Application of Reservoir Characterization and Advanced Technology to Improve Recovery and Economics in a Lower Quality Shallow Shelf San Andres Reservoir

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DISCLAIMER

OBJECTIVES

The Class 2 Project at West Welch was designed to demonstrate the use of advanced technologies to enhance the economics of improved oil recovery (IOR) projects in lower quality Shallow Shelf Carbonate (SSC) reservoirs, resulting in recovery of additional oil that would otherwise be left in the reservoir at project abandonment. Accurate reservoir description is critical to the effective evaluation and efficient design of IOR projects in the heterogeneous SSC reservoirs. Therefore, the majority of Budget Period 1 was devoted to reservoir characterization. Technologies being demonstrated include:

1. Advanced petrophysics
2. Three-dimensional (3-D) seismic
3. Crosswell bore tomography
4. Advanced reservoir simulation
5. Carbon dioxide (CO_2) stimulation treatments
6. Hydraulic fracturing design and monitoring
7. Mobility control agents

SUMMARY OF TECHNICAL PROGRESS

West Welch Unit is one of four large waterflood units in the Welch Field in the northwestern portion of Dawson County, Texas. The Welch Field was discovered in the early 1940's and produces oil under a solution gas drive mechanism from the San Andres formation at approximately 4800 ft. The field has been under waterflood for 30 years and a significant portion has been infill-drilled on 20-ac density. A 1982-86 pilot CO_2 injection project in the offsetting South Welch Unit yielded positive results. Recent installation of a CO_2 pipeline near the field allowed the phased development of a miscible CO_2 injection project at the South Welch Unit.

The reservoir quality at the West Welch Unit is poorer than other San Andres reservoirs due to its relative position to sea level during deposition. Because of the proximity of a CO_2

source and the CO_2 operating experience that would be available from the South Welch Unit, West Welch Unit is an ideal location for demonstrating methods for enhancing economics of IOR projects in lower quality SSC reservoirs. This Class 2 project concentrates on the efficient design of a miscible CO_2 project based on detailed reservoir characterization from advanced petrophysics, 3-D seismic interpretations and crosswell tomography interpretations.

During this quarter the extraction of spatial statistics from the porosity and permeability variograms and the generation of conditional simulation model was completed. Alternative porosity distribution maps were also generated using cokriging to honor two independent sets of porosity data. The CO2 was refocused on six contiguous injectors to improve the performance surveillance and interpretation.

INTERWELL SEISMIC

In third quarter of 1999, Advanced Reservoir Technologies completed and delivered work related to integrating tomography results from Phase 1 baseline surveys into 3-D models which could be used for reservoir simulation work. Specifically, work was completed in three different areas. Using the new porosity maps derived from interwell seismic data calibrated to core porosity at observation wells 7916 and 4852, the appropriate spatial statistics were extracted for use in generating the conditional simulation model for the 3-D porosity distribution over the study area surrounding the north and south patterns. The same procedure was carried out for the conditional simulation of permeability, using the permeability maps derived from cross-plots which were obtained from core analysis and differentiated by rock type.

Alternate maps of 3-D porosity distribution were also generated by updating the maps derived from the interwell seismic data and core data by cokriging these results with the neutron porosity data from logs available at most of the wells in the study area. Cokriging allows the statistics of two independent data sets (neutron porosity logs and calibrated interwell seismic results) to be used simultaneously to produce a map which honors both sets of statistics. One data set is chosen as the primary data set (largely honored), with the other data set chosen as secondary, acting as an additional constraint on the primary data set. Two separate models were created for comparison using the interwell data as primary, with the neutron porosity data as secondary; then using neutron porosity data as primary and interwell seismic data as secondary. Time was also spent in the third quarter planning the new monitor surveys to be carried out early in the fourth quarter of 1999.

3-D SEISMIC INTEGRATION

No activities involving 3-D seismic integration were undertaken during the third quarter of 1999.

NUMERICAL SIMULATION

No simulation work was conducted during the third quarter of 1999.

FIELD DEMONSTRATION PHASE

CO_2 injection began in October 1997 and through September 1999 a total of 2.9 BCF of CO_2 had been injected into the project area. To better manage the field demonstration phase and interpret the performance, the decision was made to restrict the CO_2 injection to six contiguous injectors-4805, 4806, 4808, 4809, 4810 and 4811. These injectors are either directly or diagonally offset by 21 producers forming six- inverted 7 spot patterns. This CO_2 focus area covers about 400 acres as shown on Figure 1. Total CO_2 injection in the focus area has been 2.0 BCF through September 1999. CO_2 injection into the other four wells that have been active at various times has been discontinued.

A summary of the focus area performance by months for the third quarter of 1999 is given on Table 1. A baseline production level of 160 BOPD with an 8% annual decline was established for the focus area as of June 1998. Initial oil response to CO_2 injection occurred in 4844 during the second quarter of 1999. This well continues to produce 10 BOPD above its base level. During the third quarter oil response occurred in 4647 and 4854. The incremental gain in production from these three wells exceeds the summary incremental for the whole area due to other factors influencing production. Primarily CO_2 injection was reduced overall because of a supply and balance problem and water was not injected to maintain the input/withdrawal ratio. Gas production has increased significantly between the second to the third quarter from 7% to 18% of injected volume. Initial gas breakthrough occurred in 4854, 4841 and 4843.

Project surveillance has been hampered by poor data quality relating to individual well testing. The focus area database has been revised beginning January 1996 using a more accurate methodology. Therefore some data may not be consistent with prior reporting.

AREA PREPARATION AND CONSTRUCTION

There was no construction, stimulation or workovers done in the DOE project area during the third quarter of 1999.

TECHNOLOGY TRANSFER

No formal technology transfer activity occurred during the quarter.

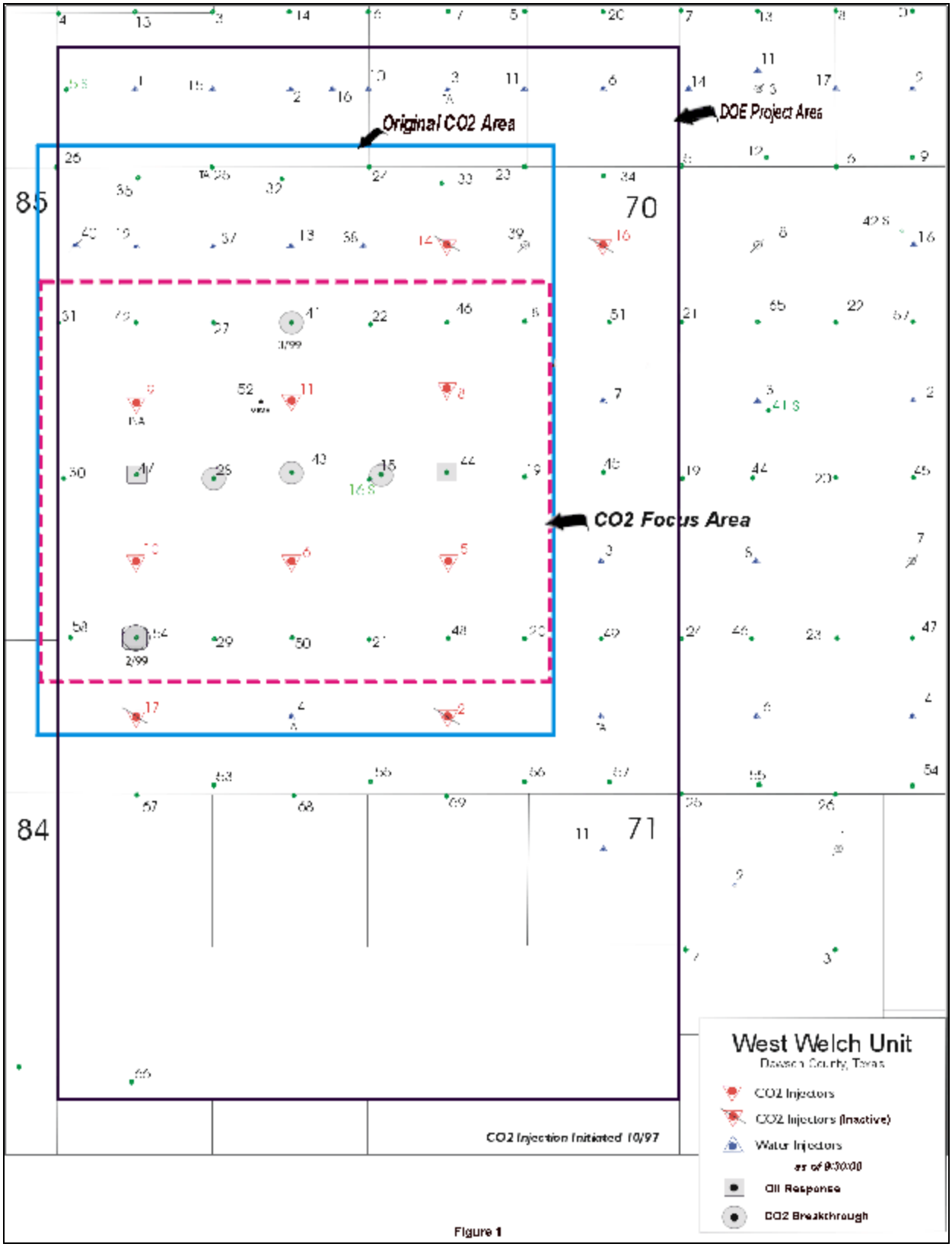
Original CO2 Area
DOE Project Area
CO2 Focus Area
85
70
84
71
CO2 Injection Initiated 10/97
West Welch Unit
Dawson County, Texas
CO2 Injectors
CO2 Injectors (Inactive)
Water Injectors
as of 9/30/00
Oil Response
CO2 Breakthrough

Figure 1

Table 1

CO2 Focus Area Performance
Third Quarter - 1999
West Welch Unit DOE Project
Dawson County, Texas

		July	Aug	Sept	3rd Qtr
Injection					
	Average CO2 injection rate (mcfd)	2689	2682	1514	2295
	# of Injectors on CO2	5	6	5	
	Average rate per injector (mcfd)	536	447	303	382
	% HCPV injected	0.3%	0.3%	0.2%	0.8%
	Cum % HCPV injected	6.2%	6.5%	6.7%	
	Average water injecton rate (bwpd)	0	0	0	0
	# of Injectors on water	0	0	0	0
	Average rate per injector	0	0	0	0
	Water+CO2 % HCPV injected	0.3%	0.3%	0.2%	0.8%
	Water+CO2 Cum % HCPV injected	6.4%	6.7%	7.0%	
Production					
	Base oil production (bopd)	147	146	145	146
	Actual oil production (bopd)	164	159	136	153
	Incremental oil production (bopd)	17	13	-9	7
	Cum % OOIP	0.0%	0.0%	0.0%	
	Gas production (mcfd)	447	392	403	414
	Gas production as % injection	17%	15%	27%	18%
	Base WOR	13	13	13	
	WOR	5	5	6	