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Waterflooding of Oilfields in Wyoming to 1968

UNITED STATES DEPARTMENT OF THE INTERIOR

Report of Investigations 7469

Waterflooding of Oilfields in Wyoming to 1968

By Paul Biggs and Charles A. Koch

UNITED STATES DEPARTMENT OF THE INTERIOR
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WATERFLOODING OF OILFIELDS IN WYOMING TO 1968

by

Paul Biggs[1] and Charles A. Koch[2]

ABSTRACT

This Bureau of Mines report provides information on 138 waterflood projects in Wyoming. Injection was in 25 producing zones and 65 fields. Specific data presented include field location, discovery and development, water supply and injection, oil and water production, estimates of oil in place, and oil recoveries by primary and secondary methods.

The 138 projects studied will, if successful, recover about 800 million barrels of secondary oil. Almost all of the injection water is from deep water wells.

INTRODUCTION

This Bureau of Mines study contains individual reports on 65 Wyoming oilfields (fig. 1) that encompass 138 waterflood projects. Significant information sought was (1) the amount and source of water needed for waterflooding and (2) the oil to be recovered by waterflooding. All water-injection projects active before 1968 are covered in this report. The overall objective is to provide Government and industry with a detailed résumé of waterflooding in an area on which little such information has been published.

Bureau of Mines Bulletin 582 (2)[3/] was used freely in developing data for the field reports.

1/ Project coordinator.

2/ Petroleum engineer.

Both authors are with the Mineral Resources Field Office, Bureau of Mines, U. S. Department of the Interior, Laramie, Wyo.

3/ Underlined numbers in parentheses refer to items in the list of references at the end of this report.

In several field reports that follow, the term "unit" refers to formal agreements between operators and royalty owners approved by the U.S. Geological Survey and/or the Wyoming Oil and Gas Conservation Commission. The term "project" usually refers to single ownership or informal agreements, but in some instances project may be used in place of unit. All water injection programs are projects.

Oil production and recovery estimates were developed from the public records of the Wyoming Oil and Gas Conservation Commission. In some cases the records did not mention recovery. Thus, for some pressure maintenance projects, no estimates of oil recovery were given. Oil recovery estimates from public records may not be valid after an injection project has been in operation for some time.

The volumetric method was used to estimate original oil in place in each reservoir. For barrels of stock tank (surface) oil, the estimate was obtained by inserting data in the following equation:

$$\text{Stock tank oil} = \frac{7{,}758\ Ah\ \phi\ (1-SW)}{Bo}$$

In the equation, 7,758 barrels is the volume of 1 acre-foot; A is the productive area expressed in acres; h is the average net pay thickness expressed in feet; ϕ is the average porosity as a fraction of bulk; Sw is the interstitial water as a fraction of the pore volume; and Bo is the original formation volume factor expressed in reservoir barrels per stock tank barrel. In some instances part of the data had to be surmised. Data cutoff date was January 1, 1968.

Basic data for volumetric determinations and water requirements were obtained or derived from the Wyoming Oil and Gas Conservation records.

Formation names used in the field reports are those commonly employed by industry personnel at the time the wells were drilled and are intended solely to aid in identifying projects.

The well status or number of wells shown on the maps are only for the date shown. Well count is extremely flexible, and seldom will the number of wells conform on two different dates.

The study on water requirements for secondary recovery was made for the Interior Missouri River Basin Field Committee.

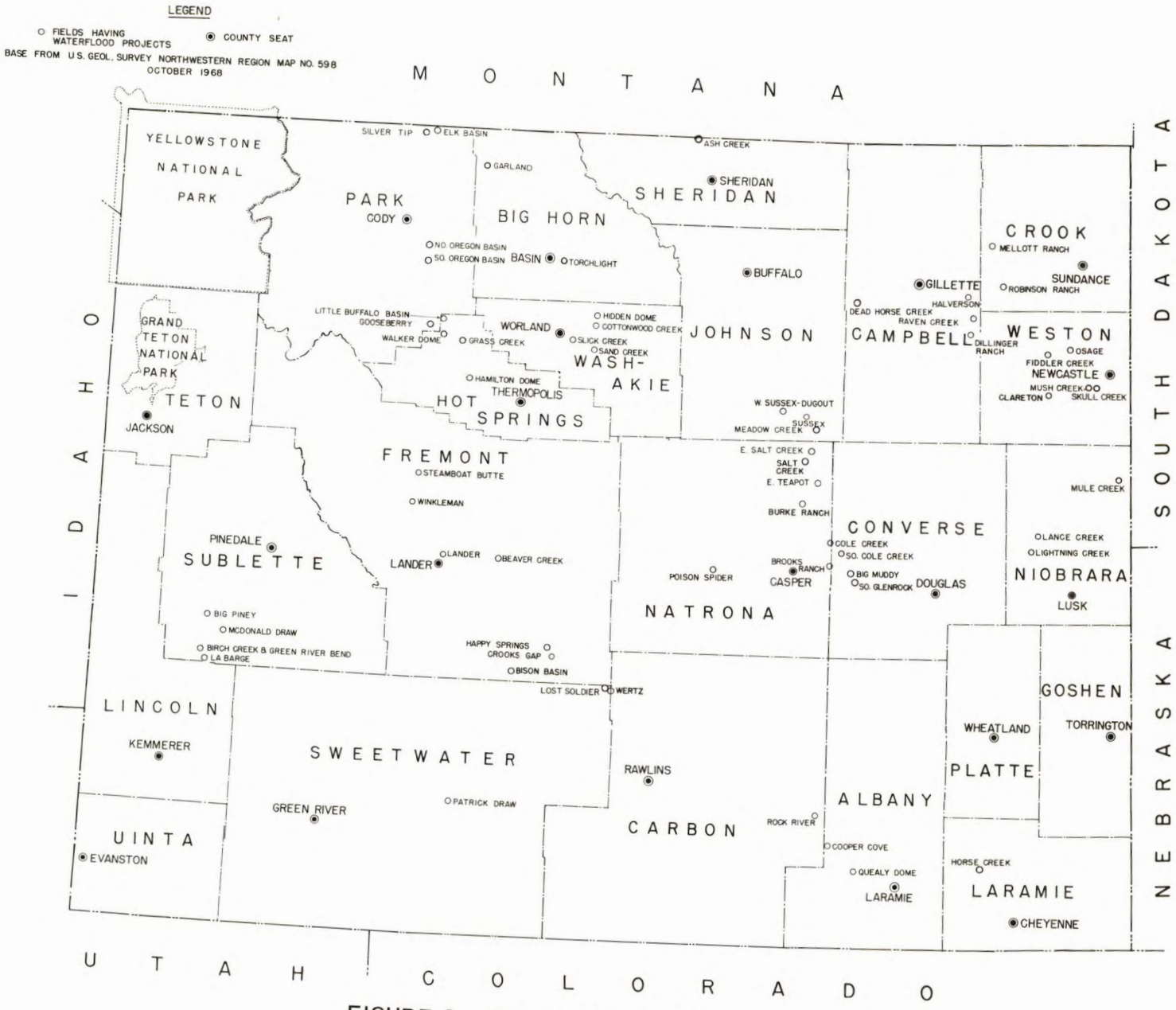


FIGURE 1. - Wyoming Waterflood Projects.

ACKNOWLEDGMENTS

The authors are grateful to Donald B. Basko, supervisor of the Wyoming Oil and Gas Conservation Commission, and to former Commission staff members John C. Lannan and Leo Kozola, for their help and cooperation in obtaining and verifying data. Thanks also are due the oil companies that granted Bureau engineers access to their projects.

WATER SUPPLY

About 100 years ago Wyoming was a part of the "Great American Desert"; only 30 or 40 perennial streams or rivers exist within the State. The lack of abundant surface water caused oil well operators to drill water wells for waterflooding supply. Most of the supply wells are completed in saline zones deeper than the oil zones.

The Madison Formation of Mississippian age was the source of about 75 percent of the water injected in Wyoming in 1967. One of the best water wells was the No. 2 Madison, in the SW1/4 sec 26, T 40 N, R 79 W, in the Salt Creek field. The well was completed for an initial open flow of 325,000 barrels of water per day from the interval from 4,675 to 4,889 feet. Temperature of the water at the surface was 186° F. Seven Madison water wells in the Salt Creek field were supplying daily about 350,000 barrels of water for injection in December 1967.

The Shiloh water system (fig. 2) is the most elaborate floodwater supply arrangement in the State. The system serves the projects in the Sussex-Meadow Creek area. Initially the two Madison water wells at the west end of the system supplied all the water. Late in 1966 the two Madison wells at the eastern end were added to the system.

Produced water is used to supplement the water supply in many cases. A few projects have shallow potable water supply wells, and two small projects purchase water from city water systems.

WATERFLOOD PROJECTS

Each of the individual oilfield reports contains the location, structure, discovery well and date, comments on field development, unitization, size of project(s), start of flooding, and status of operations and oil recovery as of December 31, 1967. Maps are included showing some of the fields or projects.

Four general tabulations concerning the projects are presented. Table 1 gives reservoir data by project. Table 2 contains estimates of oil in place and recoveries anticipated. Table 3 lists active

wells as of January 1, 1968, water injection and requirements, and oil and water production for December 1967. Oil production before and after water injection started is given in table 4.

Ash Creek

Ash Creek field (fig. 3) was discovered on May 19, 1952, upon completion of the No. 1 Elsie Barry well in the NW1/4NW1/4SW1/4 sec 24, T 58 N, R 84 W, Sheridan County, Wyo. Initial daily production by pumping was 174 barrels of 33.7° API gravity oil and 55 barrels of water. Production was from the Shannon sand (locally called Ash Creek sand) at depth intervals of 4,715 to 4,721 and 4,746 to 4,750 feet. The top of the Shannon sand was logged at 4,714 feet.

The producing interval has an average permeability of 275 millidarcys and an average porosity of 22 percent. The oil is reported to be undersaturated having a gas-oil ratio of less than 25 cubic feet per barrel.

In a deep-test well in the NE1/4 sec 23, the reported depth, in feet, to the top of formations is as follows: Claggett, 3,698; Eagle, 4,344; Telegraph Creek, 4,550; Shannon, 4,886; Cloverly, 7,628; Sundance, 7,890; Red Beds, 7,900; Tensleep, 9,140; Amsden, 9,259; Madison, 9,493; and Big Horn, 10,580.

Thirty oil wells were completed in the field, but two of the wells (in Montana) were noncommercial completions. Average initial daily oil production was 178 barrels. Seven wells reported initial daily water production ranging from 2 to 130 barrels. Initial reservoir producing mechanism was a limited water drive and fluid expansion. J. Ray McDermott & Co., Inc., unitized the entire field in September 1964. The Shannon sand reservoir covers about 980 acres, and average pay thickness is 17 feet.

Water injection started in September 1964 with water from the Parkman sand (±4,200 feet). The flood was expanded into a line drive from the north and south sides in January 1965. During December 1967 average daily production was 775 barrels of oil and 579 barrels of water. Daily water injection averaged 1,830 barrels at 1,240 psi. On January 1, 1968, the project contained 18 producing wells, 15 injection wells, two water supply wells, and five shut-in wells.

Cumulative oil production to the start of injection was 4,524,000 barrels or 28.8 percent of the estimated original oil in place. Production after injection to January 1, 1968, was 810,000 barrels. Production attributed to water injection was estimated to be 280,000 barrels. Cumulative water injection was 1,976,000 barrels.

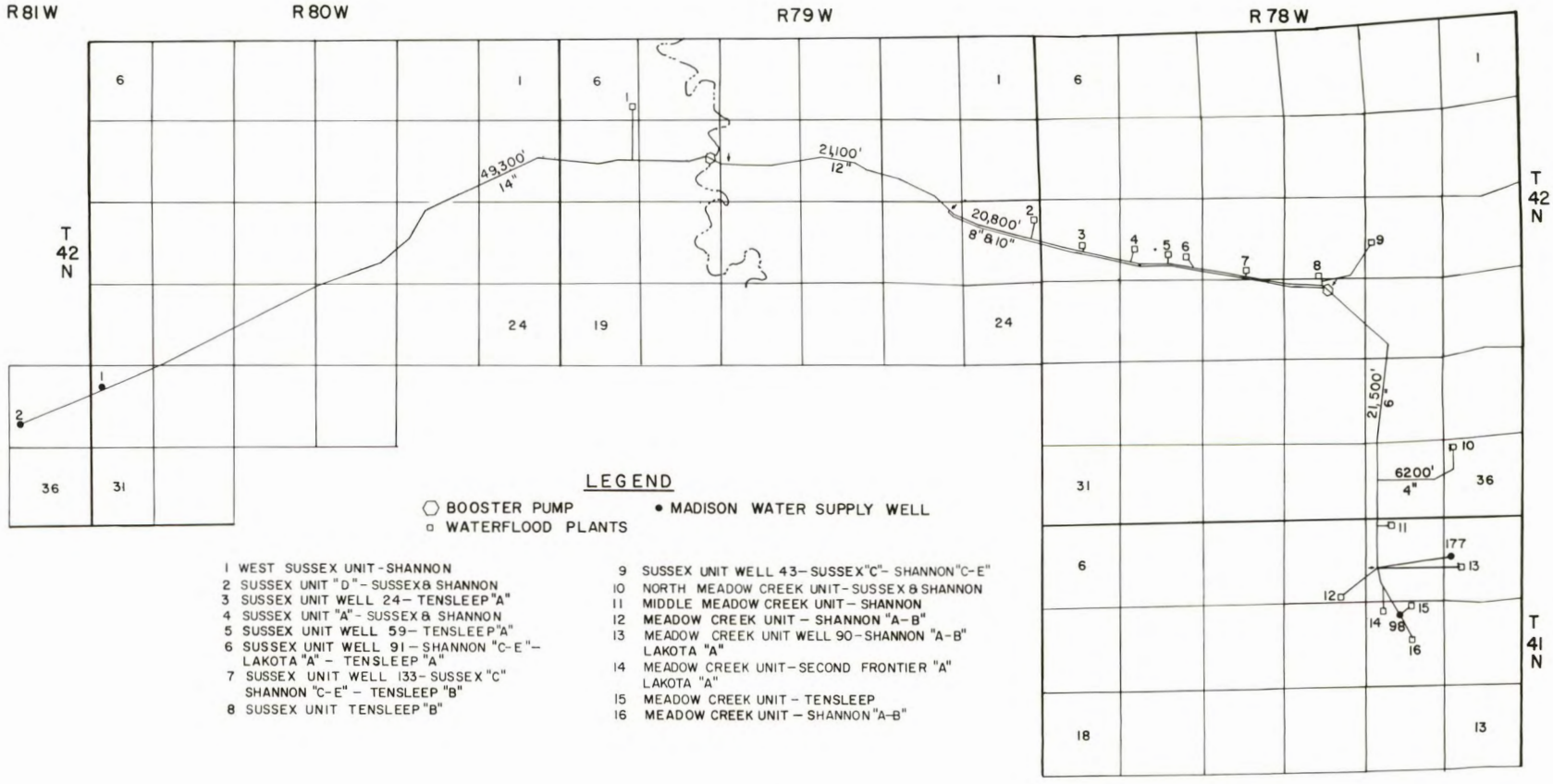


FIGURE 2. - Shiloh Water Supply System, Johnson County, Wyo.

TABLE 1. - Reservoir data, Wyoming waterflood projects[1/]

Project	Productive area, acres	Average pay thickness, ft	Reservoir volume, acre ft[2/]	Average porosity, pct	Average permeability, md	Oil gravity, °API[3/]
Ash Creek - Shannon	980	17	16,700	22	275	35
Beaver Creek - Second Cody	977	24	23,400	17	81	38
Beaver Creek - Madison	1,260	150	189,000	9	12	42
Big Muddy - Wall Creek	3,560	38	135,300	18	31	36
Big Muddy - Dakota	1,941	10	19,400	14	65	36
Big Muddy - Dakota, East	520	11	6,000	14	31	35
Big Muddy - Dakota, South	200	5	1,000	14	25	35
Big Muddy - Wall Creek, South	507	20	10,100	19	70	36
Big Piney - "P" sand	878	16	14,000	21	113	44
Birch Creek - Birch Creek	600	31	18,600	19	34	47
Bison Basin - Frontier[4/]	270	75	20,200	23	67	16
Brooks Ranch - Second Frontier	2,880	8	23,000	17	3	38
Burke Ranch - Dakota	1,282	12	15,400	13	32	35
Clareton Projects - True	22,000	10	220,000	7	14	40
Cole Creek - Dakota "A"	995	10	10,000	14	43	36
Cole Creek - Shannon	1,653	17	28,100	19	56	36
Cole Creek, South - Lakota	470	20	9,400	15	40	35
Cooper Cove - Muddy "D"	480	10	4,800	14	32	34
Cottonwood Creek - Phosphoria	14,200	20	284,000	10	16	30
Crooks Gap - Frontier	70	30	2,100	18	24	- -
Crooks Gap - Lakota	320	38	12,200	15	150	41
Crooks Gap - Muddy	280	11	3,100	19	- -	39
Dead Horse Creek - North Block	2,100	15	31,500	17	33	37
Dead Horse Creek - South Block	2,200	24	52,800	18	50	39
Dead Horse Creek - Caballo	2,340	10	23,400	15	33	39
Dillinger Ranch - Minnelusa	1,200	30	36,000	17	100	35
Elk Basin - Frontier	1,280	40	51,200	26	- -	43
Elk Basin - Madison	5,097	336	1,712,600	12	20	28
Elk Basin, South - Tensleep	520	77	40,000	14	119	28
Fiddler Creek	2,888	8	23,100	24	30	40
Fiddler Creek, West	5,207	6	31,200	23	33	40
Garland - Embar	1,303	60	78,200	24	- -	22
Garland - Tensleep	1,508	59	89,000	14	53	22

TABLE 1. - Reservoir data, Wyoming waterflood projects[1] --Continued

Project	Productive area, acres	Average pay thickness, ft	Reservoir volume, acre ft[2]	Average porosity, pct	Average permeability, md	Oil gravity, °API[3]
Glenrock, South - Dakota "A"	1,284	28	36,000	14	75	35
Glenrock, South - Dakota "B"	4,249	27	114,700	14	106	37
Glenrock, South - Muddy "A"	320	6	1,900	20	200	38
Glenrock, South - Lower Muddy "B"	1,129	17	19,200	13	84	38
Glenrock, South - Lower Muddy "C"	2,253	12	27,000	15	68	38
Glenrock, South - Upper Muddy "A-B"	4,838	6	29,000	20	255	38
Gooseberry - Tensleep	277	50	13,800	12	23	23
Grass Creek - Curtis	5,800	20	116,000	17	120	27
Grass Creek - Darwin	460	19	8,700	7	- -	25
Grass Creek - Frontier	1,660	55	91,300	22	35	40
Green River Bend - T-5 Almy	270	23	6,200	22	54	42
Green River Bend - Birch Creek	240	7	1,700	22	- -	- -
Halverson Ranch - Minnelusa	1,360	30	40,800	12	64	23
Hamilton Dome - Fourth Curtis[4]	240	14	3,400	15	20	20
Happy Springs - Frontier "A"	236	14	3,300	19	50	37
Hidden Dome - Frontier[3]	60	18	1,080	19	80	41
Horse Creek - Muddy	2,340	23	53,800	13	5	30
La Barge - Almy	935	61	57,000	25	- -	28
La Barge - Mesaverde	320	30	9,600	24	52	46
Lance Creek - OPC Sundance	958	26	24,900	21	223	42
Lance Creek - Basal Sundance	1,715	64	109,800	22	250	37
Lance Creek - First Sundance	455	25	11,400	11	- -	37
Lance Creek - Morrison	179	21	3,800	11	35	40
Lance Creek - Muddy	500	7	3,500	17	- -	42
Lander - Phosphoria	350	68	23,800	20	10	24
Lightning Creek - Newcastle[4]	600	6	3,600	21	- -	24
Little Buffalo Basin - Tensleep	1,840	28	51,500	10	74	21
Lost Soldier - Cambrian	670	94	63,000	12	18	35
Lost Soldier - Madison	709	188	133,300	13	137	35
Lost Soldier - Tensleep	1,193	250	298,300	10	10	35
McDonald Draw - M-9	200	12	2,400	22	34	42
McDonald Draw - M-13	350	10	3,500	22	7	42
McDonald Draw - M-20	480	16	7,700	18	52	30
McDonald Draw - M-42	260	10	2,600	17	40	- -
McDonald Draw - M-47	480	30	14,400	- -	- -	25
Meadow Creek - Second Frontier	964	20	19,300	12	13	40

TABLE 1. - Reservoir data, Wyoming waterflood projects[1/] --Continued

Project	Productive area, acres	Average pay thickness, ft	Reservoir volume, acre ft[2/]	Average porosity, pct	Average permeability, md	Oil gravity, °API[3/]
Meadow Creek - Lakota "A"	1,230	15	18,500	15	86	41
Meadow Creek - Lakota "B"	350	19	6,600	15	- -	39
Meadow Creek - Shannon "A-B"	3,759	16	60,100	17	29	37
Meadow Creek - Tensleep "A"	2,918	17	49,600	13	3	30
Meadow Creek, North - Shannon	1,214	13	15,800	16	20	41
Meadow Creek, North - Sussex	962	32	30,800	20	22	41
Mellott Ranch - Minnelusa "B"	700	25	17,500	16	1,850	27
Mule Creek - Minnelusa	120	23	2,800	12	4	27
Mush Creek - CRA	1,400	8	11,200	17	193	39
Mush Creek - J. G. Dyer[4/]	160	8	1,300	12	33	41
Mush Creek - Texaco-Thorson	1,680	6	10,100	17	45	41
Mush Creek, West - Coronado	640	8	5,100	12	- -	39
Mush Creek, West - Thorson	1,507	13	19,600	12	20	39
Mush Creek, West - Western Plains Petroleum, Inc.[4/]	210	11	2,300	12	- -	39
Mush Creek, West - Oil and Realty Development, Inc.[4/]	303	9	2,700	12	- -	39
Oregon Basin - Embar	7,670	38	291,500	14	10	22
Oregon Basin - Tensleep	7,640	60	458,400	16	150	21
Osage - Deep	960	10	9,600	23	428	39
Osage - Shallow	1,240	8	9,900	22	55	39
Osage - Jones	40	8	300	22	- -	39
Osage - International	149	7	1,000	24	125	39
Osage - Juniper, West	1,600	8	12,800	17	55	39
Osage - Juniper	2,400	5	12,000	- -	- -	39
Osage - Lake[3/]	600	7	4,200	- -	- -	39
Patrick Draw - Arch	5,965	21	121,300	21	136	43
Patrick Draw - Monell	7,500	21	157,500	20	36	43
Poison Spider - Sundance	120	30	3,600	18	241	22
Quealy Dome - Tensleep	260	90	23,400	15	105	25
Raven Creek - Minnelusa	4,510	38	171,400	15	92	32
Robinson Ranch - Minnelusa	550	29	15,900	17	320	28
Rock River - Lakota	- - -	- -	- - -	- -	- -	- -
Rock River - Muddy[5/]	1,071	15	16,100	19	- -	36

TABLE 1. - Reservoir data, Wyoming waterflood projects[1/] --Continued

Project	Productive area, acres	Average pay thickness, ft	Reservoir volume, acre ft[2/]	Average porosity, pct	Average permeability, md	Oil gravity, °API[3/]
Salt Creek - Lakota	1,885	40	75,400	19	- -	33
Salt Creek - Second Sundance	1,935	10	19,300	16	15	36
Salt Creek - First Wall Creek	4,035	80	322,800	15	80	38
Salt Creek - Second Wall Creek	15,350	59	905,700	18	100	37
Salt Creek - Second Wall Creek South	6,100	25	152,500	18	30	37
Salt Creek, East - Lakota	400	27	10,800	16	- -	35
Salt Creek, East - Second Wall Creek	440	28	12,320	19	- -	37
Salt Creek, West - Second Wall Creek	491	12	5,900	21	40	32
Salt Creek, West - Fishtooth	257	15	3,900	22	95	40
Sand Creek - Third Frontier	684	30	20,500	17	41	46
Silver Tip - Frontier[4/]	240	17	4,100	13	- -	46
Skull Creek - McAlester	2,200	13	28,600	14	70	32
Skull Creek, East - Lynx Oil Corp.[4/]	- - -	- -	- - -	- -	- -	32
Slick Creek - Phosphoria	1,967	20	39,300	9	6	33
Steamboat Butte - Phosphoria	904	40	36,200	10	5	30
Steamboat Butte - Tensleep	1,270	200	254,000	13	30	21
Sussex - Lakota "A"	328	25	8,200	16	85	39
Sussex - Shannon "A"	368	14	5,200	17	34	40
Sussex - Shannon "C-E"	867	12	10,400	17	66	40
Sussex - Shannon "D"	377	38	14,300	16	89	40
Sussex - Sussex "A"	306	18	5,500	20	32	40
Sussex - Sussex "C"	453	26	11,800	20	66	40
Sussex - Sussex "D"	147	33	4,900	21	92	40
Sussex - Tensleep "A"	320	35	11,200	11	55	30
Sussex - Tensleep "B"	1,092	103	112,500	11	78	31
Sussex, West - Shannon "A-B"	1,738	24	41,700	20	121	40
Sussex, West-Dugout - Shannon	1,010	17	17,200	20	100	40
Teapot, East - Upper Shannon	722	17	12,300	27	261	40
Torchlight - Madison	685	67	45,900	21	34	23
Torchlight - Tensleep	291	23	6,700	17	204	34
Walker Dome - Torchlight[4/]	360	26	9,400	17	4	- -

TABLE 1. - Reservoir data, Wyoming waterflood projects[1/] --Continued

Project	Productive area, acres	Average pay thickness, ft	Reservoir volume, acre ft[2/]	Average porosity, pct	Average permeability, md	Oil gravity, °API[3/]
Wertz - Amsden	550	30	16,500	14	128	36
Wertz - Tensleep	1,150	150	172,500	11	23	35
Winkleman Dome - Phosphoria	1,414	54	76,400	14	13	25
Winkleman Dome - Tensleep	1,000	160	160,000	15	- -	25

1/ Unless otherwise noted, data are from Wyoming Oil and Gas Conservation Commission records.
2/ Figures are rounded to nearest hundred.
3/ Mostly from Bureau of Mines crude oil analyses records.
4/ Data assumed.
5/ Data for entire reservoir.

TABLE 2. - Original oil in place and recovery estimates, Wyoming waterflood projects[1/]

Project	Initial oil in place, thousand STB[2/]	Primary recovery estimate		Secondary recovery estimate[3/]		Ultimate recovery estimate	
		Oil in place, pct	Thousand STB	Oil in place, pct	Thousand STB	Oil in place, pct	Thousand STB
Ash Creek - Shannon	15,670	39	6,111	8	1,254	47	7,365
Beaver Creek - Second Cody	14,400	12	1,730	25	3,600	37	5,330
Beaver Creek - Madison	76,860	15	11,500	25	19,200	40	30,700
Big Muddy - Wall Creek	91,436	21	19,200	9	7,795	30	26,995
Big Muddy - Dakota	14,284	23	3,280	25	3,570	48	6,850
Big Muddy - Dakota, East	4,231	38	1,720	16	680	54	2,400
Big Muddy - Dakota, South	758	18	136	22	168	40	304
Big Muddy - Wall Creek, South	15,681	14	2,200	9	1,410	34	3,610
Big Piney - "P" sand	15,422	17	2,622	12	1,851	29	4,473
Birch Creek - Birch Creek	25,724	16	4,116	16	4,116	32	8,232
Bison Basin - Frontier	9,461	15	1,420	11	1,041	26	2,461
Brooks Ranch - Second Frontier	19,479	13	2,532	10	1,948	23	4,480
Burke Ranch - Dakota	11,425	28	3,200	20	2,280	48	5,480
Clareton Projects - True	100,320	15	15,048	12	12,038	27	27,086
Cole Creek - Dakota "A"	6,124	41	2,500	11	690	52	3,190
Cole Creek - Shannon	23,200	17	3,944	24	5,568	41	9,512
Cole Creek, South - Lakota	9,192	40	3,677	16	1,471	56	5,148
Cooper Cove - Muddy "D"	3,333	9	300	12	400	21	700
Cottonwood Creek - Phosphoria	182,109	9	16,390	2	3,460	11	20,030
Crooks Gap - Frontier	909	40	363	20	182	60	545
Crooks Gap - Lakota	5,000	30	1,500	20	1,000	50	2,500
Crooks Gap - Muddy	2,701	18	486	14	378	32	864
Dead Horse Creek - North Block	16,100	5	805	15	2,250	20	3,055
Dead Horse Creek - South Block	31,100	14	4,350	15	4,660	29	9,010
Dead Horse Creek - Caballo	10,120	12	1,215	5	507	17	1,722
Dillinger Ranch - Minnelusa	21,726	15	3,259	7	1,521	22	4,780
Elk Basin - Frontier	71,000	15	10,650	15	10,650	30	21,300
Elk Basin - Madison	1,240,000	25	310,000	9	111,600	34	421,600
Elk Basin, South - Tensleep	34,453	35	12,140	1	344	36	12,484
Fiddler Creek	25,911	14	3,750	25	6,436	39	10,186
Fiddler Creek, West	34,580	16	5,536	16	5,650	32	11,186

TABLE 2. - Original oil in place and recovery estimates, Wyoming waterflood projects[1/] --Continued

Project	Initial oil in place, thousand STB[2/]	Primary recovery estimate		Secondary recovery estimate[3/]		Ultimate recovery estimate	
		Oil in place, pct	Thousand STB	Oil in place, pct	Thousand STB	Oil in place, pct	Thousand STB
Garland - Embar	23,688	16	3,790	8	1,895	24	5,685
Garland - Tensleep	83,500	15	12,500	25	20,900	40	33,400
Glenrock, South - Dakota "A"	16,869	20	3,374	12	2,024	32	5,398
Glenrock, South - Dakota "B"	81,062	21	17,000	20	16,200	41	33,200
Glenrock, South - Muddy "A"	1,308	14	183	8	105	22	288
Glenrock, South - Lower Muddy "B"	14,140	32	4,550	10	1,360	42	5,910
Glenrock, South - Lower Muddy "C"	22,100	24	5,300	26	5,700	50	11,000
Glenrock, South - Upper Muddy "A-B"	27,978	18	5,040	26	7,260	44	12,300
Gooseberry - Tensleep	10,900	16	1,731	15	1,693	31	3,424
Grass Creek - Curtis	116,000	16	18,523	21	24,677	37	43,200
Grass Creek - Darwin	31,536	12	3,784	12	3,784	24	7,568
Grass Creek - Frontier	160,725	20	32,100	18	28,930	38	61,030
Green River Bend - T-5 Almy	8,788	20	1,758	20	1,758	40	3,516
Green River Bend - Birch Creek	1,700	20	340	20	340	40	680
Halverson Ranch - Minnelusa	15,765	7	1,069	7	1,069	14	2,138
Hamilton Dome - Fourth Curtis	2,639	16	422	16	422	32	844
Happy Springs - Frontier "A"	2,696	30	812	18	487	48	1,299
Hidden Dome - Frontier	1,013	18	182	18	182	36	364
Horse Creek - Muddy	27,000	16	4,249	8	2,126	24	6,375
La Barge - Almy	74,700	21	15,650	20	14,940	41	30,590
La Barge - Mesaverde	11,520	15	1,728	12	1,382	27	3,110
Lance Creek - OPC Sundance	21,550	28	6,040	28	6,040	56	12,080
Lance Creek - Basal Sundance	131,000	20	26,200	16	20,960	36	47,160
Lance Creek - First Sundance	6,177	20	1,235	12	741	32	1,976
Lance Creek - Morrison	2,298	25	575	2	46	27	621
Lance Creek - Muddy	3,868	20	774	10	387	30	1,161
Lander - Phosphoria	56,000	4	2,240	13	7,280	17	9,520
Lightning Creek - Newcastle	3,413	7	225	16	556	23	781
Little Buffalo Basin - Tensleep	180,000	14	25,200	7	12,600	21	37,800
Lost Soldier - Cambrian	50,000	32	15,939	13	6,561	45	22,500
Lost Soldier - Madison	112,500	25	28,150	9	9,700	34	37,850
Lost Soldier - Tensleep	190,000	38	72,176	16	30,400	54	102,576

TABLE 2. - Original oil in place and recovery estimates, Wyoming waterflood projects[1/] --Continued

Project	Initial oil in place, thousand STB[2/]	Primary recovery estimate		Secondary recovery estimate[3/]		Ultimate recovery estimate	
		Oil in place, pct	Thousand STB	Oil in place, pct	Thousand STB	Oil in place, pct	Thousand STB
McDonald Draw - M-9	2,400	17	401	3	80	20	481
McDonald Draw - M-13	3,930	17	655	3	131	20	786
McDonald Draw - M-20	4,602	20	920	10	460	30	1,380
McDonald Draw - M-42	1,150	20	230	10	115	30	345
McDonald Draw - M-47	5,609	17	953	3	168	20	1,121
Meadow Creek - Second Frontier	7,202	23	1,622	4	258	27	1,880
Meadow Creek - Lakota "A"	9,402	26	2,475	15	986	41	3,461
Meadow Creek - Lakota "B"	3,385	25	846	- -	- - -	25	846
Meadow Creek - Shannon "A-B"	36,823	13	4,591	11	4,011	24	8,602
Meadow Creek - Tensleep "A"	39,090	32	12,648	14	5,642	46	18,290
Meadow Creek, North - Shannon	9,784	19	1,860	23	2,250	42	4,110
Meadow Creek, North - Sussex	22,000	25	5,500	26	5,720	51	11,220
Mellott Ranch - Minnelusa "B"	13,333	6	800	8	960	14	1,760
Mule Creek - Minnelusa	2,170	40	868	30	651	70	1,519
Mush Creek - CRA	9,335	18	1,680	10	933	28	2,613
Mush Creek - J. G. Dyer	897	16	145	9	80	25	225
Mush Creek - Texaco-Thorson	5,662	28	1,589	13	736	41	2,325
Mush Creek, West - Coronado	597	15	90	8	56	23	146
Mush Creek, West - Thorson	12,655	15	1,898	8	1,012	23	2,910
Mush Creek, West - Western Plains Petroleum, Inc.	597	15	90	8	56	23	146
Mush Creek, West - Oil and Realty Development, Inc.	4,012	12	481	11	441	23	922
Oregon Basin - Embar	363,000	30	109,000	- -	- - -	30	109,000
Oregon Basin - Tensleep	492,000	22	108,000	- -	- - -	22	108,000
Osage - Deep	8,938	12	1,073	18	1,609	30	2,682
Osage - Shallow	9,236	10	93	12	1,108	22	1,201
Osage - Jones	298	20	60	25	75	45	135
Osage - International	1,490	20	298	30	447	50	745
Osage - Juniper, West	9,362	11	1,029	16	1,498	27	2,527
Osage - Juniper	11,172	9	1,005	14	1,564	23	2,569

TABLE 2. - Original oil in place and recovery estimates, Wyoming waterflood projects[1/] --Continued

Project	Initial oil in place, thousand STB[2/]	Primary recovery estimate		Secondary recovery estimate[3/]		Ultimate recovery estimate	
		Oil in place, pct	Thousand STB	Oil in place, pct	Thousand STB	Oil in place, pct	Thousand STB
Osage - Lake	4,468	10	447	18	804	28	1,251
Patrick Draw - Arch	91,947	18	16,557	17	15,400	35	31,957
Patrick Draw - Monell	133,112	18	23,960	9	11,980	27	35,940
Poison Spider - Sundance	3,062	46	1,417	7	217	53	1,634
Quealy Dome - Tensleep	21,300	25	5,325	- -	- - -	25	5,325
Raven Creek - Minnelusa	58,820	22	12,940	22	12,940	44	25,880
Robinson Ranch - Minnelusa	14,780	32	4,710	7	1,090	39	5,800
Rock River - Lakota	- - -	- -	- - -	- -	- - -	- -	- - -
Rock River - Muddy	- - -	- -	- - -	- -	- - -	- -	- - -
Salt Creek - Lakota	72,384	28	20,267	14	10,134	42	30,401
Salt Creek - Second Sundance	14,857	28	5,310	7	1,040	35	6,350
Salt Creek - First Wall Creek	206,000	28	57,600	12	24,700	40	82,300
Salt Creek - Second Wall Creek	687,000	26	178,500	22	151,000	48	329,500
Salt Creek - Second Wall Creek South-	108,750	25	27,000	17	18,000	42	45,000
Salt Creek, East - Lakota	7,336	30	2,201	20	1,467	50	3,668
Salt Creek, East - Second Wall Creek-	9,856	30	2,957	20	1,971	50	4,928
Salt Creek, West - Second Wall Creek-	5,050	25	1,273	9	432	34	1,705
Salt Creek, West - Fishtooth	2,126	6	127	5	104	11	231
Sand Creek - Third Frontier	10,400	13	1,300	15	1,560	28	2,860
Silver Tip - Frontier	3,488	20	698	- -	- - -	20	698
Skull Creek - McAlester	14,900	14	2,086	13	1,937	27	4,023
Skull Creek, East - Lynx Oil Corp.	- - -	- -	- - -	- -	- - -	- -	- - -
Slick Creek - Phosphoria	14,066	26	3,700	5	650	31	4,350
Steamboat Butte - Phosphoria	15,730	12	1,890	8	1,300	20	3,190
Steamboat Butte - Tensleep	296,670	21	62,300	- -	- - -	21	62,300
Sussex - Lakota "A"	7,290	21	1,577	9	656	30	2,233
Sussex - Shannon "A"	3,596	25	904	15	546	40	1,450
Sussex - Shannon "C-E"	7,148	12	857	12	857	24	1,714
Sussex - Shannon "D"	10,100	18	1,810	8	855	26	2,665
Sussex - Sussex "A"	5,216	16	843	20	1,055	36	1,898
Sussex - Sussex "C"	11,637	15	1,713	15	1,789	30	3,502
Sussex - Sussex "D"	4,786	17	818	7	312	24	1,130

TABLE 2. - Original oil in place and recovery estimates, Wyoming waterflood projects[1/] --Continued

Project	Initial oil in place, thousand STB[2/]	Primary recovery estimate		Secondary recovery estimate[3/]		Ultimate recovery estimate	
		Oil in place, pct	Thousand STB	Oil in place, pct	Thousand STB	Oil in place, pct	Thousand STB
Sussex - Tensleep "A"	9,660	35	3,345	34	3,244	69	6,589
Sussex - Tensleep "B"	80,540	10	7,921	32	25,758	42	33,679
Sussex, West - Shannon "A-B"	40,417	19	7,680	19	7,680	38	15,360
Sussex, West-Dugout - Shannon	27,880	19	5,300	19	5,300	38	10,600
Teapot, East - Upper Shannon	9,081	19	1,707	16	1,480	35	3,187
Torchlight - Madison	12,000	25	3,600	25	3,600	50	7,200
Torchlight - Tensleep	9,322	18	1,678	20	1,864	38	3,542
Walker Dome - Torchlight	8,965	14	1,250	8	700	22	1,950
Wertz - Amsden	13,000	40	5,200	11	1,400	51	6,600
Wertz - Tensleep	100,000	50	50,000	11	11,000	61	61,000
Winkleman Dome - Phosphoria	71,900	13	9,400	13	9,400	26	18,800
Winkleman Dome - Tensleep	131,390	25	32,847	16	21,022	42	53,869

1/ Obtained or calculated from records of the Wyoming Oil and Gas Commission.
2/ Stock tank barrels.
3/ Where known, oil recovery by "pressure maintenance" is shown in this column.

TABLE 3. - Wyoming waterflood project performance[1/]

Project	Active wells January 1968		Water injected to January 1, 1968, thousand bbl	Estimated total water requirements, thousand bbl	Production, avg daily, bbl (December 1967)		Water injection daily, bbl (December 1967)	Ratio of produced water to oil (December 1967)
	Input	Oil			Oil	Water		
Ash Creek - Shannon	15	18	1,976	34,122	775	579	1,830	0.75
Beaver Creek - Second Cody	7	27	10,634	30,925	833	2,888	11,940	3.47
Beaver Creek - Madison	6	20	23,485	131,964	6,650	6,500	18,500	.98
Big Muddy - Wall Creek	16	11	54,210	188,910	300	5,100	9,600	17.00
Big Muddy - Dakota	7	9	12,222	21,700	1,212	3,887	8,000	3.20
Big Muddy - Dakota, East	7	8	4,877	7,484	316	1,450	2,100	4.59
Big Muddy - Dakota, South	2	2	629	1,195	20	251	240	12.55
Big Muddy - Wall Creek, South	4	16	4,332	13,452	63	1,467	3,300	23.45
Big Piney - "P" sand	5	10	5,642	16,021	175	700	4,480	4.00
Birch Creek - Birch Creek	4	9	10,755	30,158	930	2,000	7,960	2.15
Bison Basin - Frontier	3	14	2,168	34,562	200	1,170	1,000	5.85
Brooks Ranch - Second Frontier	22	35	998	21,400	124	59	3,300	.48
Burke Ranch - Dakota	4	8	4,872	18,618	1,688	1,449	3,550	.86
Clareton Projects - True	34	28	31,846	101,270	348	845	5,660	2.94
Cole Creek - Dakota "A"	2	7	2,771	6,740	1,764	765	3,905	.43
Cole Creek - Shannon	11	10	10,759	45,564	755	2,660	4,580	3.52
Cole Creek, South - Lakota	2	5	1,840	8,500	244	1,331	660	5.46
Cooper Cove - Muddy "D"	3	5	116	3,670	177	826	640	4.66
Cottonwood Creek - Phosphoria	7	65	31,887	235,000	3,657	3,256	4,685	.89
Crooks Gap - Frontier	2	2	422	3,226	43	65	604	1.51
Crooks Gap - Lakota	1	6	5,061	9,960	238	4,982	5,144	20.90
Crooks Gap - Muddy	1	2	69	2,970	56	39	144	.70
Dead Horse Creek - North Block	5	13	1,147	41,544	311	59	537	.19
Dead Horse Creek - South Block	9	9	4,254	73,732	417	515	1,095	1.24
Dead Horse Creek - Caballo	7	7	3,690	27,300	317	74	1,690	.23
Dillinger Ranch - Minnelusa	4	12	481	25,000	1,422	27	912	.02
Elk Basin - Frontier	3	18	1,682	78,100	80	69	6,100	.86
Elk Basin - Madison	17	74	63,771	1,434,919	21,451	36,114	35,200	1.68
Elk Basin, South - Tensleep	1	9	5,977	41,314	1,259	3,076	5,264	2.44
Fiddler Creek	8	15	40,542	52,688	646	3,108	8,300	4.81
Fiddler Creek, West	20	38	46,186	66,753	1,475	11,673	21,546	7.90

TABLE 3. - Wyoming waterflood project performance[1/] --Continued

Project	Active wells January 1968		Water injected to January 1, 1968, thousand bbl	Estimated total water requirements, thousand bbl	Production avg daily, bbl (December 1967)		Water injection daily, bbl (December 1967)	Ratio of produced water to oil (December 1967)
	Input	Oil			Oil	Water		
Garland - Embar	5	34	507	26,020	816	391	1,545	0.48
Garland - Tensleep	3	37	11,065	82,139	2,523	2,900	2,250	1.15
Glenrock, South - Dakota "A"[2/]	6	7	401	18,500	308	-	2,200	.00
Glenrock, South - Dakota "B"	34	65	35,268	161,984	4,074	13,245	29,200	3.25
Glenrock, South - Muddy "A"	1	3	35	1,440	-	-	190	-
Glenrock, South - Lower Muddy "B"	9	27	6,650	19,357	394	879	3,380	2.23
Glenrock, South - Lower Muddy "C"	16	19	10,684	34,608	492	1,060	3,350	2.16
Glenrock, South - Upper Muddy "A-B"	31	51	8,908	54,048	3,099	6,021	15,664	1.94
Gooseberry - Tensleep	2	6	2,063	12,249	364	108	830	.30
Grass Creek - Curtis	17	102	52,202	177,500	7,464	5,797	21,800	.78
Grass Creek - Darwin	1	8	446	34,700	619	418	740	.68
Grass Creek - Frontier	27	98	19,246	155,827	1,280	1,833	12,700	1.43
Green River Bend - T-5 Almy	3	3	1,155	9,539	40	241	601	6.03
Green River Bend - Birch Creek	1	3	23	1,870	106	1,069	100	10.10
Halverson Ranch - Minnelusa	4	12	1,617	17,340	1,764	302	5,700	.17
Hamilton Dome - Fourth Curtis	1	3	238	2,900	158	1,195	572	7.56
Happy Springs - Frontier "A"	1	4	774	4,870	19	158	464	8.32
Hidden Dome - Frontier[3/]	-	-	-	-	-	-	-	-
Horse Creek - Muddy	7	15	6,788	51,566	539	951	2,900	1.76
La Barge - Almy	31	96	9,321	88,500	986	2,737	9,115	2.78
La Barge - Mesaverde	1	15	69	12,680	151	99	645	.66
Lance Creek - OPC Sundance	6	5	7,245	38,551	308	142	1,221	.46
Lance Creek - Basal Sundance	1	1	27,736	168,601	18	2	402	.11
Lance Creek - First Sundance[4/]	-	-	1,302	-	-	-	-	-
Lance Creek - Morrison	3	4	1,483	2,887	68	354	549	5.21
Lance Creek - Muddy	3	8	2,012	4,154	71	103	603	1.45
Lander - Phosphoria	4	27	596	36,928	274	358	854	1.31
Lightning Creek - Newcastle	1	9	786	5,865	85	249	1,751	2.93
Little Buffalo Basin - Tensleep	3	18	813	198,000	4,410	2,005	1,360	.45
Lost Soldier - Cambrian	4	6	3,313	91,166	2,071	395	3,893	.19
Lost Soldier - Madison	2	16	6,673	170,161	3,638	1,431	3,800	.39

TABLE 3. - Wyoming waterflow project performance[1/]--Continued

Project	Active wells January 1968		Water injected to January 1, 1968, thousand bbl	Estimated total water requirements, thousand bbl	Production avg daily, bbl (December 1967)		Water injection daily, bbl (December 1967)	Ratio of produced water to oil (December 1967)
	Input	Oil			Oil	Water		
Lost Soldier - Tensleep	6	37	19,738	275,255	8,011	2,501	17,421	0.31
McDonald Draw - M-9	3	4	899	3,277	170	108	711	.64
McDonald Draw - M-13	3	14	990	7,168	38	146	777	3.85
McDonald Draw - M-20	4	14	506	5,050	570	480	856	.84
McDonald Draw - M-42	3	4	323	1,265	138	38	499	.28
McDonald Draw - M-47	3	12	647	6,160	598	472	950	.79
Meadow Creek - Second Frontier	1	11	1,144	23,334	59	90	123	1.52
Meadow Creek - Lakota "A"	5	4	2,986	21,470	145	306	51	2.11
Meadow Creek - Lakota "B"	-	3	1,018	3,720	43	173	0	4.02
Meadow Creek - Shannon "A-B"	21	43	3,410	87,254	244	87	6,190	.36
Meadow Creek - Tensleep "A"	2	15	1,801	50,300	1,965	6,678	2,660	3.40
Meadow Creek, North - Shannon	11	10	3,410	19,590	189	256	1,429	1.35
Meadow Creek, North - Sussex	24	6	19,771	47,764	92	274	2,624	2.98
Mellott Ranch - Minnelusa "B"	2	5	974	14,650	1,010	1,072	1,107	10.60
Mule Creek - Minnelusa	1	1	323	3,083	22	5	142	.23
Mush Creek - CRA	5	7	203	10,250	17	-	2,122	-
Mush Creek - Dyer[5/]	2	-	456	1,549	-	-	-	-
Mush Creek - Texaco-Thorson	14	6	4,821	11,190	74	272	1,118	3.68
Mush Creek, West - Coronado	4	5	2,382	6,196	35	199	739	5.69
Mush Creek, West - Thorson	12	21	2,986	25,500	87	139	3,527	1.60
Mush Creek, West - Western Plains Petroleum, Inc.	2	4	522	3,011	12	135	741	11.25
Mush Creek, West - Oil and Realty Development, Inc.	3	2	872	-	45	52	718	1.15
Oregon Basin, North - Embar	13	28	8,979	383,250	2,255	7,822	9,269	3.48
Oregon Basin, North - Tensleep	14	53	52,520	529,250	13,566	14,087	48,342	1.04
Oregon Basin, South - Embar	12	31	6,298	-	2,099	14,087	4,164	6.71
Oregon Basin, South - Tensleep	14	75	45,393	-	9,324	19,401	33,403	2.08
Osage - Deep	25	30	12,207	15,417	222	3,155	4,580	14.21
Osage - Shallow	12	64	1,149	20,317	91	146	550	1.61
Osage - Jones[6/]	-	-	143	150	-	-	-	-

TABLE 3. - Wyoming waterflood project performance[1/] --Continued

Project	Active wells January 1968		Water injected to January 1, 1968, thousand bbl	Estimated total water requirements, thousand bbl	Production, avg daily, bbl (December 1967)		Water injection daily, bbl (December 1967)	Ratio of produced water to oil (December 1967)
	Input	Oil			Oil	Water		
Osage - International	4	10	1,304	1,640	16	1,221	748	76.40
Osage - Juniper, West	12	26	800	20,258	175	117	1,300	.67
Osage - Juniper	18	30	622	1,798	221	0	1,430	.00
Osage - Lake	8	10	405	4,910	534	147	837	.28
Patrick Draw - Arch	28	61	2,153	181,700	2,942	52	3,254	.02
Patrick Draw - Monell	1	90	411	240,700	3,598	1	62	.00
Poison Spider - Sundance	1	14	1,183	5,030	100	774	492	7.74
Quealy Dome - Tensleep	2	6	5,027	27,231	778	4,261	3,200	5.47
Raven Creek - Minnelusa	10	27	3,836	64,700	2,890	162	10,300	.06
Robinson Ranch - Minnelusa	7	9	5,506	9,000	772	7,195	2,435	9.32
Rock River - Lakota	1	12	2,163	-	-	-	1,962	-
Rock River - Muddy	1	5	2,988	23,680	71	237	576	3.34
Salt Creek - Lakota	1	22	1,372	79,500	195	5,376	3,160	27.59
Salt Creek - Second Sundance	7	41	3,949	16,350	365	5,228	5,442	14.31
Salt Creek - First Wall Creek	190	345	285,101	375,642	10,812	93,780	116,000	8.66
Salt Creek - Second Wall Creek	104	489	306,222	1,391,154	12,869	52,259	142,850	4.06
Salt Creek - Second Wall Creek South	122	144	135,221	251,800	9,142	44,113	97,590	4.83
Salt Creek, East - Lakota	1	-	152	8,060	536	269	828	.50
Salt Creek, East - Second Wall Creek	1	-	286	10,830	194	151	1,549	.77
Salt Creek, West - Second Wall Creek	10	22	5,260	9,599	176	680	4,600	3.86
Salt Creek, West - Fishtooth	9	11	3,617	6,700	18	6,839	1,825	37.90
Sand Creek - Third Frontier	2	2	1,610	29,769	14	-	1,700	-
Silver Tip - Frontier[7/]	-	-	-	3,790	-	-	-	-
Skull Creek - McAlester	10	24	1,761	32,000	284	499	3,600	1.76
Skull Creek, East - Lynx Oil Corp.	1	10	34	-	13	87	50	6.70
Slick Creek - Phosphoria	1	6	1,430	30,200	252	226	1,235	.90
Steamboat Butte - Phosphoria	3	5	10,507	42,500	243	325	5,600	1.34
Steamboat Butte - Tensleep	4	14	109,645	230,552	2,122	10,390	20,680	4.89
Sussex - Lakota "A"	1	5	442	11,580	38	805	1,076	1.34
Sussex - Shannon "A"	9	2	3,490	7,474	35	400	250	11.41
Sussex - Shannon "C-E"	12	10	2,954	15,094	49	21	2,176	.43

TABLE 3. - Wyoming waterflood project performance[1/]--Continued

Project	Active wells January 1968		Water injected to January 1, 1968, thousand bbl	Estimated total water requirements, thousand bbl	Production, avg daily, bbl (December 1967)		Water injection daily, bbl (December 1967)	Ratio of produced water to oil (December 1967)
	Input	Oil			Oil	Water		
Sussex - Shannon "D"	5	4	7,491	17,783	59	995	1,273	16.88
Sussex - Sussex "A"	10	7	4,606	8,546	208	886	929	4.26
Sussex - Sussex "C"	6	10	1,512	18,275	90	105	1,014	1.68
Sussex - Sussex "D"	6	4	3,500	7,508	173	272	943	1.57
Sussex - Tensleep "A"	3	5	5,442	9,558	683	2,779	2,925	4.06
Sussex - Tensleep "B"	8	17	30,868	91,186	5,529	11,813	16,910	2.14
Sussex, West - Shannon "A-B"	17	28	19,727	64,720	1,369	2,204	6,830	1.61
Sussex, West-Dugout - Shannon	15	36	10,870	26,641	532	2,430	3,130	4.57
Teapot, East - Upper Shannon	18	27	6,974	10,000	184	2,596	11,093	14.09
Torchlight - Madison	4	18	1,400	13,200	1,307	12,133	2,514	9.29
Torchlight - Tensleep	-	2	4,440	9,671	-	-	-	-
Walker Dome - Torchlight	2	5	492	9,860	76	73	750	.96
Wertz - Amsden	1	4	7,400	21,784	284	14	3,075	.05
Wertz - Tensleep	2	28	16,370	123,000	4,685	3,850	5,285	.82
Winkleman Dome - Phosphoria	9	29	16,113	106,627	1,960	4,728	9,619	2.41
Winkleman Dome - Tensleep	2	29	1,160	-	4,886	7,905	2,839	1.62

1/ Developed from reports to the Wyoming Oil and Gas Conservation Commission.
2/ Includes Muddy "A" production.
3/ Project stopped in August 1967 until unit is approved.
4/ Project completed.
5/ Shut down October 1967.
6/ Project stopped October 28, 1963.
7/ Project stopped April 27, 1966.

TABLE 4. - Oil production from Wyoming waterflood projects[1/]

Project	Production, thousand bbl		
	To start of injection	From start of injection to January 1, 1968	Cumulative to January 1, 1968
Ash Creek - Shannon	4,524	810	5,334
Beaver Creek - Second Cody	1,459	1,052	2,511
Beaver Creek - Madison	6,281	22,464	28,745
Big Muddy - Wall Creek	19,600	6,688	26,288
Big Muddy - Dakota	2,700	4,183	6,883
Big Muddy - Dakota, East	1,500	735	2,235
Big Muddy - Dakota, South	105	157	262
Big Muddy - Wall Creek, South	2,100	162	2,262
Big Piney - "P" sand	1,388	514	1,902
Birch Creek - Birch Creek	1,369	1,971	3,340
Bison Basin - Frontier	654	569	1,223
Brooks Ranch - Second Frontier	2,110	123	2,233
Burke Ranch - Dakota	2,161	1,314	3,475
Clareton Projects - True	14,747	822	15,569
Cole Creek - Dakota "A"	1,730	379	2,109
Cole Creek - Shannon	1,178	7,325	8,503
Cole Creek, South - Lakota	3,310	1,334	4,644
Cooper Cove - Muddy "D"[2/]	-	-	1,131
Cottonwood Creek - Phosphoria	13,102	15,017	28,119
Crooks Gap - Frontier	188	53	241
Crooks Gap - Lakota	8,929	378	9,307
Crooks Gap - Muddy	495	23	518
Dead Horse Creek - North Block	883	683	1,556
Dead Horse Creek - South Block	1,303	1,239	2,542
Dead Horse Creek - Caballo	660	817	1,477
Dillinger Ranch - Minnelusa	1,601	434	2,035
Elk Basin - Frontier	12,669	15	12,684
Elk Basin - Madison	39,157	35,356	74,513
Elk Basin, South - Tensleep	7,550	2,804	10,354
Fiddler Creek	3,423	6,046	9,469
Fiddler Creek, West	5,536	4,411	9,947
Garland - Embar	1,730	253	1,983
Garland - Tensleep	12,800	11,320	24,120
Glenrock, South - Dakota "B"	15,900	8,543	24,443

TABLE 4. - Oil production from Wyoming waterflood projects[1/]--Continued

Project	Production, thousand bbl		
	To start of injection	From start of injection to January 1, 1968	Cumulative to January 1, 1968
Glenrock, South - Lower Muddy "B"	4,458	5,445	9,903
Glenrock, South - Lower Muddy "C"	4,806	2,028	6,834
Glenrock, South - Upper Muddy "A-B"	5,300	5,687	10,987
Glenrock, South - Dakota "A" and Muddy "A"[3/]	-	43	-
Gooseberry - Tensleep	1,000	907	1,907
Grass Creek - Curtis	12,400	20,713	33,113
Grass Creek - Darwin	2,041	366	2,407
Grass Creek - Frontier	32,100	4,245	36,345
Green River Bend - T-5 Almy	228	230	458
Green River Bend - Birch Creek	1,209	28	1,237
Halverson Ranch - Minnelusa	2,067	956	3,023
Hamilton Dome - Fourth Curtis	-	41	-
Happy Springs - Frontier "A"	563	229	792
Hidden Dome - Frontier	-	-	-
Horse Creek - Muddy	3,769	1,616	5,385
La Barge - Almy	12,986	1,849	14,835
La Barge - Mesaverde	856	18	874
Lance Creek - OPC Sundance	5,866	206	6,072
Lance Creek - Basal Sundance	23,500	2,030	25,530
Lance Creek - First Sundance[4/]	-	-	1,248
Lance Creek - Morrison	252	392	644
Lance Creek - Muddy	315	709	1,024
Lander - Phosphoria	-	-	1,946
Lightning Creek - Newcastle	213	55	268
Little Buffalo Basin - Tensleep	-	-	25,321
Lost Soldier - Cambrian	10,950	1,355	12,305
Lost Soldier - Madison	18,909	4,257	23,166
Lost Soldier - Tensleep	39,347	10,016	49,363
McDonald Draw - M-9	375	192	567
McDonald Draw - M-13	93	155	248
McDonald Draw - M-20	445	532	977
McDonald Draw - M-42	118	135	253
McDonald Draw - M-47	231	447	678
Meadow Creek - Second Frontier	1,332	231	1,563

TABLE 4. - Oil production from Wyoming waterflood projects[1/] --Continued

Project	Production, thousand bbl		
	To start of injection	From start of injection to January 1, 1968	Cumulative to January 1, 1968
Meadow Creek - Lakota "A"	1,000	1,413	2,413
Meadow Creek - Lakota "B"	587	451	1,038
Meadow Creek - Shannon "A-B"	807	4,471	5,278
Meadow Creek - Tensleep "A"	7,390	2,607	9,997
Meadow Creek, North - Shannon	920	365	1,285
Meadow Creek, North - Sussex	2,800	3,613	6,413
Mellott Ranch - Minnelusa "B"	640	435	1,075
Mule Creek - Minnelusa	39	80	119
Mush Creek - CRA	1,790	21	1,811
Mush Creek - Dyer	145	23	168
Mush Creek - Texaco-Thorson	1,239	737	1,976
Mush Creek, West - Coronado	-	137	-
Mush Creek, West - Thorson	1,772	71	1,843
Mush Creek, West - Western Plains Petroleum, Inc.	-	37	-
Mush Creek, West - Oil and Realty Development, Inc.	496	42	538
Oregon Basin - Embar	57,171	8,434	65,605
Oregon Basin - Tensleep	21,300	46,035	67,335
Osage - Deep	-	810	-
Osage - Shallow	-	144	-
Osage - Jones	-	-	-
Osage - International[5/]	-	-	-
Osage - Juniper, West	1,030	119	1,149
Osage - Juniper	940	62	1,002
Osage - Lake	-	300	-
Patrick Draw - Arch	8,130	3,643	11,773
Patrick Draw - Monell	13,365	7,318	20,683
Poison Spider - Sundance	1,197	251	1,448
Quealy Dome - Tensleep	2,149	2,737	4,886
Raven Creek - Minnelusa	8,938	1,416	10,354
Robinson Ranch - Minnelusa	2,736	2,460	5,196
Rock River - Muddy and Lakota	-	-	-
Salt Creek - Lakota	20,551	104	20,655
Salt Creek - Second Sundance	2,580	910	3,490
Salt Creek - First Wall Creek	46,788	29,650	76,438

TABLE 4. - Oil production from Wyoming waterflood projects[1/]--Continued

Project	Production, thousand bbl		
	To start of injection	From start of injection to January 1, 1968	Cumulative to January 1, 1968
Salt Creek - Second Wall Creek	249,447	19,936	269,383
Salt Creek - Second Wall Creek South	25,942	10,303	36,245
Salt Creek, East - Lakota	-	17	-
Salt Creek, East - Second Wall Creek	-	51	-
Salt Creek, West - Second Wall Creek	1,228	221	1,449
Salt Creek, West - Fishtooth	101	116	217
Sand Creek - Third Frontier	1,366	90	1,456
Silver Tip - Frontier[6/]	525	32	557
Skull Creek - McAlester	-	214	-
Skull Creek, East - Lynx Oil Corp.	-	13	-
Slick Creek - Phosphoria	2,684	274	2,958
Steamboat Butte - Phosphoria	956	1,617	2,573
Steamboat Butte - Tensleep	23,934	16,320	40,254
Sussex - Lakota "A"	1,544	33	1,577
Sussex - Shannon "A"	106	1,194	1,300
Sussex - Shannon "C-E"	555	505	1,060
Sussex - Shannon "D"	1,300	1,300	2,600
Sussex - Sussex "A"	113	1,687	1,800
Sussex - Sussex "C"	1,000	1,300	2,300
Sussex - Sussex "D"	601	315	916
Sussex - Tensleep "A"	2,300	3,500	5,800
Sussex - Tensleep "B"	4,300	21,490	25,790
Sussex, West - Shannon "A-B"	3,080	6,476	9,556
Sussex, West-Dugout - Shannon	4,259	846	5,105
Teapot, East - Upper Shannon	1,794	87	1,881
Torchlight - Madison	2,080	1,714	3,794
Torchlight - Tensleep	1,250	1,592	2,842
Walker Dome - Torchlight	449	43	492
Wertz - Amsden	2,121	358	2,479
Wertz - Tensleep	24,363	21,353	45,716
Winkleman Dome - Phosphoria	7,031	3,708	10,739
Winkleman Dome - Tensleep	25,575	1,848	27,423

1/ From records of the Wyoming Oil and Gas Conservation Commission.
2/ Muddy and Dakota commingled.
3/ Dakota "A" and Muddy "A" commingled.
4/ To 1964.
5/ Reported in Deep Lens figures.
6/ Stopped April 27, 1966.

Beaver Creek

Beaver Creek field (fig. 4), a gently folded anticline in secs 21, 28, and 34, T 34 N, R 96 W, and secs 3, 4, 9-11, 14, and 15, T 33 N, R 96 W, Fremont County, was discovered in 1938 with completion of a well in the SE1/4SE1/4 sec 3, T 33 N, R 96 W. This well had an initial daily production of 9 million cubic feet of gas from the Dakota Sandstone from 8,230 to 8,285 feet, after failure to find oil or gas in the Nugget Sandstone at 8,920 feet. The field was shut in until a market for the gas was established in November 1944. Development of the field was resumed in July 1945.

Later, gas was found in the Muddy sand and Second, Third, Fourth, and Fifth Frontier sands. Oil was found in the Second Cody (or Mesaverde) sand, Tensleep, and Madison Formations.

The first Tensleep well was completed in February 1949. Initial daily production was 481 barrels from the depth interval from 10,442 to 10,894 feet. Core samples showed the porosity to be 8 percent and the permeability less than 10 millidarcys. Although 12 wells had tested the Tensleep, only one was producing in October 1968.

The first 11 Second Cody wells reported initial flowing oil production ranging from 37 to 768 barrels per day with no water. Later, Second Cody wells reported daily pumping production ranging from 20 to 499 barrels of oil and from 7 to 769 barrels of water. Average per well daily production of 33 wells was 200 barrels of oil and 280 barrels of water.

Initial daily production of 18 Madison wells ranged from 60 to 1,574 barrels of oil and 0 to 528 barrels of water. Average per well initial production was 548 barrels of oil and 210 barrels of water.

The log of Unit well No. 30-M in the S1/2NW1/4NE1/4 sec 10 shows the following depth, in feet, to the top of formations: Mesaverde, 2,440; First Frontier, 6,717; Second Frontier, 6,820; Third Frontier, 6,913; Fourth Frontier, 7,113; Fifth Frontier, 7,235; Mowry, 7,402; Muddy, 7,920; Lakota, 8,264; Morrison, 8,298; Nugget, 8,833; Chugwater, 9,167; Dinwoody, 10,252; Phosphoria, 10,295; Tensleep, 10,625; Amsden, 11,088; Darwin sand, 11,133; and Madison, 11,204. Drillstem tests in some of the wells show that the Darwin sand contains oil in noncommercial quantities.

A unit plan for developing and operating the Beaver Creek field, with Pan American Petroleum Corp. as the operator, was approved by the Secretary of the Interior on September 1, 1937.

Second Cody Project

After a detailed study of the reservoir, prior to flooding, the operator changed the formation name from Mesaverde to Second Cody.

The Second Cody reservoir contains 977 acres and has an average pay thickness of 24 feet.

A pilot flood was started in March 1958 when water was injected into well 50, SE1/4NE1/4 sec 10, T 33 N, R 96 W. The water was from the Meeteetse sand (2,122 to 2,210 feet) in a recompleted dry hole in the NW1/4 sec 11. Reservoir pressure at the start of injection was 450 psi.

The operation was expanded in 1959 to a peripheral flood consisting of five injection wells and nine producing wells. In May 1960 a producing well in the NW1/4SE1/4 sec 10 was converted to a propane injection well. The propane injection was to dispose of excess production from the field gas-processing plant and not a planned miscible-phase recovery project.

On January 1, 1968, daily production from 27 wells was 833 barrels of oil and 2,888 barrels of water. Daily injection was 11,940 barrels of water at 1,400 psi. Part of the produced water was injected.

Cumulative oil production to the start of injection (March 1958) was 1,459,000 barrels or 10 percent of the original oil in place. From the start of injection to January 1, 1968, oil production was 1,052,353 barrels, of which 500,000 was attributed to water injection. Cumulative water injected to January 1, 1968, was 10,634,000 barrels. Water injected to secondary oil produced was 21 to 1. The project appears to be successful.

Madison Project

Madison reservoir covers 1,260 acres and has an average gross pay thickness of 150 feet. Madison pay zones are all below 11,000 feet in depth, making this the deepest water injection project in the Rocky Mountain region.

Water injection to maintain reservoir pressure was started in March 1959. The water was obtained from several wells completed in alluvial gravel of the Wind River Formation at a depth of about 100 feet.

Later the project was expanded to six injection and 19 producing wells. Five wells are dually completed permitting water injection in the lower zone below a packer and oil production from the upper zone above the packer.

On January 1, 1968, the project contained 20 producing wells and six injection wells. Daily production was 6,650 barrels of oil and 6,500 barrels of water; daily injection was 18,500 barrels of untreated water at 1,500 psi.

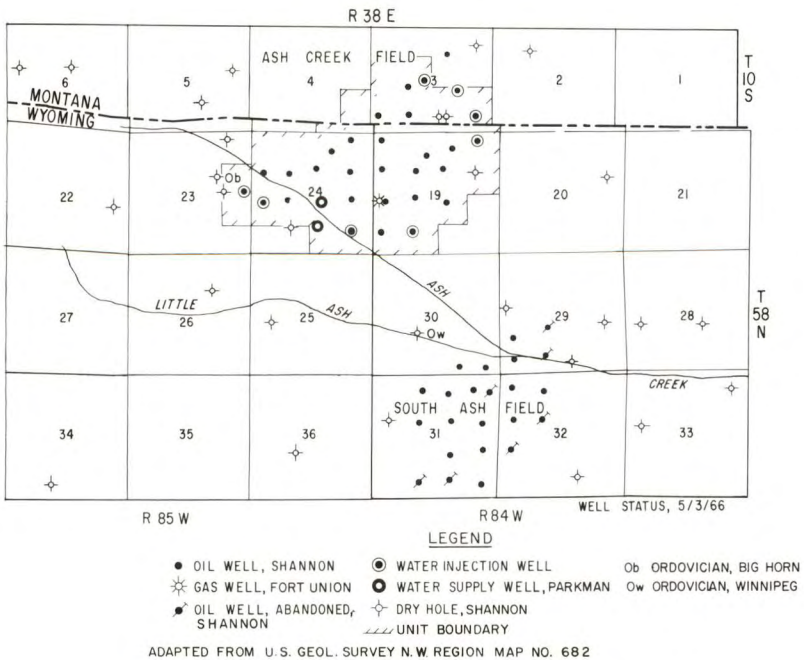


FIGURE 3. - Ash Creek and South Ash Creek Fields, Sheridan County, Wyo., and Big Horn County, Mont.

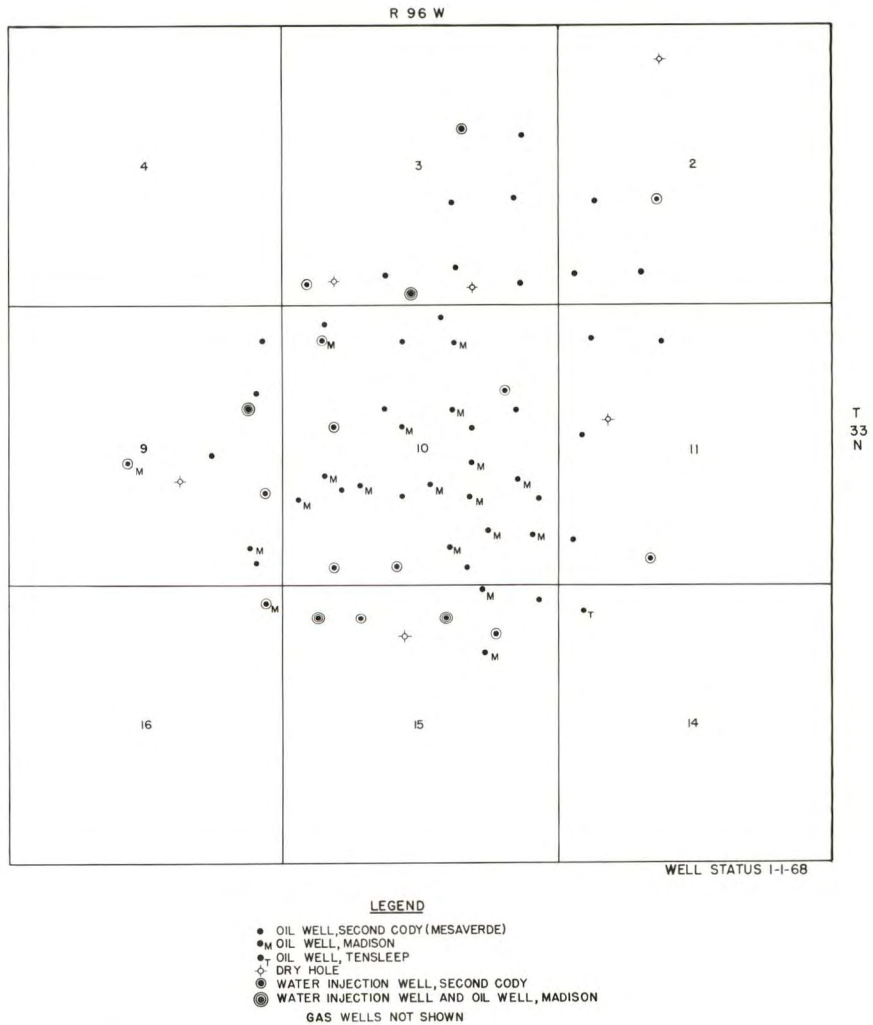


FIGURE 4. - Beaver Creek Field, Fremont County, Wyo.

Cumulative oil production to the start of injection was 6,281,000 barrels or 8.1 percent of the estimated original oil in place. From the start of injection to January 1, 1968, 22,464,681 barrels of oil was produced. The cumulative water injection was 23,485,000 barrels. The project, classified by the operator as pressure maintenance, appears successful.

Big Muddy

Big Muddy oilfield (figs. 5-6) is in the north half of T 33 N, R 76 W, Converse County. The field was discovered in 1916 when a well was completed in the NE1/4NE1/4 sec 9 with an initial daily production of 26 barrels of oil from the Shannon sand. Wells completed later in the Shannon sand averaged 35 barrels per day of 34° API gravity green oil, although a few produced 300 to 400 barrels per day. In 1917 a well in the NW1/4SE1/4 sec 7 was completed with an initial daily production of 128 barrels of oil from the deeper Wall Creek sands at 3,147 to 3,217 feet. In 1922 36° API gravity brown oil was discovered in the Dakota sand. In 1931 a well in the NE1/4NE1/4 sec 9 was completed in the Lakota sand at 4,353 to 4,364 feet; the initial daily production was 405 barrels of 32° API gravity brown oil. The Lakota sand also carried water.

A gas injection program was started in the Second Wall Creek sand during 1935. The injection well took 80,000 cubic feet of gas per day at a line pressure of 300 psi. This program soon was abandoned owing to the apparent gas channeling to offset producing wells and the high purchase price of the gas.

The areas locally called East Big Muddy and South Big Muddy are considered herein as part of the Big Muddy field.

A pilot water injection project in the Second Wall Creek sand was started in March 1953. In 1967 Continental Oil Co. was operating three projects, and Sinclair Oil and Gas Corp. and J. C. Dyer Co. were each operating one project. Injection water is obtained from the following sources: Wall Creek, Dakota, Lakota, Sundance, Tensleep and Madison Formations, and two shallow wells near the North Platte River.

Second Wall Creek Project

Second Wall Creek project, operated by Continental Oil Co., encompasses 3,560 acres and has an average pay thickness of 38 feet. The reservoir producing mechanisms were solution gas drive and a weak natural water drive. Edge-water encroachment in the Second Wall Creek had been only 1 mile in 35 years.

The pilot water injection program was later expanded to a five-spot pattern for the project area. On January 1, 1968, there were 11 producing wells, 16 injection wells, and 17 shut-in wells. Injection water was obtained from two Lakota wells and one Sundance well, plus produced water from the Wall Creek and Dakota oil wells. During December 1967 daily average project production was 300 barrels of oil and 5,100 barrels of water; daily average injection was 9,600 barrels of water at 370 psi.

Cumulative oil production to the start of waterflooding was about 19,600,000 barrels or 21.4 percent of the estimated original oil in place. Of the 6,687,500 barrels of oil produced since waterflooding started, an estimated 6,287,500 barrels was considered to be secondary oil. Cumulative water injection to January 1, 1968, was about 54,210,000 barrels. Ratio of water injected to secondary oil recovered was 8 to 1. The project is a success.

Big Muddy Wall Creek South Unit

Big Muddy Wall Creek South unit, operated by J. G. Dyer, contains a productive area of 507 acres and has an average pay thickness of 20 feet. The Wall Creek Formation contains two porous zones designated the First and Second sands. The First Wall Creek sand has a gross thickness of 15 feet and is less permeable than the Second. The Second Wall Creek sand has a gross thickness of 60 feet and permeability of 70 millidarcys. The operator is injecting water into both sands.

The project area was unitized in August 1963, and water injection was started in February 1964. The flood pattern is peripheral. On January 1, 1968, the project area contained 16 producing wells, four injection wells, and 12 inactive wells. During December 1967, daily average production was 63 barrels of oil and 1,467 barrels of water; daily average injection was 3,300 barrels of water at 450 psi.

Cumulative oil production to the start of injection was 2,100,100 barrels or 13.4 percent of the original oil in place. Cumulative oil production to January 1, 1968, was about 2,262,000 barrels or about 14.4 percent of the original oil in place. Of the 162,000 barrels of oil produced since injection was started, an estimated 90,000 barrels are attributed to fluid injection. Cumulative injection to January 1, 1968, was 4,331,600 barrels. Available data indicate a successful project.

Dakota Project

Dakota project, operated by Continental Oil Co., covers 1,941 acres and has an average pay thickness of 10 feet. The reservoir producing mechanism was solution gas drive. In 1958 a five-spot pilot waterflood was started on the crest of the structure. Later the project was expanded to a full-scale flood. Selection of injection wells was influenced by reservoir faulting. On January 1, 1968, the project area contained nine producing and seven injection wells; two wells had been shut in. Average

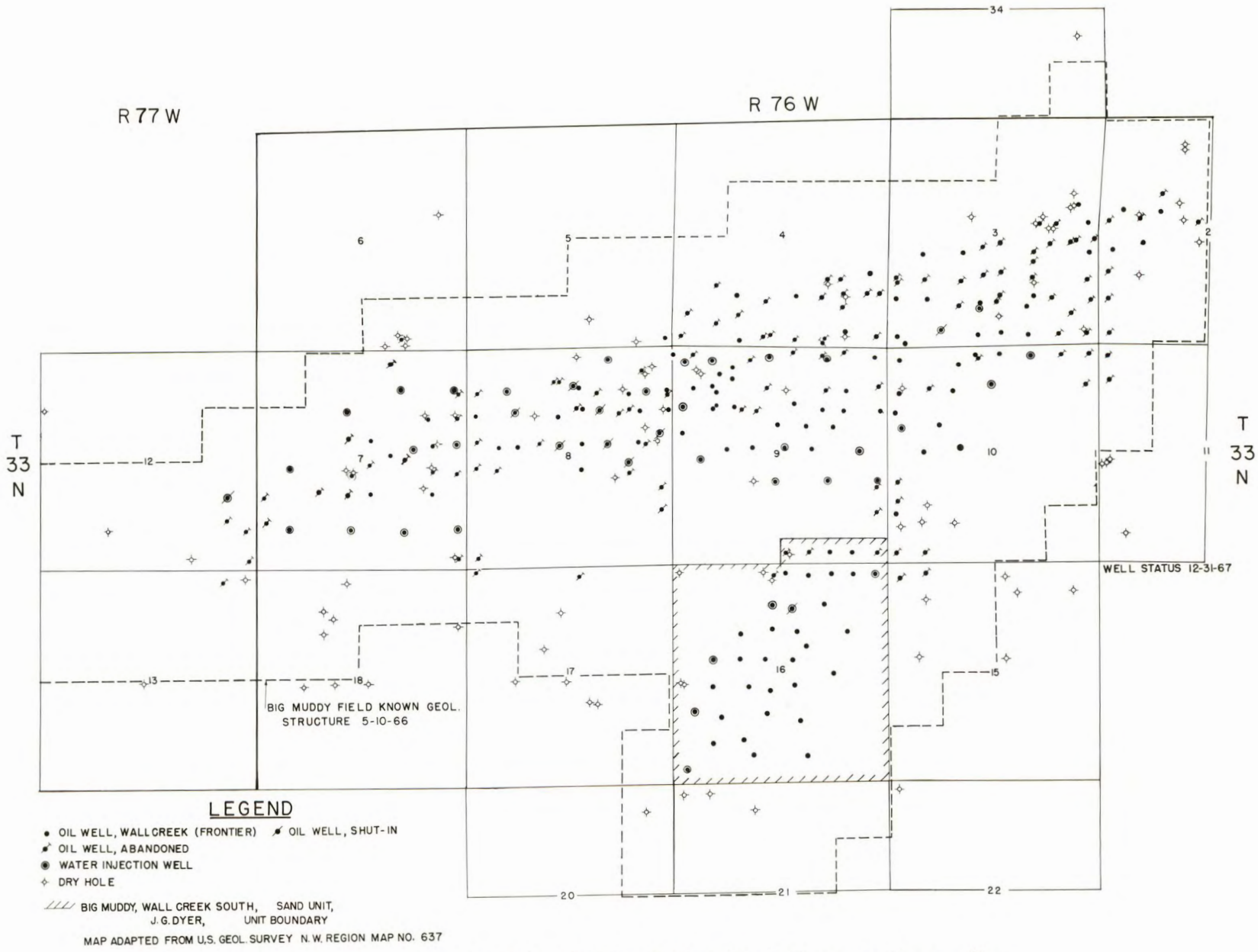


FIGURE 5. - Big Muddy Field, Wall Creek Waterflood, Converse County, Wyo.

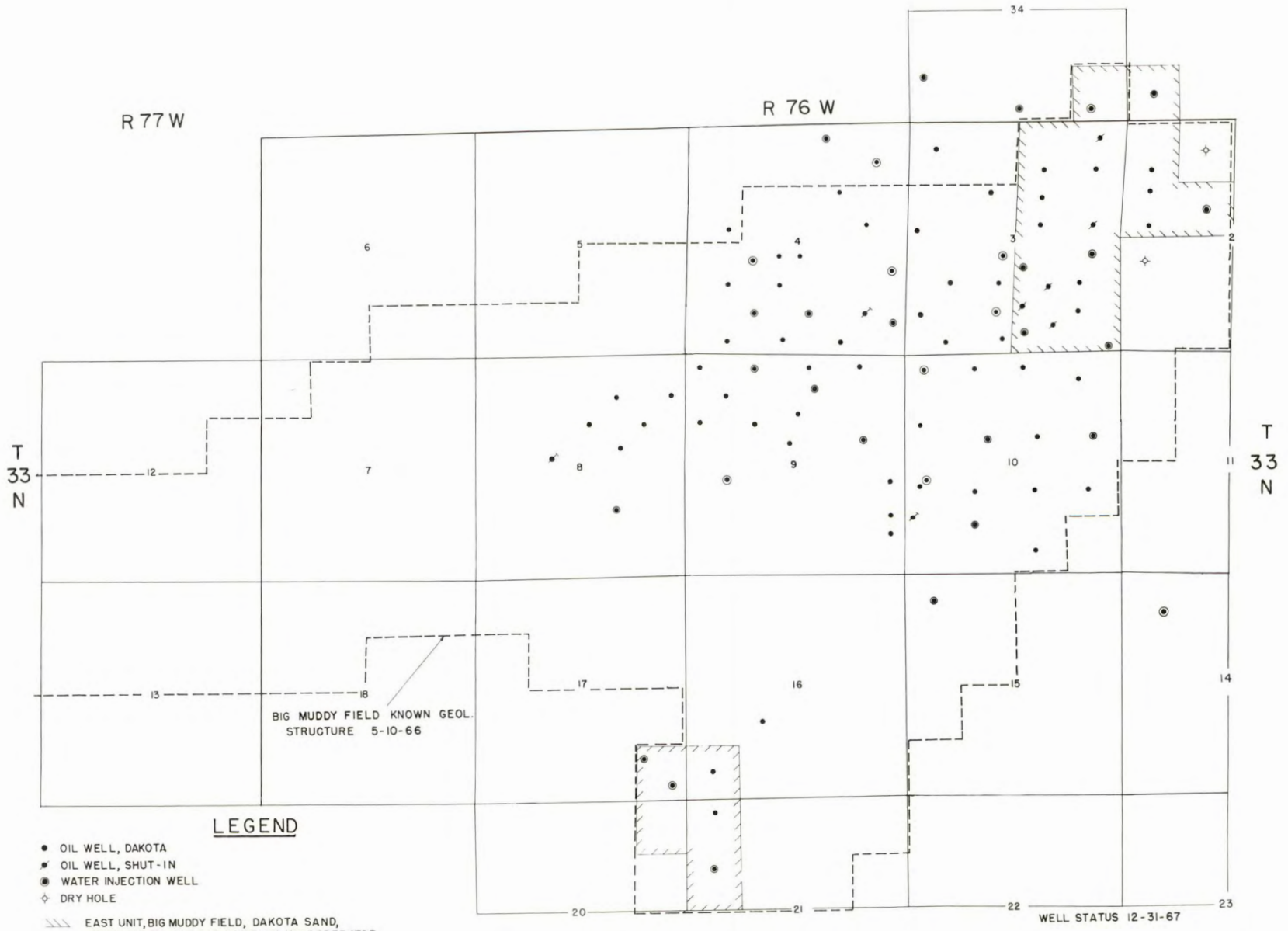


FIGURE 6. - Big Muddy Field, Dakota Waterflood, Converse County, Wyo.

daily production was about 1,212 barrels of oil and 3,887 barrels of water; average daily injection was about 8,000 barrels of water at 900 psi.

Cumulative production to the start of waterflooding was about 2,700,000 barrels of oil or 19 percent of the original oil in place. Cumulative production to January 1, 1968, was about 6,883,817 barrels or 48 percent of the original oil in place. Of the 4,183,000 barrels of oil produced since waterflooding was started, an estimated 3,900,000 barrels was secondary oil. Cumulative water injection to January 1, 1968, was about 12,222,000 barrels. The project is an apparent success.

Dakota South Project

Dakota South project, operated by J. G. Dyer, was unitized in September 1961 and contains 200 acres. The reservoir is a small dome south of the main Dakota producing area. Average pay thickness of the reservoir is about 5 feet. Water injection was started in March 1961. On January 1, 1968, the project area contained two producing, two injection, and two shut-in wells. During December 1967 average daily production was 20 barrels of oil and 251 barrels of water; average daily water injection was about 240 barrels at 2,400 psi.

Cumulative oil production to the start of injection was about 105,317 barrels or 14 percent of the original oil in place. Cumulative oil production to January 1, 1968, was 262,652 barrels or 34 percent of the original oil in place. Of the 157,335 barrels of oil produced since injection started, an estimated 130,000 barrels was from fluid injection. Cumulative water injection to January 1, 1968, was 629,000 barrels. Available data indicate a successful project.

Dakota East Unit

Dakota East project, operated by Sinclair Oil and Gas Co., unitized in February 1961, contains 520 acres in the northeast part of the field. The Continental and Sinclair Dakota units are in the same reservoir, which has an average pay thickness of 11 feet. Water injection was started in July 1961 with two injection wells. Later the project was expanded to seven injection wells. On January 1, 1968, the area contained eight producing and seven injection wells. During December 1967 average daily production was 316 barrels of oil and 1,450 barrels of water; average daily water injection was about 2,100 barrels at 1,760 psi.

Cumulative oil production to the start of waterflooding was about 1.5 million barrels or 36 percent of the original oil in place. Cumulative production to January 1, 1968, was about 2,235,000 barrels or 52 percent of the original oil in place. The oil produced as a result of water injection is an estimated 630,000 barrels. The project is a success.

Big Piney

Big Piney field is in Tps 28 and 29 N, Rs 112 and 113 W, Sublette County. The discovery well in the NE1/4NE1/4 sec 10, T 29 N, R 113 W, "blew in" in midwinter 1938 for an estimated open flow of 22 to 75 million cubic feet of gas per day. Water from sands above the gas zone was blown to the surface and formed a giant icicle encasing the entire derrick during the subzero weather. The well had been standing idle for 3 weeks, at a total depth of 1,695 feet, when the blowout occurred. Later investigation proved that the Almy gas sands at about 1,000 feet in depth had been mudded off during drilling. From 1938 to 1952 a few wells were drilled in the area searching for oil. On September 9, 1952, a well in sec 28, T 28 N, R 113 W, blew out from a depth of 984 feet. This well had been drilled through Almy gas sands from 647 to 747 feet and produced at the rate of 75 million cubic feet daily for 10 days before the well could be killed, cased, and cemented. Soon afterward the area was developed as a gasfield.

Two small oil wells were completed by September 1955 in secs 34 and 35, T 30 N, R 113 W, with initial capacities of 40 and 24 barrels per day, respectively. The oil came from sands in the Wasatch Formation.

Oil was discovered in the Almy "P" sand in July 1957. Several lenticular sands occur in the Wasatch and Mesaverde Formations in the Big Piney area. The "P" sand reservoir is a gas and oil reservoir. The gas reservoir is about 1-1/2 times larger than the oil reservoir. The oil reservoir covers 878 acres and has an average pay thickness of 16.2 feet.

Pan American Petroleum Corp. unitized the "P" sand area in November 1962. The oil reservoir was being depleted by gas cap expansion and solution gas drive. The operator decided to maintain reservoir pressure by water injection and produce the oil and gas reservoir simultaneously to increase ultimate recovery.

In August 1963 water obtained from a shallow (80-foot) well in the Green River Formation was injected into three wells near the gas-oil contact to prevent oil movement into the "dry" gas reservoir. The gas wells were to be produced after reservoir pressure was increased by water injection. Gas injection also was started in the gas cap in December 1962.

In December 1967 the "P" sand project area contained 10 producing oil wells, five water injection wells, and one gas injection well. No gas wells were being produced. Daily production was 175 barrels of oil and 700 barrels of water. Daily injection was about 4,480 barrels of water at 2,000 psi and 600,000 cubic feet of gas.

Cumulative oil production to the start of injection was about 1,388,000 barrels or 9 percent of the original oil in place. Cumulative oil production to January 1, 1968, was about 1,902,000 barrels or 12.3

percent of the original oil in place. All of the oil produced since injection was credited to fluid injection. Cumulative injection was 5,642,000 barrels of water and 2,725 million cubic feet of gas. Outcome of the project is indeterminate.

Birch Creek

Birch Creek field or unit is in the east half of T 27 N, R 113 W, Sublette County. Birch Creek unit was approved January 16, 1957, with Chevron Oil Co. as operator. The first gas well was completed in the Bear River sand from 7,543 to 7,580 feet in April 1957. Later gas was found in the Frontier Formation and oil in the Almy (Birch Creek) sand and Mesaverde Formation.

By the end of 1967, 20 Bear River-Frontier gas wells, one Mesaverde gas well, 29 Mesaverde oil wells, 21 Almy (Birch Creek) sand oil wells, and 16 dry holes had been completed in the unit.

The Birch Creek sand waterflood area is in secs 24 and 25 and covers 600 acres having an average pay thickness of 31 feet. The original production mechanism was a gas expansion drive.

Three injection wells were drilled on the south line of sec 25 between the Birch Creek and Green River Bend units. Water injection was started in these wells in December 1963 to prevent oil migration between the units. During 1965 an oil well in the SW1/4SE1/4 sec 24 was converted to an injection well. Injection water is obtained from wells in the Wasatch Formation.

On January 1, 1968, the project contained nine producing oil wells and four injection wells. During December 1967 the daily average production was 930 barrels of oil and 2,000 barrels of water; daily average water injection was 7,960 barrels at 1,650 psi.

Cumulative oil production to the start of injection was 1,369,000 barrels or 5.3 percent of the original oil in place. Cumulative oil production to January 1, 1968, was 3,339,965 barrels or 12.9 percent of the original oil in place. Of the 1,971,000 barrels of oil produced since the start of injection, an estimated 950,000 barrels was recovered by fluid injection. Cumulative water injection to January 1, 1968, was 10,755,000 barrels. Outcome of the project is indeterminate.

Bison Basin

Bison Basin (formerly Buffalo Basin) is in the northwest part of T 27 N, R 95 W, Fremont County. In 1923 a well was drilled in the NE1/4NE1/4SW1/4 sec 17 through three sands in the Frontier Formation at

603 to 620 feet, 875 to 889 feet, and 1,040 to 1,062 feet. The initial daily production was about 20 million cubic feet of gas with a shut-in wellhead pressure of 100 psi. As additional wells were drilled, oil was found in the Frontier Formation. In March 1957 a well in the SE1/4SE1/4NW1/4 sec 18 was completed in the Morrison Formation. Initial daily production was 6 barrels of oil and 6 barrels of water. The well later was abandoned. Seventeen oil wells and three gas wells were completed in the field. Average initial daily production was 26 barrels per well.

The field was unitized in March 1939 by Elmer J. Boseke, Jr.; Gulf Oil Corp. succeeded him as unit operator in May 1956. In August 1961 water injection, using water from the Nugget sand, was started in three wells at the northeast corner of the field. The injection pattern is a line drive.

The project covers 270 acres with an average pay thickness of 75 feet. The oil is heavy, about 17° API gravity.

On January 1, 1968, the project area contained 14 producing oil wells, three shut-in oil wells, one gas well (for field fuel), and three water injection wells. During December 1967, the daily average production was about 200 barrels of oil and 1,170 barrels of water; daily injection was about 1,000 barrels of water.

Cumulative oil production to the start of injection was 654,000 barrels or about 7 percent of the original oil in place. Cumulative oil production to January 1, 1968, was 1,223,246 barrels or about 12.9 percent of the original oil in place. Of the 569,246 barrels of oil produced since the project started, an estimated 430,000 barrels was produced by fluid injection. Cumulative water injection to January 1, 1968, was 2,168,497 barrels. The project is apparently successful.

Brooks Ranch

Brooks Ranch field is in T 33 N, R 77 W, Converse and Natrona Counties. The discovery well in the SE1/4SE1/4SE1/4 sec 9 was completed May 1, 1957. Initial daily production was 183 barrels of oil from the Second Frontier sand at 4,244 to 4,258 feet. Fifty-eight additional oil wells were drilled and completed in 1957-59. Completion reports showed three wells had an initial daily oil production of more than 200 barrels, and nine wells produced less than 50 barrels per day. Average initial production of all wells was 106 barrels of oil. Three wells initially made 5 or more barrels of water with the oil.

Analyses of cores from some of the wells showed an average porosity of 16.9 percent, a permeability of 3.1 millidarcys, and an average water saturation of 30 percent. Average net pay thickness was 7.7 feet. The Second Frontier sand thickens in the northwest part of the field. The

reservoir producing mechanism was solution gas drive. Water influx into the reservoir appeared to be very slight.

When the unit was formed the average daily production was about 5 barrels per well. Cooperative Refining Association, Inc., was appointed unit operator. Cumulative oil production prior to the unit effective date of May 1, 1966, was 2,109,684 barrels. Water injection in three wells started in September 1966. Water supply is obtained from a well completed in the Madison Formation.

In December 1967 there were 35 oil, 22 injection, and four shut-in wells in the unit. Daily production was 124 barrels of oil and 59 barrels of water. Daily injection was 3,300 barrels at pressures ranging from 960 to 1,950 psi. Cumulative water injected to January 1, 1968, was 998,241 barrels.

Because some of the wells had reached their economic limit by the start of the unit, probably 30,000 barrels could be credited to fluid injection. Outcome of the project is indeterminate.

Burke Ranch

Burke Ranch field (fig. 7) is in secs 7, 8, 17, and 18, T 37 N, R 78 W, and sec 12, T 37 N, R 79 W, Natrona County. The discovery well in the NW1/4NW1/4NW1/4 sec 18 was completed in August 1953. Initial daily production was 100 barrels of oil from the Dakota Sandstone at 6,658 to 6,672 feet. The well had been drilled into the Tensleep Formation, which contained water. To the end of 1967, 17 oil wells had been drilled in the field. The initial daily production of these wells ranged from 20 to 1,680 barrels of oil.

A unit plan for developing and operating the Burke Ranch field was approved by the Secretary of the Interior on September 6, 1951.

Having an average pay thickness of 12 feet, the reservoir covers about 1,282 acres. The field was being depleted by a combination of fluid expansion and solution gas drive.

A pilot water injection project, started in July 1962 using two wells, was expanded later to a field-wide peripheral flood. Injection water was obtained from the Teapot and Parkman Formations. On January 1, 1968, the project area contained eight producing oil wells, five shut-in oil wells, and four injection wells. During December 1967 the daily average production was 1,688 barrels of oil and 1,449 barrels of water; daily water injection was 3,550 barrels at 3,006 psi.

Cumulative oil production to the start of injection was 2,161,000 barrels or about 19 percent of the original oil in place. Cumulative

oil production to January 1, 1968, was 3,475,000 barrels or about 30 percent of the original oil in place. All of the 1,314,000 barrels of oil produced since the start of injection is credited to fluid injection. Cumulative water injection to January 1, 1968, was 4,872,000 barrels. The project is a success.

Clareton Projects

The general terrain of the Clareton area consists of rolling hills, steeply eroded gullies, and intermittent streams that drain toward the South Fork of the Cheyenne River. The Fort Union and Lance Formations are exposed at elevations ranging from 4,200 to 4,600 feet.

By the end of 1967, 839 wells had been drilled in the Clareton area. Well status was reported to be 213 oil wells, 235 shut-in oil wells, 10 gas wells, nine shut-in gas wells, 66 injection wells, and 306 dry holes.

Cumulative production from the Clareton area fields to 1968 was nearly 20 million barrels.

The Clareton waterflood projects (fig. 8) includes parts of the Black Thunder, Hampshire, and Clareton fields. A brief report of these fields follows.

Clareton

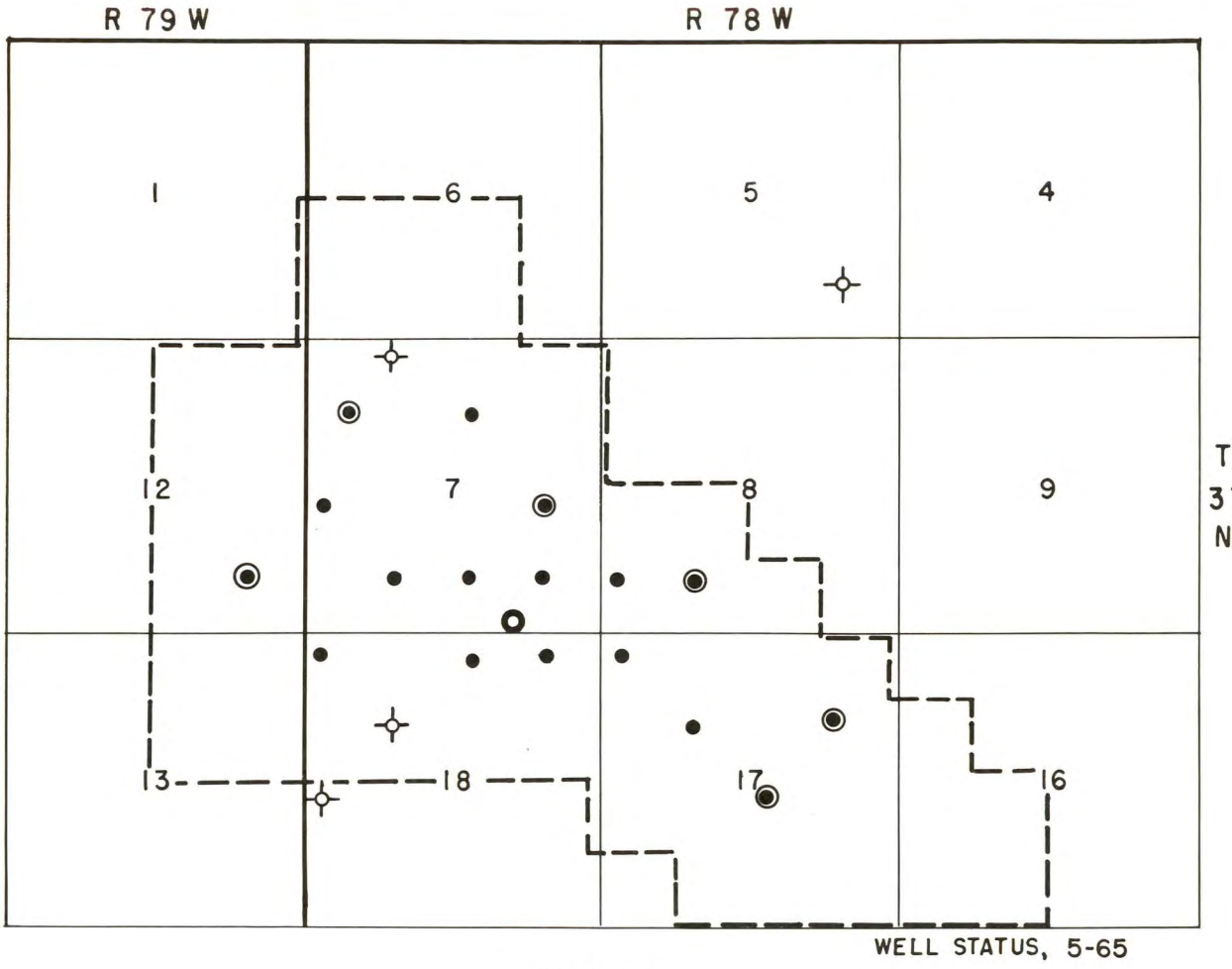
Clareton field has been designated as all of the area in T 43 N, Rs 64-66 W, Weston County. The discovery well in the SW1/4 sec 16, T 43 N, R 65 W, was completed August 15, 1950. Initial flowing production was 40 barrels of oil per day from the Newcastle (Muddy) sand, which had been shot with 60 quarts of solidified nitroglycerin in the interval from 6,147 to 6,161 feet. Reported initial production of the wells in the field ranged from 10 to 2,640 barrels of oil per day or an average of 298 barrels of oil per day.

The log of the discovery well shows the following depth, in feet, to the top of formations: Niobrara, 4,695; Wall Creek (Frontier), 5,032; Newcastle, 6,121; shale break, 6,148; and second sand (Newcastle), 6,160.

Individual well records show that at least three separate oil-bearing sand lenses occur in the Newcastle Sandstone in the Clareton field. Reported API gravity of the oil varies from 39° to 43°.

Black Thunder

Black Thunder field is in T 42 N, R 66 W, Weston County, and is southwest of Clareton field. The discovery well in the NE1/4 sec 23



LEGEND

- OIL WELL, DAKOTA
- DRY HOLE
- WATER INJECTION WELL
- WATER SUPPLY WELL
- — — KNOWN GEOLOGIC STRUCTURE

ADAPTED FROM U.S. GEOL. SURVEY N.W. REGION MAP NO. 692

FIGURE 7. - Burke Ranch Field, Natrona County, Wyo.

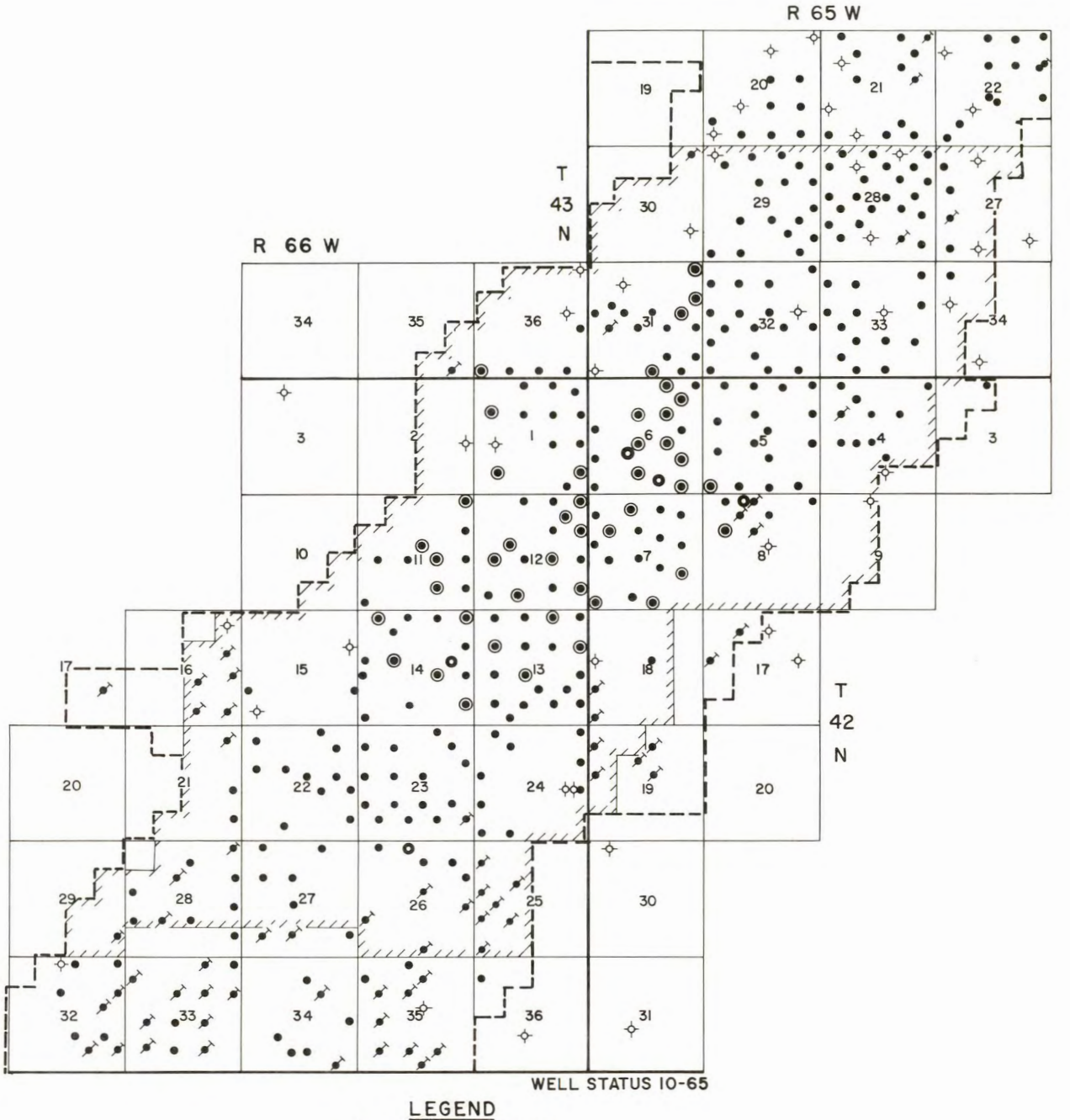


FIGURE 8. - Clareton Projects, Weston County, Wyo.

was completed in April 1953. Initial daily production by pumping was 206 barrels of 43.4° API gravity oil from the Newcastle Sandstone between 6,868 and 6,908 feet. As many as four separate oil-bearing zones have been reported in the Newcastle Sandstone in the Black Thunder field.

Reported initial daily production of wells in the field ranged from 17 to 2,328 barrels of oil. The average initial daily production was 378 barrels of oil. No water was produced with the oil from the Newcastle Sandstone.

Hampshire

Hampshire field has been designated as T 42 N, R 65 W, Weston County. The area is due east of the Black Thunder Creek field and south of the Clareton field. This area had previously been called the South Clareton field.

The first well was completed in the NE1/4 sec 6 on March 27, 1953. Initial flowing production was 2,040 barrels of oil per day from the Newcastle Sandstone. Two zones in the Newcastle sand (6,605 to 6,616 feet and 6,620 to 6,630 feet, respectively) were perforated in the well. The initial production of the 38 wells completed to the end of 1953 ranged from 50 to 2,040 barrels per day and averaged 475 barrels per day.

Pilot Waterfloods

Three separate pilot floods have operated in the Clareton area. The first, operated by True Oil Co., was started in late 1957 and later expanded into a full-scale flood. The second, operated by Otis Oil and Gas Corp., was started in November 1958. This project was taken over by Harry Thorson and discontinued in May 1964. The third, operated by Kirby Petroleum Co., was started in December 1959 and later expanded to a full-scale flood. The True and Kirby floods were combined into a single project operated by True. The combined project covers 22,000 acres and has an average pay thickness of 10 feet.

The Newcastle sand may contain more than one zone, but only the upper sand is present throughout the field. The zones have some fractures, although well tests and core analyses had not indicated such fractures. There is no gas cap. The initial reservoir producing mechanism was a solution gas drive.

Early appearance of injected water at some of the producing wells indicated poor oil recovery. Subsequently, an "imbibition-type" flood was started. Water is injected for a certain number of days, injection is stopped, and oil is then produced by flowback and pumping of injection wells. On January 1, 1968, the project area contained 28 producing

wells, 313 shut-in wells, and 34 injection wells. During December 1967 the daily average production was 348 barrels of oil and 845 barrels of water; daily average injection was 5,660 barrels of water at 2,800 psi.

Cumulative oil production to the start of injection was 13,925,000 barrels or 13.9 percent of the original oil in place. Cumulative oil production to January 1, 1968, was 14,747,461 barrels or 14.7 percent of the original oil in place. Of the 822,461 barrels of oil produced since injection was started, an estimated 800,000 barrels was recovered by fluid injection. Cumulative water injection to January 1, 1968, was 31,846,405 barrels. Available data indicate a successful project.

The Otis Oil and Gas Corp. pilot area in secs 4, 5, 8, and 9, T 43 N, R 63 W, covered 540 acres. The project operated until May 1964. A total of 1,313,316 barrels of water was injected. It is assumed that the project was not successful.

The Clareton-Thorson Newcastle sand unit was approved November 24, 1967. There was no report of activity by January 1, 1968.

Cole Creek

Cole Creek field, in T 35 N, R 77 W, Natrona County, was discovered in 1938 when a well in the C NW1/4SE1/4 sec 21 was completed in the Lakota sand at 7,978 to 8,016 feet. Initial daily production was 240 barrels of 35° API gravity oil. The Shannon Sandstone in the discovery well appeared to be oil stained and porous. In 1941 a well in the NW1/4 sec 21 was completed with an initial flowing production of 600 barrels of 36.3° API gravity oil per day from the Shannon sand at 4,530 to 4,570 feet. The Dakota Sandstone was proved oil productive in 1943. Most of the wells drilled to the Lakota were plugged back to the Dakota Sandstone because of excessive water production with the oil from the Lakota sand.

The Muddy sand was productive in a well in the C NE1/4NW1/4 sec 4 completed in March 1955. Initial production was 30 barrels of 40° API gravity oil per day. Cores of the Muddy Sandstone show it to have about 5 percent porosity and less than 1 millidarcy permeability.

A unit agreement for developing and operating the Cole Creek field was approved by the Secretary of the Interior on September 1, 1938.

Shannon Project

Shannon sand reservoir has an area of 1,653 acres and an average pay thickness of 17 feet. The operator decided that the producing bottom-hole pressure at the datum of 1,075 feet above sea level should be maintained at 600 psia or higher to increase the recovery of oil from the Shannon sand. In February 1946 injection of water into the

Shannon sand was begun to maintain the bottom-hole pressure. The flood pattern is essentially peripheral. Water is obtained from the Parkman sand.

On January 1, 1968, the project area contained 10 producing oil wells, five shut-in oil wells, 11 injection wells, and six shut-in injection wells. During December 1967 daily production was 755 barrels of oil and 2,660 barrels of water; daily water injection was 4,580 barrels at 328 psi.

Cumulative oil production to the start of injection was about 1,178,150 barrels or 5.8 percent of the original oil in place. Cumulative oil production to January 1, 1968, was 8,503,296 barrels or 40.6 percent of the original oil in place. Cumulative water injection to January 1, 1968, was 10,759,000 barrels. Probably one-half of the 7,325,146 barrels of oil produced since the start of injection could be credited to fluid injection, although the project was for pressure maintenance. Available data indicate a successful project.

Dakota Project

Dakota participating area "A" in secs 22, 23, 26, and 27, as approved March 1, 1965, contains about 995 acres. Effective pay thickness ranges from 2 to 20 feet. A pilot injection program using three wells in the south part of the area began in 1965. Injection water comes from the Shannon project.

During December 1967 seven oil wells and two injection wells were operating. Daily production from area "A" was 1,764 barrels of oil and 765 barrels of water; injection was 3,905 barrels of water at pressures ranging from 0 to 525 psi. Cumulative injection to January 1, 1968, was 2,770,505 barrels.

Oil production from the Dakota "A" area for 1966 and 1967 amounted to 379,038 barrels. The project is too new to evalute.

South Cole Creek

South Cole Creek field is in secs 5-8, 16-20, T 34 N, R 76 W, and secs 31 and 32, T 35 N, R 76 W, Converse County. The first well on the structure was drilled in 1942 to 7,214 feet in the Frontier Formation. It was abandoned after testing of a noncommercial show of oil in the Shannon sand. Unit well No. 1 in the SW1/4SW1/4NW1/4 sec 17 was completed in September 1948 for an initial flowing production of 375 barrels of oil per day from the Lakota sand. The productive interval was 8,288 to 8,320 feet. Oil-saturated zones in the Dakota sand were logged in the first wells drilled at South Cole Creek field. Unit well No. 5 in the SW1/4SW1/4SW1/4 sec 8 recovered water on tests of the Lakota Formation.

It was plugged back to the Dakota sand from 8,309 to 8,339 feet and completed in June 1950. Initial production was 85 barrels of oil per day.

During October 1951 a well in the SW1/4NE1/4NW1/4 sec 19 was completed for an initial production of 140 barrels of oil from the Muddy sand. The producing zone was 9,013 to 9,031 feet. Both the Dakota and Lakota sands contained water in this well.

The South Cole Creek unit plan was approved by the Secretary of the Interior on April 7, 1948. As the field was developed, 15 wells were completed outside the unit.

The two Lakota producing areas were designated the Lakota "A" and the Lakota "B" areas. A waterflood project was started in the Lakota "A" area by Phillips Petroleum Corp.

The Lakota "A" reservoir covers about 470 acres and has an average pay thickness of about 20 feet. The producing mechanism is a natural water drive.

The water injection project, using produced water from the Lakota Formation, was started in October 1960 to supplement the active water drive. Water was injected into one well at the north end of the project area. In 1965 an injection well was added at the south end. On January 1, 1968, the project area contained five producing oil wells and two injection wells. During December 1967 the daily average production was 244 barrels of oil and 1,331 barrels of water; daily average water injection was 660 barrels. The injection pressure was 1,500 psi for the north well and 0 for the south well.

Cumulative oil production to the start of injection was 3,310,000 barrels or 36 percent of the original oil in place. Cumulative oil production to January 1, 1968, was 4,644,400 barrels or 50.4 percent of the original oil in place. Of the 1,334,400 barrels of oil produced since the start of injection, an estimated 613,000 barrels was recovered by water injection. Cumulative water injected to January 1, 1968, was 1,839,500 barrels. Available data indicate a successful project.

Cooper Cove

Cooper Cove oilfield is in secs 7, 17-20, T 18 N, R 77 W, Carbon County. The field was discovered in 1944 when the No. 1 Johnson-Parkinson well (NW1/4SW1/4 sec 20) was completed for an initial daily production of 153 barrels of 33.4° API gravity oil from the Dakota Group.

The No. 1 USA-Chorney, the first Muddy sand well, was completed in June 1963 for an initial daily production of 121 barrels of oil and 7 barrels of water. In the following 14 months, 10 Muddy sand producing

wells and three dry holes were drilled. Six of the 11 Muddy wells were commingled with the Dakota; one Dakota well was a single completion.

The Muddy sand averages about 16 feet in thickness on the structure, but only 10 feet is considered as effective pay. The porosity of the Muddy sand averages 14.5 percent and permeability averages 32 millidarcys. The producing mechanism was fluid expansion, and about 9 percent of the oil in place was recoverable by primary methods. Waterflooding should recover an additional 12 percent of the oil in place.

The Cooper Cove Muddy sand waterflood unit was approved April 27, 1967, with Pan American Petroleum Corp. as operator. A water supply well was drilled, surface and plant equipment installed, and water injection started on October 13, 1967. About 900 barrels per day of Dakota-produced water is available for injection. By January 1, 1968, a total of 116,485 barrels had been injected. Injection pressures ranged from 1,200 to 2,350 psi.

Three Muddy injection, five Muddy producing, and six Dakota producing wells were in the unit. Because the oil production is commingled, only total production is available. In December 1967 daily production was 177 barrels of oil and 826 barrels of water. Cumulative field (Muddy and Dakota) production to January 1, 1968, was 1,130,565 barrels of oil and 5,515,937 barrels of water. The outcome of the project is indeterminate.

Cottonwood Creek

Cottonwood Creek oilfield (fig. 9) is in Washakie County, a few miles southwest of Hidden Dome field. The discovery well, the No. 1 unit, in the C SW1/4SW1/4 sec 2, was completed August 29, 1953. Initial production by pumping was 205 barrels of 27.5° API gravity oil from the Phosphoria lime at 7,270 to 7,323 feet. The well had been acidized with a total of 12,000 gallons. Original bottom-hole pressure was reported as 3,330 psia at a datum of minus 1,450 feet, and the solution gas-oil ratio was 450 cubic feet per barrel. Gas produced with the oil contains hydrogen sulfide in quantities ranging from 1 to 3 percent.

As approved on February 11, 1953, the Cottonwood Creek unit contained 32,979 acres. The unit area was expanded in May 1957 and again in May 1958 and then contracted in April 1960 (6). As of January 1, 1968, the field covers 14,227 acres and has an average pay thickness of 20 feet. The producing zone, in the upper part of the Phosphoria Formation, was at a depth of 5,000 feet on the east edge of the field and 10,000 feet on the west side.

A gas injection project to maintain reservoir pressure was approved in March 1958 and started in June. Residue gas from a gasoline plant in

the field was injected into five wells on the crest of the structure in the northeast sector of the field. In 1961 gas injection was moved to wells located halfway down structure.

A pilot water injection project with water from a well completed in the Muddy Formation was started in October 1959 and later expanded to a fieldwide flood. Water was first injected on the crest of the structure and later halfway down structure. Late in 1962 the produced gas-oil ratios began to decline. The gas and water injection program was increasing reservoir pressure. Gas injection was stopped in late 1964, when oil production declined instead of increasing. A detailed study of the field was made (7).

The field was divided into three areas. Areas I and III appeared to respond to normal water injection. Area II had too many fractures to permit normal flooding. "Flow-back" or "imbibition" was started in Area II. When gas injection was stopped, 21,878 million cubic feet had been injected. On January 1, 1968, the project contained 65 producing wells, seven water injection wells, and one water supply well. During December 1967 the daily production was 3,657 barrels of oil, 3,256 barrels of water, and 2,361,000 cubic feet of gas. Daily average injection rate was 4,685 barrels of water at 895 psi.

Cumulative oil production at the start of gas injection was 9,421,000 barrels, and at the start of water injection was 13,102,000 barrels or 5.1 percent of the original oil in place. Cumulative oil production to January 1, 1968, was 24,438,256 barrels or 13.2 percent of the original oil in place. A total of 15,017,256 barrels of oil has been produced since the start of water injection. About 1,500,000 barrels of oil is credited to the fluid injection program. Cumulative water injection was 31,887,000 barrels or 9.4 percent of the water required. The project is a success.

Crooks Gap

Crooks Gap oilfield is in secs 18 and 19, T 28 N, R 92 W, and secs 12 and 13, T 28 N, R 93 W, Fremont County. As early as 1925 a well drilled on the Crooks Gap structure reportedly produced 40 barrels of oil per day from the Frontier Formation. Not until 1944, however, was commercial oil production realized. The discovery well was completed in the NW1/4 sec 18 with an initial daily production of 1,478 barrels of oil from the Lakota Sandstone at 5,275 feet. In 1947 oil was discovered in the Muddy sand. Oil was found in the Fourth Frontier sand in February 1956 and in the Nugget sand in May 1956.

A unit agreement for the field was approved by the Acting Secretary of the Interior on October 15, 1937. Participating areas for each zone were approved later.

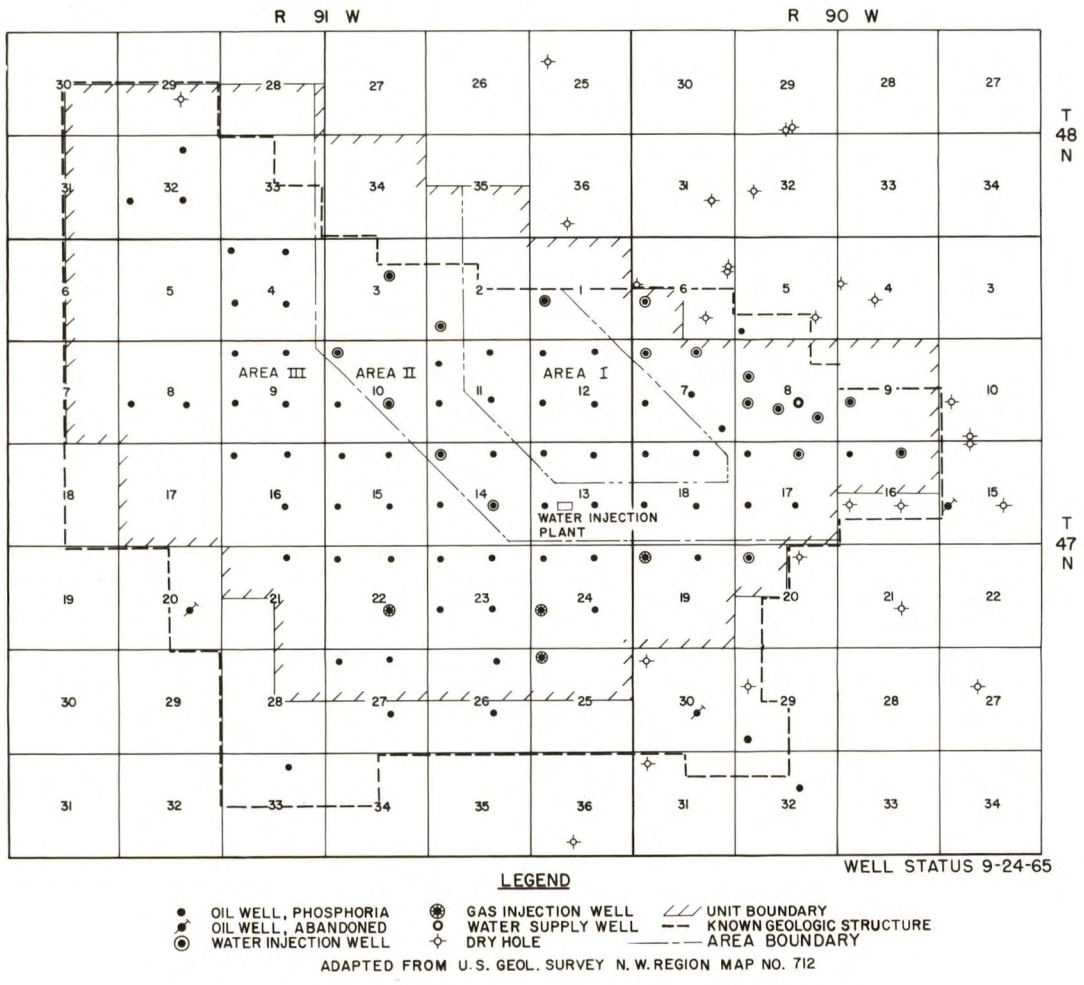


FIGURE 9. - Cottonwood Creek Field, Washakie County, Wyo.

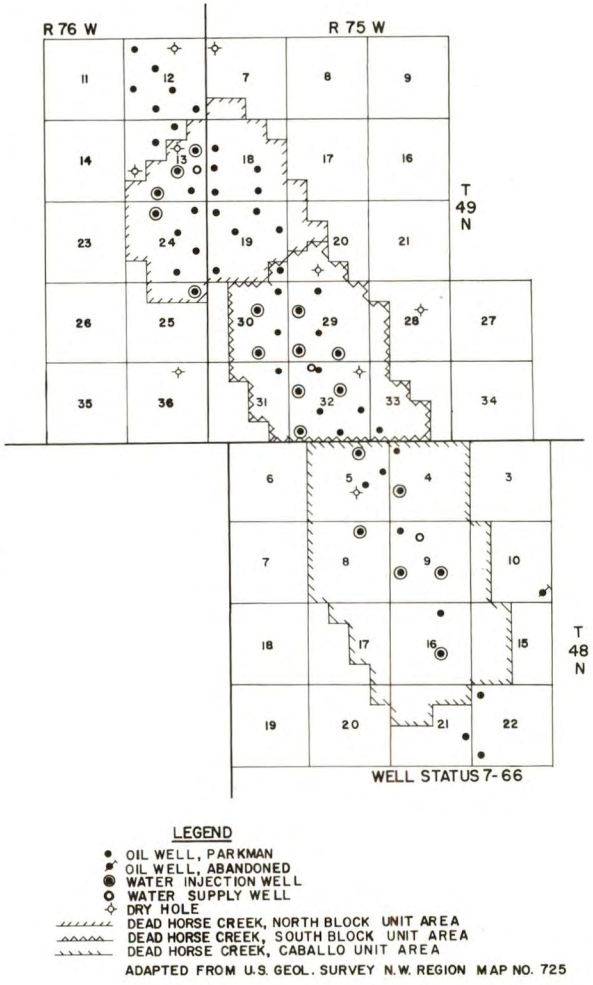


FIGURE 10. - Dead Horse Creek Field, Campbell County, Wyo.

Frontier Project

Frontier reservoir covers 70 acres with an average pay thickness of 30 feet. Injection in one well began on February 1, 1965. On January 1, 1968, the project area contained two producing wells and two injection wells. During December 1967 the daily production was 43 barrels of oil and 158 barrels of water. Daily injection was 486 barrels of water at 1,550 psi.

Cumulative oil production to January 1, 1968, was 241,300 barrels and recovery after injection started was 52,600 barrels. Cumulative injection to the end of 1967 was 422,000 barrels of water. Produced water is used for injection. Because of an increase in oil production, the project is considered successful.

Muddy Project

Water injection in Muddy reservoir began September 9, 1966, using produced water. The Muddy reservoir covers 280 acres with an average pay thickness of 11 feet. On January 1, 1968, the project contained two producing wells and one injection well. Unit well No. 4 is used as a dual injection well for the Frontier and Muddy zones. During December 1967 the daily production was 56 barrels of oil and 39 barrels of water.

Cumulative oil production to 1968 was 518,300 barrels. Production after injection started was 22,890 barrels of oil. Cumulative water injection to the end of 1967 was 68,500 barrels of water. Oil production almost doubled in 1967 indicating a successful project.

Lakota Project

Lakota reservoir covers 320 acres and has an average pay thickness of 38 feet. Water injection was started in one well on August 1, 1964, using produced water. On January 1, 1968, the project area contained six producing wells and one injection well. During December 1967 the daily production was 238 barrels of oil and 4,982 barrels of water; daily injection was 5,144 barrels of water at 120 psi.

Cumulative oil production to the end of 1967 was 9,307,700 barrels, and oil recovery since start of injection was 377,780 barrels. Cumulative water injection to 1968 was 5,061,000 barrels. The low injection pressure indicates only partial fillup in the reservoirs. There appears little or no reaction to the flood.

Dead Horse Creek

Dead Horse Creek oilfield (fig. 10) is in T 48 N, R 75 W, and T 49 N, Rs 75 and 76 W, Campbell County. The discovery well in the SE1/4SE1/4

sec 13, T 49 N, R 76 W, was completed by Farmers Union Central Exchange, Inc., in July 1957. Initial daily production was 329 barrels of oil and 58 barrels of water from the upper Parkman (locally called Ferguson) Sandstone from 6,968 to 6,981 feet. This was the first oil production from the Mesaverde Group in the Powder River Basin.

About 66 oil wells were completed in the Dead Horse Creek field. Initial daily oil production ranged from 20 to 459 barrels. The average of 56 wells was 194 barrels of oil per day per well. Gravity of the crude oil is reported to be 37° and 38° API.

The three waterflood projects and their operators are as follows: The North Block unit by Farmers Union Central Exchange, Inc., unitized in October 1961; the South Block unit by Chevron Oil Co., unitized in August 1961; and the Caballo unit by Humble Oil and Refining Co., unitized in May 1963. All three units are in the same reservoir, but faults in secs 13 and 25, T 49 N, R 76 W, may separate the reservoir into three areas. Injection water for all projects is obtained from the Fort Union Formation and some additional water for the South Block unit from the Lance Formation.

North Block Unit

North Block unit reservoir covers 2,100 acres and has an average pay thickness of 15 feet. The primary producing mechanism was a gas expansion drive.

A pilot water injection project was started in July 1962. Formation of an oil bank was in doubt because of the reservoirs high connate water saturation (45 percent). After an oil bank formed, expansion to a full-scale waterflood was approved and commenced in October 1964. The water is injected at the oil-water contact on the west side of the reservoir. On January 1, 1968, the project area contained 13 producing wells, five injection wells, two shut-in wells, and one water supply well. During December 1967 the daily production was 311 barrels of oil and 59 barrels of water; daily water injection was 537 barrels at 2,900 psi.

Cumulative oil production to the start of injection was 882,675 barrels or 5 percent of the original oil in place. Cumulative production to January 1, 1968, was 1,566,161 barrels or 8.9 percent of the original oil in place. Of the 683,486 barrels of oil produced since the start of injection, an estimated 400,000 barrels was produced by fluid injection. Cumulative water injection to January 1, 1968, was 1,146,700 barrels. Available data indicate a successful project.

South Block Unit

South Block unit reservoir covers 2,200 acres and has an average pay thickness of 24 feet. The unit is between the Caballo and North Block units.

A pilot water injection project was started as a one-well operation in August 1961 and subsequently expanded. The injection pattern is a five-spot. Source of the water is a well (NE1/4NW1/4 sec 32, T 49 N, R 75 W) completed in the Fort Union and Lance Formations. On January 1, 1968, the project area contained nine producing wells, nine injection wells, and one water supply well. During December 1967 the daily average production was 417 barrels of oil and 515 barrels of water; daily injection rate was 1,095 barrels of water at 2,870 psi.

Cumulative oil production to the start of injection was 1,303,000 barrels or 4 percent of the original oil in place. Cumulative oil production to January 1, 1968, was 2,542,363 barrels or 7.8 percent of the original oil in place. Of the 1,239,363 barrels of oil produced since the start of injection, an estimated 720,000 barrels was recovered by fluid injection. Cumulative water injection to January 1, 1968, was 4,254,000 barrels. Available data indicate a successful project.

Caballo Unit

Caballo unit reservoir covers 2,340 acres and has an average pay thickness of 10 feet. The participating area includes 4,280 acres and reflects almost 100 percent common ownership of the mineral rights. The unit is south of the South Block unit.

A water injection project was started in June 1963. Water from the Fort Union Formation was injected into four wells. The flood pattern is a five-spot. On January 1, 1968, the project area contained seven producing wells, seven injection wells, and one water supply well. During December 1967 the daily average production was 317 barrels of oil and 74 barrels of water; daily water injection was about 1,690 barrels at 1,790 psi.

Cumulative oil production to the start of injection was 660,000 barrels or about 6.5 percent of the original oil in place. Cumulative oil production to January 1, 1968, was 1,476,752 barrels or 14.5 percent of the original oil in place. Of the 816,752 barrels of oil produced since the start of injection, an estimated 595,000 barrels was recovered by fluid injection. Cumulative water injection to January 1, 1968, was 3,690,000 barrels. Available data indicate a successful project.

Dillinger Ranch

Dillinger Ranch oilfield is in secs 6-8, T 47 N, R 69 W, and secs 1 and 12, T 47 N, R 70 W, Campbell County. Oil was discovered in March 1964 when Tenneco Oil Co.'s No. 1 A-USA-Helen V. Smith, SW1/4NE1/4 sec 7, was completed for an initial production of 299 barrels per day. The productive zone was the Minnelusa from 9,132 to 9,165 feet. One-well-per-80-acre spacing was approved for the field. Fifteen additional oil wells were completed by the end of 1965, and the field was defined. In the original wells 4-1/2-inch casing was used, but flowage from a salt zone 300 to 500 feet above the Minnelusa caused the casing to collapse and five wells to be abandoned by the end of 1967. Heavier 5-1/2-inch casing, therefore, was used in later wells.

Porosity is spotty in the sandstone, and several wells were perforated at two or more depths. Water production was no problem in the field. The producing mechanism was essentially fluid expansion. Effective pay thickness is about 30 feet, porosity is 16.8 percent, and permeability measures about 100 millidarcys.

The Dillinger Ranch waterflood unit was approved and injection begun in December 1966. Three injection wells on the west side of the field were used to form a line drive.

Cumulative oil production at the start of injection was 1,601,233 barrels. During 1967, 433,547 barrels of oil and 10,295 barrels of water were produced. Twelve producing wells and four injection wells were used. Injection during 1967 was 481,000 barrels at an average pressure of 2,600 psi.

Water supply is obtained from a dry hole in sec 8, recompleted in the Fox Hills Formation at about 3,000 feet. The project is too new to evaluate.

Elk Basin

The Elk Basin oil and gas field (fig. 11) is in the north end of the Bighorn Basin in Tps 57 and 58 N, Rs 99 and 100 W, Park County, Wyo., and in T 9 S, R 23 E, Carbon County, Mont. The discovery well in the NW1/4NW1/4 sec 30, T 58 N, R 99 W, completed in 1915, had an initial daily production of 50 barrels of oil from the Torchlight (First Frontier) sand at 1,335 to 1,402 feet. Later, oil was discovered in the Peay (Second Frontier) sand, approximately 135 feet below the Torchlight sand. Because the Torchlight sand is shaly and relatively nonporous, oil is found only in scattered areas where porosity permits accumulation. The Peay sand, a porous, uniform sand, yields most of the (Frontier) oil. The average initial daily production of the Peay wells was 175 barrels of 43° API gravity green oil.

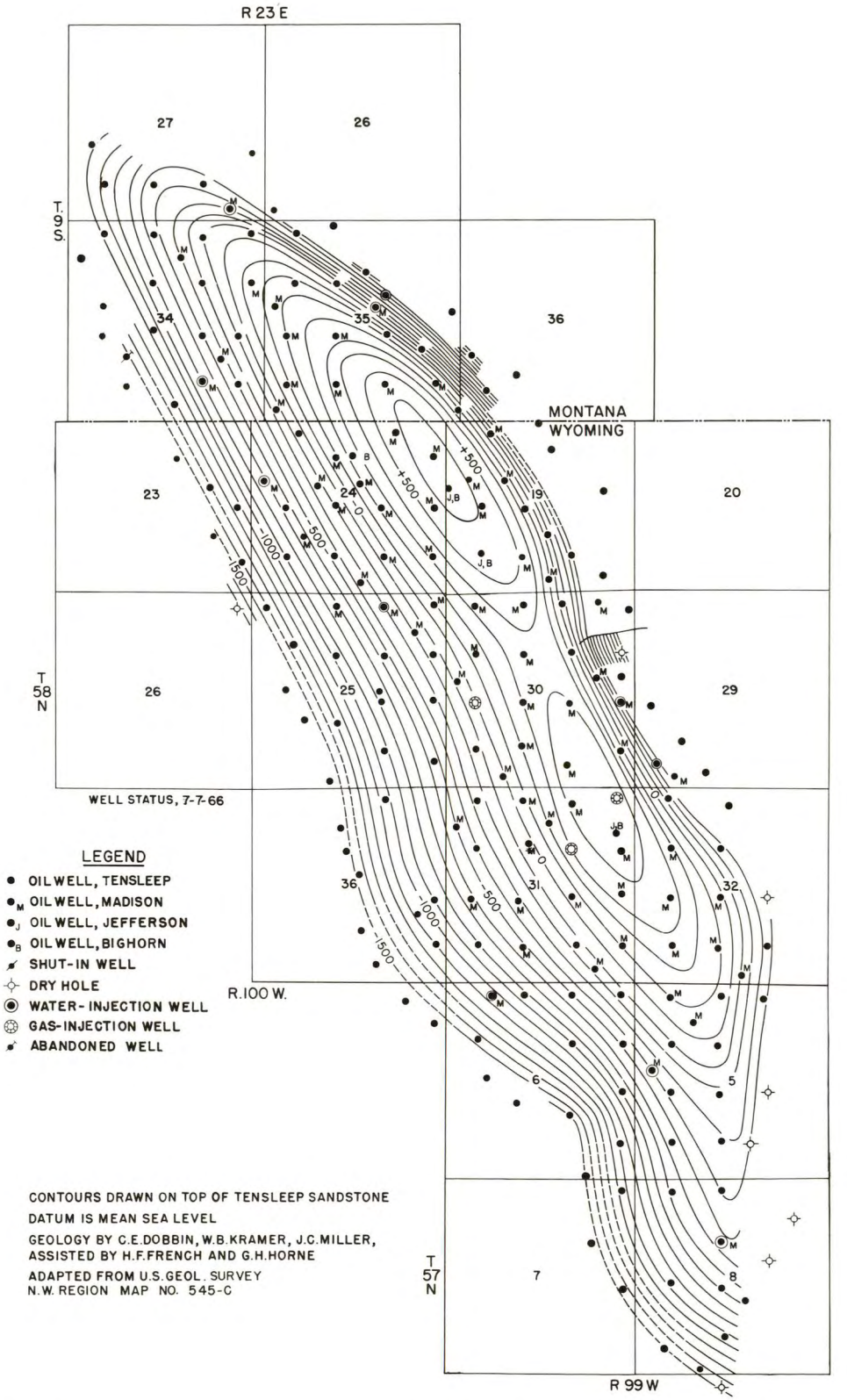


FIGURE 11. - Structure Contour Map of Elk Basin Field, Park County, Wyo., and Carbon County, Mont.

In 1922 gas was discovered in the Cloverly Formation at 2,576 to 2,593 feet, approximately 1,000 feet below the Second Frontier sand, in a well in the NE1/4SE1/4 sec 24, T 58 N, R 100 W.

In 1927, after a rapid oil production decline for several years, a gas drive was started in the Second Frontier sand by returning the gas produced to the formation. As a result, the daily production of oil increased from 600 to 1,100 barrels and later declined, but more gradually than before gas was injected.

In 1942 oil was discovered in the Tensleep Sandstone in a well in the NE1/4NE1/4 sec 31, T 58 N, R 99 W. Initial production was 2,500 barrels of 30.2° API gravity black oil in 24 hours from the Tensleep at 4,492 to 4,538 feet. It was the largest single reserve of oil discovered in the United States that year. Intensive field development followed the discovery. The gas produced with the oil contained hydrogen sulfide.

In 1946 a well in the NE1/4SE1/4NE1/4 sec 24, T 58 N, R 100 W, on the crest of the structure, was deepened to the Madison Limestone and produced 240 barrels of oil per day from a zone at 4,680 to 4,911 feet. The gas from the Madison also contains hydrogen sulfide.

Oil was discovered in the Jefferson (Devonian) and Bighorn (Ordovician) Formations in November 1961. Zones in the Flathead Formation and granite tested mostly water. Soon after completion both the Jefferson and Bighorn zones began producing water. Oil reserves in these zones are thought to be rather small.

In May 1946, with the approval of the Secretary of the Interior, the 29 working interests unitized all productive horizons below the Sundance and appointed Pan American Petroleum Corp. as unit operator. Studies conducted before unitization indicated that some form of pressure maintenance was desirable. It was apparent, however, that the sweetening and extraction processes would leave too little residue gas for injection and enough outside gas or water was not economically available. To overcome these problems, the gas was burned and inert combustion gases were injected into the reservoir.

The high hydrogen sulfide content of the gas makes obligatory elaborate safety precautions to avoid injuries to field personnel.

Oil produced at Elk Basin was 19,800,000 barrels in 1967, bringing the cumulative production to over 328 million barrels. Well status (for all zones) for January 1, 1968, was 160 oil wells, five gas wells, 118 shut-in oil wells, 21 water injection wells, and three gas injection wells.

Madison Project

Madison reservoir covers 5,097 acres and has an average pay thickness of 336 feet.

A pilot waterflood started in August 1960 was expanded to a full-scale waterflood in July 1961. The project, initially a pressure maintenance operation, was changed to a full-scale secondary operation. Fresh water from the Clark Fork River and produced Madison water are used for injection. The peripheral injection pattern was changed to a line drive.

On January 1, 1968, 74 producing oil wells and 17 active injection wells were in the Madison Formation. Daily production was 21,451 barrels of oil and 36,114 barrels of water. Daily injection was about 35,200 barrels of water at 1,600 psi.

Cumulative oil production to the start of injection was 39,157,000 barrels or 3 percent of the original oil in place. Cumulative oil production to January 1, 1968, was about 74,513,000 barrels or 5.7 percent of the original oil in place and 35,356,000 barrels since injection started. Cumulative injection for the same period was 63,771,000 barrels of water or about 4.1 percent of the estimated water requirements. Available data indicate a successful project.

Frontier Project

In June 1966 water injection was started in three Second Frontier sand wells. The pilot project is to determine whether or not waterflooding will be successful following the earlier gas injection in this zone.

Cumulative water injection on January 1, 1968, was 1,681,968 barrels, and the rate was 6,100 barrels per day at about 250 psi. Exactly how much of the reservoir should be included in the pilot effort was not determined. Daily production in December 1967 from the Wyoming part of the reservoir was 80 barrels of oil and 69 barrels of water.

Complete production records were not available, but the cumulative production to January 1, 1968, is estimated to be 12,684,000 barrels of oil and 132,000 barrels of water. There were 18 producing and three injection wells.

South Elk Basin

South Elk Basin field is in secs 17 and 19-21, T 57 N, R 99 W, Park County. The field was discovered in June 1945 when a well was completed in the SE1/4SW1/4 sec 20 that had an initial daily production of 350 barrels

of 29° API gravity oil from the Tensleep Sandstone between 6,975 and 7,135 feet. Tests of some of the upper zones showed gas. Subsequently, one Morrison and two Dakota gas wells were completed; initial production ranged from 5 to 17 million cubic feet of gas per day. Sixteen Tensleep oil wells have been completed at South Elk Basin. The Amsden and Madison Formations have not been tested. Green oil in the Frontier Formation was discovered in a well in the NE1/4SE1/4 sec 19 in February 1951. Eleven additional wells have been completed in the Frontier Formation; of these, nine were oil wells and two were gas wells.

The Tensleep reservoir has an area of 520 acres and an average pay thickness of 76.6 feet.

Water injection was started in May 1962 by Continental Oil Co. to aid the limited natural water drive in the Tensleep reservoir. Produced water is injected below the oil-water contact in the SE1/4NW1/4 sec 5. On January 1, 1968, the project area contained nine producing wells, three shut-in wells, and one water injection well. During December 1967 the daily average production was 1,259 barrels of oil and 3,076 barrels of water; daily average injection was 5,264 barrels of water at 100 psi.

Cumulative oil production to the start of injection was 7,549,765 barrels or about 21.9 percent of the original oil in place. Cumulative oil production to January 1, 1968, was 10,354,434 barrels or 30 percent of the original oil in place. Of the 2,804,669 barrels of oil produced since injection started, an estimated 1,318,000 barrels was recovered by fluid injection. Cumulative injection to January 1, 1968, was 5,977,000 barrels of water. Available data indicate a successful project.

Fiddler Creek

Fiddler Creek oilfield (fig. 12) is in secs 17-20 and 30, T 46 N, R 64 W, secs 12-16, 19-32, T 46 N, R 65 W, secs 24-26, 34-36, T 46 N, R 66 W, and sec 3, T 45 N, R 66 W, Weston County, about 2 miles west of Osage field. Oil was discovered in the Fiddler Creek field in October 1948 with completion of a well in the NW1/4NE1/4SW1/4 sec 19, T 46 N, R 64 W, for an initial flowing production of 375 barrels of oil per day from the Newcastle Formation at 4,498 to 4,510 feet. The majority of the 254 wells drilled in the field were completed during 1949-51.

Fiddler Creek field was developed rapidly, but the producing rate for the field declined very fast, indicating a fluid expansion drive.

Engineers from the U.S. Bureau of Mines studied the Newcastle Sandstone to determine in the laboratory if water injection would be feasible (1). The sandstone was found to have 23-percent porosity, 68-millidarcy permeability, and 30-percent connate water saturation.

Flood tests in the laboratory showed that a brine solution would recover 9 percent more oil from the samples than would fresh water. Although these tests disclosed some swelling clays in the Newcastle sand, they did not indicate that use of fresh water would fail.

Fiddler Creek Unit

Fiddler Creek unit (fig. 12), which has an area of 2,888 acres, was unitized on June 1, 1955. Actual water injection was begun in mid-July 1955. By September 1955, daily water injection averaged 1,609 barrels through three wells.

A well for water supply was drilled to the Madison Formation in 1956 and completed for an initial daily production of 11,000 barrels. It is reported that the temperature of this water is 135° F., or about 15° higher than the temperature recorded in the Newcastle Formation. In February 1957 injection was started in eight additional wells. By July 1957 the daily injection rate had risen to about 6,000 barrels. The injection pattern is peripheral. On January 1, 1968, the project area contained 15 producing wells, eight injection wells, 35 shut-in wells, and one water supply well. During December 1967 daily average production was 646 barrels of oil and 3,108 barrels of water; daily injection was about 8,300 barrels at 2,260 psi.

Cumulative oil production to the start of injection was 3,422,605 barrels or about 13 percent of the original oil in place. Cumulative oil production to January 1, 1968, was 9,468,812 barrels or 35.9 percent of the original oil in place. Of the 6,046,000 barrels of oil produced since the start of injection, an estimated 5,600,000 barrels was recovered by fluid injection. Cumulative water injected to January 1, 1968, was 40,542,000 barrels. The project has been operated 10-1/2 years and is a success.

West Fiddler Creek Unit

West Fiddler Creek reservoir covers 5,207 acres and has an average pay thickness of 5.8 feet.

Water injection started in 1960 in the eastern part of the unit and was expanded in 1962. In 1963 the Wyoming Oil and Gas Commission approved the drilling of three injection wells on the west boundary of the unit to prevent the movement of oil from the unit area. The injection pattern is a modified line drive. On January 1, 1968, the project area contained 38 producing wells, 20 injection wells, 33 shut-in wells, and one water supply well. During December 1967 the daily average production was 1,475 barrels of oil and 11,673 barrels of water; daily average injection was 21,546 barrels at 2,000 psi.

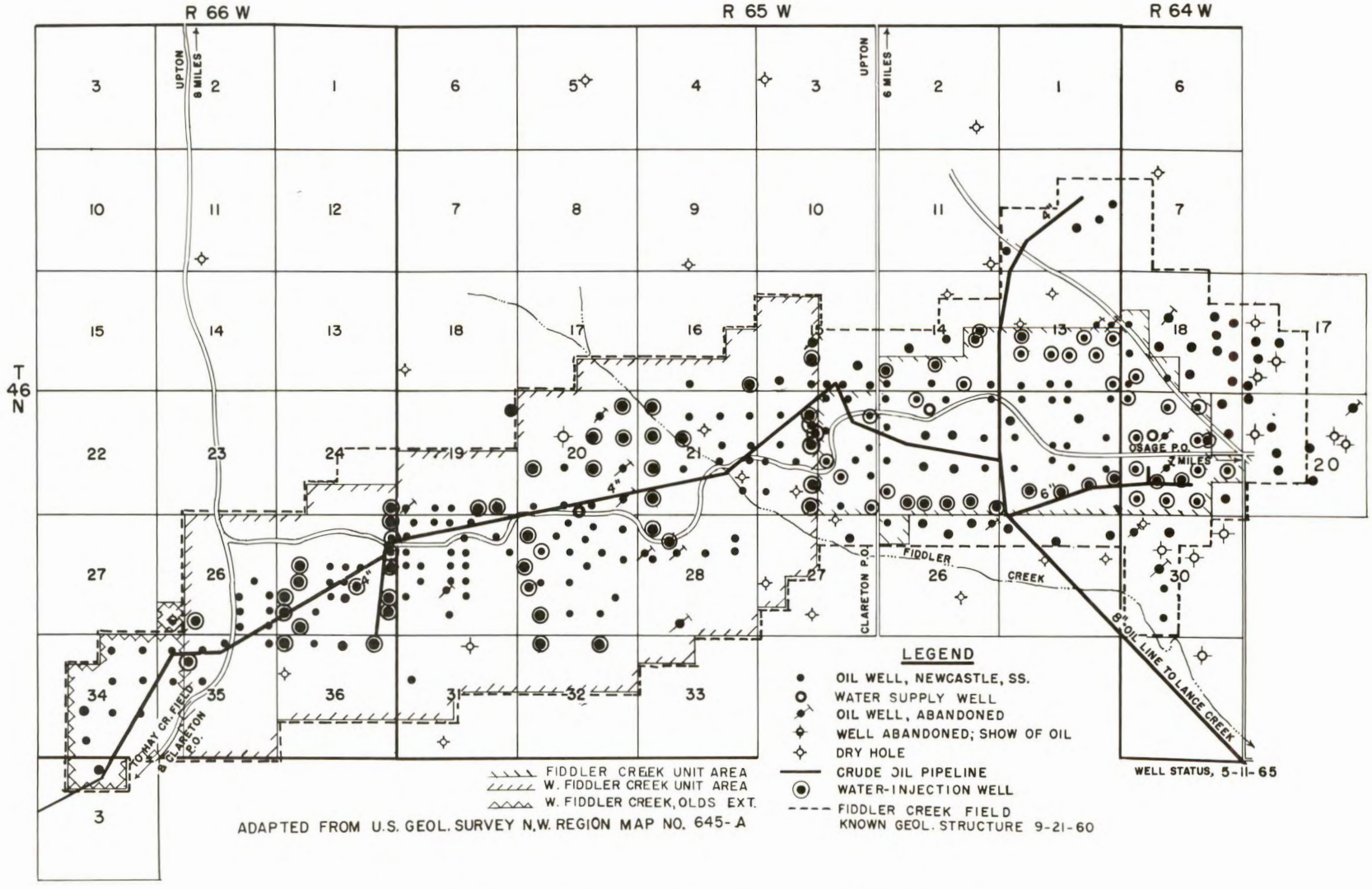


FIGURE 12. - Fiddler Creek Field, Weston County, Wyo.

Cumulative oil production to the start of injection was 5,536,300 barrels or 16 percent of the original oil in place. Cumulative oil production to January 1, 1968, was 9,947,058 barrels or 28.6 percent of the original oil in place. All of the 4,410,744 barrels of oil produced since the start of injection is credited to fluid injection. The unit wells were considered to be at the economic limit when flooding began. Cumulative water injection to January 1, 1968, was 46,186,000 barrels. The project has been operated 6 years and is a success, although recovery is less than expected.

Garland

Garland field is in Tps 55 and 56 N, Rs 97 and 98 W, Park and Big Horn Counties. The first well in the Garland field, drilled in 1906 in the NE1/4SE1/4 sec 33, T 55 N, R 97 W, disclosed 42° API gravity light oil in the Peay sand of the Frontier Formation at 624 feet. From then until 1921 more than 30 wells were drilled to this sand. In 1915 a well in the NW1/4SE1/4 sec 33 produced 28 million cubic feet of sweet gas per day from the Lakota at 1,842 to 1,868 feet.

Fifteen gas wells were completed in the Cloverly Formation; initial daily gas volume ranged from 20 to 30 million cubic feet, and shut-in wellhead pressure ranged from 500 to 650 psi. One well, with a daily open-flow volume of 1-1/4 million cubic feet and a shut-in wellhead pressure of 220 psi, was completed in the Morrison Formation at 1,945 feet; this well later was deepened to the Madison Limestone. A well was also tested in the Chugwater Formation from 2,593 to 2,615 feet, and an open-flow volume of 6 million cubic feet of gas per day was obtained. In 1927 gas was discovered in the "Embar Limestone"[4/] from 3,060 to 3,165 feet in a well in the NE1/4NW1/4 sec 33. The well could produce 40 million cubic feet of gas per day; the shut-in wellhead pressure was 1,415 psi.

The gas from the "Embar Limestone" and Tensleep Sandstone contains hydrogen sulfide. In September 1930 oil and gas were discovered in a well in the NW1/4NW1/4 sec 33 in a porous zone of the Madison Limestone from 3,970 to 4,264 feet, about 400 to 600 feet below the top of the Madison. The discovery well produced about 2,500 barrels of 19° API gravity black oil and 8 million cubic feet of sour gas per day; the shut-in wellhead pressure was 1,470 psi.

4/ In this paper, "Embar" refers to all beds between the base of the Chugwater Formation and the top of Tensleep Sandstone, or the Embar established by Darton (1906). The term is considered obsolete according to modern nomenclature; however, Embar is part of the name of some fields and units. Records and logs of wells drilled before World War II were not available to pick the Phosphoria Formation top. For these reasons, Embar is employed herein. Geologically, "Phosphoria" would be the more accurate term.

In 1940 oil was discovered in the Amsden Formation in a well in lot 53F, sec 34; the well was completed for an initial production of 100 barrels of oil per day from 4,026 to 4,060 feet.

A conditional unit operating agreement for the southern part of the Garland field was approved by the Secretary of the Interior on July 25, 1935, and a unit plan for the development and operation of the northwest part of the field was approved on July 6, 1936.

Tensleep Project

Marathon Oil Co. started a water injection project in the Tensleep Formation in 1958. Water for injection is produced water from the Madison Formation.

The Tensleep reservoir appears to be separated into three sections from north to south. The middle section had a rapid decline in pressure, indicating a solution gas drive. The north and south sections appeared to have a partial natural water drive. The project is listed as pressure maintenance.

The reservoir covers 1,508 acres and has an average pay thickness of about 59 feet. On January 1, 1968, the project area contained 37 producing wells, three injection wells, and eight shut-in wells. During December 1967 the average daily production was 2,523 barrels of oil and 2,900 barrels of water; daily injection was 2,250 barrels at 450 psi.

Cumulative oil production to the start of injection was 12,800,000 barrels or 15 percent of the original oil in place. Cumulative oil production to January 1, 1968, was 24,120,000 barrels or 29 percent of the original oil in place. Cumulative water injection to January 1, 1968, was 11,065,000 barrels. Available data indicate a successful project, which may be expanded to cover more of the reservoir.

Embar Project

A pilot project to maintain reservoir pressure by water injection was started in December 1966. By January 1, 1968, 507,293 barrels had been injected through five wells. Production in December 1967 averaged 816 barrels of oil and 391 barrels of water per day from 34 wells.

South Glenrock

South Glenrock oilfield (fig. 13), in T 33 N, Rs 75 and 76 W, Converse County, joins the Big Muddy field on the east and is about half-mile south of the Glenrock field. The field was discovered in July 1950 when a well was completed in the SW1/4SW1/4SE1/4 sec 7 at 5,880 feet in the Dakota Sandstone for an initial daily production of 185 barrels of

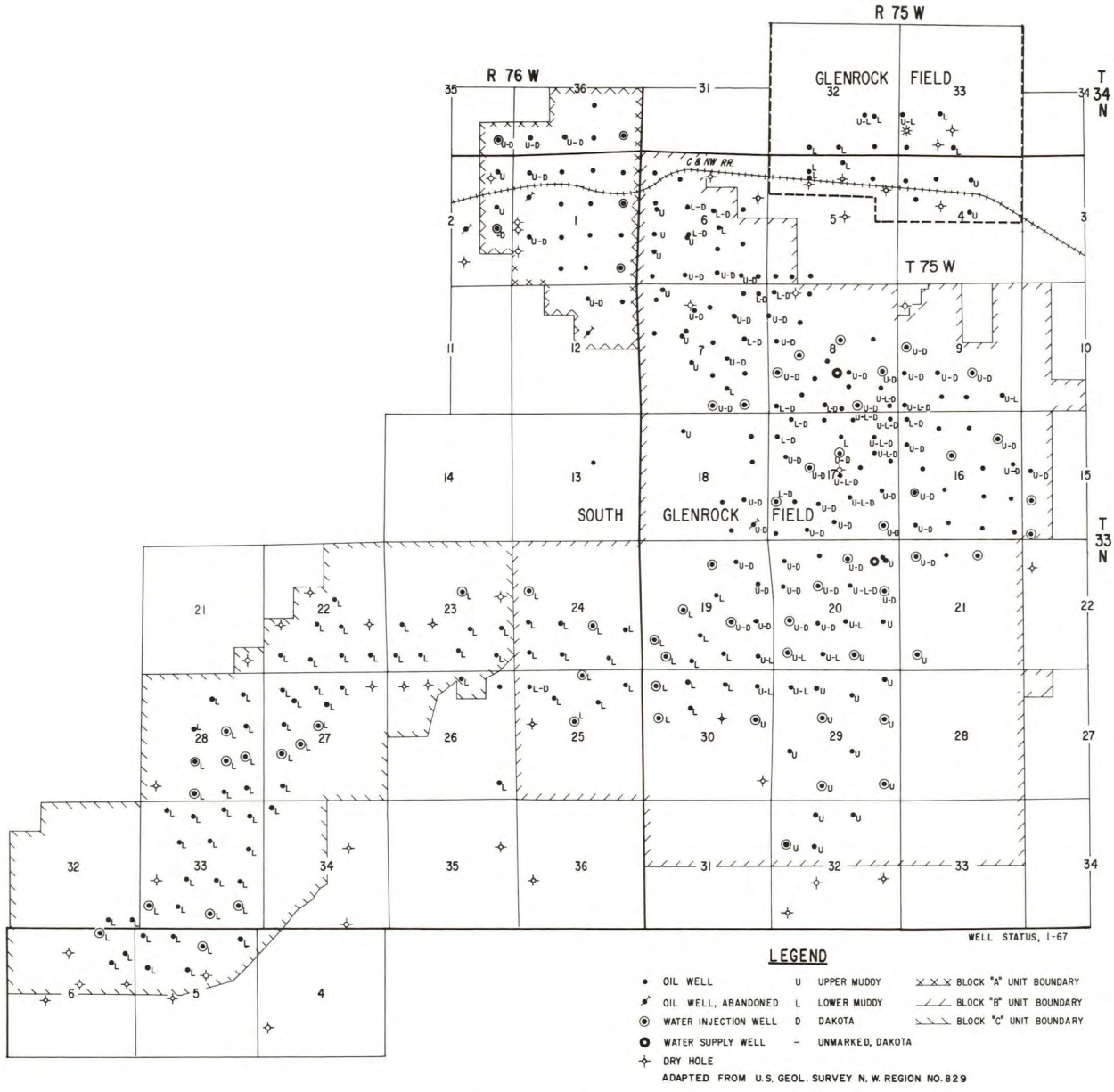


FIGURE 13. - South Glenrock Field, Converse County, Wyo.

oil. Shows of oil were recorded also in the Muddy sand at 5,664 to 5,683 feet, and the Dakota Sandstone pay was found at 5,856 to 5,880 feet. The gravity of the oil from the Dakota was 36.6° API.

A well in the NW1/4NW1/4SW1/4 sec 1, T 33 N, R 76 W, was completed in the Shannon sand in June 1953. The initial daily flowing production was 205 barrels of oil. The producing zone was 1,784 to 1,789 feet and 1,808 to 1,812 feet. This is the only well in the field completed in the Shannon sand and possibly could be an extension of the Shannon sand zone of Big Muddy field.

Analyses of cores from the Dakota Sandstone show that the permeability averages about 75 millidarcys and the porosity is about 14 percent. Cores from the lower Muddy sand also show about 14-percent porosity and an average permeability of 82 millidarcys. Cores from the upper Muddy sand show a porosity of 20 percent and an average permeability of 200 millidarcys.

The initial daily oil production of 100 wells completed in the Dakota sand ranged from 13 to 600 barrels and averaged 196. The initial daily oil production of 100 wells completed in the Muddy sand, including upper and lower Muddy zones, ranged from 4 to 1,872 barrels and averaged 260.

The field has been divided into three units. Block "A" unit with Sinclair Oil and Gas Corp. as operator was effective December 1, 1966; Block "B" unit with Continental Oil Co. as operator, and Block "C" unit with Tenneco Oil Co. as operator, were effective July 1, 1961.

Separate agreements for waterflooding in the units have been completed, and six injection projects were operating in January 1968. Continental Oil Co. operates the upper Muddy "A B," lower Muddy "B," and Dakota "B" projects; Tenneco Oil Co. operates the lower Muddy "C" project; and Sinclair Oil and Gas Corp. operates the Dakota "A" Muddy "A" projects. Injection water for the Continental projects is from a Madison well, a Madison-Tensleep well, and produced water. Water for the Tenneco project is from a Madison well. A "shallow sand" well supplies water for the Sinclair projects.

Upper Muddy "A B" Project

Upper Muddy "A B" reservoir covers 4,838 acres and has an average pay thickness of 6 feet. The producing mechanism was solution gas drive. Water injection started September 8, 1961. The injection pattern is a combination five-spot and line drive. On January 1, 1968, the project area contained 51 producing wells and 31 injection wells; 15 wells had been shut-in. During December 1967 the average daily production was 3,099 barrels of oil and 6,021 barrels of water; average daily injection was about 15,664 barrels of water at 750 psi.

Cumulative oil production to the start of waterflooding was about 5.3 million barrels or 19 percent of the original oil in place. Cumulative production to January 1, 1968, was about 10,987,000 barrels or 39.4 percent of the original oil in place. Of the 5,687,000 barrels of oil produced since waterflooding was started, an estimated 3,600,000 barrels was secondary oil. Cumulative water injection to January 1, 1968, was 8,908,000 barrels. The project is apparently successful.

Lower Muddy "B" Project

Lower Muddy "B" project is in the south-central part of the field and joins the Tenneco lower Muddy project to the west. It consists of 1,129 acres and has an average pay thickness of 17 feet. The reservoir producing mechanism was solution gas drive. Water injection began September 1, 1963. The injection pattern is a line drive. On January 1, 1968, the project area contained 27 producing wells and nine injection wells; three injection wells and 18 producing wells had been shut in. During December 1967 average daily production was 394 barrels of oil and 879 barrels of water; average daily injection was about 3,380 barrels of water at 890 psi.

Cumulative oil production to the start of waterflooding was 4,458,000 barrels or 32 percent of the original oil in place. An additional 5,445,000 barrels was produced to January 1, 1968. Cumulative water injection to January 1, 1968, was 6,650,000 barrels. Water breakthrough occurred in some of the producing wells. Outcome of the project is indeterminate.

Dakota "B" Project

Dakota "B" reservoir covers 4,249 acres and has an average pay thickness of 27 feet. The reservoir producing mechanisms were solution gas drive and partial water drive. Water injection was started September 8, 1961. The injection pattern is a line drive. On January 1, 1968, the project area contained 65 producing wells and 34 injection wells; 34 wells had been shut in. During December 1967 average daily production was 4,074 barrels of oil and 13,245 barrels of water; average daily injection was about 29,200 barrels of water at 490 psi.

Cumulative oil production to the start of waterflooding was about 15.9 million barrels or 20 percent of the original oil in place. Cumulative production to January 1, 1968, was 24,443,000 barrels or 30.7 percent of the original oil in place. Of the 8,543,000 barrels of oil produced since waterflooding was started, an estimated 6,620,000 barrels was secondary oil. Cumulative water injection to January 1, 1968, was 35,268,000 barrels. The project is apparently successful.

Lower Muddy "C" Project

Lower Muddy "C" project area of 2,253 acres is in the southwest part of the field and joins Continental's lower Muddy "B" project to the east. The average pay thickness of the reservoir is 12 feet. The reservoir producing mechanism was solution gas drive. Water injection started June 1, 1961. The injection pattern is a line drive. On January 1, 1968, the project area contained 19 producing wells, 16 injection wells, 21 shut-in producing wells, and seven shut-in injection wells. During December 1967 the average daily production was 492 barrels of oil and 1,060 barrels of water; daily average injection was 3,350 barrels of water at 1,100 psi.

Cumulative oil production to the start of waterflooding was about 4,806,000 barrels or 22 percent of the original oil in place. Cumulative production to January 1, 1968, was about 6,834,000 barrels or 28 percent of the original oil in place. Of the 2,028,000 barrels of oil produced since waterflooding was started, an estimated 1,400,000 barrels was secondary oil. Cumulative water injection to January 1, 1968, was 10,684,000 barrels. The project is apparently successful.

Block "A" Upper Muddy and Dakota Projects

Block "A" Dakota reservoir covers 1,284 acres and has an average pay thickness of 28 feet. A partial water drive and solution gas drive were active in the reservoir. The upper Muddy zone has an area of about 320 acres and an average pay thickness of 6 feet. A gas expansion drive was present. Water injection for both projects started July 21, 1967.

Four injection wells are on the east side of the project and two on the west side. In December 1967 there were seven producing wells and eight shut-in Dakota wells and three producing wells and four shut-in Muddy wells in the projects. Production in December 1967 from both zones was about 308 barrels of oil per day. Injection was 2,200 barrels of water in the Dakota and 190 in the Muddy. Cumulative injection to January 1968 was 401,000 barrels of water in the Dakota and 34,600 in the Muddy. Probably 25,000 barrels of oil produced the last half of 1967 could be credited as secondary oil. Outcome of the project is indeterminate.

Gooseberry

Gooseberry anticline, mainly in T 47 N, R 100 W, Park County, includes two structural highs. In September 1937 a well in the NW1/4NW1/4 sec 33 produced by swabbing at the daily rate of 300 barrels of 22° API gravity black oil from the Embar-Tensleep oil zone at 5,668 to 5,993 feet. After tests the well was shut in until 1943. Two dry holes and seven producing wells have been drilled since that time. One of those tested the Madison Limestone without finding any oil saturation.

One well was completed in the Phosphoria and two in the Tensleep on the north dome in 1951, 1955, and 1956, respectively.

A unit plan for the development and operation of the Gooseberry unit area was approved by the Acting Secretary of the Interior on April 28, 1937.

A pilot water injection project was started in the Tensleep Formation of the south unit in September 1960 by Mobil Oil Corp. Water is injected into two wells near the center of the area from a fresh water supply well in SE1/4 sec 29, T 47 N, R 100 W.

The south dome reservoir covers 277 acres and has an average pay thickness of 50 feet. On January 1, 1968, the area contained six producing oil wells and two injection wells. During December 1967 the daily average production was 364 barrels of oil and 108 barrels of water; daily average injection was 830 barrels of water at 100 psi.

Cumulative oil production to the start of injection was about 1 million barrels or 9.2 percent of the original oil in place. Cumulative production to January 1, 1968, was 1,907,000 barrels or 17.5 percent of the original oil in place. Of the 907,000 barrels of oil produced since injection started, an estimated 280,000 barrels was recovered from fluid injection. Cumulative water injection to January 1, 1968, was 2,063,000 barrels.

Grass Creek

Grass Creek oilfield (figs. 14-15) is in T 46 N, Rs 98 and 99 W, Hot Springs County. The field was discovered in June 1914 when a well in the NW1/4SE1/4 sec 18 was completed in the Frontier Formation at 900 to 1,152 feet with an estimated initial daily production of 50 barrels of oil. At least 421 wells were drilled in the Grass Creek field mostly in 1916-18, and oil was obtained from nine sands in the Frontier Formation at 700 to 1,200 feet; the best production came from about 1,000 feet. Some wells were completed with as much as 400 feet of open hole in the Frontier producing zone.

A well in the NE1/4NW1/4 sec 19 was drilled to the Muddy sand in 1915 and yielded a large flow of gas for several years. A compression casinghead-gasoline plant, operated initially in 1918, had a daily capacity of about 1 million cubic feet of gas. Until operations were suspended in the fall of 1936, 4,865 million cubic feet of gas had been processed and about 12.75 million gallons of gasoline had been extracted. From August 1930 to August 1932, 85 million cubic feet of residue gas from the gasoline plant was returned to the Frontier sand for gas-drive purposes. Gas injection was resumed in 1957 near the crest of the structure. Injection was stopped in 1962.

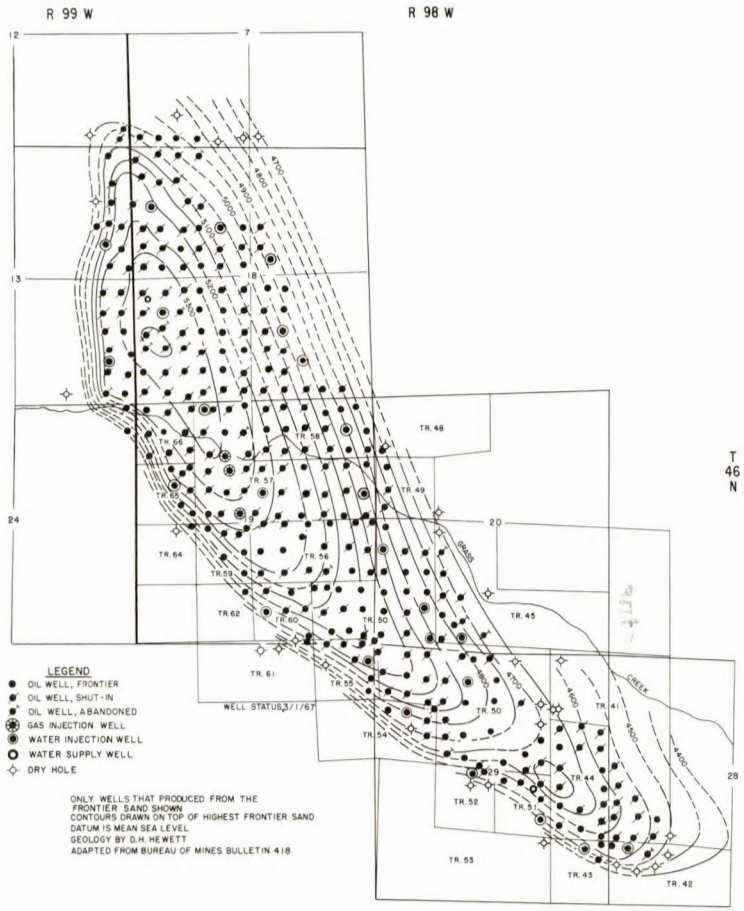


FIGURE 14. - Structure Contour Map of Grass Creek Field, Hot Springs County, Wyo.

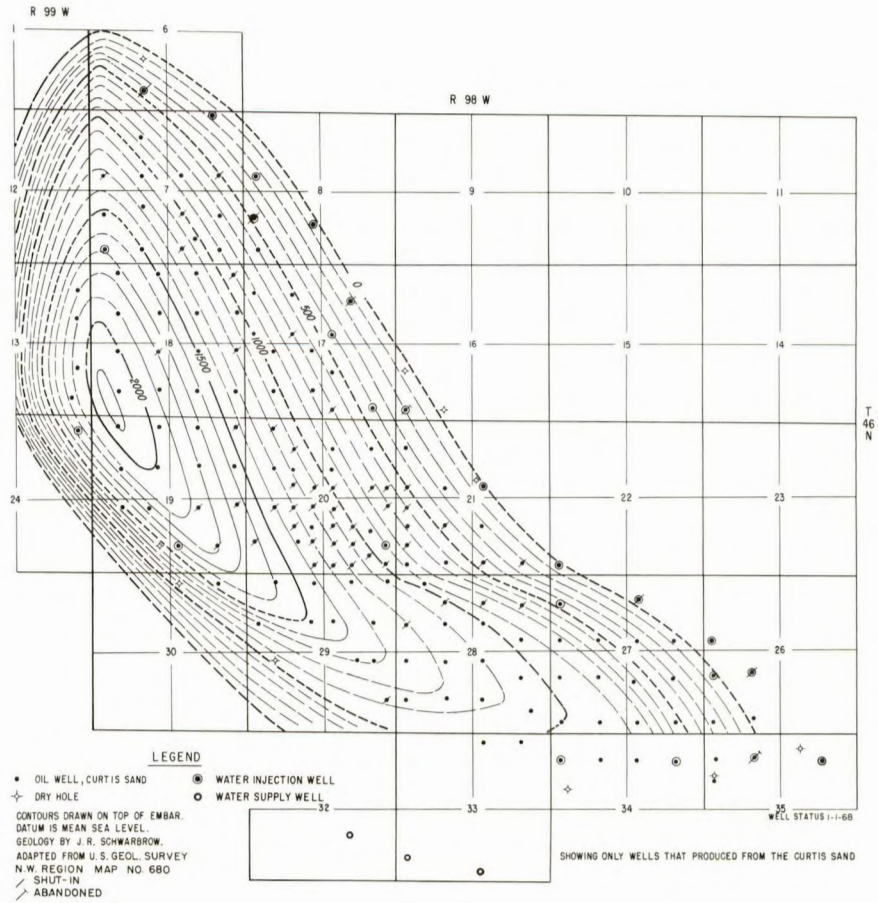


FIGURE 15. - Structure Contour Map of Grass Creek Field, Hot Springs County, Wyo.

In 1922 a well in the SW1/4NW1/4 sec 19 produced oil from the Embar Limestone and Tensleep Sandstone; later 14 wells were completed in the Embar or Embar and Tensleep at an average depth of about 3,900 feet. The Embar ranged from 250 to 280 feet in thickness, and the Tensleep Sandstone was at least 200 feet thick.

Cores of the productive sands in the Frontier Formation obtained from one well have a porosity ranging from 18 to 22 percent and a permeability ranging from 5 to 400 millidarcys.

Late in 1952 oil was found in the Curtis sand in a well about 3 miles east of the then productive area at Grass Creek field. The development program that followed resulted in 161 producing wells in the Curtis sand. Core analyses of Curtis sand samples show that the porosity averaged 17 percent and the permeability about 120 millidarcys.

A few Embar core analyses show an average porosity of 12 percent and permeability of about 140 millidarcys.

Most Tensleep production comes from the upper 50 or 60 feet of the massive sandstone. The average porosity of this zone ranges from 15 to 18 percent and the permeability range is 75 to 150 millidarcys.

Oil was found in the Darwin and Madison zones in 1958. The development is in the pre-Tensleep unit. Eleven wells were drilled. Eight were producers and three were failures. Most of the oil comes from the Darwin sand, although the Madison dolomite under the Darwin sand yields some oil.

Frontier Unit

Frontier reservoir contains 1,660 acres and has an average pay thickness of about 55 feet.

A pilot water injection project was started in September 1960 with water produced from the Embar and Tensleep wells. Because the produced water was found to be corrosive, water from the Mesaverde and Madison Formations was used when the project was expanded to a full-scale flood. The flood pattern is peripheral. On January 1, 1968, the project area contained 98 producing oil wells and 205 shut-in oil wells, and 27 injection wells. During December 1967 the daily average production was 1,280 barrels of oil and 1,833 barrels of water; daily water injection was 12,700 barrels at an average 290 psi.

Cumulative oil production to the start of injection was 32,100,000 barrels or 20 percent of the original oil in place. Cumulative oil production to January 1, 1968, was 36,345,000 barrels or 23 percent of the original oil in place. Cumulative water injected to January 1, 1968, was 19,246,000 barrels. Available data indicate a successful project.

Curtis Unit

Curtis reservoir covers 5,800 acres and has an average pay thickness of about 20 feet.

A pilot water injection project, started in October 1959 to supplement the limited water drive, was expanded to a full-scale flood in 1960. The flood pattern is a line drive. On January 1, 1968, the project area contained 102 producing wells and 17 injection wells. During December 1967 the daily production was 7,464 barrels of oil and 5,797 barrels of water; daily injection rate was 21,800 barrels of water at 1,200 psi.

Cumulative oil production to the start of injection was 12,400,000 barrels or 10.7 percent of the original oil in place. Cumulative production to January 1, 1968, was 33,113,000 barrels or 28 percent of the original oil in place. Cumulative water injection to January 1, 1968, was 52,202,000 barrels. Available data indicate a successful project.

Darwin Unit

Darwin (pre-Tensleep) unit contains about 460 acres and has an average pay thickness of 19 feet. Water injection in one well in the northeast part of the reservoir began June 29, 1966.

On January 1, 1968, the project area contained eight producing wells and one injection well. Average daily production was 619 barrels of oil and 418 barrels of water. Daily injection was 740 barrels of water at 1,000 psi. Produced water is used for injection.

Cumulative oil production to January 1, 1968, was 2,407,071 barrels. About 366,000 barrels of oil has been produced since injection started. The project is carried as pressure maintenance. Cumulative injection was 445,653 barrels of water. Outcome of the project is indeterminate.

Green River Bend

Green River Bend unit is in Tps 26 and 27 N, Rs 112 and 113 W, Lincoln and Sublette Counties. The 23,807-acre unit was effective June 16, 1958, with Belco Petroleum Corp. as operator.

Gas was discovered in the Frontier Formation in 1958. Later gas was found in the Bear River Formation and oil in zones of the Wasatch Formation. Three small oil-producing areas were developed in the southwestern part of the unit.

The T-5 sand of the Almy reservoir in sec 36, T 27 N, R 113 W, is actually a south extension of the reservoir discussed under Birch Creek. The first oil well was completed in November 1962. Nine oil wells were

completed in the T-5 reservoir. Initial daily oil production ranged from 40 to 562 barrels and averaged 270 barrels per well.

T-5 Sand Project

Belco Petroleum Corp. started water injection in the T-5 sand of the Almy Formation in September 1964. Water for injection is obtained from an upper sand in the Almy Formation. The reservoir covers 270 acres and has an average pay thickness of about 23 feet and lies south of the Birch Creek flood.

Water is injected into two wells at the oil-water contact and into a third well at the gas-oil contact. Injecting at the gas-oil contact is to prevent oil movement into the "dry" gas cap. On January 1, 1968, the project area contained three producing wells and three injection wells. During December 1967 the daily average production was 40 barrels of oil and 241 barrels of water; daily injection rate was 601 barrels of water at 1,475 psi.

Cumulative oil production to the start of injection was 228,214 barrels or 2.6 percent of the original oil in place. Cumulative oil production to January 1, 1968, was 458,600 barrels or 5.2 percent of the original oil in place. Of the 230,400 barrels of oil produced since the start of injection, an estimated 130,000 barrels was recovered by water injection. Cumulative water injection to January 1, 1968, was 1,155,000 barrels. The outcome of the project is indeterminate.

Birch Creek Sand Project

Water injection in the Birch Creek sand (below the T-5 sand) began in May 1967. On January 1, 1968, there were three producing wells, two shut-in wells, and one injection well. Average daily production in December 1967 was 106 barrels of oil and 1,069 barrels of water. Average injection was 100 barrels of water at 1,600 psi. Cumulative injection was 23,400 barrels. The project is too new to evaluate.

Halverson Ranch

Halverson Ranch oilfield, in secs 6-9, 17, and 18, T 49 N, R 69 W, and sec 1, T 49 N, R 70 W, Campbell County, is about 14 miles east-southeast of Gillette. W. C. Leone's No. 1 Halverson, in the SE1/4NW1/4 sec 9, was completed May 10, 1961, for an initial daily production of 200 barrels of oil and no water. Production was from a notch cut in the Dakota at 6,917 feet. During the next 14 months, six additional oil wells and six dry holes were completed in the field. All of the oil wells were in sec 9. Two porous zones, called "A" and "B," were found in the Dakota. Zone "B," the best zone, contained water in three of the seven oil wells. Forty-acre spacing was approved for the field. The reservoir

contained about 400 acres and about 23 feet of pay. Core analysis showed 14.1 percent porosity, 32 millidarcys permeability, and 49.3 percent water saturation. None of the wells in the Dakota area penetrated the Minnelusa Formation.

The Minnelusa discovery was R. E. Hudson's No. 1 Halverson in the SW1/4NW1/4 sec 8, completed June 18, 1962, for an initial daily production of 464 barrels of oil. The production came from perforations from 8,546 to 8,562 feet. Eighty-acre spacing was approved for the field. In the next 10 months 16 oil wells and 10 dry holes were completed and defined the field. The Minnelusa reservoir contains about 1,360 acres and a sand thickness of 30 feet. Porosity is estimated to be 12 percent.

Minnelusa Unit

The Minnelusa unit was approved April 1, 1965, and water injection began in July 1967. Injection water comes from shallow wells. In December 1967 there were 12 producing wells, four injection wells, and five shut-in wells producing 1,764 barrels of oil and 302 barrels of water per day. Injection was about 5,700 barrels at pressures ranging from 650 to 1,800 psi.

Cumulative production from unitization to January 1, 1968, was 956,496 barrels, leaving 112,504 barrels of primary oil to be recovered. Cumulative injection was 1,617,332 barrels of water to January 1, 1968. Water breakthrough to one well may have occurred. The outcome of the project is indeterminate.

Hamilton Dome

Hamilton Dome (formerly the Cottonwood Anticline) oilfield is in secs 10-15, 23, and 24, T 44 N, R 98 W, and secs 7, 18, and 19, T 44 N, R 97 W, Hot Springs County. The field was discovered in September 1918 when a well in the SW1/4SW1/4 sec 13 was completed with an estimated initial daily production of at least 20 barrels of 23° API gravity oil from the Curtis sand of the Chugwater Formation between 1,445 and 1,500 feet.

In October 1919 oil was discovered in the Embar in a well in the NE1/4SE1/4 sec 14 drilled to 2,410 feet. In August 1920 a good producing well, in the NE1/4SW1/4 sec 14, was completed in the Curtis sand of the Chugwater Formation at 1,745 to 1,760 feet; in 1924 it was deepened to the Embar; and in 1929 it was deepened again to the Tensleep Sandstone at 2,733 to 2,801 feet. Following completion of the well in the Tensleep, 300 barrels of 17° API gravity oil was produced per day. By June 1957, 122 wells had been completed in the Tensleep reservoir.

In April 1948 a well in the SE1/4NW1/4SE1/4 sec 14, T 44 N, R 98 W, was completed as a producer in the Madison Limestone at a depth of 3,506 feet. On initial tests, this well produced by swabbing 500 barrels of 14.4° API gravity oil per day. The Madison Limestone was topped at 3,105 feet in this well, but saturation was not logged until the bit had reached 3,332 feet.

The Bighorn dolomite was proved productive in November 1953. A well in the C SE1/4SE1/4 sec 14 had an initial daily production of 245 barrels of oil and 48 barrels of water.

The small Fourth Curtis sand reservoir under the common corners of secs 7 and 18, T 44 N, R 97 W, and secs 12 and 13, T 44 N, R 98 W, was chosen for waterflooding. The reservoir covers about 240 acres with a sand thickness of 14 feet. Cumulative production from the four wells to start of injection was not available.

Injection in one well, in the NW1/4SW1/4NW1/4 sec 18 started in August 1966. Injection water is produced water from the Tensleep Formation.

Cumulative production from start of injection to January 1, 1968, was 41,426 barrels of oil and 47,482 barrels of water. The project contains three producing wells and one injection well. Average daily production in December 1966 was 23 barrels of oil and 93 barrels of water, but in December 1967 it was 158 barrels of oil and 1,195 barrels of water. The producing rate indicates reaction to the flooding. Cumulative injection was 238,000 barrels to January 1, 1968. The project apparently is successful.

Happy Springs

Happy Springs oilfield, in T 28 N, T 93 W, Fremont County, is on the southern margin of the Sweetwater uplift. The discovery well in the SE1/4SW1/4SW1/4 sec 16 was drilled to 10,034 feet in the Tensleep Formation in April 1950. The Tensleep and the Nugget Formations yielded mostly water on testing. The well was completed for an initial daily production by swabbing 106 barrels of oil from the Muddy sand. A second well was drilled about 1,400 feet northwest of the discovery well. It was completed in September 1950 for an initial daily production of 98 barrels of oil from the Frontier sand.

Oil was discovered in the Dakota sand in February 1952 in a well drilled in the NW1/4NW1/4NW1/4 sec 8. The initial daily flowing production was 513 barrels of 37° API gravity oil. A well in the SE1/4SW1/4SW1/4 sec 4 was completed as an oil well in the Lakota sand in October 1952. It produced 455 barrels of oil per day from the Lakota sand (4,560 to 4,584 feet) and 1,750 barrels per day from the Dakota sand (4,480 to 4,540 feet).

In December 1953 a well in the NE1/4NE1/4SW1/4 sec 4 was completed for an initial daily production of 1,920 barrels of oil from the Phosphoria Formation. The producing interval was 6,158 to 6,190 feet.

The Jade unit, with Sinclair Oil and Gas Corp. as operator, was approved by the Secretary of the Interior on February 11, 1953. Subsequent development proved two wells in the W1/2SW1/4 sec 3 to be oil productive. On November 1, 1955, this unit was terminated and the two oil wells were included in the Happy Springs unit.

A unit plan for developing Happy Springs field was effective on March 17, 1949. Sinclair Oil and Gas Co. was designated the unit operator. The unit had a gross acreage of 10,067 acres.

The field has been divided into three areas designated "A," "B," and "C." Waterflood projects were started in the Frontier Formation in the A and C areas. Water injected in the C area, at the north end of the field, from August 1959 to August 1964, gave no response.

The productive area of the reservoir underlying the A area is 236 acres; the average pay thickness is 14 feet. The A project was started in July 1958 with injection from surface runoff water into one well. However, the system was not winterized, and the project shut down on September 25, 1958. The project was resumed October 1, 1960. On January 1, 1968, the project area contained four producing oil wells and one injection well. Daily production during December 1967 was about 19 barrels of oil and 158 barrels of water; daily injection was 464 barrels at 720 psi.

Cumulative oil production to the start of injection was 562,380 barrels or 20.8 percent of the original oil in place. Cumulative oil production to January 1, 1968, was 791,715 barrels or 29.2 percent of the original oil in place. Of the 229,335 barrels produced since the start of injection, an estimated 50,000 barrels was recovered by water injection. Cumulative water injection to January 1, 1968, was 773,800 barrels. Available data indicate a successful project.

Hidden Dome

Hidden Dome is in the southwest corner of T 48 N, R 90 W, the southeast corner of T 48 N, R 91 W, and the northwest corner of T 47 N, R 90 W, Washakie County. Gas was discovered in an upper Frontier sand in September 1917 when a well was completed in the SE1/4SE1/4 sec 31, T 48 N, R 91 W, with an initial open-flow volume of 4 million cubic feet of gas per day. Some years later the well was deepened to 1,492 feet in the Frontier Formation, and the daily production increased to 55 million cubic feet. Five additional gas wells produced initially about 160 million

cubic feet of gas per day from the Frontier Formation at depths of 1,200 to 1,500 feet; the shut-in wellhead pressure was 725 psi. In 1920 an 8-inch pipeline was laid from the field to Basin and Greybull, the first two towns in Wyoming to have natural gas for lighting and heating houses.

In August 1932 a well completed in the NE1/4NW1/4 sec 31 in the north end of the dome was at least 300 feet structurally lower than the crest; the well produced initially 35 barrels of 41.4° API gravity light oil from the Frontier Formation at 1,436 to 1,446 feet. About 48 other Frontier wells were drilled; 18 were commercial producers, yielding 10 to 140 barrels of oil per day. Some of the wells flowed when completed but soon had to be pumped.

Oil was discovered in a deeper formation in March 1947 when a well in the SE1/4SE1/4 sec 31, T 48 N, R 90 W, was completed with an initial daily production of 160 barrels of 20° API gravity oil from the Tensleep Sandstone at 4,549 to 4,685 feet. Six other deep wells were drilled; four were commercial producers. In April 1950 the discovery well was recompleted to produce from both the Phosphoria and Tensleep Formations.

Apparently the gas- and oil-producing areas in the Frontier sand are separated by a permeability block. Most of the Frontier sand wells were drilled over 30 years ago, and little reservoir data were found. Past production indicates an active water drive is not present in the Frontier sand at Hidden Dome.

Frontier Sand Project

Approval was granted in June 1966 for a pilot waterflood on the Mule Creek lease in the SE1/4SE1/4 sec 25, T 48 N, R 91 W. Water injection started in July 1966. There were 13 Frontier oil wells in the field, one injection well, and one water supply well. A second injection well on the Peterson lease in the NW1/4NW1/4 sec 31, T 48 N, R 90 W, was added in January 1967. Production for 1967 was 11,566 barrels of oil. Injection was stopped in August 1967 until a water-flooding unit was formed.

Formation of the unit indicates a favorable reaction to the pilot test. A gas injection test was operated in the Tensleep reservoir from September 1962 until April 1964. Gas was from the Cottonwood Creek field, but the supplier cancelled the contract.

Horse Creek

Horse Creek oilfield is in the SW1/4 T 17 N, and the NW1/4 T 16 N, R 68 W, Laramie County. The discovery well in the SW1/4SE1/4SE1/4 sec 31,

T 17 N, was completed in October 1942 as a Lakota Sandstone oil well. Initial daily production was 455 barrels of oil and 114 barrels of water from a depth interval of 5,449 to 5,515 feet. Analyses of cores from the Lakota sand showed an average porosity of 14.8 percent and permeability ranging from 0 to 194 millidarcys. The well was shut in 2 months later when the water production increased to 73 percent of the fluid produced. During March 1943 a well in the SW1/4SE1/4NE1/4 sec 6, T 16 N, was completed as an oil well in the Muddy sand. Initial daily production was 40 barrels of oil from the interval of 5,433 to 5,447 feet after the producing interval had been shot with 40 quarts of nitroglycerin. Examination of cores in the Muddy sand showed it to be very "tight" and silty with some fracturing. Shooting with nitroglycerin and acidizing with hydrochloric acid produced only temporary increases in oil production.

The field was unitized in February 1943 with Mobil Oil Corp. as unit operator. The Muddy sand reservoir covers 2,340 acres and has an average pay thickness of 23 feet. A water injection project was started in August 1960 to supplement a partial water drive. The water is injected down structure on the east side of the field. The water source is three wells completed at depths from 500 to 700 feet.

On January 1, 1968, the project area contained 15 producing wells, seven injection wells, and 10 shut-in wells. Daily production during December 1967 was 539 barrels of oil and 951 barrels of water; daily water injection was 2,900 barrels at 640 psi.

Cumulative oil production to the start of injection was 3,769,000 barrels or 13 percent of the estimated original oil in place. Cumulative oil production to January 1, 1968, was 5,384,511 barrels or 18.6 percent of the estimated original oil in place. Of the 1,615,511 barrels of oil produced since injection was started, an estimated 680,000 barrels was recovered by fluid injection. Cumulative water injection to January 1, 1968, was 6,788,000 barrels. Available data indicate a successful project.

La Barge

La Barge oilfield, in Tps 26 and 27 N, R 113 W, Lincoln and Sublette Counties, is on the south high of a long, narrow, north-south trending anticline with two distinct highs. Considerable excitement was caused in the summer of 1907 when an oil seepage was discovered east of La Barge Ridge in T 27 N, R 113 W. Numerous placer claims were staked. The field was discovered in the spring of 1924 when a well in the NW lot 7, sec 3, T 26 N, R 113 W, was brought in, producing initially 10 barrels of oil per day from a sand in the Almy Formation at 560 to 572 feet. The principal producing zone, at 650 to 1,100 feet, may be divided into four

distinct sands. The reservoir covers 1,160 acres and has an average pay thickness ranging from 30 to 90 feet.

La Barge-Almy

Part of the field was unitized in April 1949 with Texaco, Inc., as unit operator. Gas injection was started in 1931 and discontinued in 1962 after approximately 3,300 million cubic feet of gas had been injected. A pilot water injection project was started in December 1961. In April 1965 the pilot was expanded to a full-scale flood in the northern half of the field. Water is obtained from a shallow well near the Green River. On January 1, 1968, the project area contained 96 producing wells, 31 injection wells, 20 shut-in oil wells, and 21 shut-in injection wells. During December 1967 the daily production was 986 barrels of oil and 2,737 barrels of water; daily injection was 9,115 barrels of water at 920 psi.

Cumulative oil production to the start of injection was 12,986,000 barrels and production to January 1, 1968, was 14,834,988 barrels. Of the 1,848,988 barrels of oil produced since the start of injection, an estimated 320,000 barrels was produced by fluid injection. Cumulative water injected to January 1, 1968, was 9,321,000 barrels. Available data indicate a successful project.

La Barge-Mesaverde

La Barge-Mesaverde project, about 3 miles north of the Almy project, is actually the Saddle Ridge unit. The unit was approved April 1, 1963, with Belco Petroleum Corp. as operator.

The fifth Mesaverde reservoir covers about 320 acres and has a pay thickness of 30 feet. A shallow water supply well was drilled in the NE1/4SE1/4 sec 32, T 28 N, R 113 W. Water injection was started on September 15, 1967, in one well. On January 1, 1968, the project contained 15 oil wells, one gas injection well, and one water injection well. Average daily production in December 1967 was 151 barrels of oil and 99 barrels of water. Daily injection was 645 barrels of water at 1,275 psi.

Cumulative oil production to start of injection was 856,400 barrels or 7 percent of the original oil in place. From the start of injection to January 1, 1968, 18,200 barrels of oil and 12,500 barrels of water were produced. Cumulative injection to January 1968 was 69,000 barrels of water. The project is too new to evaluate.

Lance Creek

Lance Creek oilfield is in the northern part of T 35 N, R 65 W, and the southern part of T 36 N, T 65 W, Niobrara County. The field was

discovered in March 1918 while drilling a well in the northwest corner of sec 36, T 36 N, R 65 W, that produced 80 barrels of oil per day from the Wall Creek sand at 2,689 feet. This well was deepened and in October 1918 produced 1,500 barrels of oil from the Second Dakota sand at 3,663 feet. Later oil was also found in the Muddy, First Dakota, Third Dakota, Lakota sands, First (or Upper) and Basal Sundance sands, and the Converse and Leo sands of the Minnelusa Formation; and gas in the Dakota and Lakota sands.

Before 1926 a large volume of gas was blown to the air in the Lance Creek field. In 1926, however, a gasoline plant and a carbon black plant were built in the field. The gasoline plant was the absorption type with a capacity of 4.5 million cubic feet of gas per day. Initially (1920-23), the pressure of the gas was 900 to 1,200 psi, but by 1927 it had dropped to 450 psi. The gasoline content of the gas (based on plant recoveries) ranged from 0.4 to 1.6 gallons per thousand cubic feet and averaged 0.81 gallon. In April 1936 this plant was abandoned when another absorption plant was put in operation to process the gas produced with the oil from the Basal Sundance sand. Eight to 10 million cubic feet of gas per day was processed, yielding nearly 1 gallon of gasoline per thousand cubic feet. The residue gas was burned in a carbon black plant which operated from January 1927 to March 1938. This plant used 2,372 to 3,000 million cubic feet of gas per year, or a total of 29.4 billion cubic feet to March 1938. The yield of carbon black from 1927-32, inclusive, was approximately 1.8 pounds per thousand cubic feet of gas and from 1933-38, 2-1/4 to 2-1/2 pounds per thousand cubic feet.

On March 1, 1938, a program for arresting the pressure decline in the Basal Sundance was initiated. By June 1938 approximately 6 million cubic feet of gas per day was being returned to the sand through five wells on top of the structure. The original bottom-hole pressure on the crest was about 1,560 psia, but by March 1938 it had dropped to 800 pounds, and on June 1, 1938, was 820 psia. In March 1938 bottom-hole pressure in flank wells was about 850 psia, but by June 1938 it had dropped to 810 psia. Total gas injected into the sand by January 1958 was about 49.8 billion cubic feet. Bottom-hole pressure in the Basal Sundance sand had declined to about 400 psia by August 1953 and gas was being injected into five wells near the crest of the structure. Injection pressure at the wells ranged from 500 to 550 psia.

Injection of gas in the upper Sundance sand was begun in October 1947. For a time gas was returned to this reservoir at about the withdrawal rate. By July 1953 nearly 1.5 billion cubic feet of gas had been injected.

From 1942 to 1949 more gas was processed through the Lance Creek gasoline plant than was needed in the repressuring program for the Upper and Basal Sundance sands. About 6.5 billion cubic feet of this gas was stored in the nearly depleted Dakota Sandstone reservoir.

The Lance Creek gasoline plant was altered in 1942 when additional equipment was added to increase the recovery of butane and propane. One result of this alteration was production of butane and propane during the summer months in amounts greater than the market demands. For several years this "summer excess" was injected into the Basal Sundance reservoir.

Marathon Oil Co. has operated the Muddy, Morrison, First Sundance, and Basal Sundance projects in the field. Continental Oil Co. has the OPC project, once called the Little Buck Creek field.

Muddy Project

Muddy project reservoir covers 500 acres and has an average pay thickness of about 7 feet.

A water injection project was started in August 1960. On January 1, 1968, the project area contained eight producing wells and three injection wells. During December 1967 the daily average production was 71 barrels of oil and 103 barrels of water; daily injection was 603 barrels at 1,500 psi.

Cumulative oil production to the start of injection was 315,000 barrels or about 8 percent of the estimated original oil in place. Cumulative oil production to January 1, 1968, was 1,024,000 barrels or 26 percent of the estimated original oil in place. Of the 709,000 barrels of oil produced since the start of injection, an estimated 497,000 barrels was recovered by water injection. Cumulative water injection to January 1, 1968, was 2,012,000 barrels. Available data indicate a successful project.

Morrison Project

Morrison project covers 179 acres and has an average pay thickness of about 21 feet. A water injection project was started in July 1959 using two wells; later a third was added. On January 1, 1968, the project area contained four producing wells and three injection wells. During December 1967 the daily average production was 68 barrels of oil and 354 barrels of water; daily water injection was 549 barrels at 1,250 psi.

Cumulative oil production to the start of injection was 252,000 barrels or 11 percent of the estimated original oil in place. Cumulative oil production to January 1, 1968, was 644,000 barrels or 27 percent of the estimated original oil in place. Of the 392,000 barrels of oil produced since the start of injection, an estimated 208,000 barrels was recovered by water injection. Cumulative water injection to January 1, 1968, was 1,483,000 barrels. Available data indicate a successful project.

First Sundance Project

First Sundance reservoir covers 455 acres and has an estimated pay thickness of 25 feet. Water injection was started in July 1960. Injection stopped in 1964 after 1,302,000 barrels of water had been injected. There were four producing and two injection wells. Cumulative oil production to the end of injection was 1,248,000 barrels.

Considering the oil in place estimated by volumetric methods, the total recovery was low.

Basal Sundance Project

Basal Sundance project covers 1,715 acres and has an estimated pay thickness of 64 feet.

A pilot water injection project, which uses water produced from the Basal Sundance and Leo zones started in 1952, was later expanded to a full-scale flood.

On January 1, 1966, the project area had declined to one producing well, one water injection well, 20 shut-in producing wells, and 16 shut-in injection wells. During December 1967 the daily average production was 18 barrels of oil and 2 barrels of water; daily injection was 402 barrels of water.

Cumulative oil production to the start of injection was 23,500,000 barrels or 18 percent of the estimated original oil in place. Cumulative oil production to January 1, 1968, was 25,530,000 barrels or 19 percent of the estimated original oil in place. Of the 2,030,000 barrels of oil produced since the start of injection, an estimated 580,000 barrels was recovered by fluid injection. Cumulative water injection to January 1, 1968, was 27,736,000 barrels. Available data indicate a successful project.

Lance Creek OPC Unit

OPC unit covers 958 acres with an average pay thickness of 26 feet. The initial producing mechanisms were a solution gas drive and a limited natural water drive.

To supplement the natural water drive a pilot waterflood project was started in April 1960 with three injection wells near the east end of the unit. The project was expanded into a full-scale flood in November 1961. The flood pattern is peripheral and affects an area of about 300 acres. Water for injection is obtained from Marathon Oil Co. and from a Leo sand supply well. On January 1, 1968, the project area contained five producing wells and six injection wells; 11 producing wells and 11 injection wells were shut in. Daily average production

during December 1967 was 308 barrels of oil and 142 barrels of water; daily water injection was 1,221 barrels at 1,000 psi.

Cumulative oil production to the start of injection was 5,866,000 barrels or 27 percent of the estimated original oil in place. Cumulative production to January 1, 1968, was 6,072,000 barrels or about 29 percent of the estimated original oil in place. Of the 206,000 barrels of oil produced since injection started, an estimated 134,000 barrels was recovered by fluid injection. Cumulative water injection on January 1, 1968, was 7,245,000 barrels. Available data indicate a successful project.

Lander

Lander oilfield, also known as Hudson oilfield, is on a narrow anticline in secs 13, 24, and 25, T 2 S, R 1 E, secs 19 and 30, T 2 S, R 2 E, Wind River Indian Reservation, and sec 4, T 33 N, R 99 W, Fremont County. A noncommercial well was drilled near the river as early as 1909 in sec 3, T 33 N, R 99 W, but the important discovery was not made until January 1912 when a well in lot 2, sec 30, was completed at 1,010 to 1,050 feet in the Embar lime. About 46 wells were drilled, most of them from 1914 to 1920. Thirty-five of these wells were productive, yielding initially 15 to 100 barrels of black oil of 24° API gravity per day.

In 1926 and 1927 five wells were completed in the Tensleep Sandstone. Initial daily production ranged from 75 to 300 barrels of black oil of 22° API gravity.

The Oil and Gas Commission approved a pilot flood in the Embar Formation on September 17, 1964, with Pan American Petroleum Corp. as operator. Water injection, using produced Tensleep water, was started during May 1965.

During late 1965 water and gas were alternately injected into the same well. The number of injection wells was increased to four in 1967 and a plain waterflood started.

In December 1967 there were 27 producing wells and four injection wells in the project. Daily production averaged 274 barrels of oil and 358 barrels of water. No gas was injected in 1967. Cumulative injection to 1968 was 596,000 barrels of water and 14.2 million cubic feet of gas.

Cumulative oil production to January 1, 1968, was 1,946,000 barrels. An estimated 200,000 barrels of oil was recovered from the fluid injection. The project appears successful.

Lightning Creek

Lightning Creek oilfield is in secs 25 and 36, T 35 N, R 66 W, and sec 30, T 35 N, R 65 W, Niobrara County. The discovery well in the NW1/4 sec 36 was completed in September 1949. Initial production was 238 barrels per day of 41° API gravity oil from the Basal Sundance sand through perforations in the casing between 3,870 and 3,890 feet. In April 1950 a well in the SE1/4 sec 25 was completed as a gas well in the Basal Sundance sand. Initial daily production was 1,250,000 cubic feet of gas through perforations between 3,436 and 3,468 feet. Later this well was recompleted as an oil well.

In April 1951 a well in the SW1/4 sec 30 was completed in the Newcastle (Muddy) sand. Initial production was 7 barrels of oil per day. The top of the Newcastle was logged at 1,447 feet.

The Newcastle producing area was unitized on March 1, 1965, with the Lightning Creek Oil Co. as unit operator. The project is a pilot operation. Water is obtained from a surface runoff pond and a well completed in the White River sand at a depth of 350 to 400 feet. The reservoir covers 600 acres and has an average pay thickness of about 6 feet.

Water injection was started in November 1964 in two wells. On January 1, 1968, the project area contained nine producing wells, one active well and one shut-in injection well. During December 1967 the daily average production was 85 barrels of oil and 249 barrels of water; daily injection was 1,751 barrels of water.

Cumulative oil production to the start of injection was 212,500 barrels or 5.9 percent of the estimated original oil in place. Cumulative oil production to January 1, 1968, was 268,333 barrels or 7.4 percent of the estimated original oil in place. Recovery resulting from water injection is uncertain. Cumulative water injected to January 1, 1968, was 786,000 barrels. The project is indeterminate.

Little Buffalo Basin

Little Buffalo Basin field is on two elliptical domes (often called East and West Buffalo anticlines or domes) in Tps 47 and 48 N, R 100 W, Park County, and T 47 N, R 99 W, Hot Springs County. Gas was discovered in Little Buffalo Basin in November 1914 when a well in the SE1/4NW1/4 sec 2, T 47 N, R 100 W, was completed in the Frontier Formation, between 1,750 and 1,792 feet, that produced 3 million cubic feet of gas per day; the shut-in wellhead pressure was 350 psi. In 1919 a gas well drilled on the crest of the East dome penetrated all of the Frontier sands and blew wild at an estimated rate of over 100 million cubic feet of gas

per day. The pressure forced gas from fissures around the well and the gas ignited, causing a loss of life and property.

Oil was discovered in January 1944 when a well in the NE1/4NW1/4 sec 13, T 47 N, R 100 W, was completed for an initial daily production of 150 barrels of 21° API gravity oil from the Tensleep Sandstone at 4,881 to 4,965 feet. Oil was found in the Phosphoria Formation in September 1944. No oil-producing wells have been drilled on the West dome.

A unit plan for developing and operating Little Buffalo Basin was approved by the Secretary of the Interior on January 6, 1931.

Tensleep Project

Tensleep reservoir has an average porosity of 10 percent and average permeability of 74 millidarcys. The oil had 15 cubic feet of gas per barrel and a viscosity of 42 centipoises in the reservoir. This high viscosity would cause poor primary recovery even with the natural water drive.

A pilot gas injection test was started in June 1958. One injection well handled about 1 million cubic feet of gas per day. Gas supply was from the Second Frontier sand in the field. The injected gas would lower the oil viscosity and fill pore space in the reservoir. The project was expanded in August 1961 and the daily injection rate upped to about 6 million cubic feet.

Water injection was started in April 1966 with produced water. In December 1967 there were 18 oil wells, five gas injection wells, and three water injection wells. Daily production was 4,410 barrels of oil, 2,005 barrels of water, and 3,115,000 cubic feet of gas. Daily injection was 1,360 barrels of water and 5.7 million cubic feet of gas.

Cumulative injection to 1968 was 17.2 billion cubic feet of gas and 813,000 barrels of water. Oil recovery has been increased, but mostly from the gas injection.

Lost Soldier

Lost Soldier oil and gas field (fig. 16), known also as Little Lost Soldier, is in secs 2, 3, 10, and 11, T 26 N, R 90 W, Sweetwater County. The Lost Soldier field was discovered in June 1916 when a well drilled in the southwest corner of the NW1/4 sec 11 produced initially 200 barrels of oil daily from the Wall Creek sand at 265 to 340 feet. Later, oil was found in 11 sands at 195 to over 6,900 feet. There are nine Wall Creek sands in the Frontier Formation; five of them are oil-bearing. On the crest of the structure the First Wall Creek sand proved productive at a depth of 195 feet.

Several wells produced oil from the Mowry Shale at 1,100 feet.

In 1921 oil was found in the Dakota sand in a well in the southwest corner of the NW1/4 sec 11.

The Lakota sand, drilled late in 1923, occurs at an average depth of 1,530 feet and averages 40 feet in thickness.

In 1926 a well in the SW1/4NW1/4 sec 11 produced 200 barrels of oil per day from a sand in the Sundance Formation at 2,015 to 2,040 feet.

A well in the SW1/4NW1/4 sec 11 was completed in 1930 in the Tensleep Sandstone at 3,942 to 4,009 feet; its initial daily flowing production was 1,800 barrels of 34° API gravity brownish-black oil containing 1.2 percent sulfur. By January 1968, 34 other wells had been completed in the Tensleep Sandstone with an initial daily production of 150 to 2,200 barrels of oil.

In January 1948 a well in the SE1/4SW1/4NE1/4 sec 3 was completed in the Madison Limestone at 5,398 to 5,863 feet; initial production was 584 barrels of oil per day. Twelve other wells have since been completed in the Madison Formation.

In June 1948 a well in the SE1/4NW1/4SE1/4 sec 3 was completed in Cambrian rocks for an initial daily production of 720 barrels of 36° API gravity oil. This was the first commercial production from the Cambrian in the Rocky Mountain Region. Eight wells have been completed in the Flathead Sandstone.

In 1941 gas injection in the Tensleep reservoir was started to maintain reservoir pressure and continued until February 1, 1946. During the period of injection, 1,175 million cubic feet of gas was pumped into the reservoir. Operation of the Tensleep gas-injection project was resumed in May 1949 and continued until December 1954. During this period 487 million cubic feet of gas was injected.

Water injection into the Tensleep reservoir through one well was started in May 1955. The injection rate during December 1957 was 600 barrels of water per day with the surface pressure registering a vacuum. In October 1957 water injection into the First and Second Frontier zones was begun. In December the injection rates averaged 638 barrels per day in the First Frontier and 323 barrels per day in the Second Frontier. Surface pressure for both zones was a vacuum. Injection in the Frontier was discontinued in June 1964.

The Tensleep, Madison, and Cambrian Formations of the Lost Soldier field were unitized in September 1962 with Sinclair Oil and Gas Corp. as operator. Because all three Lost Soldier projects are listed as

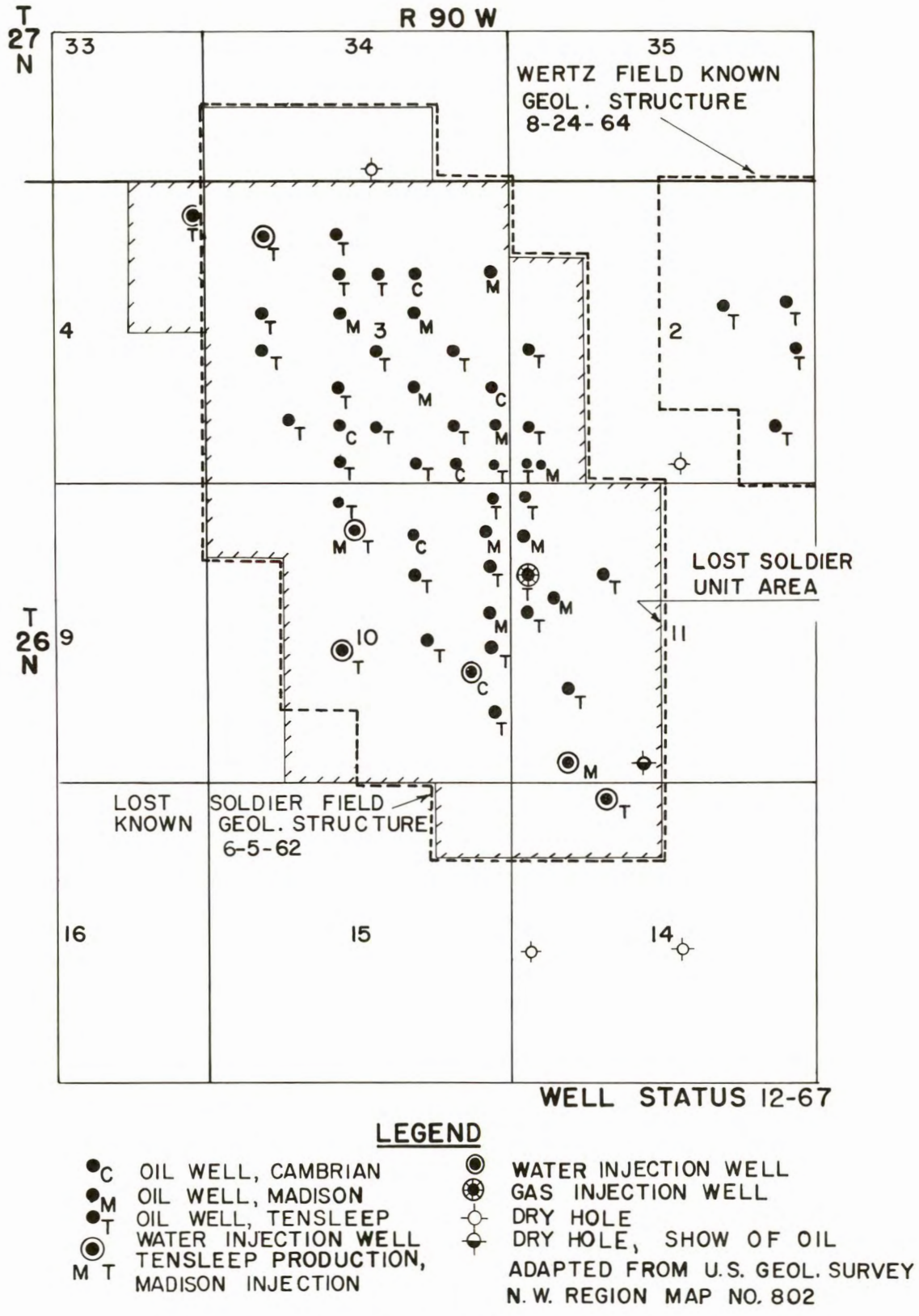


FIGURE 16. - Lost Soldier Field, Sweetwater County, Wyo.

pressure maintenance, oil recovery by water injection may be considered as accelerated recovery.

Tensleep Unit

Tensleep reservoir covers 1,193 acres and has an average pay thickness of 250 feet. The primary reservoir producing mechanism is a combination of water drive, solution gas drive, and gravity drainage.

On January 1, 1968, the unit area contained 37 producing wells and six injection wells. During December 1967 daily production was 8,011 barrels of oil and 2,501 barrels of water; daily injection was 17,421 barrels of water at 1,180 psi.

Cumulative oil production to the start of injection was 39,347,000 barrels or about 20.7 percent of the estimated original oil in place. Cumulative oil production to January 1, 1968, was 49,363,000 barrels or about 25.9 percent of the estimated original oil in place. Of the 10,016,000 barrels of oil produced since the start of injection, an estimated 2,984,000 barrels was from fluid injection. Cumulative water injected to January 1, 1968, was 19,738,000 barrels. Available data indicate a successful project.

Madison Unit

Madison reservoir covers 709 acres and has an average pay thickness of 188 feet. The initial reservoir producing mechanism was a water drive.

On January 1, 1968, the unit area contained 16 producing wells and two injection wells. During December 1967 the daily production was 3,638 barrels of oil and 1,431 barrels of water; daily injection was 3,800 barrels of water at 1,900 psi.

Cumulative oil production to the start of water injection was 18,909,000 barrels or about 16.8 percent of the estimated original oil in place. Cumulative oil production to January 1, 1968, was 23,166,000 barrels or 20.5 percent of the estimated original oil in place. Of the 4,257,000 barrels of oil produced since the start of injection, an estimated 1,286,000 barrels was recovered by fluid injection. Cumulative water injection to January 1, 1968, was 2,673,000 barrels. Available data indicate a successful project.

Cambrian Unit

Cambrian reservoir covers 670 acres and has an average pay thickness of 94 feet. The initial reservoir producing mechanism was a limited water drive and fluid expansion.

On January 1, 1968, the project area contained six producing wells and four injection wells. During December 1967 the daily production was 2,071 barrels of oil and 395 barrels of water; daily water injection was 3,893 barrels at 1,700 psi.

Cumulative oil production to the start of injection was 10,950,000 barrels or about 21.9 percent of the estimated original oil in place. Cumulative oil production to January 1, 1968, was 12,305,000 barrels or 24.6 percent of the estimated original oil in place. Of the 1,355,000 barrels of oil produced since the start of injection, an estimated 550,000 barrels was produced by fluid injection. Cumulative water injection to January 1, 1968, was about 3,313,000 barrels. Available data indicate a successful project.

McDonald Draw

McDonald Draw unit is in Tps 28 and 29 N, R 112 W, and T 28 N, R 113 W, Sublette County. Belco Petroleum Corp. was approved as operator for the 18,582-acre unit on September 29, 1960.

The Almy, usually considered as the basal member of the Wasatch Formation, is the principal producing zone. Twenty or more sands have been found in the Almy in the Big Piney area.

McDonald Draw unit well No. 1 was completed as a gas well from the Wasatch from 3,000 to 3,035 feet in November 1960. Eight other gas wells have been completed in the unit.

Unit well No. 4, SW1/4 sec 31, T 28 N, R 112 W, was completed for 56 barrels of oil and 9-1/2 barrels of water daily from the Wasatch in April 1961. This opened the "south oil pool" of the McDonald Draw unit. Unit well No. 5, SW1/4 sec 33, T 29 N, R 112 W, was completed for 15 barrels of oil daily from the Wasatch in August 1961. This was the first oil well in the "north oil pool" of the unit.

The "south pool" is the Almy participating area "C-D." Thirteen oil wells had been completed there by January 1968. The "north pool" is the Almy participating area "B-F." Thirty-two oil wells had been completed in area B-F by January 1968. There are three oil zones in area C-D and five or six oil zones in area B-F.

In area C-D (south) the M-9 and M-13 sands are being flooded. In area B-F (north) the M-20, M-42, and M-47 sands are being flooded. All of the projects are operated by Belco Petroleum Corp. Injection water is from shallow water wells and produced water.

M-9 Project

M-9 reservoir contains 200 acres and has average pay thickness of 12 feet. Average permeability was 34 millidarcys and porosity averaged 22 percent. Water injection started in October 1964. Two injection wells are near the oil-water contact, and one is near the gas-oil contact in the reservoir. In December 1967 daily production was 170 barrels of oil, 108 barrels of water, and 123,000 cubic feet of gas from four oil wells. Each of the three injection wells were receiving 237 barrels per day at about 1,900 psi.

Cumulative recovery to 1968 was 375,000 barrels of oil or 156 barrels per acre-foot. Recovery since start of water injection was 192,000 or 80 barrels per acre-foot. Nineteen barrels per acre-foot or 45,000 barrels of oil is credited to the waterflood. Cumulative injection to 1968 was 899,000 barrels.

M-13 Sand Project

M-13 reservoir covers 350 acres and has an average pay thickness of 10 feet. Contours based on well logs show the M-13 reservoir as twin-connected lenses. Water injection in the M-13 sand also started in October 1964. One injection well is in each lens and one in the connecting saddle. Gas is injected in one well. Daily production in December 1967 was 38 barrels of oil, 146 barrels of water, and 124,000 cubic feet of gas. The three injection wells each were receiving 259 barrels of water at 1,900 psi.

Cumulative recovery to 1968 was 248,000 barrels or 70 barrels per acre-foot. No oil is credited to water injection. Cumulative injection to 1968 was 990,000 barrels of water and 757 million cubic feet of gas.

M-20 Sand Project

M-20 reservoir has about 480 developed acres and an average pay thickness of 16 feet. Porosity averages 18 percent and permeability averages 52 millidarcys. Water injection began December 2, 1965. On January 1, 1968, the project contained 14 producing oil wells, four water injection wells, and two gas injection wells. Average daily production in December 1967 was 570 barrels of oil and 480 barrels of water. Daily injection was 856 barrels of water at 2,080 psi and 915,000 cubic feet of produced gas at 1,400 psi.

Cumulative oil production to January 1, 1968, was 977,000 barrels. Recovery since start of injection was 532,000 barrels or 69 barrels per acre-foot. Cumulative injection to January 1, 1968, was 757.6 million cubic feet of gas and 506,000 barrels of water. The project appears successful.

M-42 Sand Project

M-42 reservoir covers 260 acres and has an average pay thickness of 10 feet. Average porosity was 17 percent and average permeability was 40 millidarcys. Water injection began January 26, 1966. On January 1, 1968, the project contained four oil and three injection wells. Average daily production in December 1967 was 138 barrels of oil and 38 barrels of water. Daily injection was 499 barrels of water. Cumulative injection to January 1, 1968, was 322,500 barrels of water. Outcome of the project is indeterminate.

M-47 Sand Project

M-47 reservoir covers 480 acres and has an average pay thickness of 30 feet. The M-47 reservoir has the largest sand volume of the five injection projects at McDonald Draw field. Injection started December 2, 1965. On January 1, 1968, the project contained 12 oil wells and three injection wells. Average daily production in December 1967 was 598 barrels of oil and 472 barrels of water. Daily injection was 950 barrels at 1,580 psi.

Cumulative oil production to January 1968 was 678,450 barrels. Recovery since start of injection was 447,900 barrels or 31 barrels per acre-foot. Cumulative injection to January 1968 was 646,900 barrels. The project is too new to evaluate.

Meadow Creek

Meadow Creek oilfield (fig. 17) is in T 41 N, R 78 W, Johnson County. The discovery well, in the NW1/4 sec 11, was completed April 3, 1950. Initial daily flowing production was 192 barrels of 39° API gravity oil from the Lakota Sandstone between 7,475 and 7,530 feet.

Following discovery of oil in the Lakota Sandstone at Meadow Creek, the Sussex, Shannon, Second Frontier (Wall Creek), and Tensleep Formations were found to contain oil and gas.

In developing the Meadow Creek unit, production areas have been designated as "A," "B," and "C." Area A contains the productive area in secs 1-3, and 11, the east part of sec 10, and NE1/4 sec 15. Area B contains sec 9, the west part of sec 10, and north half of sec 16 (except the NW1/4NE1/4NE1/4 sec 16). Area C consists of the area at well No. 100 (or approximately the NW1/4NE1/4NE1/4 sec 16).

A gasoline plant to process the natural gas from the Meadow Creek unit and Sussex unit areas was built in the Meadow Creek field. Operation of the plant was begun about March 1, 1953. Gas has been reinjected

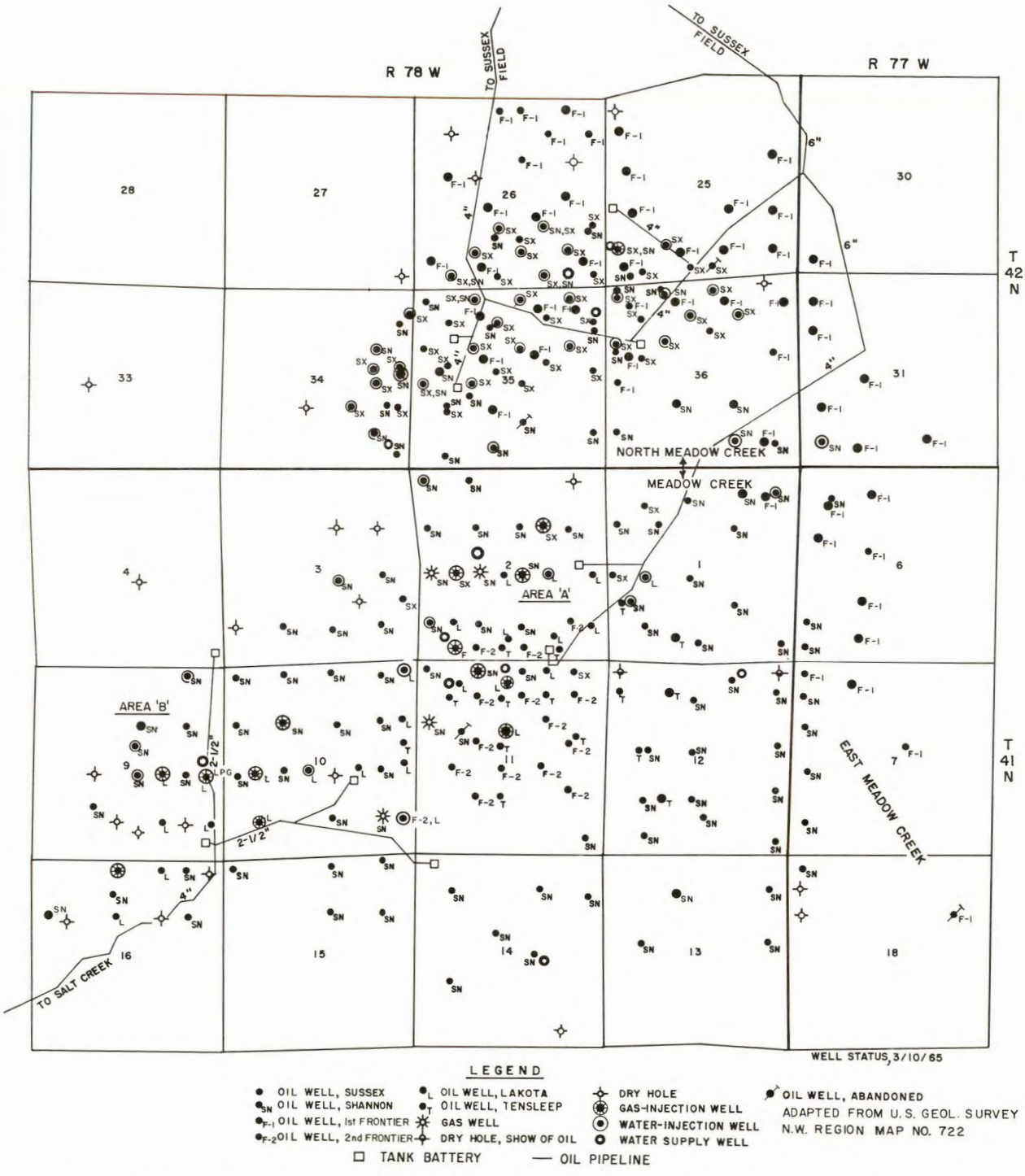


FIGURE 17. - Meadow Creek and North Meadow Creek Fields, Johnson County, Wyo.

into the Sussex, Shannon, Lakota, and Tensleep producing zones after processing to remove butane and propane.

Many normal faults exist in the Meadow Creek field limiting the size of some of the reservoirs. Water injection projects have operated in the Shannon "A and B," Second Frontier, Lakota "A," Lakota "B," and Tensleep "A" reservoirs. Some of the reservoirs are small enough to encourage experimental injection tests. The Meadow Creek unit was formed November 3, 1949.

Water supply for the Meadow Creek-Sussex area fields is obtained from two wells about 14 miles west of the field and two field wells completed in the Madison Formation. The system is called the Shiloh water supply system. Continental Oil Co. operates the water system and the Meadow Creek projects.

Shannon "A-B" Project

Shannon "A-B" reservoir covers 3,759 acres and has an average pay thickness of 16 feet. Transverse faults divide the Shannon reservoir into three distinct blocks. The largest block contains a gas cap. Reservoir producing mechanisms are solution gas drive and gas cap expansion. The operator decided to inject gas into the largest block and water into the other two blocks.

Gas injection was started in March 1953. By January 1, 1968, about 22,295 billion cubic feet of gas and 107,000 barrels of liquefied petroleum gas had been injected into the reservoir. Five injection wells were used for natural gas and one for liquefied petroleum gas. Pilot water injection was started in 1960 and later expanded to a full-scale waterflood. The flood pattern is irregular because of faults in the reservoir. On January 1, 1968, the project area contained 43 producing wells and 21 injection wells; 21 wells had been shut in. During December 1967 daily average production was 244 barrels of oil and 87 barrels of water; daily average injection was about 6,190 barrels of water at an average pressure of 1,600 psi, 85,000 cubic feet of gas, and no liquefied petroleum gas.

Cumulative oil production to the start of injection was about 807,000 barrels or 2.2 percent of the estimated original oil in place. Cumulative oil production to January 1, 1968, was 5,277,565 barrels or 14.4 percent of the estimated original oil in place. Of the 4,470,565 barrels of oil produced since injection was started, an estimated 1.6 million barrels was recovered from fluid injection. Available data indicate a successful project.

Second Frontier "A" Project

Second Frontier "A" reservoir covers 964 acres and has an average pay thickness of 20 feet. Productive limits are defined by a fault on the north, an oil-water contact on the south and west, and a permeability pinchout on the east.

Continental Oil Co. started the project in June 1963 by injecting water into one well. On January 1, 1968, the project area contained 11 producing wells, three shut-in producing wells, and one injection well. During December 1967 the daily average production was 59 barrels of oil and 90 barrels of water; daily injection was 123 barrels of water at 0 pressure.

Cumulative oil production to the start of injection was 1,332,480 barrels or 18.5 percent of the estimated original oil in place. Cumulative oil production to January 1, 1968, was 1,563,804 barrels or 21.7 percent of the estimated original oil in place. Of the 231,324 barrels of oil produced since injection started, an estimated 70,000 barrels was recovered by fluid injection. Cumulative injection was 1,144,406 barrels of water on January 1, 1968. The project appears successful.

Lakota "A" Project

Lakota "A" producing area is 1,230 acres and has an average pay thickness of 15 feet. Two porous zones separated by shale exist in the Lakota A zone. Productive limits are defined by a fault on the north and by an oil-water contact on the other sides. The producing mechanism was solution gas drive.

Gas injection was started in 1953 and stopped in 1960. During that period about 12.8 billion cubic feet was injected. Waterflooding was started in June 1963. The water is injected into wells on the periphery of the reservoir. On January 1, 1968, the project area contained four producing wells and five injection wells; 18 wells had been shut in. During December 1967 daily average production was 145 barrels of oil and 306 barrels of water; daily average injection was about 51 barrels of water at 2,400 psi.

Cumulative oil production to the start of injection was about 1 million barrels or 11.1 percent of the estimated original oil in place. Cumulative oil production to January 1, 1968, was 2,413,434 barrels or 26.8 percent of the estimated original oil in place. Of the 1,413,434 barrels of oil produced since injection started, an estimated 1 million barrels was recovered from fluid injection. Cumulative injection to January 1, 1968, was 2,985,600 barrels. Available data indicate a successful project.

Lakota "B" Project

Lakota "B" reservoir covers 350 acres and has an average pay thickness of 19 feet. Productive limits are defined by a normal fault and an oil-water contact.

The project was started in 1956 as a miscible-phase recovery project. Some water injection is required as part of the miscible project, but no injection has occurred since 1964. Cumulative water injection to December 1, 1965, was 651,330 barrels. Miscible-phase recovery usually means injection of a quantity of liquefied petroleum gas followed by regular water injection.

In December 1967 there were three producing oil wells, four shut-in oil wells, and three shut-in injection wells in the project. Average daily production was 43 barrels of oil and 173 barrels of water. We cannot classify the project a success or a failure.

Tensleep "A" Project

Tensleep "A" reservoir covers 2,918 acres and has an average pay thickness of 17 feet. Productive limits are defined by an oil-water contact. Predominant producing mechanism was a natural water drive, encroaching from the west and northwest.

Fluid injection was started in August 1963 when natural gas and water were injected into one well. On January 1, 1968, the project area contained 15 producing wells, four shut-in producing wells, and two injection wells.

Average daily production in December 1967 was 1,965 barrels of oil and 6,678 barrels of water. Average daily injection was 2,660 barrels.

Cumulative oil production to January 1, 1968, was 9,996,937 barrels. Cumulative injection to January 1, 1968, was 1,800,544 barrels of water and 1,018,391,000 cubic feet of gas. An estimated 15,000 barrels of oil was recovered by fluid injection. Outcome of the project is indeterminate.

North Meadow Creek

North Meadow Creek oilfield, in secs 25, 26, 34-36, T 42 N, R 78 W, Johnson County, lies between the Meadow Creek unit and the Sussex unit. On December 21, 1949, the field was discovered on completion of a well in the NE1/4 sec 35. Initial flowing production was 400 barrels of 40.2° API gravity oil per day from the Sussex sand. Flowing tubing pressure was 80 psi, and the casing pressure was 110 psi.

On September 25, 1952, a well in the SW1/4 sec 36 was completed in the First Frontier (Wall Creek) sand. Initial production by pumping was 17 barrels of 41.5° API gravity oil per day. Early in 1956 oil production from the Frontier was established in sec 26. Initial production of the first four wells averaged 200 barrels per day.

A unit for operation of the Sussex sand reservoir at North Meadow Creek was effective September 1, 1953.

Sussex Project

Sussex sand reservoir includes 962 acres and has an average pay thickness of 32 feet. Productive limits are defined by a sealing fault on the south and by the oil-water contact on the other sides. The primary reservoir producing mechanism was solution gas drive. Waterflooding was started in December 1953 with the flood pattern being an irregular five-spot. On January 1, 1968, the project area contained six producing wells and 24 injection wells; 20 wells had been shut in. During December 1967 daily average production was 92 barrels of oil and 274 barrels of water; daily average injection was about 2,624 barrels of water at an average pressure of 1,000 psi.

Cumulative oil production to the start of waterflooding was about 2.8 million barrels or 12.5 percent of the original oil in place. Cumulative production to January 1, 1968, was 6,413,258 barrels or 28.6 percent of the original oil in place. Of the 3,613,258 barrels of oil produced since waterflooding was started, an estimated 3 million barrels are secondary oil. Cumulative water injection to January 1, 1968, was 19,770,577 barrels. The project is apparently successful.

Shannon Project

Shannon reservoir includes 1,214 acres and has an average thickness of 13 feet. Productive limits are defined by a fault on the south (the same fault that defines the productive limits of the Sussex reservoir), and the oil-water contact on the other sides. The primary producing mechanism was solution gas drive. In March 1959 the waterflood project was started with a five-spot and peripheral flood pattern. On January 1, 1968, the Shannon project area contained 10 producing wells and 11 injection wells; seven producing wells had been shut in. During December 1967 daily average production was 189 barrels of oil and 256 barrels of water; daily average injection was about 1,429 barrels of water at 1,500 psi.

Cumulative oil production to the start of waterflooding was about 920,000 barrels or 9.4 percent of the original oil in place. Cumulative production to January 1, 1968, was 1,285,457 barrels of oil or 13.1 percent of the original oil in place. Of the 365,457 barrels of oil

produced since waterflooding was started, an estimated 200,000 barrels are secondary oil. Cumulative water injection to January 1, 1968, was about 3,410,389 barrels. Possibly some of the injection water has gone into the aquifer. Nevertheless, available data indicate a successful project.

Mellott Ranch

Mellott Ranch oilfield is in secs 2, 10, and 11, T 52 N, R 68 W, Crook County.

The Minnelusa discovery well, in the SW1/4NE1/4 sec 11, was completed August 18, 1961, for an initial production of 377 barrels of oil in 16 hours. The producing interval was from 6,782 to 6,804 feet. By March 1963 seven additional Minnelusa wells in the field had been drilled and completed. Initial oil production ranged from 82 to 784 barrels per day. Average depth to top of the Minnelusa was 6,758 feet.

The reservoir covers about 700 acres and has an average pay thickness of 25 feet. Core analyses showed 16 percent porosity and 30 percent connate water. The crude oil had a bubble point of 175 psi and fluid expansion was the reservoir producing mechanism. Anticipated primary oil recovery was only about 6 percent of the oil in place.

The waterflood project was approved June 9, 1965, with Shell Oil Co. as operator. Actual injection started in December 1965. Water supply is from two wells completed at about 1,000 feet in depth. The two injection wells are near the middle of sec 11 between the two "highs" and form a line drive.

On January 1, 1968, the project contained five producing wells and two injection wells. Daily injection in December 1967 was 1,107 barrels.

Cumulative oil production to start of injection was 640,124 barrels and to January 1, 1968, was 1,075,450 barrels. Recovery since start of injection was 435,326 barrels. Production in December 1965 was 5,148 barrels of oil and no water and in December 1967 it was 31,232 barrels of oil and 33,312 barrels of water. Production is responding to the fluid injection. Cumulative injection to January 1, 1968, was 974,082 barrels.

Mule Creek

Mule Creek oilfield occupies an elongated dome, the axis lying along the line between Rs 60 and 61 W, and the crest being about the center of T 39 N, Niobrara County. The first oil well, in the SW1/4NW1/4 sec 19,

was completed in 1919 for an initial daily production of 160 barrels of 31.5° API gravity green oil from the Lakota sand at 1,300 to 1,355 feet. In 1929 a well in the SW1/4NW1/4 sec 19 found 25.5° API gravity black oil in the Minnelusa Sandstone at 3,145 to 3,184 feet. After the well had been pumped for several days, the production did not exceed 10 barrels per day.

Because the entire field is leased by Sioux Oil Co., unitization was unnecessary. The pilot project is in the Minnelusa Formation. Water for injection is obtained from the Dakota Formation.

The Minnelusa reservoir contains 120 acres and has an average pay thickness of about 23 feet. Water injection was started in September 1959 in one well. On January 1, 1968, the project area contained one producing well and one injection well. During December 1967 the daily average production was 22 barrels of oil and 5 barrels of water; daily injection was 142 barrels of water at 880 psi.

Cumulative oil production to the start of injection was 39,063 barrels or 1.8 percent of the original oil in place. Cumulative oil production to January 1, 1968, was 119,097 barrels or 5.5 percent of the original oil in place. Of the 80,034 barrels of oil produced since the start of injection, an estimated 56,000 barrels was recovered by water injection. Cumulative water injection to January 1, 1968, was 323,000 barrels. Available data indicate a successful project.

Mush Creek

Mush Creek oilfield (fig. 18), in T 44 N, R 63 W, Weston County, is west of Skull Creek field and east of West Mush Creek field. The discovery well in the W1/2NE1/4SW1/4 sec 24 was completed in May 1944 and produced initially 40 barrels of oil per day. The oil was produced from the Newcastle Formation at 3,851 to 3,875 feet. By the end of 1953 at least 307 wells had been drilled; 185 of them were completed as oil wells. Estimates of the original solution gas-oil ratio vary between 600 and 800 cubic feet of gas per barrel of oil. Although some wells were drilled into the Dakota and Lakota Sandstones, no commercial quantities of oil or gas were found below the Newcastle Sandstone.

Test water injections were started by Texaco, Inc., in 1950 and continued intermittently for several years. Later Texaco and H. T. Thorson formed a cooperative project. J. G. Dyer and CRA, Inc., also started projects.

Texaco and Thorson Cooperative Area

Texaco-Thorson project area covers 1,680 acres and has an average pay thickness of 5.6 feet. The reservoir extends east and west beyond the limits of the project.

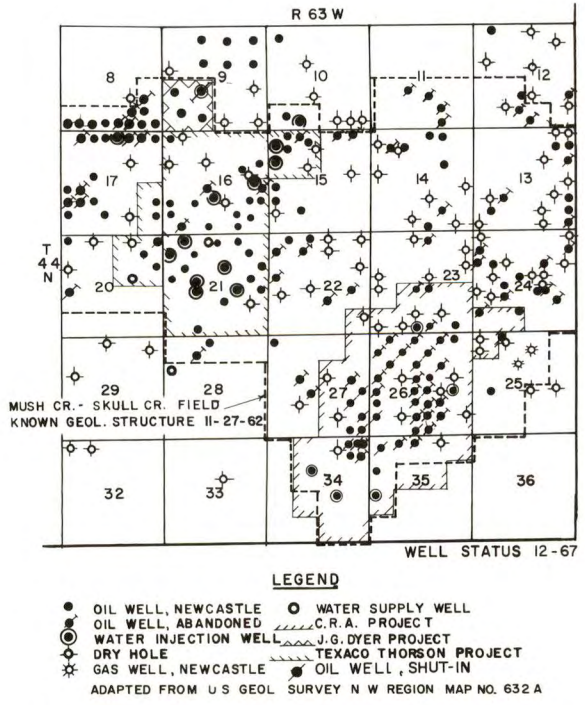


FIGURE 18. - Mush Creek Waterflood Projects, Weston County, Wyo.

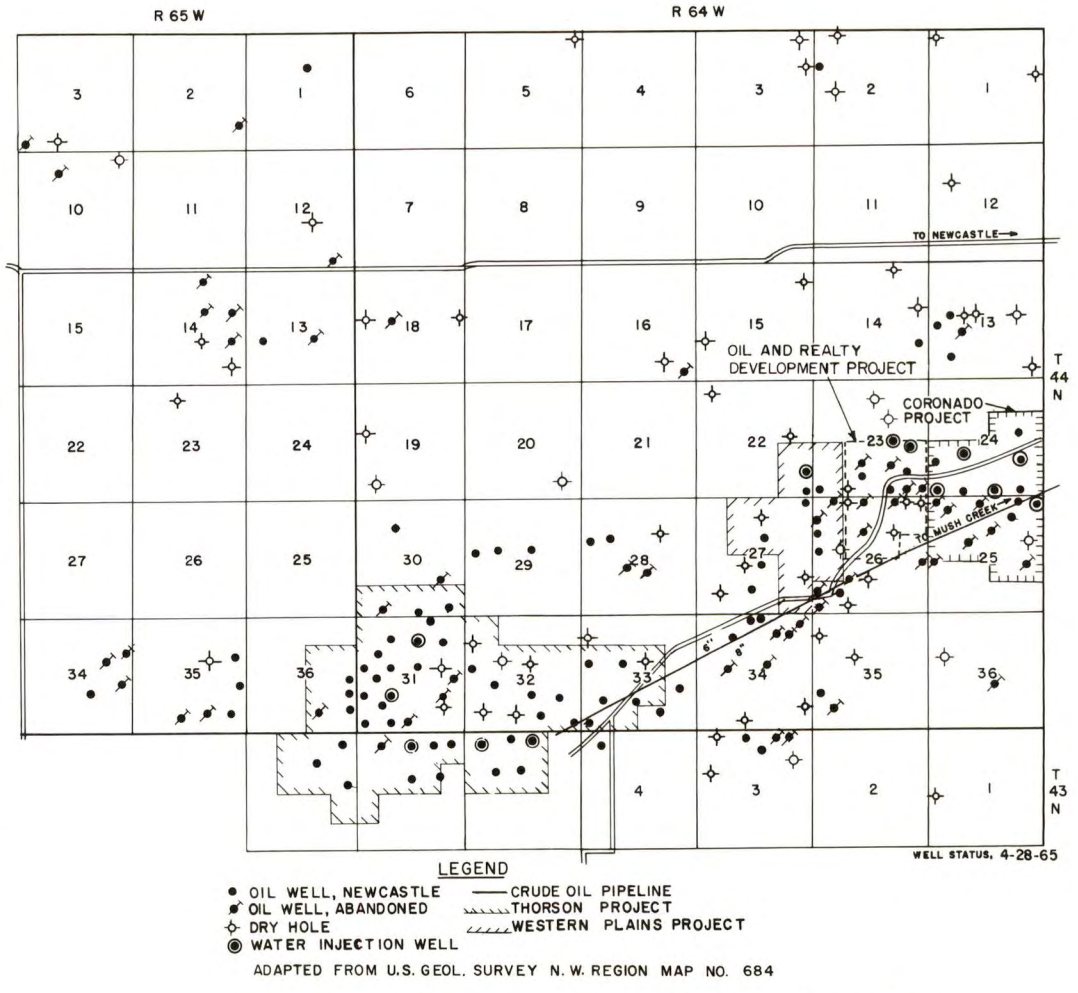


FIGURE 19. - West Mush Creek Field, Weston County, Wyo.

The Texaco project, started in September 1950, was expanded to five injection wells in 1953. The Thorson project was added in November 1962. Each operator has a water supply well and water injection system. Three injection wells and five producing wells outside the cooperative area were included as part of the project in this report. On January 1, 1968, the project area contained six producing wells, 14 injection wells, six shut-in wells, and two water supply wells. During December 1967 daily average production was 74 barrels of oil and 272 barrels of water; daily average injection was 1,118 barrels at 1,620 psi.

Cumulative oil production to the start of injection was 1,239,000 barrels or 22 percent of the estimated original oil in place. Cumulative oil production to January 1, 1968, was 1,975,702 barrels or 35 percent of the estimated original oil in place. Of the 736,702 barrels of oil produced since the start of injection, an estimated 395,000 barrels was recovered by water injection. Cumulative water injected to January 1, 1968, was 4,820,611 barrels. Available data indicate a successful project.

J. G. Dyer Unit

J. G. Dyer reservoir (project area) covers 160 acres and has an average pay thickness of about 8 feet. Productive limits are defined by permeability changes to the east, northwest, and south. The reservoir extends beyond the project area in other directions.

Water injection was started in June 1964 in one well. The water for injection was purchased from Harry Thorson, but after September was obtained from a well completed in the Lakota sand. On August 15, 1966, the project area was transferred to Wind River Drilling Co. The project was shut down in October 1967.

Cumulative oil production to the start of injection was 144,700 barrels (total primary) or about 16 percent of the original oil in place. Cumulative oil production to November 1967 was 167,911 barrels or about 18.6 percent of the original oil in place. The 23,211 barrels of oil produced since the start of injection was recovered by water injection. Cumulative water injection to January 1, 1968, was 455,931 barrels. The project is a success.

CRA Project

CRA project is in secs 26, 27, 34, and 35, T 44 N, R 63 W. The productive area contains 1,400 acres and has a net pay thickness of 7.9 feet. Average porosity was 17.1 percent; permeability, 193 millidarcys; and water saturation, 30 percent.

Injection was begun October 1, 1966. Water is obtained from a Madison well. Cumulative production to start of injection was estimated

at 1,790,000 barrels. Cumulative production since start of injection was 20,976 barrels by January 1, 1968. In December 1967 there were seven producing wells, five injection wells, and 12 shut-in wells producing 17 barrels of oil per day. Cumulative water injection to January 1, 1968, was 202,632 barrels. Daily injection during December 1967 was 2,122 barrels at 2,150 psi. Outcome of the project is indeterminate.

West Mush Creek

West Mush Creek oilfield (fig. 19) has been designated as all of the area in T 44 N, Rs 64 and 65 W, Weston County. The first well completed in the area was in the NE1/4SW1/4SW1/4 sec 26, R 64 W. Initial daily flowing production was 200 barrels of 43° API gravity oil from the Newcastle Sandstone at 4,946 to 4,953 feet. Most of the wells were drilled in secs 22-27, 31-33, T 44 N, R 64 W, and in secs 13, 14, and 36, T 44 N, R 65 W.

The initial daily production of 50 wells ranged from 20 to 1,440 barrels, and the average daily production was 158 barrels per well. At least nine of the wells were shot with nitroglycerin to increase production. Results of the shooting were inconclusive because all of the wells were extremely low fluid capacity wells before they were shot. At least 171 wells were drilled in the area; 104 of them were completed as oil wells in the Newcastle Sandstone.

Four separate projects operate in the field: The Coronado Oil Co. project, started in October 1960; the Oil and Realty Development, Inc., project, started in September 1965; the Harry T. Thorson project, started in August 1964; and the Western Plains Petroleum, Inc., project, started in September 1964. Water for injection is obtained from the Dakota Formation for three of the projects and from the Fox Hills sand for the Thorson project. Oil and Realty Development, Inc., is buying water from Coronado Oil Co.

Harry T. Thorson Project

The reservoir of the Harry T. Thorson project includes 1,507 acres and has an average pay thickness of about 13 feet. The Newcastle sand contains an upper zone and a lower zone; there is some communication between zones.

The project area was unitized in August 1964, and water injection into both the upper and lower zones was started in January 1965. On January 1, 1968, the project area contained 21 producing wells and 12 injection wells. During December 1967 the daily average production was 87 barrels of oil and 139 barrels of water. Daily average injection was 3,527 barrels of water.

Cumulative oil production to the start of injection was 1,772,000 barrels or 14 percent of the original oil in place. Cumulative oil production to January 1, 1968, was 1,842,990 barrels or 14.5 percent of the original oil in place. All of the 70,990 barrels of oil produced since the start of injection is considered secondary oil. Cumulative water injected to January 1, 1968, was 2,986,388 barrels. Outcome of the project is indeterminate.

Coronado-Wade Hill Project

Wade Hill project, operated by Coronado Oil Co., contains 640 acres and has an average pay thickness of about 8 feet.

Water injection in three wells was started in October 1960. The rate of injection desired was not attained because of high injection pressure. On January 1, 1968, the project area contained five producing wells and four injection wells. During December 1967 the daily average production was 35 barrels of oil and 199 barrels of water; daily water injection was 739 barrels at 2,000 psi.

Of the 136,955 barrels of oil produced since the start of injection, an estimated 60,000 barrels was recovered by water injection. Cumulative water injected to January 1, 1968, was 2,382,178 barrels. Available data indicate a successful project.

Western Plains Petroleum Inc. Project

The Western Plains Petroleum Inc. reservoir contains 210 acres and has an average pay thickness of about 11 feet.

Water injection was started in one well in September 1964. On January 1, 1968, the project area contained four producing wells and two injection wells. During December 1967 the daily production rate was 12 barrels of oil and 135 barrels of water; daily average injection was 741 barrels of water at 1,780 psi.

Of the 36,622 barrels of oil produced since the start of injection, an estimated 30,000 barrels was recovered by water injection. Cumulative water injection to January 1, 1968, was 521,541 barrels. Available data indicate a successful project.

Oil and Realty Development, Inc., Project

The Oil and Realty Development, Inc., reservoir contains 303 acres and has an average pay thickness of 9 feet. Water injection was started in January 1966. On January 1, 1968, there were two producing wells and three injection wells. During December 1967 the average production was 45 barrels of oil and 52 barrels of water per day. Production since the start of injection was 41,810 barrels.

Cumulative injection to January 1, 1968, was 871,762 barrels. Outcome of the project is indeterminate.

Oregon Basin

Oregon Basin oil and gas field (fig. 20) in Tps 50-52 N, west half of R 100 W, Park County, is on two large domes (referred to as North and South Oregon Basin domes) adjoining one another but separated by a narrow saddle. The field was discovered in August 1912 when a gas well on the crest of the south dome in NW1/4SW1/4 sec 32 was completed in the Cloverly Formation at 1,320 feet, with an open-flow volume of 20 million cubic feet of gas per day. In 1916 a gas well was drilled in the SE1/4NW1/4 sec 5 in a fault block on the crest of the north dome; it was completed in the Cloverly Formation at 1,328 to 1,340 feet. It has an estimated open-flow volume of more than 25 million cubic feet of gas per day and a shut-in wellhead pressure of 680 psi.

In March 1927 oil was discovered in the Embar Limestone and Tensleep Sandstone at 3,354 to 3,650 feet in a well in the NW1/4NE1/4 sec 8, north dome. The well produced 800 barrels of 22° API gravity black oil per day. In 1928 a well in the SW1/4NE1/4 sec 32, north dome, produced initially 1 million cubic feet of gas per day from the Chugwater Formation at 2,850 to 2,890 feet; the shut-in wellhead pressure was 1,580 psi. In 1930 a well drilled in the SW1/4SW1/4 sec 33, north dome, produced initially 1.6 million cubic feet of gas per day from the Chugwater Formation at 2,785 feet; the shut-in wellhead pressure was 1,150 psi. In 1929 a well in the SE1/4SE1/4 sec 6, north dome, produced initially 6 million cubic feet of gas per day from the Embar Limestone at 3,276 to 3,291 feet; the shut-in wellhead pressure was 1,600 psi. In 1934 a well in the NW corner, lot 2, sec 9, on a fault block in the south end of the south dome produced 7.6 million cubic feet of gas per day from the Frontier Formation at 898 to 1,154 feet; the shut-in wellhead pressure was 520 psi.

In 1943 oil was discovered in the Madison in a well in the NW1/4NE1/4NE1/4 sec 5 on the south dome. The initial production was 320 barrels of 18° API gravity oil per day with some water, from various porous zones in the Madison Limestone between 4,165 and 4,295 feet. Oil in the Madison was established on the north dome when a well in the NE lot 4, sec 5, T 51 N, R 100 W, pumped 264 barrels of oil per day from 3,930 to 3,965 feet.

A unit plan for developing and operating the Oregon Basin field was approved by the Secretary of the Interior on March 1, 1948.

Gas injection into the Embar-Tensleep zone on the south dome was begun in March 1953. The first injection well was the Rousseau No. 4, in the NW1/4SE1/4SW1/4 sec 23, T 51 N, R 100 W. The total volume of gas injected to the end of 1957 was 2,921 million cubic feet.

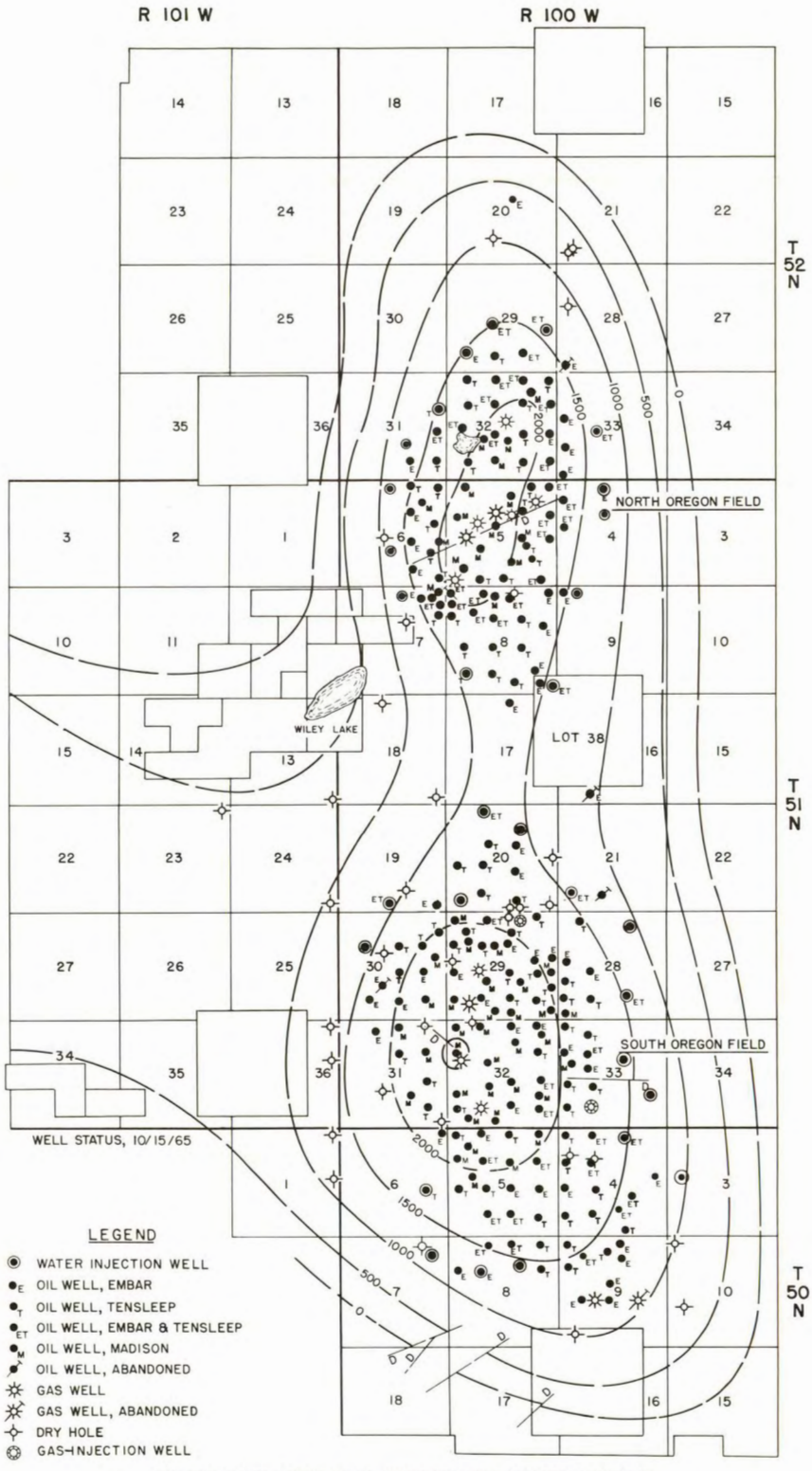


FIGURE 20. - Structure Contour Map of Oregon Field, Park County, Wyo.

An experimental water injection project on the north dome was begun in March 1956. The purpose of the experiment was injection of water into the Embar zone and observation of surrounding wells for any effects of this injection. The injection well was the Frisby "A" 4, in the NE1/4SE1/4NW1/4 sec 32, T 52 N, R 100 W. Water entered the injection well by gravity feed. After 468,078 barrels of water had been injected, the project was stopped on June 15, 1956.

Water injection for pressure maintenance into the Embar and Tensleep zones on both the north and south domes is in progress. For convenience the injection will be discussed as four projects. All projects are carried as pressure maintenance.

The Embar and Tensleep (north and south domes) reservoirs cover about 8,500 acres. The Embar has an effective pay thickness of 38 feet and permeability of 10 millidarcys or less. Some fracture system must exist in the reservoir. The Tensleep pay zone is about 60 feet thick and has a permeability of about 150 millidarcys. From limited core data the Embar has 14 percent porosity and the Tensleep 16 percent.

Water produced from the Embar, Tensleep, and Madison zones is used for injection in all projects. Three Madison wells drilled primarily for water supply in 1967 unexpectedly produced over 2,000 barrels of oil per day.

Cumulative oil production of all four projects since start of injection to January 1, 1968, was 54,469,000 barrels. Because the projects are reported as pressure maintenance, increases in production were not estimated.

North Oregon Basin "Embar"

Water injection in North Oregon Basin Embar was resumed in June 1962. On January 1, 1968, the project contained 28 producing wells, 13 injection wells, and 23 shut-in wells. Daily production in December 1967 was 2,255 barrels of oil and 7,822 barrels of water; daily water injection was 9,269 barrels at 433 psi. Cumulative injection was 8,979,324 barrels.

North Oregon Basin Tensleep

Water injection in North Oregon Basin Tensleep was begun in August 1960. On January 1, 1968, the project contained 53 producing wells, 14 injection wells, and seven shut-in wells. Daily production in December 1967 was 13,566 barrels of oil and 14,087 barrels of water; daily injection was 48,342 barrels at 313 psi. Cumulative injection to January 1, 1968, was 52,519,551 barrels.

South Oregon Basin Embar

Water injection in South Oregon Basin Embar zone began in July 1963. On January 1, 1968, the project contained 31 oil wells, 12 injection wells, and 50 shut-in wells. Daily production in December 1967 was 2,099 barrels of oil and 14,087 barrels of water; daily injection was 4,164 barrels at 112 psi. Cumulative injection was 6,298,414 barrels.

South Oregon Basin Tensleep

Water injection in South Oregon Basin Tensleep began in May 1958. The project contained 75 producing wells, 14 injection wells, and seven shut-in wells on January 1, 1968. Daily production in December 1967 was 9,324 barrels of oil and 19,401 barrels of water; daily water injection was 33,403 barrels at 323 psi.

Osage

Osage oilfield (figs. 21-22), in T 46 N and the south part of T 47 N, Rs 63 and 64 W, Weston County, is on a westerly dipping monocline on the southwest flank of the Black Hills uplift.

The first well, in the SE1/4NW1/4 sec 5, T 46 N, R 63 W, was completed in 1919 in one of the upper shale members of the Graneros Shale at about 350 feet. In 1920 a well in the NW1/4NE1/4 sec 19, T 46 N, R 63 W, was completed in the Newcastle sand (locally known as Muddy) at 1,335 to about 1,400 feet, with an estimated initial daily production of 200 barrels of 40° API gravity oil.

In 1931 oil was discovered in the west extension of the field. Wells drilled in the west half of sec 15 and east half of sec 16, T 46 N, R 64 W, produced as much as 70 barrels of oil per day from the Newcastle sand.

The "shooting" of sand wells with 10 to 40 quarts of nitroglycerin was general practice, and good results were obtained. The shooting of shale or sandy shale wells in the upper terrace ruined them. The shale and Newcastle sand do not produce water, but the Dakota and Lakota sands do.

There is no evidence of an active water drive in the Osage field. It was generally thought that the Newcastle sand contained swelling clays that would prevent successful waterflooding. In the 1950-60 period, several wells were drilled and cored to obtain better information on the reservoir rock. Laboratory tests indicated the Newcastle sand would water flood.

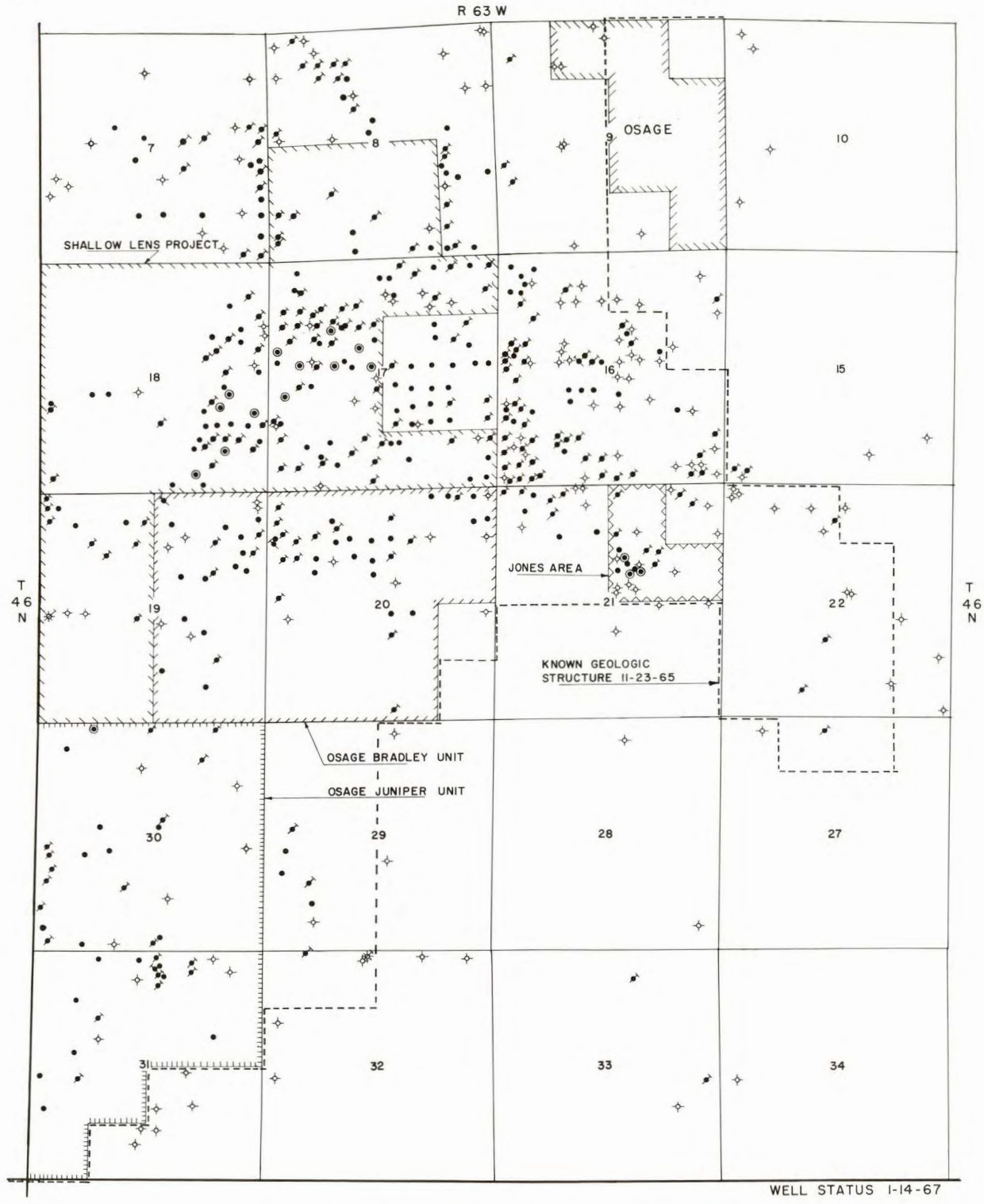


FIGURE 21. - Eastern Part of Osage Field, Weston County, Wyo.

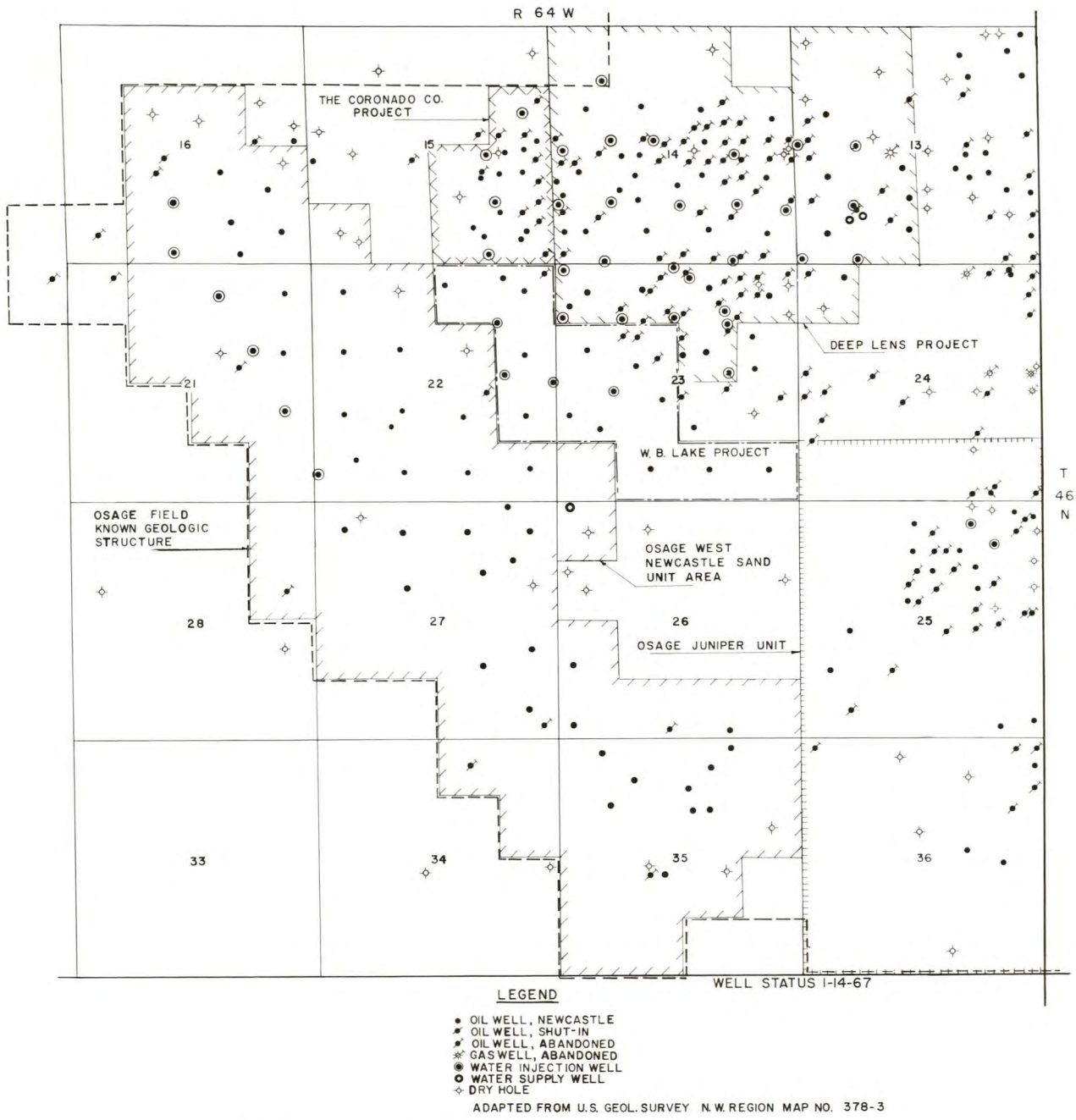


FIGURE 22. - Western Part of Osage Field, Weston County, Wyo.

Detailed reservoir studies indicated varied permeability development throughout the field and thus the possible presence of several reservoirs.

The first pilot injection test was started in 1959. By 1968 Coronado Oil Co., Juniper Oil and Gas Co. (a Division of Buttes Oil and Gas Co.), and William B. Lake were operating projects in the field. Injection water is obtained from the Lakota and Madison Formations. Complete production figures are not available for all leases.

Coronado Jones Area Project

Coronado Jones project has a surface area of 40 acres and an average pay thickness of about 8 feet.

Water injection was started in August 1959 to determine whether or not the Newcastle sand was floodable. Water for injection was obtained from the Lakota Formation. This was the first Osage project and covered only 2.5 acres. A five-spot pattern was used. Production began increasing within a few months; about 2,100 barrels per acre, from the five-spot, was produced by 1964. Injection was stopped October 28, 1963. Cumulative injection was 143,444 barrels. The project was successful.

Coronado Deep Lens Project

Coronado Deep Lens project has an area of about 960 acres and an average pay thickness of about 10 feet. Water injection was started in August 1959. Cores from 13 wells showed averages of 23.3 percent porosity, 428 millidarcys permeability, and 25 percent connate water. At the start of injection the average oil production was between a 1/2 and 1 barrel of oil per day per well. On January 1, 1968, the project area contained 30 producing wells, 25 injection wells, and two water supply wells. During December 1967 the daily production was 222 barrels of oil and 3,155 barrels of water; daily injection was 4,580 barrels at 785 psi.

Cumulative oil production from the start of injection to January 1, 1968, was 809,500 barrels. Of this production, an estimated 600,000 barrels was recovered by water injection. Cumulative water injected to January 1, 1968, was 12,206,600 barrels. Available data indicate a successful project.

International Oil and Gas Corp. Project

International Oil and Gas Corp. project has an area of about 149 acres with an average pay thickness of about 7 feet. The original International Oil and Gas Corp. project was taken over by Coronado Oil Co. and is a continuation of the Deep Lens reservoir.

Water injection was started in three wells in February 1963. On January 1, 1968, the project area contained 10 producing wells and four injection wells. During December 1967 the daily average production was 16 barrels of oil and 1,221 barrels of water; daily average injection was 748 barrels at 840 psi.

Cumulative oil production from start of injection to January 1, 1968, was 329,313 barrels; an estimated 260,000 barrels was recovered by water injection. Cumulative water injected to January 1, 1968, was 1,303,659 barrels. Available data indicate a successful project.

Coronado Shallow Lens Project

Coronado Shallow Lens project has an area of about 1,240 acres and an average pay thickness of about 8 feet. Analyses of cores from 10 wells showed averages of 22-percent porosity, 55-millidarcy permeability, and 25-percent connate water saturation.

Water injection was started in February 1960 with water from the Lakota Formation. At the start of injection the average daily oil production was between a 1/2 and 1 barrel per well. On January 1, 1968, the project area contained 64 producing oil wells, 12 injection wells, and one water supply well. During December 1967 the daily average production was 91 barrels of oil and 146 barrels of water; daily average injection was 550 barrels at 430 psi.

Cumulative oil production from the start of injection to January 1, 1968, was 144,011 barrels. Of this production, an estimated 100,000 barrels was recovered by water injection. Cumulative water injected to January 1, 1968, was 1,148,626 barrels. The project is a success.

William B. Lake Project

William B. Lake project contains 600 acres and has a pay thickness of 6 to 8 feet. The project is between the Coronado Oil Co. and Juniper Oil and Gas Co. projects.

Initial injection was in two wells on April 12, 1966, with water purchased from Juniper Oil and Gas Co. A third injection well was added in May 1966 and a fourth in November 1966. Oil production began increasing in the first month of injection, possibly from the offsetting Coronado and Juniper floods.

On January 1, 1968, the project contained 10 oil wells and eight injection wells. Daily production in December 1967 was 534 barrels of oil and 147 barrels of water; daily injection was 837 barrels at 485 psi.

Cumulative oil production since start of injection to January 1, 1968, was 299,872 barrels. Estimated recovery from the waterflood was

185,000 barrels. Cumulative injection to January 1, 1968, was 404,906 barrels. The project is a success.

Juniper Osage West Unit

Juniper Osage West unit contains 1,600 acres and has an average pay thickness of about 8 feet. The Osage West unit (Juniper Oil and Gas Co., operator) was approved by the U.S. Geological Survey in February 1964 and by the Wyoming Oil and Gas Conservation Commission in July 1964. Two or more sand lens are in the unit area.

Water for the Juniper projects is from a Madison well in the east Fiddler Creek field, just west of Osage West unit. Water injection in three wells started July 22, 1965. Response to the water injection was soon noted and the project expanded; a few new producing wells were drilled. On January 1, 1968, the project contained 26 active oil wells, 10 shut-in oil wells, and 12 injection wells. Daily production in December 1967 was 175 barrels of oil and 117 barrels of water; daily injection was 1,300 barrels of water at an average of 1,450 psi.

Cumulative oil production to start of injection was about 1,030,000 barrels or 11 percent of original oil in place. Cumulative production to January 1, 1968, was 1,149,000 barrels or 11.3 percent of original oil in place. Because of new wells being drilled, a reasonable estimate of the recovery by waterflooding is impossible from our data. Cumulative water injection to January 1, 1968, was 800,200 barrels. Available data indicate a successful project.

Juniper Osage (Newcastle Sand) Unit

Juniper Osage unit covers about 2,400 acres and has an average pay thickness of about 5 feet. Probably more than one sand lens occurs in the unit area. The unit was approved in November 1965 by the Wyoming Oil and Gas Conservation Commission and by the U.S. Geological Survey in December 1965. Injection water is from a Madison well in sec 23, T 46 N, R 64 W.

Water injection in six wells started in April 1966. Daily production at that time was about 40 barrels of oil and no water. On January 1, 1968, the project contained 30 active and 11 shut-in oil wells and 18 active and two shut-in injection wells. During December 1967 daily production averaged 221 barrels of oil and no reported water; daily injection was 1,430 barrels of water at an average of 580 psi.

Cumulative oil production to start of injection was about 940,000 barrels. Oil production from start of injection to January 1, 1968, was 61,700 barrels. An estimated 39,000 barrels was recovered by waterflooding. Cumulative injection to January 1, 1968, was 621,000 barrels. The project is a success.

Patrick Draw

Patrick Draw oil and gas field (fig. 23) is in Tps 18-20 N, Rs 98 and 99 W, Sweetwater County. The oil discovery was El Paso Products Co's. No. 1 Patrick Draw in the SE1/4SW1/4 sec 1, T 18 N, R 98 W. Initial daily production was 636 barrels of oil from the Almond Formation at intervals of 5,172 to 5,198 feet on October 12, 1959. The field was reasonably well developed in 2 years, using 80-acre well spacing.

The original Patrick Draw area contained the Arch, Beacon Ridge, Patrick Draw, and Playa units. The Arch, Beacon Ridge, and Patrick Draw formed a common pool. Waterflooding for the Arch unit was approved with Forest Oil Co. as operator. Beacon Ridge and Patrick Draw units were combined in the Monell unit for waterflooding, with El Paso Products Co. as the operator.

Arch Unit

Arch reservoir includes about 5,965 acres and has an average pay thickness of about 21 feet. Core analyses indicate the following: Average porosity, 21 percent; average permeability, 136 millidarcys; and water saturations from 43 to 53 percent. The reservoir extends under the Monell unit to the south.

Gas injection for pressure maintenance was started in December 1961 in one well at the gas-oil contact. On January 1, 1968, about 21,748 million cubic feet of gas had been injected into two wells. A pilot water injection project was started in September 1964; the injection pattern was a standard five-spot. The pilot was expanded to 28 injection wells by January 1, 1968. On January 1, 1968, the unit area contained two producing gas wells, 61 producing oil wells, two gas injection wells, 28 water injection wells, and one water supply well. During December 1967 the daily average production was 2,942 barrels of oil and 52 barrels of water; daily average injection was 14,655,000 cubic feet of gas and 3,254 barrels of water at 2,020 psi.

Cumulative oil production to the start of gas injection was 2,365,000 barrels or 2.6 percent of the original oil in place. Cumulative oil production to the start of water injection was about 8,130,000 barrels or 8.8 percent of the original oil in place. Cumulative oil production to January 1, 1968, was 11,772,973 barrels or 12.7 percent of the original oil in place. The project is carried as pressure maintenance. Cumulative water injected to January 1, 1968, was 2,153,210 barrels.

Monell Unit

Monell reservoir includes about 7,500 acres and has an average pay thickness of about 21 feet. Core analyses showed average porosity, 19.7

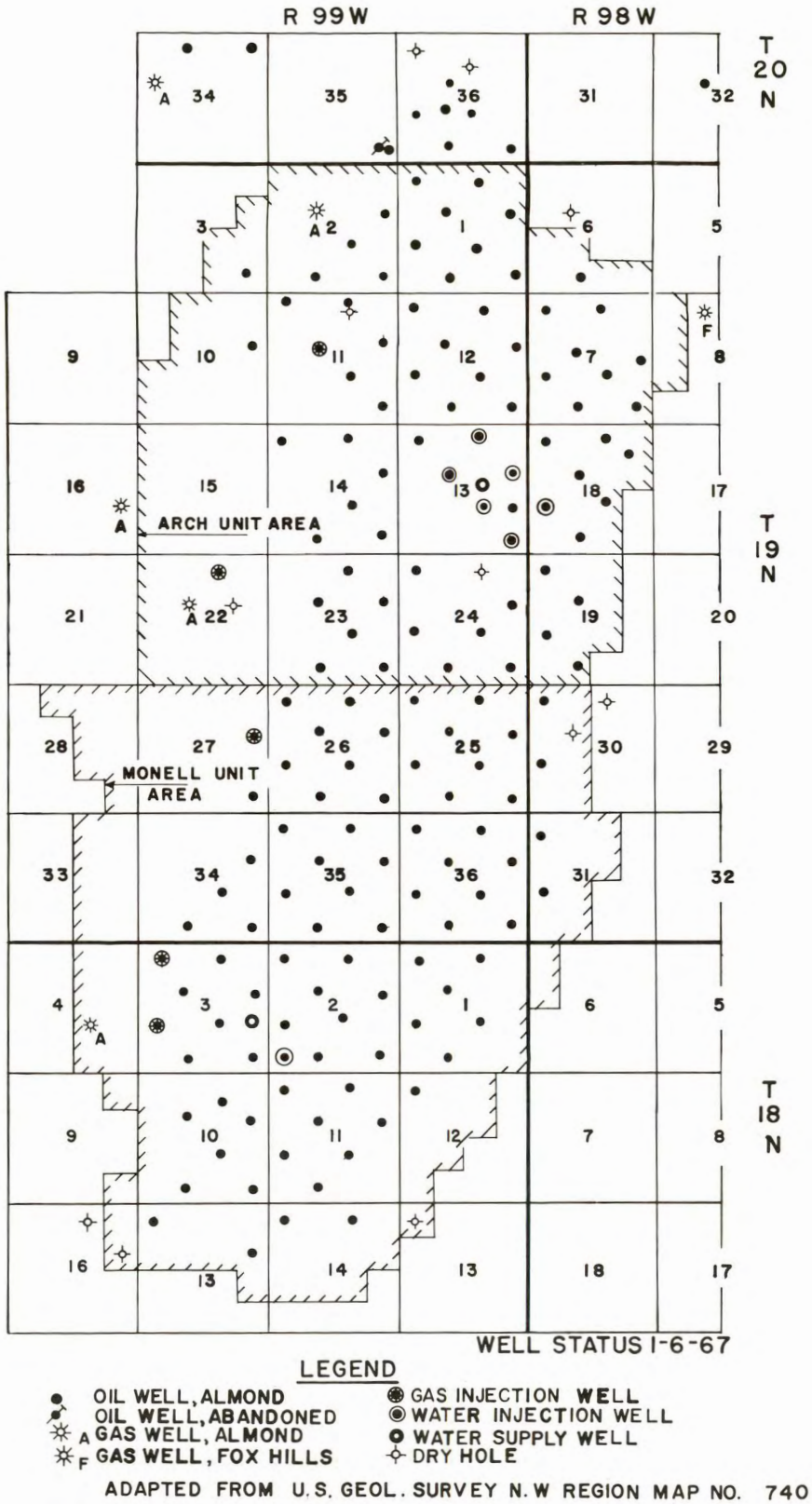


FIGURE 23. - Patrick Draw Area, Sweetwater County, Wyo.

percent; average permeability, 36 millidarcys; and average water saturation, 30 percent. Original solution gas-oil ratio was 542 cubic feet per stock tank barrel. The reservoir extends under the Arch unit to the north.

Gas injection at the gas-oil contact was started in one well in August 1962 for pressure maintenance. The project was expanded to three injection wells. On January 1, 1968, about 21,843 million cubic feet had been injected. In July 1963 a one-well pilot water injection project was started to determine the water sensitivity of the Almond sand. The sand contains kaolinite and illite. Montmorillonite was not found in the samples tested. On January 1, 1968, the unit area contained two shut-in wells, 90 oil-producing wells, three gas injection wells, one water-injection well, and one water supply well. During December 1967 the daily average production was 3,598 barrels of oil and 1 barrel of water; daily average injection was 17,783,000 cubic feet of gas and 62 barrels of water at 2,425 psi.

Cumulative oil production to the start of gas injection was 11,144,850 barrels or 8.4 percent of the original oil in place. Cumulative oil production to the start of water injection was 13,364,830 barrels or 10 percent of the original oil in place. Cumulative oil production to January 1, 1968, was 20,682,746 barrels or 15.6 percent of the original oil in place. The project is carried as pressure maintenance. Cumulative water injected to January 1, 1968, was 411,189 barrels.

Poison Spider

Poison Spider oil and gas field is in the northeast corner of T 33 N, R 83 W, and in secs 7 and 18, T 33 N, R 82 W, Natrona County.

The field was discovered in 1917 when a well was completed in the NW1/4NW1/4 sec 12 that could produce 5 million cubic feet of gas daily from the upper Sundance Formation at 1,242 feet. Between 1917 and 1924, 10 gas wells were completed in the upper Sundance sand. The average thickness of the upper Sundance sand is 23 feet.

In 1919 oil was discovered at 1,506 feet in a lower Sundance sand in a well in the NE1/4SE1/4 sec 12. The initial production of this well was 100 barrels of oil per day. By the summer of 1937 about 21 oil wells had been completed in the lower Sundance sand. One gas well was completed in the lower Sundance sand at 1,479 feet with an initial production of 13.5-million cubic feet of gas per day. The lower sand averaged 91 feet in thickness and is the principal oil-producing sand, although initially it also contained gas on top of the structure.

Oil was discovered in June 1948 in a well in the SE1/4SW1/4SE1/4 sec 12, T 33 N, R 83 W. Initial production was 5 barrels of 35.4° API gravity oil from 546 to 558 feet per day in the Muddy sand.

Between 1942 and 1946 several wells were drilled to the Tensleep Sandstone and completed in this sand. The wells had an initial capacity of 30 to 60 barrels of oil per day, but soon oil production declined as water production increased. By 1949 all producing wells were completed in the Sundance at about 1,500 feet except for three small wells completed in the Muddy sand.

Gas production reported from 1920 to 1927 was 5.5 billion cubic feet. No gas has been sold since 1927. The initial gas-bearing area probably was not over 160 acres; the initial oil-bearing area was about 480 acres.

The part of the Sundance reservoir being flooded includes about 120 acres and has an average pay thickness of about 30 feet. The area may be separated from the rest of the field by faulting.

A pilot water injection project was started in March 1961. Produced water is being injected into one well at the southeast end of the field to supplement a natural water drive. On January 1, 1968, the project area contained 14 producing oil wells, one injection well, and one water supply well. During December 1967 the daily average production was 100 barrels of oil and 774 barrels of water; daily average injection was 492 barrels at atmospheric pressure.

Cumulative oil production to the start of injection was 1,197,439 barrels or 38.7 percent of the original oil in place. Cumulative oil production to January 1, 1968, was 1,448,452 barrels or 46.8 percent of the original oil in place. Of the 251,013 barrels of oil produced at the start of injection, an estimated 120,000 barrels was recovered by water injection. Cumulative water injected to January 1, 1968, was 1,182,601 barrels. Available data indicate a successful project.

Quealy Dome

Quealy Dome oilfield is on one of several structures on the west margin of the Laramie basin; the crest of the dome is in sec 13, T 17 N, R 77 W, Albany County.

In November 1934 a well was drilled in the SE1/4SE1/4 sec 13 to the Muddy sand at 3,146 to 3,165 feet. An initial production of about 50 barrels of 36° API gravity green oil per day was obtained. Later the well was deepened to the Dakota sand at 3,231 to 3,263 feet, and production increased to 450 barrels per day. In February 1937 a well was drilled on the crest of the structure to the Sundance Formation at 3,660 to 3,764 feet; the initial flowing production was 15 barrels of oil per day. Oil was discovered in 1947 in the Tensleep sand at 5,318 to 5,470 feet in a well in the CW1/2SW1/4 sec 18. Initial production was 493 barrels of 27° API gravity oil per day. Seven other wells have been completed in the Tensleep sand.

The Tensleep reservoir includes 260 acres and has an average pay thickness of 90 feet. Core analyses show porosity of 15 percent and permeability of 105 millidarcys.

The field was unitized in March 1961 with Chevron Oil Co. as unit operator. Water injection started in one Tensleep Formation well in May 1961, using produced water from the Dakota and Tensleep Formations. Later another injection well was added. Both injection wells are on the west side of the reservoir near a thrust fault. On January 1, 1968, the project area contained six producing wells and two injection wells. During December 1967 the daily production was 778 barrels of oil and 4,261 barrels of water; daily injection rate was 3,200 barrels at 2,010 psi.

Cumulative oil production to the start of injection was about 2,149,000 barrels or about 10 percent of the original oil in place. Cumulative oil production to January 1, 1968, was 4,885,803 barrels or 22.7 percent of the original oil in place. Of the 2,736,803 barrels of oil produced since the start of injection, an estimated 1,890,000 barrels was recovered by fluid injection. Cumulative water injection to January 1, 1968, was 5,027,255 barrels. Available data indicate a successful project.

Raven Creek

Raven Creek field is in secs 2-4, 10, 11, 13-15, 23, and 24, T 48 N, R 69 W, and secs 33-35, T 49 N, R 69 W, Campbell County.

The Dakota (or Fall River) discovery well in the SE1/4SE1/4 sec 1, T 48 N, R 69 W, was completed in November 1956. Initial daily production was 96 barrels of oil and 20 barrels of water. The producing interval was from 6,763 to 6,817 feet. Production declined rapidly and after the well had produced 1,818 barrels of oil, it was shut-in in 1957. Obviously it was a noncommercial discovery.

The Minnelusa discovery well was Kewanee Oil Co's. No. 1 Norman in the NE1/4NW1/4 sec 14, T 48 N, R 69 W, about 2 miles southwest of the Dakota discovery. Initial pumping production was 440 barrels of oil on March 18, 1960. The producing interval was from 8,338 to 8,365 feet in the Minnelusa "B" sand. The field was developed with 80-acre well spacing.

Forty-one producing wells, including three redrills, and 15 dry holes were drilled in defining the field. Some casing failures have occurred. Raven Creek unit, with Mobil Oil Corp. as operator, was effective May 1, 1966.

The unit contains 4,510 acres and has pay thickness averaging 38 feet. The average porosity is 15 percent, and the permeability averages

92 millidarcys. Water injection was begun February 1967 in eight wells; one water supply well was completed. Four of the injection wells were recompleted dry holes. All injection wells are along the western edge of the field forming a line-drive pattern of flooding.

On January 1, 1968, the unit contained 27 producing oil wells, 10 injection wells, and four shut-in wells. Daily production in December 1967 was 2,890 barrels of oil and 162 barrels of water; daily injection was 10,300 barrels of water at 2,100 psi.

The project is too new to evaluate. Cumulative oil production to January 1, 1968, was 10,354,000 barrels. Production since formation of the unit was 1,416,000 barrels of oil. Water injection to January 1, 1968, was 3,836,317 barrels.

Ultimate recovery should be 20 to 30 million barrels of oil, or roughly 34 to 51 percent of the original oil in place.

Robinson Ranch

Robinson Ranch oilfield in secs 28, 29, and 32, T 50 N, R 67 W, Crook County, is about 3 miles east of Moorecroft. Pan American Petroleum Corp's. No. 1 L. H. Robinson, in the NW1/4NE1/4 sec 32, was completed November 28, 1958. Initial daily pumping production was 294 barrels of 26.4° API gravity oil from the Minnelusa interval from 6,065 to 6,080 feet.

The field was developed essentially in 1 year with 10 oil wells drilled. A Federal unit for operation of the field, effective January 1, 1962, contained 800 acres. Low gas-oil ratios and a limited water drive were indicated early in the life of the field.

Experimental gas injection began in August 1961 with gas purchased and piped from the Donkey Creek field about 10 miles west of Robinson Ranch field.

A full-scale gas-water injection program was approved by the Wyoming Oil and Gas Conservation Commission on May 29, 1962. The project is unusual in its technical and mechanical aspects. Technically, the plans called for injection of slugs of gas followed by water. The amounts and time of the two-phase injection would be determined by results. Mechanically, the Minnelusa "A" and "B" zones are separated by packers in the injection wells permitting injection of either fluid in either zone. In theory, the gas will lower the viscosity of the oil and occupy void space in the reservoir, and the injected water will tend to maintain reservoir pressure and drive the oil. Water supply is the produced water from the field.

Initially, three gas injection wells were used. The combination of gas and water injection started in July 1962 with five injection wells. On January 1, 1968, there were nine oil wells, seven active injection wells, and three shut-in injection wells. During December 1967 average daily production was 772 barrels of oil and 7,195 barrels of water; average daily injection was 2,435 barrels of water. No gas was injected during the last half of 1967. Estimated recoveries were 30 to 35 percent of the oil in place by primary methods, and 10 to 15 percent by secondary methods.

Cumulative oil production to the start of injection was about 2,736,500 barrels or 11 percent of the original oil in place. Cumulative oil production to January 1, 1968, was about 5,195,888 barrels or 20.9 percent of the original oil in place. Of the 2,459,388 barrels of oil produced since injection started, an estimated 450,000 barrels was recovered by fluid injection. Cumulative injection for the same period was 5,506,020 barrels of water and 1,652,806,000 cubic feet of gas. Technically, the project is an apparent success.

Rock River

Rock River oilfield, known also as Rock Creek oilfield, is in the northeast corner of T 19 N, and the southeast corner of T 20 N, R 78 W, Carbon County. The discovery well, in the SE1/4SW1/4 sec 35 was completed in May 1918. Initial daily production was 50 barrels of oil from the Muddy sand at 2,581 to 2,609 feet. Dakota and Lakota Formations, directly below the Muddy sand, also are oil-producing zones. Wall Creek sand (about 750 feet above the Muddy sand) yielded 40 barrels of oil per day in one well. In June 1935 oil was discovered in the Sundance sand when a well on the crest of the structure was deepened from the Dakota to the Sundance sand at 3,096 to 3,200 feet. Initial daily production was 200 barrels of oil.

Since 1929 residue gas from the plant, above field requirements, has been recycled in the Dakota-Lakota reservoirs. During summer months propane and butane production, above sales and storage, has been injected in the Lakota zone. Daily gas injection in December 1967 averaged 674,000 cubic feet. Cumulative gas injection to January 1, 1968, was 17,672 million cubic feet, and liquid petroleum gas cumulative injection was 137,000 barrels.

A pilot water injection project in the Muddy sand was started in May 1961 and in the Lakota sand in October 1964.

Muddy Sand Project

The total Muddy sand reservoir covers more than 1,000 acres, but the test area is probably less than 400 acres. The pay thickness is

estimated to range from 14 to 20 feet. Water for injection is runoff collected in ponds.

One injection well and six producing oil wells made up the original project in 1961. On January 1, 1968, the project contained five oil wells and one injection well. During December 1967 average daily production was 71 barrels of oil and 237 barrels of water. Daily injection was 576 barrels of water.

Cumulative oil production to 1968 was about 2 million barrels. Cumulative injection was 2,988,000 barrels. Because of some increase in production, the project is probably successful.

Lakota Sand Project

Lakota sand reservoir covers about 1,500 acres, but we were unable to define the test area. The pay zone is estimated to be 25 to 30 feet thick. Injection water is obtained from a Tensleep well in the NE1/4 sec 3. The recycling of gas for years probably has drained oil from the crestal area. One water-injection well and two gas-injection wells in the NW1/4 sec 2 were active in December 1967. Twelve Lakota or Dakota-Lakota oil wells were active in secs 2 and 3. Average daily injection in December 1967 was 674,000 cubic feet of gas and 1,962 barrels of water.

Cumulative water injection to 1968 was 2,163,000 barrels. With available data, we could not clearly classify the Lakota pilot test a success or failure.

Salt Creek

Salt Creek field in Tps 39 and 40 N, Rs 78 and 79 W, Natrona County, is the largest oilfield in the Rocky Mountain Region (4). The contour map of the field (fig. 24) is intended to portray the general features of the structure rather than to present contours accurate in detail.

Oil seepages were known to exist at Salt Creek before 1880. In 1889 a well was drilled into the Shannon sand on the north end of the Salt Creek dome. This sand crops out less than 2 miles south of the Shannon pool and forms the escarpment around the Salt Creek dome.

The Shannon oil sand in the Shannon pool was found at depths of 700 to 1,000 feet. The wells were small producers and had a daily yield of 5 to 15 barrels of green, paraffin base, 24.7° API gravity oil, which contained little gasoline. By June 1, 1938, 48 wells had been drilled in the pool; 39 of these were shut in and nine were abandoned. The productive area of the Shannon pool was about 160 acres. Production

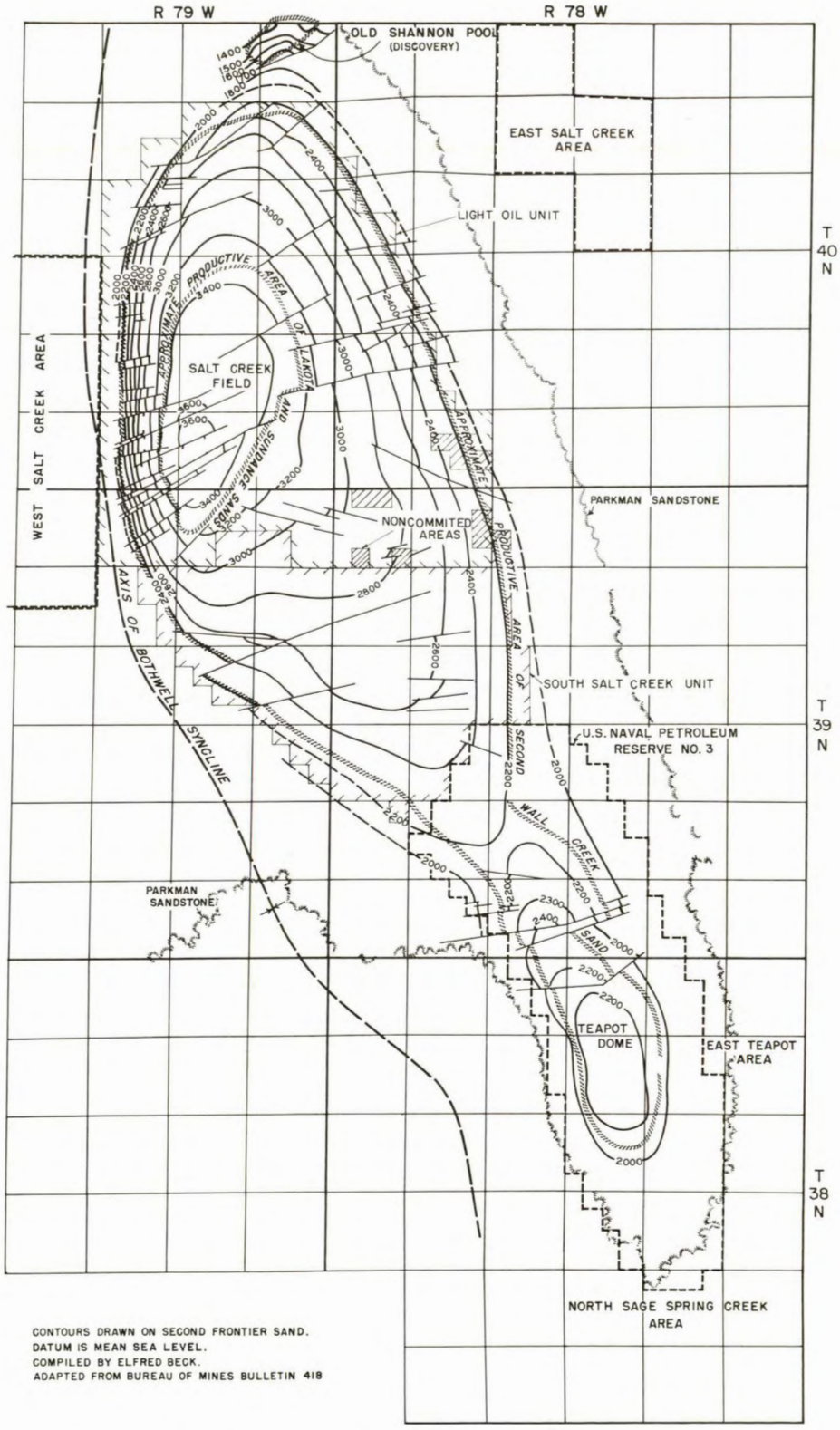


FIGURE 24. - Structure Contour Map of Salt Creek Anticline, Natrona County, Wyo.

of oil from the pool during 1893-1915, as estimated by Estabrook and Rader (3), totaled 53,441 barrels; 15,000 barrels (production from 1893-96) was hauled by teams to Casper, and 38,441 barrels (production from January 1913 to May 1915) was piped to Casper. The wells were shut down in May 1915.

In July 1958 Pan American Petroleum Corp. started an underground combustion test. Results of the test are reported by Parrish, Rausch, Beaver, and Wood (5).

Although some oil had been discovered in the shales above the First Wall Creek sand in 1906, the Salt Creek dome did not attract the attention of oil producers until 1908 when a well drilled to the First Wall Creek sand "came in" producing 200 barrels of oil per day; this well was plugged and abandoned in 1937. In chronological order, the following formations proved to be oil bearing in the Salt Creek field: Second Wall Creek sand, 1917; Lakota Sandstone, 1921; Third Wall Creek sand, 1924; Second Sundance sand and Lakota Shale, 1925; Third Sundance sand, 1926; Morrison, 1929; Tensleep sand, 1930; First Sundance sand, 1953; and Fishtooth Shale, 1954. Figure 25 shows the approximate boundaries of the First Wall Creek, Second Wall Creek, and Second Sundance reservoirs.

Gas injection into the First Wall Creek sand through three wells was begun in 1927. Later five wells were used as injection wells and some gas was injected until 1950. The gas injected totaled 2,411 million cubic feet.

From 1911-18 all gas over that required for field operations was burned. In January 1918 the first gasoline plant, having a capacity of 3 million cubic feet per day, was completed. Later, this plant was enlarged, two other plants were built, and six "booster" plants were erected in the field; by 1924 the gasoline plants had a total capacity of 60 million cubic feet.

On May 1, 1924, when approximately 183 million cubic feet of gas was produced, 49 million was processed at gasoline plants, 15 million was used as fuel in the field, and 119 million was being wasted. As a result of the large wastage of gas and the realization that repressuring of the producing zones would be profitable, a program of returning excess gas to the oil sands was initiated in 1926. By 1930 little gas was being wasted. All the gas returned to producing formations was returned to the Second Wall Creek sand, except for the following: From 1931-37, 3 to 6 million cubic feet was returned annually to the Lakota sand; and from 1927-45, 1.3 to 487 million cubic feet was returned annually to the First Wall Creek sand.

A pilot water injection test of the Second Wall Creek sand was operated during 1944-49. One injection well was used and 163,000 barrels was injected.

The Salt Creek light oil operating unit was effective September 1, 1939, with 15,338 acres (about the northern two-thirds of the field). Midwest Oil Corp., the operator, contracted actual operation to Pan American Petroleum Corp. The South Salt Creek unit, with CRA, Inc., as operator, was effective January 31, 1962, and contained 7,335 acres.

The five active waterfloods in the Salt Creek field on January 1, 1968, were as follows; First Wall Creek sand; Second Wall Creek sand (light oil unit area); Lakota; and Second Sundance sand; all operated by Pan American Petroleum Corp.; and the Second Wall Creek sand (south unit) operated by CRA, Inc.

First Wall Creek

First Wall Creek sand flood contains 4,035 acres and has an average pay thickness of 80 feet. Core analyses of the First Wall Creek sand showed 16-percent porosity, 80-millidarcy permeability, and 30- to 35-percent water saturation. A total of 2.4 billion cubic feet of gas was injected from 1927 to 1950.

A twin five-spot pilot waterflood was started in January 1955. A well was drilled to the Madison Formation for water supply and, when completed, was capable of flowing about 80,000 barrels of water per day. In a year and a half the pilot area showed an increase in oil production in excess of 500 barrels per day. Expansion to a full-scale waterflood was started in 1957, and by 1961, drilling of peripheral injection wells was completed.

On January 1, 1968, the project contained 345 producing oil wells and 190 water-injection wells. Average daily production during December 1967 was 10,812 barrels of oil and 93,780 barrels of water, and 183,000 cubic feet of gas. Daily water injection was 116,000 barrels at 346 psi.

Cumulative oil production to the start of water injection was 46,788,000 barrels or about 20.3 percent of the original oil in place. Cumulative production to January 1, 1968, was 76,437,800 barrels or 33.2 percent of the original oil in place. Of the 29,649,800 barrels of oil produced since water injection started, an estimated 25 million barrels was the result of water injection. Cumulative water injection to January 1, 1968, was 285,101,000 barrels. The project is a success.

Second Wall Creek

The Light Oil unit (Pan American) contains 15,350 acres. The original producing mechanism was solution gas drive. The Second Wall Creek sand averages 59 feet in thickness. Core analyses showed 18-percent porosity, 100-millidarcy permeability, and 30-percent water saturation.

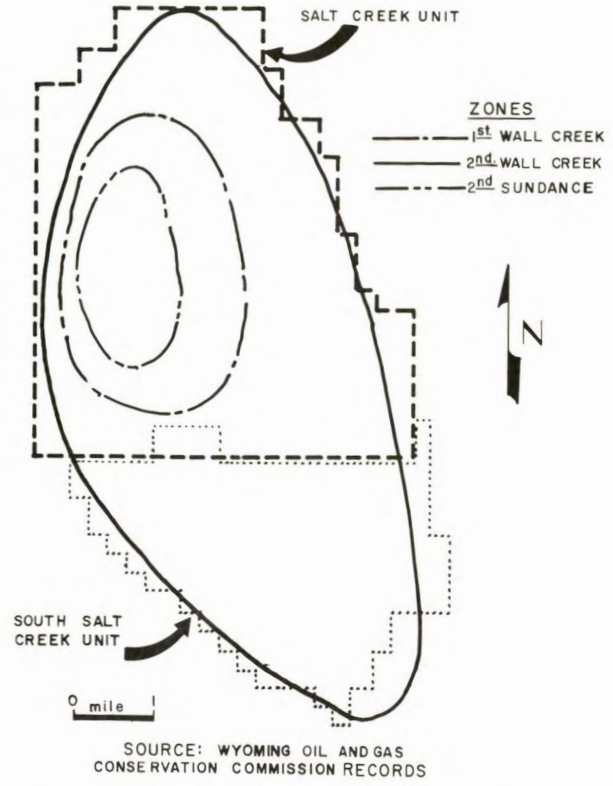


FIGURE 25. - Approximate Productive Limits of Three Salt Creek Field Reservoirs.

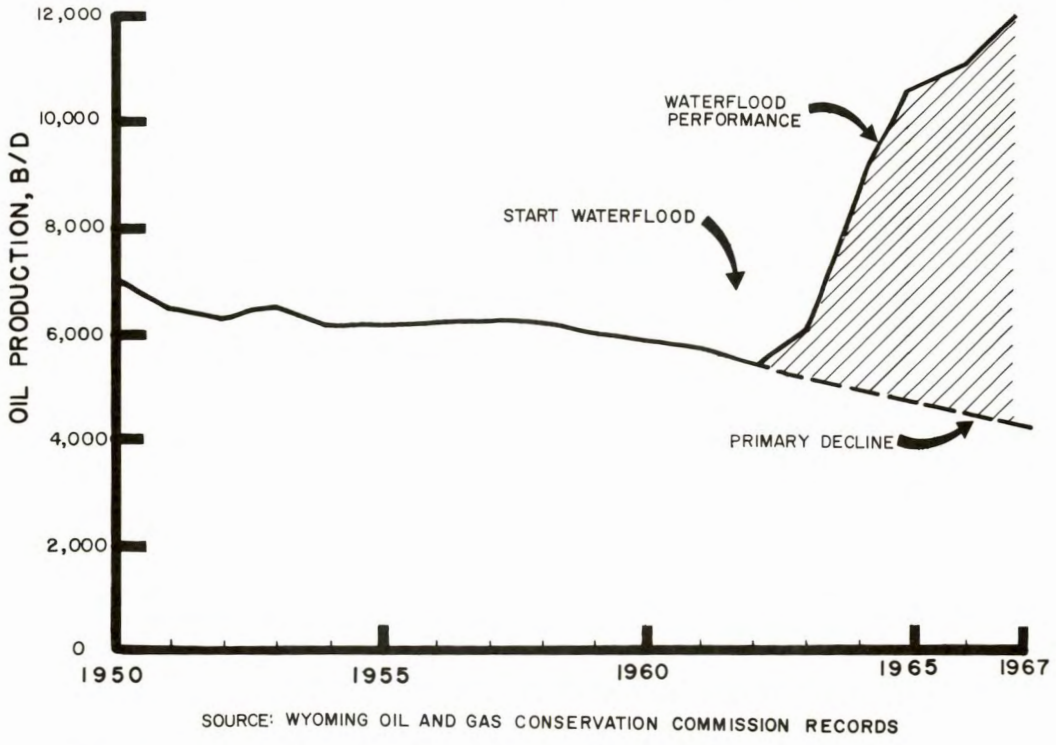


FIGURE 26. - Salt Creek Light Oil Unit, Second Wall Creek Reservoir Performance With Waterflood.

Four Madison water supply wells had a combined open flow of over 250,000 barrels of water per day. Temperature of the water at the surface is about 184° F. A chemical is added to the injection water to control sulfate-reducing bacteria.

Gas injection started in 1924 is still active. On January 1, 1968, there were 65 gas injection wells. Daily gas injection in December 1967 was 6.8 million cubic feet. Cumulative gas injection to January 1, 1968, was about 273.9 billion cubic feet. About 258 billion cubic feet was from the Salt Creek field; the rest was purchased elsewhere. Starting in 1945, some gas from outside the field has been purchased for injection in the Salt Creek field. The gas injection near the crest of the Second Wall Creek reservoir is for pressure maintenance and has increased oil recovery.

The second pilot water injection project was started in June 1960 with expansion to full-scale waterflood beginning in November 1961. Water injection is generally up-dip to supplement natural gravity drainage.

On January 1, 1968, the project contained 489 producing oil wells and 104 active water-injection wells. Daily production in December 1967 was 12,869 barrels of oil, 52,259 barrels of water, and 8,543,000 cubic feet of gas. Daily water injection was 142,850 barrels at 439 psi.

Cumulative oil production to the start of injection was about 249,447,000 barrels or 36.3 percent of the original oil in place. Cumulative oil production to January 1, 1968, was 269,382,800 barrels or 39.3 percent of the original oil in place. Of the 19,935,800 barrels of oil produced since water injection started, an estimated 8,570,000 barrels was recovered by water injection. Cumulative water injection to January 1, 1968, was 306,221,600 barrels. Figure 26 shows the excellent response of the Second Wall Creek reservoir to waterflooding. The project is a success.

CRA Project

South unit Second Wall Creek sand reservoir contains 6,110 acres with an average pay thickness of 24.6 feet. The producing mechanism was solution gas drive and gravity drainage.

One Madison water supply well was drilled. Water injection into four wells started on August 1, 1962. Location of injection wells along the north and south unit boundaries was designed to prevent oil migration across these boundaries.

On January 1, 1968, the project contained 144 producing oil wells and 122 active injection wells. During December 1967 the daily average

production was 9,142 barrels of oil and 44,113 barrels of water; daily injection was 97,590 barrels of water at 916 psi.

Cumulative oil production for the CRA project to the start of injection was 25,942,300 barrels or 24 percent of the original oil in place. Cumulative oil production to January 1, 1968, was 36,245,600 barrels or 33.5 percent of the original oil in place. Of the 10,303,300 barrels of oil produced since injection started, an estimated 8 million barrels was recovered by fluid injection. Cumulative water injection to January 1, 1968, was 135,221,000 barrels. The CRA project appears successful.

Lakota

Lakota reservoir covers 1,885 acres and has an average pay thickness of 40 feet.

A pilot waterflood was started in June 1966. On January 1, 1968, the project had 22 producing oil wells and one active injection well. Daily average production for December 1967 was 195 barrels of oil and 5,376 barrels of water; daily injection was 3,160 barrels of water at 960 psi.

Cumulative production to January 1, 1968, was 20,655,400 barrels of oil, and injection was 1,372,000 barrels of water. The test is too new to evaluate.

Second Sundance

Second Sundance reservoir includes 1,935 acres and has an average pay thickness of 10 feet.

A pilot waterflood was started in August 1964 and has been expanded into a full-scale flood. Because the reservoir contains a secondary gas cap, water is injected near the crest to prevent oil loss to the gas cap. Separate reservoirs exist between faults and several may be separate floods. On January 1, 1968, the project area contained 41 producing wells and seven injection wells. During December 1967 daily average production was 365 barrels of oil and 5,228 barrels of water; daily injection was 5,442 barrels at 722 psi.

Cumulative oil production to the start of flooding was 2,580,000 barrels or about 17.3 percent of the original oil in place. Cumulative oil production to January 1, 1968, was 3,490,300 barrels or 23.4 percent of the original oil in place. Of the 910,300 barrels of oil produced since injection started, an estimated 400,000 barrels was recovered from fluid injection. Cumulative water injection to January 1, 1968, was 3,949,400 barrels. Outcome of the project is indeterminate.

East Salt Creek

East Salt Creek oilfield is in secs 4, 9, 10, and 22, T 40 N, R 78 W, Natrona County. The discovery well, in the SW1/4 sec 10, was completed December 4, 1951, as a dual completion in the Second Wall Creek and Lakota sands. Initial flowing production from the Second Wall Creek sand was 48 barrels of 37° API gravity oil per day from perforations in the casing at 4,922 to 4,960 feet and 203 barrels of 35° API gravity oil from the Lakota sand in 21 hours from perforations in the casing at 5,910 to 5,950 feet.

Oil was found in the Tensleep sand in October 1956. The discovery well, in the SE1/4NW1/4SW1/4 sec 10, had an initial open flow of 1,944 barrels of oil per day.

Completions by zones were Second Wall Creek, six wells; Lakota, seven; and Tensleep, 16. The Second Wall Creek reservoir covered 440 acres and had a pay thickness of 28 feet. Porosity was 19 percent and water saturation was 34 percent. The Lakota reservoir covered 400 acres and had a pay thickness of 27 feet. Porosity was 16 percent and water saturation was 30 percent. The Tensleep reservoir covered 1,280 acres and had a pay thickness of 25 feet. Porosity was 11 percent and water saturation was 28 percent.

Second Wall Creek and Lakota Projects

The East Salt Creek waterflood agreement was approved late in 1966. Water injection in the Second Wall Creek and Lakota started in May 1967. A dually completed well is used for injection in each zone. Produced Tensleep water is used for injection.

Oil production for the last 8 months of 1967 was 16,609 barrels from the Lakota and 51,483 barrels from the Second Wall Creek. Cumulative injection was 152,160 barrels in the Lakota and 286,223 barrels in the Second Wall Creek. The projects are too new to evaluate.

West Salt Creek

West Salt Creek field (fig. 27) in secs 28, 29, 31-33, T 40 N, R 79 W, Natrona County, is west of the axis of the Bothwell syncline. Discovery of the West Salt Creek field resulted from step-out drilling at Salt Creek. No record was found of the location and date of discovery of oil in the Niobrara-Carlile at about 2,200 feet and the Second Wall Creek (Second Frontier) at about 2,600 feet. The discovery well for the Fishtooth was in the SE1/4SW1/4SW1/4 sec 32. Initial production was 3-1/2 barrels of oil per day from open hole from 742 to 790 feet on March 20, 1954. The well was abandoned later in 1954.

Most of the Fishtooth production is in sec 31 and the Second Wall Creek production in secs 28, 29, 32, and 33. The Fishtooth reservoir covers about 257 acres and averages about 15 feet of pay. The Second Wall Creek reservoir (ignoring faults) covers about 640 acres and averages about 43 feet in thickness. Porosity of the Fishtooth is estimated to be 22 percent, and porosity of the Second Wall Creek is estimated to be 21 percent.

The West Salt Creek Second Wall Creek unit was approved in May 1964.

A Madison water supply well was drilled in the NE1/4SW1/4NW1/4 sec 31 in September 1961. The well furnishes water for all West Salt Creek projects.

Fishtooth Project

Water injection in the Fishtooth project, started in one well in September 1961, was expanded to nine wells by 1963. On January 1, 1968, the project area contained 11 producing wells, nine injection wells, and one water supply well. During December 1967 daily average production was 18 barrels of oil and 6,839 barrels of water; daily injection was 1,825 barrels at 675 psi.

Cumulative oil production to the start of injection was 100,738 barrels or 1 percent of the original oil in place. Cumulative oil production to January 1, 1968, was 217,131 barrels or 2.1 percent of the original oil in place. Of the 116,393 barrels of oil produced since the start of injection, an estimated 74,000 barrels was recovered by water injection. Cumulative water injected to January 1, 1968, was 3,617,000 barrels. Available data indicate a successful project.

Second Wall Creek Project

CRA, Inc., started a one-injection well test in Second Wall Creek project on the Stoch lease in the SW1/4 sec 28 in early 1964. Injection was stopped July 31, 1966, after 234,886 barrels had been injected. Apparently the test was unsuccessful.

Water injection at the West Salt Creek unit started July 12, 1964. A peripheral flood pattern is used. The injection water, containing hydrogen sulfide, is chemically treated.

On January 1, 1968, the project area contained 22 producing wells and 10 injection wells. During December 1967 the daily production was 176 barrels of oil and 680 barrels of water; daily injection was 4,600 barrels at 1,170 psi.

Cumulative oil production to the start of injection was 1,228,000 barrels or 24 percent of the original oil in place. Cumulative oil production to January 1, 1968, was 1,448,779 barrels or 28 percent of the

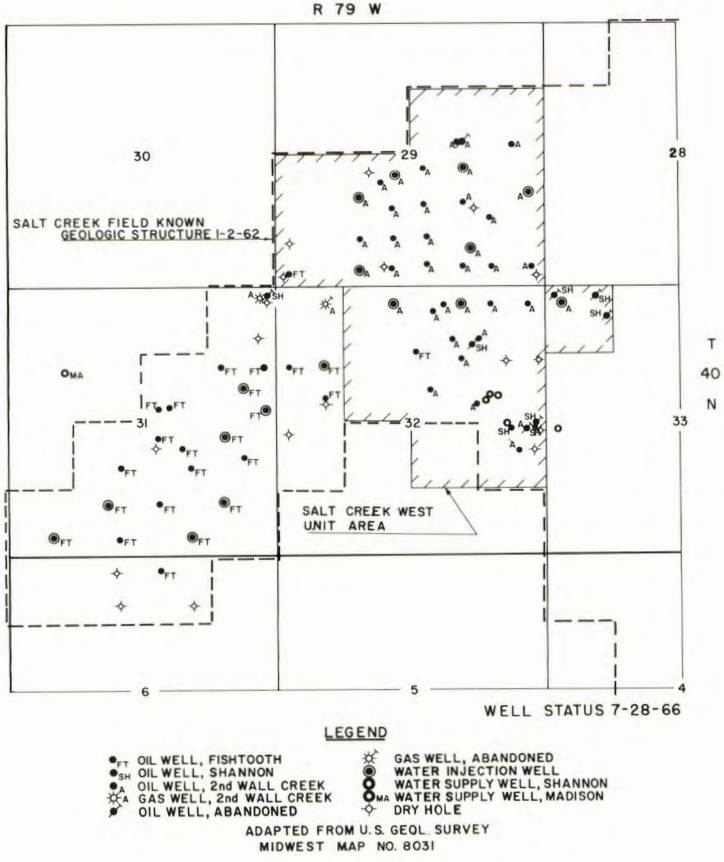


FIGURE 27. - West Salt Creek Field, Natrona County, Wyo.

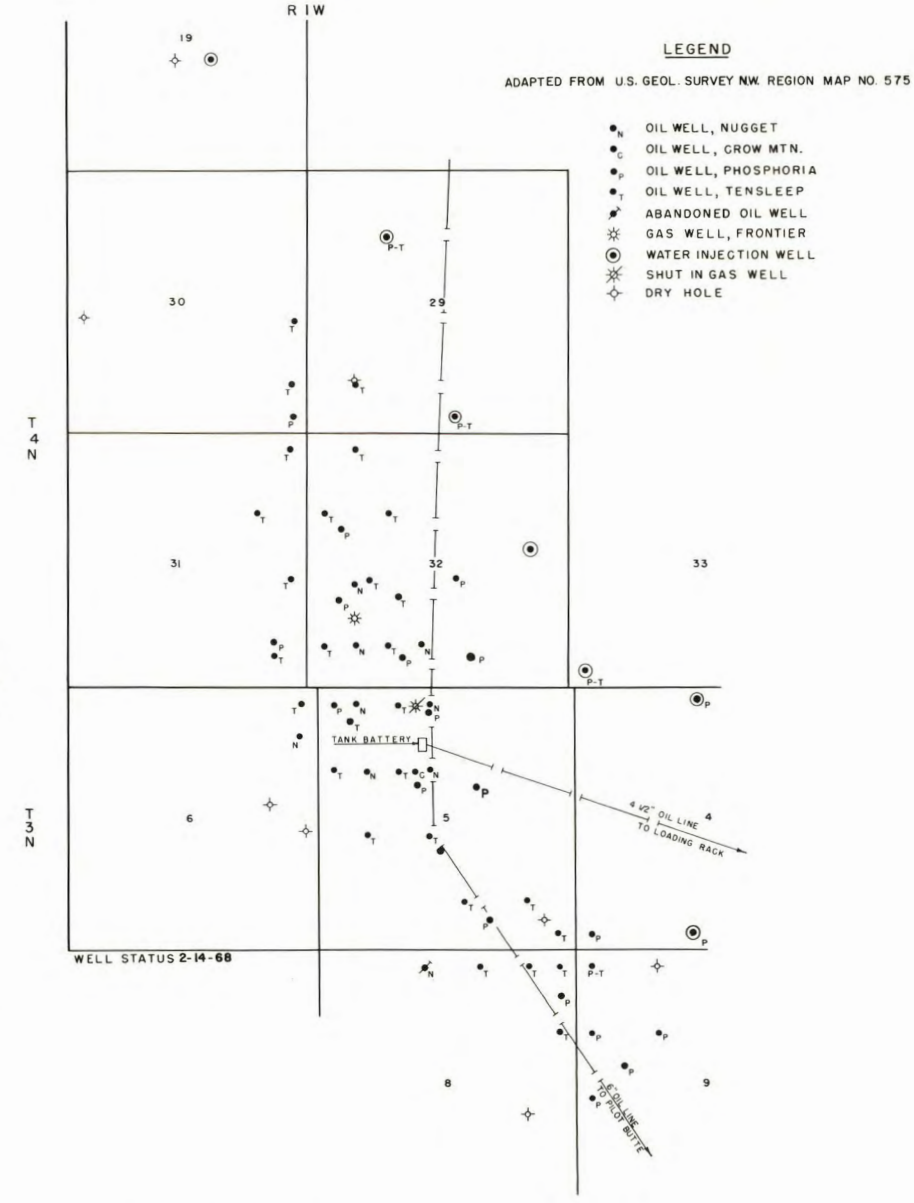


FIGURE 28. - Steamboat Butte Field, Fremont County, Wyo.

original oil in place. Of the 220,779 barrels of oil produced since the start of injection, an estimated 143,000 barrels was recovered by water injection. Cumulative water injection to January 1, 1968, was 5,259,797 barrels. Available data indicate a successful project.

Sand Creek

Sand Creek field, in the southeast part of T 46 N, R 91 W, Washakie County, is on a dome having about 200 feet of closure. The field was discovered in September 1947 when a well in the NE1/4SW1/4 sec 26 flowed 600 barrels of 45° API gravity oil daily from the upper Third Frontier sand at 6,690 to 6,753 feet. In August 1948 gas was discovered in the lower Third Frontier sand in a well in the NE1/4SE1/4 sec 27; the producing interval was 6,880 to 6,887 feet.

The upper Third Frontier reservoir includes 684 acres and has an average pay thickness of 30 feet.

The field was unitized in October 1947 with Mobil Oil Corp. as unit operator. A pressure maintenance project was started in January 1949 with the injection of the produced gas from the upper and lower Third Frontier into the upper Third Frontier zone. This project was discontinued in July 1951 after 1,600 million cubic feet of gas had been injected. In 1957 a miscible flood was started in the upper zone. Two wells in the SW1/4SW1/4 of sec 26 were used for injection. About 45,000 barrels of liquefied petroleum gas (propane and butane) was injected into the reservoir. Because performance indicated the miscible front was dispersed before an oil bank could form, the project was discontinued in 1959.

In 1960 a one-well pilot waterflood was started in the SW1/4 of sec 26. Later the pilot was expanded to three injection wells. Water was obtained from a fresh water supply well completed in the Fort Union Formation. On January 1, 1968, the project contained two producing oil wells and two water injection wells. During December 1967 the daily average production was 14 barrels of oil and 1/2 barrel of water; water injection averaged 1,700 barrels at 2,400 psi.

Cumulative oil production to the start of water injection was 1,366,000 barrels or 13.6 percent of the original oil in place. Cumulative oil production to January 1, 1968, was 1,455,600 barrels or 13.8 percent of the original oil in place. Cumulative water injected to January 1, 1968, was 1,609,500 barrels. The project appears to be a failure.

Silver Tip

Silver Tip field is in the northern part of T 57 N, R 100 W, and the southern part of T 58 N, R 100 W, Park County. Silver Tip was discovered in April 1948 when a well in the SW1/4NE1/4 sec 33, T 58 N, R 100 W, flowed 1,200 barrels of 47° API gravity oil and 4.2 million cubic feet of (32 percent hydrogen sulfide) gas per day from the Phosphoria Limestone at 8,496 to 8,550 feet. In the same month production was established in the Frontier Formation (Peay sand) when a well in the SW1/4NE1/4 sec 33 flowed 120 barrels of 47° API gravity oil per day from a zone at 5,927 to 5,988 feet. Good showings of oil and sour gas had been encountered in the Tensleep Formation while some of the wells were being drilled, and in 1949 several wells were dually completed in the Phosphoria and Tensleep Formations.

In July 1961 well No. 55-33 Unit in the NW1/4SE1/4 sec 33, T 58 N, R 101 W, was completed as a Madison oil well. Initial daily production was 130 barrels of oil and 98 barrels of water from 9,107 to 9,120 feet. Well No. 74A produced only 5 months from the Madison before recompletion as a small gas well in the shallow Lance Formation. Well No. 81 was drilled as a Madison test and also completed as a small Lance gas well at 2,100 feet.

The field was unitized in November 1953 with Texaco, Inc., as unit operator. Two fluid injection projects have operated in the field. One was a gas injection project in the Phosphoria Formation, discontinued because of mechanical and safety problems of handling the "sour gas." The other was a water injection project in the Frontier Formation. Water for injection was obtained from three shallow water wells in lot 3, sec 21, T 58 N, R 101 W.

The Frontier reservoir has an area of 240 acres and has an average thickness of about 17 feet. A pilot water injection project was started in 1961 and was not expanded. Water injection was discontinued April 27, 1966, because of lack of injection water.

Cumulative oil production to the start of injection was 524,500 barrels or 15 percent of the original oil in place. Cumulative oil production to April 27, 1966, was 557,000 barrels or 16 percent of the original oil in place. Cumulative water injection was 846,000 barrels. No real increase in production was evident. Available data indicate the project is a failure.

Skull Creek

Skull Creek oilfield is in Tps 44 and 45 N, R 62 W, Weston County and adjacent to the east end of the Mush Creek field. The discovery well, in the NW1/4SW1/4NE1/4 sec 16, was completed in April 1946 in the Newcastle Sandstone for an initial daily production of 3 barrels of oil

and 7 barrels of water. The producing zone was 3,330 to 3,364 feet. Three gas wells have been completed in the Skull Creek field. Initial open-flow volumes of gas from these wells were 19.75, 10.0, and 0.5 million cubic feet per day.

The Newcastle Sandstone is the only oil- and gas-productive formation in the field. Average thickness of the Newcastle is about 50 feet. The oil-bearing portion, 8 to 38 feet thick, is found near the bottom of the formation. Average initial daily production of the oil wells was 161 barrels, but such productions ranged from 4 to 1,440 barrels. Although some water was produced, most of it was thought to come from sands other than the Newcastle.

Averages of several Skull Creek field core analyses show 15.8-percent porosity, 89-millidarcy permeability, and 27-percent water saturation.

The Skull Creek unit, with McAlester Fuel Co. as operator, was approved April 1, 1965, and contains 2,200 acres. The South Skull Creek unit, with American Petrofina of Texas as operator, was approved May 1, 1965, and contains 960 acres. In December 1967 the Skull Creek unit and South Skull Creek unit were both operated by McAlester Fuel Co. and reported as one unit.

Skull Creek Unit

Water injection into one well in the Skull Creek unit started August 4, 1965. A water supply well, for both projects, in the SW1/4 sec 22, T 44 N, R 62 W, was completed in the Lakota Formation. The project was expanded to 22 oil wells and 10 injection wells in 1966. On January 1, 1968, there were 24 oil wells and 10 injection wells. Average daily production in December 1967 was 284 barrels of oil and 499 barrels of water; average daily water injection was 3,600 barrels at 925 psi.

Cumulative production prior to start of injection was not available, but since then it was 213,899 barrels. Cumulative injection to January 1, 1968, was 1,761,341 barrels. Although the project is relatively new, results so far look favorable.

East Skull Creek

East Skull Creek project in sec 31, T 45 N, R 61 W, is about 5 miles northeast of the Skull Creek unit. The Newcastle sand is 400 to 500 feet deep here compared to about 3,300 feet in the main Skull Creek field. Little information is available on structural conditions, but a stratigraphic trap probably exists.

Oil City Supply Co.'s. No. 1 Wyo Farm, the discovery well, was completed December 28, 1960, for an initial daily production of 2-1/2 barrels of 25° API gravity oil from the Newcastle sand from 478 to 499 feet. Gamma-ray neutron logs of two wells suggest two zones in the Newcastle, each 8 to 10 feet thick, with the lower zone wet. Ten wells have been drilled in the project area. Water injection started in early 1967; the water was purchased from the city of Newcastle.

Lack of reservoir data prevented calculation of reserves. About 24,500 barrels of oil had been produced to 1967. During 1967 production was 12,700 barrels. During December 1967 the 10 wells produced 13 barrels of oil and 87 barrels of water per day. The one injection well handled about 50 barrels per day at 240 psi. Cumulative injection to January 1, 1968, was 33,503 barrels.

Because the wells have reacted to the water injection, the project is considered successful.

Slick Creek

Slick Creek field, in secs 32-35, T 47 N, R 92 W, and secs 2 and 3, T 46 N, R 92 W, Washakie County, is about 2-1/2 miles southeast of the town of Worland.

The discovery well, in the SE1/4SE1/4NE1/4 sec 32, was completed October 8, 1950. Initial daily flow was 732 barrels of oil and 797,000 cubic feet of sour gas (containing 19.8 percent hydrogen sulfide). The Phosphoria limestone producing zone was 10,460 to 10,554 feet. The entire producing zone was cored, with 100-percent core recovery. Only 69 feet of the core appeared saturated. The average effective porosity of the entire zone is 9 percent. Only 26 feet near the bottom of the cored zone tested permeable.

Of the 10 wells drilled in the field, eight were completed as oil wells. Because of the high hydrogen sulfide content of the gas, the wells were shut in, except for testing, until the sulfur recovery plant at Manderson field was completed early in 1955.

A unit plan for the development and operation of the Slick Creek field, with Mobil Oil Corp. as operator, was effective July 14, 1950. A total of 3,675 acres was committed to the unit.

The Phosphoria reservoir includes 1,967 acres and has an average effective pay thickness of 20 feet. Water injection, using water purchased from the city of Worland, was started in July 1965. On January 1, 1968, the project contained six producing oil wells and one injection well. During December 1967 average daily production was 252 barrels of oil and 226 barrels of water; daily water injection was 1,235 barrels at 1,600 psi.

Cumulative production to start of water injection was 2,683,900 barrels or 5.9 percent of the original oil in place. Production from start of injection to January 1, 1968, was 274,000 barrels. Cumulative injection to 1968 was 1,429,870 barrels. Oil production in 1966 was greater than for 1965 and may indicate a reaction to the waterflood. The outcome of the project, however, is indeterminate.

Steamboat Butte

Steamboat Butte field (fig. 28) is about 3-1/2 miles northwest of Pilot Butte field in secs 29-32, T 4 N, R 1 W, and secs 5, 6, 8, and 9, T 3 N, R 1 W, Wind River Indian Reservation, Fremont County.

Oil was discovered at Steamboat Butte in April 1943 with completion of a well in the NE lot 4, sec 5, in the Nugget Sandstone from 5,093 to 5,119 feet. This well had an initial daily production of 623 barrels of oil of 28.4° API gravity by pumping. It was deepened 21 months later with cable tools through the entire 134 feet of Nugget sand and recompleted to pump 630 barrels of oil of 27° API gravity with no water. The original bottom-hole pressure was 2,082 psia at a datum elevation of 525 feet below sea level. The solution gas-oil ratio from bottom-hole sample data was 73 cubic feet of gas per barrel of oil. Core analyses showed the sand to have a permeability of 0 to 430 millidarcys with an average of 147.5 millidarcys and a porosity of 8.7 to 24.9 percent.

Oil was discovered in the Tensleep Sandstone in March 1944 when a well in the NE1/4SE1/4 sec 31 was completed with an initial production by pumping of 1,000 barrels of oil per day of 28° API gravity. The producing section was in the Tensleep from 6,771 to 7,034 feet. The original bottom-hole pressure was 2,954 psia at a datum of 1,125 feet below sea level. From bottom-hole samples the solution gas-oil ratio was 56 cubic feet per barrel. Cores of the Tensleep Sandstone had an average permeability of 38 to 45 millidarcys and an average porosity of 12 to 13 percent.

In November 1944 a well in the NE1/4SE1/4NW1/4 sec 5 was completed as a flowing well in the Lakota Sandstone at 4,493 to 4,543 feet. The initial daily production was 298 barrels of green oil of 38.5° API gravity with an estimated gas-oil ratio of 400 cubic feet per barrel. The well had produced 13,126 barrels of oil from the Lakota Sandstone before it was deepened to the Nugget Sandstone.

In August 1945 a well in the NE1/4SW1/4SW1/4 sec 32 was completed in the Third Frontier sand at 3,261 to 3,295 feet as a gas well, with an initial calculated open flow of 13 million cubic feet of gas per day. In April 1948 a well in the NW1/4SE1/4NW1/4 sec 9 was completed with an initial daily flow of 225 barrels of oil of 34° API gravity from the Phosphoria Formation at 6,745 to 6,792 feet.

Tensleep Project

A study of bottom-hole pressures in the Tensleep reservoir indicated a rapid decline in pressure. Water injection in the Tensleep reservoir to maintain the bottom-hole pressure was begun July 3, 1953. Water is obtained from shallow wells near the Wind River to the south. The water is filtered.

The Tensleep reservoir being flooded covers about 1,270 acres and has an average pay thickness of about 200 feet. The Tensleep and Phosphoria reservoirs south of the permeability barrier in the S1/2SE1/4 sec 5 are not being flooded.

On January 1, 1968, the project area contained 14 producing oil wells and four injection wells. During December 1967 the daily average production was 2,122 barrels of oil and 10,390 barrels of water; daily average injection was 20,680 barrels of water at 1,022 psi.

Cumulative oil production to the start of injection was 23,934,000 barrels or 8 percent of the estimated original oil in place. Cumulative oil production to January 1, 1968, was 40,254,400 barrels or 13.5 percent of the estimated original oil in place. Of the 16,320,400 barrels of oil produced since the start of injection, an estimated 10,200,000 barrels was recovered by water injection. Cumulative water injected to January 1, 1968, was 109,644,700 barrels. The project is a success.

Phosphoria Project

The Phosphoria reservoir being flooded covers about 900 acres and has an average pay thickness of about 40 feet.

Water injection was started in November 1962 in three wells. The wells were dually completed for injection into the Phosphoria and Tensleep Formations. A fourth Phosphoria injection well was drilled later. On January 1, 1968, the project area contained five producing oil wells and three injection wells. During December 1967 the daily average production was 243 barrels of oil and 325 barrels of water; daily average injection was 5,600 barrels of water at 1,940 psi.

Cumulative oil production to the start of injection was 956,000 barrels or 6 percent of the estimated original oil in place. Cumulative oil production to January 1, 1968, was 2,572,959 barrels or 16.1 percent of the estimated original oil in place. Of the 1,616,959 barrels of oil produced since the start of injection, an estimated 700,000 barrels was recovered by water injection. Cumulative water injected to January 1, 1968, was 10,507,055 barrels. The project is a success.

Sussex

Sussex oilfield (fig. 29) is in T 42 N, Rs 78 and 79 W, Johnson County. The discovery well for the Sussex field, in the SE1/4 sec 17, was completed July 15, 1948. Initial production was 241 barrels of oil and 128,000 cubic feet of gas per day from the Lakota sand, at a depth interval of 7,700 to 7,726 feet. On June 29, 1949, a well in the NW1/4 sec 17 was completed in the Shannon sand. The estimated initial production was 240 barrels of 40° API gravity oil per day. The first well was completed in the Sussex sand, in the NW1/4 sec 17, on April 13, 1950. Initial flowing production was 168 barrels of oil per day. On June 4, 1951, a well in the SE1/4 sec 17 was completed in the Tensleep sand. Initial flowing production was 62 barrels of oil per hour. The top of the producing sand was 9,115 feet. On August 17, 1952, a discovery was made in the Second Frontier sand in a well in the SE1/4 sec 18. Initial flowing production was 130 barrels of oil per day. On January 9, 1950, a well in the SW1/4 sec 23 was completed in the First Frontier sand. Initial flowing production was 6 barrels of 40.5° API gravity oil per hour. Oil was discovered in the Sundance sand in April 1953 when a well in the SW1/4SE1/4NE1/4 sec 18 was completed for an initial oil production of 192 barrels per day. The discovery well in the Parkman sand was completed in December 1953 in the SE1/4SW1/4NW1/4 sec 17. Initial production was 192 barrels of oil per day.

No gas zones have been found in the Sussex unit. Reservoir data indicate that a natural water drive, to a varying degree, will be effective in most of the reservoirs. The average net thickness, in feet, of the pay zones in the Sussex area, as shown by well logs, follows: Parkman, 40; Sussex sand, 30; Shannon sand, 32; First Frontier, 9; Second Frontier, 20; Lakota, 35; Sundance, 11; and Tensleep, 90.

The 13,376-acre Sussex unit, with Continental Oil Co. as operator, was effective December 29, 1947. Eighteen separate oil reservoirs were found in the Sussex field. The unit was divided into areas "A," "B," "C-E," "D," and "F." Nine waterfloods were active in the field in December 1967. Two projects previously had some gas injection. The projects are reported here in descending order of formation.

Sussex Sand "A"

Sussex sand "A" reservoir includes 306 acres and has an average pay thickness of 18 feet. The producing mechanism is solution gas drive. A pilot water injection project started in 1951 was expanded to a full-scale waterflood in 1957. The flood pattern, essentially peripheral, was designed to conform with the fault pattern in the project area.

On January 1, 1968, the project contained seven producing wells, 10 injection wells, and two shut-in wells. During December 1967 the average daily production was 208 barrels of oil and 886 barrels of water; daily water injection was 929 barrels at 1,540 psi.

Cumulative production to the start of waterflooding was 113,300 barrels of oil or 2.2 percent of the original oil in place. Cumulative production to January 1, 1968, was about 1.8 million barrels or 35 percent of the original oil in place. Of the 1.7 million barrels of oil produced since waterflooding was started, an estimated 890,000 barrels resulted from water injection. Cumulative water injection to January 1, 1968, was 4,606,300 barrels. The project is a success.

Sussex Sand "C"

Sussex sand "C" reservoir includes 453 acres and has an average pay thickness of 26 feet. The original producing mechanisms were gas cap expansion and solution gas drive. The gas cap, a small one, is on the structural crest of the reservoir. Water and gas injection was started in December 1959. Gas injection in only one well was discontinued after about 3.5 billion cubic feet had been injected. The waterflood pattern is peripheral. On January 1, 1968, the project contained 10 producing wells, six injection wells, and two shut-in wells. Daily oil and water production during December 1967 was 90 and 105 barrels, respectively; daily water injection was about 1,014 barrels at 2,300 psi.

Cumulative production to the start of waterflooding was about 1 million barrels or 8.8 percent of the original oil in place. Cumulative production to January 1, 1968, was about 2.3 million barrels of oil or 20.2 percent of the original oil in place. Of the 1.3 million barrels of oil produced since waterflooding was started, an estimated 700,000 barrels was from fluid injection. Cumulative water injection to January 1, 1968, was 1,512,000 barrels. Available data indicate a successful project.

Sussex Sand "D"

Sussex sand "D" reservoir includes 147 acres and has an average pay thickness of 33 feet. The original producing mechanism was solution gas drive.

Waterflooding was started May 1958. The water is injected into wells on the west, north, and east sides of the reservoir. On January 1, 1968, the project contained four producing wells, six injection wells, and five shut-in wells. During December 1967 the average daily production was 173 barrels of oil and 272 barrels of water; daily water injection was 943 barrels at 1,090 psi.

Cumulative production to the start of waterflooding was about 601,000 barrels of oil or 12.6 percent of the original oil in place. Cumulative production to January 1, 1968, was 916,000 barrels or 19.1 percent of the original oil in place. Of the 315,000 barrels of oil produced since waterflooding was started, an estimated 80,000 barrels was secondary oil. Cumulative water injection was about 3.5 million

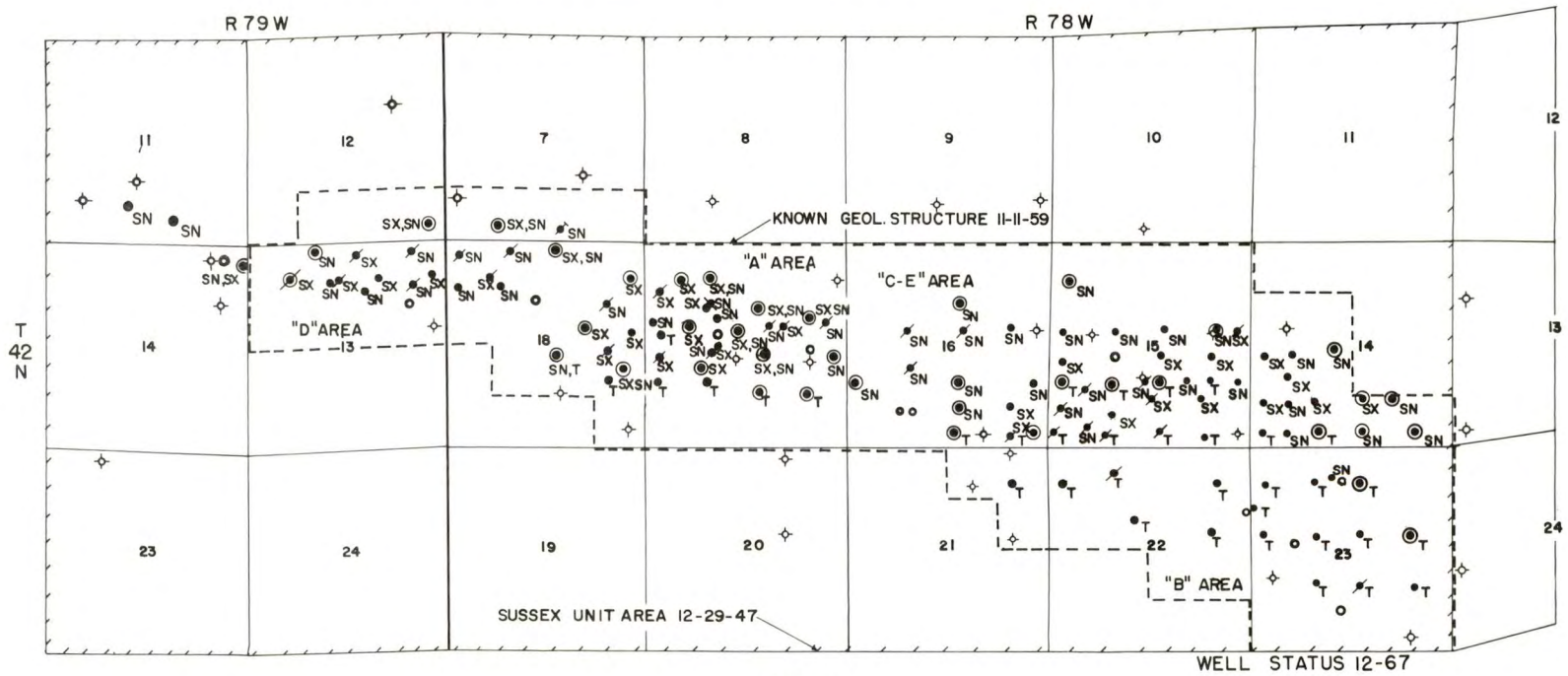


FIGURE 29. - Sussex Unit Area, Johnson County, Wyo.

barrels or roughly one-half of the estimated water requirements. The project is a success.

Shannon Sand "A"

Shannon sand "A" reservoir includes 368 acres and has an average pay thickness of 14 feet. The original producing mechanisms were a solution gas drive and a partial natural water drive. Pilot injection was started in August 1951 and was expanded to a full-scale operation in 1957. The flood pattern is essentially peripheral. In some injection wells water is injected down the tubing under a packer into the Shannon sand reservoir and down the casing annulus into the Sussex sand reservoir. On January 1, 1968, the project contained two producing wells, nine injection wells, and eight shut-in wells. During December 1967 the average daily production was 35 barrels of oil and 400 barrels of water; daily water injection was 250 barrels at 1,560 psi.

Cumulative production to the start of waterflooding was about 106,000 barrels or 2.9 percent of the original oil in place. Cumulative production to January 1, 1968, was about 1.3 million barrels or 35 percent of the original oil in place. Of the 1.2 million barrels of oil produced since waterflooding was started, an estimated 380,000 barrels was secondary oil. Cumulative water injection to January 1, 1968, was 3,489,555 barrels. The project is a success.

Shannon Sand "C-E"

Shannon sand "C-E" reservoir includes 867 acres and has an average pay thickness of 12 feet. Solution gas drive was the original producing mechanism. Started in 1959 the waterflood project covers only 555 acres of the reservoir. The flood pattern is peripheral. On January 1, 1968, the project contained 10 producing wells, 12 injection wells, and eight shut-in wells. About 1.6 billion cubic feet of gas had been injected into one of the shut-in wells. During December 1967 the average daily production was 49 barrels of oil and 21 barrels of water; daily injection was 2,176 barrels at 2,240 psi.

Cumulative production to the start of waterflooding was about 555,000 barrels of oil or 7.8 percent of the original oil in place. Cumulative production from the start of waterflooding to January 1, 1968, was about 505,154 barrels of oil, of which about 200,000 barrels are credited to fluid injection. Cumulative water injection to January 1, 1968, was 2,954,300 barrels. Available data indicate a successful project.

Shannon Sand "D"

Shannon sand "D" reservoir includes 377 acres and has an average pay thickness of 38 feet. The reservoir contains three separate producing zones or "benches." Solution gas drive was the original producing mechanism.

Waterflooding was started in May 1958. All the injection wells are dually completed. Water is injected down the tubing under a packer into the Shannon reservoir and down the casing annulus into the Sussex reservoir. All three Shannon benches are being flooded. On January 1, 1968, the project area contained four producing oil wells, five injection wells, and six shut-in wells. During December 1967 the average daily production was 59 barrels of oil and 995 barrels of water.

Cumulative production to the start of waterflooding was about 1.3 million barrels of oil or 12.5 percent of the original oil in place. Cumulative production to January 1, 1968, was about 2.6 million barrels of oil or 25.7 percent of the original oil in place. Of the 1.3 million barrels of oil produced since waterflooding was started, an estimated 900,000 barrels was secondary oil. Cumulative water injection to January 1, 1968, was 7,491,400 barrels. The project is a success.

Lakota Sand "A"

Lakota "A" reservoir includes 328 acres and has an average pay thickness of 25 feet. Porosity of the rock was reported to be 15.8 percent and water saturation 22 percent. The reservoir energy was from fluid expansion plus a partial water drive. Injection water is obtained from the Shiloh water system.

Water was injected into the Lakota "A" reservoir through one well from August 1951 to November 1955. During this period a total of 248,114 barrels of water was injected. No response was observed during this period.

Injection was resumed about January 1, 1967, through one well. At the end of 1967 there were five producing wells, three shut-in oil wells, and one injection well. In January 1967 the monthly Lakota "A" production was 3,349 barrels of oil and 27,744 barrels of water, and in December 1967 it was 1,176 barrels of oil and 24,970 barrels of water. The monthly production does not show a reaction to the current water injection. Water injection during 1967 was 195,900 barrels.

Tensleep Sand "A"

Tensleep sand "A" reservoir contains 320 acres and has an average pay thickness of 35 feet. The original producing mechanism was a natural water drive. Waterflooding was started in June 1958 to speed recovery. It was estimated that the waterflood would shorten the producing life of the field by 12 years. The oil contains only 15.8 cubic feet of gas per barrel. On January 1, 1968, the project area contained five producing wells and three injection wells. During December 1967 the average daily production was 683 barrels of oil and 2,779 barrels of water; daily water injection was 2,925 barrels at 2,660 psi.

Cumulative production to the start of waterflooding was about 2.3 million barrels of oil or 23.5 percent of the original oil in place. Cumulative production to January 1, 1968, was about 5.8 million barrels of oil or 60 percent of the original oil in place. Obviously the water injection has accelerated oil production. Cumulative water injection to January 1, 1968, was 5,442,200 barrels. The project is a success.

Tensleep Sand "B"

Tensleep sand "B" reservoir includes 1,092 acres and has an average pay thickness of 103 feet. The original producing mechanism was fluid and rock expansion; the oil contains very little gas. The primary recovery estimate was low, only 9.2 percent of the original oil in place. A peripheral waterflood was started in March 1958. The estimated recovery by waterflooding was 23.8 percent of the estimated original oil in place. On January 1, 1968, the project area contained 17 producing wells, eight injection wells, and seven shut-in wells. During December 1967 the daily average production was about 5,529 barrels of oil and 11,813 barrels of water; daily water injection was 16,910 barrels at 2,795 psi.

Cumulative production to the start of waterflooding was about 4.3 million barrels of oil or 5.3 percent of the original oil in place. Cumulative production to January 1, 1968, was 25.79 million barrels of oil or 31.9 percent of the original oil in place. Of the 21.5 million barrels of oil produced since waterflooding was started, an estimated 17.2 million barrels was secondary oil. Cumulative water injection to January 1, 1968, was 30,868,100 barrels. The project is a success.

West Sussex-Dugout Creek

West Sussex-Dugout Creek field (fig. 30) is in Tps 42 and 43 N, Rs 79 and 80 W, Johnson County. On August 21, 1951, a well in the NE1/4 sec 8, T 42 N, R 79 W, was completed in the Shannon sand. The initial hourly flowing production was 9 barrels of 39.5° API gravity oil, with a casing pressure of 200 psi and a tubing pressure of 125 psi. This well had been drilled to 6,160 feet in the Lakota sand where a flow of salt water was obtained. On March 18, 1952, oil was discovered in the Lakota sand in a well in the SE1/4 sec 8. The initial estimated production by pumping was 240 barrels of 33° API gravity oil. A well in the SE1/4 sec 8 was completed in the Tensleep sand in April 1955 for an initial daily flowing production of 64 barrels.

Subsequent drilling has developed a field about 7 miles long and up to 1 mile wide. The area has been divided into unit areas "A" and "B" and Dugout Creek. By 1958, 114 oil and six gas wells had been completed in the Shannon sand, one well in the Lakota sand, and one well in the Tensleep sand. A gross area of 10,173 acres was unitized, effective June 25, 1951.

Water for injection is obtained from the Madison Formation for the Dugout Creek unit and from the Shiloh water system for the West Sussex unit.

West Sussex Shannon "A-B"

West Sussex Shannon "A-B" reservoir includes 1,738 acres and has an average pay thickness of 23.8 feet. The original producing mechanism was a solution gas drive.

A complex system of fault blocks exists in the unit. Seven blocks are separate reservoirs, and three have small gas caps. All of the blocks are being flooded.

Continental Oil Co. is operator of the West Sussex unit. Texaco is operator of the 1,399-acre Dugout Creek unit approved July 1, 1963.

Water injection was started in April 1955 near the water-oil and gas-oil contacts. On January 1, 1968, the project area contained 28 producing wells, 21 shut-in oil wells, and 17 injection wells. During December 1967 daily average production was 1,369 barrels of oil and 2,204 barrels of water; daily average water injection was about 6,830 barrels at 1,900 psi.

Cumulative oil production to the start of injection was 3,080,000 barrels or about 7.6 percent of the original oil in place. Cumulative oil production to January 1, 1968, was 9,555,700 barrels or 23.1 percent of the original oil in place. Of the 6,475,700 barrels of oil produced since the start of injection, an estimated 3,771,000 barrels was recovered by fluid injection. Cumulative water injection for the same period was 19,727,000 barrels of water. Available data indicate a successful project.

Dugout Creek Shannon

Dugout Creek reservoir covers about 1,010 acres and has an average pay thickness of 17 feet.

Faults divide the reservoir into five distinct blocks. Four of the blocks have small gas caps. Water is injected into all of the blocks.

Water injection was started in 11 wells during October 1963. Eight of the wells are near the oil-water contact on the north side of the unit; three are near the gas-oil contact. Two injection wells were added later. The flood pattern is peripheral. On January 1, 1968, the project area contained 36 producing wells, 15 injection wells, and 12 shut-in wells. During December 1967 daily average production was 532 barrels of oil and 2,430 barrels of water; daily average injection was 3,130 barrels of water at 1,500 psi.

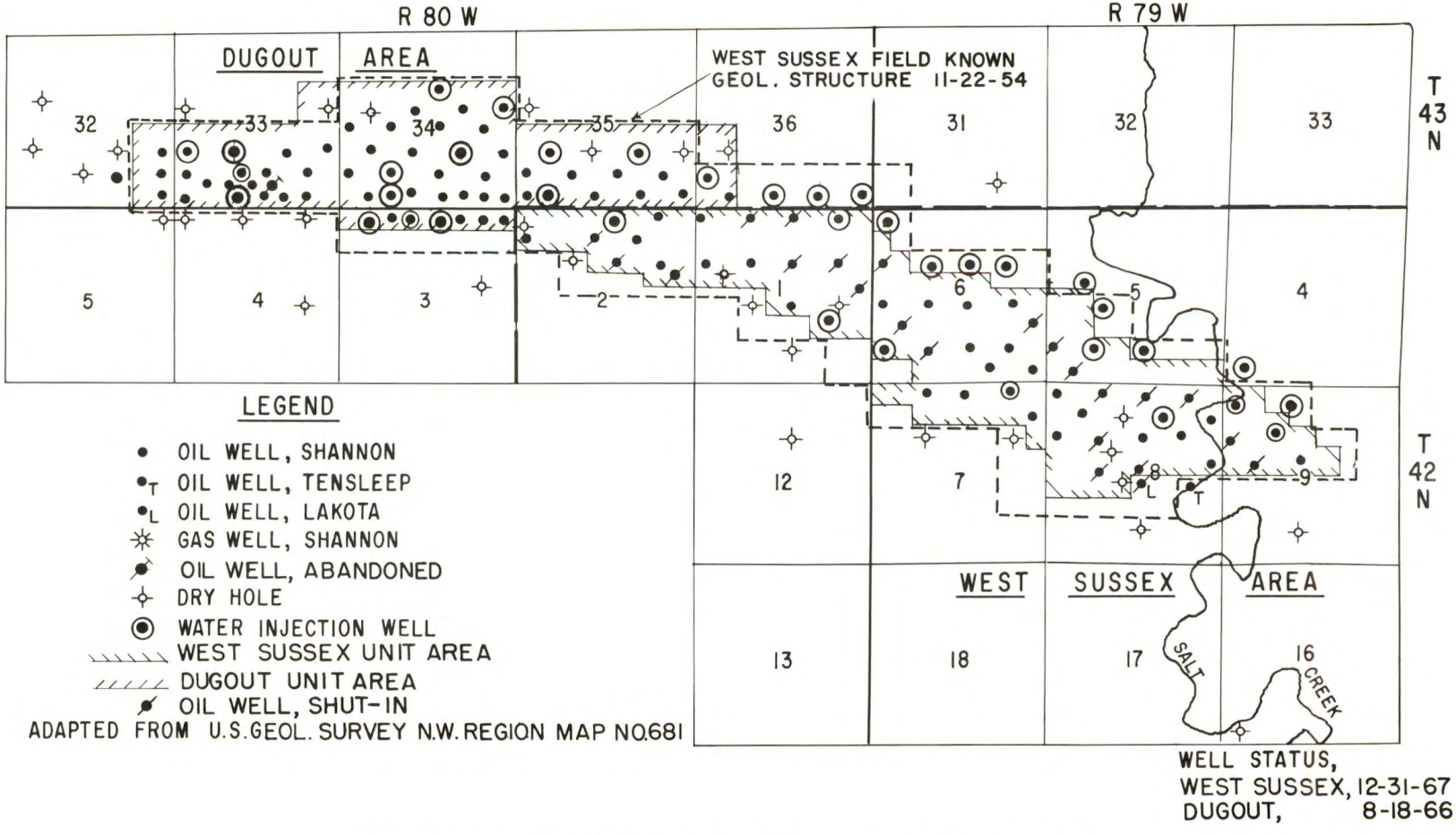


FIGURE 30. - West Sussex-Dugout Area, Johnson County, Wyo.

Cumulative production to the start of injection was 4,258,900 barrels of oil or 15 percent of the original oil in place. Cumulative oil production to January 1, 1968, was 5,104,855 barrels or 18.8 percent of the original oil in place. Of the 845,955 barrels of oil produced since injection was started, an estimated 500,000 barrels was recovered from fluid injection. Cumulative water injection to January 1, 1968, was 10,870,110 barrels. Available data indicate a successful project.

East Teapot

East Teapot oilfield is in secs 1, 2, and 11-14, T 38 N, and secs 26, 35, and 36, T 39 N, R 78 W, Natrona County. The field is adjacent to the eastern boundary line of Naval Petroleum Reserve No. 3 and is on the Teapot Dome structure, or the eastern flank, southern dome, Salt Creek anticline.

The first well, in the NE1/4 sec 11, was completed in July 1927. Initial daily production was 297 barrels of 42° API gravity oil from shale zones of 2,440 to 2,780 feet. In April 1928 a second well was completed in the NE1/4 sec 2, and this well produced 250 barrels of 35° API gravity oil per day from a shale at 2,660 to 2,708 feet. Two or three small producing wells also were developed in the Shannon sand. During 1955 intensive drilling activity developed in the area north of the old producing wells.

Development of the Shannon sand at about 1,300 feet represented advancement of technology of well completions. Early wells in the area reported the Shannon as an "oil show." Ninety or more wells were drilled to the Shannon. Average initial daily oil production of the wells was about 50 barrels. After a year most of the wells started a steep decline in production, indicating a gas expansion drive.

East Teapot north unit with MKM Oil Co. as operator was approved December 27, 1965. The unit contains about 900 acres in secs 26 and 35, T 39 N, R 78 W. East Teapot unit with CRA, Inc., as operator, was approved September 26, 1966. Only the north unit was operating January 1, 1968.

The north unit Shannon sand reservoir contains 722 acres and has an average net pay of 17.2 feet. A Madison water supply well capable of flowing 32,000 barrels per day was drilled in the SE1/4SW1/4 sec 26. The flooding plan called for a line of injection wells on the western edge of the unit offsetting Naval Petroleum Reserve No. 3. After the response to these wells is evaluated, a line of injection wells will be started on the eastern edge of the unit.

Water injection began March 1, 1966. Secondary recovery is estimated to about equal primary. On January 1, 1968, the project contained 27 oil wells, 18 injection wells, and 29 shut-in wells. During December 1967 average daily production was 184 barrels of oil and 2,596 barrels of water; average daily water injection was 11,093 barrels at 740 psi.

Cumulative oil production to March 1, 1966, was 1,794,191 barrels or 20 percent of the original oil in place, and production from then to January 1, 1968, was 87,363 barrels. Cumulative injection was 6,974,240 barrels. Evaluation of the East Teapot north unit flood would be premature.

Torchlight

The Torchlight structure is an elliptical dome in the center of T 51 N, on the line between Rs 92 and 93 W, Big Horn County. Wells were drilled as early as 1904 on the Torchlight dome, and showings of oil and gas were reported. The first oil well to develop commercial production was drilled in 1913 near the center of sec 24; most of the drilling in the field was done in 1914-16. The Greybull Sandstone between 1,110 and 1,130 feet was water bearing in wells on the crest of the structure. The Madison Limestone yielded an estimated flow of 10,000 barrels of fresh water per day in a well about 200 feet down from the crest of the structure. This well was drilled in 1933 and logged a saturated sand in the Tensleep Formation and 50 feet of saturated limestone in the Madison Formation. In October 1947 a well in the NE1/4 sec 24 was completed for an initial production of 1,632 barrels of oil per day flowing from the Tensleep Sandstone between 3,045 and 3,140 feet. This well also tested 1.5 million cubic feet of sour gas per day from the Phosphoria. A well drilled in the SE1/4 sec 24 was completed in April 1948 for an initial daily production of 450 barrels of oil from the Madison Limestone.

No production from wells in the Kimball or Octh Louie sands was reported after 1932; by December 1950 all of these wells had been abandoned.

Tensleep Project

Tensleep reservoir includes 291 acres and has an average pay thickness of 23 feet. The original producing mechanism was a limited water drive.

A pilot waterflood project was started in October 1957 and subsequently was expanded to a full-scale flood in August 1958. Water for injection is produced water from the Madison and Tensleep Formations. The flood pattern is peripheral. In May 1962 gas from the Phosphoria and water were injected alternately in the same wells. On January 1, 1968, the project area contained two producing wells and two shut-in

injection wells. Injection was stopped July 31, 1967. During December 1965 daily average production was 40 barrels of oil and 1,320 barrels of water.

Cumulative oil production to the start of injection was 1,250,000 barrels or 13.4 percent of the original oil in place. Cumulative oil production to January 1, 1968, was 2,841,500 barrels or 30.5 percent of the original oil in place. Cumulative injection to January 1, 1968, was 4,440,344 barrels of water and 344,554,000 cubic feet of gas. The project was successful in maintaining reservoir pressure.

Madison Project

Madison (unitized) reservoir contains 685 acres. Four oil saturated zones have been logged in the Madison with a combined pay thickness of 67 feet. Core analyses for the four zones averaged 21 percent porosity, 33.5 millidarcys permeability, and 30 percent water saturation.

Gas injection was started in September 1962 in one well. On May 15, 1963, the Wyoming Oil and Gas Conservation Commission approved expansion of a gas and water injection program to full scale. Water is produced from the Madison, and the gas is obtained from the Phosphoria zone in the field.

On January 1, 1968, the project contained 18 oil wells and four injection wells. All four injection wells are used for both gas and water. Average daily production in December 1967 was 1,307 barrels of oil and 12,133 barrels of water; daily injection was 2,514 barrels of water at 387 psi and 558,000 cubic feet of gas at 1,650 psi.

Cumulative production to September 1962 was 2,080,000 barrels of oil or about 17 percent of the original oil in place, and to January 1, 1968, was 3,793,960 barrels of oil. Probably 800,000 barrels of oil was accelerated or produced by the combination of gas and water injection. Cumulative injection to January 1, 1968, was 1.3 billion cubic feet of gas and 1.4 million barrels of water. The project is a success.

Walker Dome

Walker Dome field, in secs 4, 5, 8, and 9, T 46 N, R 99 W, Hot Springs County, is on a small, dome-shaped structure. In 1929 a well in the SE1/4NW1/4 sec 8 produced gas from the Frontier Formation between 3,130 and 3,138 feet. It was drilled 4,412 feet into the Cloverly Formation, which was water bearing. The well was completed in the Torchlight sand (Frontier Formation) with an initial daily open-flow volume of 1.1 million cubic feet of gas; the shut-in wellhead pressure

was 980 psi. The well was shut in after completion until 1953 when it was operated to supply fuel for drilling operations.

Oil was discovered in the "Embar Limestone" in August 1953 with completion of a well in the SE1/4NE1/4SE1/4 sec 8.

Torchlight Sand Project

Walker Dome Torchlight sand unit was approved by the U.S. Department of the Interior December 1, 1965. Information concerning pay thickness, probable reserves, and probable recoveries was not a part of the hearing for approval of waterflooding. Assuming a productive area of 360 acres, sand thickness of 25.9 feet, porosity of 17.1 percent, connate water of 30 percent, the original oil in place would total about 8,965,000 barrels. A reasonable expectation for primary recovery would be 1,250,000 barrels. Secondary recovery by flooding should approach 700,000 barrels. These reserves are based on assumed, not measured, data and may be high.

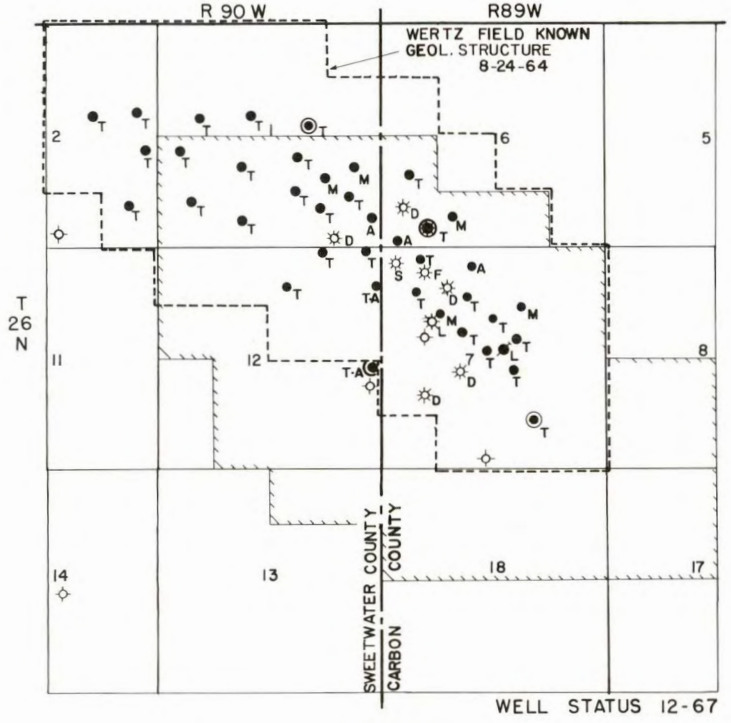
Water injection began December 26, 1965. Water was from a Mesaverde water well in the NE1/4 sec 17. On January 1, 1968, the project contained five producing oil wells and two injection wells. Average daily production in December 1965 was 44 barrels of oil and 38 barrels of water. In December 1967 the daily production was 76 barrels of oil and 73 barrels of water. Production from start of injection to January 1, 1968, was 42,399 barrels of oil. This is 10,000 or 11,000 barrels more than expected by primary decline.

Daily water injection in December 1967 was 750 barrels at 1,900 psi. Cumulative injection to 1968 was 492,402 barrels. The project is too new to evaluate.

Wertz

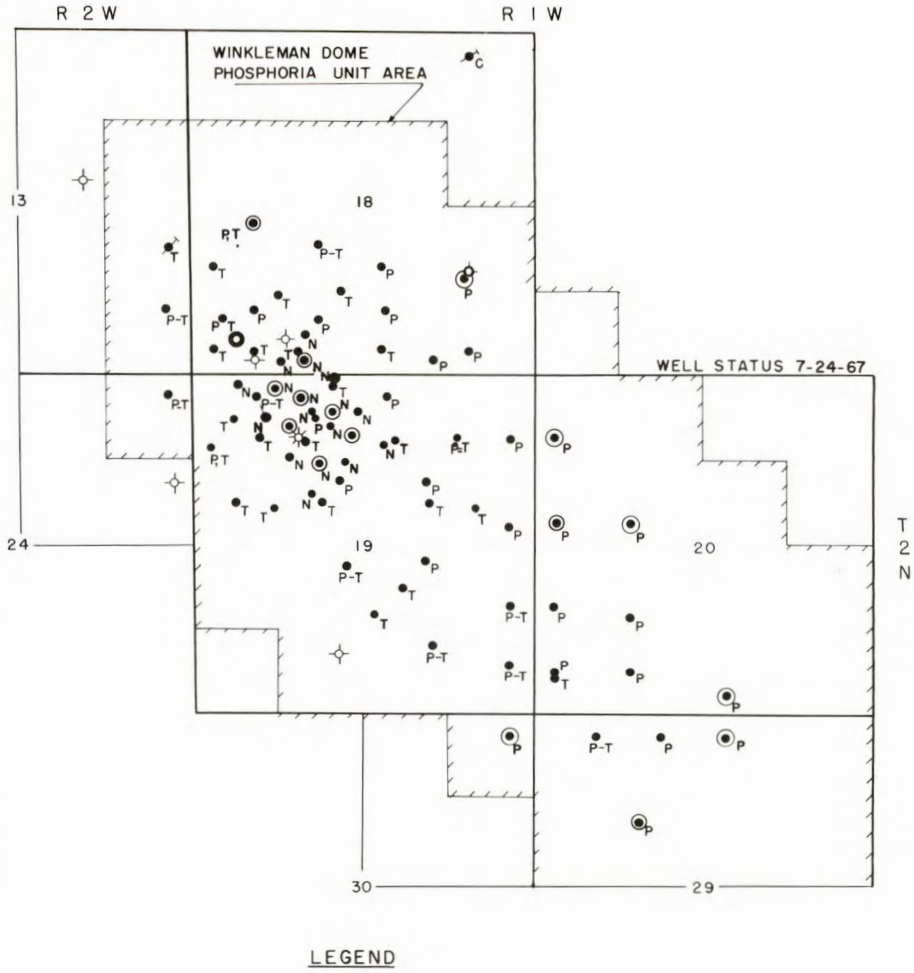
Wertz field (fig. 31) is an elliptical dome in secs 1, 2, and 12, T 26 N, R 90 W, Sweetwater County, and secs 6 and 7, T 26 N, R 89 W, Carbon County. Gas was discovered on Wertz dome in 1920 when a well in the NE1/4 SW1/4 sec 7, T 26 N, R 89 W, was completed in the Dakota sand at 3,427 to 3,435 feet. The initial production was 42 million cubic feet per day, and the shut-in wellhead pressure was 1,800 psi. A 40° API gravity oil was obtained from the Mowry Shale at 3,210 feet in this well. The well was cased so that oil from the shale flowed to the surface between the casings.

Three other wells were completed in the Dakota sand, including two temporarily in the Frontier Formation at 2,160 to 2,265 feet; the daily open-flow volume ranged from 6 to 7 million cubic feet of gas, and the shut-in wellhead pressures averaged 850 psi.



ADAPTED FROM U.S. GEOL. SURVEY N.W. REGION MAP NO. 802

FIGURE 31. - Wertz Field, Carbon and Sweetwater Counties, Wyo.



ADAPTED FROM U.S. GEOL. SURVEY N.W. REGION MAP NO. 719

FIGURE 32. - Winkleman Dome Field, Fremont County, Wyo.

In 1928 a well in the SW1/4NW1/4 sec 7 produced initially 6 million cubic feet of gas per day from the Lakota sand at 3,549 to 3,610 feet; the shut-in wellhead pressure was 1,340 psi. In 1929 the Sundance Formation at 4,150 feet proved to be gas bearing in a well in the NW1/4NW1/4 sec 7, which produced initially 57 million cubic feet of gas per day The shut-in wellhead pressure was 1,520 psi.

In 1936 oil was found in the Tensleep Sandstone at 5,872 to 5,886 feet in a well drilled in the SE1/4NW1/4 sec 7. Initial daily production was 1,700 barrels of 35° API gravity oil. In 1939 the well was deepened to 6,161 feet, and the daily production was increased to 8,350 barrels of oil. Initial daily production of 24 Tensleep wells ranged from 35 to 8,350 barrels of oil.

In 1948 deeper drilling resulted in the discovery of three new oil-producing zones: A well in the SE1/4SE1/4 sec 1 produced 600 barrels of 35° API gravity oil daily from the Basal Amsden at 6,494 to 6,570 feet; a well in the SW1/4NE1/4 sec 1 was completed in the Madison Limestone at 6,820 to 7,158 feet for an initial daily production of 1,145 barrels of 35° API gravity oil; and a well in the SE1/4SE1/4 sec 1 was completed in the Cambrian at 7,630 to 7,785 feet with an initial daily production of 277 barrels of 36° API gravity oil.

In 1941 a pressure maintenance program was initiated in the Tensleep reservoir to supplement the natural water drive. The gas produced with the oil, plus some makeup gas from the upper sands, is injected into a well on the crest of the structure. The injected gas is compressed in three stages, from an intake pressure of 30 psi to a discharge pressure of 2,000 psi, in four compressors driven by 600-horsepower gas engines. About 1.7 million cubic feet is injected daily at 1,823 psi at a sea-level datum of 1,200 feet. The total gas injected to January 1, 1958, was the equivalent in volume of 21,918,000 barrels at reservoir conditions. Some benefits derived from this operation are (1) the Tensleep gas, which has low fuel value (contains 52 percent carbon dioxide), was put to good use instead of being wasted; (2) the flowing life of the wells was prolonged; and (3) increased rate of recovery has been possible without damage to the reservoir. The program was begun before the bottom-hole pressure had declined below that necessary to flow the wells.

Wertz field unit, with Sinclair Oil and Gas Corp. as operator, was approved in 1937. In addition to the gas injection in the Tensleep, water is injected into the Tensleep and Amsden reservoir. Water for injection is the produced water from the Amsden and Madison wells. Produced water from the Tensleep proved too corrosive.

Tensleep Project

Tensleep reservoir includes 1,150 acres and has an average pay thickness of 150 feet. Solution gas drive aided by water influx from the

southeast was the initial drive mechanism. Water injection was started in October 1955 to supplement reservoir pressure.

On January 1, 1968, the project contained 28 producing wells, two water injection wells, and one gas injection well. During December 1967 the daily production was 4,685 barrels of oil and 3,850 barrels of water; daily injection was 5,285 barrels of 490 psi.

Cumulative oil production to the start of injection was 24,363,000 barrels or 24 percent of the original oil in place. Cumulative oil production to January 1, 1968, was 45,716,100 barrels or about 45.6 percent of the original oil in place. Cumulative water injected to January 1, 1968, was 16,369,992 barrels. The project is a success.

Amsden Project

Amsden reservoir includes 550 acres and has an average pay thickness of 30 feet. The initial reservoir producing mechanism was a solution gas drive aided by limited water influx from the northwest.

Water injection was begun in October 1955 to supplement reservoir pressure. On January 1, 1968, the project contained four producing wells and one injection well. During December 1967 the daily production was about 284 barrels of oil and 14 barrels of water; daily water injection was 3,075 barrels at 600 psi.

Cumulative oil production to the start of injection was 2,121,000 barrels or 13 percent of the original oil in place. Cumulative oil production to January 1, 1968, was about 2,479,413 barrels or about 15.8 percent of the original oil in place. Cumulative water injection to January 1, 1968, was 7,399,900 barrels. The project is a success.

Winkleman Dome

Winkleman Dome oilfield (fig. 32) is in secs 18-20, and 29, T 2 N, R 1 W, and secs 13 and 24, T 2 N, R 2 W, Wind River Indian Reservation, Fremont County. The first drilling at Winkleman Dome was in 1917 when a well in the SW1/4SW1/4 sec 18 was drilled to 970 feet; the well had a show of gas in the Lakota Sandstone and a show of oil and gas in the Sundance. Not until February 1944 was the discovery well completed in the SW1/4SE1/4SW1/4 sec 18, in the Tensleep Sandstone from 2,915 to 3,205 feet with an initial daily production, by pumping, of 480 barrels of oil of 23° API gravity. In 1945 a well in the SW1/4NE1/4NW1/4 sec 19 was completed as a gas well in the Lakota Sandstone and Morrison Formation with a daily open flow of 600,000 cubic feet of gas.

The first completion in the Phosphoria Formation was made in 1948 when a well in the NW1/4SW1/4SW1/4 sec 18 was drilled to 2,921 feet and

completed for an initial daily production, by pumping, of 285 barrels of 25° API gravity oil.

The 2,269-acre Winkleman Dome unit was approved August 1, 1962, with Pan American Petroleum Corp. as operator. Phosphoria and Tensleep waterfloods were active in the field in December 1967. An experimental steam drive was operated in the Nugget Formation. SPE paper 2131 presented at the Rocky Mountain Regional Meeting of the Society of Petroleum Engineers of AIME, Billings, Mont., June 5-7, 1968, describes the steam injection project.

Phosphoria Project

Phosphoria reservoir includes about 1,414 acres with a gross thickness of 275 feet. Net pay is calculated to be 54 feet. Three oil-saturated zones are present on the crest of the structure. Pressure data indicate the producing mechanism was fluid expansion with a limited water drive. It was estimated that primary recovery would be 17 percent of the oil in place and that secondary recovery would be 7-1/2 percent of the oil in place. A small area on the north and south ends of the field may be isolated from the main reservoir by faulting.

Well No. 501 was drilled to the Madison for water supply. Produced water from the Phosphoria and Tensleep is also used for injection. Some natural gas, purchased from outside the field, has been injected with the water. Cumulative gas injected to January 1, 1968, was 344.5 million cubic feet.

Water injection was initiated in August 1962. On January 1, 1968, the project area contained 29 producing Phosphoria oil wells and nine injection wells. During December 1967 the daily average production was 1,960 barrels of oil and 4,728 barrels of water; daily average water injection was 9,619 barrels at 1,044 psi.

Cumulative oil production to the start of injection was 7,031,000 barrels or 9.8 percent of the original oil in place. Cumulative oil production to January 1, 1968, was 10,738,661 barrels or 14.9 percent of the original oil in place. Of the 3,707,661 barrels of oil produced since the start of injection, an estimated 2,200,000 barrels was recovered by water injection. Cumulative water injected to January 1, 1968, was 16,113,085 barrels. The project is a success.

Tensleep Project

Tensleep reservoir includes about 1,000 acres and has a pay thickness of 160 feet. Because the reservoir has an active water drive, oil production would be accelerated by water injection.

Water injection started in January 1967. On January 1, 1968, the project contained 29 oil wells and two active injection wells. Average

daily production in December 1967 was 4,886 barrels of oil and 7,905 barrels of water; daily average injection was 2,839 barrels at 1,090 psi. Injection during 1967 was 1,159,981 barrels. Cumulative oil production through 1967 was 27,423,000 barrels. The project is a success.

SUMMARY

Dallas Dome, Wyoming's first oilfield, was discovered in 1884. Sixty years later the first water injection experiment in Wyoming was started in the Second Wall Creek sand of the Salt Creek field. The next test was in 1946 in the Shannon sand of the Cole Creek field. Oddly enough, the Wall Creek test was for secondary oil recovery whereas the Shannon test was for pressure maintenance.

The 138 waterflood projects cited in this report are in 65 fields and 25 producing formations. Only two projects are considered to be failures, although some others may later prove to be disappointing. Project size ranges from one injection well and two producing wells to 226 injection wells and 633 producing wells.

Gas injection is mentioned if relevant in the water injection descriptions.

By volumetric methods, it is estimated that the 138 projects will produce 1,599 million barrels of oil by primary methods and 834 million barrels by waterflooding. Estimated water requirements total 1,225,000 acre-feet. The equivalent of 237,000 acre-feet had been injected by January 1968. The Elk Basin-Madison and Salt Creek-Second Wall Creek projects each expect to recover more than 100 million barrels of oil by waterflooding.

Totaling all projects, the daily production in December 1967 was 195,600 barrels of oil and 501,500 barrels of water.

Most of the injection water is from the Madison Formation and is unfit for d mestic or agricultural use. Usually a closed water system is used, and occasionally filtering and chemical additives are necessary.

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