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A Four-County Appraisal of the San Andres Residual Oil Zone (ROZ) "Fairway" of the Permian Basin

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A Four-County Appraisal of the San Andres Residual Oil Zone (ROZ) "Fairway" of the Permian Basin

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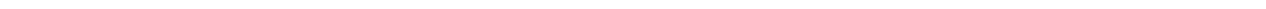
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LIST OF EXHIBITS

ACRONYMS AND ABBREVIATIONS

AF	Acre foot		MM	Million
ARI	Advanced Resources International, Inc.		MPZ	Main pay zone
			mt	Metric ton
bbl	Barrel		NETL	National Energy Technology Laboratory
B	Billion			
B/AF	Barrels per acre foot		O&M	Operation and maintenance
Bcf	Billion cubic feet		OIP	Oil in-place
CBP	Central Basin Platform		PEF	Photo-electric
CO_2	Carbon dioxide		ROZ	Residual oil zone
DOE	Department of Energy		RPSEA	Research Partnership to Secure Energy for America
EIA	Energy Information Administration			
			Rt	Resistivity of formation
EOR	Enhanced oil recovery		Rw	Water resistivity
FE	Office of Fossil Energy		Tcf	Trillion cubic feet
ft	Feet		U.S.	United States
FVF	Formation volume of factor		UTPB	University of Texas Permian Basin
g/cc	grams per cubic centimeter			
HCPV	Hydrocarbon pore volume		WACC	After tax weighted average cost of capital
km	Kilometer			
Mcf	Thousand cubic feet		WAG	Water-alternating-gas
MESA	Mission Execution and Strategic Analysis		WTI	West Texas Intermediate
			$/bbl	Dollars per barrel
mi	Mile		μ-sec/ft	Microsecond per foot

EXECUTIVE SUMMARY

This report addresses the four-county San Andres Residual Oil Zone (ROZ) "fairway" within the West Texas portion of the Permian Basin—Gaines, Yoakum, Terry, and Dawson counties (Exhibit ES-1). In this report, the term "ROZ fairway" refers to the portion of the ROZ where there is no overlying oil field. The ROZ under a conventional oil field is not included in the assessment.

Exhibit ES-1. San Andres ROZ fairway resources: four-county area of West Texas
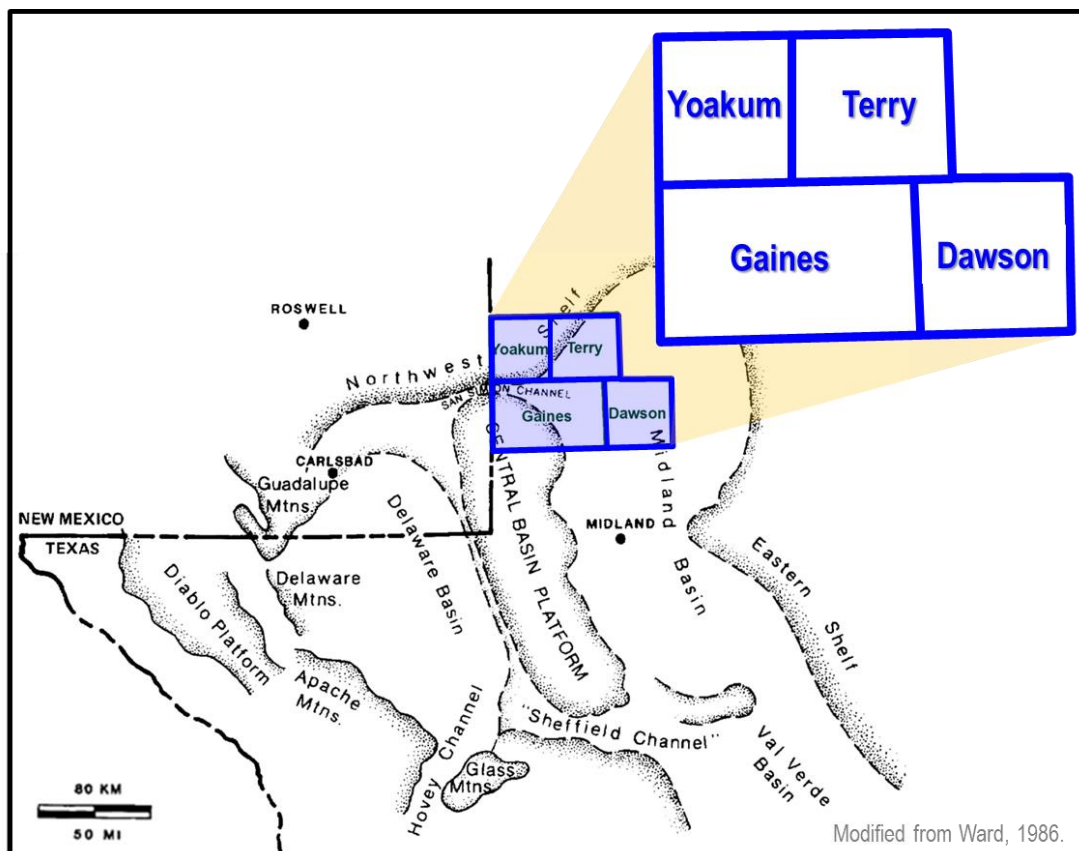
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This four-county San Andres ROZ fairway resource assessment has been undertaken to address five fundamental questions:

1. *What is the size and distribution of the in-place San Andres ROZ fairway oil resource favorable for CO_2-enhanced oil recovery (EOR)?*

The San Andres ROZ fairway resource in Gaines, Yoakum, Terry, and Dawson counties of the Permian Basin, West Texas, hold 104.3 billion barrels of oil in-place (OIP). Much of this resource is higher quality (porosity greater than 8 percent and oil saturation greater than 25 percent), offering promise for commercially viable development (Exhibit ES-2).

Exhibit ES-2. In-place San Andres ROZ fairway resources: four-county area of West Texas

County	In-Place Resources		
	Total	Higher Quality	Lower Quality
	B bbls	B bbls	B bbls
Gaines	41.4	32.0	9.3
Yoakum	17.7	14.1	3.6
Terry	16.8	10.5	6.3
Dawson	28.4	15.2	13.3
Total	104.3	71.8	32.5

2. *How much of this in-place San Andres ROZ fairway oil resource can be mobilized and technically produced using CO_2 EOR?*

The application of miscible CO_2 EOR enables 28.1 billion barrels (about 27 percent) of the San Andres ROZ fairway OIP to become technically recoverable (Exhibit ES-3)(.

Exhibit ES-3. Technically recoverable San Andres ROZ fairway resources: four-county area of West Texas

County	Technically Recoverable Resources	
	B bbls	% OIP
Gaines	12.1	29%
Yoakum	4.3	24%
Terry	4.3	25%
Dawson	7.4	26%
Total	28.1	27%

3. *How much CO_2 can be stored by developing the San Andres ROZ fairway resource in this four-county area?*

Major volumes, 20.0 billion metric tons (378 Tcf), of primarily anthropogenic CO_2 will be needed to develop the San Andres ROZ fairway resource (Exhibit ES-4). At the completion of the CO_2 flood, essentially all of the purchased CO_2 will be stored in the San Andres ROZ fairway interval. During the operation of the CO_2 flood, the produced CO_2 is re-injected.

Exhibit ES-4. Volume of purchased CO_2 necessary for developing the San Andres ROZ fairway resource: four-county area of West Texas

County	Purchased			
	CO_2 Injection		CO_2/Oil Recovery Ratio	
	Tcf	B mt	Mcf/bbl	mt/bbl
Gaines	132	7.0	10.9	0.58
Yoakum	47	2.5	10.9	0.58
Terry	73	3.9	17.1	0.90
Dawson	125	6.6	16.9	0.89
Total	**378**	**20.0**	**13.4**	**0.71**

Considerably more CO_2 can be stored in the San Andres fairway resource, 0.71 metric tons per barrel of oil produced, than the 0.4 metric tons of CO_2 per barrel in the oil recovered from the San Andres ROZ fairway resource after the oil is combusted.[a]

4. *What portion of the San Andres ROZ fairway resource can be economically developed while providing by-product storage of CO_2?*

A significant portion of the San Andres ROZ fairway resource, equal to 20.4 billion barrels, is <u>commercially viable</u> at an initial oil price of $75 per barrel, associated with a CO_2 cost of $28.35/metric tons ($1.50/Mcf), and a minimum financial hurdle rate of 10 percent after tax average weighted cost of capital. Producing this oil with CO_2 EOR will provide geologically secure space for 9.9 billion metric tons (186 Tcf) of by-product storage of CO_2 (Exhibit ES-5), assuming all of the purchased CO_2 is stored.

Exhibit ES-5. Commercially viable oil recovery with by-product CO_2 storage: San Andres ROZ fairway resource, four-county area of West Texas

County	Oil Recovery (B bbls)	Purchased CO_2		Purchased CO_2/ Oil Recovery Ratio	
		Tcf	B mt	Mcf/bbl	mt/bbl
Gaines	10.1	86.3	4.57	8.5	0.45
Yoakum	2.8	27.6	1.46	9.7	0.51
Terry	2.8	29.4	1.56	10.4	0.55
Dawson	4.7	43.1	2.28	9.2	0.49
Total	**20.4**	**186.4**	**9.87**	**9.1**	**0.48**

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[a] Note that this is a marginal, rather than a full life-cycle, analysis of CO_2 emissions associated with CO_2 EOR. It is provided to show the magnitude of the difference in carbon-intensity between conventionally produced and CO_2 EOR-produced crude oil. Both conventional oil production and CO_2 EOR use additional energy, with their associated CO_2 emissions, for drilling wells, injecting and producing fluids, and conducting other oil field activities.

5. *What value could the uneconomic portion of the San Andres ROZ fairway resource provide?*

While the remaining portion of the San Andres ROZ fairway resource is not commercially viable (at the above oil price and CO_2 costs), this portion of the resource offers <u>geologically viable</u> potential for storing 10.1 billion metric tons (192 Tcf) of CO_2, while providing 7.8 billion barrels of by-product oil recovery (Exhibit ES-6).

Exhibit ES-6. Geologically viable storage of CO_2 with by-product oil recovery: San Andres ROZ fairway resource, four-county area of West Texas

County	Purchased CO_2		By-Product Oil Recovery	Purchased CO_2/ Oil Recovery Ratio	
	Tcf	B mt	(B bbls)	Mcf/bbl	mt/bbl
Gaines	45.9	2.43	2.0	22.7	1.20
Yoakum	19.5	1.03	1.5	13.2	0.70
Terry	43.9	2.32	1.5	30.2	1.60
Dawson	82.4	4.36	2.8	30.0	1.59
Total	191.7	10.14	7.8	24.6	1.30

The above assessment of oil recovery and CO_2 storage capacity offered by the San Andres ROZ fairway in the four-county area of West Texas has been conducted assuming the use of currently available CO_2 EOR technology. Use of "Next Generation" CO_2 EOR technology would enable significantly more of this resource to become commercially viable and would also enable more CO_2 to be geologically stored.

<p style="text-align:center">*   *   *   *   *</p>

1 THE FOUR-COUNTY SAN ANDRES RESIDUAL OIL ZONE FAIRWAY STUDY AREA

1.1 INTRODUCTION

The San Andres Residual Oil Zone (ROZ) "fairway" resource represents the remnant trapped oil from a massive paleo-oil reservoir that was swept by a multi-million-year natural waterflood during the Tertiary period. Establishing the size and economic viability of oil recovery from this ROZ fairway resource is a primary purpose of this study. Equally important is establishing the size of the opportunity for geologic storage of CO_2 with CO_2 enhanced oil recovery (EOR).

This study addresses a four-county area within the West Texas portion of the Permian Basin—Gaines, Yoakum, Terry, and Dawson counties (Exhibit 1-1). The resource assessment targets the Slaughter and Roswell ROZ fairways where they merge with the Artesia fairway in the northern Permian Basin.

Exhibit 1-1. San Andres ROZ fairways of the Permian Basin, West Texas
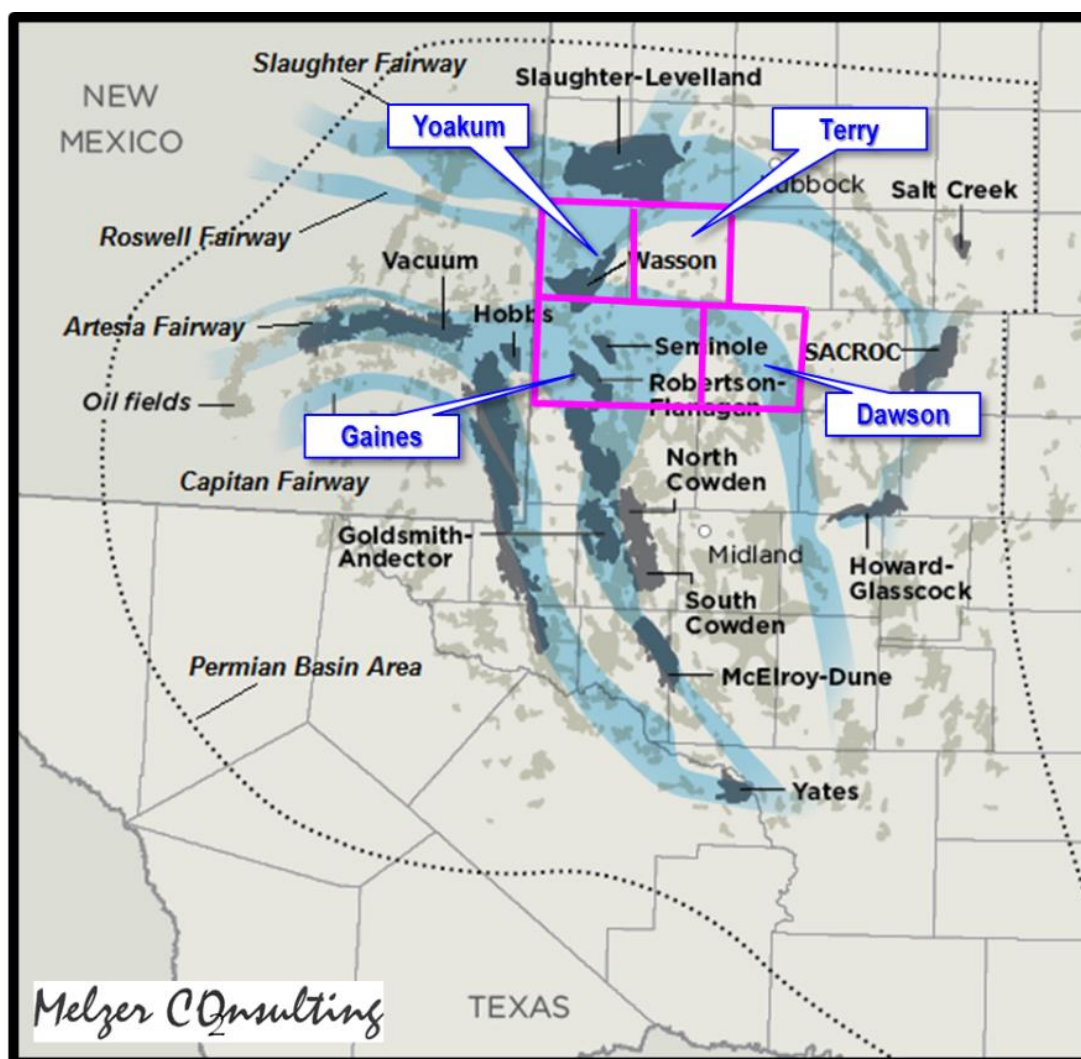
A series of major oil fields—Wasson, Seminole, and Robertson, among many others—are located within these four counties. The areas underneath the structural closure of these oil fields have been excluded from the San Andres ROZ fairway resource assessment. An initial estimate for the volumes of San Andres ROZ resources below existing Permian Basin oil fields is available in a separate report prepared by Advanced Resources International (ARI). [2]

1.2 THE PERMIAN BASIN

1.2.1 Geologic Setting

The Permian Basin, located in West Texas and Southeast New Mexico, contains one of the world's thickest deposits of sediments below a massive land area: 250 miles east to west and 300 miles north to south.

Throughout the Permian, the Central Basin Platform (CBP) was the site of carbonate shelf and shelf/margin deposition on top of a basement uplift that separated the deep Delaware Basin on the west and the shallower Midland Basin on the east. Broad and extensive carbonate shelves developed along the eastern, northern, and northwestern margins of the Midland Basin and Delaware Basin. [1]

The four-county area addressed by this San Andres ROZ fairway resource assessment includes four distinct paleogeographic features of the Permian Basin that have significantly influenced the distribution and accumulation of the remaining oil in the ROZ, namely

- Northwest Shelf
- San Simon Channel
- CBP
- Midland Basin and its prograding carbonate shelf margins

These four prominent features are shown in Exhibit 1-2. Exhibit 1-2 superimposes the location of the four-county study area on the configuration of the Permian Basin during the initial deposition of the San Andres Formation.

Exhibit 1-2. Key Permian Basin paleographic features

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The San Andres Formation in the study area is 1,200–1,600 feet thick. It is characterized by an overall shallowing-upward sequence of shelf carbonates. [3] The San Andres is underlain by the Glorieta/San Angelo Formation and overlain by the Grayburg and other formations of the Upper Permian Artesia Group (Exhibit 1-3). [4]

In the four-county study area, notable reservoir porosity in the ROZ interval occurs in the Middle to Lower San Andres, in dolostones originating as subtidal and intertidal deposits of the middle and inner shelf. In other portions of the Midland Basin, the ROZ interval occurs in the Upper San Andres. The multiple stratigraphic sequences within the overall shoaling-upward framework of the San Andres compartmentalize the porous reservoir. Principal pore types in the Lower San Andres include interparticle and intercrystalline porosity, moldic pores, and vugs of various sizes. [5]

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Exhibit 1-3. Stratigraphic column: Permian interval of the Permian Basin

SYSTEM		Series	Permian Basin - Northwest Shelf	
PERMIAN	UPPER	Ochoan	*Absent*	
		Guadalupian	Tansill	Artesia Group
			Yates	
			Seven Rivers	
			Queen	
			Grayburg	
			San Andres	Upper
	LOWER	Leonardian		Lower
			Glorieta/ San Angelo	
			Upper Clearfork	Clearfork Group
			Tubb	
			Lower Clearfork	
			Abo	

1.3 PERMIAN BASIN ROZ

1.3.1 The San Andres ROZ Resource

Permian Basin operators have known for some time about the presence of low oil and high water saturation intervals below the main pay zones (MPZs) of their San Andres oil fields. Testing of these low residual oil intervals typically led to the production of large volumes of water with, at best, low to non-commercial volumes of oil.

Initially, the reservoir engineering community judged these low oil saturation intervals below the MPZ to be "transition" zones created by capillary forces. In contrast, the exploration community viewed these low oil saturation intervals and fairways as the remnants of oil migration pathways that might indicate the direction and location of new, structurally confined oil fields. [6]

The pioneering work by Mr. Steve Melzer and Dr. Robert Trentham of the University of Texas Permian Basin (UTPB) helped establish that these low oil saturation settings consisted of residual oil left behind by Tertiary-age hydrodynamic flow ("mother nature's waterflooding") through the San Andres interval giving birth to the term "the ROZ." [7]

Industry's initial efforts targeted the ROZ intervals below existing oil fields at Wasson, Seminole, and Goldsmith, among others. Laboratory tests showed that the application of high pressure, miscible CO_2 EOR could mobilize this residual oil. Based on this positive information, industry began completing wells into the ROZ below their San Andres oil fields and started injecting high

pressure CO_2 to produce this residual oil. In geologically favorable settings, these initial efforts demonstrated potential for commercial levels of oil production.

As miscible CO_2 flooding of the ROZ below existing oil fields began to be established as commercially viable, [8] Dr. Trentham and Mr. Melzer proposed that the ROZ fairway areas (i.e., residual oil where no "main pay" zones are present) of the San Andres Formation might also be favorable for development. Their modeling work, published in 2012, identified hydrodynamic flow fairways in the San Andres Formation where extensive "greenfield" ROZs would be expected. [9]

Only very recently has industry ventured beyond the structural limits of their existing oil fields to define and develop the oil resources of the San Andres ROZ "fairway." Development of the San Andres ROZ resource has been constrained due to 1) uncertainties about the ability of existing logs to establish reliable oil saturation values and 2) limitations on available CO_2 supplies.

1.3.2 Comparative Analysis of ROZ Fairway Development

Publicly available information on industry's pursuit of the ROZ fairway resource is limited. Fortunately, in 2015, KinderMorgan initiated their Tall Cotton CO_2 EOR project in the San Andres ROZ fairway of western Gaines County. The field development plan and fluid production information for Tall Cotton was obtained from the Texas Railroad Commission Oil & Gas Production Data Query data system.

Exhibit 1-4 provides the daily oil production from Phase I and Phase II of Tall Cotton. Oil production has steadily climbed reaching 2,500 barrels per day during the first five months of 2018, demonstrating that the oil resource in the San Andres ROZ fairway can be mobilized and produced with injection of high-pressure CO_2.

Exhibit 1-4. Tall Cotton oil production: Phase I and Phase II
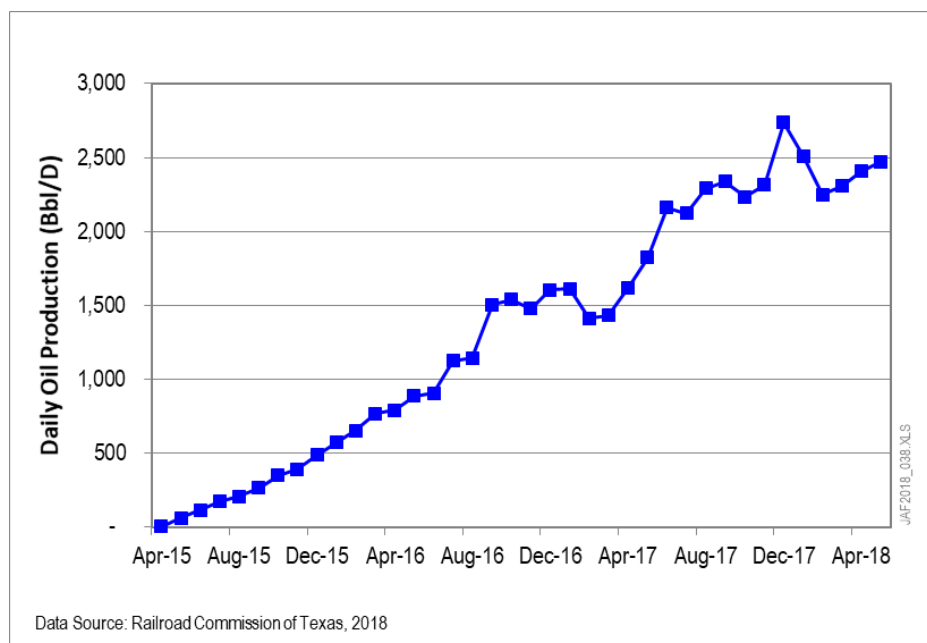
Data Source: Railroad Commission of Texas, 2018

Exhibit 1-5 provides the status of field development at Tall Cotton, including the newly drilled CO_2 injection and oil production wells, as of the end of 2017.

Exhibit 1-5. Tall Cotton field development patterns: Phase I and Phase II
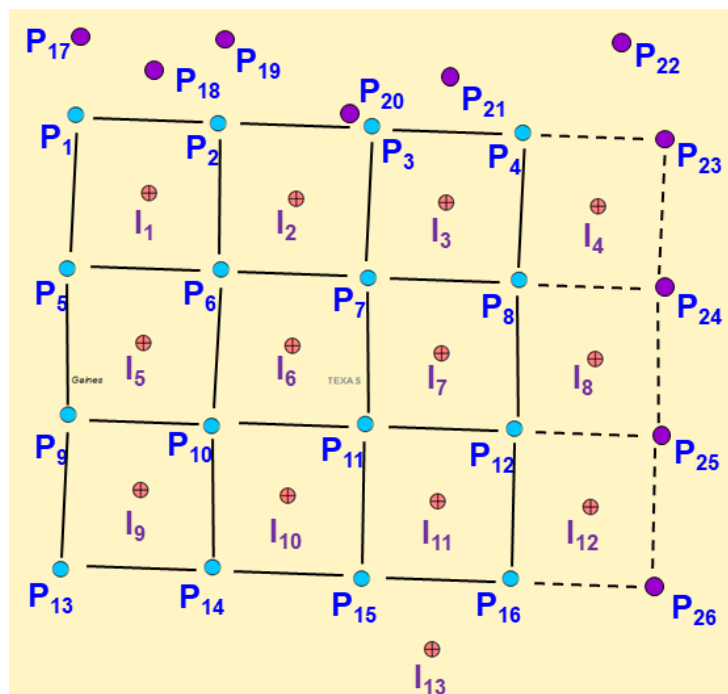
In their 2018 Analyst Day Presentation, KinderMorgan states that their 2018 program includes completing the Phase II expansion at Tall Cotton and activating 10 of the 50 patterns planned for the Phase III expansion area. [10]

1.3.3 Characteristics of the San Andres ROZ

The primary oil producing interval of the San Andres Formation in the study area is porous dolomite located approximately 400 to 500 feet below the top of the San Andres Formation. This section, referred to as the MPZ, can have a gross thickness of 100 to 200 feet and consist of multiple porous dolomite intervals, typically 10 to 30 feet thick on well logs, interbedded with mudstone, siltstone and anhydrite.

Below the MPZ (where present) and its producing oil/water contact is a thick Lower San Andres section of porous and permeable dolomite. This interval comprises the ROZ. If no MPZ is present, the entire porous San Andres interval is called a "greenfield" ROZ.

In the four-county study area, the porous dolomite of the ROZ interval ranges from 100 feet to more than 600 feet thick. In the eastern portion of the study area, the dolomite interval loses its oil saturation in the lower portion of the ROZ.

The porous San Andres ROZ is indicated by a drilling break on mud logs and by a distinctive increase in porosity and a corresponding decrease in resistivity on open-hole logs. Hydrocarbon shows are common while drilling through the Lower San Andres ROZ including gas shows, oil

stain, fluorescence, and a streaming "cut" of oil from drill cuttings and core. Typically, the ROZ interval has brighter fluorescence in the upper portion and duller fluorescence in its deeper section, suggesting the oil properties may be changing in the ROZ interval. Oil saturations in conventional whole core commonly range from below 20 percent to above 30 percent for the ROZ interval.

The lowermost boundary of the ROZ is typically determined by the change in lithology from dolomite to limestone or by the top of the Glorieta Formation. Because distinct differences in porosity and oil saturation are often observed between the upper ROZ and the lower ROZ, this four-county study divided the San Andres ROZ into two informal intervals: ROZ "1" and ROZ "2."

Exhibit 1-6 is a two-well cross-section with the first well located on the Northwest Shelf of the Permian Basin in Yoakum County and the second well located 27 miles to the southeast near the eastern edge of the CBP. This two-well cross-section illustrates many of the characteristics of the San Andres ROZ fairway interval addressed by this resource assessment.

Exhibit 1-6. Stratigraphic cross-section illustrating the San Andres ROZ fairway resources of Yoakum and Gaines Counties
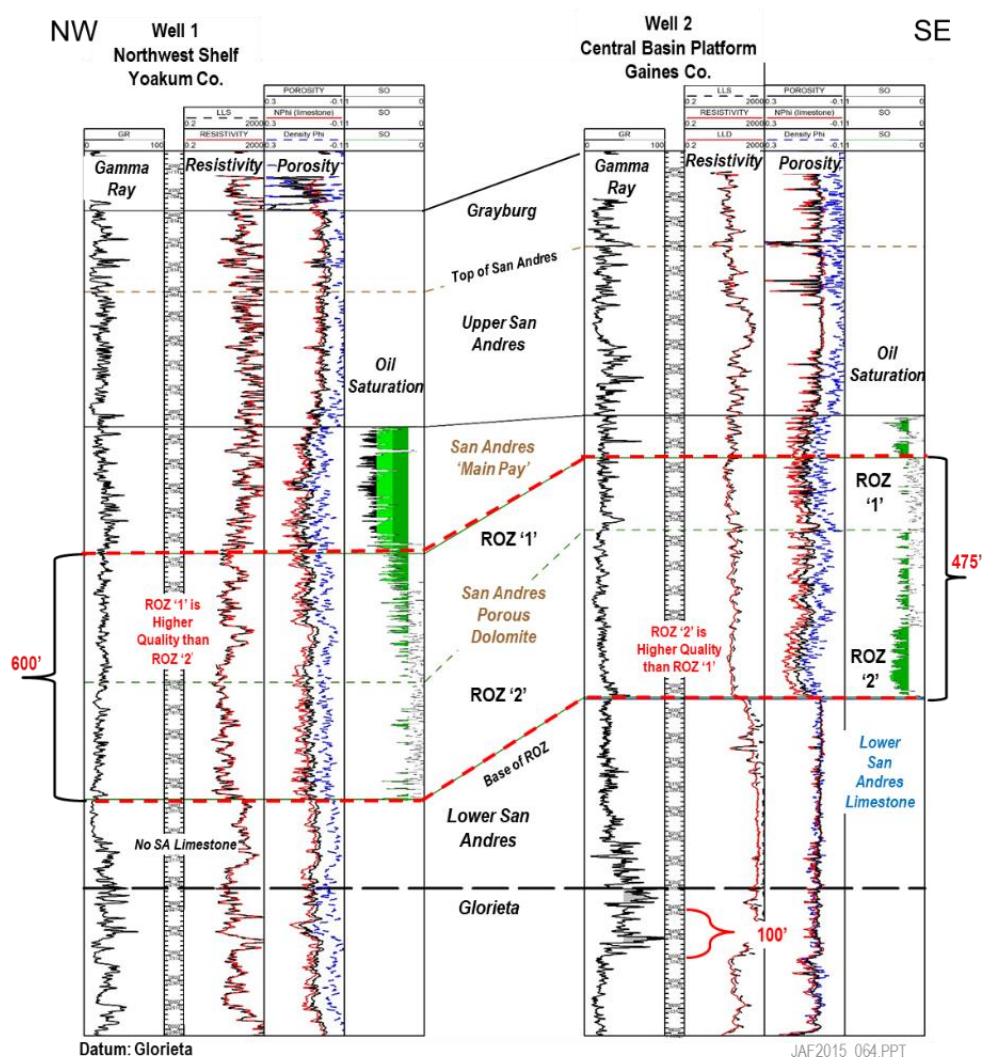
Well 1, located below a San Andres oil field, has a thick, well-developed MPZ with a higher quality ROZ interval located in the upper porous dolomite, in ROZ 1. Well 2, located outside the structural closure of a San Andres oil field, has a thin zone of higher oil saturation at the top of the San Andres ROZ. In this well, the higher quality ROZ resource occurs deeper in the Lower San Andres porous dolomite, in ROZ 2.

Exhibit 1-7 illustrates a typical ROZ oil saturation profile for a study well without a San Andres main pay. The calculated oil saturation of net pay shown in Exhibit 1-7 (shaded in green) ranges from 25 percent to 45 percent. A dashed vertical line corresponding to an oil saturation of 45 percent shows that the calculated residual oil saturation is highest in the upper ROZ and declines with depth through the ROZ. In this example, ROZ 1 and ROZ 2 are separated by a low porosity interval in the middle of the ROZ. The base of the ROZ is defined by a change in lithology from dolomite to limestone.

Exhibit 1-7. Typical oil saturation profile for the San Andres ROZ fairway in the four-county study area
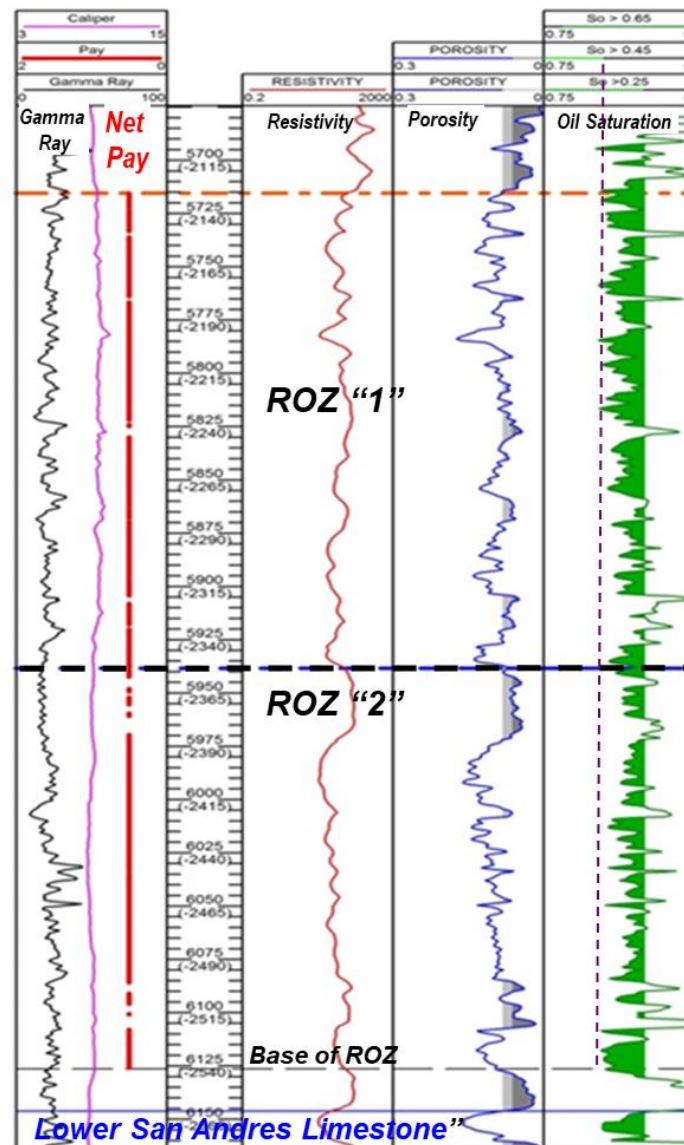
1.4 ESTIMATING ROZ FAIRWAY RESOURCES

1.4.1 Overview of Methodology

The San Andres ROZ fairway resource study assembled logs for 123 wells drilled in the four-county area, concentrating on logs that fully penetrated the San Andres ROZ interval. From this larger data set, digital logs (LAS files) were acquired for 90 wells with higher quality log data. The digital logs were analyzed using IHS Petra workstation software to establish volumetric reservoir properties and calculate the San Andres ROZ fairway oil in-place (OIP). A primary objective of the analysis was to apply as consistent a log analysis methodology as possible to the ROZ interval across the entire study area.

A significant number of working cross-sections were constructed using all the study wells to correlate geophysical log characteristics and guide understanding of reservoir thickness, lithology, and stratigraphic continuity within the San Andres ROZ. Based on these cross-sections, each county in the study area was divided into three to five geologically similar partitions, corresponding to features such as apparent porosity, total dolomite thickness, calculated oil saturation, and log character (particularly the gamma ray and resistivity logs.) Selected cross-section examples are provided in the discussion of individual county results later in this report.

1.4.2 Data Sources

Exhibit 1-8 shows the location of the study wells and the core data used by this study. The log data were calibrated to core data from four previously drilled wells into the San Andres ROZ interval in this four-county area.

Exhibit 1-8. Location of data for four-county San Andres ROZ fairway resource assessment
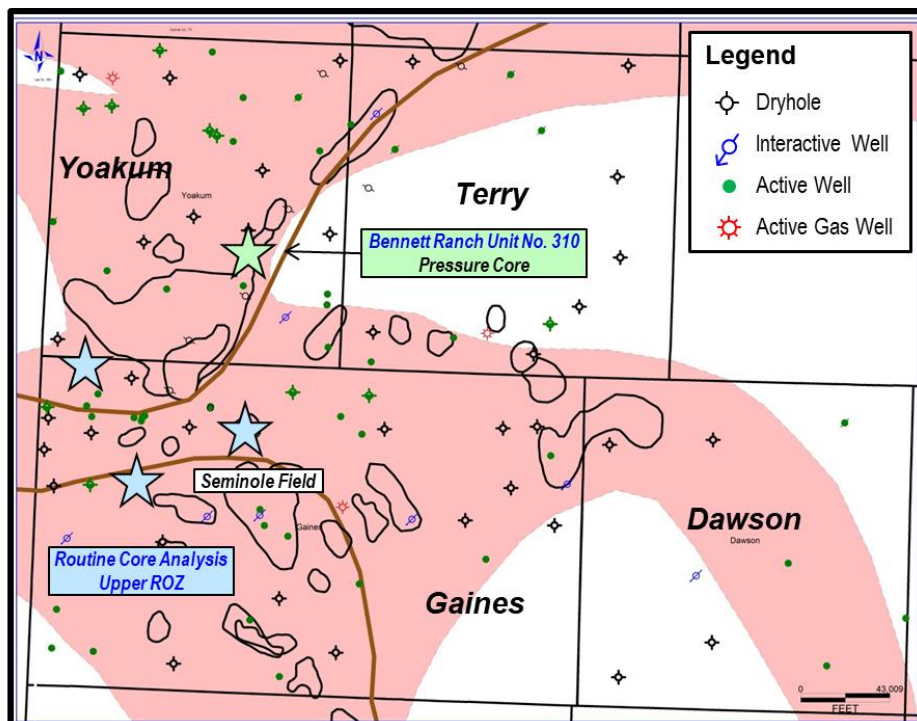
Three of the cores included routine analyses of whole core and plugs, which provided data on porosity, grain density, fluid saturation, and lithology for the upper ROZ. One of the cores, at the Bennett Ranch Unit of the Wasson oil field, included pressure core and other whole core data for a 210-foot interval from 5,175 to 5,385 feet. [11] This key core study provided porosity, fluid saturations, grain density, and electrical properties data for establishing the important Archie parameters of 'm' and 'n' subsequently used in the more detailed analyses of the 90 San Andres logs in the study area.

1.4.3 Computing Porosity in the ROZ

Porosity was computed using all available logs, including compensated neutron, density, and sonic logs. Lithology corrections and environmental corrections were applied as needed; bad values and obvious shale zones were excluded from the analysis. Compensated neutron and sidewall neutron logs were corrected for dolomite, which reduced the compensated neutron porosity by approximately 6 to 8 porosity units and the sidewall neutron porosity by 1 to 3 porosity units. Standard published dolomite log corrections were used for all logs.

Density porosity was calculated from bulk density using a matrix density of 2.83 to 2.85 g/cc (based on core data) and a fluid density of 1.05 g/cc. Sonic porosity was computed using the Wylie relationship and fluid travel time of 188 μ-sec/ft. For most wells in the study area, a matrix travel time of 43 μ-sec/ft was used to compute sonic porosity. For wells with multiple porosity logs, the best available porosity log (usually the density-neutron cross-plot porosity log) was selected for calculating oil saturation.

1.4.4 Computing Oil Saturation in the ROZ

The water saturation (Sw) in the ROZ was computed for the 90-log data set using the classic Archie model:

$$Sw^n = ((a \times Rw)/(Rt \times \phi^m))$$

Oil saturation (So) at reservoir conditions was computed as 1-Sw. The parameters used for the Archie equation are defined and summarized in Exhibit 1-9.

Exhibit 1-9. Input parameters for calculating oil saturation in the ROZ

Porosity Φ	Study wells were selected with available open hole neutron, density, and/or sonic logs	Density porosity: used matrix grain density of 2.85 g/cc for Northwest Shelf and northwest CBP wells. Used 2.83 g/cc for most of CBP and Midland Basin. Used fluid density of 1.05 g/cc
	Lithology-corrected density-neutron cross-plot porosity log was most commonly used	Sonic porosity: used matrix and fluid travel times of 43 μ-sec/ft and 188 μ-sec/ft for most wells. Varied the matrix travel time from 41 μ-sec/ft west and north of study area to 46 μ-sec/ft in the Midland Basin
Archie Parameters	'm' = cementation exponent 'n' = saturation exponent 'a' = further correction for tortuosity of electrical pathway	Used 'a' = 1 (common default for carbonates) Used 'm' & 'n' = 2.3 for northern Yoakum, Terry, Dawson, and eastern Gaines (Midland Basin) Used 'm'=2.3, 'n'= 3.4 for Gaines CBP Used 'm' = 2.3, 'n' = 3 for Gaines in the San Simon Channel area, northern Gaines (Northwest Shelf) and southern Yoakum (Northwest Shelf)
Rw	Regional formation water salinity values for the San Andres were used to compute Rw at formation temperature	Rw values used for log analysis range from 0.03 to 0.07 ohm-m (see individual county chapters for details)
Rt	Deep resistivity or 'Rt' log	Used deep reading resistivity log, corrected for invasion where needed (used 'Rt' log if available)

The calculation of water saturation, Sw, is most sensitive to porosity and the parameter 'm,' cementation exponent. The parameter 'n,' saturation exponent, is also important for pore systems that may not be entirely water-wet. While the parameters 'm' and 'n' are commonly assumed to be '2.0' in carbonates, calibration of the logs from the ROZ interval with core data and published results from field studies led to the use of somewhat higher values for the parameters "m" and "n." Laboratory derived values of 'm' are frequently higher than 2.0 for carbonate pore systems with vugs and moldic. In addition, laboratory-derived values for 'n' range from 1.4 to 4 or greater (for oil wet reservoirs).

Values for 'm' and 'n' for the Northwest Shelf area were selected based on special core analysis data published for the San Andres porous dolomite from the Bennett Ranch Unit at Wasson Field. The value of 'n' selected for the CBP area is an empirical value that calibrates the oil saturation calculation from three logs for the Seminole oil field to the range of published oil saturation values and estimated OIP available for the San Andres ROZ at the Seminole oil field. This empirical 'n' value is further supported by some of the laboratory-derived values of 'n' from the Bennett Ranch core study that contains values greater than 3. Data on formation water

salinity for computing Rw were obtained from a basin-wide compilation and analysis of water samples from oil and gas fields by the Texas Water Development Board. [12]

1.4.5 Comparing Log Derived Characterization with Published Data

This study's assessments of the key volumetric San Andres ROZ fairway properties—gross and net pay, porosity, and oil saturation—are consistent with publicly available data. For example, the geologic data reported for the ROZ interval below the MPZ of the Seminole oil field in central Gaines County are similar to the data derived from this study's log analysis for Partition #3 of Gaines County (Exhibit 1-10).

Exhibit 1-10. Comparison of Gaines County Partition #3 volumetric reservoir properties with Seminole oil field ROZ

Volumetric Reservoir Properties	Seminole Oil Field ROZ [8, 13]	This Study Partition #3
	Upper ROZ	ROZ 1 Only
Gross Pay (ft)	246	244
Net Pay (ft)	197	220
Porosity (%)	13% to 15%	12%
Oil Saturation (%)	32%	36%

1.4.6 Computing Oil In-Place and High-Grading the ROZ Resource

A porosity cut-off of 6 percent was applied to define net pay. No oil saturation cut-off was applied. Questionable high porosity and oil saturation values were excluded from net pay. A gamma ray index of 0.4 was used to exclude apparent shale zones from net pay.

After porosity cut-offs and pay exclusions were applied, the net pay intervals were flagged and summed for the ROZ interval. Next, the average porosity of net pay and the average oil saturation of net pay were computed. The value of total net pay, average porosity, and average oil saturation were then used to compute OIP for the ROZ interval. A partition-specific formation volume of factor (FVF), typically ranging from 1.1 to 1.3, was applied to convert reservoir barrels to stock tank barrels.

The ROZ fairway resources were further analyzed to establish volumes of "higher quality" and "lower quality" resources with higher quality defined by a porosity value of greater than 8 percent and an oil saturation value greater than 25 percent. If either the porosity or the oil saturation of net pay was below these values, then the ROZ resources in the area represented by the study well was characterized as lower quality.

Exhibit 1-11 shows an example calculation of porosity, oil saturation, and net pay for ROZ 1 for a well in Gaines County. In this example, the gross thickness of ROZ 1 is 336 feet. Total net pay is 259 feet, defined by the porosity cut-off of 6 percent. The average porosity of net pay is 12.6 percent and the average oil saturation of net pay is 30 percent. Total OIP is 59,338 barrels/acre or 229 barrels/acre-ft of net pay.

Exhibit 1-11. Identifying the ROZ fairway resource and computing OIP
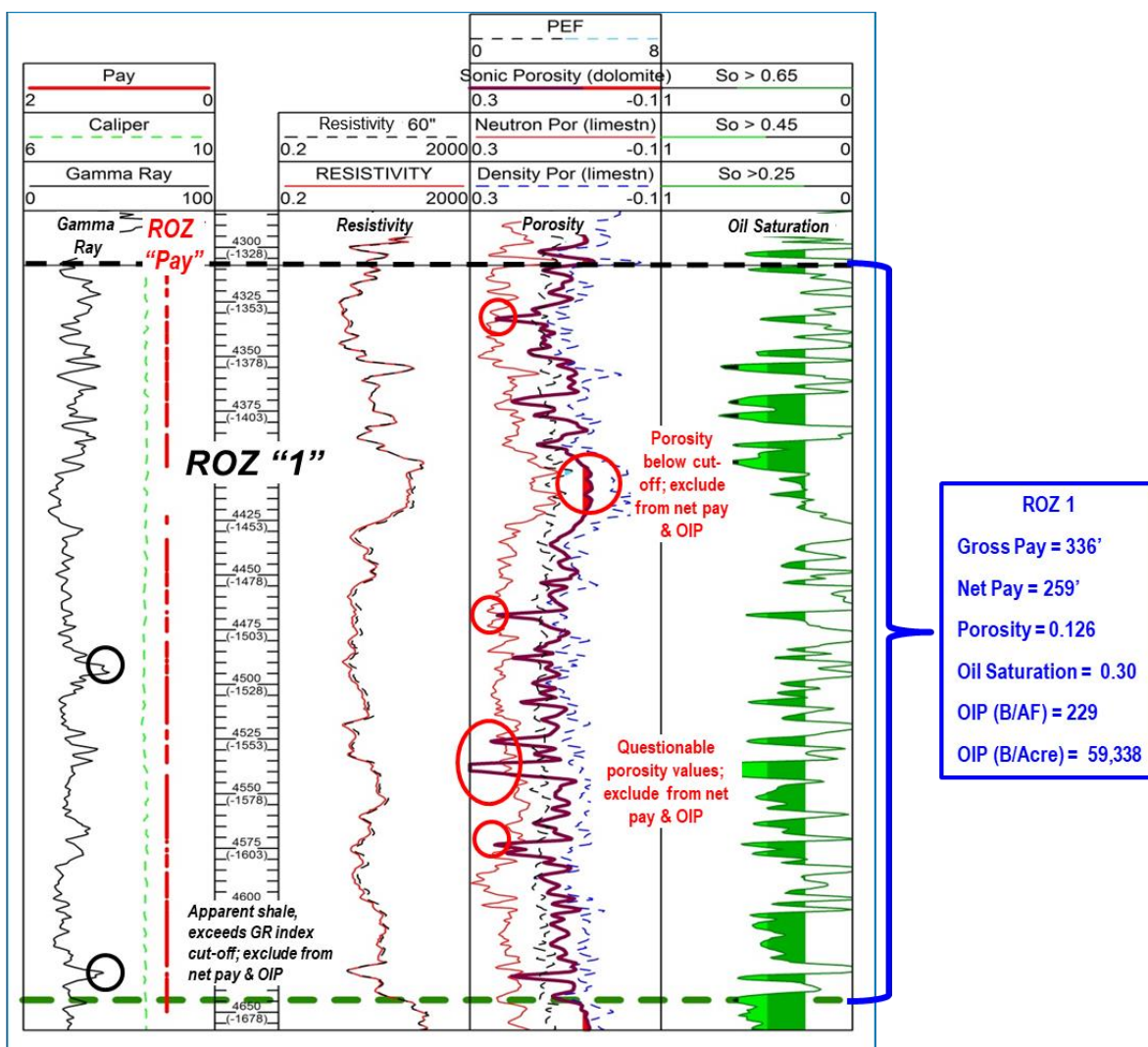
1.5 SIZE AND QUALITY OF THE SAN ANDRES ROZ FAIRWAY RESOURCE

1.5.1 Areal Coverage of the ROZ Fairway Resource Assessment

The four-county ROZ study assessed a significant land area of 2,622,660 acres. A portion of this land area, 232,660 acres, where the San Andres ROZ is below the structural closure of existing San Andres oil fields, was excluded, leaving a ROZ fairway assessment area of 2,390,000 acres (Exhibit 1-12).

Exhibit 1-12. San Andres ROZ fairway assessment area: four-county area

County	Total Area	Below Existing Oil Fields	Assessment Area
	Acres	Acres	Acres
Gaines	961,900	103,900	858,000
Yoakum	512,400	91,400	421,000
Terry	570,660	21,660	549,000
Dawson	570,700	15,700	562,000
Total San Andres	2,622,660	232,660	2,390,000

This large ROZ fairway resource area was further divided into 16 partitions containing 72 distinct analytical ROZ reservoir units, as further discussed in the individual county results in this report. The reservoir data developed for each partition is stored in an open-source database available on the National Energy Technology Laboratory (NETL) website. [14]

1.5.2 Oil In-Place of the ROZ Fairway Resource Assessment

The San Andres ROZ fairway resources in Gaines, Yoakum, Terry, and Dawson counties of West Texas contains 104.3 billion barrels of OIP. Much of this OIP is higher quality, estimated at 71.8 billion barrels, offering promise for commercially viable development with by-product storage of CO_2 (Exhibit 1-13).

Exhibit 1-13. In-place San Andres ROZ fairway resources: four-county area

County	In-Place Resource		
	Total	Higher Quality	Lower Quality
	B bbls	B bbls	B bbls
Gaines	41.4	32.0	9.3
Yoakum	17.7	14.1	3.6
Terry	16.8	10.5	6.3
Dawson	28.4	15.2	13.3
Total	104.3	71.8	32.5

- Gaines County, the site of the CO_2 flood in the ROZ below the Seminole oil field as well as Tall Cotton, holds 41.4 billion barrels of San Andres ROZ fairway OIP, with over three-quarters of the in-place resource judged as higher quality.

- Yoakum County holds 17.7 billion barrels of San Andres ROZ fairway OIP with about 80% of its in-place resource higher quality.

- Terry County holds 16.8 billion barrels of San Andres ROZ fairway OIP, with about 60% of the resource judged as higher quality.

- In the areally extensive Dawson County, with 28.4 billion barrels of San Andres ROZ fairway OIP, about half of the resource is higher quality.

1.6 TECHNICALLY RECOVERABLE ROZ RESOURCES

1.6.1 Applying CO_2 EOR to the ROZ

A miscible CO_2 flood, involving a "tapered" CO_2-water-alternating-gas (WAG) with one hydrocarbon pore volume (HCPV) of CO_2 injection, was used to establish oil recovery from the four-county San Andres ROZ fairway area. (A tapered CO_2-WAG involves a large initial volume of CO_2 injection with a modest volume of water injection, followed by progressively smaller volumes of CO_2 injection and larger volumes of water injection.) Analytical modeling by ARI of alternative miscible CO_2 EOR designs showed that a tapered CO_2-WAG provided an optimum CO_2 flooding design.

The above miscible CO_2 EOR design, along with data on volumetric and other reservoir properties specific to each of the 72 analytical ROZ reservoir units, was incorporated into the Office of Fossil Energy (FE)/NETL Onshore CO_2 Prophet Model ("Prophet Model") to calculate oil recovery, water production, CO_2 injection and recycling, and CO_2 storage. The Prophet Model is a simplified streamline and stream tube reservoir simulator program comprised of two programs, StrmtbGen, and StrmtbFlow. The StrmtbFlow program, which simulates multiphase flow in porous media, was used in this evaluation.[b]

The model input data for each analytic unit consisted of the volumetric data calculated by the study (presented in more detail in the individual chapters for each of the four counties), and other reservoir-specific data contributed from ARI's proprietary Big Oil Fields Data Base for the Permian Basin.

1.6.2 Technically Recoverable ROZ Resources and Demand for Purchased CO_2

The study established that 28.1 billion barrels (27 percent) of the San Andres ROZ fairway OIP is technically recoverable, primarily from higher quality portions of the four-county assessment area (Exhibit 1-14).

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[b] The FE/NETL CO_2 Prophet Model (including StrmtbFlow) and the FE/NETL Onshore CO_2 EOR Cost Model are being posted to the NETL website at the same time as this report. The FE/NETL Onshore CO_2 EOR Evaluation Tool is a Python script that was used to apply StrmtbFlow and the CO_2 EOR Cost Model to each ROZ analytical unit in a systematic manner. The Evaluation Tool will eventually be posted to the NETL website. Until this resource is posted, a copy can be obtained by contacting David Morgan or Derek Vikara at NETL.

Exhibit 1-14. Volumes of technically recoverable resources and demand for purchased CO$_2$: San Andres ROZ fairway, four-county area

County	Technically Recoverable Oil		Purchased			
			CO$_2$ Injection		CO$_2$/Oil Recovery Ratio	
	B bbls	% OIP	Tcf	B mt	Mcf/B	mt/B
Gaines	12.1	29%	132.2	7.0	10.9	0.58
Yoakum	4.3	24%	47.1	2.5	10.9	0.58
Terry	4.3	25%	73.2	3.9	17.1	0.90
Dawson	7.4	26%	125.5	6.6	16.9	0.89
Total	**28.1**	**27%**	**378.0**	**20.0**	**13.4**	**0.71**

To produce the technically recoverable ROZ oil, a purchased CO$_2$ volume of 20.0 billion metric tons (378 Tcf) will be required (Exhibit 1-14). Overall, considerably more CO$_2$ is stored, 0.71 metric tons of CO$_2$ per barrel of oil produced, than is contained in the oil recovered as part of developing the San Andres ROZ fairway resource.[c] A barrel of oil releases approximately 0.4 metric tons of CO$_2$ when combusted.

1.7 ESTIMATING COMMERCIALLY VIABLE OIL RECOVERY

1.7.1 Cost and Economics Models

The FE/NETL Onshore CO$_2$ EOR Cost Model ("CO$_2$ EOR Cost Model")[b] was utilized for estimating the commercial (economic) viability of producing oil and storing CO$_2$ in the San Andres ROZ fairway of the four-county study area.

Project costs for this study were based on "greenfield" ROZ partitions, with no existing oil field infrastructure in place. CO$_2$ EOR Cost Model assumptions included up-front costs for legal agreements with surface and mineral rights owners, drilling and construction permits, installing characterization wells, operation design, and building and road construction, as well as installation of new wells, pipelines, and fluid processing facilities. Costs also include construction of a CO$_2$ pipeline spur from a main CO$_2$ transportation pipeline, and a new CO$_2$ recycling plant. The CO$_2$ EOR Cost Model also accounts for the costs of well operation and maintenance (O&M), for lifting the produced fluids, and for capturing, separating, and reinjecting the produced CO$_2$. The capital costs for a greenfield ROZ operation are considerably higher than the capitals costs associated with implementing CO$_2$ EOR at a conventional oil field. The O&M costs for the two project types are comparable.

The economic analysis for this study included a traditional cash flow model, consistent with industry standards that provides results on a field-wide basis. The CO$_2$ EOR Cost Model accounts

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[c] Please note that this is a marginal, rather than a full life-cycle, analysis of CO$_2$ emissions associated with CO$_2$ EOR. It is provided to show the magnitude of the difference in carbon-intensity between conventionally produced and CO$_2$ EOR-produced crude oil. Both conventional oil production and CO$_2$ EOR use additional energy, with their associated CO$_2$ emissions, for drilling wells, injecting and production fluids, and conducting other oil field activities.

for royalties and severance and ad valorem taxes, as well as any oil gravity and market location discounts (or premiums) from the West Texas Intermediate (WTI) crude oil "marker" oil price.

The inputs and assumptions of the CO_2 EOR Cost Model used for this San Andres ROZ fairway resource assessment include the following key items:

- Oil Price—$75 per barrel (WTI reference price), escalating at 2.3% per year. The oil price selected for the analysis is consistent with a mid-term outlook for oil prices in the Energy Information Administration's (EIA) 2018 Annual Energy Outlook

- CO_2 Sales Price—$1.50/Mcf, equal to $28.35/mt, escalating at 2.3% per year, (delivered at pressure to the oil field). The CO_2 sales price used by the ROZ study is consistent with historical ratios relating the CO_2 sales price to the oil price

- Project Financing – 60% equity and 40% debt, based on EIA's assumptions in their Oil and Gas Supply Module within the National Energy Modeling System

- Financial Hurdle Rate—10% after tax weighted average cost of capital (WACC); (13% for equity and 6.6% for debt, adjusted for tax effects)

- Royalties—17% on gross production

- State Severance/Ad Valorem Taxes—The Texas state severance and ad valorem tax rates used by the study did not incorporate special incentives for operating a CO_2 flood or for storing CO_2

- Federal Income Tax—21% on earnings after state and local taxes

More detailed results are presented on a county and partition basis in the subsequent chapters and sections of this report.

1.7.2 Commercially Viable Oil Recovery with By-Product CO_2 Storage

Using the above cost and economic variables, the study estimates that the San Andres ROZ fairway in the four-county area would provide 20.4 billion barrels of commercially viable[d] oil recovery.

The pursuit of this ROZ oil would also provide 9.87 billion metric tons of by-product CO_2 storage (Exhibit 1-15). This assumes essentially all the purchased CO_2 is stored.

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[d] Commercially viable means the after tax rate of return for a specific ROZ partition would exceed the WACC. The expression "after tax" includes all state and federal taxes.

Exhibit 1-15. Commercially viable oil recovery with by-product storage of CO_2: San Andres ROZ fairway resource, four-county area

County	Oil Recovery (B bbls)	Purchased CO_2		Purchased CO_2/Oil Recovery Ratio	
		Tcf	B mt	Mcf/B	mt/B
Gaines	10.1	86.3	4.57	8.5	0.45
Yoakum	2.8	27.6	1.46	9.7	0.51
Terry	2.8	29.4	1.56	10.4	0.55
Dawson	4.7	43.1	2.28	9.2	0.49
Total	**20.4**	**186.4**	**9.87**	**9.1**	**0.48**

*Totals may not add due to rounding.

The CO_2 EOR project in the <u>commercially viable</u> portion of the San Andres ROZ fairway stores, at the margin, 0.48 metric tons of CO_2 per barrel of oil produced. As such, this produced oil is carbon neutral or "green" given the approximately 0.4 metric tons of CO_2 content (when combusted) in a barrel of oil.[e]

1.8 GEOLOGICALLY VIABLE CO_2 STORAGE WITH BY-PRODUCT OIL RECOVERY

Significant portions of the San Andres ROZ fairway are not commercially viable to develop at the above combination of oil prices and CO_2 costs. However, in nearly all partitions considerable volumes of by-product oil is recovered that would help defray a portion of the costs of capturing and storing CO_2.

Overall, the <u>geologically viable</u> but non-commercial portion of the San Andres ROZ fairway in the four-county area could provide 10.14 billion metric tons of CO_2 storage capacity along with 7.8 billion barrels of by-product oil recovery, providing revenues that would help lower the net costs of CO_2 capture and storage (Exhibit 1-16). This assumes essentially all the purchased CO_2 is stored.

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[e] Please note that this is a marginal, rather than a full life-cycle, analysis of CO_2 emissions associated with CO_2 EOR. It is provided to show the magnitude of the difference in carbon-intensity between conventionally produced and CO_2 EOR produced crude oil. Both conventional oil production and CO_2 EOR use additional energy, with their associated CO_2 emissions, for drilling wells, injecting and production fluids, and conducting other oil field activities

Exhibit 1-16. Geologically viable CO_2 storage with by-product recovery of oil: San Andres ROZ fairway resource, four-county area

County	Purchased CO_2		By-Product Oil Recovery	Purchased CO_2/Oil Recovery Ratio	
	Tcf	B mt	(B bbls)	Mcf/B	mt/B
Gaines	45.9	2.43	2.0	22.7	1.20
Yoakum	19.5	1.03	1.5	13.2	0.70
Terry	43.9	2.32	1.5	30.2	1.60
Dawson	82.4	4.36	2.8	30.0	1.59
Total	191.7	10.14	7.8	24.6	1.30

2 GAINES COUNTY

2.1 GEOLOGIC SETTING

Gaines County, Texas, covers a 961,900-acre area in the western portion of the Permian Basin. Approximately half of the county encompasses the CBP, the San Simon Channel, and the southern tip of the Northwest Shelf. The remainder of Gaines County is east of these prominent Permian Basin features and is located within the south-eastward prograding Lower and Middle San Andres shelf margins of the Midland Basin.

Gaines County contains numerous San Andres oil fields, including Seminole, Cedar Lake, Robertson, and Hanford, among others. The ROZ resource below these and other existing San Andres oil fields has been excluded from the San Andres ROZ fairway resource assessment.

The Gaines County map (Exhibit 2-1) shows 1) the location of 39 study wells, 2) the five San Andres ROZ fairway partitions established by the study, 3) the boundaries of the previously established San Andres ROZ fairway, 4) outlines of the Northwest Shelf and CBP, and 5) the location of three regional cross-sections for the San Andres ROZ. The map also shows the major San Andres oil fields excluded from the San Andres ROZ fairway resource assessment in Gaines County.

Exhibit 2-1. Gaines County: geologic partitions, major oil fields, and study well locations
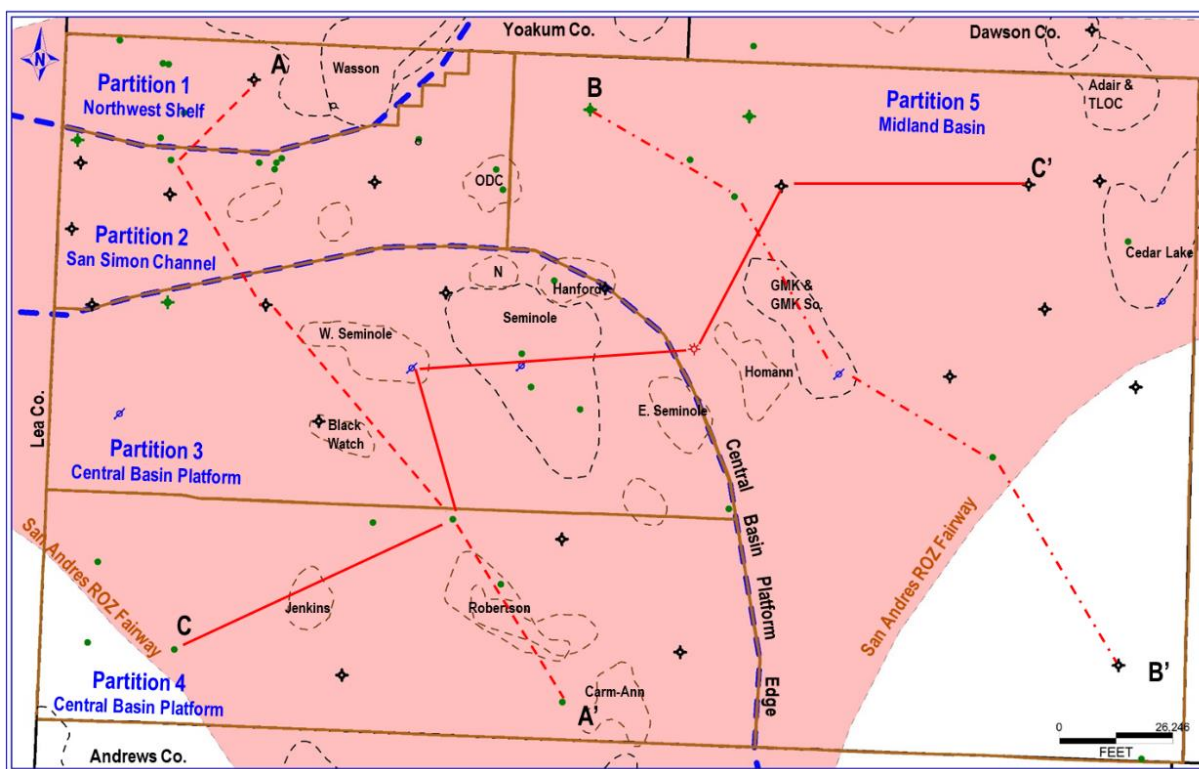
2.1.1 Example Gaines County Cross-Sections

The characterization of the San Andres ROZ fairway interval in Gaines County has drawn on the construction of a series of working cross-sections. Three of these cross-sections are included in this report.

- Gaines Co. Cross-Section A-A' (Exhibit 2-2) provides a NW-SE view of the San Andres ROZ interval starting on the Northwest Shelf, traversing through the San Simon Channel, and ending in the CBP.

- Gaines Co. Cross-Section B-B' (Exhibit 2-3) provides a NW-SE view of the San Andres ROZ interval in the Midland Basin.

- Gaines Co. Cross-Section C-C' (Exhibit 2-4) provides a SW-NE view of the variability of the San Andres ROZ interval from the CBP to the Midland Basin.

Exhibit 2-2. Gaines County NW-SE cross-section A-A'
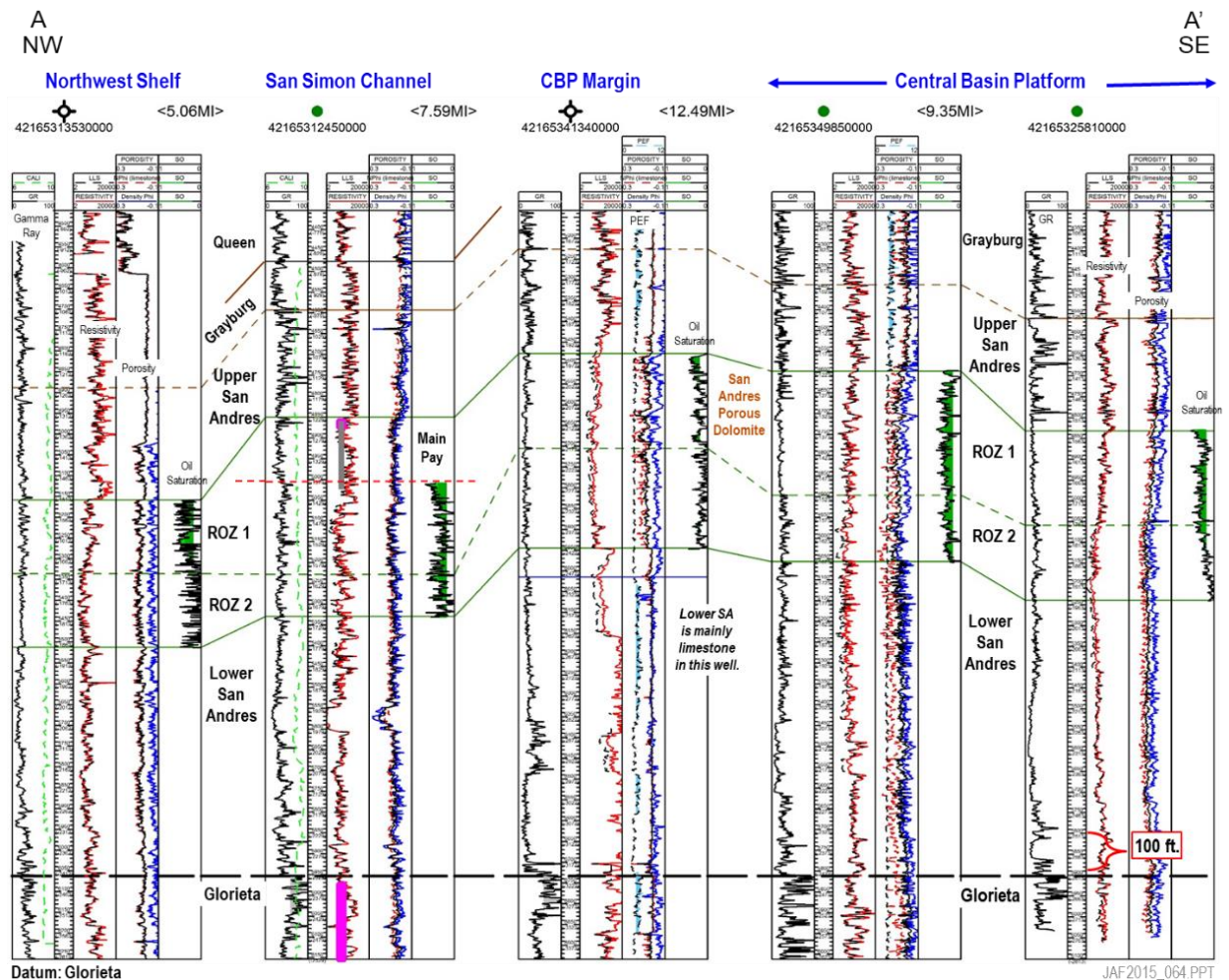
Exhibit 2-3. Gaines County NW-SE cross-section B-B'
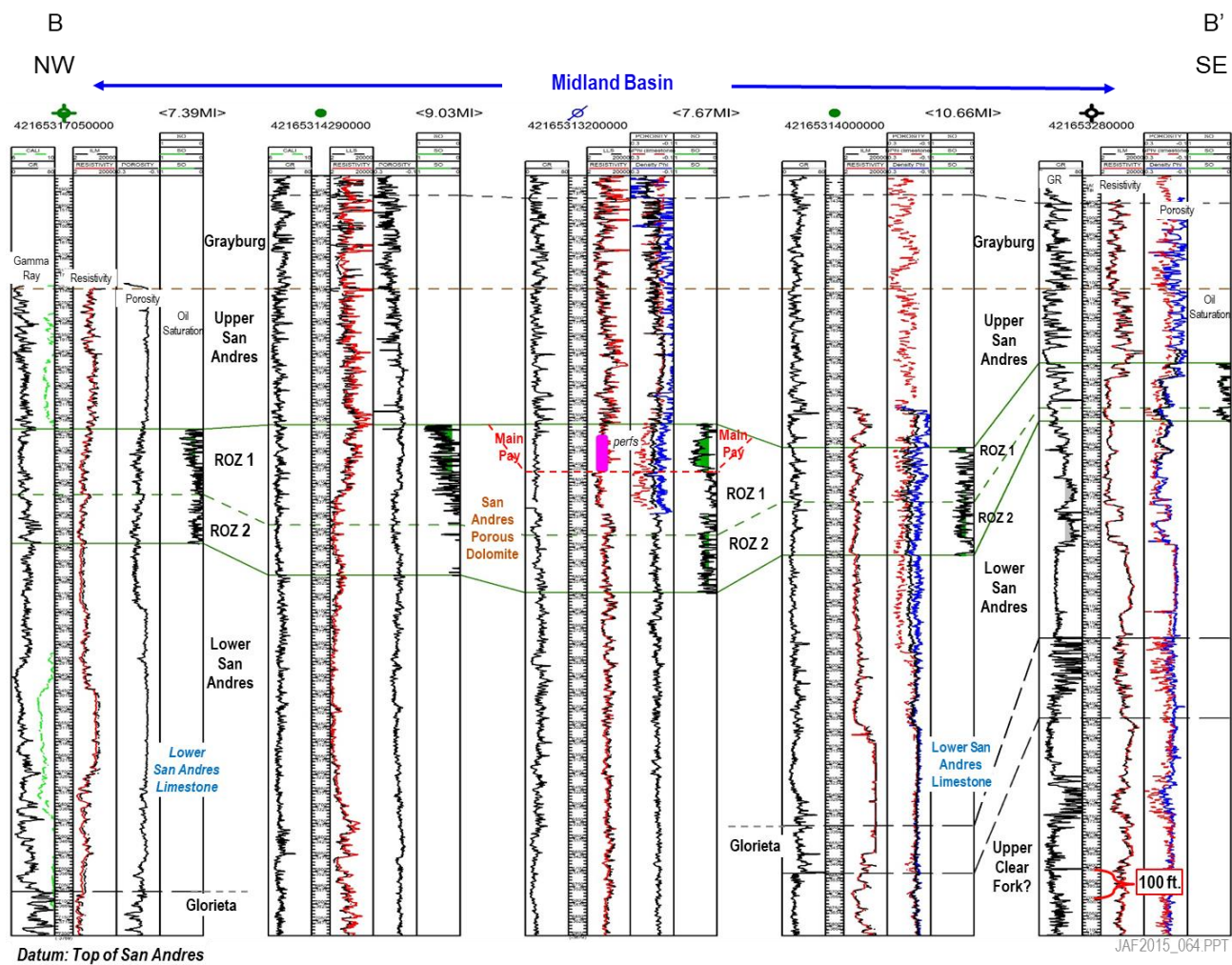
Datum: Top of San Andres

JAF2015_064.PPT

Exhibit 2-4. Gaines County SW-NE cross-section C-C'
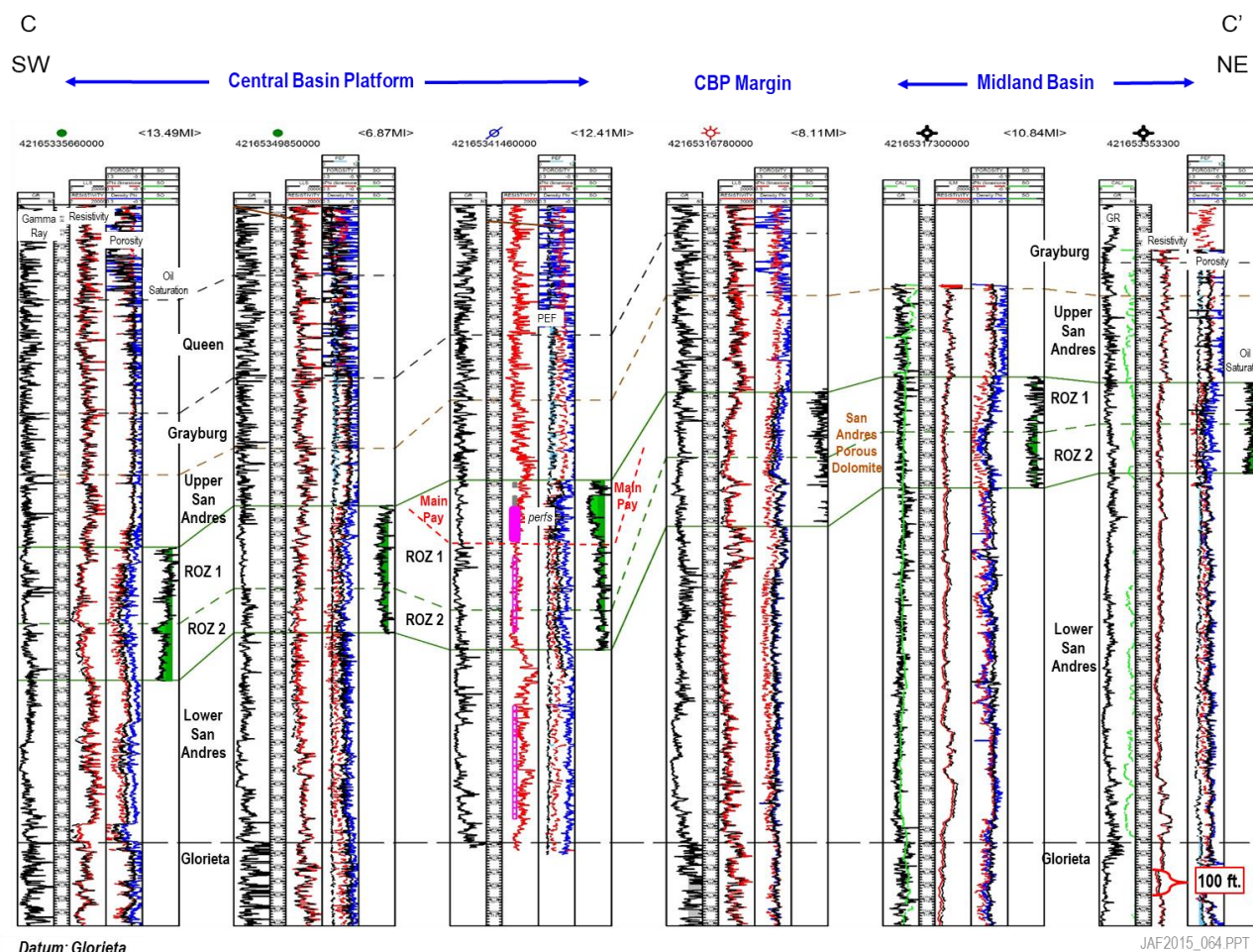
2.1.2 Interpretation of Gaines County Cross-Sections

For logs from the ROZ fairway, the top of the San Andres porous dolomite is picked as the top of the ROZ for this resource assessment. The porous dolomite intervals, informally designated as ROZ 1 and ROZ 2, are illustrated on the cross-sections.

The cross-sections display gamma-ray and caliper logs in Track 1 on the left. Resistivity logs are shown in Track 2, with the deep resistivity log shown in red. Track 3 shows the porosity logs. Uncorrected neutron porosity (for limestone) is red; uncorrected density porosity (for limestone) is blue. The porosity curve used for the OIP calculation is black.

The photo-electric (PEF) curve, if available, is also displayed in Track 3. PEF values greater than 4 are shaded in blue. Within and below the ROZ interval, high PEF values generally indicate the presence of limestone, dolomitic limestone, or anhydrite.

Track 4 on the right shows the calculated oil saturation. Calculated oil saturations between 25 percent and 40 percent are dark green; calculated oil saturations between 45 percent and 60 percent are light green; and oil saturation greater than 65 percent, typically present in only the MPZ, are black.

The base of the ROZ is where either calculated oil saturation or apparent porosity (or both) diminish in the Lower San Andres. If a Lower San Andres limestone is prominent, the top of the limestone defines the base of the ROZ.

2.1.3 Gaines County Type Log

A "type log" was selected from the Gaines County study wells to illustrate the ROZ resource analysis undertaken for the county (Exhibit 2-5). The type log illustrates two distinct San Andres ROZ resource intervals—ROZ 1 in the upper portion of the porous dolomite, and ROZ 2 in the lower portion of the porous dolomite.

Exhibit 2-5. Type log for Gaines County San Andres ROZ fairway
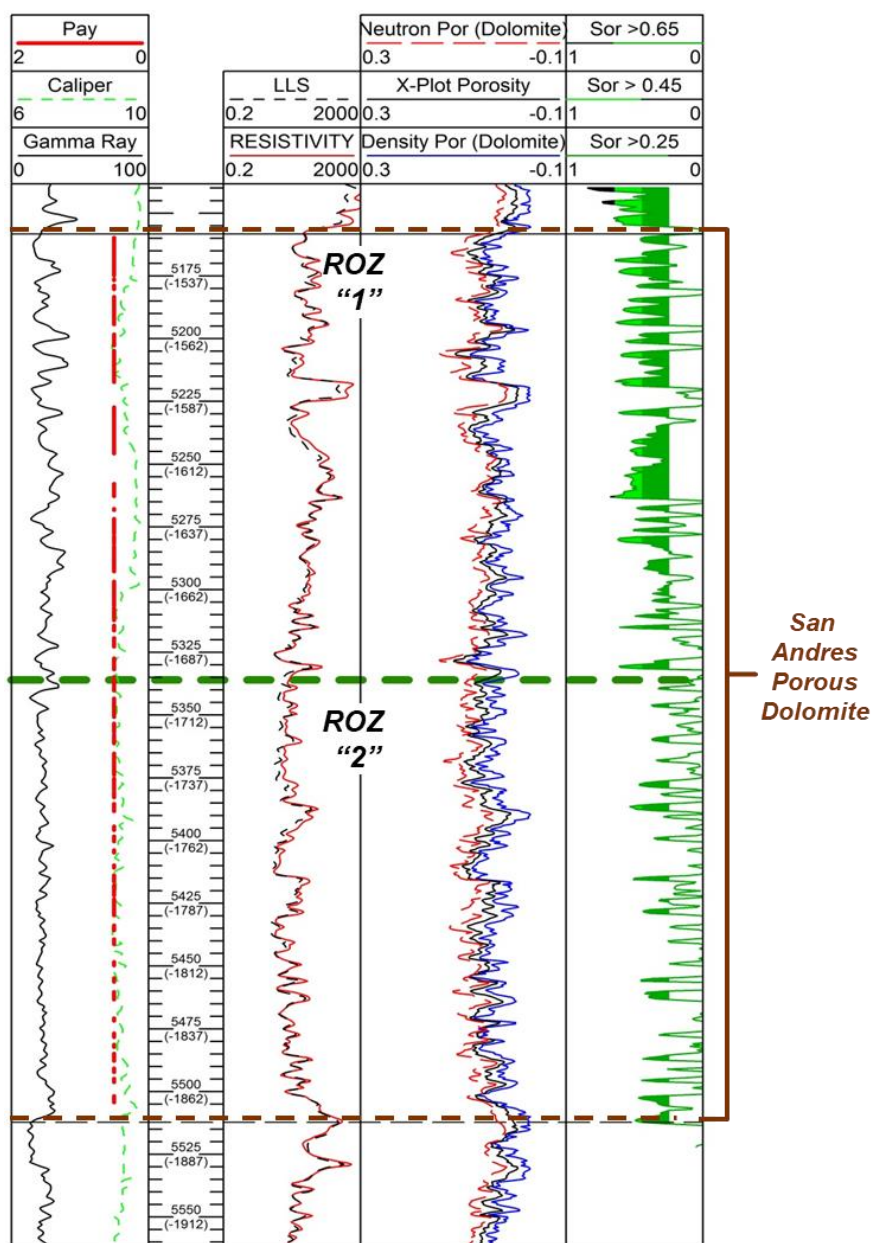
The type log shows lithology-corrected neutron (red dash) and density (blue) porosity. The density-neutron cross-plot porosity is shown in black. Porosity is fairly uniform through the ROZ, but calculated oil saturation diminishes significantly at the base of ROZ 1, Exhibit 2-5 illustrates that the base of the ROZ is often not clearly defined. In this well, porosity diminishes below 5,430 feet. From the gamma ray log, more shale appears to be present in the ROZ interval below this depth. The base of the ROZ is at the top of a thick low porosity interval that occurs at approximately 5,510 feet.

The oil saturation for the type log ROZ was calculated using the following Archie parameters— 'm' of 2.3, 'n' of 3.0, 'a' of 1.0, and formation water resistivity (Rw) of 0.055 ohm-m. A porosity cut-off of 6 percent was applied to define net pay in the ROZ. Intervals identified as ROZ pay are shown by the red "pay" flag in Track 1 of Exhibit 2-5.

For ROZ 1, the average porosity of net pay is 8.4 percent and average oil saturation of net pay is 36 percent, with the highest calculated oil saturations at the top of ROZ 1. For ROZ 2, the average porosity of net pay is 9.1 percent and average oil saturation is only 18 percent.

2.2 PARTITIONING THE GAINES COUNTY SAN ANDRES ROZ FAIRWAY

The San Andres ROZ fairway in Gaines County was divided into five distinct partitions, as illustrated previously in Exhibit 2-1. Individual San Andres ROZ fairway resource assessments were undertaken for each of the five partitioned areas.

- Partition #1. Covers a 34,000-acre area of northwest Gaines County on the Northwest Shelf. The southern portion of the Wasson oil field, covering 11,200 acres, has been excluded from the ROZ fairway resource assessment of Partition #1.

- Partition #2. Covers a 75,000-acre area of northwest Gaines County in the San Simon Channel. Three small San Andres oil fields—Russell South (1,700 acres), Havemeyer (1,200 acres), and ODC (2,800 acres)—have been excluded from the ROZ fairway resource assessment for Partition #2.

- Partition #3. Covers a 142,000-acre area of western Gaines County on the northern portion of the CBP. The Seminole oil field (23,700 acres) and the various Seminole oil field extensions (13,200 acres) have been excluded from the ROZ fairway resource assessment for Partition #3, as have the Blackwatch oil field (2,000 acres) and a portion of the Hanford oil field (2,200 acres). The total area excluded from the ROZ fairway resource assessment for Partition #3 is 41,000 acres.

- Partition #4. Covers an 184,000-acre area of southern Gaines County. A 15,500-acre area, encompassing Robertson, No. Robertson, Jenkins, and Carm-Ann oil fields, has been excluded from the ROZ fairway resource assessment for Partition #4.

- Partition #5. Covers a 423,000-acre area encompassing the eastern half of Gaines County beyond the current extent of the CBP. A total of 30,500 acres from five oil fields (Hanford, GMK, Adair/TLOC, Cedar Lake, and Homann) has been excluded from the ROZ fairway resource assessment for Partition #5.

Of Gaines County's 961,900 acres, a total of 103,900 acres under the structural closure of existing San Andres oil fields has been excluded, leaving a remaining San Andres ROZ fairway assessment area of 858,000 acres (Exhibit 2-6).

Exhibit 2-6. Gaines County ROZ fairway partitions

Partition	Total Area	Excluded Area	Assessment Area
	Acres	Acres	Acres
#1	45,200	11,200	34,000
#2	80,700	5,700	75,000
#3	183,000	41,000	142,000
#4	199,500	15,500	184,000
#5	453,500	30,500	423,000
Total	961,900	103,900	858,000

2.3 SIZE AND QUALITY OF THE GAINES COUNTY ROZ FAIRWAY RESOURCE

Gaines County holds 41,370 million barrels of OIP in the San Andres ROZ fairway outside the structural closure of the existing oil fields. The OIP and resource quality values for each of the five partitions of Gaines County are shown in Exhibit 2-7.

- Higher Quality ROZ Fairway Resources. A significant portion, 32,030 million barrels, of the San Andres ROZ fairway OIP in Gaines County has higher quality reservoir properties (porosity greater than 8% and oil saturation equal to or greater than 25%).

- Lower Quality ROZ Fairway Resources. The remainder, 9,340 million barrels, of the San Andres ROZ fairway OIP in Gaines County has lower quality reservoir properties (porosity equal to or less than 8% and/or oil saturation of less than 25%).

Exhibit 2-7. Gaines County San Andres ROZ fairway resource in-place (MM bbls)

Partition	ROZ 1			ROZ 2			Total		
	Higher Quality	Lower Quality	Total	Higher Quality	Lower Quality	Total	Higher Quality	Lower Quality	Total
1	540	130	670	310	130	440	850	260	1,110
2	2,000	280	2,280	1,280	370	1,650	3,280	650	3,930
3	5,630	320	5,950	4,640	230	4,870	10,270	550	10,820
4	5,180	310	5,490	3,600	1,540	5,140	8,780	1,850	10,630
5	3,030	3,740	6,770	5,820	2,290	8,110	8,850	6,030	14,880
Total*	16,380	4,780	21,160	15,650	4,560	20,210	32,030	9,340	41,370

*Totals may not add due to rounding.

2.4 TECHNICALLY RECOVERABLE GAINES COUNTY ROZ FAIRWAY RESOURCE

2.4.1 Methodology for Estimating Technically Recoverable Resources

The average volumetric reservoir properties for each partition of Gaines County, along with proprietary reservoir properties from ARI's Big Oil Fields Data Base, were used as input into the Prophet Model. Additionally, it was assumed that 80 percent of each partition area was suitable for development, while 20 percent of the partition had a combination of net pay, porosity, or oil saturation that was not suitable for development. It was also assumed that 90 percent of the OIP in each partition resides in the area suitable for development. The net pay for the developed portion of the partition was increased so that the OIP in the developed portion equaled 90 percent of the OIP calculated for the entire partition. The Prophet Model was then used to calculate the volumes of recoverable oil and water as well as the volumes of injected and stored CO_2. The Prophet Model was run assuming five-spot patterns were implemented for each partition. ROZ fairway well pattern spacings of 20 to 80 acres per CO_2 injection well were selected to achieve a target of approximately 30 years of operation for the miscible CO_2 flood.

2.4.2 Summary of Technically Recoverable Resources

A significant portion of the San Andres ROZ fairway OIP in Gaines County is technically recoverable using miscible CO_2 EOR, while also providing major volumes of pore space for storing CO_2 (Exhibit 2-8).

- Total technically viable oil recovery is estimated at 12,130 million barrels, produced primarily from the higher quality portions of the ROZ resource.

- While the oil recovery efficiencies vary by partition, overall recovery efficiency is 29% of OIP in response to one HCPV injection of CO_2 using a tapered WAG miscible CO_2 flood.

- The San Andres ROZ fairway interval in Gaines County offers the potential for significant storage of CO_2, equal to 6,994 million metric tons (132,190 Bcf).

Exhibit 2-8. Gaines County technically recoverable San Andres ROZ fairway resource

Partitions	Oil Recovery		Purchased CO$_2$	
	MM bbls	%OIP	Bcf	MM mt
#1	300	27%	3,270	173
#2	1,150	29%	8,760	463
#3	3,360	31%	34,890	1,846
#4	3,200	30%	31,520	1,668
#5	4,120	28%	53,750	2,844
Total	12,130	29%	132,190	6,994

2.5 VIABILITY OF OIL RECOVERY AND CO_2 STORAGE IN THE GAINES COUNTY ROZ FAIRWAY

The CO_2 EOR Cost Model used by the study assumes a first-year oil price (WTI) of $75 per barrel, linked to an initial CO_2 purchase cost of $1.50 per Mcf ($28.35 per metric ton of CO_2).

2.5.1 Commercially Viable Oil Recovery with By-Product CO_2 Storage

The five San Andres ROZ fairway partitions of Gaines County offer the potential for 10,100 million barrels of <u>commercially viable oil recovery</u> with 4,569 million metric tons (86,350 Bcf) of by-product storage of CO_2 (Exhibit 2-9).

The commercially viable portion of the ROZ resource has a purchased CO_2 to produced oil ratio of 0.45 metric tons of CO_2 per barrel of recovered oil (8.5 Mcf per barrel).

Exhibit 2-9. Gaines County commercially viable oil recovery with by-product CO_2 storage

Partition	Oil Recovery (MM bbls)	Purchased CO_2		Purchased CO_2/Oil Recovery (Ratio)	
		Bcf	MM mt	Mcf/B	mt/B
#1	150	1,490	79	9.9	0.53
#2	1,030	7,430	393	7.2	0.38
#3	3,240	31,120	1,647	9.6	0.51
#4	2,700	22,700	1,201	8.4	0.44
#5	2,980	23,610	1,249	7.9	0.42
Total	10,100	86,350	4,569	8.5	0.45

2.5.2 Geologically Viable CO_2 Storage with By-Product Oil Recovery

The five San Andres ROZ fairway partitions of Gaines County also offer the promise of 2,426 million metric tons (45,860 Bcf) of <u>geologically viable CO_2 storage</u> with 2,020 million barrels of by-product oil recovery, as shown in Exhibit 2-10.

Exhibit 2-10. Gaines County geologically viable CO_2 storage with by-product oil recovery

Partition	Purchased CO_2		By-Product Oil Recovery (MM bbls)	Purchased CO_2/ Oil Recovery (Ratio)	
	Bcf	MM mt		Mcf/B	mt/B
#1	1,790	95	150	11.9	0.63
#2	1,330	70	120	11.1	0.59
#3	3,770	199	110	34.3	1.81
#4	8,820	467	500	17.6	0.93
#5	30,150	1,595	1,140	26.4	1.40
Total	45,860	2,426	2,020	22.7	1.20

2.6 PARTITION #1. NORTHWEST GAINES COUNTY

2.6.1 Geologic Setting

Partition #1, located in northwestern Gaines County, covers a San Andres ROZ fairway area of 34,000 acres (Exhibit 2-11). The partition area excludes the southern portion of the Wasson oil field (11,200 acres). Partition #1 is located within the previously established San Andres ROZ fairway boundaries, on the Northwest Shelf.

Exhibit 2-11. San Andres ROZ fairway Partition #1, Gaines County
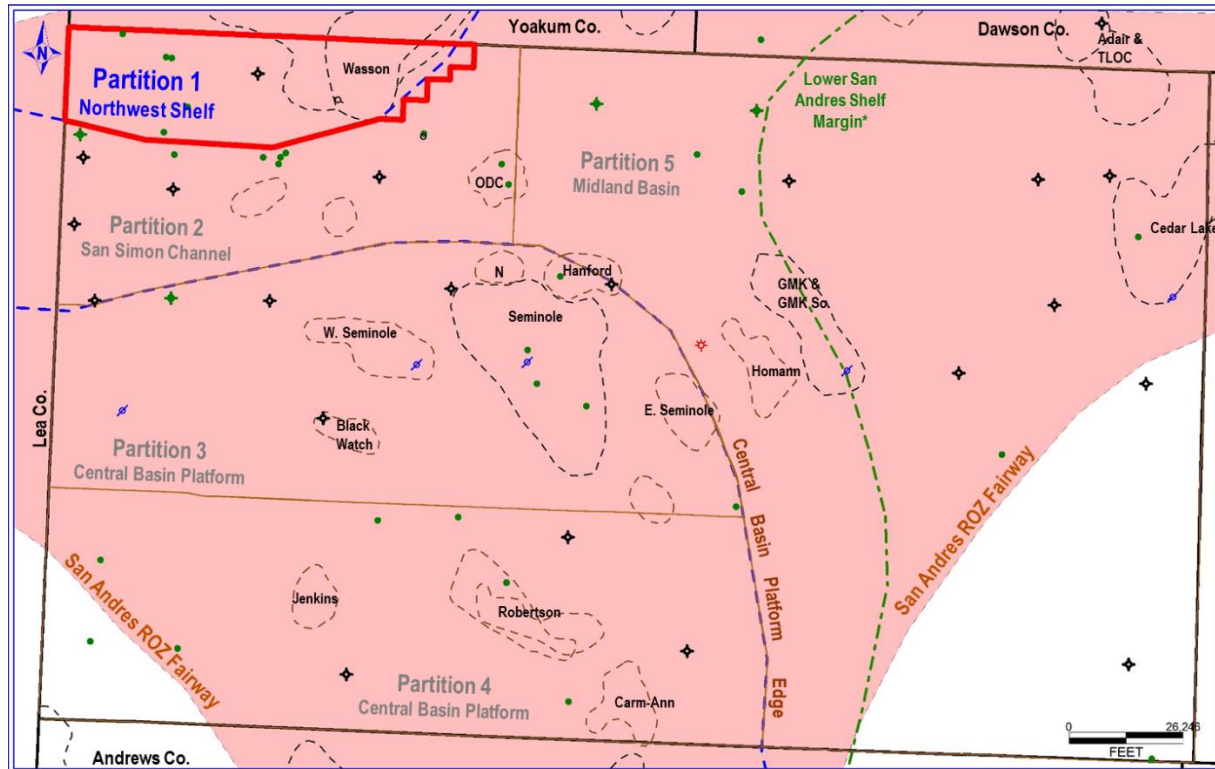
2.6.2 Analytical ROZ Reservoir Units

Six well log-based reservoir data sets plus a series of working level cross-sections were used to further divide the San Andres ROZ fairway resource in Partition #1 of Gaines County into four analytical ROZ fairway reservoir units, as set forth below:

- A higher quality ROZ #1 (Upper ROZ) interval
- A lower quality ROZ #1 (Upper ROZ) interval
- A higher quality ROZ #2 (Lower ROZ) interval
- A lower quality ROZ #2 (Lower ROZ) interval

The average volumetric reservoir properties for the four analytical San Andres ROZ fairway reservoir units of Partition #1 of Gaines County are provided in Exhibit 2-12.

Exhibit 2-12. Average San Andres ROZ fairway reservoir properties: Partition #1, Gaines County

Property	ROZ 1		ROZ 2	
	Higher Quality	Lower Quality	Higher Quality	Lower Quality
Depth (ft)	5,370	5,370	5,540	5,540
Gross Thickness (ft)	210	138	144	188
Net Pay (ft)	190	68	133	73
Avg. Porosity (fraction)	0.089	0.076	0.096	0.077
Avg. Oil Saturation (fraction)*	0.40	0.31	0.46	0.22
Avg. Formation Volume Factor (res B/bbl)	1.31	1.31	1.31	1.31
OIP (B/AF, for net pay)	211	140	262	100

*Oil saturation for the study wells in Partition #1 was calculated using Archie parameters: 'm' = 2.3; 'n' = 2.3; 'a' = 1; Rw = 0.055 ohm-m.

2.6.3 ROZ Oil In-Place

The San Andres ROZ fairway in Partition #1 of Gaines County contains 1,110 million barrels of OIP (Exhibit 2-13). The bulk of the ROZ OIP (850 million barrels) meets the higher ROZ resource quality criteria. The remainder of the ROZ OIP of 260 million barrels meets the lower resource quality criteria (Exhibit 2-13).

Exhibit 2-13. San Andres ROZ fairway OIP: Partition #1, Gaines County

Property	ROZ 1		ROZ 2	
	Higher Quality	Lower Quality	Higher Quality	Lower Quality
Oil In-Place (B/Acre)	40,110	9,450	34,790	7,310
Area Extent (Acres)	13,600	13,600	8,800	18,400
Oil In-Place (MM bbls)	540	130	310	130

2.6.4 Technically Recoverable Resources

Of the 1,110 million barrels of San Andres ROZ OIP in Partition #1 of Gaines County, approximately 300 million barrels is technically recoverable from the application of miscible CO_2 EOR, giving a recovery efficiency of 27 percent of OIP.

Significant volumes of CO_2 are stored as part of recovering a portion of the ROZ OIP. Approximately 173 million metric tons (3,270 Bcf) of CO_2 are purchased for the EOR project in Partition #1 of Gaines County, with essentially all of the purchased CO_2 securely stored at the end of the CO_2 flood.

2.6.5 Commercially Viable Oil Recovery with By-Product CO_2 Storage

Of the 300 million barrels of technically recoverable San Andres ROZ fairway oil resource available from Partition #1 of Gaines County, 150 million barrels are commercially viable to develop under the economic assumptions used in this study.

The application of CO_2 EOR to the commercially viable portion of the San Andres ROZ fairway resource in Partition #1 of Gaines County also provides 79 million metric tons (1,490 Bcf) of by-product storage of CO_2 (Exhibit 2-14).

The production of one barrel of San Andres ROZ fairway oil in Partition #1 of Gaines County brings with it, at the margin, the storage of 0.53 metric tons of CO_2.

Exhibit 2-14. Commercially viable oil recovery with by-product CO_2 storage: Partition #1 Gaines County

Oil Recovery (MM bbls)	Purchased CO_2		Purchased CO_2/ Oil Recovery (Ratio)	
	Bcf	MM mt	Mcf/B	mt/B
150	1,490	79	9.9	0.53

2.6.6 Geologically Viable CO_2 Storage with By-Product Oil Recovery

Pursuing the geologically viable, but economically non-viable, portion of the San Andres ROZ fairway resource in Partition #1 of Gaines County with miscible CO_2 flooding provides 95 million metric tons (1,790 Bcf) of CO_2 storage capacity, with 150 million barrels of by-product oil recovery (Exhibit 2-15).

Exhibit 2-15. Geologically viable storage of CO_2 with by-product oil recovery: Partition #1 Gaines County

Purchased CO_2		By-Product Oil Recovery (MM bbls)	Purchased CO_2/ Produced Oil (Ratio)	
Bcf	MM mt		Mcf/B	mt/B
1,790	95	150	11.9	0.63

2.7 PARTITION #2. NORTHWEST GAINES COUNTY – SAN SIMON CHANNEL

2.7.1 Geologic Setting

Partition #2, located in northwest Gaines County, covers a San Andres ROZ fairway area of 75,000 acres (Exhibit 2-16). The partition area excludes the Russell South, Havemeyer, and ODC oil fields (5,700 acres). Partition #2 is located within the previously established San Andres ROZ fairway boundaries, in the San Simon Channel between the Northwest Shelf and the CBP.

Exhibit 2-16. San Andres ROZ fairway Partition #2, Gaines County
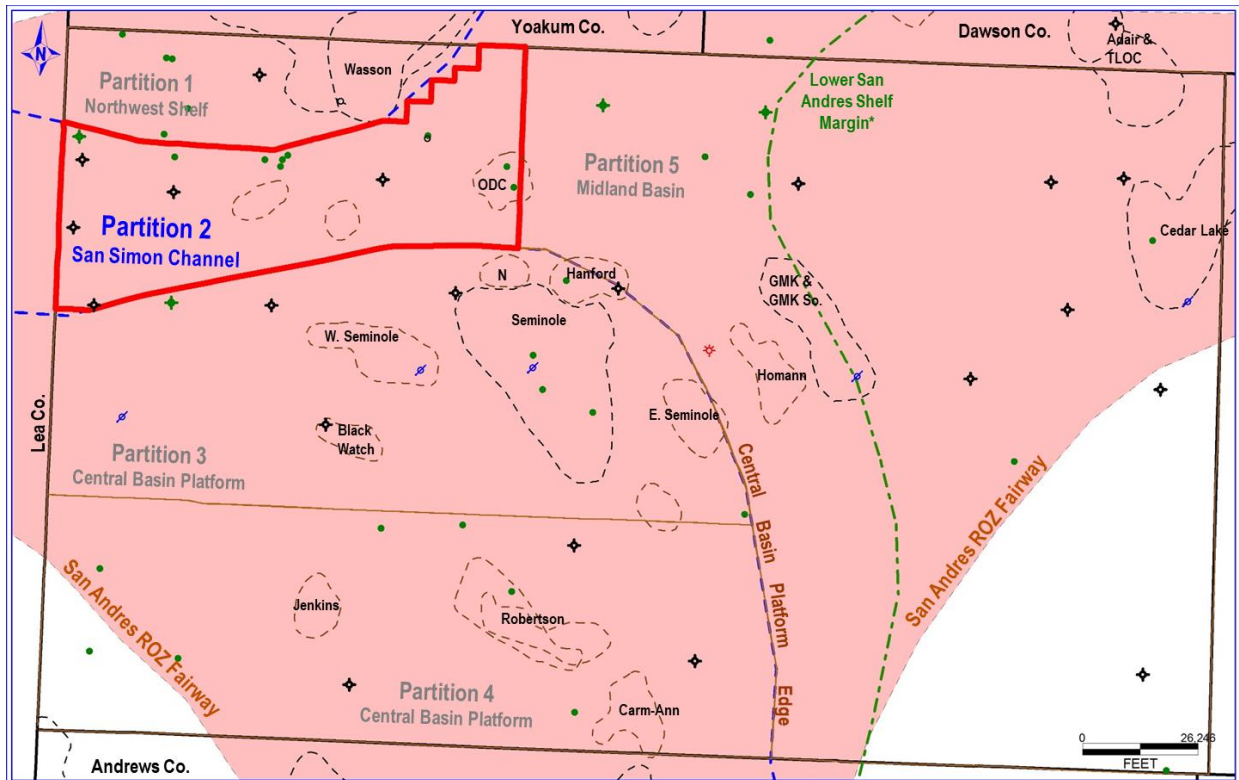
2.7.2 Analytical ROZ Reservoir Units

Eight well log-based reservoir data sets plus a series of working level cross-sections were used to further divide the San Andres ROZ fairway resource in Partition #2 of Gaines County into four analytical ROZ fairway reservoir units, as set forth below:

- A higher quality ROZ #1 (Upper ROZ) interval

- A lower quality ROZ #1 (Upper ROZ) interval

- A higher quality ROZ #2 (Lower ROZ) interval

- A lower quality ROZ #2 (Lower ROZ) interval

The average volumetric reservoir properties for the four analytical San Andres ROZ fairway reservoir units of Partition #2 of Gaines County are provided in Exhibit 2-17.

Exhibit 2-17. Average San Andres ROZ fairway reservoir properties: Partition #2, Gaines County

Property	ROZ 1		ROZ 2	
	Higher Quality	Lower Quality	Higher Quality	Lower Quality
Depth (ft)	5,630	5,630	5,780	5,780
Gross Thickness (ft)	186	151	155	138
Net Pay (ft)	179	104	151	123
Avg. Porosity (fraction)	0.090	0.080	0.090	0.087
Avg. Oil Saturation (fraction)*	0.44	0.36	0.40	0.25
Avg. Formation Volume Factor (res B/bbl)	1.24	1.24	1.24	1.24
OIP (B/AF, for net pay)	248	180	225	136

*Oil saturation for the study wells in Partition #2 was calculated using Archie parameters: 'm' = 2.3 to 2.5; 'n' = 3; 'a' = 1; Rw = 0.055 ohm-m.

2.7.3 ROZ Oil In-Place

The San Andres ROZ fairway in Partition #2 of Gaines County contains 3,930 million barrels of OIP (Exhibit 2-18). The bulk of the ROZ OIP (3,280 million barrels) meets the higher ROZ resource quality criteria. The remainder of the ROZ OIP of 650 million barrels meets the lower resource quality criteria.

Exhibit 2-18. San Andres ROZ fairway OIP: Partition #2, Gaines County

Property	ROZ 1		ROZ 2	
	Higher Quality	Lower Quality	Higher Quality	Lower Quality
Oil In-Place (B/Acre)	44,370	18,630	33,930	16,670
Area Extent (Acres)	45,000	15,000	37,600	22,400
Oil In-Place (MM bbls)	2,000	280	1,280	370

2.7.4 Technically Recoverable Resources

Of the 3,930 million barrels of San Andres ROZ OIP in Partition #2 of Gaines County, approximately 1,150 million barrels is technically recoverable from the application of miscible CO_2 EOR, giving a recovery efficiency of 29 percent of OIP.

Significant volumes of CO_2 are stored as part of applying miscible CO_2 EOR for recovering a portion of the ROZ OIP. Approximately 463 million metric tons (8,760 Bcf) of CO_2 are purchased for the San Andres ROZ fairway EOR project in Partition #2 of Gaines County, with essentially all of the purchased CO_2 securely stored at the end of the CO_2 flood.

2.7.5 Commercially Viable Oil Recovery with By-Product CO_2 Storage

Of the 1,150 million barrels of technically recoverable San Andres ROZ fairway oil resource available from Partition #2 of Gaines County, 1,030 million barrels are economically viable to develop under the economic assumptions used in the study.

The application of CO_2 EOR to the commercially viable portion of the San Andres ROZ fairway resource in Partition #2 of Gaines County also provides 393 million metric tons (7,430 Bcf) of by-product storage of CO_2 (Exhibit 2-19).

The production of one barrel of San Andres ROZ fairway oil in Partition #2 of Gaines County brings with it the storage, at the margin, of 0.38 metric tons of CO_2.

Exhibit 2-19. Commercially viable oil recovery with by-product CO_2 storage: Partition #2 Gaines County

Oil Recovery (MM bbls)	Purchased CO_2		Purchased CO_2/ Oil Recovery (Ratio)	
	Bcf	MM mt	Mcf/B	mt/B
1,030	7,430	393	7.2	0.38

2.7.6 Geologically Viable CO_2 Storage with By-Product Oil Recovery

Pursuing the geologically viable but economically non-viable remaining 120 million barrels of technically recoverable San Andres ROZ fairway oil in Partition #2 of Gaines County with miscible CO_2 flooding provides 70 million metric tons (1,330 Bcf) of CO_2 storage capacity, with 120 million barrels of by-product oil recovery (Exhibit 2-20).

Exhibit 2-20. Geologically viable storage of CO_2 with by-product oil recovery: Partition #2 Gaines County

Purchased CO_2		By-Product Oil Recovery (MM bbls)	Purchased CO_2/ Produced Oil (Ratio)	
Bcf	MM mt		Mcf/B	mt/B
1,330	70	120	11.1	0.59

2.8 PARTITION #3. WEST CENTRAL GAINES COUNTY

2.8.1 Geologic Setting

Partition #3, located in west-central Gaines County, covers a San Andres ROZ fairway area of 142,000 acres (Exhibit 2-21). The partition area excludes several large oil fields such as Seminole, Hanford, and Blackwatch (41,000 acres). Partition #3 is located within the previously established San Andres ROZ fairway boundaries, on the CBP.

Exhibit 2-21. San Andres ROZ fairway Partition #3, Gaines County
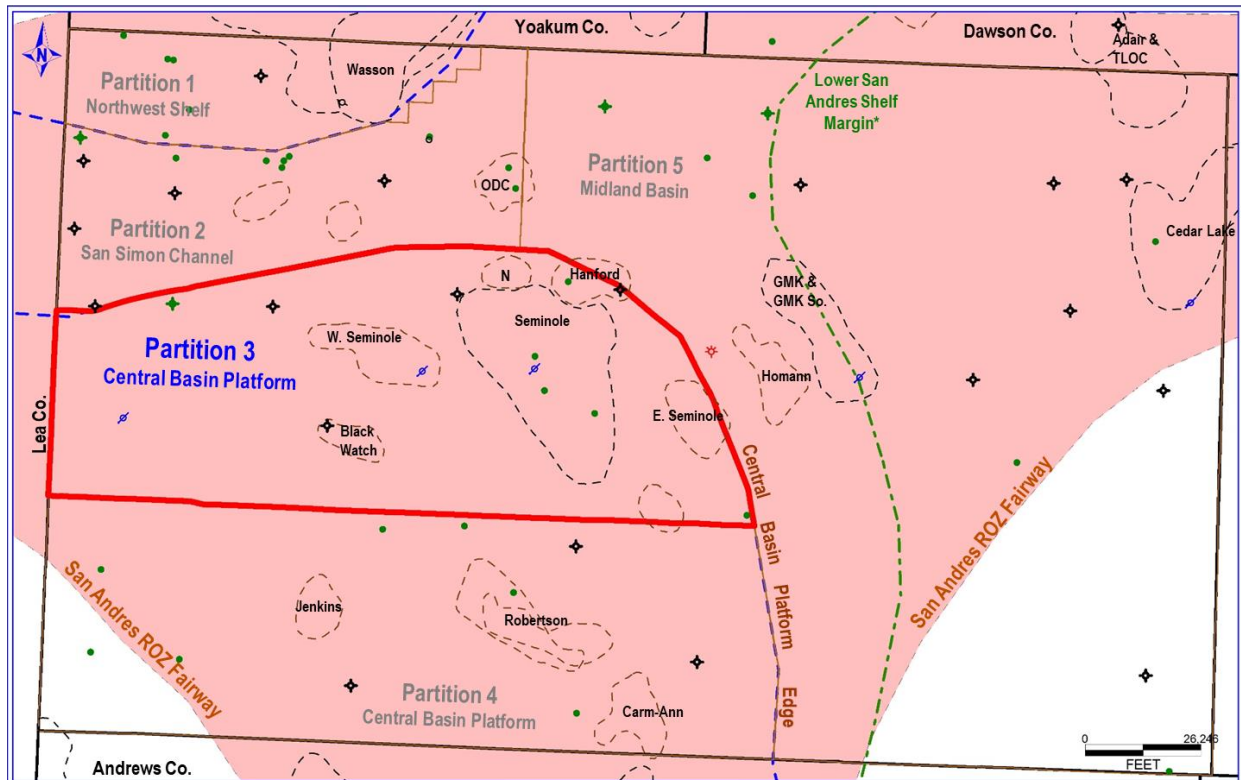
2.8.2 Analytical ROZ Reservoir Units

Six well log-based reservoir data sets plus a series of working level cross-sections were used to further divide the San Andres ROZ fairway resource in Partition #3 of Gaines County into four analytical ROZ fairway reservoir units, as set forth below:

- A higher quality ROZ #1 (Upper ROZ) interval
- A lower quality ROZ #1 (Upper ROZ) interval
- A higher quality ROZ #2 (Lower ROZ) interval
- A lower quality ROZ #2 (Lower ROZ) interval

The average volumetric reservoir properties for the four analytical San Andres ROZ fairway reservoir units of Partition #3 of Gaines County are provided in Exhibit 2-22.

Exhibit 2-22. Average San Andres ROZ fairway reservoir properties: Partition #3, Gaines County

Property	ROZ 1		ROZ 2	
	Higher Quality	Lower Quality	Higher Quality	Lower Quality
Depth (ft)	5,340	5,340	6,070	5,580
Gross Thickness (ft)	272	235	277	215
Net Pay (ft)	248	194	252	185
Avg. Porosity (fraction)	0.120	0.092	0.097	0.077
Avg. Oil Saturation (fraction)*	0.36	0.17	0.36	0.15
Avg. Formation Volume Factor (res B/bbl)	1.39	1.39	1.39	1.39
OIP (B/AF, for net pay)	241	87	195	64

*Oil saturation for the study wells in Partition #3 was calculated using Archie parameters: 'm' = 2.3; 'n' = 3.4; 'a' = 1; Rw = 0.07 ohm-m.

2.8.3 ROZ Oil In-Place

The San Andres ROZ fairway in Partition #3 of Gaines County contains 10,820 million barrels of OIP (Exhibit 2-23). The bulk of the ROZ OIP (10,270 million barrels) meets the higher ROZ resource quality criteria. The remainder of the ROZ OIP of 550 million barrels meets the lower resource quality criteria.

Exhibit 2-23. San Andres ROZ fairway OIP: Partition #3, Gaines County

Property	ROZ 1		ROZ 2	
	Higher Quality	Lower Quality	Higher Quality	Lower Quality
Oil In-Place (B/Acre)	59,650	16,830	49,140	11,810
Area Extent (Acres)	94,400	19,200	94,400	19,200
Oil In-Place (MM bbls)	5,630	320	4,640	230

2.8.4 Technically Recoverable Resources

Of the 10,820 million barrels of San Andres ROZ OIP in Partition #3 of Gaines County, approximately 3,360 million barrels is technically recoverable from the application of miscible CO_2 EOR, giving a recovery efficiency of 31 percent of OIP.

Significant volumes of CO_2 are stored as part of applying miscible CO_2 EOR for recovering a portion of the ROZ OIP. Approximately 1,846 million metric tons (34,890 Bcf) of CO_2 are purchased for the EOR project in Partition #3 of Gaines County, with essentially all of the purchased CO_2 securely stored at the end of the CO_2 flood.

2.8.5 Commercially Viable Oil Recovery with By-Product CO_2 Storage

Of the 3,360 million barrels of technically recoverable San Andres ROZ fairway oil resource available from Partition #3 of Gaines County, 3,240 million barrels are economically viable to develop under the economic assumptions used for this study.

The application of CO_2 EOR to the commercially viable portion of the San Andres ROZ fairway resource in Partition #3 of Gaines County also provides 1,647 million metric tons (31,120 Bcf) of by-product storage of CO_2 (Exhibit 2-24).

Exhibit 2-24. Commercially viable oil recovery with by-product CO_2 storage: Partition #3 Gaines County

Oil Recovery (MM bbls)	Purchased CO_2		Purchased CO_2/ Oil Recovery (Ratio)	
	Bcf	MM mt	Mcf/B	mt/B
3,240	31,120	1,647	9.6	0.51

The production of one barrel of San Andres ROZ fairway oil in Partition #3 of Gaines County brings with it, at the margin, the storage of 0.51 metric tons of CO_2.

2.8.6 Geologically Viable CO_2 Storage with By-Product Oil Recovery

Pursuing the geologically viable, but economically non-viable, portion of the San Andres ROZ fairway resource in Partition #3 of Gaines County with miscible CO_2 flooding provides 199 million metric tons (3,770 Bcf) of CO_2 storage capacity, with 110 million barrels of by-product oil recovery (Exhibit 2-25).

Exhibit 2-25. Geologically viable storage of CO_2 with by-product oil recovery: Partition #3 Gaines County

Purchased CO_2		By-Product Oil Recovery (MM bbls)	Purchased CO_2/ Produced Oil (Ratio)	
Bcf	MM mt		Mcf/B	mt/B
3,770	199	110	34.3	1.81

2.9 PARTITION #4. SOUTHERN GAINES COUNTY – CBP

2.9.1 Geologic Setting

Partition #4, located in southern Gaines County, covers a San Andres ROZ fairway area of 184,000 acres (Exhibit 2-26). The partition area excludes the Robertson, N. Robertson, Jenkins, and Carm-Ann oil fields (15,500 acres). Partition #4 is located within the previously established San Andres ROZ fairway boundaries, except in the extreme southwest corner of the county on the CBP.

Exhibit 2-26. San Andres ROZ fairway Partition #4, Gaines County
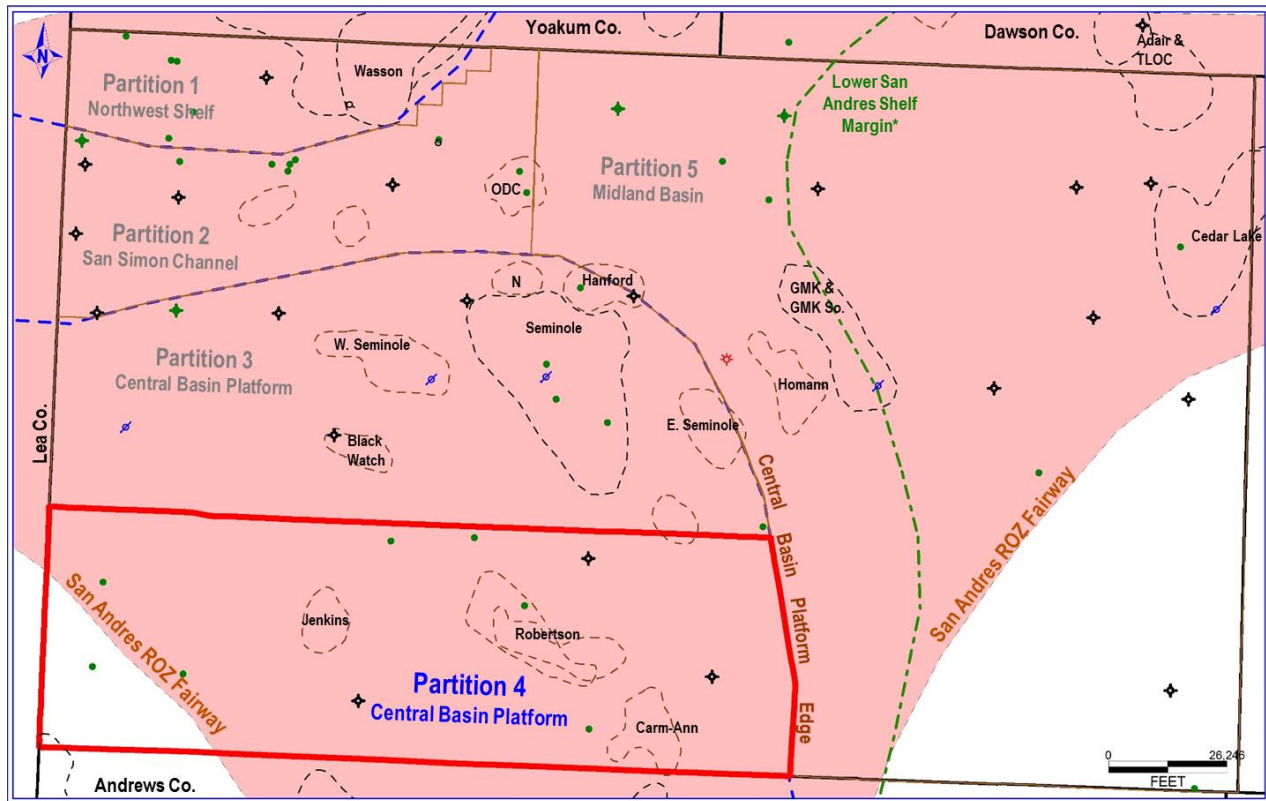
2.9.2 Analytical ROZ Reservoir Units

Eight well log-based reservoir data sets plus a series of working level cross-sections were used to further divide the San Andres ROZ fairway resource in Partition #4 of Gaines County into four analytical ROZ fairway reservoir units, as set forth below:

- A higher quality ROZ #1 (Upper ROZ) interval

- A lower quality ROZ #1 (Upper ROZ) interval

- A higher quality ROZ #2 (Lower ROZ) interval

- A lower quality ROZ #2 (Lower ROZ) interval

The average volumetric reservoir properties for the four analytical San Andres ROZ fairway reservoir units of Partition #4 of Gaines County are provided in Exhibit 2-27.

Exhibit 2-27. Average San Andres ROZ fairway reservoir properties: Partition #4, Gaines County

Property	ROZ 1		ROZ 2	
	Higher Quality	Lower Quality	Higher Quality	Lower Quality
Depth (ft)	4,920	4,920	5,130	5,130
Gross Thickness (ft)	248	192	198	218
Net Pay (ft)	225	114	189	177
Avg. Porosity (fraction)	0.106	0.086	0.107	0.096
Avg. Oil Saturation (fraction)*	0.35	0.15	0.43	0.22
Avg. Formation Volume Factor (res B/bbl)	1.38	1.38	1.38	1.38
OIP (B/AF, for net pay)	209	73	259	119

*Oil saturation for the study wells in Partition #4 was calculated using Archie parameters: 'm' = 2.3; 'n' = 3.4; 'a' = 1; Rw = 0.07 ohm-m.

2.9.3 ROZ Oil In-Place

The San Andres ROZ fairway in Partition #4 of Gaines County contains 10,630 million barrels of OIP (Exhibit 2-28). The bulk of the ROZ OIP (8,780 million barrels) meets the higher ROZ resource quality criteria. The remainder of the ROZ OIP of 1,850 million barrels meets the lower resource quality criteria.

Exhibit 2-28. San Andres ROZ fairway OIP: Partition #4, Gaines County

Property	ROZ 1		ROZ 2	
	Higher Quality	Lower Quality	Higher Quality	Lower Quality
Oil In-Place (B/Acre)	47,030	8,290	48,950	21,020
Area Extent (Acres)	110,400	36,800	73,600	73,600
Oil In-Place (MM bbls)	5,180	310	3,600	1,540

2.9.4 Technically Recoverable Resources

Of the 10,630 million barrels of San Andres ROZ OIP in Partition #4 of Gaines County, approximately 3,200 million barrels is technically recoverable from the application of miscible CO_2 EOR, giving a recovery efficiency of 30 percent of OIP.

Significant volumes of CO_2 are stored as part of applying miscible CO_2 EOR for recovering a portion of the ROZ OIP. Approximately 1,668 million metric tons (31,520 Bcf) of CO_2 are purchased for the EOR project in Partition #4 of Gaines County, with essentially all of the purchased CO_2 securely stored at the end of the CO_2 flood.

2.9.5 Commercially Viable Oil Recovery with By-Product CO_2 Storage

Of the 3,200 million barrels of technically recoverable San Andres ROZ fairway oil resource available from Partition #4 of Gaines County, 2,700 million barrels are economically viable to develop under the economic assumptions used in this study.

The application of CO_2 EOR to the commercially viable portion of the San Andres ROZ fairway resource in Partition #4 of Gaines County also provides 1,201 million metric tons (22,700 Bcf) of by-product storage of CO_2 (Exhibit 2-29).

The production of one barrel of San Andres ROZ fairway oil in Partition #4 of Gaines County brings with it, at the margin, the storage of 0.44 metric tons of CO_2.

Exhibit 2-29. Commercially viable oil recovery with by-product CO_2 storage: Partition #4 Gaines County

Oil Recovery (MM bbls)	Purchased CO_2		Purchased CO_2/ Oil Recovery (Ratio)	
	Bcf	MM mt	Mcf/B	mt/B
2,700	22,700	1,201	8.4	0.44

2.9.6 Geologically Viable CO_2 Storage with By-Product Oil Recovery

Pursuing the geologically viable but economically non-viable portion of the San Andres ROZ fairway resource in Partition #4 of Gaines County with miscible CO_2 flooding provides 467 million metric tons (8,820 Bcf) of CO_2 storage capacity, with 500 million barrels of by-product oil recovery (Exhibit 2-30).

Exhibit 2-30. Geologically viable storage of CO_2 with by-product oil recovery: Partition #4 Gaines County

Purchased CO_2		By-Product Oil Recovery (MM bbls)	Purchased CO_2/ Produced Oil (Ratio)	
Bcf	MM mt		Mcf/B	mt/B
8,820	467	500	17.6	0.93

2.10 PARTITION #5. EASTERN GAINES COUNTY

2.10.1 Geologic Setting

Partition #5, located in eastern half of Gaines County, covers a San Andres ROZ fairway area of 423,000 acres (Exhibit 2-31). The partition area excludes portions of the Adair/TLOC, Cedar Lake, and Hanford oil fields as well as the Homann and GMK oil fields (30,500 acres). Partition #5 is located within the previously established San Andres ROZ fairway boundaries (except for the southeast corner of the county), in the Midland Basin.

Exhibit 2-31. San Andres ROZ fairway Partition #5, Gaines County
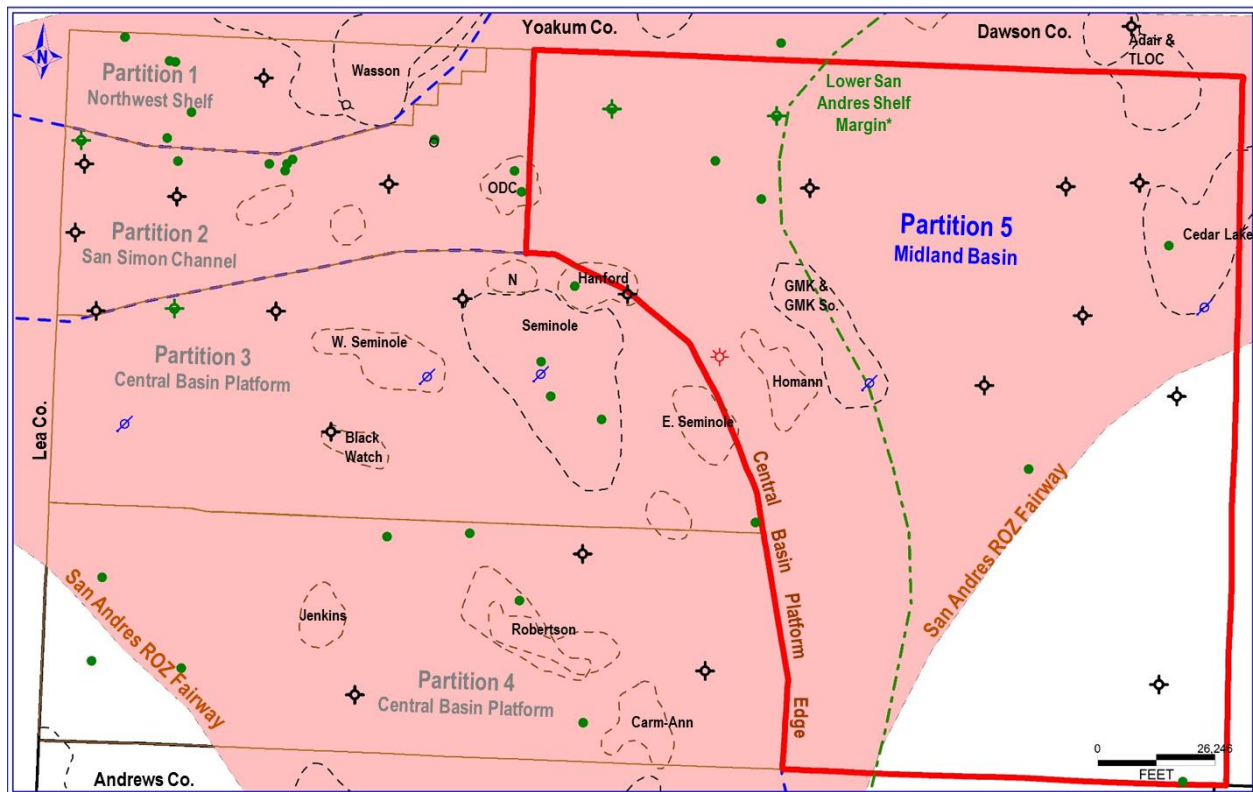
2.10.2 Analytical ROZ Reservoir Units

A series of eleven well log-based reservoir data sets plus a series of working level cross-sections were used to further divide the San Andres ROZ fairway resource in Partition #5 of Gaines County into four analytical ROZ fairway reservoir units, as set forth below:

- A higher quality ROZ #1 (Upper ROZ) interval

- A lower quality ROZ #1 (Upper ROZ) interval

- A higher quality ROZ #2 (Lower ROZ) interval

- A lower quality ROZ #2 (Lower ROZ) interval

The average volumetric reservoir properties for the four analytical San Andres ROZ fairway reservoir units of Partition #5 of Gaines County are provided in Exhibit 2-32.

Exhibit 2-32. Average San Andres ROZ fairway reservoir properties: Partition #5 Gaines County

Property	ROZ 1		ROZ 2	
	Higher Quality	Lower Quality	Higher Quality	Lower Quality
Depth (ft)	5,270	5,270	5,430	5,430
Gross Thickness (ft)	174	168	218	148
Net Pay (ft)	153	122	198	89
Avg. Porosity (fraction)	0.109	0.112	0.118	0.113
Avg. Oil Saturation (fraction)*	0.30	0.17	0.31	0.16
Avg. Formation Volume Factor (res B/bbl)	1.18	1.18	1.18	1.18
OIP (B/AF, for net pay)	215	125	240	119

*Oil saturation for the study wells in Partition #1 was calculated using Archie parameters: 'm' = 2.3; 'n' = 2.3; 'a' = 1; Rw = 0.055 ohm-m.

2.10.3   ROZ Oil In-Place

The San Andres ROZ fairway in Partition #5 of Gaines County contains 14,880 million barrels of OIP (Exhibit 2-33). The bulk of the ROZ OIP (8,850 million barrels) meets the higher ROZ resource quality criteria. The remainder of the ROZ OIP of 6,030 million barrels meets the lower resource quality criteria.

Exhibit 2-33. San Andres ROZ fairway OIP: Partition #5, Gaines County

Property	ROZ 1		ROZ 2	
	Higher Quality	Lower Quality	Higher Quality	Lower Quality
Oil In-Place (B/Acre)	32,900	15,190	47,520	10,580
Area Extent (Acres)	92,000	246,400	122,400	216,000
Oil In-Place (MM bbls)	3,030	3,740	5,820	2,290

2.10.4   Technically Recoverable Resources

Of the 14,880 million barrels of San Andres ROZ OIP in Partition #5 of Gaines County, approximately 4,120 million barrels is technically recoverable from the application of miscible CO_2 EOR, giving a recovery efficiency of 28 percent of OIP.

Significant volumes of CO_2 are stored as part of applying miscible CO_2 EOR for recovering a portion of the ROZ OIP. Approximately 2,844 million metric tons (53,750 Bcf) of CO_2 are purchased for the EOR project in Partition #5 of Gaines County, with essentially all of the purchased CO_2 securely stored at the end of the CO_2 flood.

2.10.5 Commercially Viable Oil Recovery with By-Product CO_2 Storage

Of the 4,120 million barrels of technically recoverable San Andres ROZ fairway oil resource available from Partition #5 of Gaines County, 2,980 million barrels are economically viable to develop under the economic assumptions used for this study.

The application of CO_2 EOR to the commercially viable portion of the San Andres ROZ fairway resource in Partition #5 of Gaines County also provides 1,249 million metric tons (23,610 Bcf) of by-product storage of CO_2 (Exhibit 2-34).

The production of one barrel of San Andres ROZ fairway oil in Partition #5 of Gaines County brings with it, at the margin, the storage of 0.42 metric tons of CO_2.

Exhibit 2-34. Commercially viable oil recovery with by-product CO_2 storage: Partition #5 Gaines County

Oil Recovery (MM bbls)	Purchased CO_2		Purchased CO_2/ Oil Recovery (Ratio)	
	Bcf	MM mt	Mcf/B	mt/B
2,980	23,610	1,249	7.9	0.42

2.10.6 Geologically Viable CO_2 Storage with By-Product Oil Recovery

Pursuing the geologically viable but economically non-viable portion of the San Andres ROZ fairway resource in Partition #5 of Gaines County with miscible CO_2 flooding provides 1,595 million metric tons (30,150 Bcf) of CO_2 storage capacity, with 1,140 million barrels of by-product oil recovery (Exhibit 2-35).

Exhibit 2-35. Geologically viable storage of CO_2 with by-product oil recovery: Partition #5 Gaines County

Purchased CO_2		By-Product Oil Recovery (MM bbls)	Purchased CO_2/ Produced Oil (Ratio)	
Bcf	MM mt		Mcf/B	mt/B
30,150	1,595	1,140	26.4	1.40

3 YOAKUM COUNTY

3.1 GEOLOGIC SETTING

Yoakum County covers a 512,400-acre area in the western portion of the Permian Basin, primarily on the Northwest Shelf.

The county contains numerous major San Andres Formation oil fields, including Wasson, Brahaney, Prentice, Reeves, and Ownby, among others. The ROZ resource below these and other existing San Andres oil fields has been excluded from the San Andres ROZ fairway resource assessment.

The Yoakum County map (Exhibit 3-1) shows 1) the location of 28 study wells, 2) the four ROZ fairway partitions established by the study, 3) the boundaries of the previously established San Andres ROZ fairway, 4) the edge of the Northwest Shelf, and 5) the location of three regional cross-sections for the San Andres ROZ. The map also shows the major San Andres oil fields that have been excluded from the San Andres ROZ fairway resource assessment in Yoakum County.

3.1.1 Example Yoakum County Cross-Sections

The characterization of the San Andres ROZ fairway interval in Yoakum County has drawn on the construction of a series of working cross-sections. Three of these cross-sections are included in this report.

- Yoakum Co. Cross-Section A-A' (Exhibit 3-2) provides a NW-SE view of the San Andres ROZ interval starting on the Northwest Shelf in the NW corner of the county, traversing through the middle of the county, and ending in the Midland Basin in the SE corner of the county.

- Yoakum Co. Cross-Section B-B' (Exhibit 3-3) provides a SW-NE view of the San Andres ROZ interval on the Northwest Shelf, starting near the NW boundary of Wasson Field, traversing through the middle of the county, and ending in the NE corner of the county.

- Yoakum Co. Cross-Section C-C' (Exhibit 3-4) provides another NW-SE view of the of the San Andres ROZ interval in the southern part of the county, starting on the west boundary of the county, traversing through a portion of the Wasson oil field, and ending in the Midland Basin at the Reeves oil field.

Exhibit 3-1. Yoakum County: geologic partitions, major oil fields, and study well locations
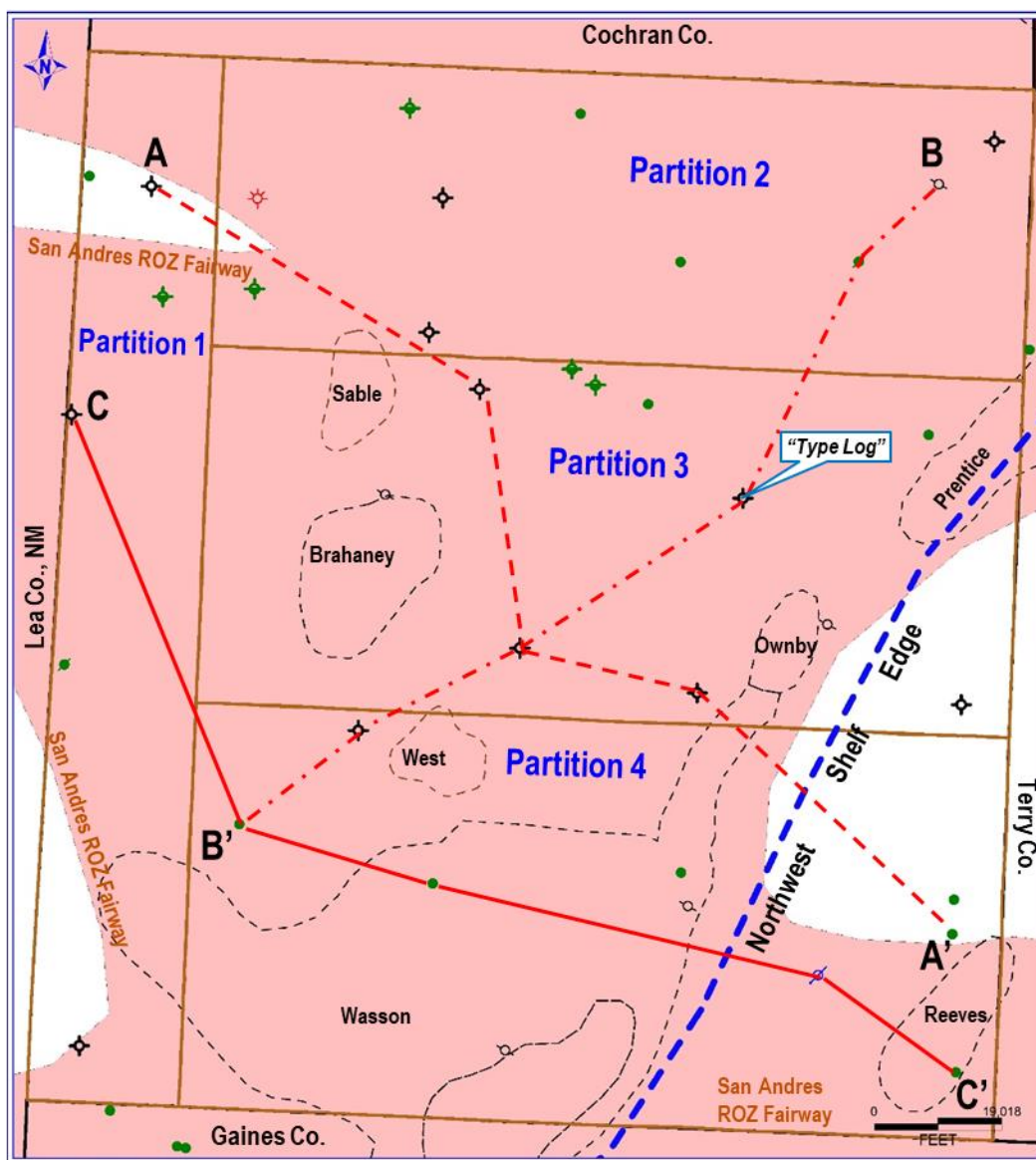
Exhibit 3-2. Yoakum County NW-SE cross-section A-A'
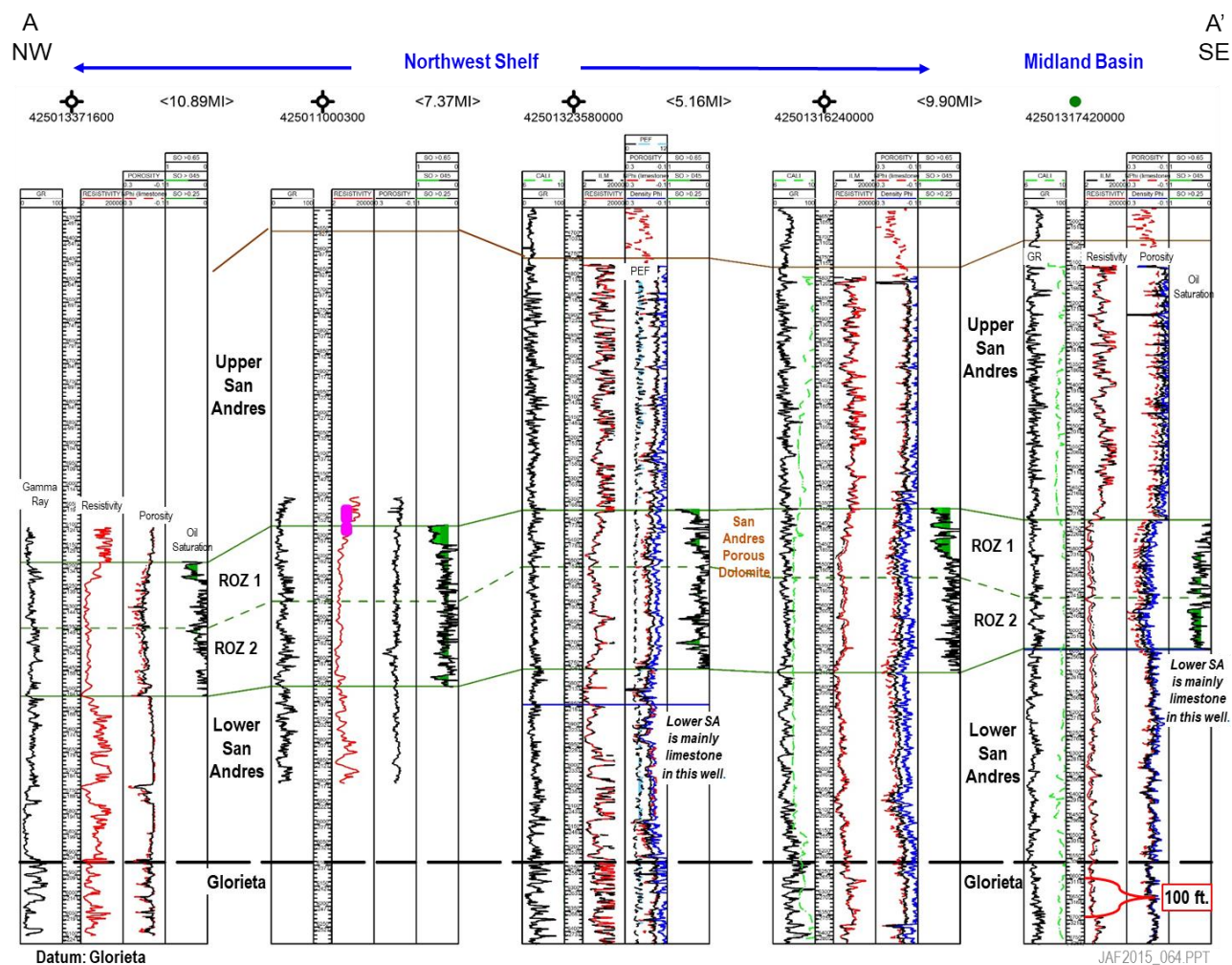
JAF2015_064.PPT

Exhibit 3-3. Yoakum County SW-NE cross-section B-B'
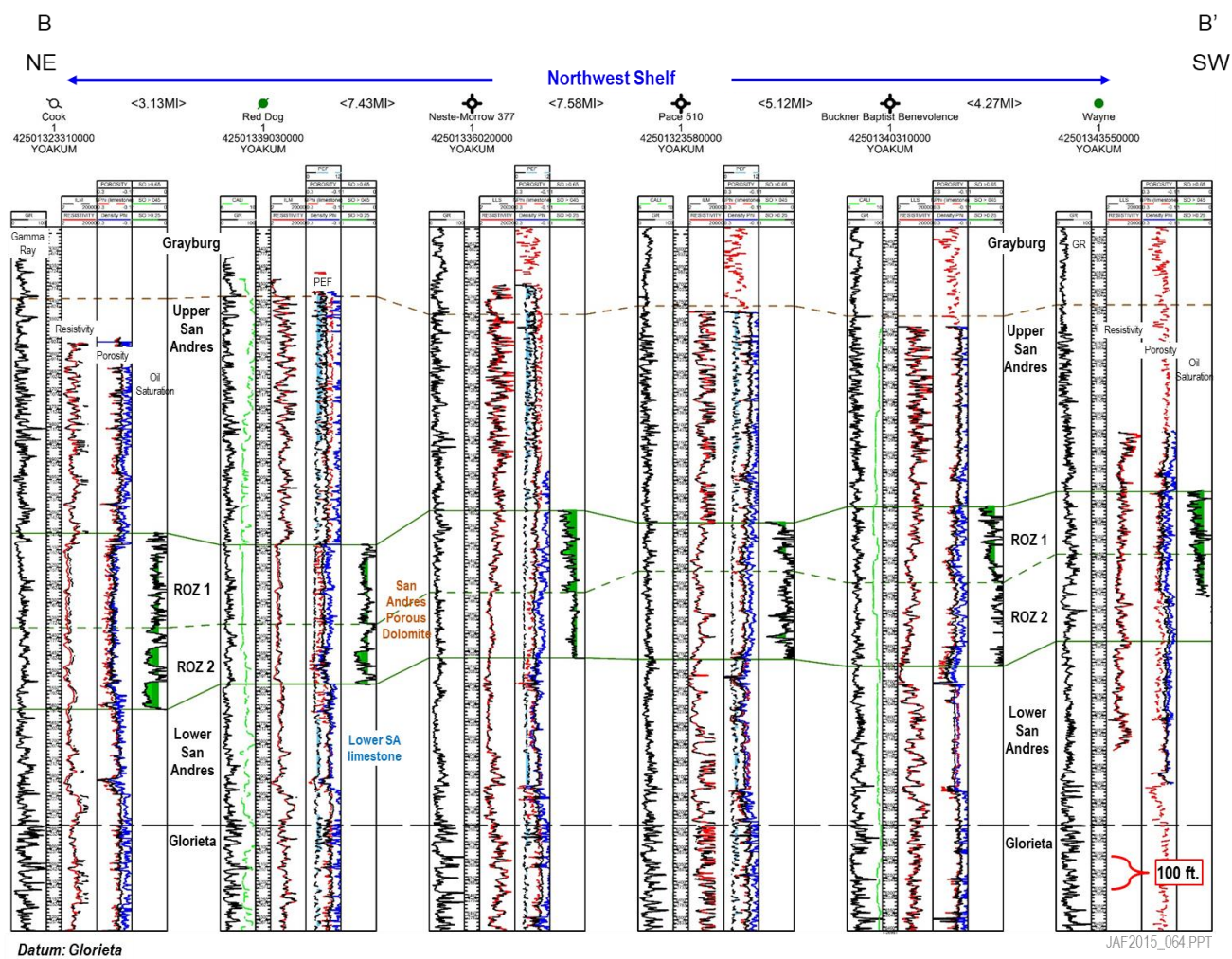
Datum: Glorieta

JAF2015_064.PPT

Exhibit 3-4. Yoakum County NW-SE cross-section C-C'

Datum: Top of San Andres
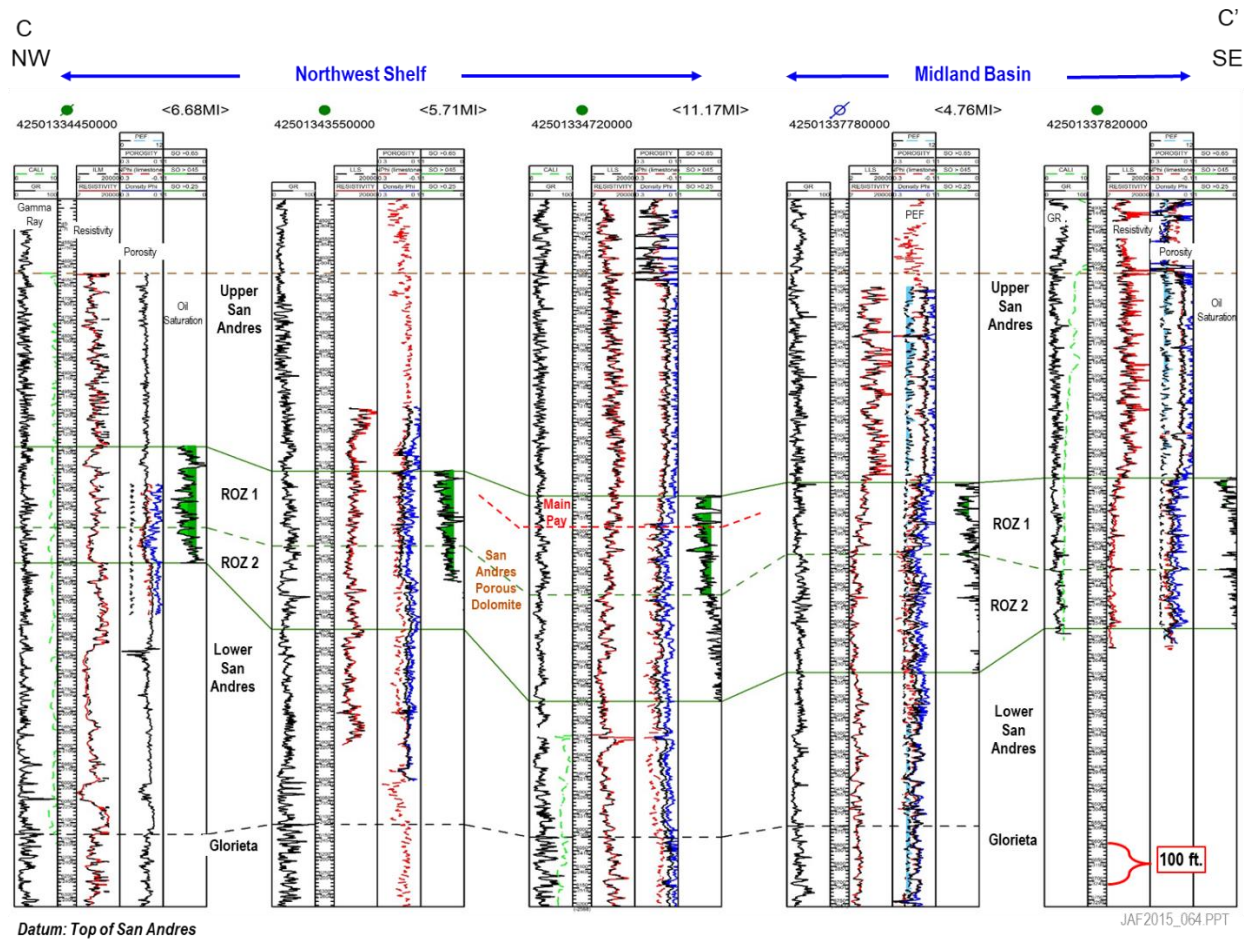
3.1.2 Interpretation of Yoakum County Cross-Sections

For logs in the ROZ fairway, the top of the San Andres porous dolomite is picked as the top of the ROZ for this resource assessment. The porous dolomite intervals, informally designated as ROZ 1 and ROZ 2, are illustrated on the cross-sections.

The cross-sections display gamma-ray and caliper logs in Track 1 on the left. Resistivity logs are shown in Track 2, with the deep resistivity log shown in red. Track 3 shows the porosity logs. Uncorrected neutron porosity (for limestone) is red; uncorrected density porosity (for limestone) is blue. The porosity curve used for the OIP calculation is black.

The PEF curve, if available, is also displayed in Track 3. PEF values greater than 4 are shaded in blue. Within and below the ROZ interval, high PEF values generally indicate the presence of limestone, dolomitic limestone, or anhydrite.

Track 4 on the right shows the calculated oil saturation. Calculated oil saturations between 25 percent and 45 percent are dark green; calculated oil saturations between 45 percent and 65 percent are light green; and oil saturation greater than 65 percent, typically present in only the MPZ, are black.

The base of the ROZ is where either calculated oil saturation or apparent porosity (or both) diminish in the Lower San Andres. If a Lower San Andres limestone is prominent, the top of the limestone defines the base of the ROZ.

3.1.3 Yoakum County Type Log

A type log was selected from the Yoakum County study wells to illustrate the ROZ resource analysis undertaken for the county (Exhibit 3-5). The type log illustrates two distinct San Andres ROZ resource intervals—ROZ 1 in the upper portion of the porous dolomite, and ROZ 2 in the lower portion of the porous dolomite.

Uncorrected neutron and density porosity curves illustrate the change in lithology below the ROZ, from porous dolomite to limestone. In this type log, the porosity is fairly uniform but low through the ROZ. The calculated oil saturation diminishes at the base of ROZ 1 at approximately 5,550 feet, shown by the distinct reduction in apparent resistivity on the log. The gamma ray curve shows that the ROZ 2 interval appears to have more shale and thinner interbeds of porous dolomite compared to ROZ 1. The base of the ROZ is at 5,720 feet, reflecting a change in lithology from porous dolomite to a thick section of interbedded limestone and shale/siltstone.

Exhibit 3-5. Type log for Yoakum County San Andres ROZ fairway
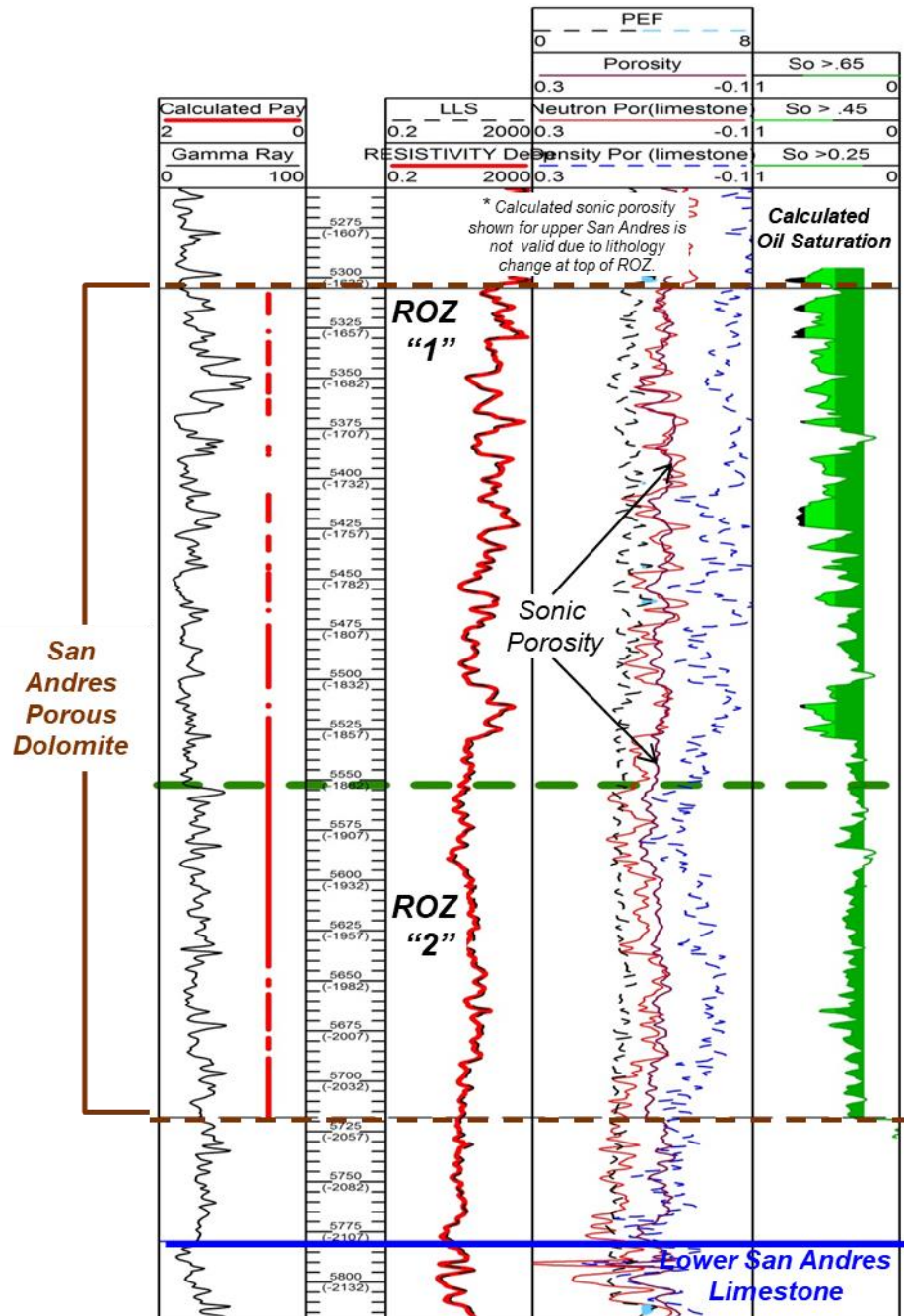
The oil saturation for the type log ROZ was calculated using the following Archie parameters—'m' of 2.3, 'n' of 3, 'a' of 1, and formation Rw of 0.045 ohm-m. A porosity cut-off of 6 percent was applied to define net pay in the ROZ. Intervals identified as ROZ pay are shown by the red "pay" flag in Track 1 of Exhibit 3-5.

For ROZ "1," the average porosity of net pay is 7.4 percent and average oil saturation is 44 percent, with the highest calculated oil saturations at the top of ROZ "1." For ROZ "2," the average porosity of net pay is 8.1 percent and average oil saturation is 32 percent. Core analysis from the Bennett Ranch Unit of the Wasson Field was used to establish log analysis parameters for the ROZ interval in Yoakum County.

3.2 PARTITIONING THE YOAKUM COUNTY ROZ FAIRWAY RESOURCE

The ROZ fairway in Yoakum County were divided into four partitions, as illustrated previously in Exhibit 3-1. Individual ROZ fairway resource assessments were undertaken for each of the four partitioned areas.

- Partition #1. Covers a 73,000-acre area of western Yoakum County. A portion of the Roberts Unit of the Wasson oil field (4,500 acres) has been excluded from the ROZ fairway resource assessment area for Partition #1.

- Partition #2. Covers a 120,000-acre area of northern Yoakum County. No existing oil field area has been excluded from Partition #2.

- Partition #3. Covers a 129,000-acre area of central Yoakum County. The area encompassed by Brahaney (8,400 acres), Prentice (4,800 acres), Sable (3,200 acres), and Ownby (2,500 acres) oil fields has been excluded from the ROZ fairway resource assessment for Partition #3.

- Partition #4. Covers a 99,000-acre area of southern Yoakum County. The area encompassed by Wasson (59,000 acres), Reeves (6,200 acres), and West (2,800 acres) oil fields has been excluded from the ROZ fairway resource assessment for Partition #4.

Of Yoakum County's 512,400 acres, a total of 91,400 acres under the structural closure of existing San Andres oil fields has been excluded, leaving a remaining ROZ assessment area of 421,000 acres (Exhibit 3-6).

Exhibit 3-6. Yoakum County ROZ fairway partitions

Partition	Total Area	Excluded Area	Assessment Area
	Acres	Acres	Acres
#1	77,500	4,500	73,000
#2	120,000	-	120,000
#3	147,900	18,900	129,000
#4	167,000	68,000	99,000
Total	512,400	91,400	421,000

3.3 SIZE AND QUALITY OF THE YOAKUM COUNTY ROZ FAIRWAY RESOURCE

Yoakum County holds 17,700 million barrels of OIP in the San Andres ROZ fairway, outside the structural closure of the existing oil fields. The OIP and resource quality values for each of the four partitions of Yoakum County are shown in Exhibit 3-7.

- Higher Quality ROZ Fairway Resources. A significant portion, 14,090 million barrels, of the San Andres ROZ fairway OIP in Yoakum County has higher quality reservoir properties (porosity greater than 8% and oil saturation equal to or greater than 25%).

- Lower Quality ROZ Fairway Resources. The remainder, 3,610 million barrels, of the San Andres ROZ fairway OIP in Yoakum County has lower quality reservoir properties (porosity equal to or less than 8% and/or oil saturation of less than 25%).

Exhibit 3-7. Yoakum County San Andres ROZ fairway resource in-place (MM bbls)

Partition	ROZ 1			ROZ 2			Total		
	Higher Quality	Lower Quality	Total	Higher Quality	Lower Quality	Total	Higher Quality	Lower Quality	Total
#1	160	640	800	-	260	260	160	900	1,060
#2	3,510	490	4,000	4,110	-	4,110	7,620	490	8,110
#3	2,740	1,500	4,240	1,580	630	2,210	4,320	2,130	6,450
#4	1,790	30	1,820	200	60	260	1,990	90	2,080
Total*	8,200	2,660	10,860	5,890	950	6,840	14,090	3,610	17,700

*Totals may not add due to rounding.

3.4 TECHNICALLY RECOVERABLE YOAKUM COUNTY ROZ FAIRWAY RESOURCE

3.4.1 Methodology for Estimating Technically Recoverable Resources

The average volumetric reservoir properties for each partition of Yoakum County, along with proprietary reservoir properties from ARI's Big Oil Fields Data Base, were used as input into the Prophet Model. Additionally, it was assumed that 80 percent of each partition area was suitable for development, while 20 percent of the partition had a combination of net pay, porosity, or oil saturation that was not suitable for development. It was also assumed that 90 percent of the OIP in each partition resides in the area suitable for development. The net pay for the developed portion of the partition was increased so that the OIP in the developed portion equaled 90 percent of the OIP calculated for the entire partition. The Prophet Model was then used to calculate the volumes of recoverable oil and waters as well as the volumes of injected and stored CO_2. The Prophet Model was run assuming five-spot patterns were implemented at each partition. ROZ fairway well pattern spacings of 20 to 80 acres per CO_2 injection well were selected to achieve a target of approximately 30 years of operation for the CO_2 flood.

3.4.2 Summary of Technically Recoverable Resources

A significant portion of the San Andres ROZ fairway OIP of 17,700 million barrels in Yoakum County is technically recoverable using miscible CO_2 EOR, while also providing major volumes of pore space for storing CO_2 (Exhibit 3-8).

- Total technically viable oil recovery is estimated at 4,310 million barrels, produced primarily from the higher quality portions of the ROZ resource.

- While the oil recovery efficiencies vary by partition, overall recovery efficiency is 24% of OIP, in response to one HCPV injection of CO_2 using a tapered WAG miscible CO_2 flood.

- The San Andres ROZ fairway interval in Yoakum County offers the potential for significant storage of CO_2, equal to 2,490 million metric tons (47,060 Bcf).

Exhibit 3-8. Yoakum County technically recoverable San Andres ROZ fairway resource

Partitions	Oil Recovery		Purchased CO₂	
	MM bbls	%OIP	Bcf	MM mt
#1	320	30%	2,970	157
#2	1,810	22%	20,380	1,078
#3	1,590	25%	17,540	928
#4	590	28%	6,170	327
Total	4,310	24%	47,060	2,490

3.5 VIABILITY OF OIL RECOVERY AND CO_2 STORAGE IN THE YOAKUM COUNTY ROZ FAIRWAY

The CO_2 EOR Cost Model used by the study assumes a first-year oil price (WTI) of $75 per barrel linked to an initial CO_2 purchase cost of $1.50 per Mcf ($28.35 per metric ton of CO_2).

3.5.1 Commercially Viable Oil Recovery with By-Product CO_2 Storage

The four San Andres ROZ fairway partitions of Yoakum County offer the potential for 2,840 million barrels of underlined commercially viable oil recovery and 1,460 million metric tons (27,590 Bcf) of by-product storage of CO_2 (Exhibit 3-9).

The commercially viable portion of the ROZ resource has a purchased CO_2 to produced oil ratio of 0.51 metric ton of CO_2 per barrel of recovered oil (9.7 Mcf per barrel).

Exhibit 3-9. Yoakum County commercially viable oil recovery with by-product CO_2 storage

Partition	Oil Recovery (MM bbls)	Purchased CO_2		Purchased CO_2/Oil Recovery (Ratio)	
		Bcf	MM mt	Mcf/B	mt/B
#1	-	-	-	-	-
#2	1,690	18,390	973	10.9	0.58
#3	1,110	8,740	462	7.9	0.42
#4	40	460	24	11.5	0.61
Total*	2,840	27,590	1,460	9.7	0.51

*Totals may not add due to rounding

3.5.2 Geologically Viable CO_2 Storage with By-Product Oil Recovery

The four San Andres ROZ fairway partitions of Yoakum County also offer the potential for 1,030 million metric tons (19,470 Bcf) of underlined geologically viable CO_2 storage with 1,470 million barrels of by-product oil recovery (Exhibit 3-10).

Exhibit 3-10. Yoakum County geologically viable CO_2 storage with by-product oil recovery

Partition	Purchased CO_2		By-Product Oil Recovery (MM bbls)	Purchased CO_2/ Oil Recovery (Ratio)	
	Bcf	MM mt		Mcf/B	mt/B
#1	2,970	157	320	9.3	0.49
#2	1,980	105	120	16.5	0.87
#3	8,800	466	480	18.3	0.97
#4	5,720	303	550	10.4	0.55
Total	19,470	1,030	1,470	13.2	0.70

3.6 PARTITION #1. WESTERN YOAKUM COUNTY

3.6.1 Geologic Setting

Partition #1, located in western Yoakum County, covers a San Andres ROZ fairway area of 73,000 acres (Exhibit 3-11). The partition area excludes the western portion of the Wasson oil field (4,500 acres). Except for two small areas in the northern and southern portion of the county, Partition #1 is located within the previously established San Andres ROZ fairway boundaries, on the Northwest Shelf.

Exhibit 3-11. San Andres ROZ fairway Partition #1, Yoakum County
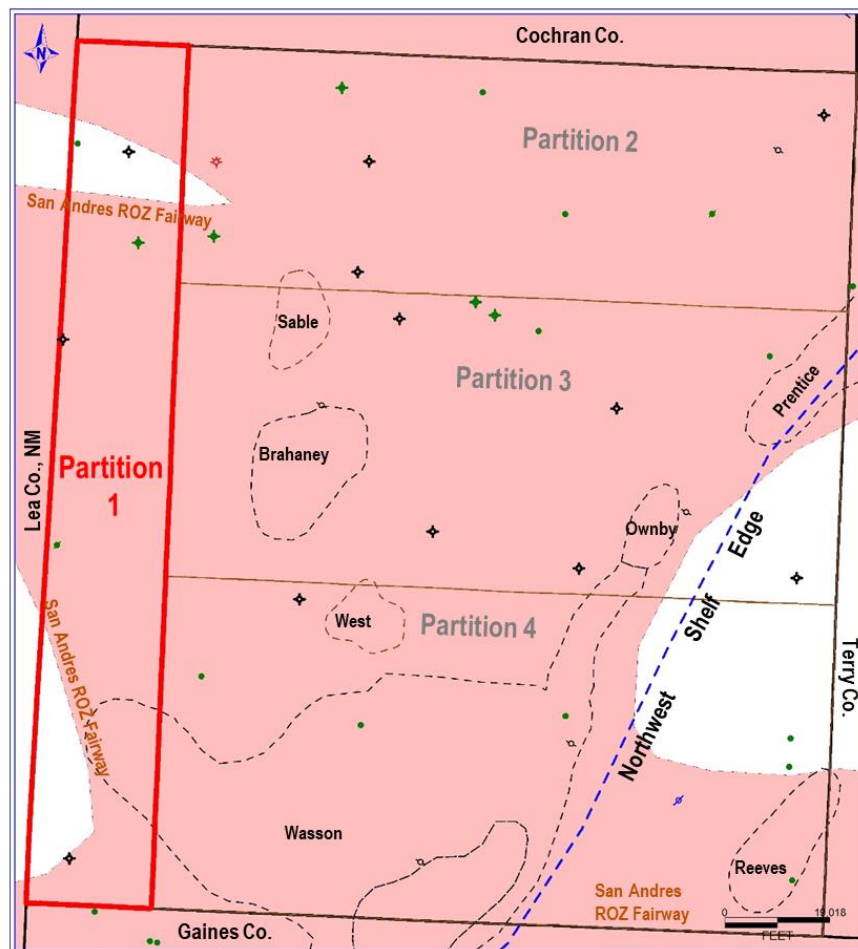
3.6.2 Analytical ROZ Reservoir Units

Five well log-based reservoir data sets plus a series of working level cross-sections were used to further divide the San Andres ROZ fairway resource in Partition #1 of Yoakum County into three analytical ROZ fairway reservoir units:

- A higher quality ROZ #1 (Upper ROZ) interval

- A lower quality ROZ #1 (Upper ROZ) interval

- A lower quality ROZ #2 (Lower ROZ) interval

The average volumetric reservoir properties for the three analytical San Andres ROZ fairway reservoir units of Partition #1 of Yoakum County are provided in Exhibit 3-12.

Exhibit 3-12. Average San Andres ROZ fairway reservoir properties: Partition #1, Yoakum County

Property	ROZ 1		ROZ 2	
	Higher Quality	Lower Quality	Higher Quality	Lower Quality
Depth (ft)	5,310	5,310	-	5,430
Gross Thickness (ft)	209	206	-	125
Net Pay (ft)	63	88	-	33
Avg. Porosity (fraction)	0.092	0.081	-	0.083
Avg. Oil Saturation (fraction)*	0.36	0.30	-	0.26
Avg. Formation Volume Factor (res B/bbl)	1.21	1.21	-	1.21
OIP (B/AF, for net pay)	212	156	-	138

*Oil saturation for the study wells in Partition #1 was calculated using Archie parameters: 'm' = 2.3; 'n' = 2.3; 'a' = 1; Rw = 0.029 ohm-m.

3.6.3 ROZ Oil In-Place

The San Andres ROZ fairway in Partition #1 of Yoakum County contains 1,060 million barrels of OIP (Exhibit 3-13). Only a modest portion of the ROZ OIP (160 million barrels) meets the higher ROZ resource quality criteria. The remainder of the ROZ OIP of 900 million barrels meets the lower resource quality criteria.

Exhibit 3-13. San Andres ROZ fairway OIP: Partition #1, Yoakum County

Property	ROZ 1		ROZ 2	
	Higher Quality	Lower Quality	Higher Quality	Lower Quality
Oil In-Place (B/Acre)	13,360	13,700	-	4,500
Area Extent (Acres)	12,000	46,400	-	58,400
Oil In-Place (MM bbls)	160	640	-	260

3.6.4 Technically Recoverable Resources

Of the 1,060 million barrels of San Andres ROZ OIP in Partition #1 of Yoakum County, 320 million barrels is technically recoverable from the application of miscible CO_2 EOR, giving a recovery efficiency of 30 percent of OIP.

Significant volumes of CO_2 are stored as part of recovering a portion of the ROZ OIP. Approximately 157 million metric tons (2,970 Bcf) of CO_2 is purchased for the EOR project in Partition #1 of Yoakum County, with essentially all of the purchased CO_2 stored at the end of the CO_2 flood.

3.6.5 Commercially Viable Oil Recovery with By-Product CO_2 Storage

Of the 320 million barrels of technically recoverable San Andres ROZ fairway oil resource in Partition #1 of Yoakum County, no portion of this oil resource is economically viable to develop under the economic assumptions used by the study (Exhibit 3-14).

Exhibit 3-14. Commercially viable oil recovery with by-product CO_2 storage: Partition #1 Yoakum County

Oil Recovery (MM bbls)	Purchased CO_2		Purchased CO_2/ Oil Recovery (Ratio)	
	Bcf	MM mt	Mcf/B	mt/B
-	-	-	-	-

3.6.6 Geologically Viable CO_2 Storage with By-Product Oil Recovery

Pursuing the geologically viable, but economically non-viable, portion of the San Andres ROZ fairway resource in Partition #1 of Yoakum County with miscible CO_2 flooding provides 157 million metric tons (2,970 Bcf) of CO_2 storage capacity, with 320 million barrels of by-product oil recovery (Exhibit 3-15).

Exhibit 3-15. Geologically viable storage of CO_2 with by-product oil recovery: Partition #1 Yoakum County

Purchased CO_2		By-Product Oil Recovery (MM bbls)	Purchased CO_2/ Produced Oil (Ratio)	
Bcf	MM mt		Mcf/B	mt/B
2,970	157	320	9.3	0.49

3.7 PARTITION #2. NORTHERN YOAKUM COUNTY

3.7.1 Geologic Setting

Partition #2, located in northern Yoakum County, covers a San Andres ROZ fairway area of 120,000 acres (Exhibit 3-16). The partition area does not contain any major San Andres oil fields. Partition #2 is located within the previously established San Andres ROZ fairway boundaries, on the Northwest Shelf.

Exhibit 3-16. San Andres ROZ fairway Partition #2, Yoakum County

3.7.2 Analytical ROZ Reservoir Units

Nine well log-based reservoir data sets plus a series of working level cross-sections were used to further divide the San Andres ROZ fairway resource in Partition #2 of Yoakum County into three analytical ROZ fairway reservoir units:

- A higher quality ROZ #1 (Upper ROZ) interval

- A lower quality ROZ #1 (Upper ROZ) interval

- A higher quality ROZ #2 (Lower ROZ) interval

The average volumetric reservoir properties for the three analytical San Andres ROZ fairway reservoir units of Partition #1 of Yoakum County are provided in Exhibit 3-17.

Exhibit 3-17. Average San Andres ROZ fairway reservoir properties: Partition #2, Yoakum County

Property	ROZ 1		ROZ 2	
	Higher Quality	Lower Quality	Higher Quality	Lower Quality
Depth (ft)	6,150	6,150	6,310	-
Gross Thickness (ft)	196	265	157	-
Net Pay (ft)	191	236	138	-
Avg. Porosity (fraction)	0.105	0.089	0.116	-
Avg. Oil Saturation (fraction)*	0.36	0.24	0.44	-
Avg. Formation Volume Factor (res B/bbl)	1.28	1.28	1.28	-
OIP (B/AF, for net pay)	229	129	309	-

*Oil saturation for the study wells in Partition #2 was calculated using Archie parameters: 'm' = 2.3; 'n' = 2.3; 'a' = 1; Rw = 0.038 ohm-m.

3.7.3 ROZ Oil In-Place

The San Andres ROZ fairway in Partition #2 of Yoakum County contains 8,110 million barrels of OIP (Exhibit 3-18). The bulk of the ROZ OIP (7,620 million barrels) meets the higher ROZ resource quality criteria. The remainder of the ROZ OIP of 490 million barrels meets the lower resource quality criteria.

Exhibit 3-18. San Andres ROZ fairway OIP: Partition #2, Yoakum County

Property	ROZ 1		ROZ 2	
	Higher Quality	Lower Quality	Higher Quality	Lower Quality
Oil In-Place (B/Acre)	43,810	30,480	42,770	-
Area Extent (Acres)	80,000	16,000	96,000	-
Oil In-Place (MM bbls)	3,510	490	4,110	-

3.7.4 Technically Recoverable Resources

Of the 8,110 million barrels of San Andres ROZ OIP in Partition #2 of Yoakum County, 1,810 million barrels is technically recoverable from the application of miscible CO_2 EOR, giving a recovery efficiency of 22 percent of OIP.

Significant volumes of CO_2 are stored as part of recovering a portion of the ROZ OIP. Approximately 1,078 million metric tons (20,380 Bcf) of CO_2 are purchased for the EOR project in Partition #2 of Yoakum County, with essentially all of the purchased CO_2 stored at the end of the CO_2 flood.

3.7.5 Commercially Viable Oil Recovery with By-Product CO_2 Storage

Of the 1,810 million barrels of technically recoverable San Andres ROZ fairway oil resource in Partition #2 of Yoakum County, 1,690 million barrels are economically viable to develop under the economic assumptions used by the study.

The application of CO_2 EOR to the commercially viable portion of the San Andres ROZ fairway resource in Partition #2 of Yoakum County also provides 973 million metric tons (18,390 Bcf) of by-product storage of CO_2 (Exhibit 3-19).

Exhibit 3-19. Commercially viable oil recovery with by-product CO_2 storage: Partition #2 Yoakum County

Oil Recovery (MM bbls)	Purchased CO_2		Purchased CO_2/ Oil Recovery (Ratio)	
	Bcf	MM mt	Mcf/B	mt/B
1,690	18,390	973	10.9	0.58

The production of one barrel of San Andres ROZ fairway oil in Partition #2 of Yoakum County brings with it the storage of 0.58 metric tons of CO_2.

3.7.6 Geologically Viable CO_2 Storage with By-Product Oil Recovery

Pursuing the geologically viable, but economically non-viable, portion of the San Andres ROZ fairway resource in Partition #2 of Yoakum County with miscible CO_2 flooding provides 105 million metric tons (1,980 Bcf) of CO_2 storage capacity, with 120 million barrels of by-product oil recovery (Exhibit 3-20).

Exhibit 3-20. Geologically viable storage of CO_2 with by-product oil recovery: Partition #2 Yoakum County

Purchased CO_2		By-Product Oil Recovery (MM bbls)	Purchased CO_2/ Produced Oil (Ratio)	
Bcf	MM mt		Mcf/B	mt/B
1,980	105	120	16.5	0.87

3.8 PARTITION #3. CENTRAL YOAKUM COUNTY

3.8.1 Geologic Setting

Partition #3, located in central Yoakum County, covers a San Andres ROZ fairway area of 129,000 acres (Exhibit 3-21). The partition area excludes several large oil fields such as Brahaney, Prentice, Sable, and Ownby (a combined 18,900 acres). Partition #3 is located on the Northwest Shelf.

Exhibit 3-21. San Andres ROZ fairway Partition #3, Yoakum County
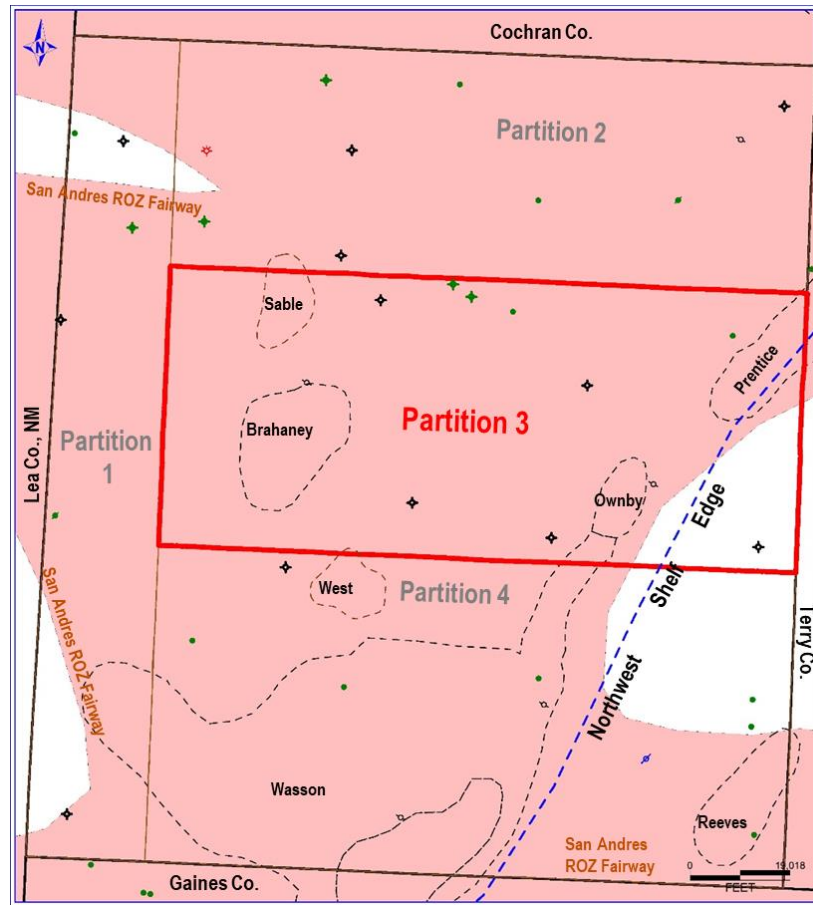
3.8.2 Analytical ROZ Reservoir Units

Nine well log-based reservoir data sets plus a series of working level cross-sections were used to further divide the San Andres ROZ fairway resource in Partition #3 of Yoakum County into four analytical ROZ fairway reservoir units:

- A higher quality ROZ #1 (Upper ROZ) interval

- A lower quality ROZ #1 (Upper ROZ) interval

- A higher quality ROZ #2 (Lower ROZ) interval

- A lower quality ROZ #2 (Lower ROZ) interval

The reservoir properties for the analytical San Andres ROZ fairway reservoir units of Partition #3 of Yoakum County are provided in Exhibit 3-22.

Exhibit 3-22. Average San Andres ROZ fairway reservoir properties: Partition #3, Yoakum County

Property	ROZ 1		ROZ 2	
	Higher Quality	Lower Quality	Higher Quality	Lower Quality
Depth (ft)	5,530	5,925	6,190	5,780
Gross Thickness (ft)	218	277	230	277
Net Pay (ft)	200	211	209	105
Avg. Porosity (fraction)	0.105	0.09	0.10	0.094
Avg. Oil Saturation (fraction)*	0.40	0.25	0.39	0.14
Avg. Formation Volume Factor (res B/bbl)	1.22	1.23	1.20	1.22
OIP (B/AF, for net pay)	267	137	242	84

*Oil saturation for most of the study wells in Partition #3 was calculated using Archie parameters: 'm' = 2.3; 'n' = 2.3; 'a' = 1; Rw = 0.045 ohm-m. For some wells, the parameter 'n' was increased to '3'.

3.8.3 ROZ Oil In-Place

The San Andres ROZ fairway in Partition #3 of Yoakum County contains 6,450 million barrels of OIP (Exhibit 3-23). The bulk of the ROZ OIP (4,320 million barrels) meets the higher ROZ resource quality criteria. The remainder of the ROZ OIP of 2,130 million barrels meets the lower resource quality criteria.

Exhibit 3-23. San Andres ROZ fairway OIP: Partition #3, Yoakum County

Property	ROZ 1		ROZ 2	
	Higher Quality	Lower Quality	Higher Quality	Lower Quality
Oil In-Place (B/Acre)	53,480	28,850	50,550	8,790
Area Extent (Acres)	51,200	52,000	31,200	72,000
Oil In-Place (MM bbls)	2,740	1,500	1,580	630

3.8.4 Technically Recoverable Resources

Of the 6,450 million barrels of San Andres ROZ OIP in Partition #3 of Yoakum County, 1,590 million barrels is technically recoverable from the application of miscible CO_2 EOR, giving a recovery efficiency of 25 percent of OIP.

Significant volumes of CO_2 are stored as part of recovering a portion of the ROZ OIP. Approximately 928 million metric tons (17,540 Bcf) of CO_2 is purchased for the EOR project in Partition #3 of Yoakum County, with essentially all of the purchased CO_2 stored at the end of the CO_2 flood.

3.8.5 Commercially Viable Oil Recovery with By-Product CO_2 Storage

Of the 1,590 million barrels of technically recoverable San Andres ROZ fairway oil resource in Partition #3 of Yoakum County, 1,110 million barrels are economically viable to develop under the economic assumptions used by the study.

The application of CO_2 EOR to the commercially viable portion of the San Andres ROZ fairway resource in Partition #3 of Yoakum County also provides 462 million metric tons (8,740 Bcf) of by-product storage of CO_2 (Exhibit 3-24).

Exhibit 3-24. Commercially viable oil recovery with by-product CO_2 storage: Partition #3 Yoakum County

Oil Recovery (MM bbls)	Purchased CO_2		Purchased CO_2/ Oil Recovery (Ratio)	
	Bcf	MM mt	Mcf/B	mt/B
1,110	8,740	462	7.9	0.42

The production of one barrel of San Andres ROZ fairway oil in Partition #3 of Yoakum County brings with it the storage of 0.42 metric tons of CO_2.

3.8.6 Geologically Viable CO_2 Storage with By-Product Oil Recovery

Pursuing the geologically viable, but economically non-viable, portion of the San Andres ROZ fairway resource in Partition #3 of Yoakum County with miscible CO_2 flooding provides 466 million metric tons (8,800 Bcf) of CO_2 storage capacity, with 480 million barrels of by-product oil recovery (Exhibit 3-25).

Exhibit 3-25. Geologically viable storage of CO_2 with by-product oil recovery: Partition #3 Yoakum County

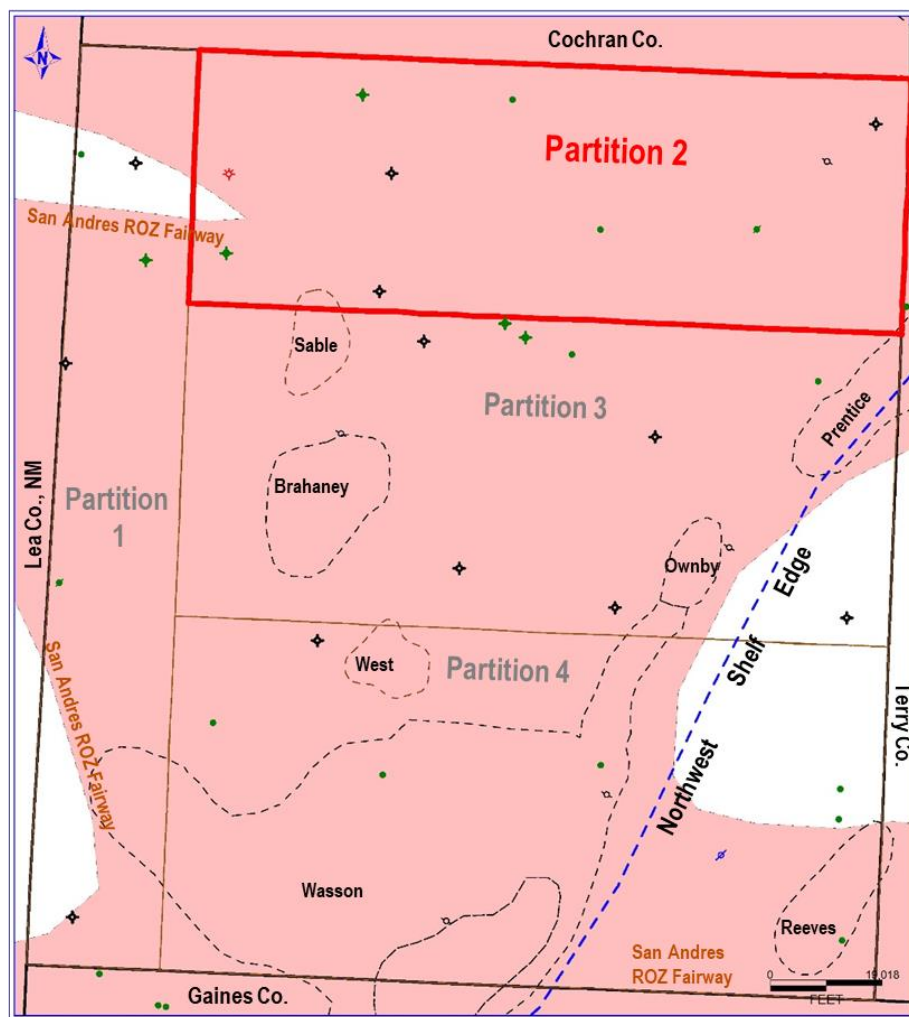| Purchased CO_2		By-Product Oil Recovery (MM bbls)	Purchased CO_2/ Produced Oil (Ratio)	
Bcf	MM mt		Mcf/B	mt/B
8,800	466	480	18.3	0.97

3.9 PARTITION #4. SOUTHERN YOAKUM COUNTY

3.9.1 Geologic Setting

Partition #4, located in southern Yoakum County, covers a San Andres ROZ fairway area of 99,000 acres (Exhibit 3-26). The partition area excludes the Reeves, West, and Wasson oil fields (a combined 68,000 acres). Partition #4 is located on the Northwest Shelf.

Exhibit 3-26. San Andres ROZ fairway Partition #4, Yoakum County
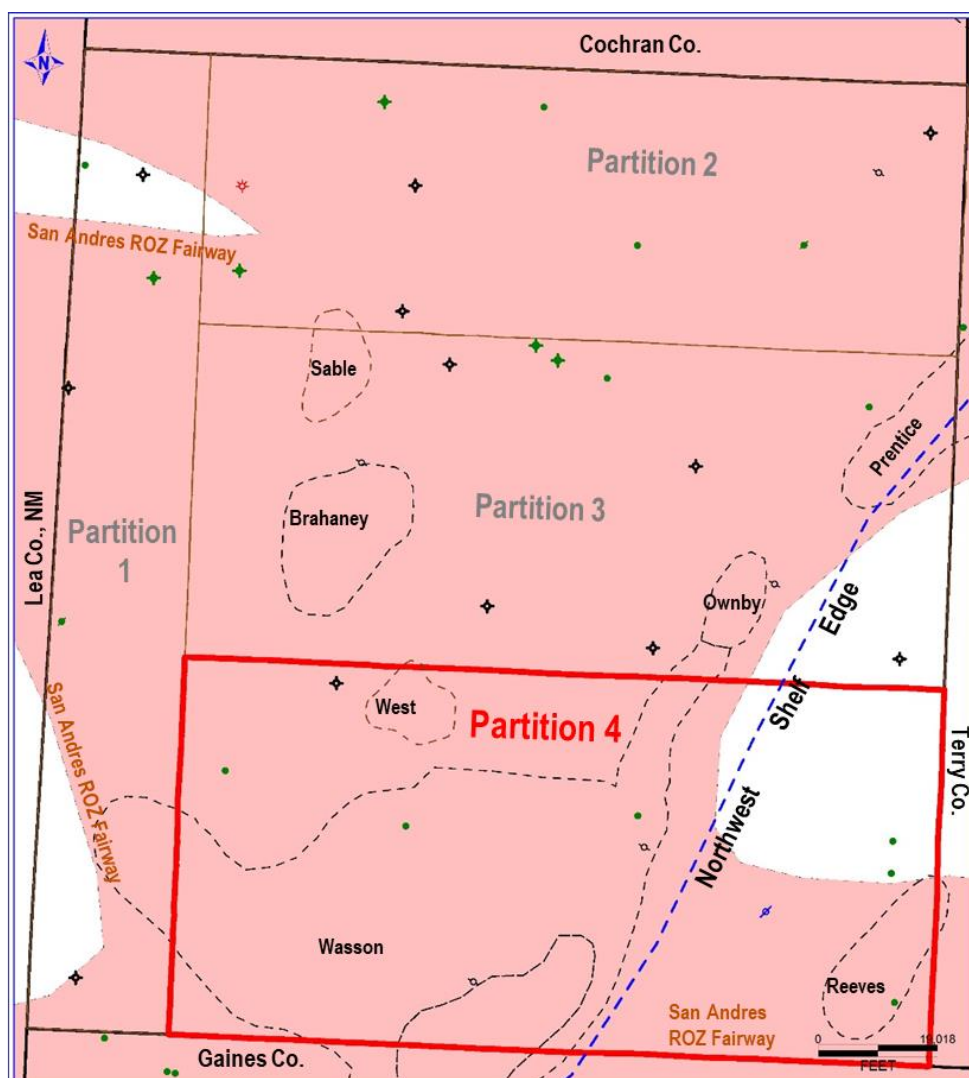
3.9.2 Analytical ROZ Reservoir Units

Seven well log-based reservoir data sets plus a series of working level cross-sections were used to further divide the San Andres ROZ fairway resource in Partition #4 of Yoakum County into four analytical ROZ fairway reservoir units:

- A higher quality ROZ #1 (Upper ROZ) interval
- A lower quality ROZ #1 (Upper ROZ) interval
- A higher quality ROZ #2 (Lower ROZ) interval
- A lower quality ROZ #2 (Lower ROZ) interval

The volumetric reservoir properties for the analytical San Andres ROZ fairway reservoir units of Partition #4 of Yoakum County are provided in Exhibit 3-27.

Exhibit 3-27. Average San Andres ROZ fairway reservoir properties: Partition #4, Yoakum County

Property	ROZ 1		ROZ 2	
	Higher Quality	Lower Quality	Higher Quality	Lower Quality
Depth (ft)	5,555	5,790	5,745	6,000
Gross Thickness (ft)	196	182	342	260
Net Pay (ft)	121	107	50.00	116
Avg. Porosity (fraction)	0.09	0.124	0.10	0.127
Avg. Oil Saturation (fraction)*	0.36	0.18	0.32	0.15
Avg. Formation Volume Factor (res B/bbl)	1.31	1.28	1.29	1.28
OIP (B/AF, for net pay)	192	135	192	115

*Oil saturation for the study wells in the Northwest Shelf portion of Partition #4 was calculated using Archie parameters: 'm' = 2.3; 'n' = 3; 'a' = 1; Rw = 0.05 ohm-m. Oil saturation for the study wells in the Midland Basin portion of Partition #4 was calculated using Archie parameters: 'm' = 2.3; 'n' = 2.3; 'a' = 1; Rw = 0.045 ohm-m.

3.9.3 ROZ Oil In-Place

The San Andres ROZ fairway in Partition #4 of Yoakum County contains 2,080 million barrels of OIP (Exhibit 3-28). The bulk of the ROZ OIP (1,990 million barrels) meets the higher ROZ resource quality criteria. The remainder of the ROZ OIP of 90 million barrels meets the lower resource quality criteria.

Exhibit 3-28. San Andres ROZ fairway OIP: Partition #4, Yoakum County

Property	ROZ 1		ROZ 2	
	Higher Quality	Lower Quality	Higher Quality	Lower Quality
Oil In-Place (B/Acre)	23,250	14,430	9,600	13,330
Area Extent (Acres)	76,800	2,400	20,400	4,800
Oil In-Place (MM bbls)	1,790	30	200	60

3.9.4 Technically Recoverable Resources

Of the 2,080 million barrels of San Andres ROZ OIP in Partitions #4 of Yoakum County, 590 million barrels is technically recoverable from the application of miscible CO_2 EOR, giving a recovery efficiency of 28 percent of OIP.

Significant volumes of CO_2 are stored as part of applying miscible CO_2 EOR for recovering a portion of the ROZ OIP. Approximately 327 million metric tons (6,170 Bcf) of CO_2 is purchased for the EOR project in Partition #4 of Yoakum County, with essentially all of the purchased CO_2 securely stored at the end of the CO_2 flood.

3.9.5 Commercially Viable Oil Recovery with By-Product CO_2 Storage

Of the 590 million barrels of technically recoverable San Andres ROZ fairway oil available from Partition #4, 40 million barrels are economically viable to develop under the economic assumptions used by the study.

The application of CO_2 EOR to the commercially viable portion of the San Andres ROZ fairway resource in Partition #4 of Yoakum County also provides 24 million metric tons (460 Bcf) of by-product storage of CO_2 (Exhibit 3-29).

The production of one barrel of San Andres ROZ fairway oil in Partition #4 of Yoakum County brings with it the storage of 0.61 metric tons of CO_2.

Exhibit 3-29. Commercially viable oil recovery with by-product CO_2 storage: Partition #4 Yoakum County

Oil Recovery (MM bbls)	Purchased CO_2		Purchased CO_2/ Oil Recovery (Ratio)	
	Bcf	MM mt	Mcf/B	mt/B
40	460	24	11.5	0.61

3.9.6 Geologically Viable CO_2 Storage with By-Product Oil Recovery

Pursuing the geologically viable, but economically non-viable, portion of the San Andres ROZ fairway resource in Partition #4 of Yoakum County with miscible CO_2 flooding provides 303 million metric tons (5,720 Bcf) of CO_2 storage capacity, with 550 million barrels of by-product oil recovery (Exhibit 3-30).

Exhibit 3-30. Geologically viable storage of CO_2 with by-product oil recovery: Partition #4 Yoakum County

Purchased CO_2		By-Product Oil Recovery (MM bbls)	Purchased CO_2/ Produced Oil (Ratio)	
Bcf	MM mt		Mcf/B	mt/B
5,720	303	550	10.4	0.55

4 TERRY COUNTY

4.1 GEOLOGIC SETTING

Terry County covers a 570,700-acre area in the western portion of the Permian Basin. The northwest corner of the county is located on the Northwest Shelf. The remainder of Terry County, east of this prominent Permian Basin feature, is located within the southward prograding Lower and Middle San Andres shelf margins of the Midland Basin.

Terry County contains several large San Andres oilfields—Prentice, Welch, and Adair/TLOC—as well as the southern portion of the Slaughter oil field. The ROZ resources below these and other existing San Andres oil fields have been excluded from the San Andres ROZ fairway resource assessment for Terry County.

The Terry County map (Exhibit 4-1) shows 1) the location of 19 study wells, 2) the four ROZ fairway partitions established by the study, 3) the boundaries of the previously established San Andres ROZ fairway, 4) the edge of the NW Shelf and the prograding Lower and Middle San Andres shelf margins, and 5) the location of three regional cross-sections for the San Andres ROZ. The map also shows the locations of the major San Andres oil fields excluded from the San Andres ROZ fairway resource assessment in Terry County.

Exhibit 4-1. Terry County geologic partitions, major oil fields, and study well locations
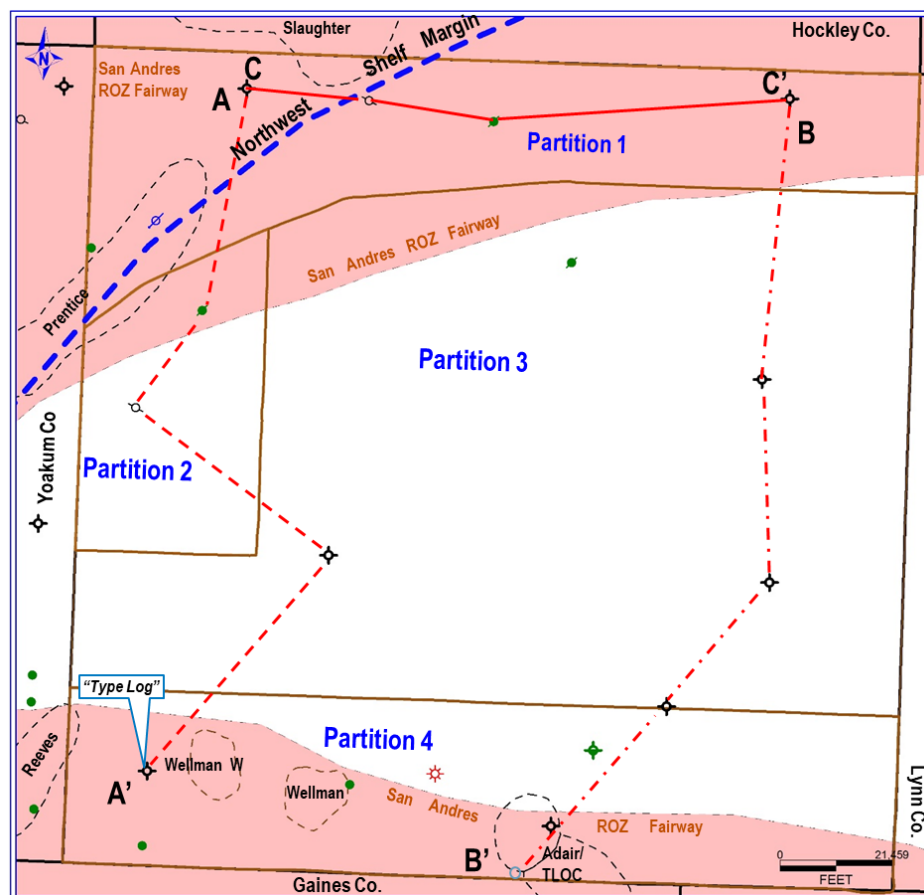
4.1.1 Example Terry County Cross-Sections

The characterization of the San Andres ROZ fairway interval in Terry County has drawn on the construction of a series of working cross-sections. Three of these cross-sections are included in this report.

- Terry Co. Cross-Section A-A' (Exhibit 4-2) provides a N-S view of the San Andres ROZ interval starting near the margin of the Northwest Shelf in the northwest corner of Terry Co., traversing south through the Midland Basin, and ending in the merged Roswell/Artesia fairway of the Midland Basin in southwest Terry Co.

- Terry Co. Cross-Section B-B' (Exhibit 4-3) provides a N-S view of the San Andres ROZ, to the east of Cross-Section A-A'. Cross-Section B-B' starts in the Slaughter fairway of the Midland Basin in northeast Terry Co., traverses south through the Midland Basin, and ends in the Roswell/Artesia fairway of the Midland Basin in southcentral Terry Co.

- Terry Co. Cross-Section C-C' (Exhibit 4-4) provides a W-E view of the San Andres ROZ interval in northern Terry Co., extending from the Northwest Shelf to the Midland Basin.

Exhibit 4-2. Terry County N-S cross-section A-A'
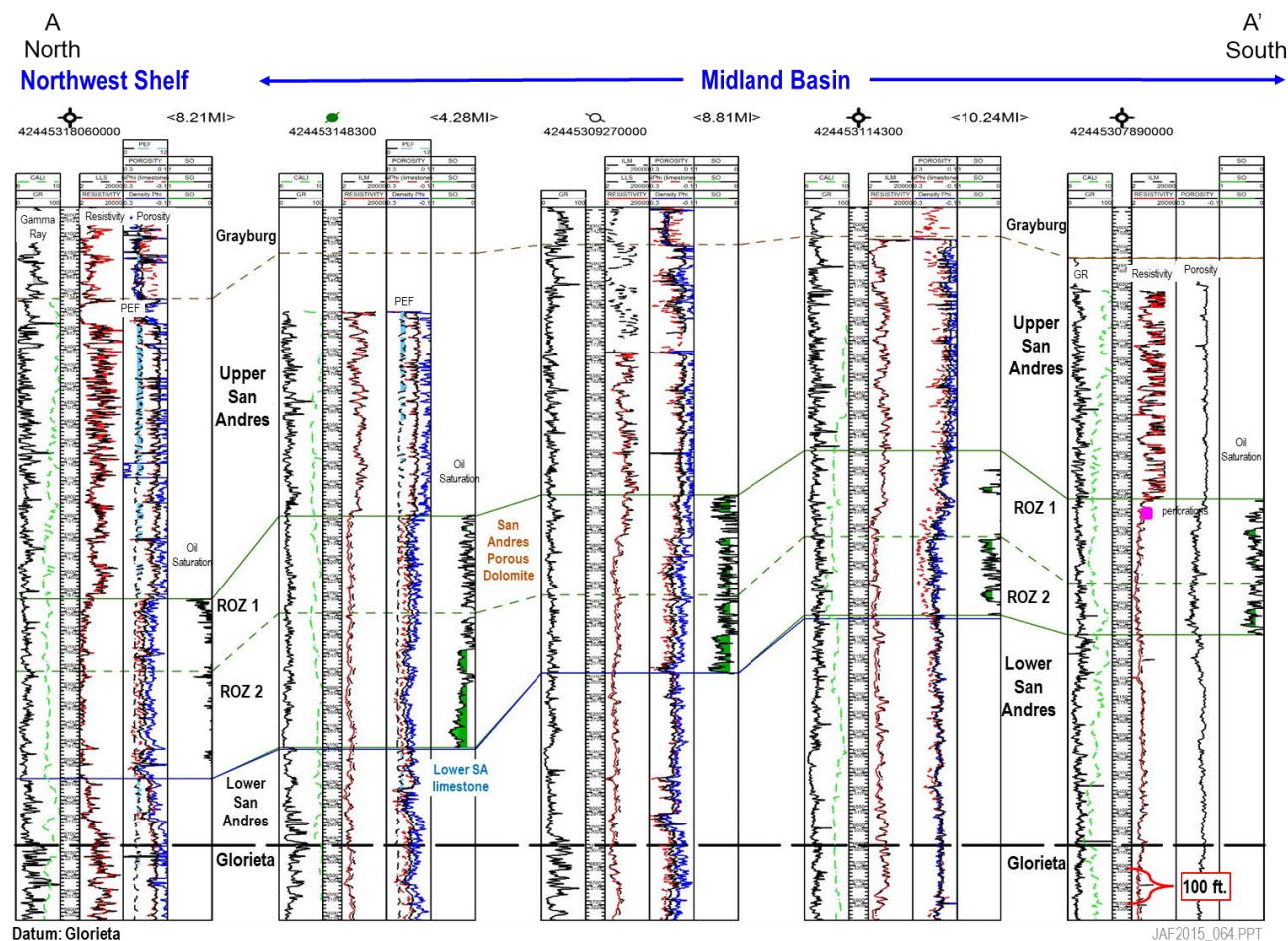
Exhibit 4-3. Terry County N-S cross-section B-B'
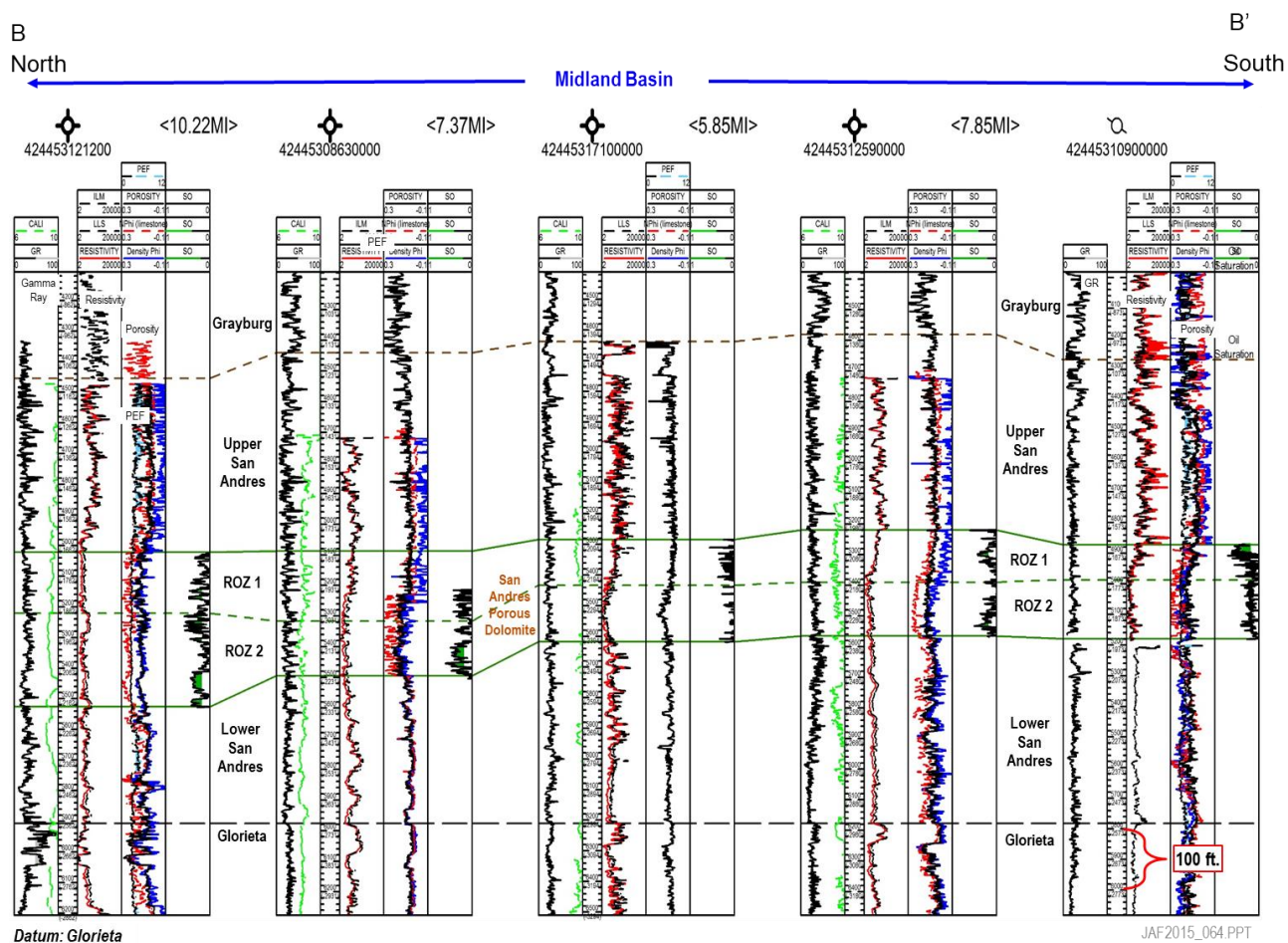
Datum: Glorieta

JAF2015_064.PPT

Exhibit 4-4. Terry County W-E cross-section C-C'
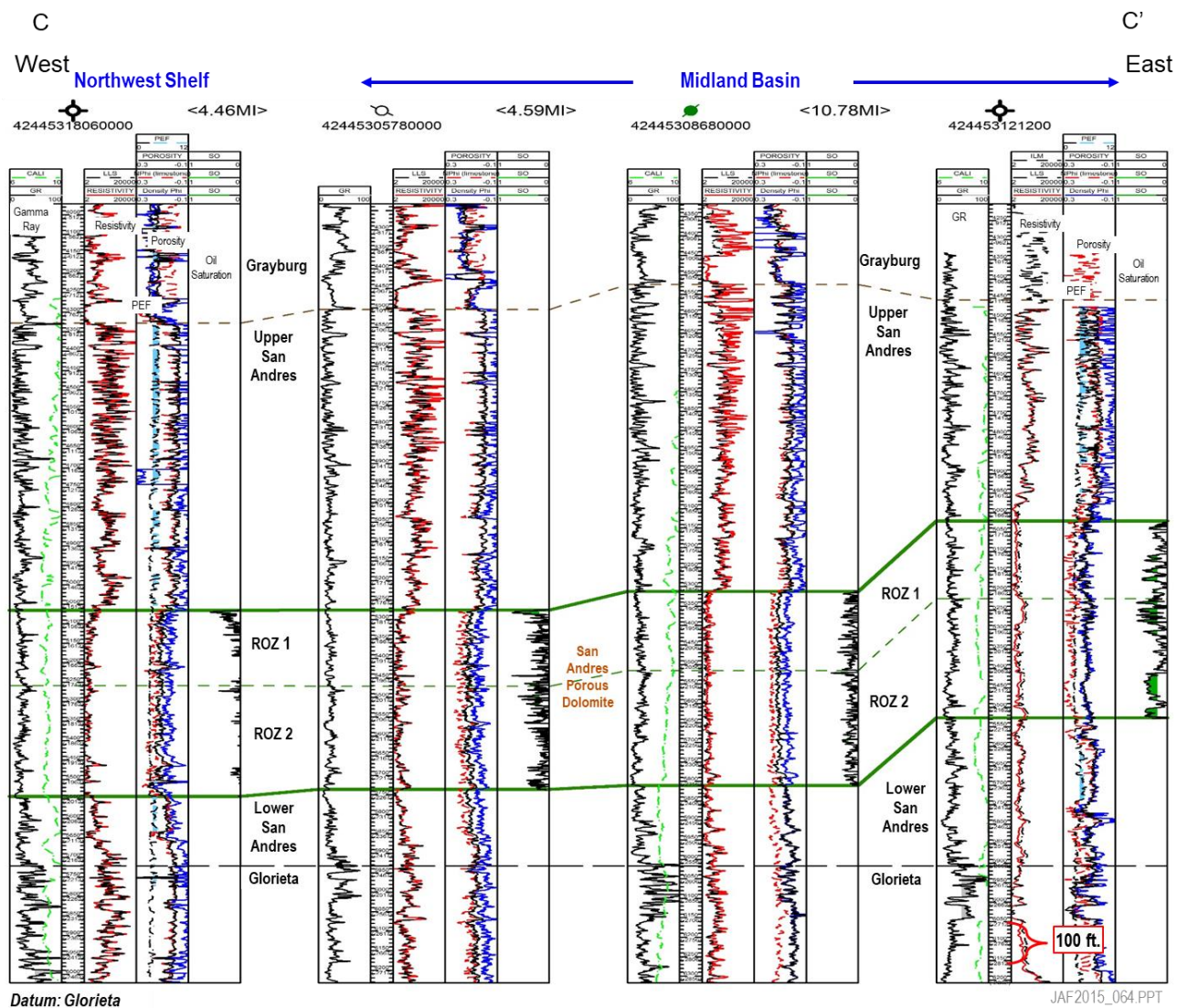
4.1.2 Interpretation of Terry County Cross-Sections

For logs in the ROZ fairway, the top of the San Andres porous dolomite is picked as the top of the ROZ for this resource assessment. The porous dolomite intervals, informally designated as ROZ 1 and ROZ 2, are illustrated on the cross-sections.

The cross-sections display gamma-ray and caliper logs in Track 1 on the left. Resistivity logs are shown in Track 2, with the deep resistivity log shown in red. Track 3 shows the porosity logs. Uncorrected neutron porosity (for limestone) is red; uncorrected density porosity (for limestone) is blue. The porosity curve used for the OIP calculation is black.

The PEF curve, if available, is also displayed in Track 3. PEF values greater than 4 are shaded in blue. Within and below the ROZ interval, high PEF values generally indicate the presence of limestone, dolomitic limestone or an anhydrite.

Track 4 on the right shows the calculated oil saturation. Calculated oil saturations between 25 percent and 40 percent are dark green; calculated oil saturations between 45 percent and 60 percent are light green; and oil saturation greater than 65 percent, typically present in only the MPZ, are black.

The base of the ROZ is where either calculated oil saturation or apparent porosity (or both) diminish in the Lower San Andres. If a Lower San Andres limestone is prominent, the top of the limestone defines the lower boundary of the ROZ.

4.1.3 Terry County Type Log

A type log was selected from the Terry County study wells to illustrate the ROZ resource analysis undertaken for the county (Exhibit 4-5). The type log illustrates two distinct San Andres ROZ resource intervals—ROZ 1 in the upper portion of the porous dolomite, and ROZ 2 in the lower portion of the porous dolomite.

The type log shows lithology-corrected sidewall neutron porosity through the San Andres porous dolomite. Porosity is fairly uniform through the ROZ 1 and increases in ROZ 2. Calculated oil saturation diminishes significantly at the base of ROZ 1. A second, higher oil saturated interval is shown at the base of ROZ 2. In this well, the base of the ROZ is defined by an apparent lithology change to predominately shale, representing the marine facies of the Lower San Andres in the Midland Basin.

The oil saturation for the type log ROZ was calculated using the following Archie parameters— 'm' of 2.3, 'n' of 2.3, 'a' of 1, and formation Rw of 0.045 ohm-m. A porosity cut-off of 6 percent was applied to define net pay in the ROZ. Intervals identified as ROZ pay are shown by the red pay flag in Track 1 of Exhibit 4-5.

Exhibit 4-5. Type log for Terry County San Andres ROZ fairway
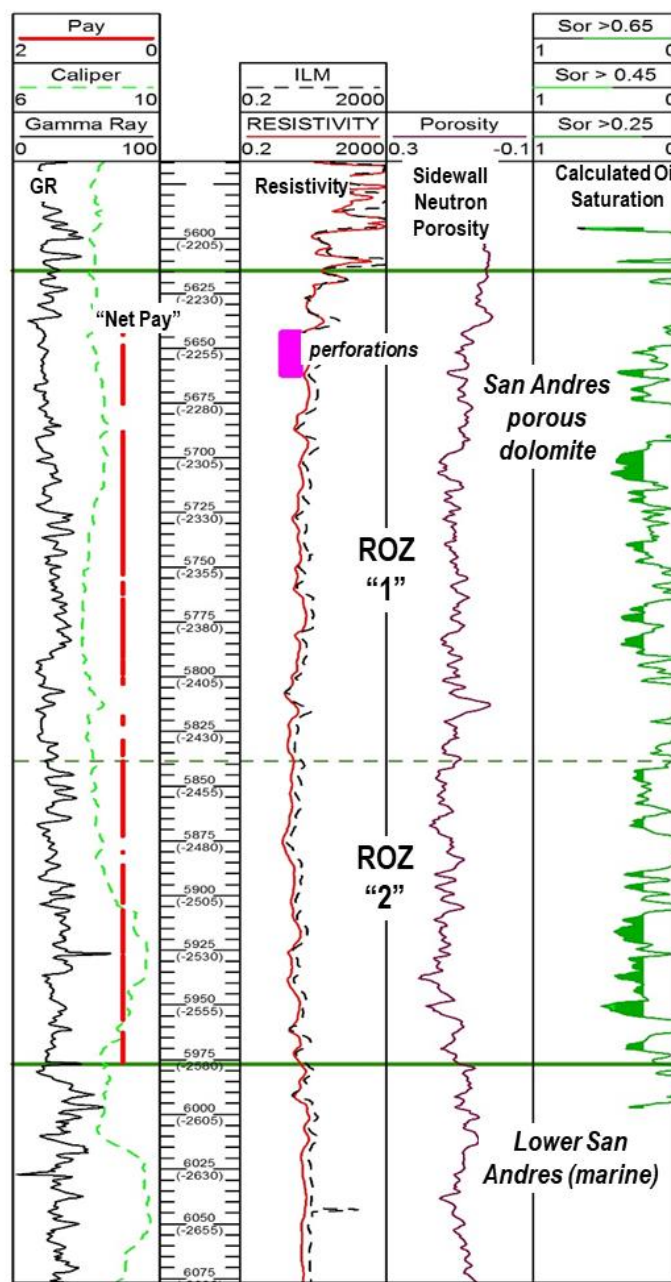
For ROZ 1, the average porosity of net pay is 11.3 percent and average oil saturation is 21 percent, with the highest calculated oil saturations at the top of ROZ 1. For ROZ 2, the average porosity of is 14.4 percent and average oil saturation is 25 percent.

4.2 PARTITIONING THE TERRY COUNTY ROZ FAIRWAY RESOURCE

The ROZ fairway in Terry County was divided into four distinct partitions, as illustrated previously in Exhibit 4-1. Individual ROZ fairway resource assessments were undertaken for each of the four partitioned areas.

- Partition #1. Covers 93,000-acre area of northern Terry County. Portions of the Slaughter (1,600 acres) and the Prentice oil fields (8,000 acres) have been excluded from the resource assessment area for Partition #1.

- Partition #2. Covers a 42,000-acre area of western Terry County. A small portion (1,200 acres) of the Prentice oil field has been excluded from the resource assessment area for Partition #2.

- Partition #3. Covers a 303,000-acre area of central Terry County. No existing oil field area has been excluded from Partition #3.

- Partition #4. Covers an 111,000-acre area of southern Terry County. The area encompassed by the Wellman (4,900 acres) and Adair/TLOC (5,900 acres) oil fields has been excluded from the resource assessment area for Partition #4.

Of Terry County's 570,700 acres, a total of 21,700 acres under the structural closure of existing San Andres oil fields has been excluded, leaving a remaining San Andres ROZ fairway assessment area of 549,000 acres (Exhibit 4-6).

Exhibit 4-6. Terry County ROZ fairway partitions

Partition	Total Area	Excluded Area	Assessment Area
	Acres	Acres	Acres
#1	102,660	9,660	93,000
#2	43,200	1,200	42,000
#3	303,000	-	303,000
#4	121,800	10,800	111,000
Total	570,660	21,660	549,000

4.3 SIZE AND QUALITY OF THE TERRY COUNTY ROZ FAIRWAY RESOURCE

Terry County holds 16,800 million barrels of OIP in the San Andres ROZ fairway, outside the structural closure of the existing oil fields. The OIP and resource quality values for each of the four partitions of Terry County are shown in Exhibit 4-7.

- Higher Quality ROZ Fairway Resources. A significant portion of the San Andres ROZ fairway OIP in Terry County of 10,460 million barrels has higher quality reservoir properties (porosity greater than 8% and oil saturation equal to or greater than 25%).

- Lower Quality ROZ Fairway Resources. The remainder of the San Andres ROZ fairway OIP in Terry County of 6,340 million barrels has lower quality reservoir properties (porosity equal to or less than 8% and/or oil saturation of less than 25%).

Exhibit 4-7. Terry County San Andres ROZ fairway resource in-place (MM bbls)

Partition	ROZ 1			ROZ 2			Total		
	Higher Quality	Lower Quality	Total	Higher Quality	Lower Quality	Total	Higher Quality	Lower Quality	Total
#1	-	1,440	1,440	680	-	680	680	1,440	2,120
#2	480	400	880	1,940	-	1,940	2,420	400	2,820
#3	180	1,480	1,660	5,040	1,120	6,160	5,220	2,600	7,820
#4	490	1,160	1,650	1,650	740	2,390	2,140	1,900	4,040
Total*	1,150	4,480	5,630	9,310	1,860	11,170	10,460	6,340	16,800

*Totals may not add due to rounding.

4.4 TECHNICALLY RECOVERABLE TERRY COUNTY ROZ FAIRWAY RESOURCE

4.4.1 Methodology for Estimating Technically Recoverable Resources

The average volumetric reservoir properties for each partition of Terry County, along with proprietary reservoir properties from ARI's Big Oil Fields Data Base, were used as input into the Prophet Model. Additionally, it was assumed that 80 percent of each partition area was suitable for development, while 20 percent of the partition had a combination of net pay, porosity, or oil saturation that was not suitable for development. It was also assumed that 90 percent of the OIP in each partition resides in the area suitable for development. The net pay for the developed portion of the partition was increased so that the OIP in the developed portion equaled 90 percent of the OIP calculated for the entire partition. The Prophet Model was then used to calculate the volumes of recoverable oil and water as well as the volumes of injected and stored CO_2. The Prophet Model was run assuming five-spot patterns were implemented at each partition. ROZ fairway well pattern spacings of 20 to 40 acres per CO_2 injection well were selected to achieve a target of approximately 30 years of operation for the CO_2 flood.

4.4.2 Summary of Technically Recoverable Resources

A significant portion of the San Andres ROZ fairway OIP of 16,800 million barrels in Terry County is technically recoverable using CO_2 EOR, while also providing major volumes of pore space for storing CO_2 (Exhibit 4-8).

- Total technically viable oil recovery is estimated at 4,280 million barrels, produced primarily from the higher quality portions of the ROZ resource.

- While the oil recovery efficiencies vary by partition, overall recovery efficiency is 25% of OIP in response to one HCPV injection of CO_2 using a tapered WAG miscible CO_2 flood.

- The San Andres ROZ fairway interval in Terry County offers the potential for significant storage of CO_2, equal to 3,876 million metric tons (73,250 Bcf).

Exhibit 4-8. Terry County technically recoverable San Andres ROZ fairway resource

Partitions	Oil Recovery		Purchased CO_2	
	MM bbls	%OIP	Bcf	MM mt
#1	390	18%	11,430	605
#2	710	25%	9,590	507
#3	2,120	27%	34,370	1,819
#4	1,060	26%	17,860	945
Total	4,280	25%	73,250	3,876

4.5 VIABILITY OF OIL RECOVERY AND CO_2 STORAGE IN THE TERRY COUNTY ROZ FAIRWAY

The CO_2 EOR Cost and Economic model used by the study assumes a first-year oil price (WTI) of $75 per barrel, linked to an initial CO_2 purchase cost of $1.50 per Mcf ($28.35 per metric ton of CO_2).

4.5.1 Commercially Viable Oil Recovery with By-Product CO_2 Storage

The four San Andres ROZ fairway partitions of Terry County offer the potential for 2,830 million barrels of commercially viable oil recovery with 1,560 million metric tons (29,390 Bcf) of by-product storage of CO_2, as shown in Exhibit 4-9.

The commercially viable portion of the ROZ resource has a purchased CO_2 to produced oil ratio of 0.55 metric ton of CO_2 per barrel of recovered oil (10.4 Mcf per barrel).

Exhibit 4-9. Terry County commercially viable oil recovery with by-product CO_2 storage

Partition	Oil Recovery (MM bbls)	Purchased CO_2		Purchased CO_2/ Oil Recovery (Ratio)	
		Bcf	MM mt	Mcf/B	mt/B
#1	-	-	-	-	-
#2	510	5,800	310	11.4	0.60
#3	1,610	17,370	920	10.8	0.57
#4	710	6,220	330	8.8	0.46
Total	2,830	29,390	1,560	10.4	0.55

4.5.2 Geologically Viable CO_2 Storage with By-Product Oil Recovery

The four San Andres ROZ fairway partitions of Terry County can also provide 2,320 million metric tons (43,850 Bcf) of geologically viable CO_2 storage with 1,450 million barrels of by-product oil recovery (Exhibit 4-10).

Exhibit 4-10. Terry County geologically viable CO₂ storage with by-product oil recovery

Partition	Purchased CO_2		By-Product Oil Recovery (MM bbls)	Purchased CO_2/ Oil Recovery (Ratio)	
	Bcf	MM mt		Mcf/B	mt/B
#1	11,430	605	390	29.3	1.55
#2	3,780	200	200	18.9	1.00
#3	17,000	899	510	33.3	1.76
#4	11,640	616	350	33.3	1.76
Total	43,850	2,320	1,450	30.2	1.60

4.6 PARTITION #1. NORTHERN TERRY COUNTY

4.6.1 Geologic Setting

Partition #1, located in northern Terry County, covers a San Andres ROZ fairway area of 93,000 acres (Exhibit 4-11). The partition area excludes the small southern portion (1,600 acres) of the Slaughter oil field and the eastern portion (8,000 acres) of the Prentice oil field. Partition #1 is located in the Northwest Shelf and the Midland Basin.

Exhibit 4-11. San Andres ROZ fairway Partition #1, Terry County
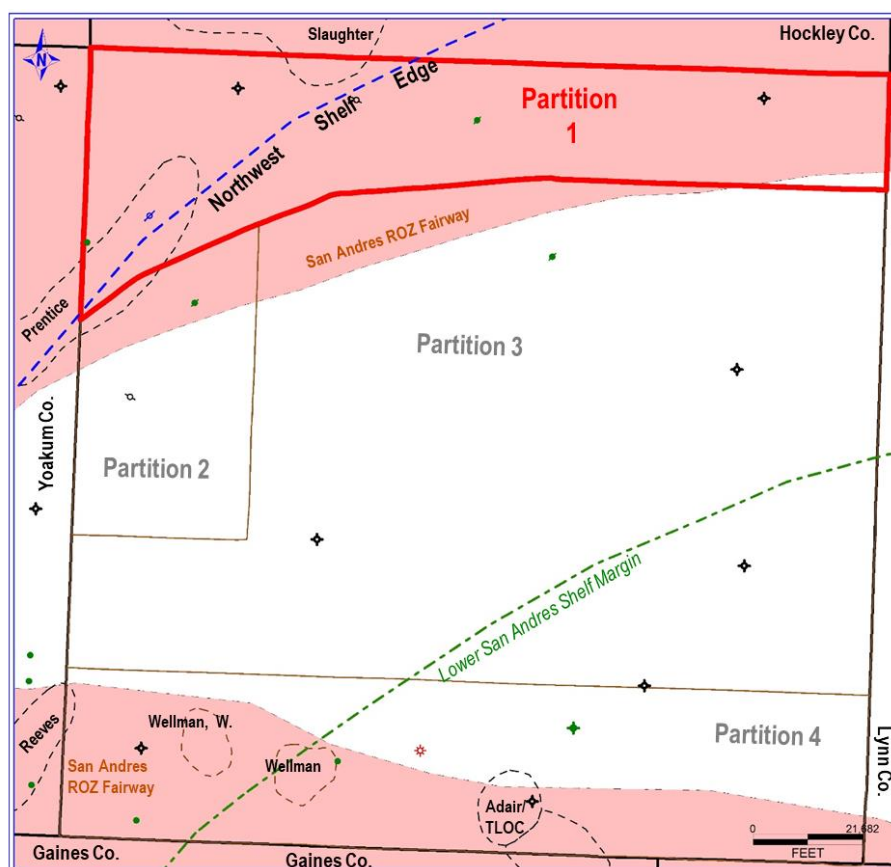
4.6.2 Analytical ROZ Reservoir Units

Six well log-based reservoir data sets plus a series of working level cross-sections were used to further divide the San Andres ROZ fairway resource in Partition #1 of Terry County into two analytical ROZ fairway reservoir units, as set forth below:

- A lower quality ROZ #1 (Upper ROZ) interval

- A higher quality ROZ #2 (Lower ROZ) interval

The volumetric reservoir properties for the two analytical San Andres ROZ fairway reservoir units of Partition #1 of Terry County are provided in Exhibit 4-12.

Exhibit 4-12. Average San Andres ROZ fairway reservoir properties: Partition #1, Terry County

Property	ROZ 1		ROZ 2	
	Higher Quality	Lower Quality	Higher Quality	Lower Quality
Depth (ft)	-	6,180	6,470	-
Gross Thickness (ft)	-	226	347	-
Net Pay (ft)	-	171	315	-
Avg. Porosity (fraction)	-	0.117	0.118	-
Avg. Oil Saturation (fraction)*	-	0.16	0.25	-
Avg. Formation Volume Factor (res B/bbl)	-	1.28	1.28	-
OIP (B/AF, for net pay)	-	113	179	-

*Oil saturation for the study wells in Partition #1 was calculated using Archie parameters: 'm' = 2.3; 'n' = 2.3 (Midland Basin) – 3.0 (NW Shelf); 'a' = 1; Rw = 0.03 – 0.04 ohm-m.

4.6.3 ROZ Oil In-Place

The San Andres ROZ fairway in Partition #1 of Terry County contains 2,120 million barrels of OIP (Exhibit 4-13). Only a modest portion of the ROZ OIP, 680 million barrels, meets the higher ROZ resource quality criteria. The remainder of the ROZ OIP of 1,440 million barrels meets the lower resource quality criteria.

Exhibit 4-13. Average San Andres ROZ fairway OIP: Partition #1, Terry County

Property	ROZ 1		ROZ 2	
	Higher Quality	Lower Quality	Higher Quality	Lower Quality
Oil In-Place (B/Acre)	-	19,320	56,390	-
Area Extent (Acres)	-	74,400	12,000	-
Oil In-Place (MM bbls)	-	1,440	680	-

4.6.4 Technically Recoverable Resources

Of the 2,120 million barrels of San Andres ROZ OIP in Partition #1 of Terry County, approximately 390 million barrels is technically recoverable from the application of miscible CO_2 EOR, giving a recovery efficiency of 18 percent of OIP.

Significant volumes of CO_2 are stored as part of recovering a portion of the ROZ OIP. Approximately 605 million metric tons (11,430 Bcf) of CO_2 are purchased for the EOR project in Partition #1 of Terry County, with essentially all of the purchased CO_2 stored at the end of the CO_2 flood.

4.6.5 Commercially Viable Oil Recovery with By-Product CO_2 Storage

Of the 390 million barrels of technically recoverable San Andres ROZ fairway oil resource in Partition #1 of Terry County, no portion of this oil resource is economically viable to develop under the economic assumptions used by the study (Exhibit 4-14).

Exhibit 4-14. Commercially viable oil recovery with by-product CO_2 storage: Partition #1 Terry County

Oil Recovery (MM bbls)	Purchased CO_2		Purchased CO_2/ Oil Recovery (Ratio)	
	Bcf	MM mt	Mcf/B	mt/B
-	-	-	-	-

4.6.6 Geologically Viable CO_2 Storage with By-Product Oil Recovery

Pursuing the geologically viable, but commercially non-viable portion of the San Andres ROZ fairway resource in Partition #1 of Terry County with miscible CO_2 flooding provides 605 million metric tons (11,430 Bcf) of CO_2 storage capacity, with 390 million barrels of by-product oil recovery (Exhibit 4-15).

Exhibit 4-15. Geologically viable storage of CO_2 with by-product oil recovery: Partition #1 Terry County

Purchased CO_2		By-Product Oil Recovery (MM bbls)	Purchased CO_2/ Produced Oil (Ratio)	
Bcf	MM mt		Mcf/B	mt/B
11,430	605	390	29.3	1.55

4.7 PARTITION #2. WESTERN TERRY COUNTY

4.7.1 Geologic Setting

Partition #2, located in western Terry County, covers a San Andres ROZ fairway area of 42,000 acres (Exhibit 4-16). The partition area partition excludes a portion (1,200 acres) of the Prentice oil field. Partition #2 is located in the western portion of the southeastward prograding Midland Basin.

Exhibit 4-16. San Andres ROZ fairway Partition #2, Terry County
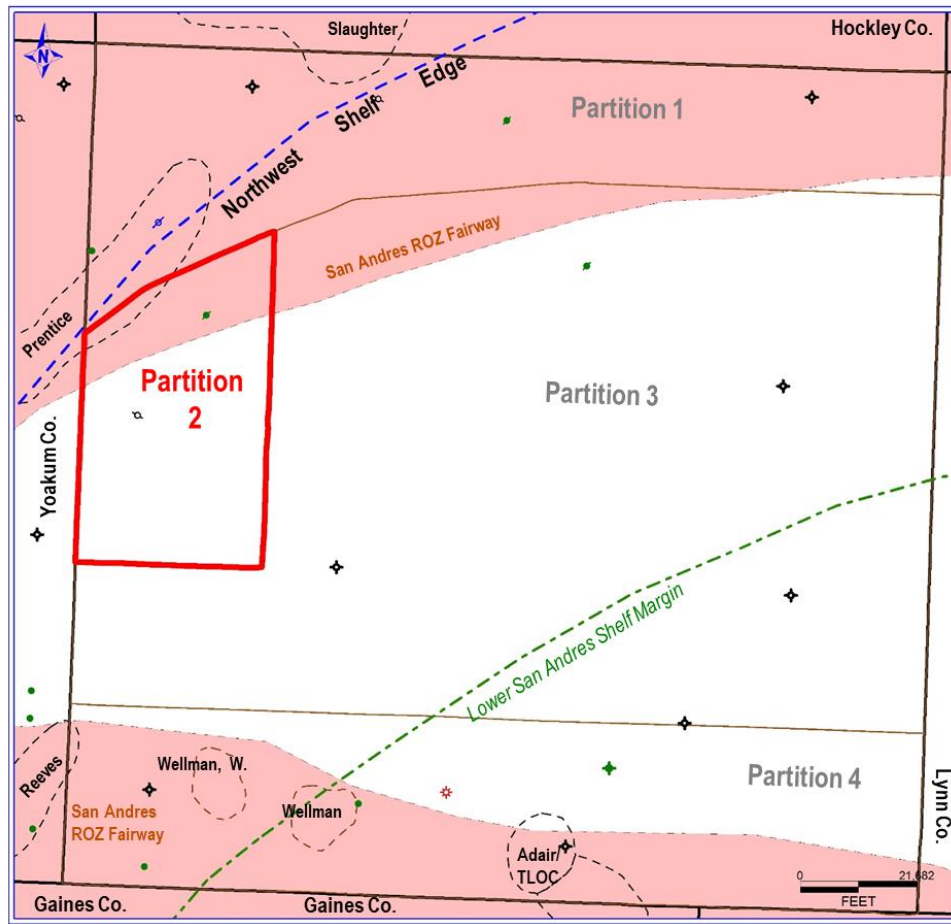
4.7.2 Analytical ROZ Reservoir Units

Three well log-based reservoir data sets plus a series of working level cross-sections were used to further divide the San Andres ROZ fairway resource in Partition #2 of Terry County into three analytical ROZ fairway reservoir units, as set forth below:

- A higher quality ROZ #1 (Upper ROZ) interval

- A lower quality ROZ #1 (Upper ROZ) interval

- A higher quality ROZ #2 (Lower ROZ) interval

The volumetric reservoir properties for the three analytical San Andres ROZ fairway reservoir units of Partition #1 of Terry County are provided in Exhibit 4-17.

Exhibit 4-17. Average San Andres ROZ fairway reservoir properties: Partition #2, Terry County

Property	ROZ 1		ROZ 2	
	Higher Quality	Lower Quality	Higher Quality	Lower Quality
Depth (ft)	6,210	6,210	6,500	-
Gross Thickness (ft)	267	253	294	-
Net Pay (ft)	161	223	263	-
Avg. Porosity (fraction)	0.095	0.103	0.113	-
Avg. Oil Saturation (fraction)*	0.31	0.17	0.32	-
Avg. Formation Volume Factor (res B/bbl)	1.28	1.28	1.28	-
OIP (B/AF, for net pay)	178	106	219	-

*Oil saturation for the study wells in Partition #2 was calculated using Archie parameters: 'm' and 'n' = 2.3; 'a' = 1; Rw = 0.04 ohm-m.

4.7.3 ROZ Oil In-Place

The San Andres ROZ fairway in Partition #2 of Terry County contains 2,820 million barrels of OIP (Exhibit 4-18). The bulk of the ROZ OIP, 2,420 million barrels, meets the higher ROZ resource quality criteria. The remainder of the ROZ OIP of 400 million barrels meets the lower resource quality criteria.

Exhibit 4-18. San Andres ROZ fairway OIP: Partition #2, Terry County

Property	ROZ 1		ROZ 2	
	Higher Quality	Lower Quality	Higher Quality	Lower Quality
Oil In-Place (B/Acre)	28,640	23,620	57,660	-
Area Extent (Acres)	16,800	16,800	33,600	-
Oil In-Place (MM bbls)	480	400	1,940	-

4.7.4 Technically Recoverable Resources

Of the 2,820 million barrels of San Andres ROZ OIP in Partition #2 of Terry County, approximately 710 million barrels is technically recoverable from the application of miscible CO_2 EOR, giving a recovery efficiency of 25 percent of OIP.

Significant volumes of CO_2 are injected and stored as part of recovering a portion of the ROZ OIP. Approximately 507 million metric tons (9,590 Bcf) of CO_2 are purchased for the EOR project in Partition #2 of Terry County, with essentially all of the purchased CO_2 stored at the end of the CO_2 flood.

4.7.5 Commercially Viable Oil Recovery with By-Product CO_2 Storage

Of the 710 million barrels of technically recoverable San Andres ROZ fairway oil resource in Partition #2 of Terry County, 510 million barrels is economically viable to develop under the economic assumptions used by the study (Exhibit 4-19).

Exhibit 4-19. Commercially viable oil recovery with by-product CO_2 storage: Partition #2, Terry County

Oil Recovery (MM bbls)	Purchased CO_2		Purchased CO_2/ Oil Recovery (Ratio)	
	Bcf	MM mt	Mcf/B	mt/B
510	5,800	310	11.4	0.60

The application of CO_2 EOR to the commercially viable portion of the San Andres ROZ fairway resource in Partition #2 of Terry County also provides 310 million metric tons (5,800 Bcf) of by-product storage of CO_2 (Exhibit 4-19).

The production of one barrel of San Andres ROZ fairway oil in Partition #2 of Terry County brings with it, at the margin, the storage of 0.60 metric tons of CO_2.

4.7.6 Geologically Viable CO_2 Storage with By-Product Oil Recovery

Pursuing the geologically viable, but economically non-viable, portion of the San Andres ROZ fairway resource in Partition #2 of Terry County with miscible CO_2 flooding provides 200 million metric tons (3,780 Bcf) of CO_2 storage capacity with 200 million barrels of by-produce oil recovery (Exhibit 4-20).

Exhibit 4-20. Geologically viable storage of CO_2 with by-product oil recovery: Partition #2 Terry County

| Purchased CO_2		By-Product Oil Recovery (MM bbls)	Purchased CO_2/ Produced Oil (Ratio)	
Bcf	MM mt		Mcf/B	mt/B
3,780	200	200	18.9	1.00

4.8 PARTITION #3. CENTRAL TERRY COUNTY

4.8.1 Geologic Setting

Partition #3, located in central Terry County, covers a San Andres ROZ fairway area of 303,000 acres (Exhibit 4-21). The partition area does not contain any major San Andres oil fields. Partition #3 is located in the Midland Basin.

Exhibit 4-21. San Andres ROZ fairway Partition #3, Terry County
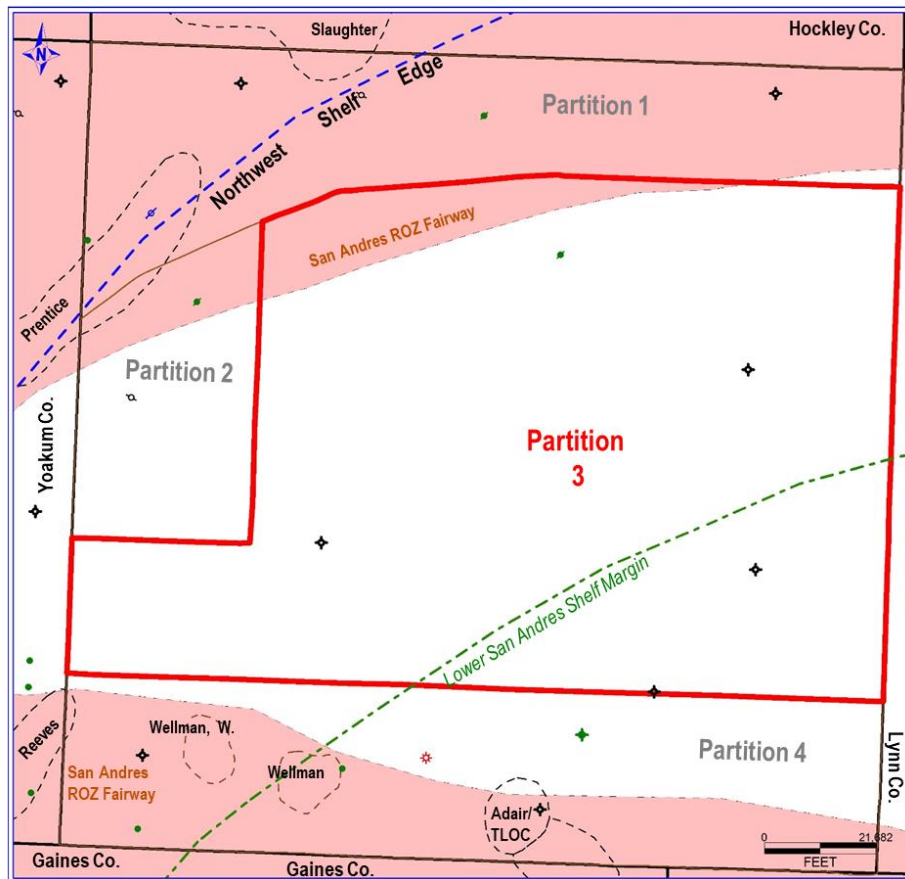
4.8.2 Analytical ROZ Reservoir Units

Five well log-based reservoir data sets plus a series of working level cross-sections were used to further divide the San Andres ROZ fairway resource in Partition #3 of Terry County into four analytical ROZ fairway reservoir units:

- A higher quality ROZ #1 (Upper ROZ) interval

- A lower quality ROZ #1 (Upper ROZ) interval

- A higher quality ROZ #2 (Lower ROZ) interval

- A lower quality ROZ #2 (Lower ROZ) interval

The volumetric reservoir properties for the four analytical San Andres ROZ fairway reservoir units of Partition #3 of Terry County are provided in Exhibit 4-22.

Exhibit 4-22. Average San Andres ROZ fairway reservoir properties: Partition #3, Terry County

Property	ROZ 1		ROZ 2	
	Higher Quality	Lower Quality	Higher Quality	Lower Quality
Depth (ft)	5,040	5,040	5,230	5,230
Gross Thickness (ft)	229	159	194	180
Net Pay (ft)	25	65	141	87
Avg. Porosity (fraction)	0.082	0.105	0.133	0.136
Avg. Oil Saturation (fraction)*	0.27	0.16	0.27	0.14
Avg. Formation Volume Factor (res B/bbl)	1.12	1.12	1.12	1.12
OIP (B/AF, for net pay)	153	116	249	132

*Oil saturation for the study wells in Partition #3 was calculated using Archie parameters: 'm' = 2.3; 'n' = 2.3 (most wells); 'a' = 1; Rw = 0.045 – 0.05 ohm-m.

4.8.3 ROZ Oil In-Place

The San Andres ROZ fairway in Partition #3 of Terry County contains 7,820 million barrels of OIP (Exhibit 4-23). The bulk of the ROZ OIP, 5,220 million barrels, meets the higher ROZ resource quality criteria. The remainder of the ROZ OIP of 2,600 million barrels meets the lower resource quality criteria, offering pore space for the storage of CO_2 with by-product production of oil.

Exhibit 4-23. San Andres ROZ fairway OIP: Partition #3, Terry County

Property	ROZ 1		ROZ 2	
	Higher Quality	Lower Quality	Higher Quality	Lower Quality
Oil In-Place (B/Acre)	3,790	7,570	35,010	11,430
Area Extent (Acres)	48,000	194,400	144,000	98,400
Oil In-Place (MM bbl)	180	1,480	5,040	1,120

4.8.4 Technically Recoverable Resources

Of the 7,820 million barrels of San Andres ROZ OIP in Partition #3 of Terry County, 2,120 million barrels is technically recoverable from the application of miscible CO_2 EOR, giving a recovery efficiency of 27 percent of OIP.

Significant volumes of CO_2 are injected and stored as part of recovering a portion of the ROZ OIP. Approximately 1,819 million metric tons (34,370 Bcf) of CO_2 are purchased for the EOR project in Partition #3 of Terry County, with essentially all of the purchased CO_2 stored at the end of the CO_2 flood.

4.8.5 Commercially Viable Oil Recovery with By-Product CO_2 Storage

Of the 2,120 million barrels of technically recoverable San Andres ROZ fairway oil resource in Partition #3 of Terry County, 1,610 million barrels are economically viable to develop under the economic assumptions used by the study (Exhibit 4-24).

Exhibit 4-24. Commercially viable oil recovery with by-product CO_2 storage: Partition #3 Terry County

Oil Recovery (MM bbls)	Purchased CO_2		Purchased CO_2/ Oil Recovery (Ratio)	
	Bcf	MM mt	Mcf/B	mt/B
1,610	17,370	920	10.8	0.57

The application of CO_2 EOR to the commercially viable portion of the San Andres ROZ fairway resource in Partition #3 of Terry County also provides 920 million metric tons (17,370 Bcf) of by-product storage of CO_2 (Exhibit 4-24).

The production of one barrel of San Andres ROZ fairway oil in Partition #3 of Terry County brings with it, at the margin, the storage of 0.57 metric tons of CO_2.

4.8.6 Geologically Viable CO_2 Storage with By-Product Oil Recovery

Pursuing the geologically viable, but economically non-viable, portion of the San Andres ROZ fairway resource in Partition #3 of Terry County with miscible CO_2 flooding provides 899 million metric tons (17,000 Bcf) of CO_2 storage capacity with 510 million barrels of by-product oil recovery (Exhibit 4-25).

Exhibit 4-25. Geologically viable storage of CO_2 with by-product oil recovery: Partition #3 Terry County

| Purchased CO_2		By-Product Oil Recovery (MM bbls)	Purchased CO_2/ Produced Oil (Ratio)	
Bcf	MM mt		Mcf/B	mt/B
17,000	899	510	33.3	1.76

4.9 PARTITION #4. SOUTHERN TERRY COUNTY

4.9.1 Geologic Setting

Partition #4, located in southern Terry County, covers a San Andres ROZ fairway area of 111,000 acres (Exhibit 4-26). The partition excludes the Wellman and Adair/TLOC oil fields (10,800 acres). The southern portion of Partition #4 is located in the Midland Basin.

Exhibit 4-26. San Andres ROZ fairway Partition #4, Terry County
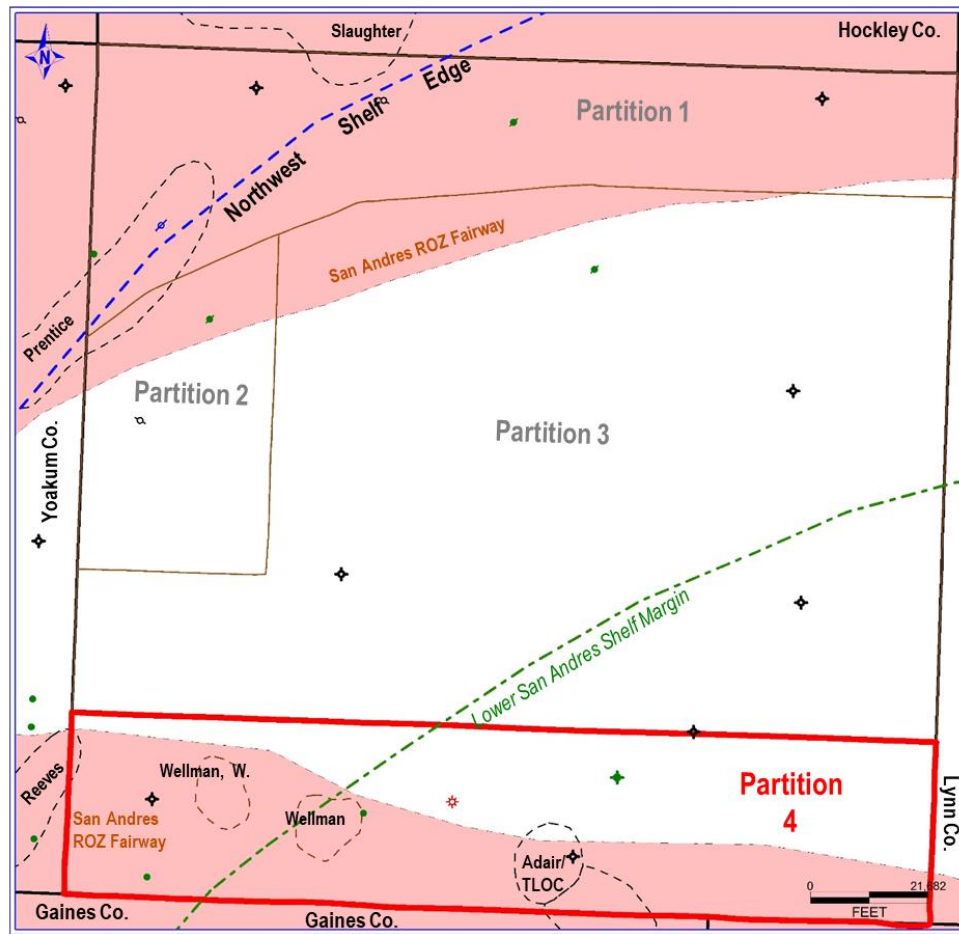
4.9.2 Analytical ROZ Reservoir Units

Five well log-based reservoir data sets plus a series of working level cross-sections were used to further divide the San Andres ROZ fairway resource in Partition #4 of Terry County into four analytical ROZ fairway reservoir units, as set forth below:

- A higher quality ROZ #1 (Upper ROZ) interval

- A lower quality ROZ #1 (Upper ROZ) interval

- A higher quality ROZ #2 (Lower ROZ) interval

- A lower quality ROZ #2 (Lower ROZ) interval

The volumetric reservoir properties for the four analytical San Andres ROZ fairway reservoir units of Partition #4 of Terry County are provided in Exhibit 4-27.

Exhibit 4-27. Average San Andres ROZ fairway reservoir properties: Partition #4, Terry County

Property	ROZ 1		ROZ 2	
	Higher Quality	Lower Quality	Higher Quality	Lower Quality
Depth (ft)	5,050	5,050	5,230	5,230
Gross Thickness (ft)	163	184	155	191
Net Pay (ft)	143	119	154	106
Avg. Porosity (fraction)	0.092	0.122	0.147	0.121
Avg. Oil Saturation (fraction)*	0.32	0.16	0.32	0.15
Avg. Formation Volume Factor (res B/bbl)	1.12	1.12	1.12	1.12
OIP (B/AF, for net pay)	204	135	326	126

*Oil saturation for the study wells in Partition #4 was calculated using Archie parameters: 'm' = 2.3; 'n' = 2.3; 'a' = 1; Rw = 0.045 – 0.05 ohm-m.

4.9.3 ROZ Oil In-Place

The San Andres ROZ fairway in Partition #4 of Terry County contains 4,040 million barrels of OIP (Exhibit 4-28). A little over half of the ROZ OIP, 2,140 million barrels, meets the higher ROZ resource quality criteria. The remainder of the ROZ OIP of 1,900 million barrels meets the lower resource quality criteria.

Exhibit 4-28. San Andres ROZ fairway OIP: Partition #4, Terry County

Property	ROZ 1		ROZ 2	
	Higher Quality	Lower Quality	Higher Quality	Lower Quality
Oil In-Place (B/Acre)	29,150	16,110	50,240	13,330
Area Extent (Acres)	16,800	72,000	32,800	56,000
Oil In-Place (MM bbls)	490	1,160	1,650	740

4.9.4 Technically Recoverable Resources

Of the 4,040 million barrels of San Andres ROZ OIP in Partition #4 of Terry County, approximately 1,060 million barrels is technically recoverable from the application of miscible CO_2 EOR, giving a recovery efficiency of 26 percent of OIP.

Significant volumes of CO_2 are stored as part of applying miscible CO_2 EOR for recovering a portion of the ROZ OIP. Approximately 945 million metric tons (17,860 Bcf) of CO_2 are purchased for the miscible San Andres ROZ fairway EOR project in Partition #4 of Terry County, with essentially all of the purchased CO_2 stored at the end of the CO_2 flood.

4.9.5 Commercially Viable Oil Recovery with By-Product CO_2 Storage

Of the 1,060 million barrels of technically recoverable San Andres ROZ fairway oil in Partition #4, 710 million barrels are economically viable to develop under the economic assumptions used by the study.

The application of CO_2 EOR to the commercially viable portion of the San Andres ROZ fairway resource in Partition #4 of Terry County also provides 330 million metric tons (6,220 Bcf) of by-product storage of CO_2 (Exhibit 4-29).

The production of one barrel of San Andres ROZ fairway oil in Partition #4 of Terry County brings with it, at the margin, the storage of 0.46 metric tons of CO_2.

Exhibit 4-29. Commercially viable oil recovery with by-product CO_2 storage: Partition #4 Terry County

Oil Recovery (MM bbls)	Purchased CO_2		Purchased CO_2/ Oil Recovery (Ratio)	
	Bcf	MM mt	Mcf/B	mt/B
710	6,220	330	8.8	0.46

4.9.6 Geologically Viable CO_2 Storage with By-Product Oil Recovery

Pursuing the geologically viable but economically non-viable portion of the San Andres ROZ fairway resource in Partition #4 of Terry County with miscible CO_2 flooding provides 616 million metric tons (11,640 Bcf) of CO_2 storage capacity with 350 million barrels of by-product oil recovery (Exhibit 4-30).

Exhibit 4-30. Geologically viable storage of CO_2 with by-product oil recovery: Partition #4 Terry County

Purchased CO_2		By-Product Oil Recovery (MM bbls)	Purchased CO_2/ Produced Oil (Ratio)	
Bcf	MM mt		Mcf/B	mt/B
11,640	616	350	33.3	1.76

5 DAWSON COUNTY

5.1 GEOLOGIC SETTING

Dawson County covers a 577,700-acre area in the western portion of the Permian Basin. The county is located within the southward prograding Middle San Andres shelf margins of the Midland Basin.

Dawson County contains the large Welch and Cedar Lake (San Andres) oil fields in the northwest corner of the county. The ROZ resource below these San Andres oil fields has been excluded from the resource assessment of the San Andres ROZ fairway in Dawson County.

The Dawson County map (Exhibit 5-1) shows 1) the location of the 9 study wells, 2) the three ROZ fairway partitions established by the study, 3) the boundaries of the previously established San Andres ROZ fairway, 4) the extent of the Middle San Andres shelf margin, and 5) the location of three regional cross-sections for the San Andres ROZ. The map also shows the major San Andres oil fields excluded from the San Andres ROZ fairway resource assessment in Dawson County.

Exhibit 5-1. Dawson County geologic partitions, major oil fields, and study well locations
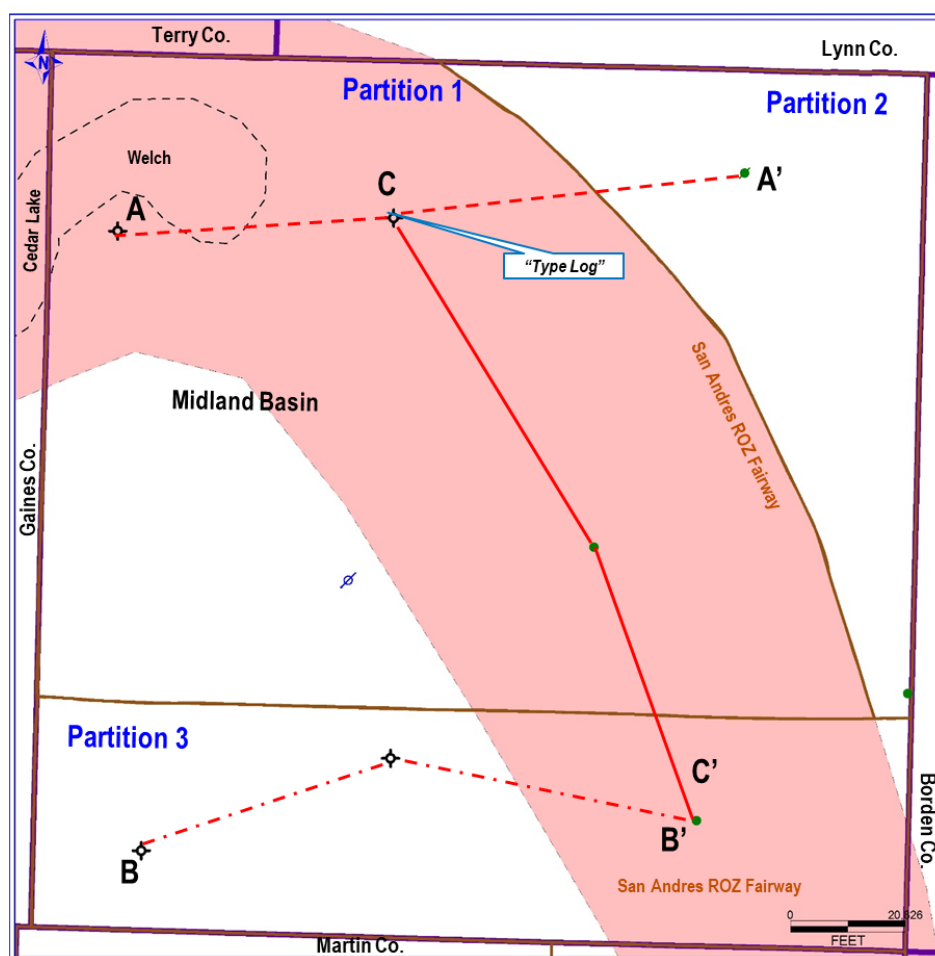
5.1.1 Example Dawson County Cross-Sections

The characterization of the San Andres ROZ fairway interval in Dawson County has drawn on a series of working stratigraphic cross-sections. Three of these cross-sections are included in this report.

- Dawson Co. Cross-Section A-A' (Exhibit 5-2) provides a W-E view of the San Andres ROZ interval through the Midland Basin in northern Dawson Co. This cross-section is hung on the Glorieta Formation. The base of the San Andres in the Dawson Co. (Midland Basin) consists of marine shale and limestone, which can be difficult to distinguish from the underlying Glorieta Formation and leads to some uncertainty in picking the top of the Glorieta on well logs. The entire section from the upper Spraberry through the San Andres ROZ was correlated to help identify the Glorieta and Clearfork formation tops.

- Dawson Co. Cross-Section B-B' (Exhibit 5-3) provides a W-E view of the San Andres ROZ interval through the Midland Basin in southern Dawson Co. This cross-section is hung on the Clearfork Formation top because the top of the Glorieta Formation is uncertain.

- Dawson Co. Cross-Section C-C' (Exhibit 5-4) provides a N-S view of the San Andres ROZ interval through the central portion of the mapped ROZ fairway in Dawson Co. This cross-section is hung on the Glorieta Formation. The base of the San Andres in the Midland Basin in Dawson Co. consists of marine shale and limestone, which can be difficult to distinguish from the underlying Glorieta Formation.

Exhibit 5-2. Dawson County W-E cross-section A-A'
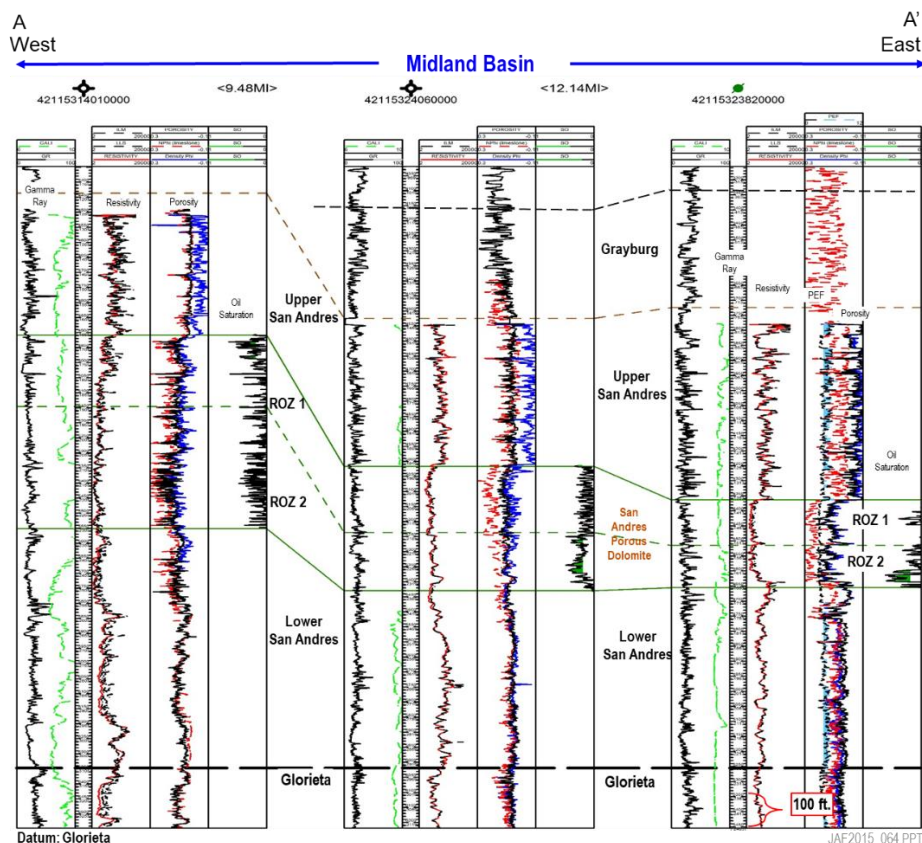
Exhibit 5-3. Dawson County W-E cross-section B-B'
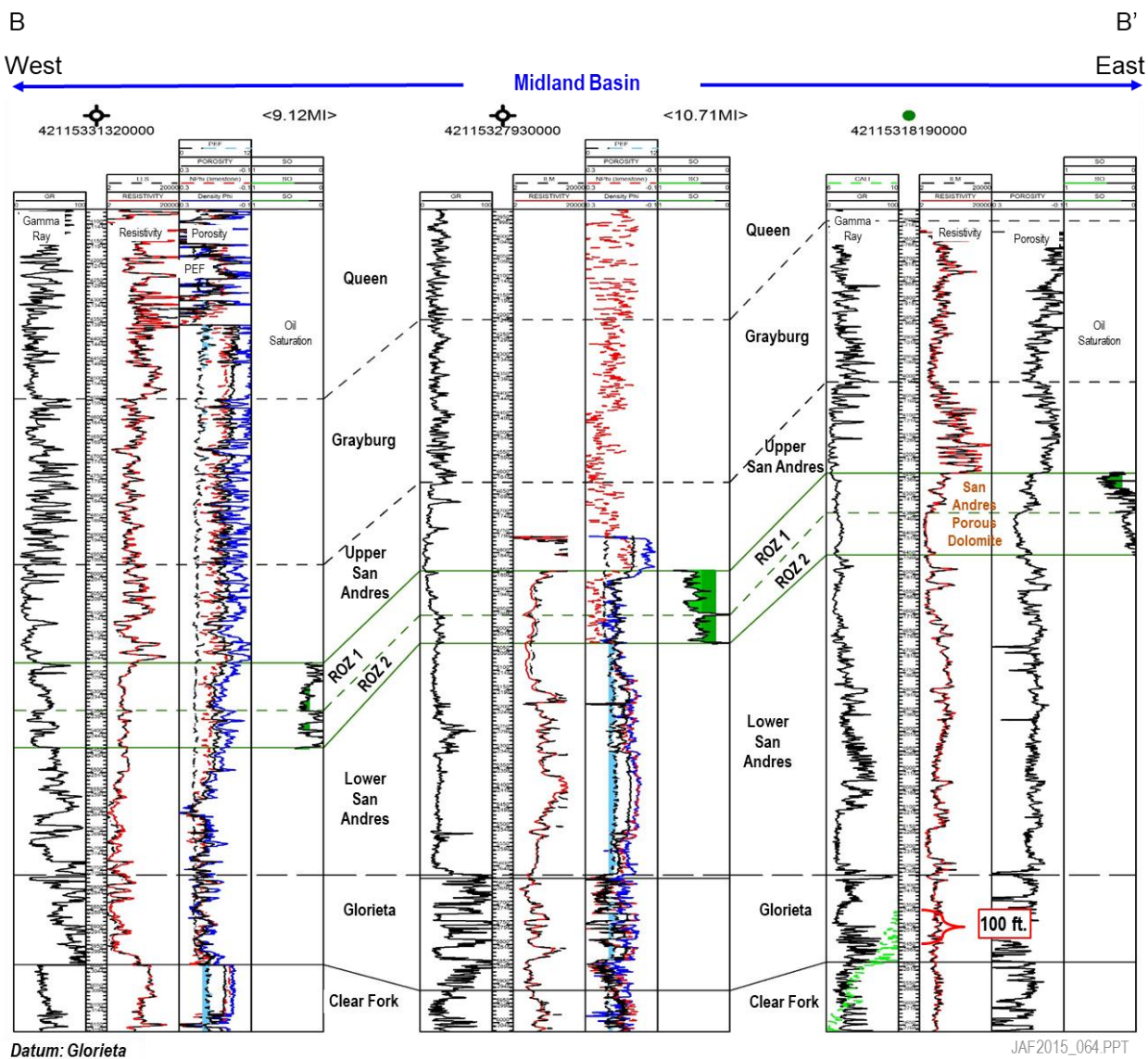
Exhibit 5-4. Dawson County N-S cross-section C-C'

Datum: Glorieta

JAF2015_064.PPT
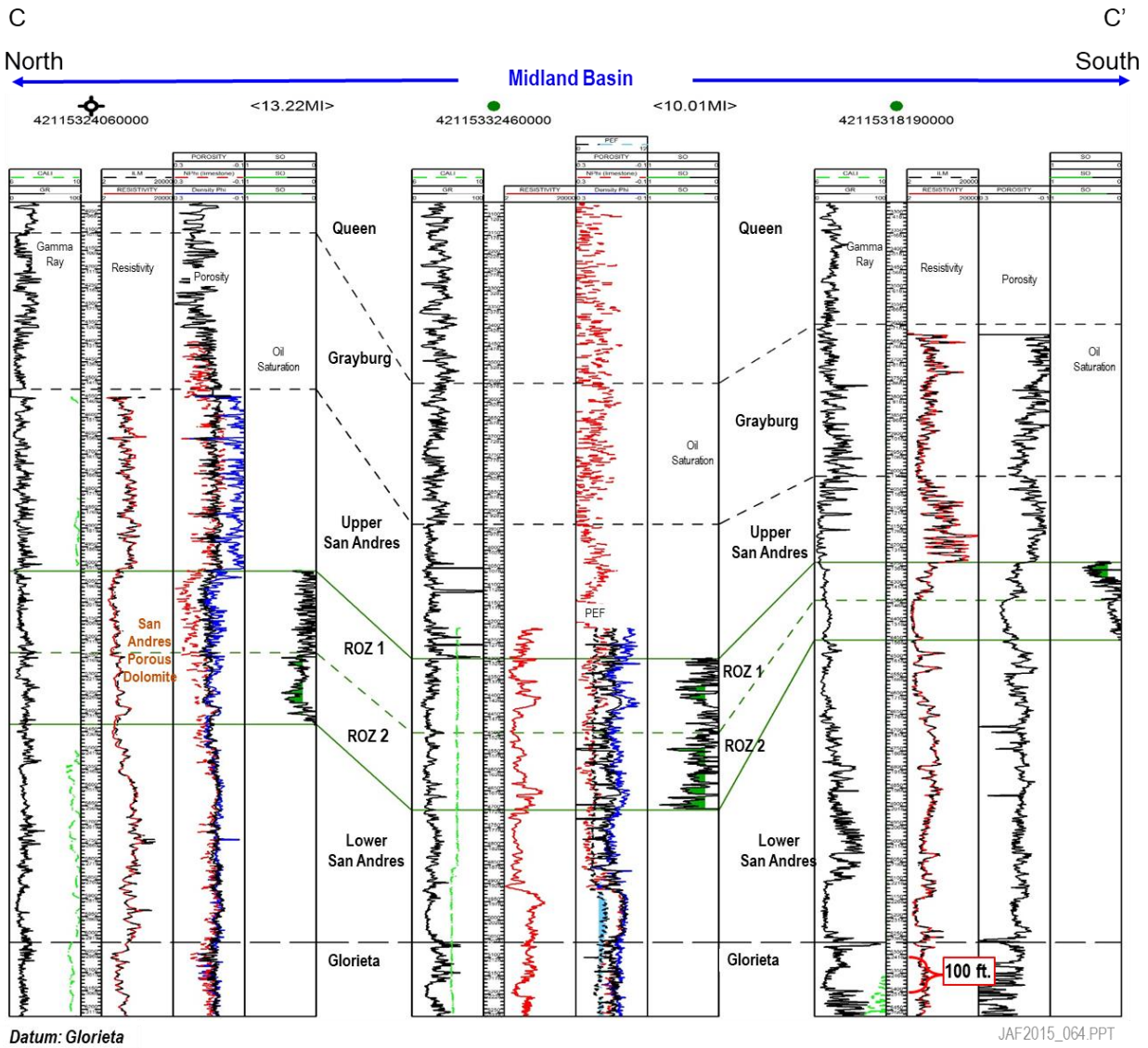
5.1.2 Interpretation of Dawson County Cross-Sections

For logs in the ROZ fairway, the top of the San Andres porous dolomite is picked as the top of the ROZ for this resource assessment. The porous dolomite intervals, informally designated as ROZ 1 and ROZ 2, are illustrated on the cross-sections.

The cross-sections display gamma-ray and caliper logs in Track 1 on the left. Resistivity logs are shown in Track 2, with the deep resistivity log shown in red. Track 3 shows the porosity logs. Uncorrected neutron porosity (for limestone) is red; uncorrected density porosity (for limestone) is blue. The porosity curve used for the OIP calculation is black.

The PEF curve, if available, is also displayed in Track 3. PEF values greater than 4 are shaded in blue. Within and below the ROZ interval, high PEF values generally indicate the presence of limestone, dolomitic limestone or anhydrite.

Track 4 on the right shows the calculated oil saturation. Calculated oil saturations between 25 percent and 45 percent are dark green; calculated oil saturations between 45 percent and 65 percent are light green; and oil saturation greater than 65 percent, typically present in only the MPZ, are black.

The base of the ROZ is picked where either calculated oil saturation or apparent porosity (or both) diminish in the Lower San Andres. If a Lower San Andres limestone is prominent, the top of the limestone defines the lower boundary of the ROZ.

5.1.3 Dawson County Type Log

A type log was selected from the Dawson County study wells to illustrate the ROZ resource analysis undertaken for the county (Exhibit 5-5). The type log illustrates two distinct San Andres ROZ resource intervals—ROZ 1 in the upper portion of the porous dolomite, and ROZ 2 in the lower portion of the porous dolomite.

Exhibit 5-5. Type log for Dawson County San Andres ROZ fairway
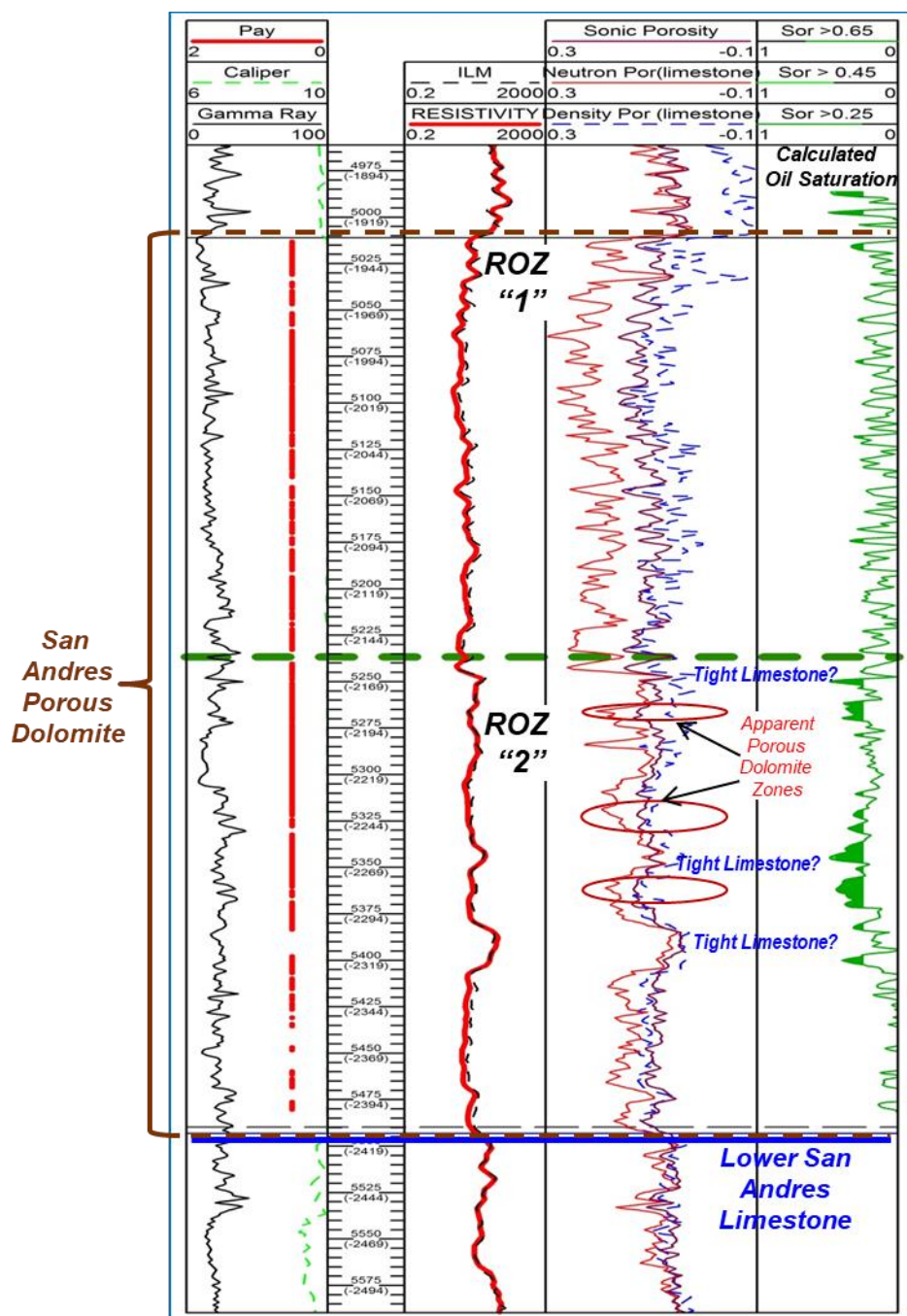
The ROZ 1 and ROZ 2 intervals are variable across Dawson County and often appear to be shaley. ROZ 1 has more shale and thinner individual porous dolomite zones with ROZ 2 being the primary interval of interest. These two intervals are readily distinguished by gamma ray, porosity, and resistivity log character and by the calculated oil saturation.

The type log shows "uncorrected" neutron (red dash) and density (blue) limestone porosity. The porous dolomite in the San Andres ROZ is indicated by neutron and density logs, which

often indicate high porosity, even after lithology correction. Sonic porosity was used to calculate reservoir volume for this Dawson County type log. The lithology corrected sonic porosity is shown in black. Resistivity is lower overall in ROZ 1 than ROZ 2 and porosity is higher in ROZ 1, particularly at the top of the ROZ 1 interval. Several low porosity, apparent limestone zones are interbedded with porous dolomite in the ROZ 2 interval. The best calculated oil saturation in ROZ 2 occurs in the porous zones between the limestone intervals. The Lower San Andres limestone forms the base for ROZ 2.

The oil saturation for the type log ROZ was calculated using the following Archie parameters— 'm' of 2.3, 'n' of 2.3, 'a' of 1, and formation Rw of 0.05 ohm-m. A porosity cut-off of 6 percent was applied to define net pay in the ROZ. Intervals identified as ROZ pay are shown by the red pay flag in Track 1 of Exhibit 5-5.

For ROZ 1, the average porosity is 11.5 percent and average oil saturation is 14 percent. For ROZ 2, the average porosity is 10.1 percent and average oil saturation is 21 percent.

5.2 PARTITIONING THE DAWSON COUNTY ROZ FAIRWAY RESOURCE

The ROZ fairway in Dawson County was divided into three distinct partitions, as illustrated previously in Exhibit 5-6. Individual ROZ fairway resource assessments were undertaken for each of the three partitioned areas.

- Partition #1. Covers a 332,000-acre area of central Dawson County. The area underneath the Welch and Cedar Lake oil fields (15,700 acres) has been excluded from the resource assessment area for Partition #1.

- Partition #2. Covers a 97,000-acre area of northeastern Dawson County. No existing oil field area has been excluded from Partition #2.

- Partition #3. Covers a 133,000-acre area of southern Dawson County. No existing oil field area has been excluded from Partition #3.

Of Dawson County's 577,700 acres, a total of 15,700 acres under the structural closure of existing San Andres oil fields has been excluded, leaving a remaining ROZ assessment area of 562,000 acres (Exhibit 5-6).

Exhibit 5-6. Dawson County ROZ fairway partitions

Partition	Total Area	Excluded Area	Assessment Area
	Acres	Acres	Acres
#1	347,700	15,700	332,000
#2	97,000	-	97,000
#3	133,000	-	133,000
Total	577,700	15,700	562,000

5.3 SIZE AND QUALITY OF THE DAWSON COUNTY ROZ FAIRWAY RESOURCE

Dawson County, Texas, holds 28,420 million barrels of OIP in the San Andres ROZ fairway, outside the structural closure of the existing oil fields. The OIP and resource quality values for each of the three partitions of Dawson County are shown in Exhibit 5-7.

- Higher Quality ROZ Fairway Resources. A significant portion, 15,160 million barrels, of the San Andres ROZ fairway OIP in Dawson County has higher quality reservoir properties (porosity greater than 8% and oil saturation equal to or greater than 25%).

- Lower Quality ROZ Fairway Resources. The remainder, 13,260 million barrels, of the San Andres ROZ fairway OIP in Dawson County has lower quality reservoir properties (porosity equal to or less than 8% and/or oil saturation of less than 25%).

Exhibit 5-7. Dawson County San Andres ROZ fairway resource in-place (MM bbls)

Partition	ROZ 1			ROZ 2			Total		
	Higher Quality	Lower Quality	Total	Higher Quality	Lower Quality	Total	Higher Quality	Lower Quality	Total
#1	4,760	5,040	9,800	5,420	5,650	11,070	10,180	10,690	20,870
#2	-	1,620	1,620	730	320	1,050	730	1,940	2,670
#3	2,210	630	2,840	2,040	-	2,040	4,250	630	4,880
Total*	6,970	7,290	14,260	8,190	5,970	14,160	15,160	13,260	28,420

*Totals may not add due to rounding.

5.4 TECHNICALLY RECOVERABLE DAWSON COUNTY ROZ FAIRWAY RESOURCE

5.4.1 Methodology for Estimating Technically Recoverable Resources

The average volumetric reservoir properties for each partition of Dawson County, along with proprietary reservoir properties from ARI's Big Oil Fields Data Base, were used as input into the Prophet Model. Additionally, it was assumed that 80 percent of each partition area was suitable for development, while 20 percent of the partition had a combination of net pay, porosity, or oil saturation that was not suitable for development. It was also assumed that 90 percent of the OIP in each partition resides in the area suitable for development. The net pay for the developed portion of the partition was increased so that the OIP in the developed portion equaled 90 percent of the OIP calculated for the entire partition. The Prophet Model was then used to calculate the volumes of recoverable oil and water as well as the volumes of injected and stored CO_2. The Prophet Model was run assuming five-spot patterns were implemented at each partition. ROZ fairway well pattern spacings of 20 to 40 acres per CO_2 injection well were selected to achieve a target of approximately 30 years of operation for the miscible CO_2 flood.

5.4.2 Summary of Technically Recoverable Resources

A significant portion of the San Andres ROZ fairway OIP in Dawson County is technically recoverable using miscible CO_2 EOR, while also providing major volumes of pore space for storing CO_2 (Exhibit 5-8).

- Total technically viable oil recovery is estimated at 7,410 million barrels, produced primarily from the higher quality portions of the ROZ resource.

- While the oil recovery efficiencies vary by partition, overall recovery efficiency is 26% of OIP in response to one HCPV injection of CO_2 using a tapered WAG miscible CO_2 flood.

- The San Andres ROZ fairway interval in Dawson County offers the potential for significant storage of CO_2, equal to 6,640 million metric tons (125,500 Bcf).

Exhibit 5-8. Dawson County technically recoverable San Andres ROZ fairway resource

Partitions	Oil Recovery		Purchased CO_2	
	MM bbls	%OIP)	Bcf	MM mt
#1	5,430	26%	95,680	5,062
#2	530	20%	14,860	786
#3	1,450	30%	14,960	792
Total	7,410	26%	125,500	6,640

5.5 VIABILITY OF OIL RECOVERY AND CO_2 STORAGE IN THE DAWSON COUNTY ROZ FAIRWAY

The CO_2 EOR Cost Model used by the study assumes a first-year oil price (WTI) of $75 per barrel, linked to an initial CO_2 purchase cost of $1.50 per Mcf ($28.35 per metric ton of CO_2).

5.5.1 Commercially Viable Oil Recovery with By-Product CO_2 Storage

The three San Andres ROZ fairway partitions of Dawson County offer the potential for 4,660 million barrels of commercially viable oil recovery and 2,279 million metric tons (43,070 Bcf) of by-product storage of CO_2 (Exhibit 5-9).

The commercially viable portion of the ROZ resource has a purchased CO_2 to produced oil ratio of 0.49 metric ton of CO_2 per barrel of recovered oil (9.2 Mcf per barrel).

Exhibit 5-9. Dawson County commercially viable oil recovery with by-product CO_2 storage

Partition	Oil Recovery (MM bbls)	Purchased CO_2		Purchased CO_2/ Oil Recovery (Ratio)	
		Bcf	MM mt	Mcf/B	mt/B
#1	3,370	31,220	1,652	9.3	0.49
#2	-	-	-	-	-
#3	1,290	11,850	627	9.2	0.49
Total	4,660	43,070	2,279	9.2	0.49

5.5.2 Geologically Viable CO_2 Storage with By-Product Oil Recovery

The three San Andres ROZ fairway partitions of Dawson County also offer potential for 4,361 million metric tons (82,430 Bcf) of geologically viable CO_2 storage with 2,750 million barrels of by-product oil recovery (Exhibit 5-10).

Exhibit 5-10. Dawson County geologically viable CO_2 storage with by-product oil recovery

Partition	Purchased CO_2		By-Product Oil Recovery (MM bbls)	Purchased CO_2/ Oil Recovery (Ratio)	
	Bcf	MM mt		Mcf/B	mt/B
#1	64,460	3,411	2,060	31.3	1.66
#2	14,860	786	530	28.0	1.48
#3	3,110	165	160	19.4	1.03
Total	82,430	4,361	2,750	30.0	1.59

5.6 PARTITION #1. CENTRAL DAWSON COUNTY

5.6.1 Geologic Setting

Partition #1, located in central Dawson County, covers a San Andres ROZ fairway area of 332,000 acres (Exhibit 5-11). The partition area excludes portions of the Cedar Lake and Welch oil fields (15,700 acres). Except for its southwestern segment, Partition #1 is located within the previously established San Andres ROZ fairway boundaries.

Exhibit 5-11. San Andres ROZ fairway Partition #1, Dawson County
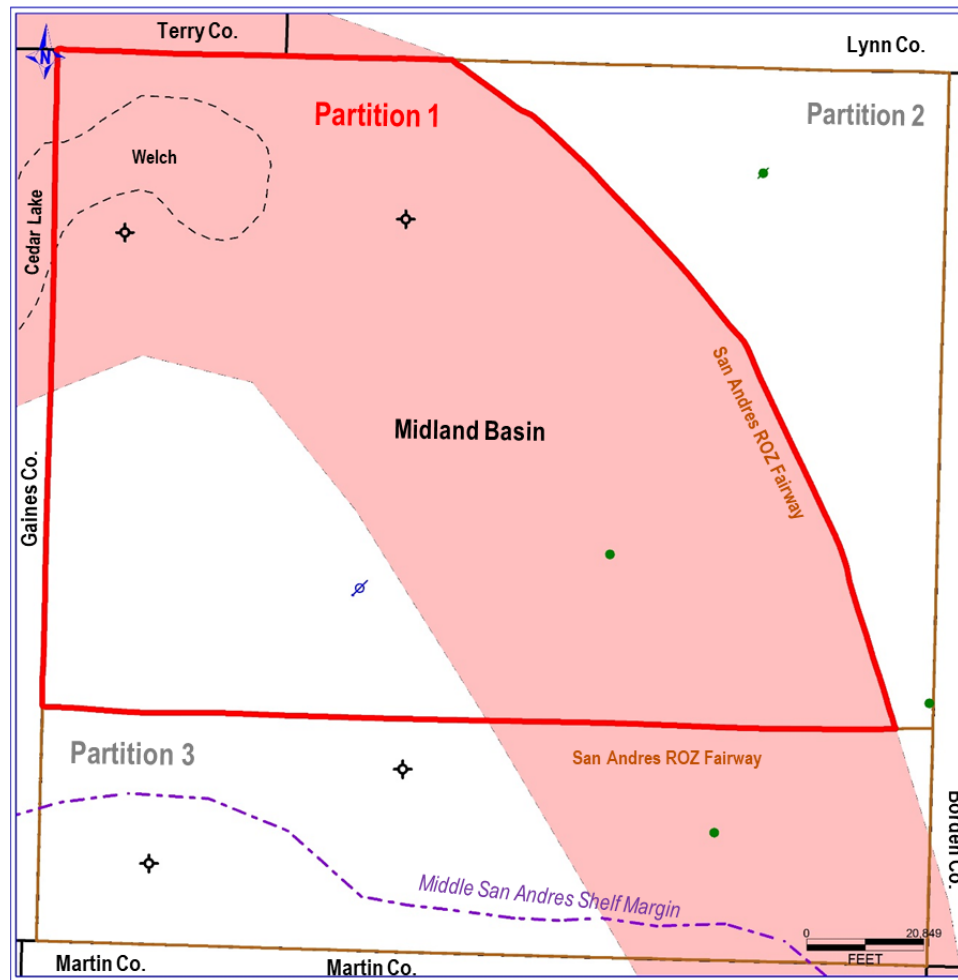
5.6.2 Analytical ROZ Reservoir Units

Four well log-based reservoir data sets plus a series of working level cross-sections were used to further divide the San Andres ROZ fairway resource in Partition #1 of Dawson County into four analytical ROZ fairway reservoir units:

- A higher quality ROZ #1 (Upper ROZ) interval

- A lower quality ROZ #1 (Upper ROZ) interval

- A higher quality ROZ #2 (Lower ROZ) interval

- A lower quality ROZ #2 (Lower ROZ) interval

The volumetric reservoir properties for the four analytical San Andres ROZ fairway reservoir units of Partition #1 of Dawson County are provided in Exhibit 5-12.

Exhibit 5-12. Average San Andres ROZ fairway reservoir properties: Partition #1, Dawson County

Property	ROZ 1		ROZ 2	
	Higher Quality	Lower Quality	Higher Quality	Lower Quality
Depth (ft)	5,190	5,190	5,490	5,490
Gross Thickness (ft)	316	281	238	330
Net Pay (ft)	272	223	212	206
Avg. Porosity (fraction)	0.127	0.108	0.128	0.131
Avg. Oil Saturation (fraction)*	0.30	0.15	0.32	0.17
Avg. Formation Volume Factor (res B/bbl)	1.11	1.11	1.11	1.11
OIP (B/AF, for net pay)	266	113	286	156

*Oil saturation for the study wells in Partition #1 was calculated using Archie parameters: 'm' = 2.3; 'n' = 2.3 − 3.0; 'a' = 1; Rw = 0.05 ohm-m.

5.6.3 ROZ Oil In-Place

The San Andres ROZ fairway in Partition #1 of Dawson County contains 20,870 million barrels of OIP (Exhibit 5-13). About half of the ROZ OIP of 10,190 million barrels meets the higher ROZ resource quality criteria. The remainder of the ROZ OIP of 10,680 million barrels meets the lower resource quality criteria.

Exhibit 5-13. San Andres ROZ fairway OIP: Partition #1, Dawson County

Property	ROZ 1		ROZ 2	
	Higher Quality	Lower Quality	Higher Quality	Lower Quality
Oil In-Place (B/Acre)	72,430	25,180	60,490	32,120
Area Extent (Acres)	65,600	200,000	89,600	176,000
Oil In-Place (MM bbls)	4,760	5,040	5,420	5,650

*Totals may not add due to rounding.

5.6.4 Technically Recoverable Resources

Of the 20,870 million barrels of San Andres ROZ OIP in Partition #1 of Dawson County, approximately 5,430 million barrels is technically recoverable from the application of miscible CO_2 EOR, giving a recovery efficiency of 26 percent of OIP

Significant volumes of CO_2 are stored as part of recovering a portion of the ROZ OIP. Approximately 5,062 million metric tons (95,680 Bcf) of CO_2 are purchased for the EOR project in Partition #1 of Dawson County, with essentially all of the purchased CO_2 securely stored at the end of the CO_2 flood.

5.6.5 Commercially Viable Oil Recovery with By-Product CO_2 Storage

Of the 5,430 million barrels of technically recoverable San Andres ROZ fairway oil resource available from Partition #1 of Dawson County, 3,370 million barrels are economically viable to develop under the economic assumptions used in this study.

The application of CO_2 EOR to the economically viable portion of the San Andres ROZ fairway resource in Partition #1 of Dawson County also provides 1,652 million metric tons (31,220 Bcf) of by-product storage of CO_2 (Exhibit 5-14).

The production of one barrel of San Andres ROZ fairway oil in Partition #1 of Dawson County brings with it, at the margin, the storage of 0.49 metric tons of CO_2.

Exhibit 5-14. Commercially viable oil recovery with by-product CO_2 storage: Partition #1 Dawson County

Oil Recovery (MM bbls)	Purchased CO_2		Purchased CO_2/ Oil Recovery (Ratio)	
	Bcf	MM mt	Mcf/B	mt/B
3,370	31,220	1,652	9.3	0.49

5.6.6 Geologically Viable CO_2 Storage with By-Product Oil Recovery

Pursuing the geologically viable, but economically non-viable, 2,060 million barrels of technically recoverable San Andres ROZ fairway oil in Partition #1 of Dawson County with miscible CO_2 flooding provides 3,411 million metric tons (64,460 Bcf) of CO_2 storage capacity, with 2,060 million barrels of by-product oil recovery (Exhibit 5-15).

Exhibit 5-15. Geologically viable storage of CO_2 with by-product oil recovery: Partition #1 Dawson County

Purchased CO_2		By-Product Oil Recovery (MM bbls)	Purchased CO_2/ Produced Oil (Ratio)	
Bcf	MM mt		Mcf/B	mt/B
64,460	3,411	2,060	31.3	1.66

5.7 PARTITION #2. NORTHEASTERN DAWSON COUNTY

5.7.1 Geologic Setting

Partition #2, located in northwest Dawson County, covers a San Andres ROZ fairway area of 97,000 acres (Exhibit 5-16). The partition area does not contain any significant oil fields. Partition #2 is located outside the previously established San Andres ROZ fairway boundaries, in the Midland Basin of the larger Permian Basin.

Exhibit 5-16. San Andres ROZ fairway Partition #2, Dawson County
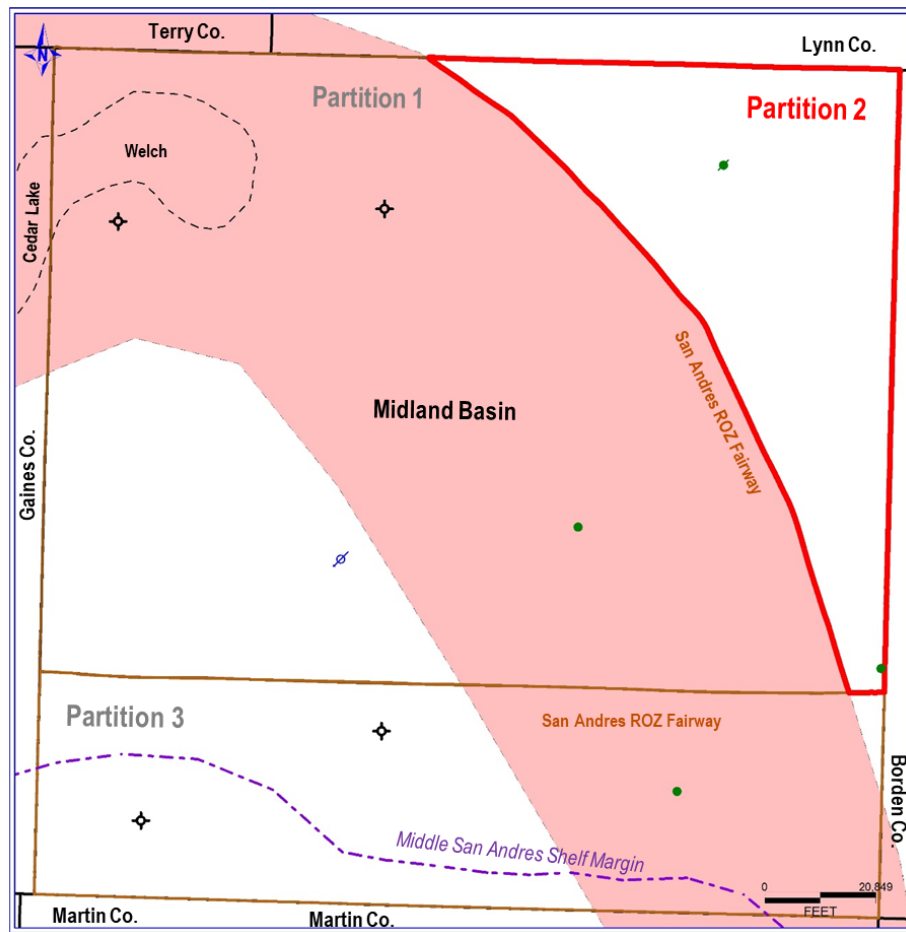
5.7.2 Analytical Reservoir Units

Two well log-based reservoir data sets plus a series of working level cross-sections were used to further divide the San Andres ROZ fairway resource in Partition #2 of Dawson County into three analytical ROZ fairway reservoir units, as set forth below:

- A lower quality ROZ #1 (Upper ROZ) interval

- A higher quality ROZ #2 (Lower ROZ) interval

- A lower quality ROZ #2 (Lower ROZ) interval

The volumetric reservoir properties for the three analytical San Andres ROZ fairway reservoir units of Partition #2 of Dawson County are provided in Exhibit 5-17.

Exhibit 5-17. Average San Andres ROZ fairway reservoir properties: Partition #2, Dawson County

Property	ROZ 1		ROZ 2	
	Higher Quality	Lower Quality	Higher Quality	Lower Quality
Depth (ft)	-	5,150	5,310	5,310
Gross Thickness (ft)	-	249	118	199
Net Pay (ft)	-	156	47	77
Avg. Porosity (fraction)	-	0.132	0.156	0.101
Avg. Oil Saturation (fraction)*	-	0.15	0.37	0.15
Avg. Formation Volume Factor (res B/bbl)	-	1.11	1.11	1.11
OIP (B/AF, for net pay)	-	134	403	106

*Oil saturation for the study wells in Partition #2 was calculated using Archie parameters: 'm' = 2.3; 'n' = 2.3; 'a' = 1; R_w = 0.05 – 0.055 ohm-m.

5.7.3 ROZ Oil In-Place

The San Andres ROZ fairway in Partition #2 of Dawson County contains 2,670 million barrels of OIP (Exhibit 5-18). Only a modest portion of the ROZ OIP of 730 million barrels meets the higher ROZ resource quality criteria. The remainder of the ROZ OIP of 1,940 million barrels meets the lower resource quality criteria.

Exhibit 5-18. San Andres ROZ fairway OIP: Partition #2, Dawson County

Property	ROZ 1		ROZ 2	
	Higher Quality	Lower Quality	Higher Quality	Lower Quality
Oil In-Place (B/Acre)	29,150	16,110	50,240	13,330
Area Extent (Acres)	16,800	72,000	32,800	56,000
Oil In-Place (MM bbls)	490	1,160	1,650	740

5.7.4 Technically Recoverable Resources

Of the 2,670 million barrels of San Andres ROZ OIP in Partition #2 of Dawson County, approximately 530 million barrels is technically recoverable from the application of miscible CO_2 EOR, giving a recovery efficiency of 20 percent of OIP.

Significant volumes of CO_2 are stored as part of applying miscible CO_2 EOR for recovering a portion of the ROZ OIP. Approximately 786 million metric tons (14,860 Bcf) of CO_2 are purchased for the EOR project in Partition #2 of Terry County, with essentially all of the purchased CO_2 securely stored at the end of the CO_2 flood.

5.7.5 Commercially Viable Oil Recovery with By-Product CO_2 Storage

Of the 530 million barrels of technically recoverable San Andres ROZ fairway oil resource available from Partition #2 of Dawson County, no portion of this oil resource is economically viable to develop under the economic assumptions used in this study (Exhibit 5-19).

Exhibit 5-19. Commercially viable oil recovery with by-product CO_2 storage: Partition #2 Terry County

Oil Recovery (MM bbls)	Purchased CO_2		Purchased CO_2/ Oil Recovery (Ratio)	
	Bcf	MM mt	Mcf/B	mt/B
-	-	-	-	-

5.7.6 Geologically Viable CO_2 Storage with By-Product Oil Recovery

Pursuing the geologically viable, but economically non-viable, portion of the San Andres ROZ fairway resource in Partition #2 of Dawson County with miscible CO_2 flooding provides 786 million metric tons (14,860 Bcf) of CO_2 storage capacity, with 530 million barrels of by-product oil recovery (Exhibit 5-20).

Exhibit 5-20. Geologically viable storage of CO_2 with by-product oil recovery: Partition #2 Dawson County

Purchased CO_2		By-Product Oil Recovery (MM bbls)	Purchased CO_2/ Produced Oil (Ratio)	
Bcf	MM mt		Mcf/B	mt/B
14,860	786	530	28.0	1.48

## 5.8 PARTITION #3. SOUTHERN DAWSON COUNTY

5.8.1 Geologic Setting

Partition #3, located in southern Dawson County, covers a San Andres ROZ fairway area of 113,000 acres (Exhibit 5-21). The partition area does not contain any major San Andres oil fields. The eastern portion of Partition #3 is located within the previously established San Andres ROZ fairway boundaries, within the Middle San Andres Shelf Margin.

Exhibit 5-21. San Andres ROZ fairway Partition #3, Dawson County
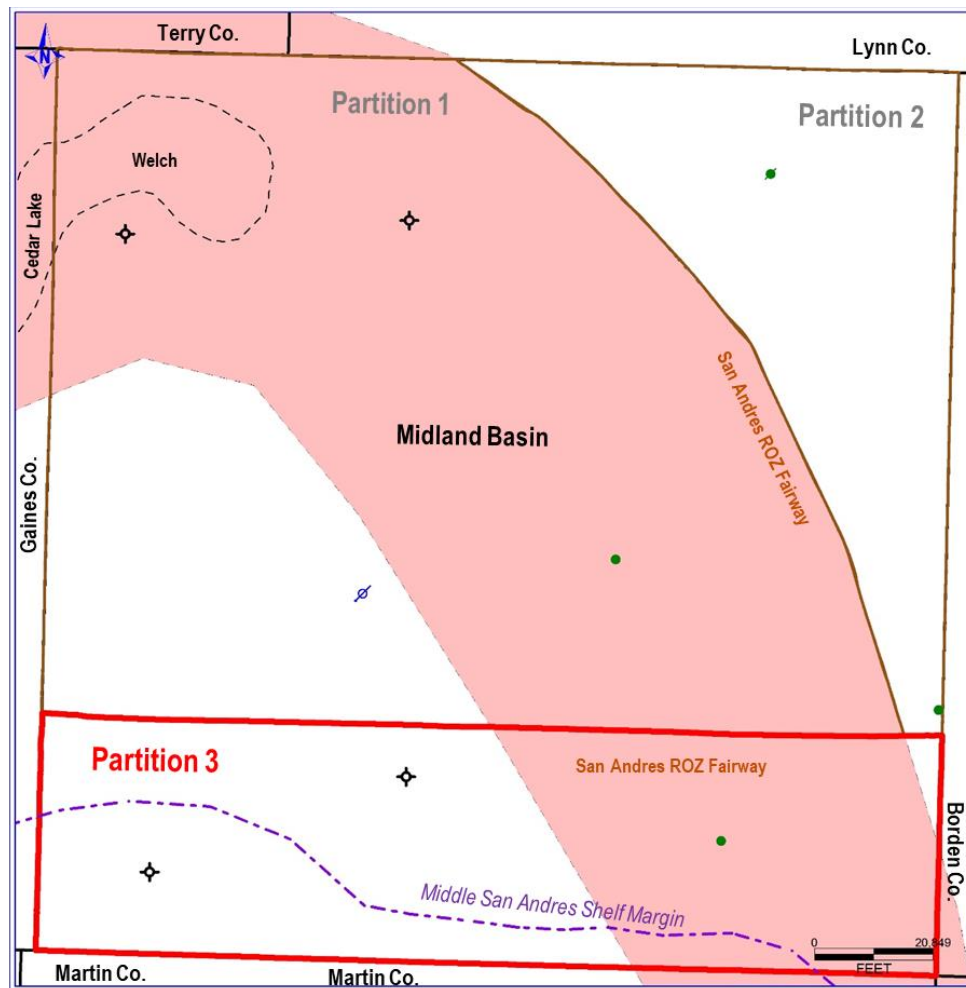
5.8.2 Analytical ROZ Reservoir Units

Three well log-based reservoir data sets plus a series of working level cross-sections were used to further divide the San Andres ROZ fairway resource in Partition #3 of Dawson County into four analytical ROZ fairway reservoir units, as set forth below:

- A higher quality ROZ #1 (Upper ROZ) interval

- A lower quality ROZ #1 (Upper ROZ) interval

- A higher quality ROZ #2 (Lower ROZ) interval

- A lower quality ROZ #2 (Lower ROZ) interval

The volumetric reservoir properties for the four analytical San Andres ROZ fairway reservoir units of Partition #3 of Dawson County are provided in Exhibit 5-22.

Exhibit 5-22. Average San Andres ROZ fairway reservoir properties: Partition #3, Dawson County

Property	ROZ 1		ROZ 2	
	Higher Quality	Lower Quality	Higher Quality	Lower Quality
Depth (ft)	5,010	5,010	5,110	-
Gross Thickness (ft)	108	140	121	-
Net Pay (ft)	104	127	110	-
Avg. Porosity (fraction)	0.112	0.103	0.113	-
Avg. Oil Saturation (fraction)*	0.38	0.20	0.33	-
Avg. Formation Volume Factor (res B/bbl)	1.11	1.11	1.11	-
OIP (B/AF, for net pay)	297	144	257	-

*Oil saturation for the study wells in Partition #3 was calculated using Archie parameters: 'm' = 2.3; 'n' = 2.3; 'a' = 1; Rw = 0.055 – 0.06 ohm-m.

5.8.3 ROZ Oil In-Place

The San Andres ROZ fairway in Partition #3 of Dawson County contains 4,880 million barrels of OIP (Exhibit 5-23). The bulk of the ROZ OIP of 4,250 million barrels meets the higher ROZ resource quality criteria. The remainder of the ROZ OIP of 630 million barrels meets the lower resource quality criteria.

Exhibit 5-23. San Andres ROZ fairway OIP: Partition #3, Dawson County

Property	ROZ 1		ROZ 2	
	Higher Quality	Lower Quality	Higher Quality	Lower Quality
Oil In-Place (B/Acre)	30,740	18,300	28,350	-
Area Extent (Acres)	72,000	34,400	72,000	-
Oil In-Place (MM bbls)	2,210	630	2,040	-

5.8.4 Technically Recoverable Resources

Of the 4,880 million barrels of San Andres ROZ OIP in Partition #3 of Dawson County, approximately 1,450 million barrels is technically recoverable from the application of miscible CO_2 EOR, giving a recovery efficiency of 30 percent of OIP.

Significant volumes of CO_2 are stored as part of applying miscible CO_2 EOR for recovering a portion of the ROZ OIP. Approximately 792 million metric tons (14,960 Bcf) of CO_2 are purchased for the EOR project in Partition #3 of Dawson County, with essentially all of the purchased CO_2 securely stored at the end of the CO_2 flood.

5.8.5 Commercially Viable Oil Recovery with By-Product CO_2 Storage

Of the 1,450 million barrels of technically recoverable San Andres ROZ fairway oil available from Partition #3 of Dawson County, 1,290 million barrels are economically viable to develop under the economic assumptions used in this study.

The application of CO_2 EOR to the economically viable portion of the San Andres ROZ fairway resource in Partition #3 of Dawson County also provides 627 million metric tons (11,850 Bcf) of by-product storage of CO_2 (Exhibit 5-24).

Exhibit 5-24. Commercially viable oil recovery with by-product storage of CO_2: Partition #3 Dawson County

Oil Recovery (MM bbls)	Purchased CO_2		Purchased CO_2/ Oil Recovery (Ratio)	
	Bcf	MM mt	Mcf/B	mt/B
1,290	11,850	627	9.2	0.49

The production of one barrel of San Andres ROZ fairway oil in Partition #3 of Dawson County brings with it, at the margin, the storage of 0.49 metric tons of CO_2.

5.8.6 Geologically Viable CO_2 Storage with By-Product Oil Recovery

Pursuing the geologically viable, but economically non-viable, portion of the San Andres ROZ fairway resource in Partition #3 of Dawson County with miscible CO_2 flooding provides 165 million metric tons (3,110 Bcf) of CO_2 storage capacity, with 160 million barrels of by-product oil recovery (Exhibit 5-25).

Exhibit 5-25. Geologically viable storage of CO_2 with by-product oil recovery: Partition #3 Dawson County

Purchased CO_2		By-Product Oil Recovery (MM bbls)	Purchased CO_2/ Produced Oil (Ratio)	
Bcf	MM mt		Mcf/B	mt/B
3,110	165	160	19.4	1.03

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