

## **Chapter B**

# **Summary of Deep Oil and Gas Wells in the United States Through 1998**

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## Introduction

In 1990, the U.S. Geological Survey summarized the geologic and production characteristics of deep wells and reservoirs in the United States (wells drilled more than 15,000 feet—4,572 m or deeper) based on data compilations from published computer files (Dyman and others, 1990; 1993). In those reports, tables were compiled on deep wells from Petroleum Information (PI) Corporation's Well History Control System (WHCS) available through 1988 (Petroleum Information Corp., 1988). WHCS contains location, identification, and geologic and engineering data on more than 2 million wells drilled in the U.S. The WHCS file (now referred to as PI-Dwights WHCS files; IHS Energy Group, 1998) is currently available to the U.S. Geological Survey under contract with IHS Energy Group, Denver, Colo. In the reports by Dyman and others, well summaries included the distribution of (1) the 10 deepest wells drilled in the U.S., (2) deep wells in the U.S. based on depth interval and final well classification, (3) deep producing wells based on final completion classification, (4) deep producing wells by region, and (5) deep producing wells by depth interval and decade of completion. The purpose of these reports was to summarize deep drilling in the U.S. in order to develop a better understanding of the distribution of deep wells and reservoirs, to define geologic and engineering factors associated with deep drilling, and to more precisely assess deep natural gas resources.

During the 1990's, deep drilling has continued in the U.S. at a robust pace, and technologic advancements have played an important role in the development of new deep gas plays. Deep drilling frontiers that seemed economically prohibitive in past decades have been reached thanks to technologic advances in the 1990's. The purpose of this report is to update the data summaries of Dyman and others (1990; 1993) based on well information through 1998 (PI-Dwights WHCS data from IHS Energy Group through 1998) and to compare deep drilling activity during the 1990's with deep drilling activity of previous decades.

## Data Analysis

The December 1998 version of PI-Dwights WHCS includes a subset of wells drilled deeper than 15,000 feet (4,572 m) that contains 20,715 wells, of which 11,522 are classed as producing gas and (or) oil. This figure is up from 16,650 total wells in 1988, an increase of 4,065 wells or a 24 percent increase in the 1990's decade. Of the 11,522 producing wells, 5,119 have a formation reported at total depth that is the same as

the first producing formation reported. Wells may contain more than one producing formation, but only the first producing formation listed in the file was recognized for this study. These 5,119 wells, although a minimum number, form a subset of wells actually producing gas or oil below 15,000 feet (4,572 m). The remaining 6,403 producing wells of the original 11,522 producing wells produce from a formation other than the formation at total depth (above or below 15,000 feet—4,572 m) or have no producing formation reported. Some of these 6,403 wells may be producing oil or gas below 15,000 feet (4,572 m), but they were not considered for this report. The following discussion is based solely on observations from PI-Dwights WHCS and does not take into account oil and gas wells that are not in these data files. The inclusion of non-WHCS wells could affect the results reached in this report.

## Deepest Wells in the U.S.

Dyman and others (1990; 1993, table 1) identified the 10 deepest wells in the U.S. through 1985 regardless of completion classification. In order to more fully represent the distribution of these and other ultra deep wells, we have selected and summarized wells drilled to depths exceeding 25,000 feet (7,620 m) throughout the U.S. (table 1). The deepest well drilled in the U.S. still remains the Lone Star No. 1 Bertha Rogers, which was completed in 1974 in the Ordovician Arbuckle Formation as a wildcat well to a depth of 31,441 feet (9,583 m) in Beckham County, Okla., in the Anadarko basin. Fifty-one other wells have been drilled below 25,000 feet (7,620 m) in eight regions of the U.S. Despite the record-setting Bertha Rogers and other deep wells in the Anadarko basin, the Permian basin currently holds the record for the number of ultra deep wells based on data from PI-Dwights WHCS (table 1) with 21 wells, of which 10 were completed as gas wells. The Anadarko basin ranks second with 19 ultra deep wells of which 12 were completed as gas wells. For the U.S. as a whole, 27 of these 52 ultra deep wells were completed as gas or oil wells (producing at any depth), and based on a set of 48 ultra deep dry holes (after subtracting four abandoned, suspended, or injection wells from the original 52 ultra deep wells), a historic success ratio of more than 50 percent has been achieved. Exxon holds the record as operator for the largest number of ultra deep wells in the U.S. with 12; ten of these wells were drilled in the Permian basin.

Twenty-six of the 52 ultra deep wells reported a producing formation. Of these, six wells were reported as producing from the Ordovician Ellenburger Formation of the Permian basin, six

**Table 1.** Summary data for wells drilled deeper than 25,000 feet by province/basin in the U.S.

[Con., Concepts; OK, Oklahoma; no., number; Inj., injection; prod., producing; Off., Offshore; TD, total depth of well; —, no data; GHK and LLE are company names]

Basin/province	No. wells by completion (gas-oil-dry)	Dominant rock units at TD (no. wells)	Important prod. unit (no. wells)	Representative fields (no. wells)	Wildcat wells	Deepest wells (ft)	Operators (no. wells)	Completion (no. wells)
Anadarko	12-0-7	Hunton (4) Arbuckle (3) Sylvan (6)	Hunton (5) Morrow (2) Springer (1) Arbuckle (1) Atoka (1)	Mayfield (7) Mills Ranch (3) Elk City (2)	3 (dry)	31,441 30,050	GHK (3) Chevron (3) Exxon (2) Mesa (2) Union (2)	1970's (7) 1980's (8) 1990's (4)
Arkansas/N. Louisiana	0-0-1	Cotton Valley (1)	—	—	1 (dry)	25,015	SOHIO (1)	1980's (1)
Chautauqua Platform	0-0-1	—	—	Adair (1-Inj.)	—	30,835	Econ Con. (1)	1970's (1)
Permian	10-4-7	Ellenburger (15) Granite (2)	Ellenburger (6) Permian (5) Leonardian (2) Wolfcampian (3)	McComb (5)	4 (dry)	29,670	Exxon (10)	Pre 1970's (2) 1970's (3) 1980's (12) 1990's (4)
Florida-Atlantic Off.	0-0-4	Pliocene (4)	—	Garden Banks Block (3)	1 (dry)	28,600	Shell (2) Amerada (1) Conoco (1)	1990's (4)
Gulf Coast	1-0-3	Cotton Valley (1) Smackover (1) Tuscaloosa (1)	Cotton Valley (1)	Bogalusa (1)	3 (dry)	25,703	Placid (2) Martin (1) LLE (1)	1970's (3) 1980's (1)
Green River Basin	0-0-1	Mississippian (1)	—	—	1 (dry)	25,764	Williams (1)	1980's (1)
S. OK Foldbelt	0-0-1	Arbuckle (1)	—	—	1 (dry)	25,726	Getty (1)	1980's (1)

<sup>a</sup> Data taken from PI-Dwights WHCS file updated through December, 1998 (IHS Energy Group, 1998).

wells were reported as producing from Permian reservoirs of the Permian basin (three in the Wolfcampian, two in the Leonardian, and one in the Guadalupian), and five wells were reported as producing from the Hunton Group of the Anadarko basin.

## Total Deep Wells by Completion Classification

Table 2 summarizes the final well classification by depth interval for all 20,715 wells in the PI-Dwights WHCS database drilled 15,000 feet (4,572 m) or deeper. Depths in table 2 are total well depths, and production may be at any depth, above or below 15,000 feet (4,572 m). Gas wells account for nearly 75 percent of producing wells with total depths below 15,000 feet (4,572 m). More gas wells (8,600) occur than dry holes (8,414), although Dyman and others (1990; 1993) reported more dry holes (7,090) than gas wells (6,347) based on 1988 WHCS data. Gas wells (8,600) are three times more abundant than oil wells (2,829). Of the 20,715 deep wells drilled, 1,676 wells have total depths exceeding 20,000 feet (6,096 m). This figure represents an increase of 234 wells since 1988 when 1,442 wells exceeded 20,000 feet (6,096 m). Of these 1,676 wells, 974 are producing wells, of which 847 (87 percent of producing wells) are producing gas at any depth. This is up slightly from 86 percent based on 1988 data (Dyman and others, 1990; 1993). The ratio of gas producing wells to total producing wells increases with increasing total depth of well.

## Deep Producing Wells by Final Well Classification

Table 3 summarizes the final well classification by depth interval for 5,119 wells in the PI-Dwights WHCS file that produce oil or gas from the formation encountered at total depth. These 5,119 wells represent a 42 percent increase based on 1988 data, when 2,981 wells were reported by Dyman and others (1990; 1993) as producing from the formation at total depth. Based on data through 1998, gas wells continue to outnumber oil wells for every depth interval. The percent of gas wells to total producing wells ranges from 73 percent in the 15,000 to 16,000 foot interval (4,572 to 4,877 m interval) to 100 percent in both the 25,000 to 26,000 foot interval (7,620 to 7,925 m interval) and the 26,000 to 27,000 foot interval (7,925 to 8,230 m interval). For all depths together, gas wells make up nearly 78 percent of the deep wells producing from formations encountered at total depth. This is the same percent reported by Dyman and others (1990; 1993) for deep well data through 1988.

## Deep Producing Wells by Petroleum Region

Table 4 summarizes deep producing wells from PI-Dwights WHCS by depth interval and geographic region. Of the six regions with deep productive wells, the onshore Gulf Coast region includes the greatest number of deep producing wells (2,496). This represents an increase of 601 wells from 1988 data when 1,895 deep producing wells were reported for the Gulf Coast. The Rocky Mountain region includes 298 deep

producing wells, up from 265 in 1988. The U.S. Federal Offshore region includes 1,097 deep producing wells. For most depth intervals below 15,000 feet (4,572 m), gas producing wells form the majority of deep producers. For all depths together, the Rocky Mountain and California-Alaska regions have the smallest percentage (34 and 8 percent respectively) of deep gas wells to total producing wells. Deep oil production in some Rocky Mountain basins such as the Powder River and Uinta basins is an important factor in the regional resource base. The deepest oil producing wells in California are in Ventura field in the Ventura basin and Yowlumne field in the San Joaquin basin. Production ranges in depth from 15,000 to 22,000 feet (4,572 to 6,706 m). The deepest producing wells in the Rocky Mountain region are gas producers in the Wind River basin at Madden field in north-central Wyoming.

The deepest gas producing wells in the Gulf Coast onshore region are in Smackover, Norphlet, and Tuscaloosa reservoirs at fields such as Chunchula in southern Alabama (about 18,000 feet), False River in southern Louisiana (about 19,000–21,000 feet—5,791–6,401 m), and Thomasville in southern Mississippi (about 20,000–21,000 feet—6,096–6,401 m). The deepest gas well currently reported by PI-Dwights WHCS in the Gulf Coast onshore region is from a Cotton Valley Formation well at Bogalusa field in southern Louisiana at a depth of 25,415 feet (7,746 m). The deepest offshore gas wells are located in Mobile Blocks 8 and 9 and produce gas from Smackover, Norphlet, and Pleistocene(?) reservoirs at depths ranging from about 15,000 to 22,000 feet. Only eastern U.S. basins including the Appalachian and Michigan basins are not represented in table 4.

## Deep Producing Wells by Decade of Completion

Table 5 contains well summaries from PI-Dwights WHCS data files illustrating deep producing wells for year of completion, in 10-year increments by depth. The 1960's decade was the first to show significant deep production (125 deep producing wells were completed). Only eight deep producing wells were completed prior to 1960. Deep producing well completions subsequently peaked in the deep drilling boom of the early 1980's (1,650 deep producing completions). For all years together, nearly 90 percent of the wells that are classed as producers below 20,000 feet (6,096 m) are gas producers. For each decade through the 1980's, the ratio of deep gas producing wells to total producing wells increased with depth to a peak of 83 percent in the 1980's. During the 1990's, an increase in the number of completed oil producing wells resulted in a decrease in the ratio to 75 percent.

The decade of the 1980's had the greatest number of ultra deep completions (>25,000 feet—7,620 m deep) for all regions with 24, but all of these wells were completed during 1980–1985 before the industry downturn of the late 1980's.

## Summary

Deep wells are widely distributed throughout many basins in the U.S. Twenty thousand seven hundred fifteen wells have

4 **Table 2.** Total deep wells by depth interval for U.S. based on final completion classification<sup>a</sup>.

[Dry, dry holes; Oil, oil producing wells; Gas, gas producing wells; Mul, wells producing from multiple horizons, either oil or gas; Oil-gas, oil and gas producing wells; Prod. total, total producing wells; Prod. gas, wells from gas and multiple gas columns together]

Depth <sup>b</sup>	Final well classification							Total wells	Prod. total <sup>d</sup>	Prod. gas	Total prod. wells/ total wells (%)	Total gas wells/ total prod. wells (%)
	Misc <sup>c</sup>	Dry	Oil	Gas	-----Producing wells-----							
					Oil mul	Gas mul	Oil- Gas					
15-16	270	3,072	1,249	2,905	140	171	49	7,856	4,514	3,076	57	68
16-17	203	2,199	621	1,952	69	119	21	5,184	2,782	2,071	54	74
17-18	125	1,279	354	1,302	26	61	5	3,152	1,748	1,363	55	78
18-19	72	832	176	768	5	21	4	1,878	974	789	52	81
19-20	43	396	72	426	2	29	1	969	530	455	55	86
20-21	24	268	63	279	2	17	2	655	363	296	55	82
21-22	22	159	29	229	0	17	1	457	276	246	60	89
22-23	20	111	15	213	0	6	0	365	234	219	64	94
23-24	4	39	2	46	0	0	0	91	52	46	57	88
24-25	1	36	0	17	0	0	0	54	18	17	33	94
25-26	1	15	1	14	0	0	0	31	16	14	52	88
26-27	1	3	2	3	0	0	0	9	6	3	67	50
27-28	0	0	0	2	0	0	0	2	2	2	100	100
28-29	1	2	1	0	0	0	0	4	2	0	50	0
29-30	0	3	0	2	0	0	0	5	2	2	40	100
30-31	1	0	0	1	0	0	0	2	2	1	100	50
31-32	0	0	0	1	0	0	0	1	1	1	100	100
Totals	788	8,414	2,585	8,160	244	441	83	20,715	11,522	8,600	56	75

<sup>a</sup> Data taken from PI-Dwights WHCS file updated through December 1998 (IHS Energy Group, 1998).

<sup>b</sup> Depth interval in thousands of feet.

<sup>c</sup> Miscellaneous wells include those with unknown final completion classification, sulfur wells, suspended wells, dry development wells, injection wells, and drilled and abandoned wells.

<sup>d</sup> Producing wells may be producing at any depth.

**Table 3.** Total deep producing wells by depth interval in U.S. based on final completion classification<sup>a</sup>.

[Oil, oil producing wells; Gas, gas producing wells; mul, wells producing from multiple horizons, either gas or oil; Oil-gas, oil and gas producing wells. Total gas, gas and multiple gas column wells]

Depth (X1,000 ft)	Final well classification								
	Oil	Gas	Oil mul	Gas mul	Misc wells <sup>b</sup>	Oil- gas	Total gas	Total wells	% gas <sup>c</sup>
15-16	522	1,501	28	47	4	17	1,548	2,119	73
16-17	244	924	11	40	4	7	964	1,230	78
17-18	130	563	7	11	8	2	574	721	80
18-19	66	338	0	9	2	3	347	418	83
19-20	27	199	1	11	1	0	210	239	88
20-21	18	115	0	1	8	0	116	142	82
21-22	7	86	0	1	2	0	87	96	91
22-23	2	119	0	0	3	0	119	124	96
23-24	0	14	0	0	3	0	14	17	82
24-25	0	4	0	0	1	0	4	5	80
25-26	0	7	0	0	0	0	7	7	100
26-27	0	1	0	0	0	0	1	1	100
27-28	0	0	0	0	0	0	0	0	
28-29	0	0	0	0	0	0	0	0	
Total	1,016	3,871	47	120	36	29	3,991	5,119	

<sup>a</sup> Data taken from PI-Dwights WHCS file updated through December 1998 (IHS Energy Group, 1998). Only includes wells having producing formation same as formation at total depth.

<sup>b</sup> Includes miscellaneous wells, injection wells, and wells with no designation.

<sup>c</sup> % gas equals percent total producing wells completed as gas wells (gas and gas mul columns combined).

**6 Table 4.** Numbers of deep producing wells by depth interval in U.S. by region<sup>a</sup>.

[Depth intervals in thousands of feet where 15= interval of 15,000 to 16,000 ft. Total number of producing wells for each depth interval is on left and number of gas producing wells is on right]

Depth interval..... Region	15	16	17	18	19	20	21	22	23	24	25	26	Total
Rocky Mountains	143-39	79-20	41-13	21-16	8-7	6-6							298-101
Midcontinent	239-214	138-134	125-122	79-77	28-26	14-14	6-6	4-4	1-1	3-3	1-1	1-1	639-603
Permian basin	109-100	56-43	73-63	35-32	47-38	41-32	48-46	103-100	8-5	2-1	5-5	0-0	527-465
Gulf Coast (onshore)	1,095-829	638-522	311-247	216-172	122-105	69-57	29-27	10-8	5-5		1-1		2,496-1,973
California-Alaska	31-3	17-1	8-0	3-0	1-1	0-0	2-0	0-0					62-5
Federal Offshore	502-316	302-204	163-118	64-41	33-22	12-6	11-7	7-7	3-3				1,097-724
Total	2,119-1,501	1,230-924	721-563	418-338	239-199	142-115	96-86	124-119	17-14	5-4	7-7	1-1	5,119-3,871 <sup>b</sup>

<sup>a</sup> Data taken from PI-Dwights WHCS file updated through December 1998 (IHS Energy Group, 1998). Only includes wells with producing formation same as formation at total depth (total= 5,119 wells).

<sup>b</sup> Total number of gas producing wells does not include 120 wells from multiple producing formations.

**Table 5.** Total deep producing wells by depth interval in U.S. by decade of completion<sup>a</sup>.

[Data for 1980's decade incomplete because PI-WHCS available only through 1988. Data for 1990's decade only through December 1998 (IHS Energy Group, 1998). First number represents total producing wells for that depth interval and decade; second number (following dash) represents wells producing gas for that depth interval]

Depth interval (X1,000 ft)	1930	1940	1950	1960	1970	1980-88	1989-98
15-16		1-0	5-5	61-21	394-260	678-534	708-506
16-17			1-1	14-9	319-224	365-281	376-307
17-18			1-1	9-3	152-106	233-200	201-156
18-19				1-1	108-90	157-137	99-76
19-20				1-0	67-59	99-96	53-38
20-21				13-5	45-38	44-42	24-16
21-22				9-8	25-23	44-44	13-7
22-23				17-17	76-74	17-16	9-9
23-24					6-6	6-6	3-3
24-25					3-2	1-1	1-1
25-26					1-1	6-6	
26-27					2-1		
27-28							
Total		1-0	7-7	125-64	1,198-884	1,650-1,363	1,487-1,113
Grand Total							4,468-3,431

<sup>a</sup> For columns through 1988, data taken from PI-WHCS file updated through February 1988 (Petroleum Information Corp., 1988). This data set does not include 292 deep producing wells with unlisted well completion year. For column 1989-98, data taken from PI-Dwights WHCS file updated from January 1989 through December 1998. Only includes wells having producing formation same as formation at total depth. Data for 651 wells completed from March through December 1988 not included.

been drilled deeper than 15,000 feet (4,572 m) in the U.S. since the first deep well was drilled in 1920, according to data in PI-Dwights WHCS data files through December 1998. Of these 20,715 wells, 11,522 wells are classed as producing wells that could be producing oil and (or) gas at any depth (above or below 15,000 feet—4,572 m). Nearly as many gas wells exist as dry holes; gas wells (8,600) are more than three times more abundant than oil wells (2,829). In the PI-Dwights WHCS files, 1,676 wells have a total depth greater than 20,000 feet (6,096 m).

Of the 11,522 producing wells in PI-Dwights, 5,119 wells have a formation at total depth equal to the producing formation. These wells represent a minimum number that are producing oil and gas below 15,000 feet (4,572 m). For all depths together, gas wells make up nearly 78 percent of the deep wells producing from formations encountered at total depth. Deep producing wells are distributed in six regions of the U.S.: Rocky Mountains, Midcontinent, Permian basin, Gulf Coast onshore, California-Alaska, and the Federal Offshore. Of these six regions, the onshore Gulf Coast region includes the greatest number of

deep producing wells with 2,496 wells, followed by the Federal Offshore region with 1,097 wells.

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