaks and vented emissions of CO2 from equipment located on the surface between the flow meter used to measure injection quantity and the injection wellhead.
- Annual records of information used to calculate the CO2 emitted from equipment leaks and vented emissions of CO2 from equipment located on the surface between the production wellhead and the flow meter used to measure production quantity.

These data will be collected as generated and aggregated as required for reporting purposes.

12. Appendix

12.1 Well Identification Numbers

The following table presents the well name and number, API number, type, and status for active wells in WSSAU as of September 2020. The table is subject to change over time as new wells are drilled, existing wells change status, or existing wells are repurposed. The following terms are used:

- Well Status
  - ACTIVE refers to active wells
  - DRILL refers to wells under construction
  - TA refers to wells that have been temporarily abandoned
  - SHUT_IN refers to wells that have been temporarily idled or shut-in
  - INACTIVE refers to wells that have been completed but are not in use
- Well Type
  - DISP_H2O refers to wells for water disposal
  - INJ_GAS refers to wells that inject CO2 Gas
  - INJ_WAG refers to wells that inject water and CO2 Gas
  - INJ_H2O refers to wells that inject water
  - OBSERVATION refers to observation or monitoring wells
  - PROD_GAS refers to wells that produce natural gas
  - PROD_OIL refers to wells that produce oil
  - SUP_H2O refers to wells that supply water

• Well Name & Number	API Number	Well Type	Well Status as of September 2020
WSSAU-0002WD	4216500675	DISP_H2O	ACTIVE
WSSAU-0101	4216501591	PROD_OIL	TA
WSSAU-0104	4216532613	INJ_H2O	ACTIVE
WSSAU-0201	4216500642	PROD_OIL	ACTIVE
WSSAU-0202	4216500643	PROD_OIL	ACTIVE
WSSAU-0203	4216500645	PROD_OIL	TA
WSSAU-0207	4216534204	PROD_OIL	ACTIVE
WSSAU-0208	4216537800	PROD_OIL	ACTIVE
WSSAU-0209	4216537801	PROD_OIL	ACTIVE
WSSAU-0210	4216537802	PROD_OIL	ACTIVE
WSSAU-0211	4216537803	PROD_OIL	ACTIVE
WSSAU-0212	4216538559	PROD_OIL	ACTIVE
WSSAU-0213	4216538558	PROD_OIL	ACTIVE
WSSAU-0214	4216538557	PROD_OIL	ACTIVE
WSSAU-0301R	4216538445	PROD_OIL	ACTIVE
WSSAU-0302R	4216538446	PROD_OIL	ACTIVE

WSSAU-0303	4216500644	PROD_OIL	ACTIVE
WSSAU-0303R	4216538447	PROD_OIL	ACTIVE
WSSAU-0304R	4216538448	PROD_OIL	ACTIVE
WSSAU-0305RW	4216538449	INJ_WAG	ACTIVE
WSSAU-0305W	4216530388	INJ_H2O	TA
WSSAU-0306RW	4216538450	INJ_WAG	ACTIVE
WSSAU-0307RW	4216538451	INJ_WAG	ACTIVE
WSSAU-0309	4216531624	INJ_WAG	ACTIVE
WSSAU-0310	4216531626	INJ_WAG	ACTIVE
WSSAU-0311RW	4216537493	INJ_WAG	ACTIVE
WSSAU-0312	4216531743	PROD_OIL	ACTIVE
WSSAU-0313	4216531744	PROD_OIL	ACTIVE
WSSAU-0314	4216531745	PROD_OIL	ACTIVE
WSSAU-0315	4216531787	INJ_H2O	INACTIVE
WSSAU-0316W	4216531786	INJ_H2O	ACTIVE
WSSAU-0317W	4216531790	INJ_H2O	INACTIVE
WSSAU-0318W	4216531788	INJ_H2O	ACTIVE
WSSAU-0319	4216531789	INJ_H2O	INACTIVE
WSSAU-0320	4216531838	PROD_OIL	ACTIVE
WSSAU-0321	4216531837	INJ_WAG	ACTIVE
WSSAU-0322	4216532404	INJ_WAG	ACTIVE
WSSAU-0323	4216532405	INJ_WAG	ACTIVE
WSSAU-0324	4216532566	INJ_WAG	ACTIVE
WSSAU-0325	4216534144	PROD_OIL	ACTIVE
WSSAU-0326	4216534203	INJ_WAG	ACTIVE
WSSAU-0327	4216538560	INJ_WAG	ACTIVE
WSSAU-0328	4216538561	INJ_WAG	ACTIVE
WSSAU-0329	4216538562	INJ_WAG	ACTIVE
WSSAU-0330	4216538563	INJ_WAG	ACTIVE
WSSAU-03WD	4216538439	DISP_H2O	ACTIVE
WSSAU-0401	4216501587	PROD_OIL	ACTIVE
WSSAU-0404	4216501590	PROD_OIL	TA
WSSAU-0405RW	4216538452	INJ_WAG	ACTIVE
WSSAU-0406	4216531978	INJ_H2O	ACTIVE
WSSAU-0407	4216531979	PROD_OIL	TA
WSSAU-0408	4216534205	INJ_H2O	ACTIVE
WSSAU-0409	4216538556	PROD_OIL	ACTIVE
WSSAU-0410	4216538550	INJ_WAG	ACTIVE

WSSAU-0411	4216538571	INJ_WAG	ACTIVE
WSSAU-0412	4216538583	INJ_WAG	ACTIVE
WSSAU-0413	4216538572	INJ_WAG	ACTIVE
WSSAU-0414	4216538573	INJ_WAG	ACTIVE
WSSAU-0415	4216538585	PROD_OIL	ACTIVE
WSSAU-0416	4216538586	PROD_OIL	ACTIVE
WSSAU-0417	4216538574	PROD_OIL	ACTIVE
WSSAU-0418	4216538580	PROD_OIL	ACTIVE
WSSAU-0419	4216538582	PROD_OIL	ACTIVE
WSSAU-0501	4216500657	PROD_GAS	TA
WSSAU-0502	4216500610	PROD_OIL	ACTIVE
WSSAU-0503W	4216500604	INJ_H2O	ACTIVE
WSSAU-0504W	4216500625	INJ_H2O	ACTIVE
WSSAU-0505	4216581090	PROD_OIL	ACTIVE
WSSAU-0507	4216532609	PROD_OIL	TA
WSSAU-0508	4216534225	INJ_H2O	ACTIVE
WSSAU-0509	4216537203	PROD_OIL	ACTIVE
WSSAU-0601	4216500663	PROD_OIL	ACTIVE
WSSAU-0602R	4216538300	PROD_OIL	ACTIVE
WSSAU-0603	4216500665	PROD_OIL	ACTIVE
WSSAU-0603R	4216538404	PROD_OIL	ACTIVE
WSSAU-0604	4216500666	PROD_OIL	TA
WSSAU-0604R	4216538299	PROD_OIL	ACTIVE
WSSAU-0605	4216500667	PROD_OIL	TA
WSSAU-0605R	4216538298	PROD_OIL	ACTIVE
WSSAU-0606	4216500629	INJ_GAS	SHUT-IN
WSSAU-0607	4216500630	PROD_OIL	ACTIVE
WSSAU-0607R	4216538405	PROD_OIL	ACTIVE
WSSAU-0608	4216500631	PROD_OIL	ACTIVE
WSSAU-0609RW	4216538403	INJ_WAG	ACTIVE
WSSAU-0609W	4216530214	INJ_H2O	ACTIVE
WSSAU-0610RW	4216538402	INJ_WAG	ACTIVE
WSSAU-0611RW	4216538401	INJ_WAG	ACTIVE
WSSAU-0611W	4216530279	INJ_H2O	ACTIVE
WSSAU-0613	4216530531	PROD_OIL	ACTIVE
WSSAU-0614	4216531632	PROD_OIL	ACTIVE
WSSAU-0615	4216531630	PROD_OIL	ACTIVE
WSSAU-0616	4216531627	INJ_WAG	ACTIVE

WSSAU-0617	4216531629	PROD_GAS	TA
WSSAU-0617RW	4216537492	INJ_WAG	ACTIVE
WSSAU-0618	4216531628	INJ_WAG	ACTIVE
WSSAU-0619	4216531836	PROD_OIL	ACTIVE
WSSAU-0620	4216531835	PROD_OIL	ACTIVE
WSSAU-0621	4216531834	INJ_H2O	ACTIVE
WSSAU-0622	4216531833	PROD_OIL	ACTIVE
WSSAU-0623	4216531832	PROD_OIL	ACTIVE
WSSAU-0624	4216531831	PROD_OIL	ACTIVE
WSSAU-0625	4216531980	PROD_OIL	ACTIVE
WSSAU-0626	4216532403	PROD_OIL	ACTIVE
WSSAU-0627	4216532402	PROD_OIL	ACTIVE
WSSAU-0701	4216500633	PROD_OIL	ACTIVE
WSSAU-0702	4216500635	PROD_OIL	ACTIVE
WSSAU-0703	4216500637	PROD_OIL	ACTIVE
WSSAU-0704	4216500613	PROD_OIL	ACTIVE
WSSAU-0705	4216500612	PROD_OIL	ACTIVE
WSSAU-0706	4216500641	PROD_OIL	TA
WSSAU-0707RW	4216538453	INJ_WAG	ACTIVE
WSSAU-0708RW	4216538454	INJ_WAG	ACTIVE
WSSAU-0708W	4216530392	INJ_H2O	ACTIVE
WSSAU-0712	4216531981	INJ_H2O	ACTIVE
WSSAU-0713	4216531982	INJ_H2O	ACTIVE
WSSAU-0714	4216532299	INJ_H2O	ACTIVE
WSSAU-0715	4216532406	PROD_OIL	TA
WSSAU-0716	4216532567	PROD_OIL	ACTIVE
WSSAU-0717	4216534023	PROD_OIL	ACTIVE
WSSAU-0801	4216500634	PROD_OIL	TA
WSSAU-0802	4216500636	PROD_OIL	ACTIVE
WSSAU-0803	4216500638	PROD_OIL	ACTIVE
WSSAU-0804W	4216500639	INJ_H2O	ACTIVE
WSSAU-0805	4216500640	PROD_OIL	ACTIVE
WSSAU-0809	4216532595	PROD_OIL	ACTIVE
WSSAU-0810	4216532612	PROD_OIL	ACTIVE
WSSAU-0811	4216538581	PROD_OIL	ACTIVE
WSSAU-0812	4216538587	PROD_OIL	ACTIVE
WSSAU-0901W	4216500498	INJ_H2O	ACTIVE
WSSAU-0902W	4216500500	INJ_H2O	ACTIVE

WSSAU-1102W	4216500632	INJ_H2O	SHUT-IN
WSSAU-1103W	4216530285	INJ_H2O	INACTIVE
WSSAU-1105	4216531401	PROD_GAS	TA
WSSAU-1106	4216537204	SUP_H2O	TA
WSSAU-1201	4216502768	PROD_OIL	ACTIVE
WSSAU-1202R	4216538406	PROD_OIL	ACTIVE
WSSAU-1203	4216502750	PROD_OIL	ACTIVE
WSSAU-1204	4216502771	PROD_OIL	ACTIVE
WSSAU-1206RW	4216538400	INJ_WAG	ACTIVE
WSSAU-1207RW	4216538399	INJ_WAG	ACTIVE
WSSAU-1207W	4216530291	INJ_H2O	INACTIVE
WSSAU-1208RW	4216538398	INJ_WAG	ACTIVE
WSSAU-1209	4216531977	INJ_H2O	ACTIVE
WSSAU-1210	4216531976	INJ_WAG	ACTIVE
WSSAU-1211	4216531983	PROD_OIL	TA
WSSAU-1211RW	4216537491	INJ_WAG	ACTIVE
WSSAU-1212	4216531985	INJ_WAG	ACTIVE
WSSAU-1213	4216531984	PROD_OIL	ACTIVE
WSSAU-1214	4216531974	PROD_OIL	ACTIVE
WSSAU-1215	4216531975	PROD_OIL	ACTIVE
WSSAU-1216	4216531986	PROD_OIL	ACTIVE
WSSAU-1302	4216500661	PROD_OIL	SHUT-IN
WSSAU-1303	4216500626	PROD_OIL	TA
WSSAU-1304	4216500627	PROD_OIL	ACTIVE
WSSAU-1305W	4216530090	INJ_H2O	SHUT-IN
WSSAU-1309	4216532298	INJ_H2O	ACTIVE
WSSAU-1310	4216532297	INJ_H2O	ACTIVE
WSSAU-1311	4216532303	INJ_H2O	ACTIVE
WSSAU-1312	4216532302	INJ_H2O	ACTIVE
WSSAU-1313	4216532301	PROD_OIL	TA
WSSAU-1315	4216532304	PROD_OIL	ACTIVE
WSSAU-1316	4216532305	PROD_OIL	ACTIVE
WSSAU-1401	4216581121	PROD_OIL	SHUT-IN
WSSAU-1402	4216500504	PROD_OIL	TA
WSSAU-1403	4216581123	PROD_OIL	ACTIVE
WSSAU-1405W	4216530401	INJ_H2O	SHUT-IN
WSSAU-1406W	4216530400	INJ_H2O	INACTIVE
WSSAU-1407	4216530508	PROD_OIL	ACTIVE

WSSAU-1408	4216530552	PROD_OIL	ACTIVE
WSSAU-1409	4216534022	PROD_OIL	ACTIVE
WSSAU-1410	4216534145	PROD_OIL	TA
WSSAU-1502	4216501300	PROD_OIL	ACTIVE
WSSAU-1503	4216500497	PROD_OIL	ACTIVE
WSSAU-1504W	4216500499	INJ_H2O	SHUT-IN
WSSAU-1505	4216530550	PROD_OIL	ACTIVE
WSSAU-1506W	4216534146	INJ_H2O	ACTIVE
WSSAU-1601W	4216501392	INJ_H2O	SHUT-IN
WSSAU-1901	4216501464	PROD_OIL	TA
WSSAU-1902W	4216501466	INJ_H2O	INACTIVE
WSSAU-1903	4216538549	PROD_OIL	TA
WSSAU-2101W	4216502546	INJ_H2O	TA
WSSAU-2102W	4216502544	INJ_H2O	TA

12.2 Regulatory References

Regulations cited in this plan:

i. Texas Administrative Code Title 16 Part 1 Chapter 3 Oil & Gas Division - https://texreg.sos.state.tx.us/public/readtac$ext.ViewTAC?tac_view=4&ti=16&pt=1&ch=3&rl=Y

ii. TRRC Injection/Disposal Well Permitting, Testing and Monitoring Manual - https://www.rrc.state.tx.us/oil-gas/publications-and-notices/manuals/injectiondisposal-well-manual/

Request for Additional Information: West Seminole San Andres Unit
October 29, 2020

Instructions: Please enter responses into this table. Any long responses, references, or supplemental information may be attached to the end of the table as an appendix. Supplemental information may also be provided in a resubmitted MRV plan.

No.	MRV Plan		EPA Questions	Responses
	Section	Page		
1.	2.3	5	"Wells in the WSSAU are identified by name and API number, type and status. The list of wells as of May 2020 is included in Appendix 12.3." Wells are listed in section **12.1**. Please change reference in the text.	A revised table was added to Section 12.1 that includes API numbers. The text on page 5 has been updated.
2.	3.2	9	"The volume of CO2 storage is based on the estimated total pore space within WSSAU The total pore space within WSSAU, from the top of the reservoir down to the base of the oil zone, is calculated to be 1,512 million reservoir barrels (RB)." Should there be a period following the first "WSSAU"?	Yes. Corrected in revised version of MRV plan.
3.	3.3	11	"It is combined with recycled CO2 from the recompression facility (RCF) and distributed to the WAG headers for injection into the injector wells according to the pre-programmed injection plan for each well pattern alternates between water and CO2 injection." What is combined with recycled CO2? Is CO2 sent only to wells with alternating water and CO2 injection? Please clarify.	Yes. It refers to CO2 received. This has been clarified in the revised Section 3.3 of the MRV plan. In WSSAU all EOR injection wells are equipped for WAG injection; some of these start with CO2 only for a short period of time before water is reintroduced.
4.	Multiple	11, 13	In the diagram (Figure 3-5), Hydrocarbon Gases are included in the recycled CO2 stream that is reinjected. However, in the footnote on page 13, it says that injected fluids are only CO2 and water. Which is accurate? Please clarify.	The injection fluid contains CO2 and hydrocarbon gas. Figure 3.5, the text in Section 3.3, and the footnote on page 13 have been corrected to clarify this.

No.	MRV Plan		EPA Questions	Responses
	Section	Page		
5.	Multiple	11, 19, 26, 27, 29	The plan mentions several times that personal H2S monitors will be used as a means to detect leakage. Given that there are "trace" amounts of H2S entrained in the produced fluids, how will detections be observed? Is there an estimate for the H2S composition of the gas?	The following text is added in Section 7. Determination of Baselines: "Oxy's injection gas compositional analysis indicates H2S is approximately 1% of total injected fluid stream. H2S monitors are worn by all field personnel. The H2S monitors detect concentrations of H2S up to 500 ppm in 0.1 ppm increments and will sound an alarm if the detection limit exceeds 10ppm. If an H2S alarm is triggered, the immediate response is to protect the safety of the personnel, and the next step is to safely investigate the source of persistent alarms. Oxy considers H2S to be a proxy for potential CO2 leaks in the field. The person responsible for MRV documentation will receive notice of all incidents where H2S is confirmed to be present. If the incident results in a work order, this will serve as the basis for tracking the event for GHG reporting. The Annual Subpart RR Report will provide an estimate the amount of CO2 emitted from any such incidents. Records of information to calculate emissions will be maintained on file for a minimum of three years." This indicates that H2S monitors provide sensitive detection of potential leakage and are tied to field operational procedures to investigate the source of detected emissions.
6.	3.3.1	12	In Table 1, please spell out P&A and TA in the first instance.	Corrected in revised version of MRV plan.

No.	MRV Plan		EPA Questions	Responses
	Section	Page		
7.	5.1	19	"Based on an ongoing monitoring activities and review of the potential leakage risks posed by well bores, it is concluded that the risk of CO2 leakage through well bores is being mitigated by detecting problems as they arise and quantifying any leakage that does occur." Should this read, "Based **on ongoing**…"?	Yes. Corrected in revised version of MRV plan.
8.	5.3	20	Please expand upon why it was concluded that natural or induced seismicity do not pose a risk for loss of CO2 to the surface within the WSSAU. There is no reference to literature or specific operating experiences that led to the conclusion that seismicity does not pose a risk to the project.	This has been addressed in the revised Section 5.3 of the MRV plan.
9.	6	24	"Monitoring will also be used to determine the quantities in the mass balance equation and to make the demonstration that the CO2 plume will note migrate to the surface after the time of discontinuation." Should this read, "the CO2 plume will **not…**"?	Yes. Corrected in revised version of MRV plan.
10.	6.1.4	25	"Recycled CO2 is calculated using the volumetric flow meter at the outlet of the RCF. , which is an operations meter." Please correct the grammatical error where the period is before the comma.	Corrected in revised version of MRV plan.
11.	8.1	31	There are incorrect subscripts within equation RR-2: $S_{p,r}$ should be $S_{r,p}$.	Corrected in revised version of MRV plan.

No.	MRV Plan		EPA Questions	Responses
	Section	Page		
12.	Multiple	31, 32, 33	In several places in the draft plan, the document refers to making modifications to the mass balance equations. For example: "Given WSSAU's method of receiving CO2 and requirements at Subpart RR §98.444(a): • All delivery to the WSSAU is used within the unit so quarterly flow redelivered, Sr,p , is zero ("0") and will not be included in the equation. • Quarterly CO2 concentration will be taken from the gas measurement database Currently this is not needed because there is one offtake, but if additional offtakes are used, they will be summed to total Mass of CO2 Received using equation RR-3 in 98.443." (page 31) "The total Mass of CO2 Injected will be the sum of the Mass of CO2 Received (RR-3) and Mass of CO2 Recycled (modified RR-5)" (page 32) "Equation RR-9 in 98.443 will be modified to reflect the measured amount of CO2 entrained in oil and the modified equation will be used to aggregate the mass of CO2 produced including the mass of CO2 entrained in oil leaving the WSSAU prior to treatment of the remaining gas fraction in RCF as follows…" (page 33) Modification to equations is not allowed under the GHGRP. Is your plan to modify certain equations, or is the plan for certain terms in the equations to be equal to zero? Please clarify.	The MRV plan was updated as follows: - The variable $S_{r,p}$ will be zero as indicated in Section 8.1; - Equation RR-3 will be used as written in the rule so the reference to it in Section 8.1 has been removed; and, - The variable X_{oil} will be measured as described in Section 8.3.
13.	8.3	33	40 CFR 98.448(a)(5) requires "A summary of the considerations you intend to use to calculate site-specific variables for the mass balance equation. This includes . . . considerations for calculating CO2 in produced fluids." How would the mass of entrained CO_2 in oil or the value "X" in Equation RR-9 be determined?	The variable will be measured as described in the revised Section 8.3 of the MRV plan. The equation is not modified.

No.	MRV Plan		EPA Questions	Responses
	Section	Page		
14.	12.1	40-45	"The following table presents the well name and API number, type and status for active wells in WSSAU as of May 2020." There is a "Well Name & Number" column in the appendix table, but the well number does not follow the conventional nomenclature of an API number (i.e. the 10, 12 or 14 digit number with State and County codes followed by a unique well identification number). Please clarify and update the MRV plan as necessary.	A revised table with the well name and number and the API number is in Section 12.1

Oxy West Seminole San Andres Unit
Subpart RR Monitoring, Reporting and Verification (MRV) Plan

September 24, 2020

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1. Introduction

OXY USA WTP LP, a subsidiary of Occidental (Oxy) operates a CO2-EOR project in the West Seminole San Andres Unit (WSSAU). This MRV plan was developed in accordance with 40 CFR §98.440-449 (Subpart RR) to provide for the monitoring, reporting and verification of the quantity of CO2 sequestered at the WSSAU during a specified period of injection.

2. Facility Information

2.1. Reporter Number

575401 – West Seminole San Andres Unit

2.2. UIC Permit Class

The Oil and Gas Division of the Texas Railroad Commission (TRRC) regulates oil and gas activity in Texas. All wells in the WSSAU (including production, injection and monitoring wells) are permitted by TRRC through Texas Administrative Code (TAC) Title 16 Chapter 3. TRRC has primacy to implement the Underground Injection Control (UIC) Class II program in the state for injection wells. All EOR injection wells in the WSSAU are currently classified as UIC Class II wells.

2.3. Existing Wells

Wells in the WSSAU are identified by name and API number, type and status. The list of wells as of May 2020 is included in Appendix 12.3. Any changes in wells will be indicated in the annual report.

3. Project Description

This project takes place in the West Seminole San Andres Unit (WSSAU), an oil field located in West Texas that was first produced more than 70 years ago. CO2 flooding was initiated in 2013 and the injection plan calls for a total of approximately 20 million tonnes of CO2 over the lifetime of the project. The field is well characterized and is suitable for secure geologic storage. Oxy uses a water alternating with gas (WAG) injection process and maintains an injection to withdrawal ratio (IWR) of at or near 1.0. A history matched reservoir simulation of the injection at WSSAU has been constructed.

3.1. Project Characteristics

The West Seminole San Andres field was discovered in 1944 and started producing in 1948. The field was unitized in 1961 and waterflood was initiated in 1969. CO2 flooding was initiated in 2013. A long-term forecast for WSSAU was developed using the reservoir modeling approaches described in Section 3.4 that includes injection of a total of approximately 20 million tonnes of CO2 over the life of the project. Figure 3-1 shows actual and projected CO2 injection, production, and stored volumes in WSSAU.

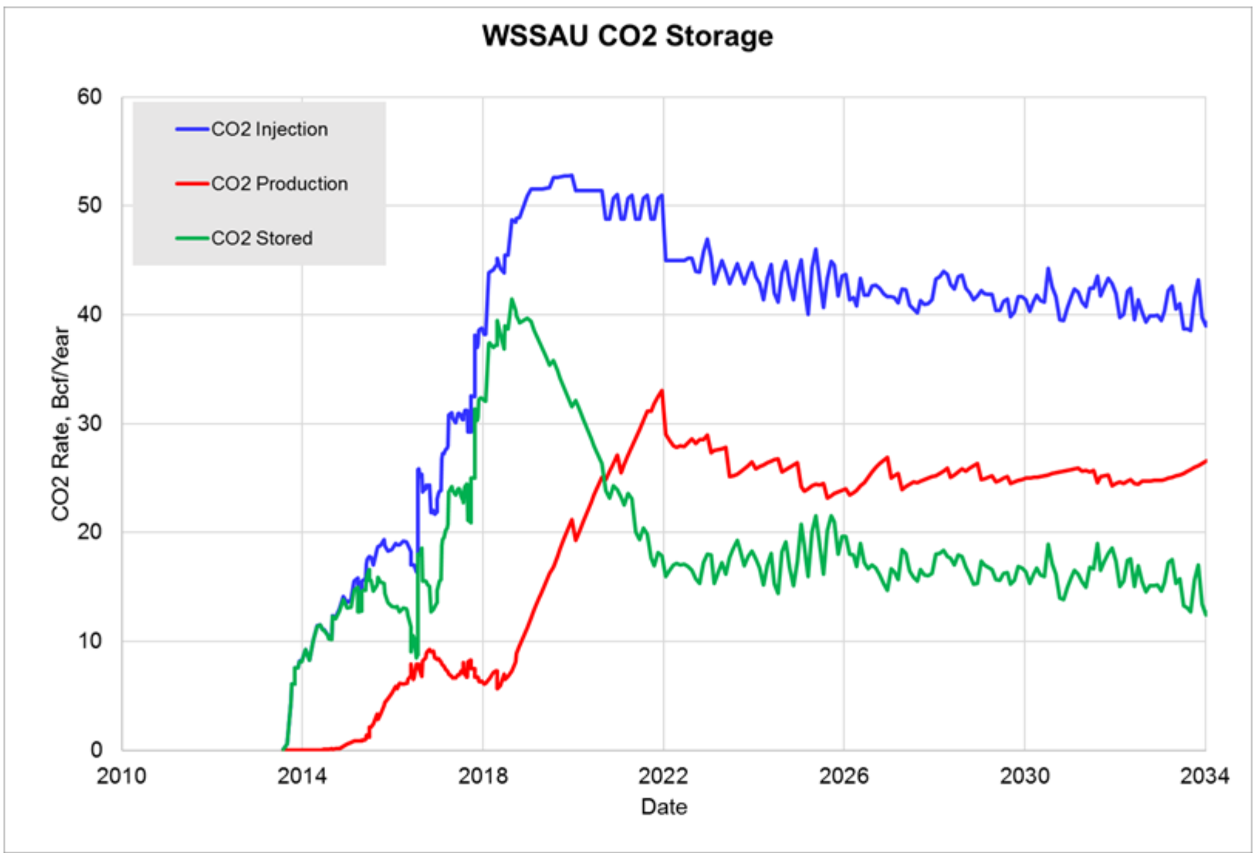

Figure 3-1 WSSAU Historic and Forecast CO2 Injection, Production, and Storage

3.2. Environmental Setting

The WSSAU is located in the NE portion of the Central Basin Platform in West Texas (See Figure 3-2).

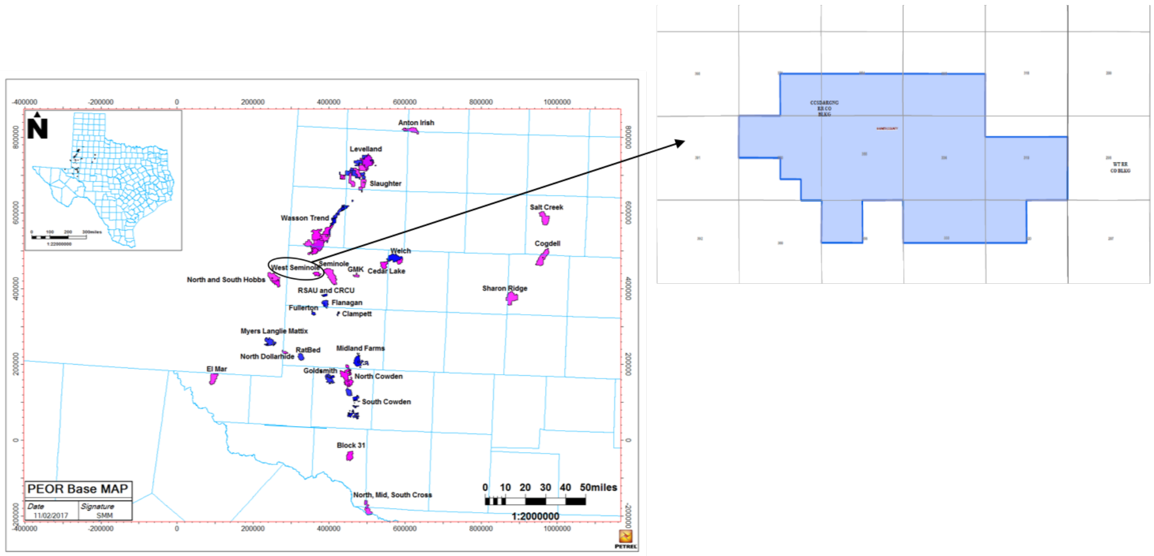

Figure 3-2 Location of WSSAU in West Texas

WSSAU produces oil from the Permian (Guadalupian) aged reservoir comprised of San Andres formation dolostone. Total thickness of the geologic unit is approximately 1500 feet, with the main reservoir within the middle 600 feet. The sequestration zone is also the oil pay completion interval, and ranges on average between 4925-5640 feet below the ground surface. See the WSSAU geologic column in Figure 3-3. The productive interval, or reservoir, is composed of layers of permeable dolomites that were deposited in a shallow marine environment during the Permian Era, some 250 to 300 million years ago.

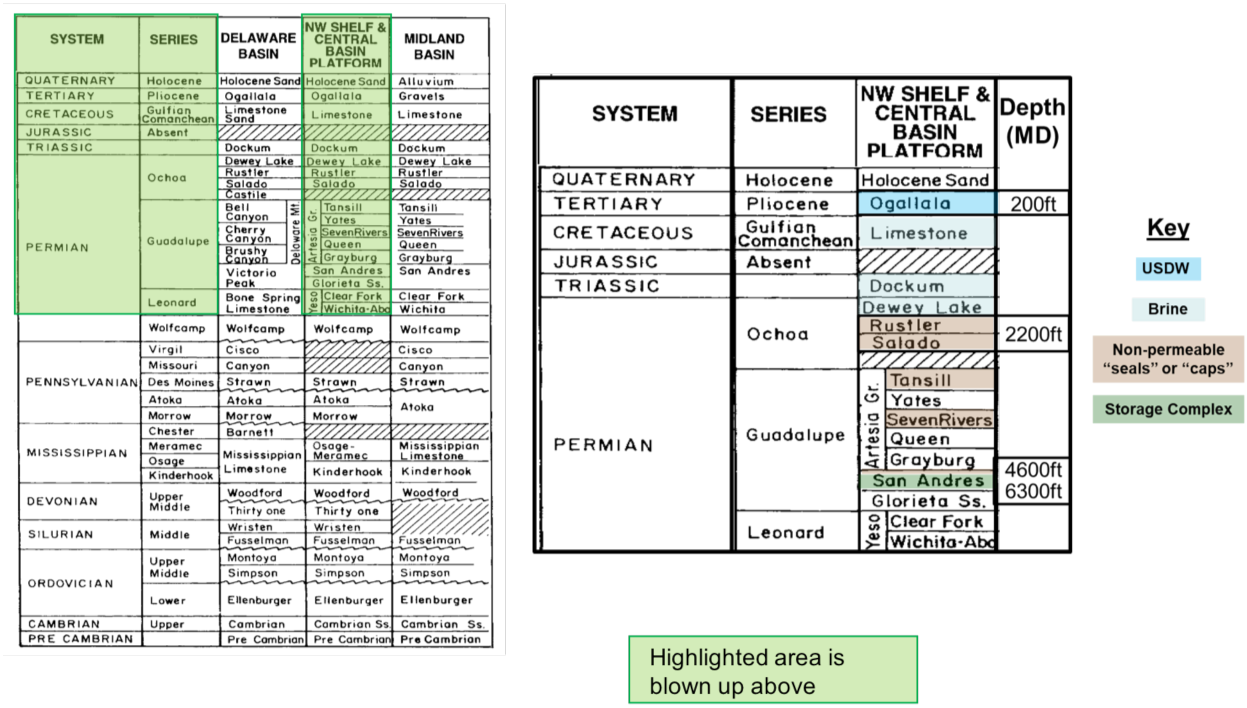

Figure 3-3 WSSAU Geologic Column

The main confining system is ~300 feet thick and is comprised of nonporous anhydrite sequences. The depth interval for the confining system ranges from top San Andres Formation to Top Pay (4545-5194 feet) with a typical range of 4660-4925 feet below ground surface. There are numerous relatively thin layers that provide additional secondary containment between the sequestration zone and freshwater aquifers. These layers are comprised of siltstones, shales, salts, and anhydrite sequences with little to no porosity or permeability.

There are no significant geologic faults or fractures identified that intersect the storage complex. There is one identified reverse fault in the Devonian interval approximately one mile below the sequestration zone. The base of sequestration zone is approximately 2175 ft. subsea depth, while the top of fault offset is interpreted to end at approximately 7500 ft. subsea depth. Fault displacement within the Devonian is approximately 200 ft. The fault is linear, subvertical, and dips toward the northeast. The presence of a gas cap is evidence of the effectiveness of the seal formed by the upper San Andres.

WSSAU is a domal structure that includes the highest elevations within the area. The elevated area forms a natural trap for oil and gas that migrated from below over millions of years. Once trapped in these high points, the oil and gas has remained in place. In the case of the WSSAU, this oil and gas has been trapped in the reservoir for 50 to 100 million years. Over time, buoyant fluids, including CO_2, rise vertically until reaching the ceiling of the dome and then migrate to the highest elevation of the structure. Figure 3-4, shows the Top San Andres pay interval structure. The colors in the structure map in Figure 3-4 indicate the subsurface elevation, with red being higher, (a shallower level) and purple being lower (a deeper level).

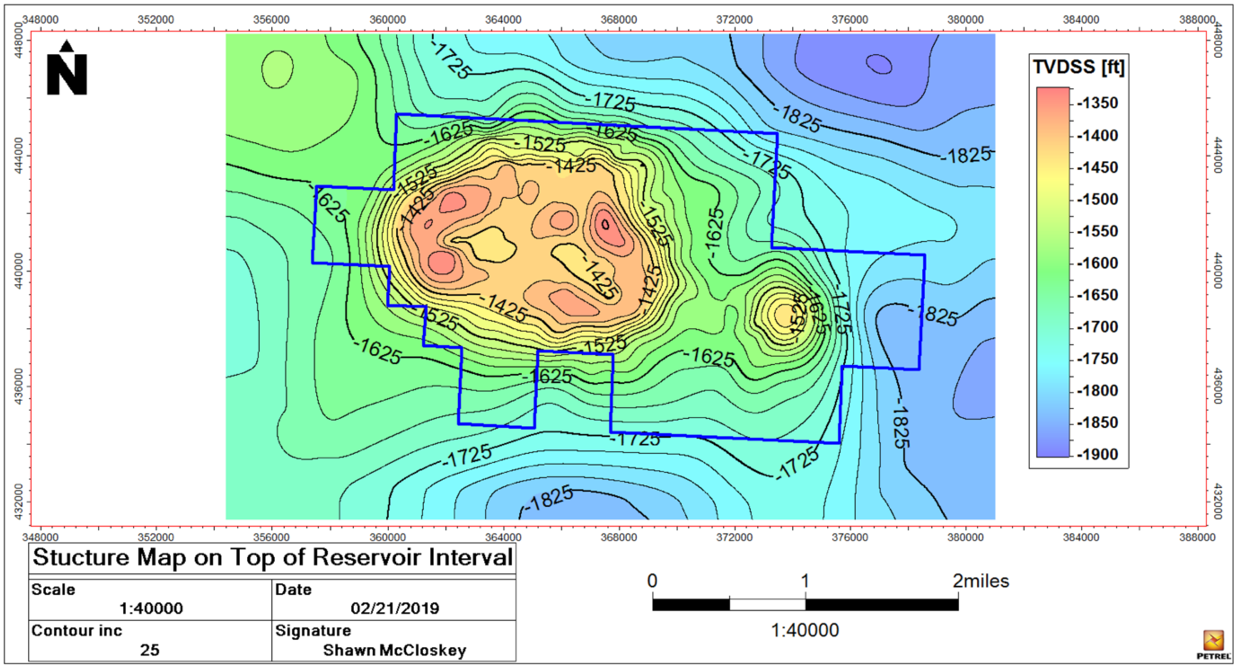

Figure 3-4 Local Area Structure on Top of San Andres

Buoyancy dominates where oil and gas are found in a reservoir. Gas, being lightest, rises to the top and water, being heavier, moves downward. Oil, being heavier than gas but lighter than water, lies in between. At the time of its discovery, natural gas was trapped at the structural high points of WSSAU, forming a “gas cap.” The presence of an oil deposit and a gas cap is evidence of the effectiveness of the seal formed by the upper San Andres. Gas is buoyant and highly mobile. If it could escape WSSAU naturally, through faults or fractures, it would have done so over the millennia. Below the gas cap is an oil accumulation, the oil zone, and below that there are no distillable hydrocarbons.

Once the CO_2 flood is complete and injection ceases, the remaining mobile CO_2 will rise slowly upward, driven by buoyancy forces. There is more than enough pore space to sequester the planned CO_2 injection. The amount of CO_2 injected will not exceed the reservoir’s secure storage capacity and, consequently, the risk that CO_2 could migrate to other reservoirs in the Central Basin Platform is negligible. The volume of CO_2 storage is based on the estimated total pore space within WSSAU The total pore space within WSSAU, from the top of the reservoir down to the base of the oil zone, is calculated to be 1,512 million reservoir barrels (RB). This is the volume of rock multiplied by porosity. Table 3-1 below shows the conversion of this amount of pore space into an estimated maximum volume of approximately 1,770 Bcf (96 million tonnes) of CO_2 storage in the reservoir. It is forecasted that at the end of EOR operations stored CO_2 will fill approximately 20% of total calculated storage capacity.

Table 3-1 Calculation of Maximum Volume of CO2 Storage Capacity at WSSAU

Top of Pay to Free Water Level (2175 ft subsea)	
Variables	WSSAU Outline
Pore Volume (**RB**)	1,511,810,594
$\mathbf{B}_{CO2}$	0.45
$\mathbf{S}_{wirr}$	0.2
$\mathbf{S}_{orCO2(volume\ weighted)}$	0.273
Max CO2 (MCF)	1,770,498,185
Max CO2 (BCF)	1,770

Max CO2 = Volume (**RB**) * $(1 - \mathbf{S}_{wirr} - \mathbf{S}_{orCO2}) / \mathbf{B}_{CO2}$

Where:
CO2(max) = the maximum amount of storage capacity
Pore Volume (RB) = the volume in Reservoir Barrels of the rock formation
B_{CO2} = the formation volume factor for CO2
S_{wirr} = the irreducible water saturation
S_{orCO2} = the irreducible oil saturation

Given that WSSAU is located at the highest subsurface elevations in the area, that the confining zone has proved competent over both millions of years and current CO2 flooding, and that the WSSAU has ample storage capacity, there is confidence that stored CO2 will be contained securely within the reservoir.

3.3. Description of CO2-EOR Project Facilities and the Injection Process

Figure 3-5 shows a simplified process flow diagram of the project facilities and equipment in the WSSAU. CO2 is delivered to the WSSAU via the Permian Basin CO2 pipeline network. The CO2 is supplied by a number of different sources. Specified amounts are drawn from the Bravo pipeline based on contractual arrangements among suppliers of CO2, purchasers of CO2, and the pipeline operator.

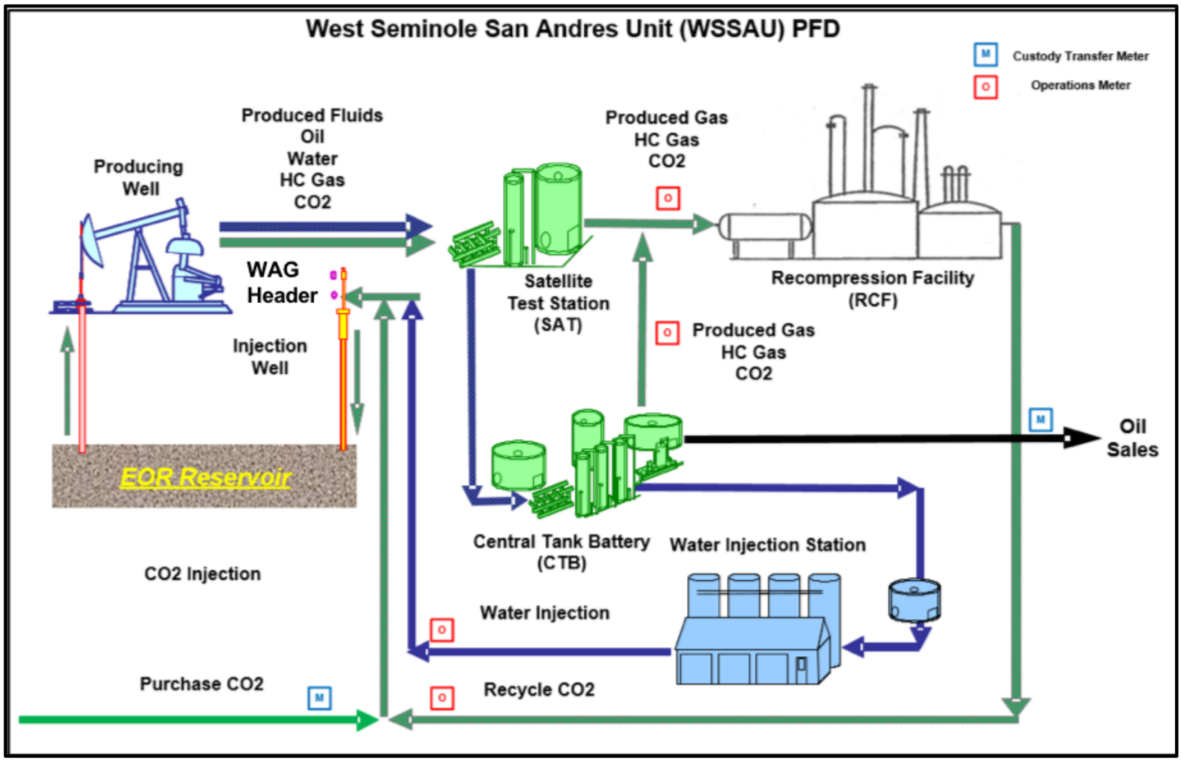

Figure 3-5 WSSAU Process Flow Diagram

Once CO2 enters WSSAU there are three main processes involved in EOR operations:

i. CO2 Distribution and Injection. The mass of CO2 received at WSSAU is metered and calculated through the Custody Transfer Meter located at the pipeline delivery point as indicated in the bottom left of Figure 3-5. It is combined with recycled CO2 from the recompression facility (RCF) and distributed to the WAG headers for injection into the injector wells according to the pre-programmed injection plan for each well pattern alternates between water and CO2 injection. WAG headers are remotely operated and can inject either CO2 or water at various rates and injection pressures as specified in the injection plans. This is an EOR project and reservoir pressure must be maintained above minimum miscibility pressure. Therefore, injection pressure must be sufficiently high to allow injectants to enter the reservoir, but below formation parting pressure (FPP).

ii. Produced Fluids Handling. Produced fluids from the production wells are a mixture of oil, hydrocarbon gas, water, CO2 and trace amounts of other constituents in the field including nitrogen and H2S. They are gathered and sent to satellite test stations (SAT) for separation into a gas/CO2 mix and a produced fluids mix of water, oil, gas, and CO2. The produced gas, which is composed primarily of hydrocarbons and CO2, is sent to the recompression facility (RCF) for dehydration and recompression before reinjection into the reservoir. An operations meter at the RCF is used to determine the total volume of produced gas that is reinjected. The separated oil is metered through the Custody Transfer Meter located at the central tank battery and sold into a pipeline.

iii. Water Treatment and Injection. Water is recovered for reuse and forwarded to the water injection station for treatment and reinjection or disposal.

3.3.1. Wells in the WSSAU

The Texas Railroad Commission (TRRC) has broad authority over oil and gas operations including primacy to implement UIC Class II wells. The rules are found in Texas Administrative Code Title 16, Part 1, Chapter 3 and are also explained in a TRRC Injection/Disposal Well Permitting, Testing and Monitoring Manual (See Appendix 12-3). TRRC rules govern well siting, construction, operation, maintenance, and closure for all wells in oilfields. Briefly, TRRC rules include the following requirements:

- Fluids must be constrained in the strata in which they are encountered;
- Activities cannot result in the pollution of subsurface or surface water;
- Wells must adhere to specified casing, cementing, drilling well control, and completion requirements designed to prevent fluids from moving from the strata they are encountered into other strata with oil and gas, or into subsurface and surface waters;
- Completion report for each well including basic electric log (e.g., a density, sonic, or resistivity (except dip meter) log run over the entire wellbore) must be prepared;
- Operators must follow plugging procedures that require advance approval from the TRRC Director and allow consideration of the suitability of the cement based on the use of the well, the location and setting of plugs; and,
- Injection well operators must identify an Area of Review (AoR), use compatible materials and equipment, test, and maintain well records.

Table 2 provides a well count by type and status. All these wells are in material compliance with TRRC rules.

Table 1 WSSAU Well Penetrations by Type and Status

TYPE	**ACTIVE**	**Dry & Abandoned**	**INACTIVE**	**P & A**	**SHUT-IN**	**TA**	**Total**
DISP_H2O	2			2			**4**
INJ_GAS					1		**1**
INJ_H2O	23		7	25	3	5	**63**
INJ_WAG	35						**35**
OBSERVATION	1					1	**2**
PROD_GAS						3	**3**
PROD_OIL	80	2	4	16		16	**118**
SUP_H2O						1	**1**
TOTAL	**141**	**2**	**11**	**43**	**4**	**26**	**227**

As indicated in Figure 3-6, wells are distributed across the WSSAU. The well patterns currently undergoing CO2 flooding are outlined in the black box and CO2 will be injected across the entire unit over the project life.

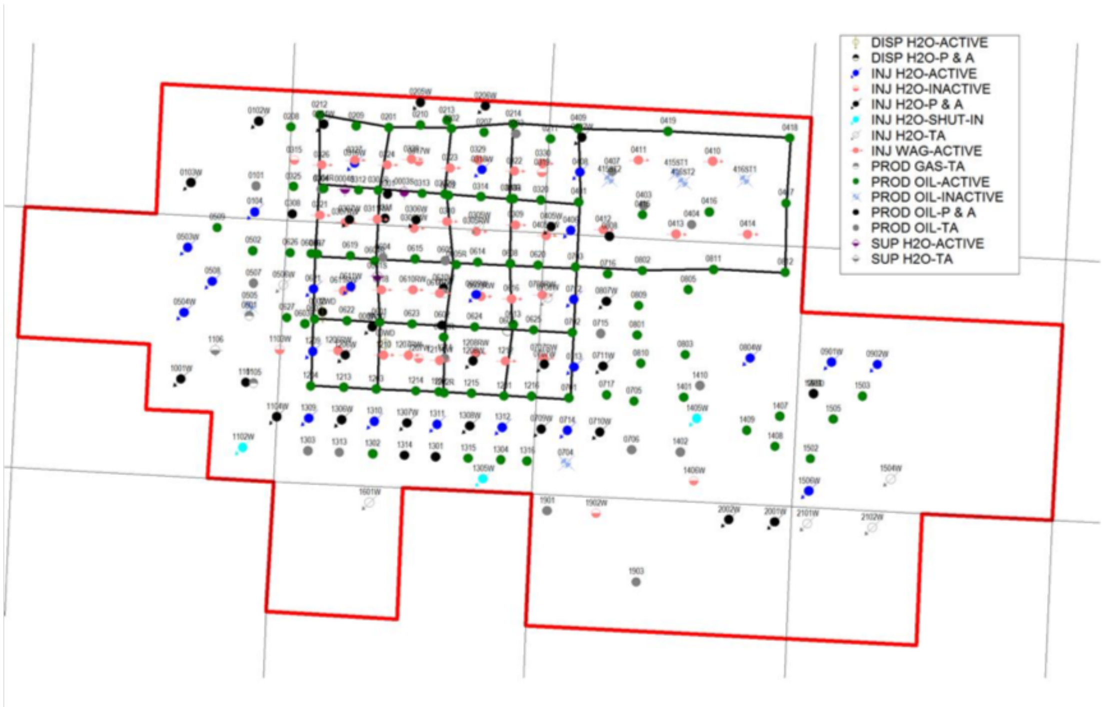

Figure 3-6 WSSAU Wells and Injection Patterns

WSSAU CO2 EOR operations are designed to avoid conditions which could damage the reservoir and cause a potential leakage pathway. Reservoir pressure in the WSSAU is managed by maintaining an injection to withdrawal ratio (IWR)[1] of approximately 1.0. To maintain the IWR, fluid injection and production are monitored and managed to ensure that reservoir pressure does not increase to a level that would compromise the reservoir seal or otherwise damage the integrity of the oil field.

Injection pressure is also maintained below the FPP, which is measured using step-rate tests.

3.4. Reservoir modeling

A history matched reservoir model of the current and forecast WSSAU CO2 injection has been made. The model was constructed using Eclipse software which is a commercially available

[1] Injection to withdrawal ratio (IWR) is the ratio of the volume of fluids injected to the volume of fluids produced (withdrawn). Volumes are measured under reservoir conditions for all fluids. Injected fluids are CO2 and water; produced fluids are oil, water, and CO2. By keeping IWR close to 1.0, reservoir pressure is held constant, neither increasing nor decreasing.

reservoir simulation code. The model simulates the recovery mechanism in which CO2 is miscible with the hydrocarbon in the reservoir.

The model was created to:

i. Demonstrate that the storage complex has, at the minimum, the capacity to contain the planned volume of purchased CO2.
ii. Track injected CO2, identify how and where CO2 is trapped in the WSSAU, and to monitor sequestration volumes and distribution.

The reservoir model utilizes four types of data:

i. Site Characteristics as described in the WSSAU Geomodel,
ii. Initial reservoir conditions and fluid property data
iii. Capillary pressure data, and
iv. Well data

The geomodel used as the foundation for the reservoir model used data from 232 wells in the area of interest that includes WSSAU. These wells have digital open- or cased-hole logs that were used for correlation of formation tops. A sequence stratigraphic framework was developed based upon core descriptions and outcrop analogs, this correlation framework was then extrapolated to well logs. The sequence stratigraphic correlations are picked at the base of mud-dominated flooding surfaces mapped out in core and extrapolated to well logs throughout the rest of the field.

The model is a four-component model consisting of water, oil, reservoir gas and injected CO2. It is an extension of the black oil model that enables the modeling of recovery mechanisms in which the injected CO2 is miscible with reservoir oil. This is a reasonable assumption since the reservoir under study is above minimum miscibility pressure (MMP). The total hydrocarbon and solvent (CO2) saturation is used to calculate relative permeability to water. The solvent and oil relative permeability are then calculated using multipliers from a look-up table. The Todd-Longstaff[2] model is used to calculate the effective viscosity and density of the hydrocarbon and solvent phases.

History matching is the process of adjusting input parameters within the range of data uncertainties until the actual reservoir performance is closely reproduced in the model. A 70-year history match was obtained. All three-phase rates (oil, gas, and water) are included in the history record. The model uses liquid rate control (combination of oil and water) for the history match.

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[2] Todd, M.R., Longstaff, W.J.: The development, testing and application of a numerical simulator for predicting miscible flood performance. J. Petrol. Tech. 24(7), 874–882 (1972)

The graphs in Figure 3-7 present the history match results of oil rate, gas rates, water rates, and water cut and show that the reservoir model provides an excellent match to actual historic data. Figure 3-8 shows the match of water and CO2 injection.

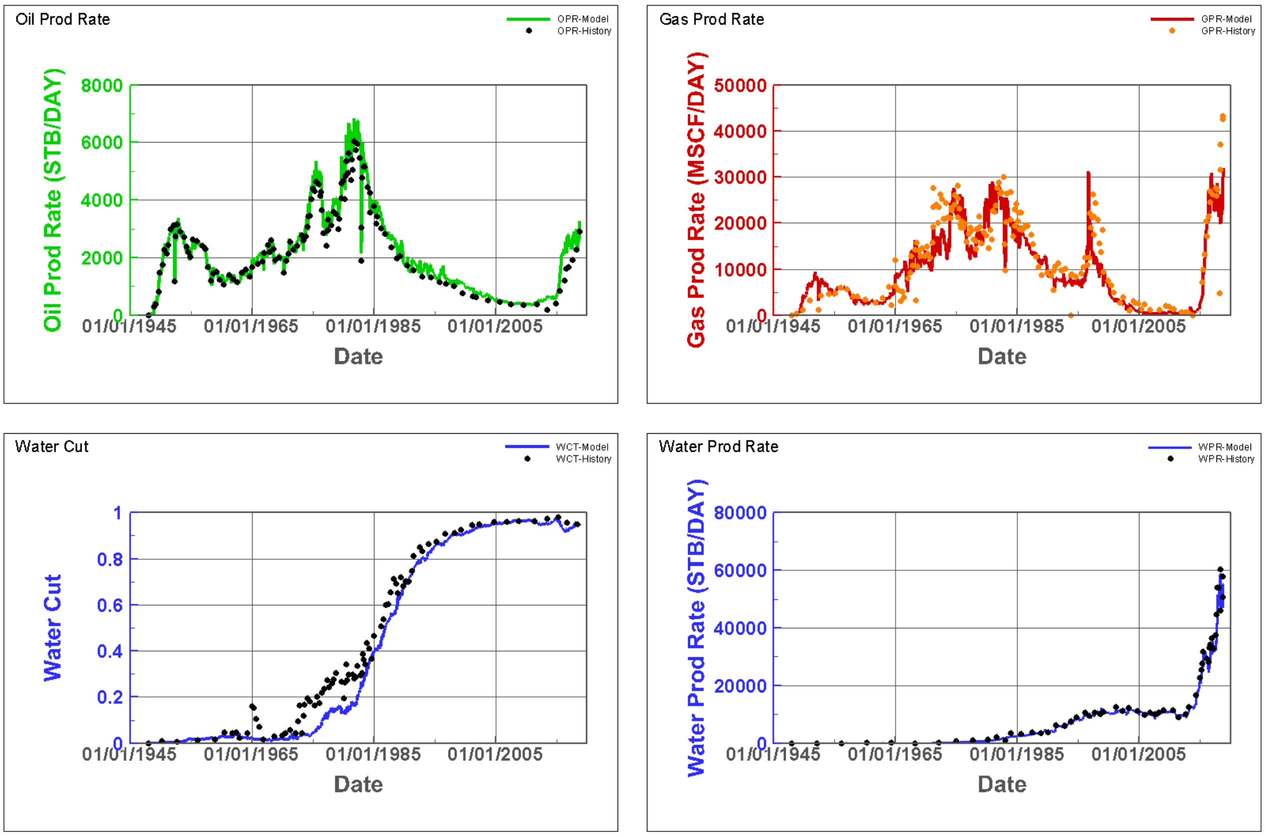

Figure 3-7 Four Parameters of History-Matched Modeling in the WSSAU Reservoir Model

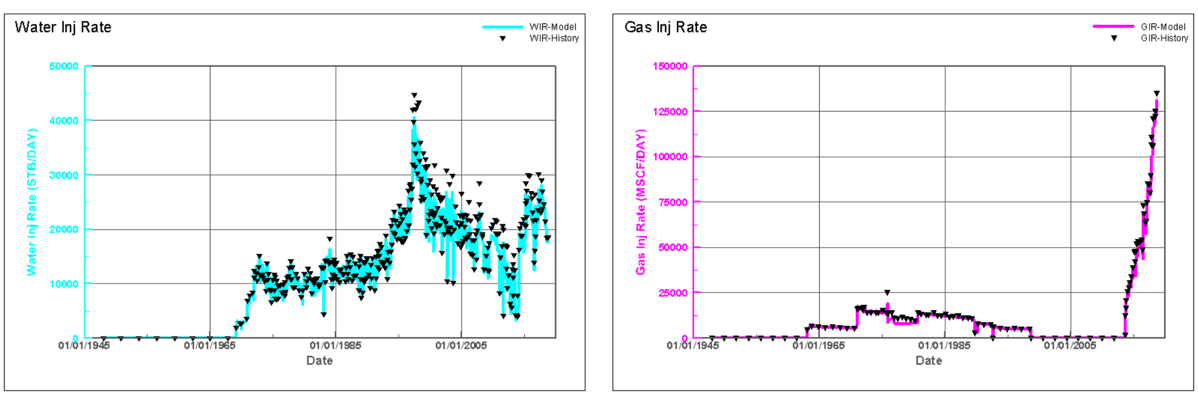

Figure 3-8 Plots of Injection History Match in the WSSAU Reservoir Model

The WSSAU reservoir model was used to evaluate the plume of CO2 using a set of injection, production, and facilities constraints that describe the injection plan. The history match indicates that the model is robust and that there is little chance that uncertainty about any specific variable will have a meaningful impact on the reservoir CO_2 storage performance. The model forecast showed that CO_2 is contained in the reservoir within the boundaries of WSSAU.

4. Delineation of Monitoring Area and Timeframes

4.1. Active Monitoring Area

The Active Monitoring Area (AMA) is defined by the boundary of the WSSAU plus the required ½ mile buffer.

4.2. Maximum Monitoring Area

The Maximum Monitoring Area (MMA) is defined by the boundary of the WSSAU plus the required ½ mile buffer as required by 40 CFR §98.440-449 (Subpart RR).

4.3. Monitoring Timeframes

The primary purpose for injecting CO2 is to produce oil that would otherwise remain trapped in the reservoir and not, as in UIC Class VI, "specifically for the purpose of geologic storage."[3] During a Specified Period, there will be a subsidiary purpose of establishing the long-term containment of CO2 in the WSSAU. The Specified Period will be shorter than the period of production from the WSSAU.

At the conclusion of the Specified Period, a request for discontinuation of reporting will be submitted. This request will be submitted with a demonstration that current monitoring and model(s) show that the cumulative mass of CO2 reported as sequestered during the Specified Period is not expected to migrate in the future in a manner likely to result in surface leakage. It is expected that it will be possible to make this demonstration almost immediately after the Specified Period ends based upon predictive modeling supported by monitoring data.

The reservoir pressure in the WSSAU is collected for use reservoir modeling and operations management. Reservoir pressure is not forecast to change appreciably since the IWR will be maintained at approximately 1.0. The reservoir model shows that by the end of CO2 injection, average reservoir pressure will be approximately 2,360 psi. Once injection ceases, reservoir pressure is predicted to stabilize within one year. Over time, reservoir pressure is expected to drop by approximately 10 psi. The trend of the reservoir pressure decline will be one of the bases of a request to discontinue monitoring and reporting.

[3] EPA UIC Class VI rule, EPA 75 FR 77291, December 10, 2010, section 146.81(b).

5. Evaluation of Potential Pathways for Leakage to the Surface, Leakage Detection, Verification, and Quantification

In the roughly 70 years since the oil field of the WSSAU was discovered, the reservoir has been studied and documented extensively. Based on the knowledge gained from that experience, this section assesses the potential pathways for leakage of stored CO2 to the surface including:

i. Existing Well Bores
ii. Faults and Fractures
iii. Natural and Induced Seismic Activity
iv. Previous Operations
v. Pipeline/Surface Equipment
vi. Lateral Migration Outside the WSSAU
vii. Drilling Through the CO2 Area
viii. Diffuse Leakage Through the Seal

This analysis shows that leakage through wellbores and surface equipment pose the only meaningful potential leakage pathways. The monitoring program to detect and quantify leakage is based on this assessment as discussed below.

5.1. Existing Wellbores

As part of the TRRC requirement to initiate CO2 flooding, an extensive review of all WSSAU penetrations was completed to determine the need for corrective action. That analysis showed that all penetrations have either been adequately plugged and abandoned or, if in use, do not require corrective action. All wells in the WSSAU were constructed and are operated in compliance with TRRC rules.

As part of routine risk management, the potential risk of leakage associated with the following were identified and evaluated:

i. CO2 flood beam wells
ii. Electrical submersible pump (ESP) producer wells, and
iii. CO2 WAG injector wells.

The risk assessment classified all risks associated with subsurface as low risk, i.e., less than 1% likelihood to occur and having a consequence that is insubstantial. The risks were classified as low risk because, the WSSAU geology is well suited to CO2 sequestration with an extensive confining zone that is free of fractures and faults that could be potential conduits for CO2 migration. The low risk is supported by the results of the reservoir model which shows that stored CO2 is not predicted to leave the WSSAU boundary. Any risks are further mitigated because the WSSAU is operated in a manner that maintains, monitors, and documents the integrity of the reservoir.

The risk of well leakage is mitigated through:

i. Adhering to regulatory requirements for well drilling and testing;

ii. implementing best practices that Oxy has developed through its extensive operating experience;
iii. monitoring injection/production performance, wellbores, and the surface; and,
iv. maintaining surface equipment.

Continual and routine monitoring of the wellbores and site operations will be used to detect leaks or other potential well problems, as follows:

- Pressure in injection wells is monitored on a continual basis. The injection plans for each pattern are programmed into the injection WAG satellite to govern the rate, pressure, and duration of either water or CO2 injection. Pressure monitors on the injection wells are programmed to flag whenever statistically significant pressure deviations from the targeted ranges in the plan are identified. Leakage on the inside or outside of the injection wellbore would affect pressure and be detected through this approach. If such events occur, they are investigated and addressed. Oxy's experience, from over 40 years of operating CO2 EOR projects, is that such leakage is very rare and there have been no incidents of fluid migration out of the intended zone at WSSAU.

- Production well performance is monitored using the production well test process conducted when produced fluids are gathered and sent to an SAT. There is a routine well testing cycle for each SAT, with each well being tested approximately once every two months. During this cycle, each production well is diverted to the well test equipment for a period of time sufficient to measure and sample produced fluids (generally 8-12 hours). These tests are the basis for allocating a portion of the produced fluids measured at the SAT to each production well, assessing the composition of produced fluids by location, and assessing the performance of each well. Performance data are reviewed on a routine basis to ensure that CO2 flooding efficiency is optimized. If production is off the plan, it is investigated and any identified issues addressed. Leakage to the outside of production wells is not considered a major risk because of the reduced pressure in the casing. Further, the personal H2S monitors are designed to detect leaked fluids around production wells during well inspections.

- Field inspections are conducted on a routine basis by field personnel. Leaking CO2 is very cold and leads to formation of bright white clouds and ice that are easily spotted. All field personnel are trained to identify leaking CO2 and other potential problems at wellbores and in the field. Any CO2 leakage detected will be documented and reported and quantified.

Based on an ongoing monitoring activities and review of the potential leakage risks posed by well bores, it is concluded that the risk of CO2 leakage through well bores is being mitigated by detecting problems as they arise and quantifying any leakage that does occur.

5.2. Faults and Fractures

After reviewing geologic, seismic, operating, and other evidence, it has been concluded that there are no known faults or fractures that transect the San Andres reservoir in the project area. As a result, there is no risk of leakage due to fractures or faults.

Measurements to determine FPP and reservoir pressure are routinely updated. This information is used to manage injection patterns so that the injection pressure will not exceed FPP. An IWR at or near 1 is also maintained. Both of these measures mitigate the potential for inducing faults or fractures. As a safeguard, WAG skids are continuously monitored and set with automatic shutoff controls if injection pressures exceed programmed levels.

5.3. Natural or Induced Seismicity

After reviewing the literature and actual operating experience, it is concluded that there is no direct evidence that natural seismic activity poses a significant risk for loss of CO2 to the surface in the Permian Basin, and specifically in the WSSAU. Oxy participates in the TexNet seismic monitoring network[4] and will continue to monitor for seismic signals that could indicate the creation of potential leakage pathways in WSSAU.

5.4. Previous Operations

CO2 flooding was initiated in WSSAU in 2013. To obtain permits for CO2 flooding, the AoR around all CO2 injector wells was evaluated to determine if there were any unknown penetrations and to assess if corrective action was required at any wells. As indicated in Section 5.1, this evaluation reviewed the identified penetrations and determined that no additional corrective action was needed. Further, Oxy's standard practice for drilling new wells includes a rigorous review of nearby wells to ensure that drilling will not cause damage to or interfere with existing wells. And, requirements to construct wells with materials that are designed for CO2 injection are adhered to at WSSAU. These practices ensure that that there are no unknown wells within WSSAU and that the risk of migration from older wells has been sufficiently mitigated. The successful experience with CO2 flooding in WSSAU demonstrates that the confining zone has not been impaired by previous operations.

5.5. Pipelines and Surface Equipment

As part of routine risk management described in Section 5, the potential risk of leakage associated with the following are identified and evaluated:

i. The production satellite
ii. The Central Tank Battery; and
iii. Facility pipelines.

As described in Section 5.1, the risk assessment classified all subsurface risks as low risk, i.e., less than 1% likelihood to occur and having a consequence that is insubstantial. The risks

[4] https://www.beg.utexas.edu/texnet-cisr/texnet

associated with pipelines and surface equipment were classified as low risk because, the WSSAU is operated in a manner that maintains, monitors, and documents the integrity of the reservoir.

The risk of well leakage is mitigated through:

i. Adhering to regulatory requirements for well drilling and testing;
ii. implementing best practices that Oxy has developed through its extensive operating experience;
iii. monitoring injection/production performance, wellbores, and the surface; and,
iv. maintaining surface equipment.

Personnel continuously monitor the pipeline system using the SCADA system and are able to detect and mitigate pipeline leaks expeditiously. Such risks will be prevented, to the extent possible, by relying on the use of prevailing design and construction practices and maintaining compliance with applicable regulations. The facilities and pipelines currently utilize and will continue to utilize materials of construction and control processes that are standard for CO2 EOR projects in the oil and gas industry. Operating and maintenance practices currently follow and will continue to follow demonstrated industry standards. CO2 delivery via the Permian Basin CO2 pipeline system will continue to comply with all applicable regulations. Finally, routine visual inspection of surface facilities by field staff will provide an additional way to detect leaks and further support the efforts to detect and remedy any leaks in a timely manner. Should leakage be detected from pipeline or surface equipment, the volume of released CO2 will be quantified following the requirements of Subpart W of EPA's GHGRP.

5.6. Lateral Migration Outside the WSSAU

It is highly unlikely that injected CO2 will migrate downdip and laterally outside the WSSAU because of the nature of the geology and the approach used for injection. First, WSSAU is situated in the highest local elevations within the San Andres. This means that over long periods of time, injected CO2 will tend to rise vertically towards the Upper San Andres and continue towards the point in the WSSAU with the highest elevation. Second, the planned injection volumes and active fluid management during injection operations will prevent CO2 from migrating laterally out of the structure. Finally, the total volume of fluids contained in the WSSAU will stay relatively constant. Based on site characterization and planned and projected operations it is estimated that the total volume of stored CO2 will be considerably less than calculated capacity.

5.7. Drilling in the WSSAU

The TRRC regulates well drilling activity in Texas. Pursuant to TRRC rules, wells casing shall be securely anchored in the hole in order to effectively control the well at all times, all usable-quality water zones shall be isolated and sealed off to effectively prevent contamination or harm, and all productive zones, potential flow zones, and zones with corrosive formation fluids shall be isolated and sealed off to prevent vertical migration of fluids, including gases, behind the casing. Where TRRC rules do not detail specific methods to achieve these objectives, operators shall make every effort to follow the intent of the section, using good engineering practices and the best currently available technology. The TRRC requires applications and approvals before a well is drilled, recompleted, or reentered. Well drilling activity at WSSAU is conducted in accordance with TRRC rules. Oxy's visual inspection process, including routine site visits, will identify unapproved drilling activity in the WSSAU.

In addition, Oxy intends to operate WSSAU for several more decades and will continue to be vigilant about protecting the integrity of its assets and maximizing the potential of its resources, including oil, gas and CO2. Consequently, the risks associated with third parties penetrating the WSSAU are negligible.

5.8. Diffuse Leakage Through the Seal

Diffuse leakage through the seal formed by the upper San Andres is highly unlikely. The presence of a gas cap trapped over millions of years confirms that the seal has been secure. Injection pattern monitoring assures that no breach of the seal will be created. Wellbores that penetrate the seal make use of cement and steel construction that is closely regulated to ensure that no leakage takes place. Injection pressure is continuously monitored and unexplained changes in injection pressure that might indicate leakage would trigger investigation as to the cause.

5.9. Leakage Detection, Verification, and Quantification

As discussed above, the potential sources of leakage include issues, such as problems with surface equipment (pumps, valves, etc.) or subsurface equipment (well bores), and unique events such as induced fractures. An event-driven process to assess, address, track, and if applicable quantify potential CO2 leakage is used. Table 3 summarizes some of these potential leakage scenarios, the monitoring activities designed to detect those leaks, the standard response, and other applicable regulatory programs requiring similar reporting.

Given the uncertainty concerning the nature and characteristics of any leaks that may be encountered, the most appropriate methods for quantifying the volume of leaked CO2 will be determined on a case by case basis. In the event leakage occurs, the most appropriate methods for quantifying the volume leaked will be determined and it will be reported as required as part of the annual Subpart RR submission.

Any volume of CO2 detected leaking to surface will be quantified using acceptable emission factors such as those found in 40 CFR Part 98 Subpart W or engineering estimates of leak amounts based on measurements in the subsurface, field experience, and other factors such as the frequency of inspection. Leaks will be documented, evaluated and addressed in a timely manner. Records of leakage events will be retained in the electronic environmental documentation and reporting system. Repairs requiring a work order will be documented in the electronic equipment maintenance system.

Table 2 Response Plan for CO2 Loss

Risk	Monitoring Plan	Response Plan
Tubing Leak	Monitor changes in tubing and annulus pressure; MIT for injectors	Wellbore is shut in and workover crews respond within days
Casing Leak	Routine Field inspection; Monitor changes in annulus pressure, MIT for injectors; extra attention to high risk wells	Well is shut in and workover crews respond within days
Wellhead Leak	Routine Field inspection, SCADA system monitors wellhead pressure	Well is shut in and workover crews respond within days
Loss of Bottom-hole pressure control	Blowout during well operations	Maintain well kill procedures
Unplanned wells drilled through San Andres	Routine Field inspection to prevent unapproved drilling; compliance with TRRC permitting for planned wells.	Assure compliance with TRRC regulations
Loss of seal in abandoned wells	Reservoir pressure in WAG headers; high pressure found in new wells	Re-enter and reseal abandoned wells
Pumps, valves, etc.	Routine Field inspection, SCADA	Workover crews respond within days
Overfill beyond spill points	Reservoir pressure in WAG headers; high pressure found in new wells	Fluid management along lease lines
Leakage through induced fractures	Reservoir pressure in WAG headers; high pressure found in new wells	Comply with rules for keeping pressures below parting pressure
Leakage due to seismic event	Reservoir pressure in WAG headers; high pressure found in new wells	Shut in injectors near seismic event

5.10. Summary

The structure and stratigraphy of the San Andres reservoir in the WSSAU is ideally suited for the injection and storage of CO2. The stratigraphy within the CO2 injection zones is porous, permeable and thick, providing ample capacity for long-term CO2 storage. The reservoir is overlain by several intervals of impermeable geologic zones that form effective seals or “caps” to fluids in the reservoir. After assessing potential risk of release from the subsurface and steps that have been taken to prevent leaks, it has been determined that the potential threat of leakage is extremely low.

In summary, based on a careful assessment of the potential risk of release of CO2 from the subsurface, it has been determined that there are no leakage pathways at the WSSAU that are likely to result in significant loss of CO2 to the atmosphere. Further, given the detailed knowledge of the field and its operating protocols, it is concluded that any CO2 leakage to the surface that could arise through either identified or unexpected leakage pathways would be detected and quantified.

6. Monitoring and Considerations for Calculating Site Specific Variables

Monitoring will also be used to determine the quantities in the mass balance equation and to make the demonstration that the CO2 plume will note migrate to the surface after the time of discontinuation.

6.1. For the Mass Balance Equation

6.1.1. General Monitoring Procedures

Flow rate, pressure, and gas composition data are monitored and collected from the WSSAU in centralized data management systems as part of ongoing operations. These data are monitored by qualified technicians who follow response and reporting protocols when the systems deliver notifications that data exceed statistically acceptable boundaries.

Metering protocols used at WSSAU follow the prevailing industry standard(s) for custody transfer as currently promulgated by the API, the American Gas Association (AGA), and the Gas Processors Association (GPA), as appropriate. This approach is consistent with EPA GHGRP's Subpart RR, section 98.444(e)(3). These meters will be maintained routinely, operated continually, and will feed data directly to the centralized data collection systems. The meters meet the industry standard for custody transfer meter accuracy and calibration frequency.

6.1.2. CO2 Received

As indicated in Figure 3-5, the volume of received CO2 is measured using a commercial custody transfer meter at the point at which custody of the CO2 from the Permian Basin CO2 pipeline delivery system is transferred to the WSSAU. This meter measures flow rate continually. The transfer is a commercial transaction that is documented. CO2 composition is governed by contract and the gas is routinely sampled. Fluid composition will be determined, at a minimum, quarterly, consistent with EPA GHGRP's Subpart RR, section 98.447(a). All meter and composition data are documented, and records will be retained for at least three years. No CO2 is received in containers.

6.1.3. CO2 Injected in the Subsurface

Injected CO2 will be calculated using the flow meter volumes at the operations meter at the outlet of the RCF and the custody transfer meter at the CO2 off-take point from the Permian Basin CO2 pipeline delivery system

6.1.4. CO2 Produced, Entrained in Products, and Recycled

The following measurements are used for the mass balance equations in Section 7:

CO2 produced in the gaseous stage is calculated using the volumetric flow meters at the inlet to the RCF.

CO_2 that is entrained in produced oil, as indicated in Figure 3-5, is calculated using volumetric flow through the custody transfer meter.

Recycled CO_2 is calculated using the volumetric flow meter at the outlet of the RCF. , which is an operations meter.

6.1.5. CO_2 Emitted by Surface Leakage

Oxy uses 40 CFR Part 98 Subpart W to estimate surface leaks from equipment at the WSSAU. Subpart W uses a factor-driven approach to estimate equipment leakage. In addition, an event-driven process to assess, address, track, and if applicable quantify potential CO_2 leakage to the surface is used. The Subpart W report and results from any event-driven quantification will be reconciled to assure that surface leaks are not double counted.

The multi-layered, risk-based monitoring program for event-driven incidents has been designed to meet two objectives: 1) to detect problems before CO_2 leaks to the surface; and 2) to detect and quantify any leaks that do occur. This section discusses how this monitoring will be conducted and used to quantify the volumes of CO_2 leaked to the surface.

<u>Monitoring for potential Leakage from the Injection/Production Zone:</u>
In addition to the measures discussed in Section 5.9, both injection into and production from the reservoir will be monitored as a means of early identification of potential anomalies that could indicate leakage from the subsurface.

Reservoir simulation modeling, based on extensive history-matched data, is used to develop injection plans (fluid rate, pressure, volume) that are programmed into each WAG satellite. If injection pressure or rate measurements are outside the specified set points determined as part of each pattern injection plan, a data flag is automatically triggered and field personnel will investigate and resolve the problem. These excursions will be reviewed by well management personnel to determine if CO_2 leakage may be occurring. Excursions are not necessarily indicators of leaks; they simply indicate that injection rates and pressures are not conforming to the pattern injection plan. In many cases, problems are straightforward to fix (e.g., a meter needs to be recalibrated or some other minor action is required), and there is no threat of CO_2 leakage. In the case of issues that are not readily resolved, more detailed investigation and response would be initiated, and support staff would provide additional assistance and evaluation. Such issues would lead to the development of a work order in the work order management system. This record enables the tracking of progress on investigating potential leaks and, if a leak has occurred, to quantify its magnitude.

Likewise, a forecast of the rate and composition of produced fluids is developed. Each producer well is assigned to a specific SAT and is isolated during each cycle for a well production test. This data is reviewed on a periodic basis to confirm that production is at the level forecasted. If there is a significant deviation from the plan, well management personnel investigate. If the issue cannot be resolved quickly, more detailed investigation and response would be initiated. As in the case of the injection pattern monitoring, if the investigation leads to a work order in the work order management system, this record will provide the basis for tracking the outcome of the investigation and if a leak has occurred, recording the quantity leaked to the surface. If leakage in the flood zone were detected, an appropriate method would be used to quantify the involved volume of CO_2. This might include use of material balance equations based on known injected quantities and monitored pressures in the injection zone to estimate the volume of CO_2 involved.

A subsurface leak might not lead to a surface leak. In the event of a subsurface leak, Oxy would determine the appropriate approach for tracking subsurface leakage to determine and quantify leakage to the surface. To quantify leakage, the relevant parameters (e.g., the rate, concentration, and duration of leakage) would be estimated to quantify the leak volume. Depending on specific circumstances, these determinations may rely on engineering estimates.

In the event leakage from the subsurface occurred diffusely through the seals, the leaked gas would include H_2S, which would trigger the alarm on the personal monitors worn by field personnel. Such a diffuse leak from the subsurface has not occurred in the WSSAU. In the event such a leak was detected, personnel would determine how to address the problem. The personnel might use modeling, engineering estimates, and direct measurements to assess, address, and quantify the leakage.

Monitoring of Wellbores*:*
WSSAU wells are monitored through continual, automated pressure monitoring of the injection zone, monitoring of the annular pressure in wellheads, and routine maintenance and inspection.

Leaks from wellbores would be detected through the follow-up investigation of pressure anomalies, visual inspection, or the use of personal H_2S monitors.

Anomalies in injection zone pressure may not indicate a leak, as discussed above. However, if an investigation leads to a work order, field personnel would inspect the equipment in question and determine the nature of the problem. If it is a simple matter, the repair would be made and the volume of leaked CO_2 would be included in the 40 CFR Part 98 Subpart W report for the WSSAU. If more extensive repair were needed, the appropriate approach for quantifying leaked CO_2 using the relevant parameters (e.g., the rate, concentration, and duration of leakage) would be determined. The work order would serve as the basis for tracking the event for GHG reporting.

Anomalies in annular pressure or other issues detected during routine maintenance inspections would be treated in the same way. Field personnel would inspect the equipment in question and determine the nature of the problem. For simple matters the repair would be made at the time of inspection and the volume of leaked CO_2 would be included in the 40 CFR Part 98 Subpart W report for the WSSAU. If more extensive repairs were needed, the well would be shut in, a work order would be generated and the appropriate approach for quantifying leaked CO_2 using the relevant parameters (e.g., the rate, concentration, and duration of leakage) would be determined. The work order would serve as the basis for tracking the event for GHG reporting.

Because leaking CO2 at the surface is very cold and leads to formation of bright white clouds and ice that are easily spotted, a visual inspection process in the area of the WSSAU is employed to detect unexpected releases from wellbores. Field personnel visit the surface facilities on a routine basis. Inspections may include tank levels, equipment status, lube oil levels, pressures and flow rates in the facility, and valves. Field personnel also check that injectors are on the proper WAG schedule and observe the facility for visible CO2 or fluid line leaks.

Finally, the data collected by the H2S monitors, which are worn by all field personnel at all times, is used as a last method to detect leakage from wellbores. The H2S monitors detection limit is 10 ppm; if an H2S alarm is triggered, the first response is to protect the safety of the personnel, and the next step is to safely investigate the source of the alarm. As noted previously, H2S is considered a proxy for potential CO2 leaks in the field. Thus, detected H_2S leaks will be investigated to determine and, if needed, quantify potential CO2 leakage. If the incident results in a work order, this will serve as the basis for tracking the event for GHG reporting.

Other Potential Leakage at the Surface:

The same visual inspection process and H2S monitoring system will be used to detect other potential leakage at the surface as it does for leakage from wellbores. Routine visual inspections are used to detect significant loss of CO2 to the surface. Field personnel routinely visit surface facilities to conduct a visual inspection. Inspections may include review of tank level, equipment status, lube oil levels, pressures and flow rates in the facility, valves, ensuring that injectors are on the proper WAG schedule, and also conducting a general observation of the facility for visible CO2 or fluid line leaks. If problems are detected, field personnel would investigate, and, if maintenance is required, generate a work order in the maintenance system, which is tracked through completion. In addition to these visual inspections, the results of the personal H2S monitors worn by field personnel will be used as a supplement for smaller leaks that may escape visual detection.

If CO2 leakage to the surface is detected, it will be reported to surface operations personnel who will review the reports and conduct a site investigation. If maintenance is required, steps are taken to prevent further leaks, a work order will be generated in the work order management system. The work order will describe the appropriate corrective action and be used to track completion of the maintenance action. The work order will also serve as the basis for tracking the event for GHG reporting and quantifying any CO2 emissions.

6.1.6. CO_2 emitted from equipment leaks and vented emissions of CO_2 from surface equipment located between the injection flow meter and the injection wellhead

Oxy evaluates and estimates leaks from equipment, the CO_2 content of produced oil, and vented CO_2, as required under 40 CFR Part 98 Subpart W.

6.1.7. CO_2 emitted from equipment leaks and vented emissions of CO_2 from surface equipment located between the production flow meter and the production wellhead

Oxy evaluates and estimates leaks from equipment, the CO_2 content of produced oil, and vented CO_2, as required under 40 CFR Part 98 Subpart W.

6.2. To Demonstrate that Injected CO_2 is not Expected to Migrate to the Surface

At the end of the Specified Period, injecting CO_2 for the subsidiary purpose of establishing the long-term storage of CO_2 in the WSSAU will cease. Some time after the end of the Specified Period, a request to discontinue monitoring and reporting will be submitted. The request will demonstrate that the amount of CO_2 reported under 40 CFR §98.440-449 (Subpart RR) is not expected to migrate in the future in a manner likely to result in surface leakage. At that time, the request will be supported with years of data collected during the Specified Period as well as two to three (or more, if needed) years of data collected after the end of the Specified Period. This demonstration will provide the information necessary for the EPA Administrator to approve the request to discontinue monitoring and reporting and may include, but is not limited to:

i. Data comparing actual performance to predicted performance (purchase, injection, production) over the monitoring period;
ii. An assessment of the CO_2 leakage detected, including discussion of the estimated amount of CO_2 leaked and the distribution of emissions by leakage pathway;
iii. A demonstration that future operations will not release the volume of stored CO_2 to the surface;
iv. A demonstration that there has been no significant leakage of CO_2; and,
v. An evaluation of reservoir pressure that demonstrates that injected fluids are not expected to migrate in a manner to create a potential leakage pathway.

7. Determination of Baselines

Existing automatic data systems will be utilized to identify and investigate excursions from expected performance that could indicate CO2 leakage. Data systems are used primarily for operational control and monitoring and as such are set to capture more information than is necessary for reporting in the Annual Subpart RR Report. The necessary system guidelines to capture the information that is relevant to identify possible CO2 leakage will be developed. The following describes the approach to collecting this information.

<u>Visual Inspections</u>

As field personnel conduct routine inspections, work orders are generated in the electronic system for maintenance activities that cannot be addressed on the spot. Methods to capture work orders that involve activities that could potentially involve CO2 leakage will be developed, if not currently in place. Examples include occurrences of well workover or repair, as well as visual identification of vapor clouds or ice formations. Each incident will be flagged for review by the person responsible for MRV documentation (the responsible party will be provided in the monitoring plan, as required under Subpart A, 98.3(g)) .The Annual Subpart RR Report will include an estimate of the amount of CO2 leaked. Records of information used to calculate emissions will be maintained on file for a minimum of three years.

<u>Personal H2S Monitors</u>

H2S monitors are worn by all field personnel. Any monitor alarm triggers an immediate response to ensure personnel are not at risk and to verify the monitor is working properly. The person responsible for MRV documentation will receive notice of all incidents where H2S is confirmed to be present. The Annual Subpart RR Report will provide an estimate the amount of CO2 emitted from any such incidents. Records of information to calculate emissions will be maintained on file for a minimum of three years.

<u>Injection Rates, Pressures and Volumes</u>

Target injection rate and pressure for each injector are developed within the permitted limits based on the results of ongoing pattern modeling. The injection targets are programmed into the WAG satellite controllers. High and low set points are also programmed into the controllers, and flags whenever statistically significant deviations from the targeted ranges are identified. The set points are designed to be conservative, because it is preferable to have too many flags rather than too few. As a result, flags can occur frequently and are often found to be insignificant. For purposes of Subpart RR reporting, flags (or excursions) will be screened to determine if they could also lead to CO2 leakage to the surface. The person responsible for the MRV documentation will receive notice of excursions and related work orders that could potentially involve CO2 leakage. The Annual Subpart RR Report will provide an estimate of CO2 emissions. Records of information to calculate emissions will be maintained on file for a minimum of three years.

<u>Production Volumes and Compositions</u>

A general forecast of production volumes and composition is developed which is used to periodically evaluate performance and refine current and projected injection plans and the forecast. This information is used to make operational decisions but is not recorded in an automated data system. Sometimes, this review may result in the generation of a work order in the maintenance system. The MRV plan implementation lead will review such work orders and identify those that could result in CO2 leakage. Should such events occur, leakage volumes would be calculated following the approaches described in Sections 5 and 6. Impact to Subpart RR reporting will be addressed, if deemed necessary.

8. Determination of Sequestration Volumes Using Mass Balance Equations

To account for the potential propagation of error that would result if volume data from flow meters at each injection and production well were utilized, it is proposed to use the data from custody and operations meters on the main system pipelines to determine injection and production volumes used in the mass balance. This issue arises because while each meter has a small but acceptable margin of error, this error would become significant if data were taken from all of the well head meters within the WSSAU.

The following sections describe how each element of the mass-balance equation (Equation RR-11) will be calculated.

8.1. Mass of CO2 Received

Equation RR-2 will be used as indicated in Subpart RR §98.443 to calculate the mass of CO2 at the receiving custody transfer meter from the Permian Basin CO2 pipeline delivery system. The volumetric flow at standard conditions will be multiplied by the CO2 concentration and the density of CO2 at standard conditions to determine mass.

$$CO2_{T,r} = \sum_{p=1}^{4} (Q_{p,r} - S_{p,r}) * D * C_{CO2,r,p} \qquad \text{(Eq. RR-2)}$$

where:

$CO2_{T,r}$ = Net annual mass of CO2 received through flow meter r (metric tons).

$Q_{r,p}$ = Quarterly volumetric flow through a receiving flow meter r in quarter p at standard conditions (standard cubic meters).

$S_{r,p}$ = Quarterly volumetric flow through a receiving flow meter r that is redelivered to another facility without being injected into a site well in quarter p (standard cubic meters).

D = Density of CO2 at standard conditions (metric tons per standard cubic meter): 0.0018682.

$C_{CO2,r,r}$ = Quarterly CO2 concentration measurement in flow for flow meter r in quarter p (vol. percent CO2, expressed as a decimal fraction).

p = Quarter of the year.

r = Receiving flow meters.

Given WSSAU's method of receiving CO2 and requirements at Subpart RR §98.444(a):

- All delivery to the WSSAU is used within the unit so quarterly flow redelivered, $S_{r,p}$, is zero ("0") and will not be included in the equation.
- Quarterly CO2 concentration will be taken from the gas measurement database

Currently this is not needed because there is one offtake, but if additional offtakes are used, they will be summed to total Mass of CO2 Received using equation RR-3 in 98.443

$$CO2 = \sum_{r=1}^{R} CO2_{T,r} \qquad \text{(Eq. RR-3)}$$

where:

$CO2$ = Total net annual mass of CO2 received (metric tons).

$CO2_{T,r}$ = Net annual mass of CO2 received (metric tons) as calculated in Equation RR-2 for flow meter r.

r = Receiving flow meter.

8.2. Mass of CO2 Injected into the Subsurface

The equation for calculating the Mass of CO2 Injected into the Subsurface at the WSSAU is equal to the sum of the Mass of CO2 Received as calculated in RR-3 of 98.443 (section 8.1 above) and the Mass of CO2 Recycled calculated using measurements taken from the flow meter located at the output of the RCF (see Figure 3-5). As previously explained, using data at each injection well would give an inaccurate estimate of total injection volume due to the large number of wells and the potential for propagation of error due to allowable calibration ranges for each meter.

The Mass of CO2 Recycled will be determined using equations RR-5 as follows:

$$CO2_u = \sum_{p=1}^{4} Q_{p,u} * D * C_{CO2,p,u} \qquad \text{(Eq. RR-5)}$$

where:

$CO2_u$ = Annual CO2 mass recycled (metric tons) as measured by flow meter u.

$Q_{p,u}$ = Quarterly volumetric flow rate measurement for flow meter u in quarter p at standard conditions (standard cubic meters per quarter).

D = Density of CO2 at standard conditions (metric tons per standard cubic meter): 0.0018682.

$C_{CO2,p,u}$ = CO2 concentration measurement in flow for flow meter u in quarter p (vol. percent CO2, expressed as a decimal fraction).

p = Quarter of the year.

u = Flow meter.

The total Mass of CO2 Injected will be the sum of the Mass of CO2 Received (RR-3) and Mass of CO2 Recycled (modified RR-5).

$$CO2_I = CO2 + CO2_u$$

8.3. Mass of CO2 Produced

The Mass of CO2 Produced at the WSSAU will be calculated using the measurements from the flow meters at the inlet to RCF and the custody transfer meter for oil sales rather than the metered data from each production well. Again, using the data at each production well would give an inaccurate estimate of total injection due to the large number of wells and the potential for propagation of error due to allowable calibration ranges for each meter.

Equation RR-8 in 98.443 will be used to calculate the Mass of CO2 Produced from all injection wells as follows:

$$CO2_w = \sum_{p=1}^{4} Q_{p,w} * D * C_{CO2,p,w} \qquad \text{(Eq. RR-8)}$$

Where:

$CO2_W$ = Annual CO2 mass produced (metric tons) .

$Q_{P,W}$ = Volumetric gas flow rate measurement for meter w in quarter p at standard conditions (standard cubic meters).

D = Density of CO2 at standard conditions (metric tons per standard cubic meter): 0.0018682.

$C_{CO2,P,W}$ = CO2 concentration measurement in flow for meter w in quarter p (vol. percent CO2, expressed as a decimal fraction).

p = Quarter of the year.

w = inlet meter to RCF.

Equation RR-9 in 98.443 will be modified to reflect the measured amount of CO2 entrained in oil and the modified equation will be used to aggregate the mass of CO2 produced including the mass of CO2 entrained in oil leaving the WSSAU prior to treatment of the remaining gas fraction in RCF as follows:

$$CO2_p = \sum_{w=1}^{W} CO2_w + X_{oil} \qquad \text{(Eq. RR-9)}$$

Where:

$CO2_P$ = Total annual CO2 mass produced (metric tons) through all meters in the reporting year.

$CO2_W$ = Annual CO2 mass produced (metric tons) through meter w in the reporting year.

X_{oil} = Mass of entrained CO2 in oil in the reporting year measured utilizing commercial meters and electronic flow-measurement devices at each point of custody transfer. The mass of CO2 will be calculated by multiplying the total volumetric rate by the CO2 concentration.

8.4. Mass of CO2 Emitted by Surface Leakage

The total annual Mass of CO2 emitted by Surface Leakage will be calculated and reported using an approach that is tailored to specific leakage events and relies on 40 CFR Part 98 Subpart W reports of equipment leakage. Oxy is prepared to address the potential for leakage in a variety of settings. Estimates of the amount of CO2 leaked to the surface will depend on a number of site-specific factors including measurements, engineering estimates, and emission factors, depending on the source and nature of the leakage.

The process for quantifying leakage will entail using best engineering principles or emission factors. While it is not possible to predict in advance the types of leaks that will occur, some approaches for quantification are described in Sections 5.9 and 6. In the event leakage to the surface occurs, leakage amounts would be quantified and reported, and records that describe the methods used to estimate or measure the volume leaked as reported in the Annual Subpart RR Report would be retained. Further, the Subpart W report and results from any event-driven quantification will be reconciled to assure that surface leaks are not double counted.

Equation RR-10 in 48.433 will be used to calculate and report the Mass of CO2 emitted by Surface Leakage:

$$CO2_E = \sum_{x=1}^{x} CO2_x \qquad \text{(Eq. RR-10)}$$

where:

$CO2_E$ = Total annual CO2 mass emitted by surface leakage (metric tons) in the reporting year.

$CO2_x$ = Annual CO2 mass emitted (metric tons) at leakage pathway x in the reporting year.

x = Leakage pathway.

8.5. Mass of CO2 Sequestered in Subsurface Geologic Formation

Equation RR-11 in 98.443 will be used to calculate the Mass of CO2 Sequestered in Subsurface Geologic Formations in the Reporting Year as follows:

$$CO2 = CO2_I - CO2_P - CO2_E - CO2_{FI} - CO2_{FP} \qquad \text{(Eq. RR-11)}$$

where:

CO2 = Total annual CO2 mass sequestered in subsurface geologic formations (metric tons) at the facility in the reporting year.

$CO2_I$ = Total annual CO2 mass injected (metric tons) in the well or group of wells covered by this source category in the reporting year.

$CO2_P$ = Total annual CO2 mass produced (metric tons) net of CO2 entrained in oil in the reporting year.

$CO2_E$ = Total annual CO2 mass emitted (metric tons) by surface leakage in the reporting year.

$CO2_{FI}$ = Total annual CO2 mass emitted (metric tons) from equipment leaks and vented emissions of CO2 from equipment located on the surface between the flow meter used to measure injection quantity and the injection wellhead, for which a calculation procedure is provided in subpart W of this part.

$CO2_{FP}$ = Total annual CO2 mass emitted (metric tons) from equipment leaks and vented emissions of CO2 from equipment located on the surface between the production wellhead and the flow meter used to measure production quantity, for which a calculation procedure is provided in subpart W of this part.

8.6. Cumulative Mass of CO2 Reported as Sequestered in Subsurface Geologic Formation

The total annual volumes obtained using equation RR-11 in 98.443 will be summed to arrive at the Cumulative Mass of CO2 Sequestered in Subsurface Geologic Formations.

9. MRV Plan Implementation Schedule

This MRV plan will be implemented starting January 2021 or within 90 days of EPA approval, whichever occurs later. Other GHG reports are filed on March 31 of the year after the reporting year and it is anticipated that the Annual Subpart RR Report will be filed at the same time. It is anticipated that the MRV program will be in effect during the Specified Period, during which time the WSSAU will be operated with the subsidiary purpose of establishing long-term containment of a measurable quantity of CO2 in subsurface geological formations at the WSSAU. It is anticipated to establish that a measurable amount of CO2 injected during the Specified Period will be stored in a manner not expected to migrate resulting in future surface leakage. At such time, a demonstration supporting the long-term containment determination will be prepared and a request to discontinue monitoring and reporting under this MRV plan will be submitted. *See* 40 C.F.R. § 98.441(b)(2)(ii).

10. Quality Assurance Program

10.1. Monitoring QA/QC

The requirements of §98.444 (a) – (d) have been incorporated in the discussion of mass balance equations. These include the following provisions.

CO2 Received and Injected

- The quarterly flow rate of CO2 received by pipeline is measured at the receiving custody transfer meters.
- The quarterly CO2 flow rate for recycled CO2 is measured at the flow meter located at the RCF outlet.

CO2 Produced

- The point of measurement for the quantity of CO2 produced from oil or other fluid production wells is a flow meter directly downstream of each separator that sends a stream of gas into a recycle or end use system.
- The produced gas stream is sampled at least once per quarter immediately downstream of the flow meter used to measure flow rate of that gas stream and measure the CO2 concentration of the sample.
- The quarterly flow rate of the produced gas is measured at the flow meters located at the RCF inlet.

CO2 emissions from equipment leaks and vented emissions of CO2

These volumes are measured in conformance with the monitoring and QA/QC requirements specified in subpart W of 40 CFR Part 98.

Flow meter provisions

The flow meters used to generate date for the mass balance equations are:

- Operated continuously except as necessary for maintenance and calibration.
- Operated using the calibration and accuracy requirements in 40 CFR §98.3(i).
- Operated in conformance with American Petroleum Institute (API) standards.
- National Institute of Standards and Technology (NIST) traceable.

Concentration of CO2

CO2 concentration is measured using an appropriate standard method. Further, all measured volumes of CO2 have been converted to standard cubic meters at a temperature of 60 degrees Fahrenheit and at an absolute pressure of 1 atmosphere, including those used in Equations RR-2, RR-5 and RR-8 in Section 8.

10.2. Missing Data Procedures

In the event data needed for the mass balance calculations cannot be collected, procedures for estimating missing data in §98.445 will be used as follows:

- A quarterly flow rate of CO_2 received that is missing would be estimated using invoices or using a representative flow rate value from the nearest previous time period.
- A quarterly CO_2 concentration of a CO_2 stream received that is missing would be estimated using invoices or using a representative concentration value from the nearest previous time period.
- A quarterly quantity of CO_2 injected that is missing would be estimated using a representative quantity of CO_2 injected from the nearest previous period of time at a similar injection pressure.
- For any values associated with CO_2 emissions from equipment leaks and vented emissions of CO_2 from surface equipment at the facility that are reported in this subpart, missing data estimation procedures specified in subpart W of 40 CFR Part 98 would be followed.
- The quarterly quantity of CO_2 produced from subsurface geologic formations that is missing would be estimated using a representative quantity of CO_2 produced from the nearest previous period of time.

10.3. MRV Plan Revisions

In the event there is a material change to the monitoring and/or operational parameters of the CO_2 EOR operations in the WSSAU that is not anticipated in this MRV plan, the MRV plan will be revised and submitted to the EPA Administrator within 180 days as required in §98.448(d).

11. Records Retention

The record retention requirements specified by §98.3(g) will be followed. In addition, the requirements in Subpart RR §98.447 will be met by maintaining the following records for at least three years:

- Quarterly records of CO_2 received at standard conditions and operating conditions, operating temperature and pressure, and concentration of these streams.
- Quarterly records of produced CO_2, including volumetric flow at standard conditions and operating conditions, operating temperature and pressure, and concentration of these streams.
- Quarterly records of injected CO_2 including volumetric flow at standard conditions and operating conditions, operating temperature and pressure, and concentration of these streams.
- Annual records of information used to calculate the CO_2 emitted by surface leakage from leakage pathways.
- Annual records of information used to calculate the CO_2 emitted from equipment leaks and vented emissions of CO_2 from equipment located on the surface between the flow meter used to measure injection quantity and the injection wellhead.
- Annual records of information used to calculate the CO_2 emitted from equipment leaks and vented emissions of CO_2 from equipment located on the surface between the production wellhead and the flow meter used to measure production quantity.

These data will be collected as generated and aggregated as required for reporting purposes.

12. Appendix

12.1 Well Identification Numbers

The following table presents the well name and API number, type and status for active wells in WSSAU as of May 2020. The table is subject to change over time as new wells are drilled, existing wells change status, or existing wells are repurposed. The following terms are used:

- Well Status
  - ACTIVE refers to active wells
  - DRILL refers to wells under construction
  - TA refers to wells that have been temporarily abandoned
  - SHUT_IN refers to wells that have been temporarily idled or shut-in
  - INACTIVE refers to wells that have been completed but are not in use
- Well Type
  - DISP_H2O refers to wells for water disposal
  - INJ_GAS refers to wells that inject CO2 Gas
  - INJ_WAG refers to wells that inject water and CO2 Gas
  - INJ_H2O refers to wells that inject water
  - OBSERVATION refers to observation or monitoring wells
  - PROD_GAS refers to wells that produce natural gas
  - PROD_OIL refers to wells that produce oil
  - SUP_H2O refers to wells that supply water

Well Name & Number	Well Type	Well Status
WSSAU-0002WD	DISP_H2O	ACTIVE
WSSAU-0101	PROD_OIL	TA
WSSAU-0104	INJ_H2O	ACTIVE
WSSAU-0201	PROD_OIL	ACTIVE
WSSAU-0202	PROD_OIL	ACTIVE
WSSAU-0203	PROD_OIL	TA
WSSAU-0207	PROD_OIL	ACTIVE
WSSAU-0208	PROD_OIL	ACTIVE
WSSAU-0209	PROD_OIL	ACTIVE
WSSAU-0210	PROD_OIL	ACTIVE
WSSAU-0211	PROD_OIL	ACTIVE
WSSAU-0212	PROD_OIL	ACTIVE
WSSAU-0213	PROD_OIL	ACTIVE
WSSAU-0214	PROD_OIL	ACTIVE
WSSAU-0301R	PROD_OIL	ACTIVE
WSSAU-0302R	PROD_OIL	ACTIVE
WSSAU-0303	PROD_OIL	ACTIVE

WSSAU-0303R	PROD_OIL	ACTIVE
WSSAU-0304R	PROD_OIL	ACTIVE
WSSAU-0305RW	INJ_WAG	ACTIVE
WSSAU-0305W	INJ_H2O	TA
WSSAU-0306RW	INJ_WAG	ACTIVE
WSSAU-0307RW	INJ_WAG	ACTIVE
WSSAU-0309	INJ_WAG	ACTIVE
WSSAU-0310	INJ_WAG	ACTIVE
WSSAU-0311RW	INJ_WAG	ACTIVE
WSSAU-0312	PROD_OIL	ACTIVE
WSSAU-0313	PROD_OIL	ACTIVE
WSSAU-0314	PROD_OIL	ACTIVE
WSSAU-0315	INJ_H2O	INACTIVE
WSSAU-0316W	INJ_H2O	ACTIVE
WSSAU-0317W	INJ_H2O	INACTIVE
WSSAU-0318W	INJ_H2O	ACTIVE
WSSAU-0319	INJ_H2O	INACTIVE
WSSAU-0320	PROD_OIL	ACTIVE
WSSAU-0321	INJ_WAG	ACTIVE
WSSAU-0322	INJ_WAG	ACTIVE
WSSAU-0323	INJ_WAG	ACTIVE
WSSAU-0324	INJ_WAG	ACTIVE
WSSAU-0325	PROD_OIL	ACTIVE
WSSAU-0326	INJ_WAG	ACTIVE
WSSAU-0327	INJ_WAG	ACTIVE
WSSAU-0328	INJ_WAG	ACTIVE
WSSAU-0329	INJ_WAG	ACTIVE
WSSAU-0330	INJ_WAG	ACTIVE
WSSAU-03WD	DISP_H2O	ACTIVE
WSSAU-0401	PROD_OIL	ACTIVE
WSSAU-0404	PROD_OIL	TA
WSSAU-0405RW	INJ_WAG	ACTIVE
WSSAU-0406	INJ_H2O	ACTIVE
WSSAU-0407	PROD_OIL	TA
WSSAU-0408	INJ_H2O	ACTIVE
WSSAU-0409	PROD_OIL	ACTIVE
WSSAU-0410	INJ_WAG	ACTIVE
WSSAU-0411	INJ_WAG	ACTIVE

WSSAU-0412	INJ_WAG	ACTIVE
WSSAU-0413	INJ_WAG	ACTIVE
WSSAU-0414	INJ_WAG	ACTIVE
WSSAU-0415	PROD_OIL	ACTIVE
WSSAU-0416	PROD_OIL	ACTIVE
WSSAU-0417	PROD_OIL	ACTIVE
WSSAU-0418	PROD_OIL	ACTIVE
WSSAU-0419	PROD_OIL	ACTIVE
WSSAU-0501	PROD_GAS	TA
WSSAU-0502	PROD_OIL	ACTIVE
WSSAU-0503W	INJ_H2O	ACTIVE
WSSAU-0504W	INJ_H2O	ACTIVE
WSSAU-0505	PROD_OIL	ACTIVE
WSSAU-0507	PROD_OIL	TA
WSSAU-0508	INJ_H2O	ACTIVE
WSSAU-0509	PROD_OIL	ACTIVE
WSSAU-0601	PROD_OIL	ACTIVE
WSSAU-0602R	PROD_OIL	ACTIVE
WSSAU-0603	PROD_OIL	ACTIVE
WSSAU-0603R	PROD_OIL	ACTIVE
WSSAU-0604	PROD_OIL	TA
WSSAU-0604R	PROD_OIL	ACTIVE
WSSAU-0605	PROD_OIL	TA
WSSAU-0605R	PROD_OIL	ACTIVE
WSSAU-0606	INJ_GAS	SHUT-IN
WSSAU-0607	PROD_OIL	ACTIVE
WSSAU-0607R	PROD_OIL	ACTIVE
WSSAU-0608	PROD_OIL	ACTIVE
WSSAU-0609RW	INJ_WAG	ACTIVE
WSSAU-0609W	INJ_H2O	ACTIVE
WSSAU-0610RW	INJ_WAG	ACTIVE
WSSAU-0611RW	INJ_WAG	ACTIVE
WSSAU-0611W	INJ_H2O	ACTIVE
WSSAU-0613	PROD_OIL	ACTIVE
WSSAU-0614	PROD_OIL	ACTIVE
WSSAU-0615	PROD_OIL	ACTIVE
WSSAU-0616	INJ_WAG	ACTIVE
WSSAU-0617	PROD_GAS	TA

WSSAU-0617RW	INJ_WAG	ACTIVE
WSSAU-0618	INJ_WAG	ACTIVE
WSSAU-0619	PROD_OIL	ACTIVE
WSSAU-0620	PROD_OIL	ACTIVE
WSSAU-0621	INJ_H2O	ACTIVE
WSSAU-0622	PROD_OIL	ACTIVE
WSSAU-0623	PROD_OIL	ACTIVE
WSSAU-0624	PROD_OIL	ACTIVE
WSSAU-0625	PROD_OIL	ACTIVE
WSSAU-0626	PROD_OIL	ACTIVE
WSSAU-0627	PROD_OIL	ACTIVE
WSSAU-0701	PROD_OIL	ACTIVE
WSSAU-0702	PROD_OIL	ACTIVE
WSSAU-0703	PROD_OIL	ACTIVE
WSSAU-0704	PROD_OIL	ACTIVE
WSSAU-0705	PROD_OIL	ACTIVE
WSSAU-0706	PROD_OIL	TA
WSSAU-0707RW	INJ_WAG	ACTIVE
WSSAU-0708RW	INJ_WAG	ACTIVE
WSSAU-0708W	OBSERVATION	ACTIVE
WSSAU-0712	INJ_H2O	ACTIVE
WSSAU-0713	INJ_H2O	ACTIVE
WSSAU-0714	INJ_H2O	ACTIVE
WSSAU-0715	PROD_OIL	TA
WSSAU-0716	PROD_OIL	ACTIVE
WSSAU-0717	PROD_OIL	ACTIVE
WSSAU-0801	PROD_OIL	TA
WSSAU-0802	PROD_OIL	ACTIVE
WSSAU-0803	PROD_OIL	ACTIVE
WSSAU-0804W	INJ_H2O	ACTIVE
WSSAU-0805	PROD_OIL	ACTIVE
WSSAU-0809	PROD_OIL	ACTIVE
WSSAU-0810	PROD_OIL	ACTIVE
WSSAU-0811	PROD_OIL	ACTIVE
WSSAU-0812	PROD_OIL	ACTIVE
WSSAU-0901W	INJ_H2O	ACTIVE
WSSAU-0902W	INJ_H2O	ACTIVE
WSSAU-1102W	INJ_H2O	SHUT-IN

WSSAU-1103W	INJ_H2O	INACTIVE
WSSAU-1105	PROD_GAS	TA
WSSAU-1106	SUP_H2O	TA
WSSAU-1201	PROD_OIL	ACTIVE
WSSAU-1202R	PROD_OIL	ACTIVE
WSSAU-1203	PROD_OIL	ACTIVE
WSSAU-1204	PROD_OIL	ACTIVE
WSSAU-1206RW	INJ_WAG	ACTIVE
WSSAU-1207RW	INJ_WAG	ACTIVE
WSSAU-1207W	INJ_H2O	INACTIVE
WSSAU-1208RW	INJ_WAG	ACTIVE
WSSAU-1209	INJ_H2O	ACTIVE
WSSAU-1210	INJ_WAG	ACTIVE
WSSAU-1211	OBSERVATION	TA
WSSAU-1211RW	INJ_WAG	ACTIVE
WSSAU-1212	INJ_WAG	ACTIVE
WSSAU-1213	PROD_OIL	ACTIVE
WSSAU-1214	PROD_OIL	ACTIVE
WSSAU-1215	PROD_OIL	ACTIVE
WSSAU-1216	PROD_OIL	ACTIVE
WSSAU-1302	PROD_OIL	SHUT-IN
WSSAU-1303	PROD_OIL	TA
WSSAU-1304	PROD_OIL	ACTIVE
WSSAU-1305W	INJ_H2O	SHUT-IN
WSSAU-1309	INJ_H2O	ACTIVE
WSSAU-1310	INJ_H2O	ACTIVE
WSSAU-1311	INJ_H2O	ACTIVE
WSSAU-1312	INJ_H2O	ACTIVE
WSSAU-1313	PROD_OIL	TA
WSSAU-1315	PROD_OIL	ACTIVE
WSSAU-1316	PROD_OIL	ACTIVE
WSSAU-1401	PROD_OIL	SHUT-IN
WSSAU-1402	PROD_OIL	TA
WSSAU-1403	PROD_OIL	ACTIVE
WSSAU-1405W	INJ_H2O	SHUT-IN
WSSAU-1406W	INJ_H2O	INACTIVE
WSSAU-1407	PROD_OIL	ACTIVE
WSSAU-1408	PROD_OIL	ACTIVE

WSSAU-1409	PROD_OIL	ACTIVE
WSSAU-1410	PROD_OIL	TA
WSSAU-1502	PROD_OIL	ACTIVE
WSSAU-1503	PROD_OIL	ACTIVE
WSSAU-1504W	INJ_H2O	SHUT-IN
WSSAU-1505	PROD_OIL	ACTIVE
WSSAU-1506W	INJ_H2O	ACTIVE
WSSAU-1601W	INJ_H2O	SHUT-IN
WSSAU-1901	PROD_OIL	TA
WSSAU-1902W	INJ_H2O	INACTIVE
WSSAU-1903	PROD_OIL	TA
WSSAU-2101W	INJ_H2O	TA
WSSAU-2102W	INJ_H2O	TA

12.2 Regulatory References

Regulations cited in this plan:

i. Texas Administrative Code Title 16 Part 1 Chapter 3 Oil & Gas Division - https://texreg.sos.state.tx.us/public/readtac$ext.ViewTAC?tac_view=4&ti=16&pt=1&ch=3&rl=Y

ii. TRRC Injection/Disposal Well Permitting, Testing and Monitoring Manual - https://www.rrc.state.tx.us/oil-gas/publications-and-notices/manuals/injectiondisposal-well-manual/