science for a changing world

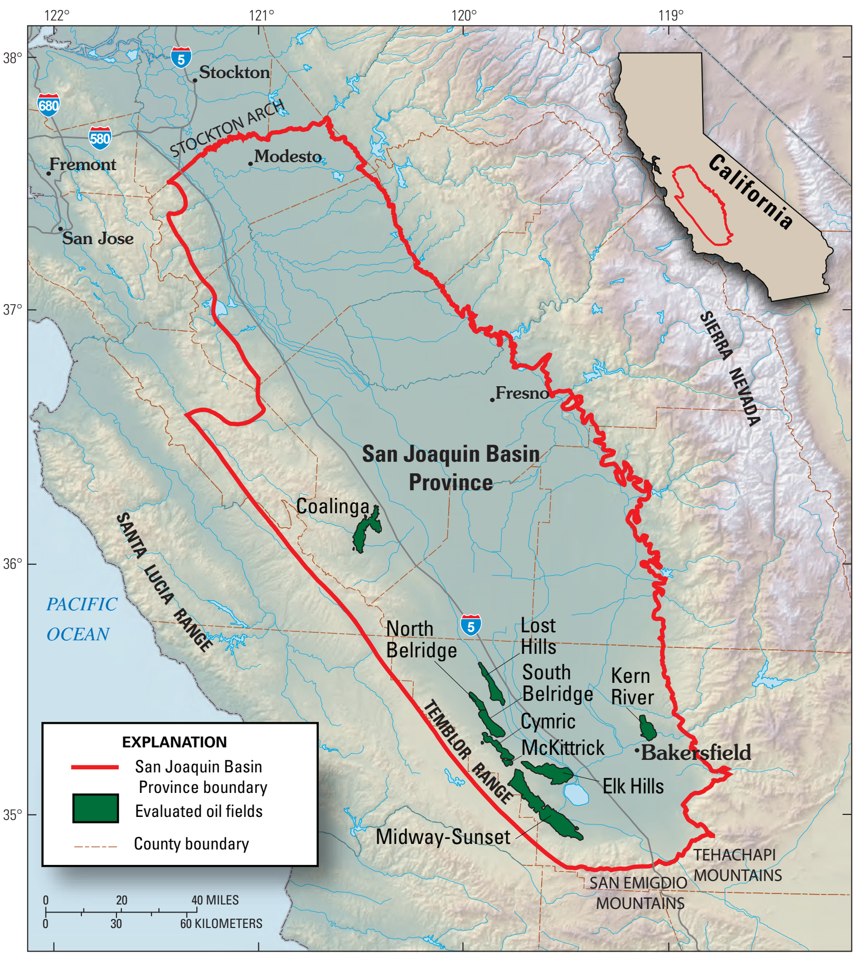
Reserve Growth Assessment Fact Sheet

Assessment of Remaining Recoverable Oil in Selected Major Oil Fields of the San Joaquin Basin, California

The U.S. Geological Survey (USGS) recently completed an estimate of volumes of technically recoverable, conventional oil that could eventually be added to reserves in nine selected major oil fields in the San Joaquin Basin in central California. The mean total volume of potential oil reserves that might be added in the nine fields using improved oil-recovery technologies was estimated to be about 6.5 billion barrels of oil.

Introduction

A team of U.S. Geological Survey (USGS) scientists recently completed an assessment of potential additions to oil reserves that could result from improved oil-recovery technologies in selected large oil fields in the San Joaquin Basin oil and gas province in central California. The basin is bounded on the east by the Sierra Nevada, on the north by the Stockton Arch, on the southwest by the Temblor Range, and on the south by the San Emigdio and Tehachapi Mountains. Oil and gas development in the San Joaquin Basin began in the late 1800s, and the basin came to be recognized as one of the largest petroleum provinces in the United States. The basin contains 21 oil fields in which known recoverable oil (cumulative production plus proved reserves) exceeds 100 million barrels of oil (MMBO), including 3 of the 10 largest fields in the Nation (Midway-Sunset, Kern River, and South Belridge).



Map of San Joaquin Basin oil and gas province in central California, showing oil fields evaluated for this study.

Recent decades have been a time of exceptional development in existing fields of the San Joaquin Basin. In the 1960s, introduction of thermal recovery technologies (application of steam technology) caused abrupt and substantial additions to reserves in fields that contain heavy oil (American Petroleum Institute (API) gravity less than 20 degrees). Similar additions to reserves have continued to the present. During the 1980s, reserve additions began to be made using hydraulic fracturing in Monterey Formation diatomites (sedimentary rock made up of the tiny silica skeletons of diatoms) on the west side of the basin. These additions have increased as production from diatomite replaces declining, but still substantial, production from overlying steam-flooded reservoirs. Since 1965, more than 8 billion barrels of recoverable oil have been added to reserves within existing fields. These additions have significantly extended the life of California oil production and slowed the decline of U.S. domestic production.

Methodology

Nine oil fields were studied, most of which have shown significant additions to reserves in the last several decades. Production and reserves information came from the California Division of Oil, Gas, and Geothermal Resources. To assess the potential for future additions to reserves, an evaluation was made of each field (Klett and others, 2011). The geology of each field was analyzed, and its development history was reviewed. Estimates of original oil in place (OOIP) in each field were based on evaluation of information from various published and proprietary sources. Potential growth of reserves was evaluated by estimating the range of recovery efficiency that might be realized with existing technology, based on levels of recovery efficiency that have (1) been achieved in analogous reservoirs, (2) modeled in engineering studies, or (3) indicated by laboratory results reported in technical literature. For each reservoir analyzed,

U.S. Department of the Interior
U.S. Geological Survey

Fact Sheet 2012–3050
April 2012

Key assessment data for oil fields individually assessed within the San Joaquin Basin, California.

[MMBO, million barrels of oil (BBO, billion barrels of oil; 1 BBO=1,000 MMBO); OOIP, original oil in place. Estimated recovery efficiency is potentially recoverable proportion of OOIP. Known recoverable oil is cumulative production plus reserves at the end of 2006, from California Division of Oil, Gas, and Geothermal Resources (2007)]

Field	Reservoir(s)	Known recoverable oil (MMBO)	Estimated OOIP (MMBO)			Estimated recovery efficiency (percent)		
			min	med	max	min	mode	max
Coalinga	Temblor reservoir	965	3,000	3,500	5,000	30	45	65
Cymric-Welport Area	Diatomite reservoir	163	425	600	1,000	25	40	55
	Pre-Monterey reservoirs	36	145	175	210	30	40	55
	Tulare reservoir	339	550	700	1,000	55	65	85
Elk Hills	Stevens/Monterey and older reservoirs	784	2,300	2,700	3,500	35	40	50
	Shallow Oil Zone	601	1,300	1,600	2,000	45	48	55
Kern River	All reservoirs	2,451	3,400	3,600	4,200	70	75	85
Lost Hills	Diatomite and older reservoirs	103	2,000	2,800	4,500	20	35	55
	Tulare-Etchegoin reservoir	374	655	700	1,500	45	55	65
McKittrick-Main Area	All reservoirs	203	525	800	1,700	40	50	60
Midway-Sunset	Diatomite reservoirs	21	300	1,500	3,000	10	20	40
	All reservoirs except diatomite	3,436	6,400	8,000	12,000	45	60	70
North Belridge	Diatomite reservoir	71	400	600	1,000	25	40	55
	Temblor and older sandstone reservoirs	70	300	350	500	25	30	40
	Tulare-Etchegoin reservoir	22	50	100	300	45	55	65
South Belridge	Diatomite reservoir	710	2,500	5,000	8,000	25	40	55
	Tulare reservoir	1,273	1,650	1,900	2,200	65	75	85

ranges of OOIP and potential recovery efficiency were estimated. Those values were used in "Monte Carlo" computer simulations to generate estimated ranges of oil volumes technically recoverable from each reservoir, without regard to economic constraints.

Results

On the basis of the analysis of recovery efficiencies and remaining oil in place, the USGS estimates that at least 3.6 additional billion barrels of oil (BBO) may be recovered from the fields studied in the San Joaquin Basin, in addition to cumulative production plus proved reserves as of 2006. The mean estimate is that an additional 6.5 BBO could be recoverable. Under extremely favorable but unlikely circumstances, reserve additions could approach 10 BBO. Much of the potential reserves could come from improved recovery in diatomite reservoirs of the Monterey Formation, given continued technological evolution. Additional volumes of oil could come from continued application of thermal-recovery technologies to shallow reservoirs containing heavy oil, although the oil remaining in such reservoirs is more difficult to recover than in similar reservoirs already exploited. In a few reservoirs, particularly deep sandstone reservoirs containing relatively light oil such as sandstone reservoirs within the Monterey Formation at Elk Hills field, additional oil could be recovered with injection of carbon dioxide.

Oil reserves will also continue to be added in fields within the San Joaquin Basin that were not included in this analysis. Most such fields are smaller than the fields studied, and their additions to reserves will also be smaller, although they may be significant. Statistical methods, like those used in previous USGS reserve growth estimates, are being used to approximate a volume of additional reserves that might be expected to come from these smaller fields.

Assessment results for volume of additional oil potentially recoverable from selected oil fields in the San Joaquin Basin, California (technically recoverable resources).

[Mean estimates add to a total mean, but fractile values for individual fields are not additive; fractiles (non-additive) for the entire group of fields are shown in the bottom row highlighted in yellow. MMBO, million barrels of oil (BBO, billion barrels of oil; 1 BBO=1,000 MMBO). F95 denotes a 95-percent chance of at least the amount tabulated, F-50 denotes a 50-percent chance, and F5 denotes a 5-percent chance. A negative value indicates a chance that reserves could decrease from currently estimated values]

Field	Reservoir(s)	Oil (MMBO)			
		F95	F50	F5	Mean
Coalinga	All reservoirs	239	676	1,252	705
Cymric-Welport Area	Diatomite reservoir	1	77	191	84
	Pre-Monterey reservoirs	21	36	56	37
	Tulare reservoir	40	139	284	148
Elk Hills	Stevens/Monterey and older reservoirs	164	342	589	355
	Shallow Oil Zone	73	188	327	193
Kern River	All reservoirs	97	315	624	332
Lost Hills	Diatomite and older reservoirs	556	917	1,451	951
	Tulare-Etchegoin reservoir	-41	18	174	35
McKittrick-Main Area	All reservoirs	79	197	447	221
Midway-Sunset	Diatomite reservoirs	112	311	637	335
	All reservoirs except diatomite	238	1,229	2,718	1,320
North Belridge	Diatomite reservoir	89	168	286	176
	Temblor and older sandstone reservoirs	20	41	73	43
	Tulare-Etchegoin reservoir	10	33	90	39
South Belridge	Diatomite reservoir	460	1,234	2,242	1,278
	Tulare reservoir	46	222	421	226
All evaluated fields	All evaluated reservoirs	3,517	6,326	9,955	6,478

References Cited

California Division of Oil, Gas, and Geothermal Resources, 2007, 2006 Annual report of the State Oil and Gas Supervisor: California Department of Conservation, Division of Oil, Gas, and Geothermal Resources, publication no. PR-06, 276 p., accessed April 2, 2012, at http://www.conservation.ca.gov/dog/pubs_stats/annual_reports/Pages/annual_reports.aspx.

Klett, T.R., Attanasi, E.D., Charpentier, R.R., Cook, T.A., Freeman, P.S., Gautier, D.L., Le, P.A., Ryder, R.T., Schenk, C.J., Tennyson, M.E., and Verma, M.K., 2011, New U.S. Geological Survey method for the assessment of reserve growth: U.S. Geological Survey Scientific Investigations Report 2011–5163, 8 p., available at http://pubs.usgs.gov/sir/2011/5163/.

Reserve Growth Assessment Team:
Marilyn E. Tennyson, Troy A. Cook, Ronald R. Charpentier, Donald L. Gautier, Timothy R. Klett, Mahendra K. Verma, Robert T. Ryder, Emil D. Attanasi, Philip A. Freeman, and *Phoung A. Le*

Edited by *James W. Hendley II*
Graphic design by *Stephen L. Scott*

For Further Information

Supporting geologic studies of total petroleum systems and assessment units and reports on the methodology used in this assessment, as well as the assessment results, are available at the USGS Energy Resources Program Web site: http://energy.usgs.gov/
or contact
Marilyn E. Tennyson (tennyson@usgs.gov)

This Fact Sheet and any updates to it are available online at

http://pubs.usgs.gov/fs/2012/3050/