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Waterflooding of Oilfields in Montana

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Waterflooding of Oilfields in Montana

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CONTENTS

ILLUSTRATIONS

TABLE

WATERFLOODING OF OILFIELDS IN MONTANA

by

Paul Biggs[1]

ABSTRACT

This report presents information on 77 waterflood projects in 31 Montana oilfields. The study shows the locations of the projects, the sources and amounts of injection water, and the results in oil produced. Waterflooding, a secondary recovery technique, began in Montana about 40 years after the initial oil discovery in 1920. Often, the difference between water disposal by injection and pressure maintenance operations is not clear. Water injected at the projects in 1973 was 157.7 million barrels. In 1973, the 31 fields having waterflood projects produced 28.3 million barrels of oil valued at $88.4 million. Both in volume and value, this represents over 80 percent of the State's 1973 oil output. The projects are making possible the recovery of additional oil, thus contributing to the conservation of oil and lessening the impact of the current oil shortage.

INTRODUCTION

Oil seeps in Montana first were reported in 1892 near Kintla Lake and the North Fork of the Flathead River 4 miles south of the Canadian border in the western part of Glacier National Park. One well, a failure, was drilled in the area.

Oil seeps along Swift Current Creek, east of Many Glaciers Hotel, were found in 1901. Downstream from the Many Glaciers Hotel, a well was reported in early 1904 to be capable of making 60 barrels of oil per day. Several wells were reported to have been drilled by 1906; they were soon abandoned. Later, Lake Sherburne was created and covers the reported wells.

Oil was discovered in the Wyoming part of Elk Basin field in 1915 and is often called the first commercial oil production in Montana. The first all-Montana oil discovery was the Cat Creek field in 1920.

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[1]Supervisory petroleum engineer.

This report is part of a continuing study by the Bureau of Mines of mineral resources and water requirements for their development in the Missouri River Basin. The individual field reports are mostly from previous Bureau of Mines publications, supplemented and updated by information from the records and files of the Montana Board of Oil and Gas Conservation.

The board formerly was known as the Montana Oil and Gas Conservation Commission, and the term "commission" frequently is used in this report. Geologic or formation names used in this report are those reported to the Montana Board of Oil and Gas Conservation. As such, they are used herein for identification or legal description and are not intended to show latest geologic interpretation.

Because information is not available concerning investment or operating expenses, no effort has been made to show economic success or failure of the projects. The report is not intended to explain the theories of waterflooding oil reservoirs, but rather is concerned with the following questions:

1. Where are the projects?
2. Where does the injection water come from?
3. How much water has been pumped into the ground?
4. How much oil has been produced from the projects since 1959?

Many of the projects also represent disposal of produced water--often very salty water. The produced water at many of the fields contains enough salt that underground disposal is required to prevent contamination of surface and shallow freshwater supplies.

In many cases, requests for permission to dispose of produced water by injection into the producing zone were followed shortly by unit agreements and waterflood proposals. The knowledge of "required" water disposal probably influenced some operators to try waterflooding.

Water production with the oil is a natural occurrence. Most operators report water produced on a per well per month basis, but such produced-water totals seldom are tabulated by the commission.

In aggregate, 77 waterflood projects are discussed. To prevent possible confusion, 20 water disposal projects also are included. East Poplar and Pondera fields are reported by the commission as disposal projects only and are not listed in table 1.

Cumulative waterflood injection through 1973 was 813.7 million barrels. Cumulative oil production for the entire State was 824.5 million barrels. The 31 fields having waterflood projects in 1973 (fig. 1 and table 1) produced 28.3 million barrels of oil out of a State total of 34.6 million barrels. According to published reports of the commission, the project fields had reserves of 323 million barrels compared with

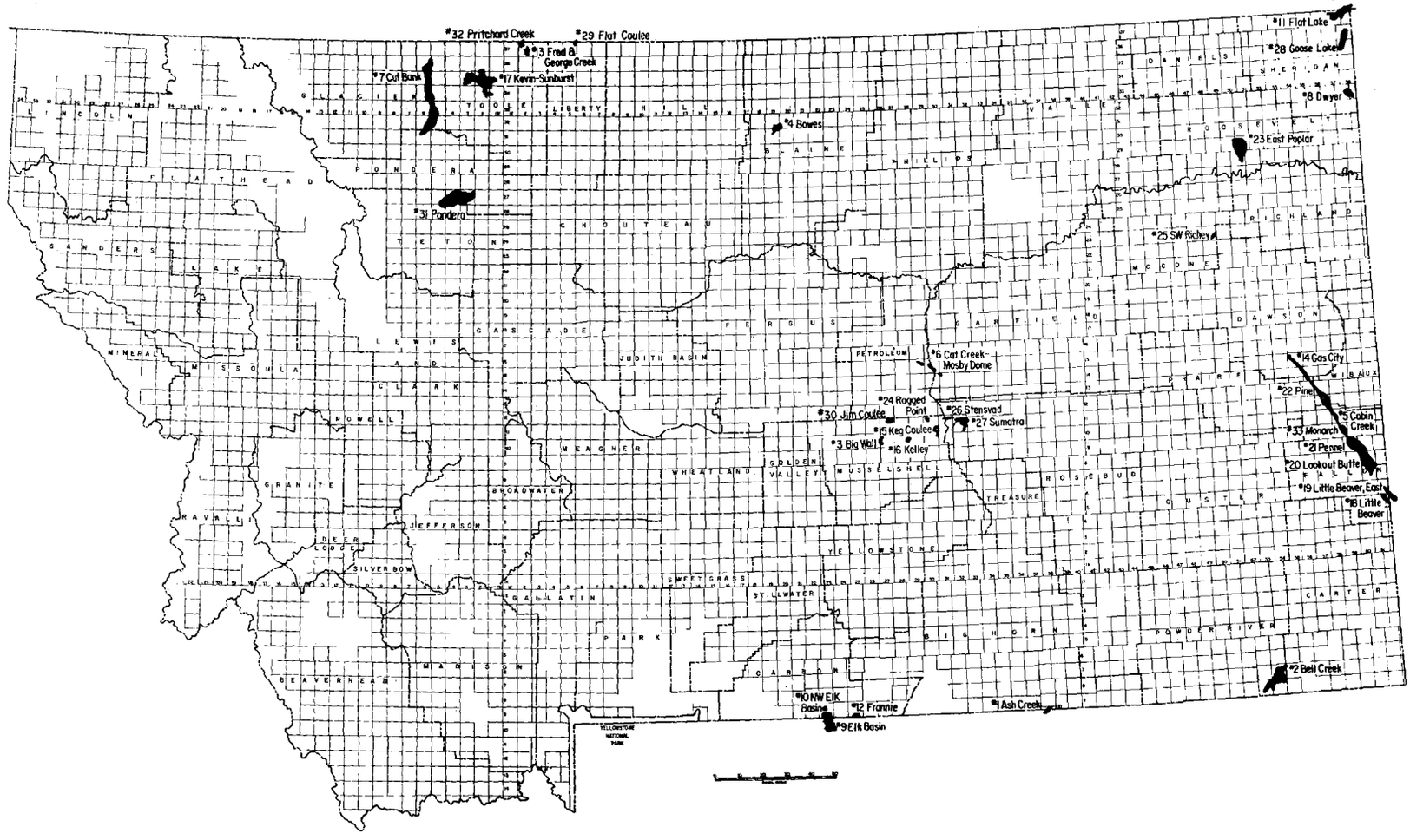

FIGURE 1. - Map, Montana waterfloods.

TABLE 1. - Annual oil production from Montana fields with waterfloods for the period 1960-73[1]
(Barrels)

Field	1959[2]	1960	1961	1962	1963
Ash Creek	280,493	30,507	28,163	26,695	25,701
Bell Creek	-	-	-	-	-
Big Wall[3]	3,404,444	263,556	400,075	363,207	276,091
Bowes	5,356,091	279,909	240,899	188,318	172,072
Cabin Creek	14,927,026	4,469,974	4,197,696	3,853,645	3,456,702
Cat Creek	19,388,240	180,760	239,050	220,182	234,089
Cut Bank[3]	89,405,163	2,421,904	2,369,269	2,367,695	2,286,640
Dwyer	-	91,890	443,682	935,842	713,450
Elk Basin	32,183,581	2,718,419	2,645,611	3,641,910	3,195,526
Northwest Elk Basin	1,482,484	45,075	44,441	51,635	59,941
Flat Coulee	29,919	1,891	4,568	56,714	321,205
Flat Lake[4]	-	-	-	-	-
Frannie	430,138	21,862	22,949	18,287	18,997
Fred and George Creek[3]	-	-	-	-	130,889
Gas City	1,224,250	186,750	442,645	860,820	845,533
Goose Lake	-	-	-	4,852	110,751
Jim Coulee	-	-	-	-	-
Keg Coulee[5]	-	232,871	698,882	493,600	327,066
Kelley	-	-	-	-	-
Kevin-Sunburst	64,779,064	743,936	666,303	614,097	549,448
Little Beaver	1,068,851	258,149	447,645	356,870	327,430
East Little Beaver	260,793	271,207	336,410	356,870	320,990
Lookout Butte	-	-	-	888,298	2,161,490
Monarch	117,088	395,352	372,047	236,935	182,601
Pennel	2,222,334	585,666	871,688	1,399,399	2,230,419
Pine[3]	21,158,986	5,112,014	5,212,260	4,725,822	4,190,687
Pritchard Creek	-	-	-	-	-
Ragged Point[3]	442,637	154,374	138,139	191,880	142,192
Southwest Richey	519,794	79,206	57,175	166,078	164,997
Stensvad	1,104,355	1,941,645	1,549,353	886,465	558,732
Sumatra	9,192,061	2,144,939	2,462,839	2,332,390	1,735,390

TABLE 1. - Annual oil production from Montana fields with waterfloods for the period 1960-73[1]--Continued
(Barrels)

Field	1964	1965	1966	1967	1968
Ash Creek	24,332	37,101	72,609	54,431	38,747
Bell Creek	-	-	-	1,671,277	16,572,472
Big Wall[3]	247,858	204,014	203,810	304,551	230,240
Bowes	157,462	159,708	180,941	175,427	175,008
Cabin Creek	3,061,917	3,136,280	3,098,631	3,397,647	3,530,308
Cat Creek	240,108	194,885	179,008	189,891	186,488
Cut Bank[3]	2,385,073	3,378,366	4,338,653	3,718,691	4,097,460
Dwyer	536,512	424,740	335,024	274,074	231,580
Elk Basin	3,358,612	3,085,649	2,950,611	2,834,602	2,594,586
Northwest Elk Basin	173,926	341,511	230,419	149,580	105,797
Flat Coulee	444,198	384,504	263,561	215,304	194,165
Flat Lake[4]	59,278	871,111	1,312,228	1,084,307	863,558
Frannie	18,254	16,513	14,702	12,615	11,091
Fred and George Creek[3]	1,169,408	1,528,837	1,547,969	1,102,773	839,693
Gas City	874,522	663,403	576,497	454,787	393,198
Goose Lake	382,397	597,493	751,763	758,990	699,439
Jim Coulee	-	-	-	-	-
Keg Coulee[5]	364,378	349,643	487,205	279,776	241,951
Kelley	-	-	14,758	151,859	165,007
Kevin-Sunburst	486,606	419,833	432,059	392,269	390,076
Little Beaver	309,973	300,534	384,593	389,809	374,309
East Little Beaver	286,941	230,957	230,846	225,801	226,926
Lookout Butte	1,698,349	1,415,827	1,881,073	1,764,310	1,217,389
Monarch	179,435	173,864	164,334	303,710	270,046
Pennel	2,693,523	2,412,391	2,091,568	1,949,541	1,724,725
Pine[3]	3,860,064	4,009,866	4,046,265	3,937,399	3,823,576
Pritchard Creek	-	-	-	-	17,118
Ragged Point[3]	88,212	65,382	72,581	146,166	105,027
Southwest Richey	199,465	138,473	126,149	104,174	79,508
Stensvad	417,950	427,683	392,242	370,391	248,576
Sumatra	1,304,576	956,026	815,130	711,981	738,081

TABLE 1. - Annual oil production from Montana fields with waterfloods for the period 1960-73[1]--Continued
(Barrels)

Field	1969	1970	1971	1972	1973	Cumulative
Ash Creek	30,149	26,783	21,146	13,254	10,797	720,908
Bell Creek	13,183,438	7,766,400	5,883,785	6,275,874	8,137,047	59,490,293
Big Wall[3]	172,717	131,845	99,403	75,488	62,266	6,439,565
Bowes	152,802	150,560	137,902	115,391	85,798	7,728,288
Cabin Creek	3,573,201	3,714,286	3,497,660	3,187,180	2,738,767	63,840,920
Cat Creek	164,145	167,613	190,990	194,748	161,866	22,132,063
Cut Bank[3]	5,208,079	5,631,105	5,734,255	4,924,327	4,181,646	142,448,326
Dwyer	228,454	299,383	278,980	215,100	151,122	5,159,833
Elk Basin	2,399,534	2,061,378	1,790,439	1,557,011	1,386,513	68,403,982
Northwest Elk Basin	141,791	139,973	79,540	45,182	36,031	3,127,326
Flat Coulee	148,204	116,357	91,746	75,955	106,723	2,455,014
Flat Lake[4]	779,856	802,885	628,998	578,933	638,294	7,619,448
Frannie	9,831	8,800	26,901	18,304	11,558	660,802
Fred and George Creek[3]	640,337	438,208	343,653	433,876	422,665	8,598,308
Gas City	327,070	292,207	286,242	269,982	268,018	7,965,924
Goose Lake	608,227	535,079	439,103	380,675	314,700	5,583,469
Jim Coulee	925	168	80,789	529,071	476,508	1,087,461
Keg Coulee[5]	136,076	140,425	123,180	179,839	297,919	4,352,811
Kelley	100,269	49,798	53,414	85,876	59,622	680,603
Kevin-Sunburst	303,816	327,401	292,884	281,261	268,239	70,947,292
Little Beaver	335,407	338,260	414,806	442,569	466,652	6,215,857
East Little Beaver	216,966	183,535	169,029	155,246	143,961	3,616,478
Lookout Butte	795,611	971,942	808,735	673,068	680,423	14,956,515
Monarch	236,396	215,119	204,463	184,590	162,028	3,398,008
Pennel	1,722,992	1,562,616	1,683,234	1,948,212	2,256,977	27,355,285
Pine[3]	3,550,873	3,311,564	3,029,175	2,827,330	2,884,405	75,680,286
Pritchard Creek	11,309	23,656	13,201	8,166	7,392	80,842
Ragged Point[3]	82,655	78,432	74,381	61,175	154,670	1,997,903
Southwest Richey	52,783	35,761	36,040	22,431	15,091	1,797,125
Stensvad	163,661	242,006	427,078	304,233	543,468	9,577,838
Sumatra	673,021	630,647	799,093	1,105,179	1,208,520	26,809,873

[1]From Montana Commission records.
[2]Cumulative through 1959.
[3]All zones production.
[4]Does not include South Flat Lake production.
[5]Includes production from Keg Coulee, East Keg Coulee, and South Keg Coulee.

a State total of 366 million barrels. Value of the oil produced in 1973 was $88.4 million for the project fields, and the State total was $108 million.

The source of injection water by formation, in barrels for 1973, was as follows: Eagle, 1,585,000; Fox Hills, 2,077,000; Lower Cretaceous, 3,320,000; Pennsylvanian, 5,463,000; Mississippian, 137,553,000; and Siluro-Ordovician, 7,679,000. Only 1,585,000 barrels or about 1 percent of the injection water could be considered usable for domestic purposes.

A few performance curves were selected for use in the report. An accompanying commentary explains some of the uses of such curves. Employing the oil production table and water injection information, a reader may draw his own performance curves and conclusions regarding additional oil recovery.

ASH CREEK

Ash Creek field straddles the Montana-Wyoming line almost due north of Sheridan, Wyo. The productive area is in secs 23 and 24, T 58 N, R 85 W, and sec 19, T 58 N, R 84 W, Sheridan County, Wyo., and sec 3, T 10 S, R 38 E, Big Horn County, Mont.

The structure was located by seismograph, but the field is a permeability pinchout-type reservoir. One or more faults trend northeast-southwest across the field. The Fort Union Formation is exposed at the surface. The terrain is hilly and dips sharply toward the middle of the field area and then east-southeast down Ash Creek. Surface elevations at the wells range from 4,050 to 4,390 feet.

Ash Creek field was discovered May 19, 1952, with the completion of the No. 1 Elsie Barry well in the NW¼NW¼SW¼ sec 24, T 58 N, R 85 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 Ash Creek sand also correlates with a member of the Eagle Formation. The Shannon sand is composed of medium-to-large, subangular, clear quartz grains and is slightly glauconitic, carbonaceous, and fairly soft. The producing interval has an average permeability of 275 millidarcys and porosity of 22 percent. The oil is undersaturated with a gas-oil ratio of less than 25 cubic feet per barrel.

The log of Shell Oil Co.'s No. 1 Government well in the SW¼NW¼ sec 23 shows the depth, in feet, to the tops of formations as follows: Claggett, 3,689; 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. A shallow gas well in the NW¼NW¼SW¼ sec 19 supplied field fuel for several years.

Thirty oil wells were completed in the field, but two of the wells (in Montana) were noncommercial. Initial daily oil production averaged 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. The entire field was unitized in September 1964 with J. Ray McDermott Co. as operator. The Shannon reservoir covers about 980 acres, and the average pay thickness is 17 feet.

Water injection started on October 15, 1964. Injection water was from the Parkman sand (±4,200 feet). The flood was expanded in January 1965.

Crow Tribal wells A-7 and A-8, sec 3, were drilled as water injection wells late in 1964. Well A-7 unexpectedly produced oil for a few months. Crow Tribal well B-2 was completed as a water well, and well B-1 was completed as a n oil well for a short time before being used as an injection well.

Annual and cumulative water injection and number of injection wells for Ash Creek field (Montana portion) are listed as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1964	22	22	1
1965	155	177	3
1966	69	246	3
1967	138	384	4
1968	168	552	4
1969	60	612	4
1970	38	650	4
1971	84	734	4
1972	87	821	2
1973	69	890	2

Cumulative oil production from the Montana portion to the start of injection was 407,995 barrels or 27 percent of the estimated original oil in place. Production after injection to January 1, 1974, was 312,911 barrels. Cumulative water injection was 890,000 barrels.

The three oil wells in the Montana part of the field averaged 27 barrels of oil and 73 barrels of water daily in December 1973. Average daily water injection in December 1973 was 1,500 barrels.

BELL CREEK

Bell Creek field is in Tps 8 and 9 S, Rs 53, 54, and 55 E, Powder River and Carter Counties. The field is named for Bell Creek, an intermittent stream in the area. The area is hilly and generally slopes or dips to the southwest. Hills are usually well rounded except for a few having almost vertical slopes. Elevations at the wells range from 3,450 feet in the southwest to about 4,000 feet in the northeast.

Exeter Drilling Co.'s well, Federal-McCarrel No. 33-1, in the NE¼NE¼ sec 33, T 8 S, R 54 E, Powder River County, was completed in June 1967. Initial daily pumping production was 230 barrels of oil from the Muddy sand. This discovery well kicked off a rapid development effort accompanied by lots of publicity.

Bell Creek field will be remembered as (1) the first major oilfield in Montana producing from the Muddy sand, (2) the first Rocky Mountain field to have two oil pipelines built to it within 6 months of discovery and four oil pipeline outlets in just over a year from discovery, (3) the first Rocky Mountain field to have an engineering committee formed within a year of discovery to plan secondary recovery, (4) the first Muddy sand oilfield to have permeabilities of 3 to 5 darcys, and (5) the first Rocky Mountain field to start waterflooding less than 5 years after discovery.

The first Muddy sand oilfield in Montana was the Ranch Creek field in secs 10 and 15, T 9 S, R 53 E, discovered in September 1965. Four oil wells and four dry holes were completed before the Bell Creek discovery in June 1967. Initial daily pumping production of the first four Ranch Creek wells in sequence of completion were 111 barrels of oil and 3 barrels of water; 100 barrels of oil and 90 barrels of water; 25 barrels of oil and 20 barrels of water; and 28 barrels of oil and 205 barrels of water. Poor results from these four oil wells and four dry holes had stopped development of the Ranch Creek field before the Bell Creek discovery was drilled. The Bell Creek discovery well is a little more than 6 miles northeast of the Ranch Creek discovery well. The Ranch Creek field later was included in the Bell Creek field.

Independent operators can be credited with speedy development of Bell Creek field and its pipeline outlets. Development activities included drilling more than 450 wells from August 1967 through 1968. Out of 550 tests, 405 oil wells and 10 gas wells were completed. Average rig time for wells was only 3 days, involving 32 hours actual drilling time and use of three bits.

Operators in the field formed a geological and engineering subcommittee in December 1968 to study unitization and secondary recovery. More than 400 oil wells and almost 18,000 acres were considered in the study. Intensive study of the Muddy sand at Bell Creek field and other fields in northeastern Wyoming was made by geologists and engineers. Barrier bar, delta front, marsh, and channel facies were found to exist in the Muddy interval in the region. "Upper" and "lower" sand occurred

in parts of the Bell Creek area. Generally, the "upper" sand would be the cleaner and more permeable sand. Twenty-six individual reservoirs were found in the Bell Creek field.

The field first was divided into the "A," "B," "C," "D," and Ranch Creek Muddy sand units. Later the "D" unit was split into the "D" and "E" units. Averages of porosity, sand thickness, and permeability are too varied for comparison in an area the size of Bell Creek field. But the most attractive unit in terms of expected oil recovery per well (or acre) is unit "A," followed by unit "B," unit "C," and unit "D." Units "E" and Ranch Creek are about equal and poorest of the lot.

Muddy sand unit "A" was approved by the commission's[2] order No. 7-70, dated March 26, 1970. Muddy sand unit "B" was established by commission order No. 23-70, dated September 17, 1970. Ranch Creek Muddy sand unit was established by order No. 8-71, dated February 11, 1971. Unit "C" was created by order No. 26-71, dated August 21, 1971. Units "D" and "E" were approved by orders No. 35-71 and No. 36-71, dated December 16, 1971.

Published estimates of oil recovery from the Bell Creek field by primary and waterflood methods range from 92 million[3] to 116 million[4] barrels, which is only about 38 percent of stock tank oil in place. The low recovery estimates reflect lack of natural water drive and high permeability.

Each of the commission orders creating the waterflood units lists probable number of injection wells and barrels of water to be injected daily when the units first reach operating strength. For all six units the total anticipated number of injection wells was 55, and daily injection would be 140,100 barrels of water. This amounts to 18 acre-feet of water a day, or 6,585 acre-feet per year.

The geological and engineering committee also was charged with obtaining a source of suitable injection water. There are no perennial rivers or lakes in the area capable of furnishing the necessary water.

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[2]In December 1971, the Montana Oil and Gas Conservation Commission became the Montana Board of Oil and Gas Conservation directing policy of the Oil and Gas Conservation Division, Montana Department of Natural Resources and Conservation. Offices and administrative personnel remain the same.

[3]Farnhan, F. E., and F. A. Haddenhorst. Four and One-Half Years--Discovery to Unitized Operation of the Major, Multi-Reservoir Bell Creek Field. Soc. Petrol. Eng., AIME, SPE Paper 3834, April 1972, 12 pp.

[4]Oil and gas Conservation Division, Montana Department of Natural Resources and Conservation. Annual Review for the Year 1971 Relating to Oil and Gas. V. 15, 28 pp.

Geological studies indicated the Madison Formation was a good prospect for water supply. The committee was authorized to drill, complete, and test a Madison Formation well. If the water well was a success, the committee then could start construction of a field injection system. When the units were approved and operating, the committee would be reimbursed for such expenses.

The first Madison water supply well, Gary Operating Co.'s Lanning well No. 1, in the NE¼SW¼ sec 29, T 8 S, R 54 E, was completed December 18, 1969. An 8-5/8-inch casing was set through the Muddy Formation and a 5½-inch liner set through the Madison zone. The well was perforated from 6,960 to 7,170 feet and acidized. Initial daily flowing production was 8,750 barrels of water. Calculated maximum daily pumping production was 18,000 barrels of water.

Because the 5½-inch liners limited the size of the pumping equipment, the second and third water wells were completed with 9-5/8-inch casing set through the Madison zone. The No. 2 water well in the SE¼NE¼ sec 21, T 8 S, R 54 E, was completed flowing 30,000 barrels daily and No. 3, in the NW¼NE¼ sec 22, T 9 S, R 53 E, flowing 33,500 barrels daily.

A system serving the entire field achieves a considerable saving in cost by reducing the number of water wells and pump stations that would be required for individual unit systems.

The sequence and depth of formations in the area as determined by the log of the No. 2 water well shows the depth, in feet, to the tops of formations as follows: Pierre, 696; Eagle, 1,897; Niobrara, 2,756; Mowry, 4,153; Muddy Formation, 4,336; Muddy sand, 4,370; Skull Creek, 4,400; Fall River, 4,655; Lakota, 4,746; Morrison, 4,877; Sundance, 5,030; Piper, 5,240; Spearfish, 5,438; Minnekahta, 6,075; Opeche, 6,100; Minnelusa, 6,166; Madison, 6,848; Stony Mountain, 7,636; Red River, 7,724; and total depth, 8,014.

Water injection at Bell Creek Muddy sand unit "A" started on July 1, 1970. Cumulative production to start of injection was 16,853,000 barrels of oil and 765,000 barrels of water.

Annual and cumulative water injection and number of injection wells for the Bell Creek Muddy sand unit "A" are as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1970	5,152	5,152	17
1971	12,278	17,430	21
1972	11,504	28,934	26
1973	8,918	37,852	26

Cumulative production through 1973 was 24,490,000 barrels of oil and 7,912,000 barrels of water. In December 1973, the unit contained 26 active water injection wells, 95 active oil wells, and 2 Madison water wells. Average daily production in December 1973 was 11,869 barrels of oil and 11,051 barrels of water.

Water injection at the Bell Creek Muddy sand unit "B" started November 1, 1970. There were six water injection wells. Cumulative production at the start of injection was 4,349,000 barrels of oil and 274,700 barrels of water. Average daily injection in December 1973 was 10,250 barrels through 11 injection wells. The 21 producing wells in December 1973 averaged 2,745 barrels of oil and 2,082 barrels of water daily.

Annual and cumulative water injection and number of injection wells for Bell Creek Muddy sand unit "B" are as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1970	331	331	6
1971	2,669	3,000	10
1972	4,014	7,014	11
1973	3,596	10,610	11

Cumulative production through 1973 was 6,834,300 barrels of oil and 1,742,600 barrels of water.

Water injection at Bell Creek Muddy sand unit "C" commenced on December 1, 1971. Cumulative production at the start of the project was 2,420,900 barrels of oil and 400,700 barrels of water. Oil and water production for December 1973 was 58,102 barrels of oil and 29,456 barrels of water from wells.

Annual and cumulative water injection and number of injection wells for Bell Creek Muddy sand unit "C" are as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1971	120	120	6
1972	1,663	1,783	6
1973	2,225	4,008	6

The Bell Creek unit "D" was approved December 1, 1971, but water injection was not started until August 1972, using 11 injection wells. Water injection for 1972 was 1,904,000 barrels and for 1973 was 3,863,000 barrels. Production prior to start of injection was 6,147,600 barrels of oil and 781,500 barrels of water. Production from start of injection to January 1, 1974, was 1,032,100 barrels of oil and 740,600 barrels of water. Daily water injection during December 1973 was 9,438 barrels, using 16 injection wells. Daily production averaged 2,173 barrels of oil and 1,997 barrels of water from 32 wells.

Water injection at unit "E" started in August 1972, using 12 injection wells. Injection for 1972 was 1,193,000 barrels and 2,407,000 barrels in 1973. Production after injection until January 1, 1974, was 809,200 barrels of oil and 613,300 barrels of water. Daily production for December 1973 was 1,710 barrels of oil and 1,241 barrels of water from 41 wells. Injection in December 1973 averaged 5,855 barrels daily using 14 injection wells.

Bell Creek-Ranch Creek Muddy sand unit was approved March 1, 1971. Cumulative production to July 1, 1971, when water injection started, was 4,784,346 barrels of oil and 889,100 barrels of water. Water injection during the last half of 1971 was 2,718,100 barrels.

Well status in December 1973 showed 13 active water injection wells, and 22 active oil wells. Injection water is from the field system. Daily production during December 1973 was 4,503 barrels of oil and 4,256 barrels of water. Cumulative production through 1973 was 7,935,000 barrels of oil and 3,150,400 barrels of water.

Turbine engines coupled to centrifugal pumps are used to pump the injection water. The engines are rated at 1,100 horsepower, and the pumps are rated at 27,000 barrels per day at 1,500 psi.

A plant to process the produced natural gas and recover the liquid gas products was built and started operating in the field in December 1968. Recovery from the plant was as follows:

Year	Gas processed, thousand cubic feet	Processed gas sold, thousand cubic feet	Liquids recovered, gallons
1968	586,214	378,374	13,199
1969	9,177,024	5,132,370	242,909
1970	7,005,136	3,469,212	349,184
1971	1,054,042	46,277	55,690
Total...	17,822,416	9,026,233	660,982

The plant shut down in March 1971 and was dismantled and moved to the Bluebell area of Utah. The Montana-Dakota Utilities Co. purchased most of the gas sold.

The Bell Creek Pipeline Co. and Permian Corp., starting in September 1967, built two 8-inch pipelines to connect with the 16-inch line of Butte Pipeline Co. at Alzada, about 20 miles east of the Bell Creek field. The Butte pipeline could only take about 12,000 barrels per day. Bell Creek Pipeline Co. and Permian Corp. combined to build a 6-inch line to connect with the Belle Fourche Pipeline Co.'s line at Lightning Flats, south of the Montana-Wyoming border. The fourth pipeline was a 110-mile, 10-3/4-inch line from Bell Creek to the Service Pipeline Co. line at Reno field, built by the Permian Corp.

The townsite of Bell Creek was platted in the SE¼SW¼ sec 16, T 8 S, R 54 E. In the spring and summer of 1968, stores, offices, homes, and a school were built.

It could be said that Bell Creek represents the "new look" in oilfields. Naturally the "firsts" at Bell Creek are important to the operators there, but the real significance is the change in the petroleum industry. The companies no longer stress secrecy in exploration, but rather try to develop fields rapidly and get the oil going to market. Unitization is recognized as necessary for effective waterflooding.

BIG WALL

The Big Wall field in T 10 N, Rs 26 and 27 E, Musselshell County, is about 10 miles north of the town of Gage and 6 miles north of Gage oilfield. Surface elevation of the area ranges between 3,200 and 3,300 feet. Although known as a "sheepherder" anticline, seismic study of the area indicated twin "domes."

Two dry holes were drilled in the NW¼ of sec 19, T 10 N, R 27 E, before the area was seismographed. Texaco's No. 1 S. Zoerb, in the SE¼NW¼SE¼ sec 18, T 10 N, R 27 E, was for practical purposes the discovery well, having been completed November 13, 1948. Initial flowing oil production was 75 barrels in 24 hours. The Amsden dolomite and the Tyler "A" and "B" sands were productive in the field. The Amsden dolomite and Tyler "A" sand do not blanket the field as well as the Tyler "B" sand, however.

The No. 6 Zoerb well in sec 18 was drilled to the Precambrian to test zones below the Tyler. The Charles zone was dry, and the Mission Canyon, Lodgepole, and Big Horn zones all contained water.

All of the wells that have been drilled produced water with the oil. Starting October 20, 1956, the produced water was disposed of in the upper Amsden zone. Water injected was 1,808,159 barrels at the end

of 1958. Injection stopped November 1, 1961, when 3,248,000 barrels had been pumped into the zone.

The commission approved the Texaco unit plans for waterflooding the Big Wall Tyler upper "B" sand on May 26, 1966. The unitized area was 596 acres. Water injection started August 20, 1966. Injection rate was about 5,500 barrels of produced water. Three injection wells were used.

Annual and cumulative water injection and number of injection wells for the Big Wall field are as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1966	735	735	3
1967	1,818	2,553	3
1968	1,700	4,253	2
1969	987	5,240	2
1970	2,715	7,955	2
1971	1,925	9,880	2
1972	1,852	11,732	2
1973	1,405	13,137	2

Primary recovery from the field was 5,600,000 barrels, and secondary recovery to 1974 was 163,000 barrels. Production in December 1973 was 2,462 barrels of oil and 49,400 barrels of water from the seven wells in the unit area. Cumulative production through 1973 from the unit area was 1,809,900 barrels of oil and 7,038,100 barrels of water.

BOWES

The Bowes oil and gas field in Tps 31 and 32 N, Rs 19 and 20 E, Blaine County, is 6 miles south of Chinook and about 20 miles east of Havre. The structure is an elongated dome associated with the Bearpaw Mountains uplift about 10 miles southwest of the field. Some shallow thrust faulting exists.

The field is on a treeless rolling plain having a surface of glacial drift. Soft shales of the Judith River Formation occasionally crop out at the surface. Other formations are exposed in stream gullies. Surface elevation for the area ranges from 2,750 to 3,000 feet.

Gas was discovered in the Eagle sand in 1924 when the California Co.'s No. 1 Johnson-Hobson, NE¼NE¼NE¼ sec 9, T 31 N, R 19 E, "blew out" and caught fire. The initial daily rate was 40,000 cubic feet of gas. Abel No. 1, SE¼SE¼ sec 4, T 31 N, R 19 E, was completed November 22, 1924,

as an Eagle gas well. The well was plugged because there was no pipeline in the vicinity. Four wells were drilled in 1926, and a pipeline was laid to Chinook and Havre.

Gas occurs in the upper 80 feet of the Eagle sand at 700 to 1,000 feet. Initial capacity of the wells ranged from 1.4 to approximately 30 million cubic feet of gas daily and averaged approximately 7 million cubic feet daily. Initial wellhead pressures ranged from 250 to 300 psi and averaged 260 psi. The gas had a heating value of 905 Btu per cubic foot. Peak gas production occurred in 1950 when 1,336,483,000 cubic feet was produced.

Oil was discovered 23 years after the gas, on September 21, 1949. The discovery well, Northern Ordnance, Inc.'s No. 1 Guertzgen, SW¼NW¼NE¼ sec 2, T 31 N, R 19 E, initially produced 200 barrels of 19.2° API gravity oil daily from the Sawtooth sand in the lower Ellis Group. By 1951, approximately 20 additional wells had been drilled with initial production rates from 100 to 400 barrels daily.

Oil occurs in three zones in the Sawtooth Formation (Jurassic). The lowermost section is a sandy, slightly calcareous shale associated with a fine sandstone. The middle section is a dense, buff, shaly, limestone but includes calcite-filled fractures. The upper unit, the most prolific producing section, consists of sandy, silty, oolitic limestone and calcareous sandstone containing limestone pebbles. The average thickness of the upper zone is about 50 feet. Hydrochloric acid treatment of the zone is a common completion procedure. Initial bottom hole pressure of the field was approximately 190 to 300 psi. Peak annual oil production of 1,094,814 barrels was in 1953.

A unit plan for waterflooding the Bowes field was approved, and water injection started May 23, 1961. The initial waterflood test was a five-spot injection pattern. Injection water is from a Madison supply well. The flood was expanded in 1965.

Annual and cumulative water injection and number of injection wells for Bowes field are as follows:

Year	Annual water injection, thousand barrels[1]	Cumulative water injection, thousand barrels[1]	Number of water injection wells[1]
1961	154	154	4
1962	259	413	4
1963	232	645	5
1964	116	761	5
1965	139	900	5
1966	540	1,440	5
1967	753	2,193	5
1968	518	2,711	4
1969	443	3,154	3
1970	206	3,360	6
1971	255	3,615	6
1972	235	3,850	3
1973	2,921	6,771	3

[1]Montana Oil and Gas Conservation Commission figures.

Daily production during December 1973 was 450 barrels of oil and 849 barrels of water from 41 wells. Daily injection was 848 barrels, using three injection wells. Cumulative production through 1973 was 7,726,000 barrels of oil and 3,825,800 barrels of water.

From November 5, 1954, through January 1955, a gas injection test was run in the Bowes field. Northern Pump Co. pumped about 62 million cubic feet of gas into their Guertzgen No. 4 in the NE¼ sec 2, T 31 N, R 19 E, in the nearly 3-month period. Injection pressure was reported to be 62 psi. The reports did not show any results for the test.

CABIN CREEK

The Cabin Creek oilfield in Tps 9-11 N, Rs 57-59 E, Fallon County, is part of a horst-block fault area on the northern half of the Cedar Creek anticline. The structure dips steeply on the west flank but gently on the east flank. The Bearpaw Shale is exposed on the surface at an average elevation of 2,800 feet.

Following detailed seismic study of the area, the discovery well, Shell No. 22-33, in the NW¼SE¼NW¼ sec 33, T 10 N, R 58 E, was completed June 9, 1953. Three zones between 8,688 and 8,957 were perforated and acidized. Initial daily flowing production was 1,248 barrels of oil and 32 barrels of water. These zones are in the Red River Member of Ordovician age. The Interlake Member of the Silurian also contained oil. The Siluro-Ordovician rocks have numerous fractures, and communication exists between the zones.

The Mission Canyon (Madison) discovery well in the C SE¼NE¼ sec 29, T 10 N, R 58 E, was completed December 13, 1956. Initial daily flowing production was 305 barrels of oil and 37 barrels of water from the interval 7,298 to 7,324 feet.

The reservoir rocks are fractured dolomite. Acid is a common completion tool at Cabin Creek field.

The Wills Creek field turned out to be an extension of the Cabin Creek field. Order No. 36-62 of the commission dated May 10, 1962, incorporated the Wills Creek field into the Cabin Creek field.

Starting in 1958, water produced with the oil from the Siluro-Ordovician zone was injected into the Dakota zone through one injection well. Injection into the Dakota zone continued until August 1962. Then disposal into the Mission Canyon (Madison) Formation was started. The Dakota injection was discontinued because of increasing injection pressures.

Saltwater disposal into the Dakota zone in the Cabin Creek well No. 12-20, sec 20, T 10 N, R 58 E, was as follows:

Year	Annual, thousand barrels	Cumulative, thousand barrels
1958	274	274
1959	1,264	1,538
1960	1,661	3,199
1961	2,007	5,206
1962	1,534	6,740

Saltwater disposal into the Mission Canyon zone in the Cabin Creek well No. 12X-17, sec 17, T 10 N, R 58 E, started in August 1962, was as follows:

Year	Annual, thousand barrels	Cumulative, thousand barrels
1962	791	791
1963	2,660	3,451
1964	1,202	4,653
1965	475	5,128
1966	998	6,126
1967	1,257	7,383
1968	1,130	8,513
1969	972	9,485
1970	724	10,209
1971	912	11,121
1972	547	11,668

Total saltwater disposal in the Dakota and Mission Canyon zones was 18,408,000 barrels.

A pilot water injection into the Siluro-Ordovician zone for the pressure maintenance was started June 12, 1959. Commission order No. 5-59 approved four wells for injectors. Order No. 15-60 approved four more injection wells and order No. 30-63 approved unit operation for the whole field.

Pressure maintenance water injection in Cabin Creek unit was as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1959	95	95	2
1960	149	244	2
1961	395	639	2
1962	1,205	1,844	2
1963	380	2,224	2
1964	1,125	3,349	12
1965	4,657	8,006	11
1966	6,330	14,336	15
1967	7,438	21,774	16
1968	9,108	30,882	25
1969	14,008	44,890	30
1970	15,810	60,700	31
1971	18,035	78,735	30
1972	18,902	97,637	30
1973	17,455	115,092	31

The Siluro-Ordovician water injection program has solved a water disposal problem and assisted in the recovery of additional oil at Cabin Creek. Daily production in December 1973 was 5,385 barrels of oil and 11,568 barrels of water from 67 wells.

CAT CREEK

Cat Creek oilfield in T 14 N, Rs 30 and 31 E, and T 15 N, Rs 28-30 E, Garfield and Petroleum Counties, is about 20 miles northeast of the town of Winnett. Cat Creek contains four "highs" or "domes." From west to east, the field includes the following: West Dome, Mosby Dome, Middle High, and East Dome. Of these, the West Dome has the most oil wells.

Frantz Oil Corp.'s No. 1 Charles in the SW¼SE¼NW¼ sec 21, T 15 N, R 30 E, was completed in February 1920. The well was drilled to a depth of 998 feet and produced 10 barrels of oil per day. By 1926, 285 wells

had been drilled in the area. The West Dome had 131 oil wells in the First Cat Creek sand and 59 in the Second Cat Creek sand. In 1958, 390 wells had been drilled in or near the field. Only 88 still produced oil and 154 had been abandoned. At the end of 1970, only 58 producing wells remained.

The Colorado Shale forms the surface at the field, although the Mosby Sandstone Member is exposed along the Musselshell River. The Eagle Sandstone forms the rim around the structure. The structure is an anticline with small domes or highs. Numerous transverse faults cross the structure, and on West Dome and Mosby Dome, these faults can be demonstrated to exist at the depth of the productive horizons and may have influenced the oil accumulation.

The Mowry and Skull Creek Shales at the West Dome have contained some oil where highly fractured. The First Cat Creek Sandstone is as much as 40 feet thick, fine-grained, and shaly. It probably is equivalent to the Greybull Sandstone Member and the Dakota Sandstone Formation of Lower Cretaceous age. The Second Cat Creek Sandstone ranges from 10 to 60 feet in thickness, is medium-grained, dirty, and contains feldspar. The Third Cat Creek Sandstone contains freshwater. The "Brindley" Sandstone in the Morrison ranges from zero to 60 feet in thickness, is coarse-grained, and contains coal and shale. The Swift Formation of the Ellis Group ranges from 25 to 50 feet in thickness, is fine-grained and glauconitic. Only the Swift Formation is consistent over the field. Extreme changes in permeability occur in the other zones. The Amsden Dolomite is not present, and the Amsden Limestone and Shale are thin and irregular here.

Herbert D. Hadley[5] reports the porosity and permeability of the producing zones as follows:

Zone	Porosity, percent	Permeability, millidarcys
First Cat Creek....	10-26	10-150
Second Cat Creek...	0-20	0-393
Morrison Formation	0-31	0-553
Swift Formation....	11-25	12-162

Three waterflood units are active in the Cat Creek field. Units 1 and 2 included the First and Second Cat Creek sands. The Swift waterflood was the last to start. Injection water is obtained from the Third Cat Creek sand.

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[5]Hadley, H. D. Cat Creek Field, Montana Oil and Gas Symposium. Billings Geol. Soc., 1956, p. 99.

Cat Creek unit No. 1, the western part of the West Dome, was unitized and approved for waterflooding August 18, 1959. Continental Oil Co. was the unit operator and stopped injection in October 1968. Farmers Union Central Exchange, Inc., took over the unit in May 1969 and resumed water injection in May 1970. Water injection at Cat Creek unit No. 1 is listed as follows:

Year	Annual water injection, thousand barrels[1]	Cumulative water injection, thousand barrels[1]	Number of water injection wells[1]
1959	43	43	8
1960	1,398	1,441	8
1961	1,839	3,280	8
1962	2,429	5,709	8
1963	2,204	7,913	15
1964	2,708	10,621	16
1965	1,875	12,496	11
1966	1,365	13,861	8
1967	1,138	14,999	8
1968	772	15,771	4
1969	-	[2]15,771	4
1970	144	15,915	3
1971	295	16,210	5
1972	390	16,600	5
1973	221	16,821	5

[1]From Montana Oil and Gas Conservation Commission reports.
[2]Farmers Union Central Exchange, Inc., assumed unit operations.

Daily production from unit 1 during December 1973 was 33 barrels of oil and 719 barrels of water from 10 wells. Daily injection was 787 barrels, using five injection wells.

Unit 2, the rest of the West Dome Area, was approved and flooding started in October 1962. Continental Oil Co. was the operator. Farmers Union Central Exchange, Inc., took over the operation of unit 2 in May 1969. Water injection at unit 2 (First and Second Cat Creek sands) was as follows:

Year	Annual water injection, thousand barrels[1]	Cumulative water injection, thousand barrels[1]	Number of water injection wells[1]
1962	76	76	4
1963	646	722	4
1964	855	1,577	7
1965	2,360	3,937	7
1966	531	3,368	4
1967	1,224	5,692	4
1968	843	6,535	4
1969	-	[2]6,535	4
1970	248	6,783	4
1971	600	7,383	7
1972	617	8,000	7
1973	826	8,826	7

[1]From reports of the Montana Oil and Gas Conservation Commission.
[2]Unit operator changed to Farmers Union Central Exchange, Inc.

Daily production from 15 wells in December 1973 was 232 barrels of oil and 2,481 barrels of water. Water injection averaged 2,245 barrels daily.

Water injection in units 1 and 2 was suspended November 1, 1969, and resumed June 1, 1970.

Individual unit production was not published. However, oil production from the whole field increased each year from 1959 through 1964, declined in 1965-67, and increased again in 1968.

Robert Hoss, operator, was given permission to start a one-well pilot waterflood test in the Ellis (Swift) sand on April 10, 1969. Expansion of the project was approved November 19, 1970. The project is on the East Dome in sec 6, T 14 N, R 31 E. Produced water from the Third Cat Creek sand is used for injection.

Annual and cumulative water injection and number of injection wells in the Swift sand, East Dome, are as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1970	24	24	1
1971	25	49	1
1972	25	74	2
1973	40	114	2

Daily production during December 1973 was 82 barrels of oil and 68 barrels of water from nine wells. Water injection averaged 98 barrels daily in two injection wells. Cumulative oil production to January 1, 1974, was 145,700 barrels.

Oil production from the four "domes" has been recorded under Cat Creek field, so the name Mosby Dome is used only to identify some waterflood projects.

Musselshell Oil Co. began water injection into the Brindley sand at Mosby Dome through one well in December 1965. Injection amounted to 8,000 barrels in 1965 and 18,000 barrels in 1966. Injected water was from the Third Cat Creek sand. The project was abandoned in 1966.

A unit plan to waterflood the Swift sand at Mosby Dome, submitted by Farmers Union Central Exchange, Inc., was approved by the commission by order No. 25-66, dated May 26, 1966. Injection water is obtained from the Third Cat Creek sand. Waterflooding started in July 1967.

Annual and cumulative water injection and number of injection wells in the Swift sand, Mosby Dome, are as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1967	119	119	4
1968	314	433	5
1969	350	783	4
1970	390	1,173	5
1971	447	1,620	5
1972	380	2,000	5
1973	500	2,500	5

Average daily production from eight wells in December 1973 was 62 barrels of oil and 787 barrels of water. Daily water injection into five wells was 1,340 barrels.

A plan to waterflood the Second Cat Creek sand under the SE¼ sec 17, T 15 N, R 30 E, at Mosby Dome was approved March 14, 1968, by commission order No. 8-68. Water injection was started in May 1968 by the Farmers Union Central Exchange, Inc.

Annual and cumulative water injection and number of injection wells in the Second Cat Creek sand, Mosby Dome, are as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1968	17	17	5
1969	42	59	2
1970	55	114	1
1971	86	200	2
1972	67	267	2
1973	0	267	0

The Amsden discovery well at Mosby Dome was Farmers Union Central Exchange, Inc.'s No. 8 State in the SW¼SW¼ sec 16, T 15 N, R 30 E, completed on December 7, 1967. Initial daily pumping production was 50 barrels of oil from the depth interval 2,014 to 2,028 feet.

The Mosby Dome Amsden unit in secs 16, 17, 20, and 21 was approved May 13, 1971, by commission order No. 11-71. Water for injection was obtained from the existing waterflood system in the field. Water injection started in June 1971 and amounted to 13,000 barrels during the rest of the year. Injection in 1972 was 11,000 barrels and 20,000 barrels in 1973.

Cumulative oil production from all of the Cat Creek reservoirs was 40,153,300 barrels to January 1, 1974. The commission reported active wells, by sands, on December 31, 1973, were Cat Creek sands, 68; Swift, 8; Ellis, 9; and Amsden, 1.

CUT BANK

The Cut Bank oil and gas field in Tps 31-37 N, Rs 3-8 W, Glacier, Pondera, and Toole Counties, is on the west flank of the Sweetgrass arch. Glacier National Park is about 40 miles to the west. The field joins the Canadian border on the north. Cut Bank, Montana's biggest field, is approximately 30 miles long and ranges up to 10 miles wide. The field area contains many "pools" or reservoirs. U.S. Highway 2 and the main line of the Great Northern Railway cross the field through the town of Cut Bank. The surface is gentle rolling plains, treeless, and very flat in places. Sharp valleys have been cut along the larger streams. Wheat farming and ranching are common in the area.

The field was discovered by "step-out" drilling, west of the Kevin-Sunburst field. Sand Point Oil Co.'s No. 1 Berger, SE¼SE¼NW¼ sec 1, T 35 N, R 5 W, was completed in November 1926. Initial flow was 8 million cubic feet of gas daily from the Cut Bank sand (lower Kootenai) from 2,778 to 2,820 feet. No gas pipelines were in the area, so the well was abandoned.

The Drumheller No. 1 Yunck well, sec 1, T 34 N, R 5 W, 8.5 miles southwest of the Berger well, was drilled in 1929. Initial daily production was 7 million cubic feet of gas and 5 barrels of oil from the Cut Bank sand about 250 feet lower structurally than the Berger well. The first oil well at Cut Bank, the B & H Oil Co.'s Haines No. 1, SE¼SE¼ sec 2, T 34 N, R 6 W, was completed April 16, 1931. Initial daily production was 50 barrels of oil from the lower Cut Bank sand of the Kootenai Formation from 2,761 to 2,778 feet.

Montana Power Co. laid about 250 miles of 20-inch gas pipeline from the field to Butte, Helena, and Anaconda in 1930. Twenty wells were drilled in 1931 northeast of the town of Cut Bank, averaging 12.7 million cubic feet of gas daily.

By 1935, the Cut Bank oilfield was an area 20 miles long and 2 to 3 miles wide, whereas the gasfield was 18 miles long and 3 to 5 miles wide. Lack of a market for the oil curtailed development from 1935 to 1940. World War II revived activity from 1940 to 1945.

Carter Oil Co.'s (later Humble Oil and Refining Co. and now Exxon Co., U.S.A.) No. 1 Brindley, NE¼NE¼ sec 12, T 36 N, R 6 W, found oil in the Madison Formation between 3,084 and 3,087 feet in the fall of 1945. Initial daily production by swabbing was 50 barrels of 37.2° API gravity oil.

The Madison oil production is from an upper zone, probably the Sun River. Previously the oil and gas came from sands in the Kootenai Formation. The Moulton (upper Sunburst), Sunburst, Lander, and Cut Bank sands were the local names used. In 40 years, records of individual "sand" oil production have become mixed. The Cut Bank sand has been divided into the gas-bearing upper zone and oil-productive lower zone.

The Cut Bank sand is productive over the entire field, whereas other sands are localized by subarea. The Cut Bank field contains all or part of these subareas: Thorpe-Border, North Cut Bank, Reagan, West Cut Bank, Central Cut Bank, South Cut Bank, and Two Medicine. Annual oil and gas production from the Cut Bank field as listed by the commission is shown by table 1.

The first waterflood in Montana was the Humble Oil and Refining Co.'s (now Exxon Co., U.S.A.) Lander sand (Cut Bank Tribal) project in 1951. At the end of 1973, there were 31 projects in "Cut Bank" as designated by the commission. Oil and gas production data from the individual projects at the start of injection were not available.

Water injection at Humble's (Exxon's) project started in June 1951. The flood area in secs 9, 10, and 15, T 35 N, R 6 W, contained about 300 acres and had four producing and three injection wells in 1967. Water injection stopped in 1968.

Annual and cumulative water injection and number of injection wells in the Cut Bank Tribal-Lander sand unit are as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1963	[1]287	3,535	5
1964	265	3,800	5
1965	192	3,992	4
1966	181	4,173	4
1967	87	4,260	3
1968	[2]499	4,759	2

[1]First report to the Montana Oil and Gas Conservation Commission.
[2]Last injection in May 1968. Shut in through 1973.

The Northwest Cut Bank sand unit started water injection on January 30, 1962. The unit area was about 2,800 acres. Initial daily injection was 1,600 barrels of water at 1,850 psig. Humble (now Exxon) operated the unit through 1970. Phillips Petroleum Co. became operator in 1971. There were 13 producing and 7 input wells originally. The project was later expanded. In December 1973, the total daily injection averaged 1,738 barrels in 15 injection wells. Cumulative injection into the Cut Bank sand was 13,119,000 barrels through 1973.

Annual and cumulative water injection and number of injection wells in the Northwest Cut Bank sand unit are as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1962	584	584	7
1963	453	1,037	8
1964	527	1,564	8
1965	1,688	3,252	31
1966	2,409	5,661	32
1967	2,460	8,121	31
1968	1,645	9,766	23
1969	937	10,703	19
1970	855	11,558	19
1971	369	11,927	17
1972	473	12,400	15
1973	719	13,119	15

The Northwest Cut Bank sand unit (Exxon-Phillips) produced 4,889 barrels of oil and 4,066 barrels of water from 13 wells during December 1973. Cumulative oil production was 3,721,100 barrels.

The next project was Texaco's Southeast Cut Bank sand unit started in April 1962. The area in the unit was about 4,250 acres. Average daily injection during December 1973 was 9,717 barrels in 51 wells. Cumulative injection through 1973 was 42,985,000 barrels.

Annual and cumulative water injection and number of water injection wells for Texaco's Southeast Cut Bank unit are as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1962	840	840	15
1963	1,438	2,278	15
1964	1,649	3,927	29
1965	2,887	6,814	48
1966	3,771	10,585	47
1967	4,234	14,819	49
1968	5,047	19,866	51
1969	4,134	24,000	51
1970	4,394	28,394	52
1971	5,258	33,652	53
1972	4,882	38,534	51
1973	4,451	42,985	51

The Southeast Cut Bank sand unit reported 16,755 barrels of oil and 179,222 barrels of water from 55 wells in December 1973. Cumulative oil production was 11,531,000 barrels.

The fourth unit was the Southwest Cut Bank sand unit operated by Phillips Petroleum Co. The unit contained 10,681 acres, and water injection started in September 1962. After operating as a pilot test, the flood was expanded unitwide. Average daily injection in December 1973 was 20,787 barrels through 111 injection wells. Cumulative injection to 1974 was 55,798,000 barrels.

Annual and cumulative water injection and number of water injection wells for Phillips Southwest Cut Bank unit are as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1962	281	281	12
1963	879	1,160	11
1964	1,174	2,334	12
1965	914	3,248	11
1966	1,550	4,798	27
1967	2,755	7,553	55
1968	4,306	11,859	118
1969	9,041	20,900	140
1970	9,100	30,000	120
1971	9,083	39,083	112
1972	8,917	48,000	114
1973	7,798	55,798	111

The Southwest Cut Bank sand unit is the largest of the Cut Bank projects. Reported oil production for December 1973 was 78,817 barrels of oil and 420,200 barrels of water from 188 wells. Cumulative oil production was 27,231,000 barrels.

The Union Oil Co. of California operated the McGuiness-Moulton sand unit as a gas injection project from February 1946 until 1960. The gas injection increased oil recovery by an estimated 375,000 barrels. The McGuiness-Moulton waterflood unit was approved, and water injection commenced in December 1962. The unit is in the northwest part of T 35 N, R 5 W. Injection water is from the Madison. Water injection in December 1973 averaged 486 barrels daily into one injection well. Cumulative water injection was 2,960,000 barrels to January 1, 1974.

Annual and cumulative water injection and number of water injection wells for Union's McGuiness-Moulton unit are as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1962	1	1	1
1963	174	175	2
1964	248	423	2
1965	358	781	2
1966	371	1,152	2
1967	247	1,399	1
1968	226	1,625	1
1969	257	1,882	1
1970	242	2,124	1
1971	316	2,440	2
1972	206	2,646	1
1973	314	2,960	1

Oil production of the Union McGuiness-Moulton unit was 2,100 barrels from two wells in December 1973. Cumulative oil production was 1,393,100 barrels and 411,200 barrels since water injection began.

The sixth unit was Union Oil Co. of California's South Central Cut Bank sand unit containing 12,123 acres and 262 producing wells. The unit was approved and water injection started on May 21, 1963. Average daily injection in December 1973 by 48 wells was 7,800 barrels of water. Cumulative water injection through 1973 was 24,972,000 barrels.

Annual and cumulative water injection and number of water injection wells for Union Oil Co.'s South Central Cut Bank unit are as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1963	975	975	21
1964	3,016	3,991	26
1965	2,002	5,993	25
1966	1,577	7,570	27
1967	2,673	10,243	39
1968	2,765	13,008	36
1969	2,292	15,300	49
1970	2,436	17,736	49
1971	2,302	20,038	56
1972	2,220	22,258	55
1973	2,714	24,972	48

The South Central Cut Bank sand unit, second largest in the field, had 148 producing oil wells in December 1973 when monthly production was 19,581 barrels of oil and 33,800 barrels of water. Cumulative oil production was 27,204,100 barrels of oil.

The seventh project was Texaco's Northeast Cut Bank sand unit in Tps 34-36 N, R 6 W. The 7,243-acre unit was approved and flooding started in June 1963. Commission order No. 24-63 mentions "repressuring by waterflooding," implying more than simple water injection. The initial pilot area was an 80-acre, five-spot pattern containing seven injection wells. Injection rates were about 350 barrels daily per injection well, and water supply was from the Madison Formation.

Annual and cumulative water injection and number of water injection wells for Texaco's Northeast Cut Bank unit are as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1963	124	124	7
1964	647	771	21
1965	1,226	1,997	34
1966	2,702	4,699	39
1967	1,933	6,632	33
1968	1,185	7,817	31
1969	1,496	9,313	31
1970	719	10,032	15
1971	688	10,720	14
1972	721	11,441	14
1973	685	12,126	20

Production from the unit was 4,489 barrels of oil and 11,507 barrels of water in December 1973. Cumulative oil production was 12,709,600 barrels.

The unit area has two "highs," and the flood plan appears to be a five-spot pattern for 80 acres on each high, advancing as the area is flooded out. The average daily injection into 20 wells was 1,257 barrels in December 1973. Cumulative water injection to 1974 was 12,126,000 barrels.

Texaco's Lander sand unit in secs 20, 21, and 29, T 35 N, R 6 W, west of the Northwest Cut Bank sand unit, was approved November 14, 1963. Water injection began in July 1964. The unit contained 770 acres. An estimated recovery of 840,000 barrels of oil by the waterflood was given in commission order No. 40-63. Revised unit area of 640 acres is given in order No. 8-64, dated April 4, 1964. Eight water injection wells were used to start the flood, and seven were in use January 1, 1974. Cumulative injection then was 5,700,000 barrels. Water injection averaged 1,500 barrels daily during December 1973.

Annual and cumulative water injection and number of water injection wells for Texaco's Lander sand unit are as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1964	130	130	7
1965	374	504	7
1966	504	1,008	7
1967	632	1,640	6
1968	376	2,016	6
1969	927	2,943	6
1970	701	3,644	8
1971	769	4,413	8
1972	681	5,094	8
1973	606	5,700	7

The Texaco Lander sand unit had five producing oil wells in December 1973 and produced 3,097 barrels of oil and 45,200 barrels of water. Cumulative oil production through 1973 was 2,077,800 barrels.

Approval to waterflood the Lander sand under Humble Oil and Refining Co.'s (now Exxon's) H. C. Lander lease, secs 16 and 17, T 35 N, R 6 W, was granted July 9, 1964. The unit contained 280 acres and four producing wells.

Water injection into two wells started in April 1965. Humble stopped injection in January 1971 and sold the property to Croft Petroleum Co. Phillips Petroleum Co. took over the operation of the unit in July 1971. The name was changed to Lander unit "A", and the number of injection wells was reduced to one. Average daily injection in December 1973 was 144 barrels. Cumulative injection to 1974 was 1,129,000 barrels. Phillips Petroleum Co. is the operator of the much larger Northwest Cut Bank sand unit, east of the H. C. Lander lease.

Annual and cumulative water injection and number of injection wells for Exxon's H. C. Lander lease are as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1965	133	133	2
1966	170	303	2
1967	230	533	2
1968	229	762	2
1969	200	962	2
1970	128	1,090	2
1971	39	1,129	1
1972	71	1,200	1
1973	70	1,270	1

The Red Creek field was discovered by a well drilled north of the Canadian border and extended into the United States. In 1958, it was added to the Cut Bank field. In June 1963, Humble Oil and Refining Co. (now Exxon) received approval (order No. 22-63) to inject about 3,000 barrels of produced water daily into the Bow Island Formation. Water was disposed of through the McAlpine well No. 1, sec 12, T 37 N, R 5 W.

Annual and cumulative water injections into the Bow Island zone and then into unit 21 in the Madison Formation are as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels
1963	40	40
1964[1]	28	68
1965[2]	60	128
1966	428	556
1967	455	1,011
1968	333	1,344
1969	318	1,662
1970	335	1,997
1971	266	2,263
1972	237	2,500
1973	307	2,807

[1]Mar. 21, 1964, shut in.
[2]Resumed injection, Aug. 12, 1965, Red Creek unit No. 21.

In June 1965, the waterflood in the Cut Bank sand was started. Eight injection wells were used in the beginning. Cumulative injection in the Cut Bank sand was 7,671,000 barrels through 1973. Average daily injection was 3,014 barrels in six wells during December 1973.

Annual and cumulative water injection and number of injection wells for the Cut Bank sand in Exxon's Red Creek unit are as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1965	285	285	8
1966	735	1,020	9
1967	1,103	2,123	9
1968	1,252	3,375	9
1969	690	4,065	2
1970	570	4,625	7
1971	731	5,356	7
1972	1,144	6,500	7
1973	1,171	7,671	6

In December 1973, the seven producing oil wells in the Red Creek unit made 5,111 barrels, bringing the cumulative oil production to 4,432,700 barrels.

No projects were started in the Cut Bank field during 1966. The North Darling-State-Moulton sand unit and the South Darling-Swanson-Moulton sand unit were approved by commission orders No. 51-65 and 52-65, respectively, dated November 18, 1965. Buttes Resources Co. was approved as operator of both units.

Water injection started at the North Darling and South Darling-Swanson units in February 1967. The North Darling unit contains about 200 acres, and the South Darling unit, about 260 acres.

Annual and cumulative water injection and number of injection wells for the North Darling-State-Moulton sand unit are as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1967	172	172	1
1968	223	395	1
1969	321	716	1
1970	320	1,036	1
1971	272	1,308	1
1972	213	1,521	1
1973	338	1,859	1

The one well in the North Darling project reported 1,062 barrels of oil and 9,294 barrels of water during December 1973. Cumulative injection was 1,859,000 barrels. Oil production since water injection began was 486,300 barrels.

Annual and cumulative water injection and number of injection wells for the South Darling-Swanson-Moulton sand unit are as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1967	404	404	2
1968	762	1,166	5
1969	1,156	2,322	6
1970	1,171	3,493	6
1971	804	4,297	6
1972	923	5,220	5
1973	865	6,085	5

Oil production from the South Darling unit in December 1973 was 7,252 barrels of oil and 32,834 barrels of water from eight wells. The cumulative oil production was 3,672,400 barrels.

The Two Medicine Cut Bank sand unit of Miami Oil Producers Co. was approved August 17, 1967, and contains 11,340 acres. This waterflood should recover more than 14 million barrels of oil in 23 years. Water injection started in December 1967.

Annual and cumulative water injection and number of injection wells for the Two Medicine Cut Bank sand units are as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1967	18	18	15
1968	3,219	3,237	63
1969	4,598	7,835	84
1970	5,598	13,433	93
1971	6,081	19,514	97
1972	6,499	26,013	99
1973	5,489	31,502	99

The Two Medicine Cut Bank sand unit had 87 producing wells in December 1973 and produced 47,616 barrels of oil. Cumulative oil production was 7,624,600 barrels.

The Northeast Darling unit of the Moulton sand reservoir of the Cut Bank field was approved October 12, 1967. The unit is small, containing only 534 acres and 10 wells. Ralph E. Fair is the operator. Recovery by waterflooding should be about 700,000 barrels of oil in 6 years.

Annual and cumulative water injection and number of injection wells for the Northeast Darling Moulton sand unit are as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1968	436	436	3
1969	436	872	3
1970	614	1,486	3
1971	694	2,180	4
1972	620	2,800	4
1973	635	3,435	4

The Northeast Darling Moulton sand unit had seven producing wells in December 1973 and produced 5,681 barrels of oil and 21,058 barrels of water. Cumulative oil production was 1,208,900 barrels.

The West Wilcox Moulton unit, operated by Decalta Oil Enterprises, Inc., commenced operation in February 1971. Annual and cumulative water injection and number of injection wells for West Wilcox Moulton unit follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1971	101	101	2
1972	246	347	1
1973	251	598	1

The five wells in the unit produced 593 barrels of oil and 6,637 barrels of water in December 1973.

The area operated by the Union Oil Co. of California in secs 2-4, T 37 N, R 4 W, known as the Moulton unit, was approved on March 14, 1968. Commission order No. 9-68 reads, in part, "A waterflood pressure maintenance program for secondary recovery of oil." This could mean large enough volumes of water will be injected to actually increase the reservoir pressure. Water injection started in August 1968.

Commission order No. 2-71, dated January 14, 1971, approved the injection of produced gas into the Moulton sand by Union Oil Co. of California. The rate was to be about 800,000 to 1,000,000 cubic feet daily. The purpose was to supplement the water injection. During December 1971, the average daily injection was 1,160,000 cubic feet. Cumulative gas injection through 1972 was 477 million cubic feet. There was no gas injection in 1973.

Annual and cumulative water injection and number of injection wells for the Moulton sand unit are as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1968	516	516	6
1969	1,607	2,123	6
1970	1,626	3,749	6
1971	2,151	5,900	7
1972	2,560	8,460	9
1973	2,704	11,164	11

The Union Oil Co.-Moulton unit had 11 oil wells and produced 79,842 barrels of oil in December 1973. Cumulative oil production was 4,261,200 barrels.

Continental Oil Co.'s Tribal F-1 lease was set up as an injection project but was taken into the Two Medicine unit on August 1, 1967.

The Texaco L. E. Tweedy lease was used for a Lander sand gas injection test. Gas injection stopped April 4, 1963, after 533 million cubic feet had been injected.

The Tesoro Petroleum Corp.'s Tesoro Cut Bank sand unit was approved by commission order No. 23-71, July 15, 1971. This unit is west of Texaco's Southeast Cut Bank unit and north of Miami Oil Producer's Two Medicine unit. Water injection in six wells commenced September 1, 1971. Annual and cumulative water injection and number of injection wells for the Tesoro Cut Bank sand unit are as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1971	21	21	6
1972	85	106	17
1973	871	977	18

The 21 wells in the Tesoro unit produced 13,248 barrels of oil and 1,816 barrels of water in November 1973. The daily injection rate was 2,569 barrels through 18 injection wells.

Buttes Resources Co.'s Tweedy South Cut Bank sand unit was approved by commission order No. 33-71, December 16, 1971. The unit contains 285 acres and is about 2 miles northwest of Texaco's Southeast Cut Bank unit. Water injection started in June 1972 using four injection wells. Water injected in 1972 was 151,000 barrels and in 1973 was 246,000 barrels. The 10 wells in the unit produced 6,395 barrels of oil and no water in December 1973. Cumulative production from the unit was 729,100 barrels to January 1, 1974.

The Marena West Cut Bank sand unit of Buttes Resources Co. was approved by commission order No. 30-72, September 14, 1972. The Marena unit, in secs 27, 33, and 34, T 34 N, R 6 W, and secs 2, 3, and 4, T 33 N, R 6 W, is west of the north end of the South Central Cut Bank unit of Union Oil Co. of California. Injection water is obtained from the Madison Formation. Water injection started in June 1972. Injection in 1972 totaled 10,000 barrels and 483,000 barrels in 1973. Daily oil production in December 1973 was 39 barrels from eight wells. Daily water injection was 1,059 barrels in nine wells. Cumulative oil production since water injection started to January 1, 1974, was 16,800 barrels.

Buttes Resources Co.'s New Border Cut Bank sand unit was established by commission order No. 22-73, July 18, 1973. It is in secs 2, 10, and 11, T 37 N, R 4 W, and is southeast of the Union Oil Co.'s Moulton-Moulton sand unit. Through 1972 this project was carried in State reports as Moulton, Moulton. In 1973 it is properly carried as Cut Bank field, Moulton lease, Moulton sand. This is not McGuiness-Moulton.

The Old Border Cut Bank sand unit of Buttes Resources Co. is in secs 1, 2, and 12, T 37 N, R 4 W, and is the rest of the Border field. The unit was established by commission order No. 38-73, October 11, 1973. Different land ownership in the field made the "Old" and "New" units necessary. The Old Border unit adjoins the New Border unit on the northeast and adjoins the United States-Canadian border on the north.

Water injection started June 1, 1973, using four injection wells and water from the Sunburst sand. Injection during 1973 was 76,000 barrels. Daily oil production from five wells in December 1973 was 16 barrels. Cumulative oil production to January 1, 1974, was estimated to be 870,000 barrels.

The Cut Bank field is the largest of all Montana fields. In December 1973, it had almost 1,200 active wells and produced 335,000 barrels of oil and 313 million cubic feet of gas. Commission records show cumulative oil production of 133,888,000 barrels and gas production of 232.7 billion cubic feet. Annual oil production for the past 5 years shows the Cut Bank waterfloods, as a group, are recovering additional oil.

DWYER

The Dwyer field is just west of the Montana-North Dakota border in T 32 N, Rs 58 and 59 E, Sheridan County. Grenora, the nearest field, is about 5 miles northeast of Dwyer and in North Dakota.

The Fort Union Formation is exposed on the surface at an elevation of about 2,077 feet. The structure was located by seismic methods. Although the structure appears to be a southeast plunging nose, permeability development in the pay zone is crucial in obtaining oil production.

Mobil Oil Co.'s Muller No. F-44-20-P, SE¼ sec 20, T 32 N, R 59 E, the discovery well, was completed January 8, 1960. Initial daily pumping production was 51 barrels of oil and 49 barrels of water from the Ratcliffe zone of Mississippian age. Depth to top of the pay zone ranges from 7,700 to 7,900 feet. Average net pay thickness is 30 feet. Porosity averages 12 percent, and permeability averages 5 millidarcys.

The log of the discovery well, in the C SE¼SE¼ sec 20, T 32 N, R 59 E, shows the depth, in feet, to formation tops, as follows: Greenhorn, 3,990; Newcastle, 4,452; Dakota, 4,703; Morrison, 4,872; Piper Limestone, 5,932; Spearfish, 6,262; Amsden, 6,463; Kibbey sand,

6,977; Charles, 7,246; Charles salt, 7,272; Mission Canyon, 8,010; Bakken, 9,304; Three Forks, 9,367; Nisku, 9,536; Duperow, 9,630; Souris River, 10,111; Dawson Bay, 10,390; Prairie evaporite, 10,492; Winnipegosis, 10,763; Ashern, 10,907; Interlake, 10,983; upper Stony Mountain, 11,630; lower Stony Mountain, 11,755; Red River, 11,787; and total depth, 12,033. Twenty-three wells were completed in the field. By the end of 1971, 14 active and 4 shut-in oil wells remained in the field; the field was developed using 80-acre spacing.

By order No. 26-63, the commission approved the disposal of produced water by injection in the Lakota, Dakota, Muddy, or Kibbey zones under the field. James A. Lewis Engineering, Inc., was approved as operator of the water disposal system. The Willumsen No. 1 well in the NE¼ sec 26, T 32 N, R 58 E, was the injection well. The Dakota zone was used to dispose of the water. Injection started in October 1963. Salt water injected in the Dakota annually and cumulative injection were as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels
1963 (Dec.)	32	32
1964	334	366
1965	133	499
1966	130	629
1967	169	798
1968	120	918

Phillips Petroleum Co.'s unit for waterflooding the Dwyer field was approved by the commission on July 11, 1968, by order No. 2-68. Water injection in the Ratcliffe zone began in October 1968.

Annual and cumulative water injection and number of injection wells in the Ratcliffe zone are as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1968	24	24	1
1969	121	145	2
1970	140	285	2
1971	176	461	2
1972	139	600	1
1973	396	996	4

Oil production almost leveled off in 1969, increased some in 1970-71, but really declined in 1972-73. Unless more water is injected, it is doubtful that the estimated 2,400,000 barrels of secondary oil will be recovered.

Oil produced at Dwyer field in December 1973 was 9,084 barrels, and cumulative oil production was 5,061,400 barrels.

ELK BASIN

The Elk Basin oil and gas field is in the northeastern part of the Big Horn Basin. Although most of the field is in Wyoming, the Montana portion contains about 22 percent of the Tensleep productive area. The surface formation in the structurally highest part of the field is the Cody Shale (Cretaceous), and the Eagle and Mesaverde Sandstones form a rimrock 400 to 500 feet high around the basin.

The initial discovery in 1915 was an oil well, Hurst No. 1, in the NW¼NW¼ sec 30, T 58 N, R 99 W, Park County. Wyo., completed in the First Wall Creek (Torchlight) sand of the Frontier Formation. Initial daily oil production was 50 barrels. Subsequent development drilling found oil in the Second Wall Creek sand. Average initial daily production from wells in this sand was 175 barrels of 43° API gravity oil.

Gas was discovered in the Cloverly Formation (Lower Cretaceous) by a well drilled in the NE¼SE¼ sec 24, T 58 N, R 100 W, in 1922. One of the early gas wells had an estimated daily open flow of 90 million cubic feet of gas. By 1949, the gas reservoir was virtually depleted and was sold (or leased) to a utility company for gas storage. Total gas production from the Cloverly Formation before abandonment was approximately 39 billion cubic feet.

The discovery well in the Tensleep (Pennsylvanian) sand in NE¼NE¼ sec 31, T 58 N, R 99 W, was completed for an initial daily production of 2,500 barrels of 30.2° API gravity black oil in 1942. It proved to be the largest single reserve of new oil found in the United States in 1942.

In 1946, a well in the NE¼SE¼NE¼ sec 24, T 58 N, R 100 W, was deepened to the Madison Limestone and completed for a daily production of 240 barrels of 27.3° API gravity oil.

The Montana portions of the field are extensions of the productive horizons found in the Wyoming portion.

The Frontier sand productive area in Montana totals about 120 acres, with 11 producing wells and 10 shut-in wells in December 1973. The Tensleep producing area totaled 1,376 acres with 18 producing and 13 shut-in wells. The Madison producing area totaled 920 acres with 20 producing wells and 8 water injection wells.

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 small.

Depths, in feet, to formation tops in a deep test in lot 5, sec 19, T 58 N, R 99 W, are as follows (tops above the Dinwoody are extrapolated from the Madison discovery well): First Wall Creek, 1,048; Second Wall Creek, 1,308; Muddy, 2,063; Cloverly, 2,358; Morrison, 2,513; Sundance, 2,778; Chugwater, 3,308; Dinwoody, 3,868; Embar, 3,886; Tensleep, 3,923; Madison, 4,308; Three Forks, 5,246; Big Horn, 5,529; Flathead, 7,133; and granite, 7,230.

In 1973, total production for the Montana portion of all formations was 1,386,500 barrels, and the cumulative production to the end of 1973 was 92,197,500 barrels. Estimated primary reserves of the Montana area were 16,830,000 barrels on January 1, 1974.

In 1946, all productive horizons below the top of the Sundance Formation (Jurassic) were unitized, and operations were placed under the direction of one operator. The largest horizon, although named "Embar-Tensleep," is mostly Tensleep. Unitization made possible comprehensive pressure maintenance and secondary recovery procedures, permitting more economical operation of the field.

There was too little gas and no economical source toutside the field for gas or water to repressure or waterflood the Tensleep zone. An extraction plant was built to remove the propane, butane, natural gasoline, and sulfur from the produced gas. The processed gas was then burned, and the "flue" gas was compressed and injected in the Tensleep reservoir. Inert gas injection began September 27, 1949, and continued until April 24, 1972. Cumulative inert gas injection amounted to 23.3 billion cubic feet. Sulfur recovered in 1971 was 12,700 long tons.

All of the gas and water injection projects in the Montana portions of the Elk Basin field are parts of the whole field operations.

A pipeline was built from the field to the Clarks Fork River in 1961, and water injection was started in the Madison Formation. Produced water is also used for injection. Water injection in the (Montana) Madison zone has been as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1962	2,243	2,243	3
1963	1,819	4,062	3
1964	3,843	7,905	4
1965	3,968	11,873	4
1966	2,517	14,390	4
1967	3,323	17,713	5
1968	3,626	21,339	5
1969	4,424	25,763	6
1970	4,392	30,155	7
1971	3,960	34,115	8
1972	3,768	37,883	8
1973	5,491	43,374	8

The inert gas injection in the Tensleep zone was on the crest of the structure. Starting in 1968, inert gas injection was tried in the Montana part of the field. The gas injection was as follows:

Year	Annual, thousand cubic feet	Cumulative, thousand cubic feet
1968	1,388,189	1,388,189
1969	125,892	1,514,081
1970	(shut-down)	1,514,081
1971	59,687	1,573,768
1972	223,232	1,797,000
1973	223,000	2,020,000

Starting in April 1969, produced water was injected in the Montana part of the Tensleep zone as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels
1969	194	194
1970	599	793
1971	338	1,131
1972	227	1,358
1973	288	1,646

A Frontier Formation water injection project was started about mid-1972 using water produced from the Madison. With no information on a much earlier Frontier waterflood, this is considered a new project.

Water injected was 696,000 barrels in 1972 and 632,000 barrels in 1973, using two injection wells. Daily production for December 1973 from 11 wells was 84 barrels of oil and 560 barrels of water. Cumulative oil production from the Montana Frontier zone to January 1, 1974, was 1,445,800 barrels.

Sale of the produced Tensleep gas to Colorado Interstate Gas Co. started in 1972. The water injection system has been enlarged. Planned water injection will be 60,000 barrels of freshwater from the Clarks Fork River and 40,000 barrels of produced water into the Madison zone; 10,000 barrels of produced water into the Embar-Tensleep zone; and 13,000 barrels of produced water into the Frontier zone.

ELK BASIN, NORTHWEST

Northwest Elk Basin is a separate producing area along the same line of folding and immediately northwest of the Elk Basin structure. The trap is structural and is believed to be a combination of faulting and folding. Surface formations are the Lance and Bearpaw Shales.

The field was discovered in 1947 when the No. 1 Unit well, SW¼NW¼ sec 28, T 9 S, R 23 E, was completed. Initial daily production was 4,942 barrels of 32° API gravity oil from the Madison Formation from 6,340 to 6,795 feet. Oil in the Second Frontier sand was confirmed by the completion of the No. 1 Helen Wilkins well in the SE¼NE¼NE¼ sec 29, on December 4, 1947, with initial daily production of 66 barrels of 45.2° API gravity oil from the interval 3,376 to 3,437 feet. The discovery well in the Lakota Formation was No. 2 H. G. Wilkins, SW¼NW¼NW¼ sec 28. Initial daily oil production was 1,584 barrels from 4,598 to 4,622 feet. The oil gravity was 49.5° API. The Lakota zone was produced only a short time. The fourth productive zone was the Tensleep Formation. The discovery well, No. 1 Government, in the NE¼NW¼ sec 29, was completed April 1, 1964. Initial daily oil production was 120 barrels from a "notch" at 6,136 feet. Peak producing area, in acres, by formations, was as follows: 120, Second Frontier; 60, Lakota; 580, Tensleep; and 390, Madison.

The log of the Madison discovery well shows the following depths, in feet, to the tops of formations: Second Frontier, 3,420; Cloverly, 4,282; Dakota, 4,385; Lakota, 4,635; Sundance, 4,817; Chugwater, 5,270; Dinwoody, 5,843; Embar, 5,885; Tensleep, 5,910; Amsden, 6,046; and Madison, 6,225.

Water injection in the Second Frontier zone started October 17, 1957, using one injection well. Peak oil production after injection

started was 46,347 barrels in 1963. Oil production declined after 1963, and the project was shut in June 8, 1971. The project lasted nearly 14 years, and almost 5 million barrels of water was injected into the Frontier zone.

Annual and cumulative water injection and number of injection wells in the Second Frontier zone are as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1957[1]	7	7	1
1958	49	56	1
1959	72	128	1
1960	330	458	1
1961	403	861	1
1962	150	1,011	1
1963	587	1,598	3
1964	682	2,280	3
1965	633	2,913	4
1966	527	3,440	4
1967	499	3,939	4
1968	435	4,374	5
1969	300	4,674	3
1970	197	4,871	2
1971[2]	97	4,968	2

[1]Started Oct. 17, 1957.
[2]Shut in June 8, 1971.

The two Frontier oil wells made 432 barrels of oil and 2,881 barrels of water in December 1973. Cumulative oil production to January 1, 1974, was 1,110,700 barrels.

The Tensleep zone waterflood started in May 1963 after the zone had been produced for 3 years. Only one injection well has been used. Through 1973, water injection amounted to 2,294,000 barrels for the Tensleep zone.

Annual and cumulative water injection and number of injection wells in the Tensleep zone are as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1967[1]	128	128	1
1968	221	349	1
1969	208	557	1
1970	353	910	1
1971	523	1,433	1
1972	530	1,963	1
1973	331	2,294	1

[1]Started in May 1967.

Water produced with the oil, mostly from the Madison zone, has been the source of injection water for both projects.

Approximate cumulative oil production by zone through 1973 was as follows: Second Frontier, 1,110,700 barrels; Lakota, 58,000 barrels; Tensleep, 1,114,000 barrels; and Madison, 918,400 barrels, for a field total of 3,201,100 barrels.

FLAT COULEE

The Flat Coulee oil and gas field is one of several fields in an area called the Sweetgrass Hills of Northern Liberty County. Eugene S. Perry in his "Oil and Gas in Montana"[6] says, "The Flat Coulee dome about 6 miles north of East Butte, is laccolithic in character . . . . A large igneous dike (minette) beginning well up on the dome extends southwestward toward the Mt. Lilly lacolith, which is about 2 miles distant."

The oil discovery well, Northern Petroleum No. 2 Northern Farms, E½NE¼NW¼ sec 10, T 37 N, R 5 E, was drilled in 1933. Initial daily oil production from the Swift Formation (Upper Jurassic) was 30 barrels of 36° API gravity.

Natural gas was found in the Bow Island zone of the Colorado Shale Group, the Dakota Formation, the Swift Sandstone, Sunburst sand, and the Sawtooth Limestone. The field was not connected to a gas pipeline until 1956.

Yearly oil production from Flat Coulee field was small until 1962. Peak oil production was 444,000 barrels in 1964.

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[6]Perry, E. S. Oil and Gas in Montana. Mont. Bur. of Mines and Geol., Memoir No. 35, 1953, p. 34.

The Flat Coulee Swift sand unit of Cardinal Petroleum Co. was approved by commission order No. 25-70, September 18, 1970. Rehearings were held and the size of the unit was altered. Insufficient water for injection was found in the Madison Formation. Special hearings were held, and order No. 22-71, July 15, 1971, approved the use of water from the Eagle sand for injection.

Injection in 15 wells started February 1, 1972; yearly injection is as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1972	556	556	15
1973	833	1,389	15

The 16 oil wells in the unit produced 9,097 barrels during December 1973.

FLAT LAKE

The Flat Lake field is in the northeast corner of Montana, northwest corner of North Dakota, and extends across the border into Saskatchewan, Canada. Contours using the top of the Ratcliffe Formation show a nonsymmetrical structure elongated in a northeast-southwest direction. Oil accumulation is dependent more on permeability development than structural position. Surface elevations in the field range from 2,152 to 2,314 feet. Only the U.S. portion of the field is reported here.

The Flat Lake discovery well, No. 1 Cal Oil-Arne Haugan, et al., in the SW¼NE¼ sec 18, T 37 N, R 58 E, Sheridan County, was completed June 15, 1964. Initial daily pumping production was 210 barrels of oil and 90 barrels of water from the Ratcliffe (Mississippian age), 6,534 to 6,537 feet. Continued drilling resulted in 56 oil wells in Montana, 1 oil well in North Dakota, and 35 oil wells in the Canadian portion of the field. Sun Oil Co.'s No. 1 Hellegaard, SE¼NE¼ sec 8, T 37 N, R 57 E, was completed December 31, 1962, as the discovery well for the Lone Tree field. The commission by order No. 33-66, October 13, 1966, made the Lone Tree field a part of the Flat Lake field. A few wells had been completed in the Nisku (Devonian) about 1,500 feet below the Ratcliffe zone.

One well, in the NE¼NW¼ sec 16, T 37 N, R 57 E, was completed in the Nesson (Mississippian) about 200 feet below the Ratcliffe zone, for an initial daily pumping production of 48 barrels of oil and 238 barrels of water.

The log of the No. 1 Hellegaard well shows the following depths, in feet, to tops of formations: Fort Union, (surface); Greenhorn, 1,200; Muddy, 3,860; Dakota sand, 4,188; Piper Limestone, 5,173; Spearfish, 5,565; Kibbey, 5,905; Ratcliffe, 6,519; Nesson, 6,740; Mission Canyon, 6,793; Lodgepole, 7,440; Bakken, 7,752; Three Forks, 7,846; Nisku, 7,990; Duperow, 8,112; Dawson Bay, 8,939; Prairie evaporite, 9,030; Interlake, 9,480; and Red River, 10,186.

Water produced with the oil from the Ratcliffe is saturated with sodium chloride so underground disposal is mandatory. Water disposal in the Dakota zone was approved November 12, 1964.

There were two projects, Chevron Oil Co. (formerly California Oil Co.) and Sun Oil Co., for saltwater (produced water) disposal in Flat Lake field.

Saltwater disposal into the Dakota zone by Chevron Oil Co. was as follows:

Year	Annual, thousand barrels	Cumulative, thousand barrels
1965[1]	129	129
1966	445	574
1967	502	1,076
1968	530	1,606
1969	568	2,174
1970	561	2,735
1971[2]	210	2,945

[1]Started in September 1965. Commission order No. 49-64, Nov. 12, 1964.
[2]Shut down July 1, 1971, water needed for waterflood project.

Commission order No. 19-67, dated April 25, 1967, approved using a well in "South" Flat Lake field for saltwater disposal. Sun Oil Co.'s well No. 3 Hellegaard, sec 5, T 37 N, R 57 E, was used as an injection well. Produced water injection in this well was as follows:

Year	Annual, thousand barrels	Cumulative, thousand barrels
1967	923	923
1968	489	1,412
1969	406	1,818
1970	416	2,234
1971[1]	209	2,443

[1]Shut down July 1, 1971, water needed for waterflood project.

Total water pumped into the Dakota (both wells) was 5,388,000 barrels.

The Ratcliffe productive zone at Flat Lake field is a carbonate rock. Cores from the zone all had some fractures. The Federal Bureau of Mines made a study of the fractures in the reservoir rock. Porosity was found to be about 13 percent, and original water saturation was 43 percent. The fractures did not show enough permeability to interfere with waterflooding.

The eastern two-thirds of the Montana portion of the field was tentatively unitized by commission order No. 24-70, dated September 18, 1970. Some compulsory action was necessary so the unit was effective March 1, 1971, with Chevron Oil Co. as operator.

Water injection started June 1, 1971, through 11 wells. Injection for the rest of 1971 was 914,000 barrels. Water injection in the Ratcliffe zone has been as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1971	914	914	11
1972	2,642	3,556	11
1973	2,331	5,887	11

Waterflooding of the Canadian part of the field is in progress. Water injection wells on both sides of the Canadian border are used to prevent oil migration across the border.

In December 1973, the Flat Lake field had 33 wells and produced 42,600 barrels of oil. Cumulative oil production was 6,817,700 barrels.

The one well in North Dakota produced 2,623 barrels of oil and 816 barrels of water in 1973. Cumulative production was 34,787 barrels of oil and 14,260 barrels of water. The percent of water in the produced fluid was 29 percent the first half of 1973 and 32 percent the last half of 1973.

FRANNIE

The Frannie oilfield is in secs 23-26, T 58 N, R 98 W, Park County, Wyo., and secs 33 and 34, T 9 S, R 25 E, Carbon County, Mont. The structure is an asymmetrical, elongated dome cut transversely on the surface by two normal faults. The axis of the structure trends northwest-southeast, with surface dips on the northeast ranging up to 45° and on the southwest flank averaging 13°. The surface formations are

the Frontier and the Cody at elevations ranging from 4,300 to 4,670 feet. The dome has at least 1,000 feet of closure, and surface evidence indicates possibly more.

The field was discovered in August 1928 when a well in the NW¼NE¼NW¼ sec 25 (Wyoming part) flowed 125 barrels of oil per day from the Tensleep Sandstone at 2,585 feet. The well was deepened to 2,612 feet, and daily production increased to 260 barrels of 27.7° API gravity oil. In September 1929, an initial daily production of 2,423 barrels of 17.6° API gravity oil was obtained from a well drilled into the Madison Limestone at 2,925 to 3,013 feet. The second was about 2,200 feet southeast of the original discovery well. The Embar (probably Phosphoria) zone was saturated in some wells. Both of these crude oils were typical "black oils" for which there was little or no market. Development of the field lagged until World War II.

Late in 1970, there were 96 active Tensleep wells and 4 Madison wells in the Wyoming portion of the field and 2 Tensleep wells in the Montana part of the field. Subsequently, both Montana wells are to be used as injection wells. The waterflood should recover about 20 million barrels of additional oil.

Only two oil wells were completed in the Montana portion of the field. Hearings were held by the Montana and Wyoming oil and gas commissions in the fall of 1970 to consider unitization and waterflooding of the Phosphoria-Tensleep zone at Frannie field. Both State commissions approved the project. Water produced with the oil and from a Madison well is used for injection. Injection in one well in Montana started November 20, 1970.

Injections in the Frannie field in Montana have been as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1970	68	68	1
1971	342	410	1
1972	741	1,151	1
1973	641	1,792	1

Total field injections were as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1970	384	384	16
1971	3,509	3,893	16
1972	10,593	14,486	18
1973	11,469	25,955	18

There was 1 Montana injection well and 18 in the Wyoming part of the field in December 1973. Oil production from the remaining well in Montana was 744 barrels for December 1973, bringing the cumulative for the Montana portion of the field to 670,400 barrels.

FRED AND GEORGE CREEK

Fred and George Creek oilfield in T 37 N, R 2 E, northeastern Toole County, is a stratigraphic trap between West and Middle Buttes of the Sweetgrass Hills. Boundaries of the Arch Apex gasfield and the Fred and George Creek oilfield overlap.

The Grannel-Sands Oil Co.'s No. 1 Fey, SW¼NW¼NE¼ sec 23, T 37 N, R 2 E, was completed August 31, 1963. Initial daily flowing production was 500 barrels of 39° API gravity oil from the Sunburst sand (Lower Cretaceous) from 2,624 to 2,654 feet. The No. 1 A.A. Oil-Joe Fey well in the NE¼SE¼ sec 34 found oil in the Swift Formation of Jurassic age in December 1963. Initial pumping oil production was 64 barrels from 2,563 to 2,570 feet. The Arch Apex gasfield produces from the Bow Island Formation (probably equivalent of the Muddy sand of Wyoming and southeastern Montana).

The log of a well in the SE¼SW¼ sec 23, showed the depths, in feet, to the tops of formations as follows: Telegraph Creek, 390; Colorado (shale), 542; Greenhorn, 1,338; Thermopolis, 1,578; Bow Island, 1,690; Dakota, 2,225; Kootenai, 2,240; Sunburst, 2,672; Swift, 2,703; Rierdon, 2,716; Sawtooth (estimated), 2,860; and Madison (estimated), 2,930.

The commission approved the unitization of the Sunburst zone in the Fred and George Creek field for waterflooding on May 14, 1970. The unit area contained 1,040 acres. William M. Fulton was the operator.

Water injection started in July 1970 using water from the Madison Formation. The Madison water well would not produce enough water for the project. On September 16, 1971, the Montana Resource Board and the Oil and Gas Conservation Commission approved the use of freshwater from the Eagle Sandstone to supplement the water from the Madison.

Water injection at Fred and George has been as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1970	422	422	1
1971	1,444	1,866	1
1972	2,089	3,955	1
1973	2,796	6,751	3

There were 29 Sunburst sand and 23 Swift Formation oil wells in the Fred and George Creek field in 1969. At the end of 1973, there were 13 Sunburst and 13 Swift wells. The field was 10th in oil production in Montana during 1973. Oil production from the Sunburst zone was 369,500 barrels, and cumulative production was 7,547,400 barrels. Oil production was 25,580 barrels from the Swift zone, and cumulative production was 973,900 barrels.

GAS CITY

The Gas City field in T 14 N, R 55 E, Dawson County, is a domal structure having gently dipping east and south flanks and a flattened surface on the north. It is situated near the north end of the northwest-southeast trending major structure known as the Cedar Creek anticline. Average elevation of the field is 2,478 feet, and Pierre Shale crops out on the surface.

Drilling has taken place in this area since 1913 when gas was discovered. The well in the NE¼ sec 20, T 14 N, R 55 E, reported gas in the Judith River Formation at 745 feet and in the Eagle sand at 906 feet. In 1915, a pipeline was laid to Glendive, and gas was sold for the first time in Montana. In 1926, the gas wells started yielding saltwater and were abandoned. Montana-Dakota Utilities Co. operated the gas unit.

In 1955, well No. 33X-21 was drilled in the NE¼NW¼SE¼ sec 21, T 14 N, R 55 E, after the area was seismographed. The well was drilled to a depth of 9,596 feet, plugged back to 9,186 feet in the Red River Formation (Ordovician), acidized, and flowed initially 202 barrels of oil per day. Later, oil was found in the Madison Formation, but the wells were not commercial.

The log of the discovery well shows the following depths, in feet, to the formation tops: Greenhorn, 3,110; Newcastle, 3,830; Dakota, 4,028; Piper lime, 5,400; Spearfish, 5,535; Minnekahta, 5,890; Amsden, 6,229; Heath, 6,410; Charles "A," 7,000; Mission Canyon, 7,487; Lodgepole,

8,020; Silurian, 8,620; Stony Mountain, 8,942; Red River, 9,088; and Winnipeg, 9,558.

The oil-producing horizon has a thickness of about 31 feet throughout the field and has approximately 11 percent porosity. The west side of the field is marked by two faults that limit the oil accumulation on this side, as proven by a dry hole drilled west of the faults. Eight wells were lost by collapsed casing in the salt section.

The field produced 38.2° API gravity oil and had a gas-oil ratio of 412 to 1. Sulfur water was produced with the oil. A gas depletion and partial water drive was thought to be the drive mechanism behind the oil.

Commission orders Nos. 32-61 and 20-64 approved the disposal of produced saltwater by injection into the Judith River Formation and the Red River Formation (below the oil-water contact in the Red River zone). The Judith River Sandstone proved to be too tight to take the saltwater at low injection pressure.

Saltwater disposal, by injection, into the Judith River Formation through unit well No. 11-28 in sec 28, T 14 N, R 55 E, has been as follows:

Year	Annual, thousand barrels	Cumulative, thousand barrels
1962	143	143
1963	269	412
1964	289	701
1965	356	1,057
1966	360	1,417
1967	469	1,886
1968	72	1,958
1969	377	2,335
1970	[1]25	2,360
1971	35	2,395
1972	0	2,395
1973	0	2,395

[1]Injection was suspended most of 1970 and 1971.

Saltwater disposal in the Red River Formation started in October 1964 with unit well No. 43-28. Water injection in this well has been as follows:

Year	Annual, thousand barrels	Cumulative, thousand barrels
1964	16	16
1965	143	159
1966	329	488
1967	418	906
1968	464	1,370
1969	388	1,758
1970	167	1,925
1971	285	2,210
1972	349	2,559
1973	434	2,993

The two saltwater disposal wells have received a total of 5,388,000 barrels.

Unitization of the field for waterflooding, with Shell Oil Co. as operator, was approved by commission order No. 16-69, dated July 17, 1969. Water injection started October 31, 1969, through five injection wells. Some water from the Mission Canyon zone is used.

Annual and cumulative water injection and number of injection wells for Gas City are as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1969	161	161	5
1970	979	1,140	7
1971	1,190	2,330	7
1972	1,218	3,548	7
1973	1,287	4,835	7

The water disposal in the Red River zone could be considered as aiding the reservoir pressure. Oil production was 266,217 barrels in 1973 to bring the cumulative production to 7,966,000 barrels. There were 17 active oil wells in 1973.

GOOSE LAKE

The Goose Lake field is in S½, T 36 N, R 58 E, and the N½, T 35 N, R 58 E, Sheridan County. The discovery well, Signal Drilling & Exploration Co.'s No. 1 Carl Peterson, sec 19, was completed on June 11, 1962. Initial daily production was 65 barrels of oil and 220 barrels of water from Ratcliffe perforations at 7,105 and 7,084 to 7,086 feet. The Ratcliffe is Mississippian in age and first was found productive in the Ratcliffe field in Saskatchewan. The zone is about 80 feet thick at Goose Lake.

Twenty-nine wells were completed in the Goose Lake field. Average initial daily production for the 29 wells was 140 barrels of oil and 277 barrels of water. Produced water was a problem, and a saltwater disposal project was approved by order No. 12-64, April 9, 1964. Signal Drilling & Exploration Co. was the operator. Two disposal wells were approved. Disposal zones were listed as Muddy, Dakota, Lakota, or Ratcliffe. Saltwater disposal by Sun Oil Co. in one well was approved on March 31, 1966 (order No. 14-66). Saltwater disposal by Saratoga Production Co. in one well was approved March 19, 1968 (order No. 12-68). The North Goose Lake unit of Cotton Petroleum Co., et al, was approved by order No. 17-72, June 8, 1972.

Produced water was to be injected in four wells. Injection started in January 1973 and totaled 330,000 barrels for the year. Oil production for 1973 was 166,000 barrels. Eighteen wells produced 12,600 barrels of oil and 96,900 barrels of water during December 1973.

JIM COULEE

The Jim Coulee field is in secs 28, 29, 30, 32, and 33, T 11 N, R 27 E, Musselshell County. The structure is described as "river channel fill" in the Tyler "B" or Stensvad zone of Lower Pennsylvanian. The first oil was produced by McAlester Fuel Co.'s well No. 33-3 Burlington Northern in sec 33. The well was drilled in 1968 and reworked, tested, and abandoned late in 1968. The first successful oil well was McAlester's well No. 29-11 Burlington Northern, NE¼SW¼ sec 29, completed January 1, 1971, for an initial daily production of 112 barrels of 31.6° API gravity oil.

Nineteen oil wells and nine dry holes have been drilled in the unit area approved by order No. 18-72, June 8, 1972. The hearing file shows 1,093 productive acres in the unit. The lower Tyler sand averages 17.5 feet in thickness and has a porosity of 14.9 percent and permeability of 177 millidarcys. Original stock tank oil in place was estimated to be 14.5 million barrels; primary recovery was estimated to be 16 percent, and secondary recovery, to be 8 percent. Injection water is from the Third Cat Creek sand. Two of the four injection wells are dually completed in the Third Cat Creek zone for water supply use. Injection started June 1, 1972.

Water injection at Jim Coulee has been as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1972	291	291	4
1973	996	1,287	5

Cumulative oil production to January 1, 1974, was 1,065,800 barrels. Production to start of injection was 389,700 barrels. Daily production from 18 wells in December 1973 was 1,190 barrels of oil and 783 barrels of water.

KEG COULEE

The Keg Coulee field is in Tps 10 and 11 N, Rs 30 and 31 E, Musselshell County, 5 miles north of the town of Melstone. The reservoir rock, the Tyler Formation, is thought to be narrow winding channel deposits. Oil accumulation is controlled by porosity development in the reservoir rock. For this report the two wells often called North Keg Coulee field are included in Keg Coulee field.

American Climax et al.'s No. 1 De Jaegher in the SE¼NE¼ sec 31, T 11 N, R 31 E, was completed in April 1960. Initial daily pumping production was 177 barrels of oil from 4,300 to 4,314 feet in the Tyler Formation. The upper Tyler "A" sand and the lower Tyler "B" and "C" sands contained oil in parts of the field. Five or more separate reservoirs are indicated.

Well spacing was 80 acres in the main part of the field and 40 acres in part of the western portion. After unitization, the 80-acre spacing was waived. Peak development was in 1967 when there were 32 producing oil wells and 47 dry holes in the field area. Peak oil production year was 1961 when 698,882 barrels was reported.

The west Keg Coulee Tyler sand unit (sometimes called northwest Keg Coulee unit) was approved with Pan American Petroleum Corp. (Amoco Production Co.) as operator in 1966. Water injection was started on August 31, 1966. Annual and cumulative water injection and number of injection wells are as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1966	201	201	1
1967	641	842	1
1968	664	1,506	3
1969	622	2,128	3
1970	674	2,802	3
1971	659	3,461	4
1972	480	3,941	2
1973	314	4,255	2

The east Keg Coulee Tyler "A" and "C" unit, with Continental Oil Co. as operator, started water injection December 3, 1969. Annual and cumulative water injection and number of injection wells for the east Keg Coulee Tyler "A" and "C" unit have been as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1969	24	24	3
1970	743	767	4
1971	633	1,400	4
1972	820	2,220	5
1973	659	2,879	4

Annual and cumulative water injection and number of injection wells for the southeast Keg Coulee, Buttes Resources Co. is as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1970	218	218	1
1971	178	396	1
1972	413	809	1
1973	160	969	1

Cumulative oil production from Keg Coulee to January 1, 1974, was 3,767,500 barrels. The west Keg Coulee Tyler sand unit had a cumulative production of 1,971,400 barrels. The two wells in the unit produced 1,851 barrels of oil and 1,719 barrels of water during December 1973. The east Keg Coulee unit had cumulative production of 938,100 barrels of oil. The six oil wells in the unit produced 2,252 barrels of oil

and 8,585 barrels of water during December 1973. The south Keg Coulee Tyler sand unit had a cumulative production of 858,000 barrels on January 1, 1974. The seven oil wells in the unit produced 2,391 barrels of oil and 8,835 barrels of water during December 1973.

KELLEY

The Kelley oilfield is in sec 13, T 10 N, R 28 E, and sec 18, T 10 N, R 29 E, Musselshell County. The oil accumulated in a permeable sand of the Tyler Formation. "River-fill" deposits are common in the area.

McAlester Fuel:Wilco Properties' No. 1 NP in the NE¼NE¼ sec 13 was completed in October 1966. The productive zone was the Tyler "B" from 4,235 to 4,245 and 4,270 to 4,280 feet. Initial flowing oil production was 520 barrels per day. The field has 40-acre spacing. Five oil wells and 10 dry holes were drilled in developing the field.

Water injection was started July 28, 1969, using one well for injection. Annual and cumulative water injection has been as follows:

Year	Annual, thousand barrels	Cumulative, thousand barrels	Number of water injection wells
1969	58	58	1
1970	165	223	1
1971	195	418	2
1972	261	679	3
1973	289	968	3

Cumulative oil production from the field through 1973 was 681,500 barrels. Oil production for 1973 was 62,524 from three wells.

KEVIN-SUNBURST

The Kevin-Sunburst oil and gas field (on the Kevin-Sunburst dome) is directly north of the town of Shelby and about 1 mile east of the Cut Bank field. The Kevin-Sunburst dome is elliptical and approximately 35 miles long and 30 miles wide. Kevin-Sunburst field, as delineated by the commission, is approximately 20 miles long and 12 miles wide. The producing area, extending from within 10 miles of the Canadian border south almost to the town of Shelby, lies within Tps 32-36 N, Rs 1-4 W, in the northwest quarter of Toole County. Discovery of the field followed surface mapping and study.

Oil shows first were observed in 1912 when a small amount of oil was recovered in drilling a water well. In consequence, a drilling company was induced to drill a test well, but it was a failure. An oil discovery well, the Gordon Campbell-Kevin Syndicate No. 1 Goeddertz, in NE¼NE¼ sec 16, T 35 N, R 3 W, was completed March 14, 1922. Initial production of the well was 10 barrels of oil daily from the basal Sawtooth of the Ellis Group at 1,768 to 1,786 feet. Gas was found in an upper sand and was used to heat buildings at the well. The well was drilled deeper in search of another oil sand but was abandoned after sulfur water was found.

The first commercial oil well, Ohio-Sunburst Oil and Gas Co.'s No. 1 Davey, SE¼SW¼ sec 21, T 34 N, R 1 W, was completed June 5, 1922. Initial production was 150 barrels daily from the Sunburst sand. The Precambrian was reached at the Lee Edwards No. 1 Inland Empire well in drilling to 4,916 feet.

Oil is produced from five different zones: Burwash, Sunburst (Kootenai), Sawtooth, Swift (Ellis Group), and the Mission Canyon (Madison). Flowing Madison wells have high initial production rates but decline to as little as one-tenth of the original rate within 1 year. Burwash is a local name of a sandstone 300 to 400 feet above the Sunburst.

Development of the gasfield started with the drilling of the Ohio-Berg No. 1, NW¼NW¼ sec 6, T 32 N, R 1 W, completed on November 10, 1922. The initial flow was 7.5 million cubic feet of gas daily from the Sunburst sand. Earlier, during 1912-14, farmers were encountering gas in usable amounts at 300 to 400 feet. In one instance, a farmer recovered gas for domestic purposes from a well drilled in 1915. During 1923, a 3-inch pipeline was laid from the Ohio-Berg well to the town of Shelby to supply gas for local use. Following intensive drilling of wells to the Sunburst gas zone in 1927, a combination 10- and 12-inch pipeline was laid to the city of Great Falls in 1928. Daily gas consumption at Great Falls was estimated to be 10 million cubic feet in 1928.

Oil, first produced in 1922, reached a peak production of 6,427,000 barrels in 1926. Gas production reached a peak of 4,950 million cubic feet in 1928. The gas is marketed through Montana Power Co.'s pipeline system. Acid treatment, initiated in 1934, increased oil production and slowed the decline slightly.

The first attempts to waterflood in the Kevin-Sunburst field were reported as "pilot tests." Reports of some early tests are incomplete. Six projects have been started in the field.

The first project was the Imperial Craig Co.'s Bluhm lease in the SE¼ sec 19, T 35 N, R 1 W. Water injection in the Madison zone was started June 4, 1956, using Bluhm well No. 18. Water used was from the Madison zone.

Annual and cumulative water injection and number of injection wells at Imperial Craig Co.'s Bluhm lease were as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1956	61	61	3
1957	102	163	4
1958	106	269	5
1959	114	383	5
1960	132	515	5
1961	131	646	5
1962	98	744	5
1963	122	866	5
1964	111	977	5
1965[1]	59	1,036	5

[1]Project abandoned in August 1966.

The second project was the Northwest Producing Co.'s M. M. Neumann lease in sec 22, T 35 N, R 2 W. The project was started January 23, 1961, as a five-spot pilot test. Water was injected into the Madison, using water from the Madison.

Annual and cumulative water injection at Northwest Producing Co.'s M. M. Neumann lease has been as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels
1961	209	209
1962	220	429
1963	220	649

Expansion of the project was approved in 1962, but it was shut in during December 1963.

The third project was the RH and Lon Crumley's Larson lease in sec 17, T 35 N, R 2 W. The project was approved by commission order No. 15-63, dated June 27, 1963. Injection of produced water in the Madison zone started in September 1963.

Annual and cumulative water injection and number of injection wells for the Crumley-Larson lease have been as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1963	18	18	1
1964	83	101	1
1965	57	158	1
1966	68	226	1
1967	93	319	2
1968	116	435	2
1969	94	529	3
1970	87	616	3
1971	76	692	3
1972	71	763	2
1973	96	859	2

The fourth project was the Texaco, Inc., Sunburst sand unit. The waterflood was approved April 14, 1964, and injection began in August 1964.

Annual and cumulative water injection and number of injection wells in Texaco's Sunburst sand unit have been as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1964	222	222	12
1965	669	891	12
1966	517	1,408	11
1967	714	2,122	10
1968	845	2,967	10
1969	857	3,824	10
1970	924	4,748	10
1971	971	5,719	10
1972	955	6,674	10
1973	702	7,376	9

The fifth project was the Juniper Oil and Gas Co. project in secs 35 and 36, T 36 N, R 2 W. The commission approved a flood for the Shaw lease by order No. 17-64, dated May 14, 1964. By order No. 36-65, dated September 9, 1965, the Homestake Sunburst sand unit, with Juniper Oil and Gas Co. as operator, was approved. The Shaw lease is included

in the Homestake unit. Water from the Madison is used to flood the Sunburst sand. Operations started in August 1964.

Annual and cumulative water injection and number of injection wells in Juniper Oil and Gas Co.'s Homestake unit have been as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1964	14	14	1
1965	58	72	1
1966	67	139	1
1967	223	362	7
1968	433	795	8
1969[1]	458	1,253	7
1970	635	1,888	7
1971	448	2,336	7
1972	530	2,866	7
1973	1,271	4,137	4

[1]Buttes Resources Co. assumed operations.

The sixth project, Cardinal Petroleum Co.'s Rocky Ridge Sunburst sand unit, was approved August 13, 1964, by commission order No. 30-64. Injection started June 28, 1965. Water source was the Madison Formation.

Annual and cumulative water injection and number of injection wells for Cardinal Petroleum Co.'s Rocky Ridge unit have been as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1965	42	42	1
1966	95	137	2
1967	146	283	6
1968	252	535	7
1969	111	646	6
1970	131	777	6

The project was shut down on Sept. 22, 1970.

Three tests by Texaco, Inc., were tried for a time. A waterflood "pilot test" was started in June 1955 and ended in October 1955. A total of 55,410 barrels of water was injected. No comments accompanied the reports. A test using exhaust gas for injection was approved by order No. 30-55. The test started April 12, 1956, using four injection wells. Amounts of gas injected in the Madison Formation were as follows:

Year	Annual, thousand cubic feet	Cumulative, thousand cubic feet
1956	19,540	19,540
1957	26,100	45,640
1958[1]	58,930	104,570

[1]Test stopped in November 1958. Serious corrosion caused abandonment of the test.

Commission order No. 31-62, dated April 12, 1962, approved an in situ thermal test in the Sunburst sand in the SE¼ sec 15, T 35 N, R 2 W. Well No. 18 was drilled 150 feet northwest of well No. 17. Air injection in well No. 18 started in September 1962 and was stopped November 21, 1962, after 10,151,000 cubic feet of gas had been injected. The test resumed August 12, 1963, and an additional 2,824,000 cubic feet of air was pumped into well No. 18. The test was discontinued October 11, 1963.

The status of the several projects in the Kevin-Sunburst field in December 1973 was as follows:

Unit or area	Number of producing oil wells	December 1973 production, barrels	Cumulative production, barrels
Buttes Resources Co. Homestake unit.....	26	1,867	1,315,300
Lon Crumley Larson unit.....	24	706	869,100
Texaco, Inc. Sunburst sand unit	11	2,652	[1]234,400
Total.....	61	5,225	2,418,800

[1]Since unitization.

LITTLE BEAVER

Little Beaver oilfield lies on the west flank of the Cedar Creek anticline in Tps 4 and 5 N, Rs 61 and 62 E, Fallon County. It is located on an anticlinal structure at an elevation of 3,085 feet. Bearpaw Shale crops out at the surface.

The area was surface mapped and seismographed before drilling started. In July 1952, the No. 23-13 unit, sec 13, T 4 N, R 61 E, was completed for an initial production of 313 barrels of oil and 33 barrels of water a day. This well was drilled to a total depth of 8,553 feet and produced from the Red River Formation. The log of the discovery well shows the following depths, in feet, to the formation tops: Telegraph Creek, 1,120; Niobrara, 1,910; "first speckled" zone, 2,102; Carlile, 2,106; Mowry, 2,335; Greenhorn, 2,774; Belle Fourche, 2,975; Newcastle, 3,500; Newcastle sand, 3,522; Dakota, 3,835; Fuson, 3,920; Third Cat Creek, 4,100; Morrison, 4,115; Swift, 4,155; Rierdon, 4,225; Piper, 4,700; Piper lime, 4,750; Spearfish, 4,823; Minnekahta, 5,558; Opeche, 5,610; Minnelusa, 5,703; Amsden, 5,895; Kibbey, 6,150; Madison, 6,265; Charles, 6,367; Mission Canyon, 6,840; Lodgepole, 7,200; Englewood, 7,604; Silurian, 7,854; Stony Mountain, 8,246; and Red River, 8,300.

A total of 30 producing wells had been drilled in the field as of January 1, 1972. They produced oil from the Red River Formation. The 1973 total field production was about 1,278 barrels of oil per day. Cumulative production to January 1974 was 6,246,200 barrels of oil. Remaining reserves were 4,253,000 barrels of oil at yearend 1973.

At least six wells were drilled in the Little Beaver area prior to the discovery and development of the present field. Four of these wells had oil shows or produced some oil. None of the four were commercial wells so they were not officially recognized as the field discovery well. These wells were as follows: (1) Montana-Dakota Utilities Co. well, Unit 8-1, in the SE¼NE¼NW¼ sec 17, T 4 N, R 62 E, drilled in 1936 to a depth of 8,186 feet. The well produced some oil from a depth of 8,130 feet, probably from the Stony Mountain Formation. (2) Montana-Dakota Utilities Co. well, No. 279 Sinclair-Dousman, in the C NE¼SW¼ sec 8, T 4 N, R 62 E, drilled in 1937 to a depth of 6,811 feet. The well produced some oil from the Madison Formation. (3) Carter Oil Co. well, N.P.R.R. No. 1, in the C SW¼SE¼ sec 19, T 4 N, R 62 E, drilled to a depth of 9,680 feet. The well produced some oil from depths of 8,320, 8,455, and 8,644 feet, probably the Red River Formation or Lower Ordovician. (4) Husky-Rangely Oil Co. well, N.P.R.R. No. 1, drilled in 1949 to a depth of 6,834 feet in the C NE¼NE¼ sec 7, T 4 N, R 62 E. The well produced some oil and considerable water from a depth of 6,817 feet in the Madison Formation.

The field was unitized by order No. 41-62, dated July 12, 1962. Shell Oil Co. was declared the operator. Waterflooding the field was approved by order No. 3-66, dated January 13, 1966. Up to 3.6 million barrels of oil should be recovered by the waterflood. Water injection started August 7, 1966.

Annual and cumulative water injection and number of injection wells in the Little Beaver field were as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1966	670	670	7
1967	2,427	3,097	12
1968	2,748	5,845	12
1969	1,675	7,520	7
1970	2,087	9,607	13
1971	2,933	12,540	13
1972	2,683	15,223	13
1973	2,713	17,936	13

Water from the Minnelusa Formation (Pennsylvanian) is used to supplement water produced with the oil. In December 1973, the 23 producing wells in Little Beaver field produced 39,806 barrels of oil and 34,921 barrels of water.

LITTLE BEAVER, EAST

East Little Beaver field is located in Tps 4 and 5 N, R 62 E, Fallon County, Mont., and T 130 N, R 107 W, Bowman County, N. Dak. It is about 1½ miles east of the Little Beaver field on a separate anticlinal closure. After surface mapping and seismic work was done in the area, a well, Unit 8-1, sec 17, T 4 N, R 62 E, was completed as a dry hole in 1936. In 1954, it was redrilled and brought in for 25 barrels of oil per day. The well log shows the following depths, in feet, to formation tops: Greenhorn, 2,720; Mowry, 3,286; Muddy sand, 3,470; Dakota sand, 3,760; Swift, 4,125; Rierdon, 4,384; Piper, 4,682; Piper lime, 4,710; Spearfish, 4,890; Minnekahta, 5,520; Opeche, 5,540; Minnelusa, 5,704; Englewood, 7,613; Devonian, 7,645; Silurian, 7,706; Stony Mountain, 8,045; and Red River, 8,213.

The field was extended into North Dakota by discovery of oil in the Red River Formation on February 22, 1960, and in the Madison Formation on July 19, 1960. The North Dakota portion of the field, called Cedar Creek field, was about twice the size of the Montana part.

The North Dakota Madison well produced 13,556 barrels of oil and 127,100 barrels of water before it was abandoned. The Cedar Creek field was unitized under North Dakota rules with Shell Oil Co. as operator. Water injection into the Red River zone started in March 1965. Injection to January 1, 1973, totaled 17,962,000 barrels of water. There were 30 producing oil wells, 14 water injection wells, 3 plugged and abandoned wells, and 3 temporarily abandoned wells in the field at the end of 1972. Production from the Cedar Creek field through 1972 was 7,680,900 barrels of oil and 4,511,700 barrels of water.

The Little Beaver, East, field unit agreement was approved by commission order No. 42-62, dated July 12, 1962.

Approval was granted in 1961 to dispose of produced saltwater in the Mission Canyon Formation through well No. 14-8 in sec 8, T 4 N, R 62 E. The disposal would also include some water from the Little Beaver and Cedar Creek (North Dakota) fields. The rate of water disposal was as follows:

Year	Annual, thousand barrels	Cumulative, thousand barrels
1962	321	321
1963	608	929
1964	601	1,530
1965	190	1,720
1966	74	1,794
1967	134	1,928

The water disposal was suspended late in 1965 but was resumed in 1966. The project was again shut down in 1967.

Shell Oil Co.'s secondary recovery operation plan was approved by commission order No. 33-64, dated September 10, 1964. Produced water and water from two Minnelusa Sandstone wells would be used for water-flooding the Red River (Ordovician) zone. At the time of the hearing, additional oil recovery was estimated at 1,800,000 barrels. Water injection started in April 1965.

Annual and cumulative water injection and number of injection wells at East Little Beaver field have been as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1965	336	336	5
1966	874	1,210	5
1967	896	2,106	5
1968	1,105	3,211	5
1969	1,043	4,254	3
1970	689	4,943	3
1971	557	5,500	3
1972	683	6,183	3
1973	776	6,959	6

There were 10 oil wells and 6 water injection wells in the field on January 1, 1974. Oil production for 1973 was 144,000 barrels, bringing cumulative oil production to 3,318,000 barrels. Remaining reserves were about 2,200,000 barrels.

LOOKOUT BUTTE

The Lookout Butte field in secs 15-36, T 7 N, R 60 E, and secs 2-5, 9-11, and 15-16, T 6 N, R 60 E, Fallon County, is south and southeast of the town of Baker. The Pierre Shale is exposed on the surface. Elevations in the field range from 2,950 to 3,150 feet above sea level.

The discovery well was Continental Oil Co.'s No. 2 NP-A-29, in the C SE¼NW¼ sec 29, T 7 N, R 60 E. Completed December 26, 1961, the well had an initial daily flowing production of 495 barrels of oil and 11 barrels of water from the Red River Formation (Ordovician). The Silurian, Stony Mountain, and Red River Formations proved to be oil productive. In January 1966, Shell Oil Co.'s No. 31X-5 unit, in the NW¼NE¼ sec 5, T 6 N, R 60 E, found oil in the Lodgepole (Mississippian) zone in the Coral Creek unit. Coral Creek unit was merged into the Lookout Butte field.

The log of well No. 42-30 B. Anderson, in the SE¼NE¼ sec 30, T 7 N, R 60 E, showed the following depths, in feet, to tops of formations: Greenhorn, 2,914; Newcastle, 3,663; Dakota silt, 3,882; Piper, 4,977; Spearfish, 5,210; Minnekahta, 5,755; Heath, 6,220; Otter, 6,332; Kibbey, 6,435; Charles "A," 6,553; Charles "B," 6,670; Mission Canyon, 6,925; Lodgepole, 7,485; Silurian, 8,106; Stony Mountain, 8,384; Red River, 8,547; and total depth, 8,840.

The field was developed on 160-acre well spacing. Maximum annual oil production was 2,161,490 barrels in 1962. The largest number of producing wells was 71 in 1965.

Commission order No. 68-62, dated December 6, 1962, approved Continental Oil Co.'s request for water disposal in the Dakota Sandstone using well No. 1 NP, sec 31, T 7 N, R 60 E. Rate of water disposal by Continental has been as follows:

Year	Annual, thousand barrels	Cumulative, thousand barrels
1964	704	704
1965	1,016	1,720
1966	1,437	3,157
1967	1,393	4,550
1968[1]	408	4,958
1968[2]	131	5,089
1969	404	5,493
1970	Shut-in	5,493
1971	Shut-in	5,493

[1]September 1968 figures.
[2]December 1968 figures. Shell took over operations in October 1968. Injection well was changed to well No. 42-31. Operations after September 1968 reported as Pennel field.

Pennel field joins Lookout Butte field on the north. Shell Oil Co. has reported saltwater disposal for both fields under Pennel field.

Commission order No. 35-66, dated October 1966, approved Shell Oil Co.'s plans to waterflood the Siluro-Ordovician zones. Water injection was estimated to reach 11,000 barrels daily. Additional oil recovery was estimated to be 5,100,000 barrels. Water injection began in April 1967. Injection water was from the Minnelusa Formation.

Annual and cumulative water injection and number of injection wells at Lookout Butte field are as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1967[1]	1,263	1,263	9
1968	2,137	3,400	12
1969	2,786	6,186	11
1970	2,496	8,682	12
1971	2,402	11,084	13
1972	1,975	13,059	13
1973[2]	2,436	15,495	13

[1]For 1967-68, listed in State report as Coral Creek.
[2]Of the cumulative total, 1,294,000 barrels was injected into the Madison zone, and 14,201,000 barrels into the Red River zone.

The largest number of Siluro-Ordovician wells was 71 in 1965. The most Lodgepole wells was 12 in 1966-69. Oil production for 1973 was 621,267 barrels from the Siluro-Ordovician and 41,400 barrels from the

Lodgepole wells. Cumulative oil production through 1973 was 13,811,800 barrels from the Siluro-Ordovician zones and 1,351,000 barrels from the Lodgepole Formation.

MONARCH

The Monarch oilfield is in secs 23, 25, 26, 35, and 36, T 9 N, R 58 E, and sec 31, T 4 N, R 59 E, Fallon County. It is one of several fields found on the narrow, northeast-southeast trending Cedar Creek anticline.

Shell Oil Co.'s well No. 12-23 was completed November 18, 1958, for an initial daily pumping production of 218 barrels of oil and 13 barrels of water from the Silurian zone from 8,400 to 8,506 feet. Well No. 34-26, C SW¼SE¼ sec 23, was completed February 14, 1959, for an initial daily pumping production of 65 barrels of oil and 64 barrels of water from three Red River zones between 8,986 to 9,002 feet. Well No. M-12-15 NP in the SW¼NW¼ sec 15, pumped 369 barrels of oil and 246 barrels of water on March 10, 1961, from the Mission Canyon from 7,282 to 7,305 feet.

The Silurian has been the main producing zone. The Mission Canyon zone had 80-acre spacing. The maxiumum number of producing wells was 16 for the years 1962, 1965-69.

For several years, produced water was pumped into the saltwater disposal system for the Pennel field. Approval of Shell Oil Co.'s Monarch Silurian waterflood unit was July 18, 1973, commission order No. 23-73. Lands approved were as follows:

T 9 N, R 58 E, Fallon County

sec 14 - SW¼	sec 15 - SE¼
sec 23 - NW¼, S½	sec 24 - SW¼
sec 25 - W½	sec 26 - all
sec 35 - N½	

A well in the NW¼ sec 15 was to be completed in the Mission Canyon zone as a water source well. The unit was effective August 1, 1973. Water injection through three wells for December 1973 was 30,000 barrels. Production was 32,376 barrels of oil.

Cumulative oil production to January 1, 1974, was 3,516,000 barrels.

PENNEL

The Pennel oilfield in Tps 7-9 N, Rs 59-60 E, Fallon County, is near the axis of the Cedar Creek anticline. The south edge of the field is a few miles north of the town of Baker. Elevations in the field average 3,000 feet. The Bearpaw Shale crops out on the surface.

Shell Oil Co.'s well No. 22X-36 State, in the SE¼SE¼NW¼ sec 36, T 8 N, R 59 E, was completed on September 8, 1955. Initial daily pumping production was 205 barrels of oil and 39 barrels of water from the Red River Formation. Later development drilling found oil in the Mission Canyon (Madison), Interlake (Silurian), and the Stony Mountain (Ordovician) Formations. The log of well No. 22X-36 State shows the following depths, in feet, to tops of formations: Newcastle, 3,714; Piper, 5,037; Piper lime, 5,072; Minnekahta, 5,796; Charles "A," 6,620; Charles "B," 6,744; Mission Canyon, 7,000; Silurian, 8,082; Stony Mountain, 8,330; Red River, 8,588; Winnipeg, 9,112; and Lower Ordovician, 9,219.

Peak oil production from the Pennel field was 2,693,000 barrels in 1964. Oil production for 1973 was 2,257,000 barrels, bringing the cumulative oil production to 28,362,100 barrels. Peak number of producing wells occurred in 1968 when there were 130 Siluro-Ordovician wells and 8 Mission Canyon wells. Lookout field joins Pennel field on the south.

Produced water disposal into the Siluro-Ordovician and Madison zones at Pennel field was approved by the commission in 1961. Water injection into the Siluro-Ordovician zone through State well No. 31-36, sec 36, T 8 N, R 59 E, started in August 1961. Yearly water disposal in well No. 31-36 has been as follows:

Year	Annual, thousand barrels	Cumulative, thousand barrels
1961	118	118
1962	269	387
1963	302	689
1964	552	1,241
1965	556	1,797
1966	646	2,443
1967	715	3,158
1968	721	3,879
1969	357	4,236
1970	19	4,255
1971	82	4,337
1972	128	4,465
1973	126	4,591

The next saltwater disposal project was Mobil Oil Co.'s well No. 11-M-1-NP, Lot 4, sec 1, T 7 N, R 59 E. This water disposal was approved by commission order No. 46-62.

Produced water pumped into the Madison zone through well No. 11-M-1, by year, has been as follows:

Year	Annual, thousand barrels	Cumulative, thousand barrels
1962	16	16
1963	87	103
1964	100	203
1965	110	313
1966	130	443
1967	244	687
1968[1]	337	1,024
1969	348	1,372
1970	19	1,391
1971	32	1,423
1972	0	1,423
1973	0	1,423

[1]Shell Oil Co. assumed operations in 1968 and changed the well number to 11-01 A.

Water disposal into the Madison Formation through well No. 44-05, sec 5, T 8 N, R 59 E, was started by Shell Oil Co. on May 13, 1964. Annual water injection into this well has been as follows:

Year	Annual, thousand barrels	Cumulative, thousand barrels
1964	139	139
1965	195	334
1966	255	589
1967	256	845
1968	251	1,096
1969	306	1,402
1970	-	1,402
1971	-	1,402
1972	-	1,402
1973	-	1,402

A total of 2,825,000 barrels of water has been pumped into the Madison zone at Pennel field.

Commission order No. 24-68, dated September 12, 1968, approved Shell Oil Co.'s application for a unit and waterflooding of the Siluro-Ordovician reservoir underlying the Pennel field. It was proposed to use up to 40 water injection wells with daily injection reaching 12,000 barrels. Water produced with the oil and brackish water from the Dakota and Minnelusa Formations were the sources of injection water. Additional oil recovery might reach 18 million barrels. Water injection was started on June 28, 1969, into the Red River and Siluro-Ordovician zones.

Annual and cumulative water injection and number of injection wells in the Red River zone in Pennel field have been as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1969	367	367	12
1970	734	1,101	12
1971	865	1,966	12
1972	1,200	3,166	12
1973	1,349	4,515	12

Annual and cumulative water injection and number of injection wells in the Siluro-Ordovician zone in Pennel field have been as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1969	1,636	1,636	26
1970	3,497	5,133	26
1971	3,877	9,010	26
1972	5,315	14,325	26
1973	6,174	20,499	26

There were 106 producing wells at Pennel field in December 1973 producing 199,603 barrels of oil per month. Cumulative oil production was 28,362,100 barrels.

PINE

The Pine field is in T 13 N, Rs 55 and 56 E, Dawson County, Tps 12 and 13 N, R 56 E, Prairie County, and Tps 11 and 12 N, R 57 E, Wibaux County, Mont. It is located near the northern end of the northwest-southeast trending Cedar Creek anticline at an average elevation of 2,719 feet. The upper Bearpaw Formation crops out on the surface.

Shell Oil Co.'s well unit No. 32-30, in the SW¼SW¼NE¼ sec 30, T 12 N, R 57 E, Wibaux County, was completed in January 1952. Initial daily pumping production was 467 barrels of oil and 148 barrels of water from perforations from 8,940 to 8,970 feet in the Interlake-Silurian zone. Later drilling proved the Madison, Stony Mountain, and Red River zones were oil productive. Oil production reports to the commission were not by formation or zone. The largest number of producing wells was 155 in 1958. Maximum yearly oil production was 5,358,000 barrels in 1958.

The log of well No. 32-30 shows the following depths, in feet, to the formation tops: Bearpaw, 20; Judith River, 865; Claggett, 1,118; Eagle, 1,515; Telegraph Creek, 1,683; Niobrara, 2,139; Greenhorn, 2,950; Newcastle, 3,695; Dakota, 4,012; Lakota, 4,240; Sundance, 4,330; Spearfish, 5,312; salt zone, 5,470; Minnekahta, 5,748; Opeche, 5,790; Minnelusa, 6,065; Amsden, 6,205; Heath, 6,395; Otter, 6,705; Kibbey, 6,870; Charles, 7,100; Mission Canyon, 7,565; Lodgepole, 7,976; Kinderhook-Englewood, 8,508; Devonian, 8,512; Ordovician, 9,020; and Cambrian, 9,642.

All of the wells produce some water with the oil. The produced water contains up to 120,000 parts per million dissolved salts, making earthen pits inadequate for disposal of the water. Water disposal by injection into the Dakota was approved on an emergency basis by commission order No. 7-58 and began in October 1958.

Saltwater disposal into the Dakota in well No. 41-10A, NE¼NE¼ sec 10, T 11 N, R 57 E, has been as follows:

Year	Annual, thousand barrels	Cumulative, thousand barrels
1958	302	302
1959	1,135	1,437
1960	1,478	2,915
1961	120	3,035
1962	-	3,035
1963	84	3,119
1964	273	3,392
1965	345	3,737
1966	266	4,003
1967	278	4,281
1968	384	4,665
1969	246	4,911
1970	162	5,073
1971	325	5,398
1972	346	5,744
1973	176	5,920

Water injection in the Red River zone was authorized by commission order No. 13-58. Injection started in March 1959. Commission order No. 37-62, dated May 10, 1962, approved the formation of the Pine unit plan offered by Shell Oil Co. The unit area has been called "South Pine" and Pine unit areas "A" and "B". Statewide rules for development were suspended for all but about 1,500 acres in the unit area.

Annual and cumulative water injection and number of injection wells at South Pine unit have been as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1959	249	249	1
1960	343	592	1
1961	2,146	2,738	1
1962	2,473	5,211	11
1963	4,631	9,842	24
1964	5,498	15,340	27
1965	7,047	22,387	29
1966	7,830	30,217	31
1967	6,762	36,979	30
1968	6,459	43,438	56
1969	8,261	51,699	50
1970	8,508	60,207	46
1971	8,373	68,580	39
1972	11,245	79,825	41
1973	14,780	94,605	37

Commission order No. 32-67, dated August 17, 1967, approved Shell Oil Co.'s plan for a waterflood in the Pine unit area to be known as the North Pine Red River waterflood. Water injection was started in March 1968.

Annual and cumulative water injection and number of injection wells at North Pine have been as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1968	1,292	1,292	10
1969	1,508	2,800	10
1970	1,649	4,449	11
1971	1,823	6,272	11
1972	1,769	8,041	11
1973	1,775	9,816	11

Injection water for the South waterflood is produced water plus water from the Fox Hills Formation. Water from the Lodgepole Formation is used for injection for the North waterflood.

The production report for December 1973 shows the following:

Unit or area	Number of producing oil wells	December 1973 production, barrels	Cumulative production, barrels
Shell Govt No. 30-07			257,161
Unit "A" Madison.....	1	1,684	145,000
Area B & C unit.....	19	31,307	7,429,719
Area A unit.....	86	224,418	68,401,500
Abandoned leases.....	-	-	128,107
Total.....	106	257,409	76,361,487

EAST POPLAR

The East Poplar field, sometimes called Poplar, in Tps 28 and 29 N, Rs 50 and 51 E, Roosevelt County, is about 5 miles northeast of the town of Poplar. Rocks of the Bearpaw Formation are exposed in the field.

East Poplar unit No. 1 in C SW¼NE¼ sec 2, T 28 N, R 51 E, was completed March 1, 1952, for an initial daily oil production of 596 barrels from two zones in the Madison. Additional drilling developed an area about 10 miles long (north-south) and up to 5 miles wide. Well unit No. 63, in the SW¼NE¼ sec 27, T 28 N, R 50 E, found oil in the Kibbey zone of the Mississippian. The well was about 1 mile southwest of the nearest production. Unit No. 63 produced oil only for a short time before it was abandoned. Formation tops in the unit No. 1 well were reported at the following depths, in feet: Judith River, 752; Claggett, 860; Eagle, 1,145; Niobrara, 2,005; Carlile, 2,120; Greenhorn, 2,350; upper Muddy, 2,677; lower Muddy, 2,898; Skull Creek, 2,933; Dakota silt, 3,112; Dakota, 3,178; Kootenai, 3,217; Second Cat Creek, 3,315; Third Cat Creek, 3,444; Morrison, 3,505; Ellis, 3,898; Rierdon, 4,077; Piper Shale, 4,255; Gypsum Springs, 4,376; Amsden, 4,706; Heath, 4,835; Otter, 4,938; Kibbey, 5,130; Charles, 5,395; Mission Canyon, 5,940 (?); Lodgepole, 6,560; Kinderhook, 7,127; Three Forks, 7,170; Jefferson, 7,280; and Ordovician, 8,185 (?).

In February 1969, the No. 5 Huber well, in the SW¼NE¼ sec 10, T 28 N, R 51 E, was completed for an initial daily production of 51 barrels of oil and 475 barrels of water from the Nisku Member of the Devonian. In May 1969, the No. 1 Huber well was recompleted in the Kibbey Member of the Mississippian for an initial daily production of 66 barrels of oil and 277 barrels of water.

East Poplar is reported here to explain the several water injection projects at the field. The saltwater produced with the oil at East Poplar has about 180,000 parts per million salt content. The city of Poplar obtains its water from gravel beds along the Poplar River. The

Poplar River flows past the oilfield so disposal of the oilfield waters was a problem from the start.

The Murphy Oil Corp. began injecting produced water into the "B" Madison zone in 1956. Later this project was approved as a pressure maintenance test.

Annual and cumulative water injection and number of injection wells were reported as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1956	321	321	2
1957	1,065	1,386	2
1958	787	2,173	2
1959	1,956	4,129	2
1960	2,380	6,509	4
1961	1,599	8,108	4
1962	662	8,770	4
1963	691	9,461	4
1964	313	9,774	4
1965[1]	332	10,106	4

[1]Injection stopped Jan. 30, 1965. No reason given.

Commission order No. 5-57, dated July 29, 1957, approved saltwater disposal in the Dakota Formation by the Murphy Corp. The Dakota Formation at East Poplar contains brackish water and no oil or gas.

Annual rates of saltwater disposal in the Dakota Formation by the Murphy Corp. have been as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1957	699	699	1
1958	2,893	3,592	1
1959	2,228	5,820	1
1960	1,903	7,723	1
1961	4,134	11,857	1
1962	5,739	17,596	2
1963	5,261	22,857	2
1964	4,988	27,845	2
1965	4,870	32,715	3
1966	5,291	38,006	3
1967	4,791	42,797	3
1968	4,652	47,449	3
1969	5,339	52,788	3
1970	5,179	57,967	3
1971	5,304	63,271	3
1972	5,103	67,374	3
1973	5,693	73,067	3

E. A. Polumbus, Jr. (operator) was given permission to dispose of saltwater by using well Huber No. 1 in sec 10, T 28 N, R 51 E, and Buck Elk wells No. 1-W and No. 2-W in sec 7, T 29 N, R 51 E. The saltwater was pumped into the Judith River zone of Upper Cretaceous age at a depth of 700 to 800 feet.

Annual and cumulative water disposal rates for the Polumbus project have been as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels
1961	[1]42	42
1962	[2]475	517
1963	518	1,035
1964	610	1,645
1965	588	2,233
1966	635	2,868
1967	641	2,509
1968	674	4,183
1969	777	4,960
1970	1,172	6,132
1971	[3]1,027	7,159
1972	870	8,029
1973	684	8,713

[1]Started Nov. 17, 1961, with well Huber No. 1
[2]Wells Buck Elk No. 1-W and No. 2-W added Feb. 10, 1962.
[3]Huber No. 1 recompleted in the Dakota zone in November 1971; 38,000 barrels pumped into the Dakota during December 1971.

E. A. Polumbus began injection in the lower Mission Canyon zone in October 1973. Injection for the rest of 1973 was 151,000 barrels.

Mesa Petroleum Corp.-John Snyder began disposing of produced water in the Judith River zone in their Biere No. 1-22 in sec 22, T 28 N, R 51 E, in 1970. Annual and cumulative injection has been as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels
1970	160	160
1971	299	459
1972	342	801
1973	366	1,167

The four projects show a combined total of 93,205,000 barrels injected at East Poplar. This amounts to 17,111 acre-feet of saltwater and represents a big effort to prevent pollution of shallow usable water resources.

Oil production at East Poplar field was 510,065 barrels in 1973 bringing the cumulative production to 40,467,900 barrels. At the close of 1973, the producing wells in the field by formation were Madison, 59; Heath (Tyler), 3; and Nisku, 1.

PONDERA

The Pondera oilfield in T 27 N, Rs 3-5 W, Pondera and Teton Counties, is about 20 miles north of the town of Chouteau. The structure appears to be a northwest plunging anticline, but it really is a structural terrace extending westward from the Sweetgrass Arch. The axis of the arch has been shifted westward about 20 miles in the area. Little structural closure has been found in the field, and oil accumulation is controlled by porosity development in the granular Madison Limestone. The field is not a single common reservoir. Graben faulting is found immediately north and northwest of the field. Elevations of the treeless plains at the field range from 3,750 to 4,150 feet.

Several commission orders covering water disposal and secondary recovery have been issued over the years. The projects at Pondera have been for water disposal rather than for waterflooding.

The discovery well in C SE¼SE¼ sec 17, T 27 N, R 4 W, was completed June 9, 1927, for an initial daily flow of 3.5 million cubic feet of gas plus a spray of oil from the Ellis-Madison contact. By the end of 1935, the field had 153 oil wells and 1 gas well. Some drilling has continued since World War II. There is no record of any gas being sold outside the field.

Five orders, starting with No. 11-56, have been issued for water disposal at the Pondera field. Order No. 16-61 was issued to Phillips Petroleum Corp. for a pilot waterflood. All disposal water injected at Pondera has been in the Madison zone. Water has been pumped into Fredia well No. 1, Erickson well No. 5, and State well B-2.

Water disposal at Pondera field, by year, has been as follows:

Year	Annual, thousand barrels	Cumulative, thousand barrels
1957	383	383
1958	405	788
1959	698	1,486
1960	883	2,369
1961	957	3,326
1962	955	4,281
1963	1,043	5,324
1964	927	6,251
1965	919	7,170
1966	859	8,029
1967	973	9,002
1968	1,099	10,101
1969	976	11,077
1970	996	12,073
1971	1,074	13,147
1972	1,144	14,291
1973	1,225	15,516

PRITCHARD CREEK

Pritchard Creek is a small stratigraphic trap in sec 11, T 37 N, R 2 E, Toole County, north of Fred and George Creek. Grannell Drilling Co. completed well No. 13-5 Clark-Beaudoin on March 11, 1968. Initial daily pumping production was 70 barrels of oil from the Sunburst sand at 2,542 to 2,547 feet.

Six oil wells were completed in the area. The productive area was estimated to be 173 acres, and the pay, 3.7 feet thick. The Pritchard Creek unit area, proposed by Fulton Producing Co., was approved by commission order 7-73 on March 15, 1973. A dry hole in the NW¼SE¼ sec 11 was completed in the Eagle Formation as a water source well. Water injection started in April 1973, using one injection well. Water injected in 1973 amounted to 146,000 barrels. Oil production prior to water injection totaled 74,700 barrels. Oil production after water injection started to January 1, 1974, was 6,101 barrels.

RAGGED POINT

The Ragged Point oilfield, about 5 miles northwest of the Keg Coulee and Stensvad fields, is in T 11 N, R 30 E, Musselshell County, and is one of several fields in central Montana. Upper Cretaceous rocks form the surface at an elevation of nearly 3,000 feet. They indicate an east-west trending domal structure.

The Kibbey discovery well was Texaco's No. 1 Manion in the SE¼SW¼SE¼ sec 5, completed in December 1947. The Kibbey Sandstone from 4,400 to 4,450 feet produced 250 barrels of oil per day following a 2,000-gallon acid treatment. Later, two other wells were completed in the Kibbey zone. The Kibbey is a blanket sand in the area but usually contains water. The first well completed in the Tyler Sandstone Member was Halbert, Jennings, and Simic's No. 1 Goit in the SE¼NW¼ sec 9. The initial daily production was 483 barrels of oil in September 1956. Nineteen wells were completed in the Tyler, and 20 dry holes were drilled near the field. The Tyler Sandstone Member is very "spotty" or erratic in the area.

Approval to dispose of produced water by injection into the Kibbey zone in the original discovery well was granted in May 1965. Later, in 1965, the Tyler "A" sand unit for waterflooding was approved. Water injection started February 3, 1966. Injection water is from the Third Cat Creek sand.

Annual and cumulative water injection rates at the Ragged Point field have been as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1966	886	886	7
1967	652	1,538	7
1968	523	2,061	7
1969	528	2,589	7
1970	465	3,054	7
1971	667	3,721	7
1972	626	4,347	4
1973	596	4,943	4

A polymer injection was started on December 5, 1968. The injection stopped March 6, 1970, after 32,000 pounds of polymer had been used. The polymer concentration was about 1 pound for 20 barrels of water. In theory, the polymer changes viscosity of the water and increases oil recovery. The oil production curve indicates additional oil from the polymer injection.

Commission order No. 19-65, dated May 10, 1965, approved the use of Texaco's Manion well No. 1, SE¼SW¼SE¼ sec 5, T 11 N, R 30 E, as a disposal well for produced water in the Ragged Point field. The rate and amount of produced water pumped into the Kibbey zone have been as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels
1966	30	30
1967	77	107
1968	81	188
1969	51	239
1970	80	319
1971	99	418
1972	23	441

Injection was stopped in September 1972; cumulative injection was 441,000 barrels.

Cumulative oil production from the Ragged Point field through 1973 was 1,694,800 barrels from the Kibbey zone and 190,300 barrels from the Tyler sand. Cumulative water production through 1973 was 4,943,000 barrels.

SOUTHWEST RICHEY

The Southwest Richey field in the south part of T 22 N, R 48 E, McCone County, is about 32 miles south of Wolf Point. The area is rolling, well-rounded hills with some wheat farming and some ranching land use. The Fort Union Formation forms the surface.

The discovery well, Shell Oil Co.'s No. 22-25-B NPR in the E½SE¼NW¼ sec 25, T 22 N, R 48 E, was completed in July 1952. Initial daily pumping production was 51 barrels of oil plus 59 barrels of water. Five zones between 9,250 and 9,834 feet had been perforated and acidized with 2,500 gallons of hydrochloric acid. The oil was from the Dawson Bay (Devonian) and Interlake (Silurian) zones. Early wells drilled in the area were disappointing and development was slow. Maximum number of wells was eight in 1966. Analyses of water from the Dawson Bay, Interlake, and Red River zones showed total dissolved solids of 85,000 parts per million, 120,000 parts per million, and 90,000 parts per million, respectively.

The log of Gulf State's well No. 1 Hudiburgh, SE¼SE¼ sec 27, drilled in 1962, showed the following depths, in feet, to formation tops: Pierre, 1,230; Greenhorn, 3,760; Piper, 5,775; Charles, 6,784; Mission Canyon, 7,240; Three Forks, 8,493; Nisku, 8,516; Duperow, 8,565; Dawson Bay, 9,060; Interlake, 9,161; Red River, 9,543; and total depth, 9,628.

The field started with well spacing of 80 acres per well. Later, by order No. 25-62, the well spacing was increased to 160 acres per well. Sinclair Oil and Gas Co. (now Atlantic Richfield Co.) was given

approval to commence a waterflood in the field by commission order No. 34-65, dated August 12, 1965. Water injection in Hudiburgh No. 3, in the NW¼SE¼SW¼ sec 27, started in December 1965 using water from the Fox Hills Formation.

Annual and cumulative water injection and number of injection wells in the Southwest Richey project have been as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1965	8	8	1
1966	285	293	2
1967	418	711	3
1968	486	1,197	4
1969	477	1,674	3
1970	183	1,857	1
1971	143	2,000	1
1972	58	2,058	1
1973	77	2,135	1

Maximum annual oil production was 199,465 barrels in 1964. Cumulative oil production through 1973 was 1,797,500 barrels, and cumulative water injection was 2,135,000 barrels. The five wells in the field produced a total of 1,117 barrels of oil for December 1973.

STENSVAD

The Stensvad field in T 11 N, R 31 E, Musselshell and Rosebud Counties, is adjacent to the Sumatra field on the northwest; however, they are separated by a fault. Permeability development is important in the accumulation of oil. A sand between the "A" and "B" sands in the Tyler Formation here is appropriately called the "Stensvad" sand. The Tyler Formation is about 1,000 feet deeper in the Stensvad field than in the Sumatra field.

Honolulu Oil Corp.'s well No. 11-9 Stensvad, in the C NE¼SE¼ sec 11, T 11 N, R 31 E, Rosebud County, was completed in December 1958. Initial daily flowing production was 1,120 barrels of oil through perforations from 5,308 to 5,380 feet in the Tyler Formation. Twenty-eight producing wells were drilled in the field.

Water disposal in the Tyler "B" zone was approved in June 1962, but no record of such disposal was found. Getchell No. 4 in the NW¼SE¼ sec 12, a dry hole, was to have been the disposal well. A unit agreement for waterflooding was approved by commission order No. 53-62, dated

September 13, 1962. Produced water and water from the Madison Formation is used for injection. Injection began in February 1963. Annual and cumulative water injection has been as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1963	970	970	4
1964	1,383	2,353	5
1965	1,717	4,070	5
1966	1,767	5,837	5
1967	2,110	7,947	5
1968	2,051	9,998	5
1969	2,802	12,800	6
1970	3,168	15,968	7
1971	2,855	18,823	5
1972	2,160	20,983	7
1973	2,688	23,671	7

Cumulative oil production from the field through 1973 was 9,544,200 barrels. The five producing wells in the field yielded 39,532 barrels of oil and 54,228 barrels of water in December 1973.

SUMATRA

Sumatra oilfield, in T 11 N, Rs 31-33 E, Rosebud County, often called Northwest Sumatra, is a few miles northwest of the town of Sumatra. A few isolated wells east of the main producing area are included in the field by the commission. Stensvad field joins the field on the northwest but is separated by a fault. Located east of the Musselshell River, the Bearpaw Shale forms the surface.

Texaco's Grebe No. 1 in the C NW¼NW¼ sec 15, T 11 N, R 32 E, completed in July 1952, was the discovery well for the main Sumatra field. Initial flowing oil production was 300 barrels a day from perforations from 4,719 to 4,732 feet in the Tyler "B" Formation. Rapid development of the field followed. The largest number of producing wells was recorded in July 1968 when there were 117 oil wells, and the highest annual oil production was 2,463,000 barrels in 1961.

The first oil well in the Sumatra area, Texaco's No. 1 NPRR "E" in the NE¼ sec 5, T 9 N, R 34 E, was completed in 1949. The well is about 4 miles southeast of the town of Sumatra. Only two oil wells were completed in the small reservoir, but the oil production records for the Sumatra field start with this well. Thus, 3 years of oil production was recorded before the main oil reservoir was discovered.

Eugene S. Perry[7] gave a good description of reservoir conditions when he said, "In spite of the presence of such definite domal structure at Northwest Sumatra, oil accumulation has been controlled largely by stratigraphic conditions, wherein the sandstones in the Tyler Formation appear to be long meandering channel deposits, ranging in thickness from 0 to 80 or more feet within a horizontal distance of a quarter of a mile."

Some oil has been reported from the Piper and Amsden zones, but most of the production has been from the Tyler "B" sand. The Tyler "A" sand was lenticularly deposited, and the Tyler "C" sand was mostly water saturated.

A saltwater disposal system was built in the field late in 1959. The produced water was collected and injected in Texaco's well NPRR No. 3 in SE¼SE¼ sec 7, T 11 N, R 32 E. The system shut down in July 1961 after a total of about 268,000 barrels had been pumped into the Amsden zone.

Four units have been formed in the field for waterflooding. The Continental Oil Co.'s West Sumatra Tyler sand unit was approved by commission order No. 48-67, dated November 7, 1967. Water for injection was from a well completed in the Mission Canyon zone of the Madison Formation. Water injection commenced in October 1968.

Rate of water injection at the West Sumatra Tyler sand unit has been as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1968	785	785	4
1969	916	1,701	5
1970	1,329	3,030	11
1971	2,073	5,103	12
1972	1,692	6,795	6
1973	2,026	8,821	11

The Southeast Sumatra Tyler sand unit of Buttes Resources Co. was approved on May 15, 1969, by commission order No. 6-69. Water injection started in December 1969 using water from the Madison Formation. Texaco, Inc., assumed operation of the unit during 1971.

Annual and cumulative water injection rates at the Southeast Sumatra Tyler sand unit have been as follows:

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[7]Perry, E. S. Oil and Gas in Montana. Mont. Bur. of Mines and Geol. Bull. 15, February 1960, p. 62.

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1969	61	61	4
1970	1,171	1,232	7
1971	891	2,123	4
1972	876	2,999	6
1973	1,226	4,225	5

The Central Sumatra Tyler sand unit, operated by Texaco, Inc., was approved on August 14, 1969, by commission order No. 19-69. This is the largest Sumatra unit in the area. Injection was started September 16, 1969, using water from the Madison Formation.

Water injections at the Central Sumatra Tyler sand unit are reported to be as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1969	718	718	15
1970	6,709	7,427	13
1971	6,520	13,947	13
1972	6,216	20,163	14
1973	8,013	28,176	15

The Northeast Sumatra Tyler sand unit was approved September 11, 1969, by commission order No. 23-69. Texaco, Inc., is the unit operator. Injection commenced September 16, 1969, using Madison Formation water.

Water injection volumes at the Northeast Sumatra Tyler sand unit have been as follows:

Year	Annual water injection, thousand barrels	Cumulative water injection, thousand barrels	Number of water injection wells
1969	38	38	1
1970	486	524	3
1971	565	1,089	3
1972	601	1,690	6
1973	569	2,259	7

Cumulative oil production to January 1, 1974, from commission reports, was 26,396,300 barrels. Annual oil production from the Sumatra field increased each year since 1969, indicating a reaction to the water injection.

The number of producing wells and the monthly and cumulative oil production for December 1973 for the Sumatra field were as follows:

Unit or area	Number of producing oil wells	December 1973 production, barrels	Cumulative production, barrels
Southeast unit.....	16	5,569	2,894,900
West unit.....	23	14,885	3,547,400
Central unit.....	17	48,562	15,857,200
Northeast unit.....	7	10,328	1,881,600
Nonunit.....	11	19,513	1,179,700
Abandoned leases....	-	-	1,035,500
Total.....	74	98,857	26,396,300

PERFORMANCE CURVES

Waterflood performance curves can be a simple graph of oil and total fluid production and water injection plotted on a time scale. Log and time graph paper has proven very useful. Ideally, oil and total fluid production for a period before water injection is needed to establish the natural production decline. After water injection is started any reaction to waterflood will be shown by the oil and total fluid production curves.

Several project performance curves from records of the commission are presented here. Some comments are given to help interpret the curves. The operators were not consulted regarding these curves. The interpretations are those of the author.

Bell Creek Projects

Bell Creek is a new, large area. Permeabilities in some areas were reported by operators to be above 5 darcys. Curves for four of the units follow (figs. 2-5). The author did not tabulate individual well production, by unit, before unitization. Although the general "cut-off date" for the report is January 1, 1972, the 1972 and 1973 data have been included on the Bell Creek curves.

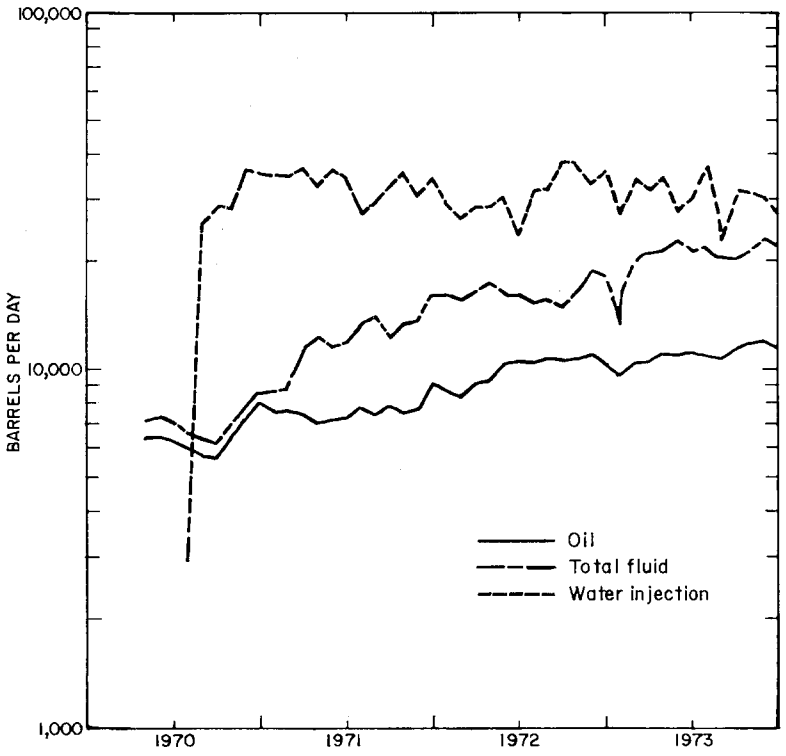

FIGURE 2. - Performance curve of Bell Creek unit "A."

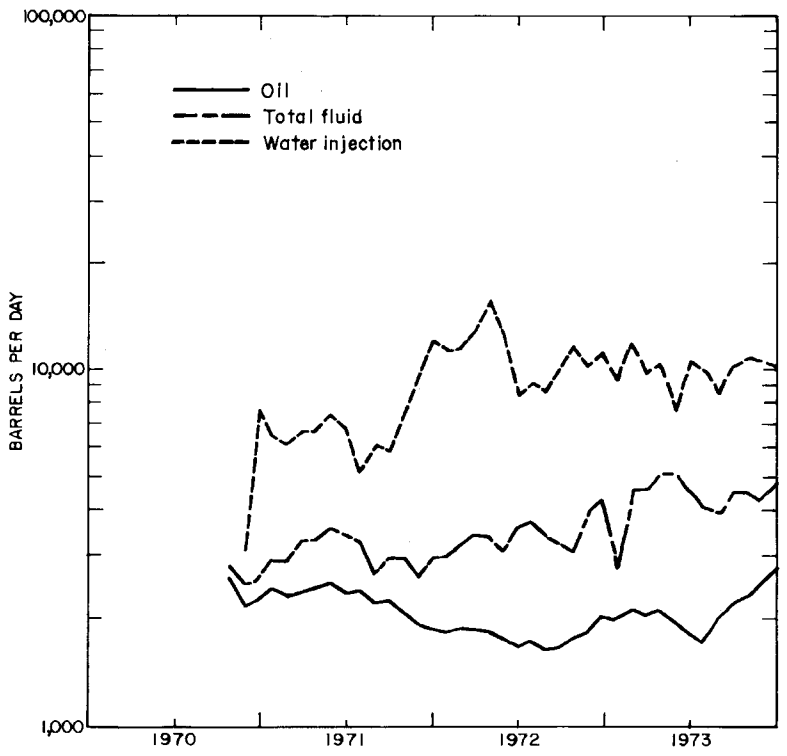

FIGURE 3. - Performance curve of Bell Creek unit "B."

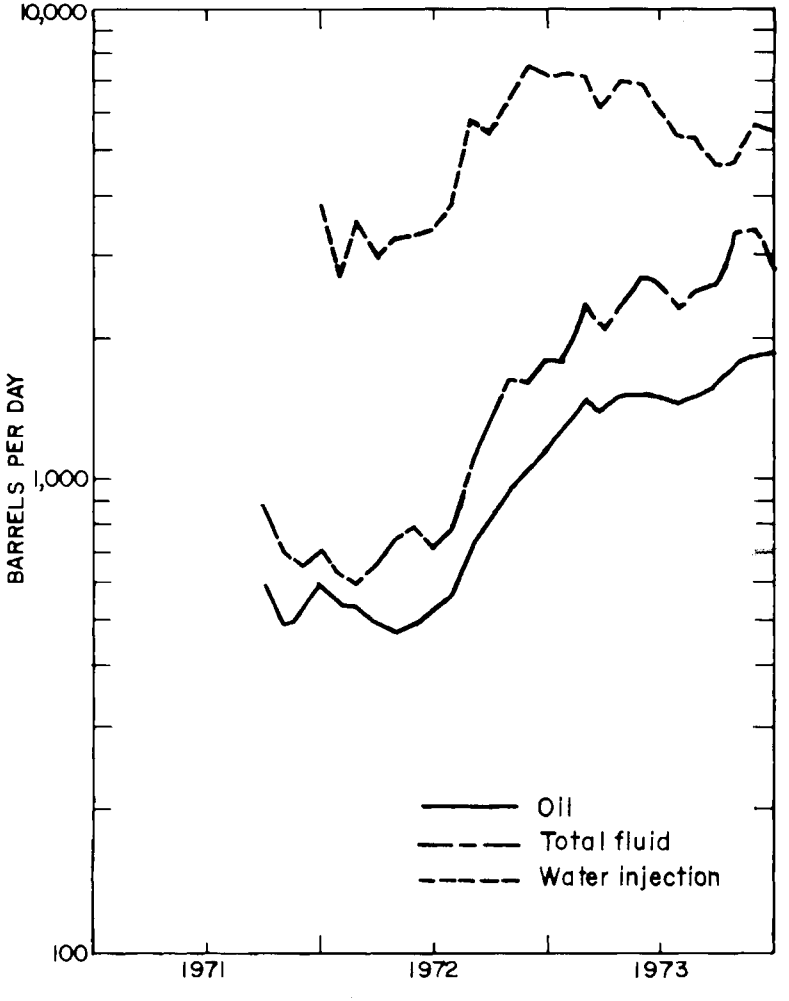

FIGURE 4. - Performance curve of Bell Creek unit "C."

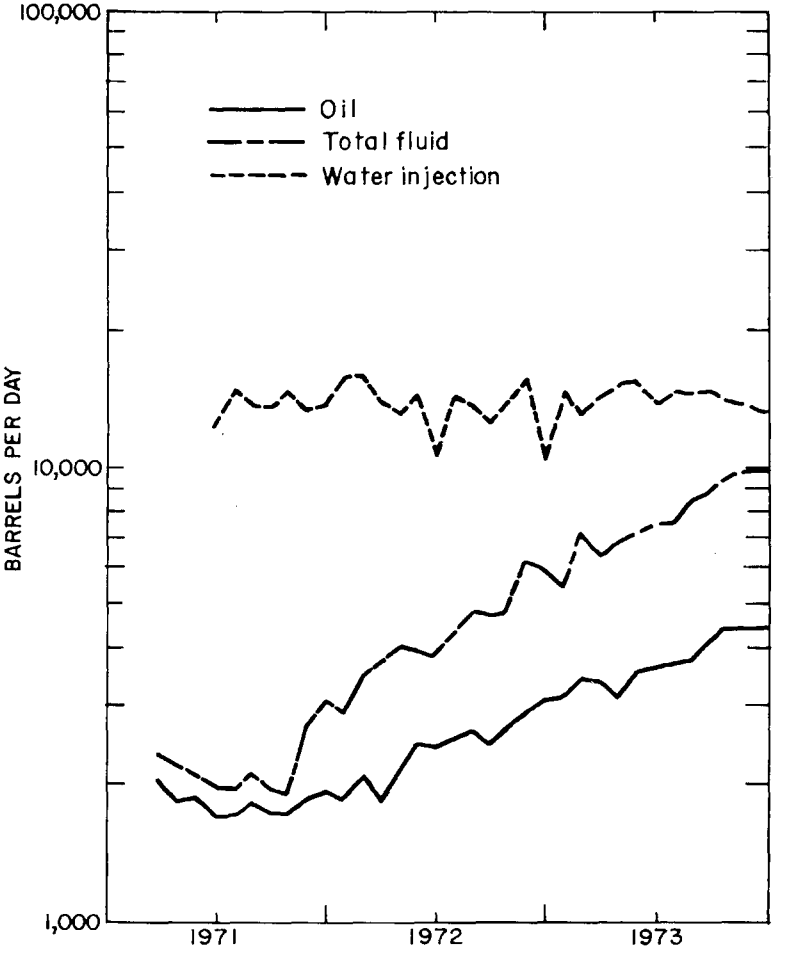

FIGURE 5. - Performance curve of Bell Creek-Ranch Creek unit.

Bell Creek Unit "A"

Water injection started in July 1970. After 2 months, oil production increased, but water production was nearly constant. Since February 1971, water production has increased steadily. Considering the high permeability of the Muddy sand, the rate of production increase has been less than anticipated. The number of producing wells declined by five, or one-third, in the time shown on the graph and may indicate some water channeling.

The water injection curve reflects only minor mechanical variations. Unit "A" is the largest of the Bell Creek units.

Bell Creek Unit "B"

Water injection started in November 1970. Water production increased slightly in 60 to 90 days. This could mean minor channeling in a well or two. A general increase in water production has continued. For the period shown, the water production increased from 8 percent to 51 percent of total production. Oil production improved until mid-1971 and then declined but may have begun a significant increase in late 1972.

Water injection, although increasing in volume, does show signs of mechanical or supply problems.

Bell Creek Unit "C"

Oil and water production showed a reaction to the water injection after 2 or 3 months. The oil production increase looks very good. Water production has about doubled but is not a problem. The water injection curve shows a generally smooth and increasing rate.

Bell Creek-Ranch Creek Unit

Water injection commenced in June 1971. Total fluid production reacted shortly after start of injection. Total fluid production increased from about 2,000 barrels to 6,000 barrels daily in 18 months. Daily water production was about 3,000 barrels at the end of 1972. Water injection has been reasonably constant. The number of producing wells declined about one-third in 18 months. Water channeling may soon be a problem.

Bowes Field

Fluid production data on the Bowes field are available for 5 years before injection began, giving a more reliable decline line. The curve for total fluid produced is generally flat for the entire time, ruling out any direct water channeling.

During the 5 years before water injection started, the daily oil production declined about 600 barrels. In the 7 years after water injection started (fig. 6), the daily oil production declined 100 barrels or less. Thus, the oil production decline was arrested. By extending the oil production before injection through 1971, one has a basis for estimating oil produced as a result of the waterflood. This oil is the difference between the actual oil production line (after injection) and the extended preinjection trend. A conservative estimate of additional recovery would be 250,000 barrels of oil; a more optimistic figure would be 800,000 barrels.

The water injection curve indicates continuing mechanical or supply problems or both. The graphs for Bowes field show a good, well-controlled waterflood. The daily oil produced per well was down to 8 barrels in December 1971. Considerable downtime occurred in mid-1972. Oil production continues to show sensitivity to water injection.

Cabin Creek Field

Disposal of produced water became necessary at Cabin Creek field in 1958. Some water was pumped into the Dakota zone and later some into the Madison zone.

Injection in the Siluro-Ordovician zones began in 1959. The Siluro-Ordovician zones are mostly carbonate rocks, fractured in part, and have a natural water-drive. The water injection at Cabin Creek is a pressure maintenance effort.

The oil production curve (fig. 7) shows some flattening but almost zero decline for the 1965-71 period. Daily water production has about doubled in the same period. Daily water injection has increased from 1,000 barrels in 1961 to about 50,000 barrels in 1971. From 1961 through 1971, the number of producing wells declined from 100 to 71.

The Cabin Creek project has been an operational success. Additional oil has been produced. Considering the amount of water pumped into the producing zone, the increased water production has been very reasonable even through 1972-73.

Cat Creek Field

Curves are available for Cat Creek waterflood units 1 and 2 and Mosby Dome (figs. 8-10). The First and Second Cat Creek sands are of Cretaceous age, mostly sandstone, and not fractured.

The total fluid and oil production curves for unit No. 1 responded almost immediately to water injection. A good increase in oil production is shown. Injection stopped in late 1968 and was resumed in mid-1970. Oil production again increased.

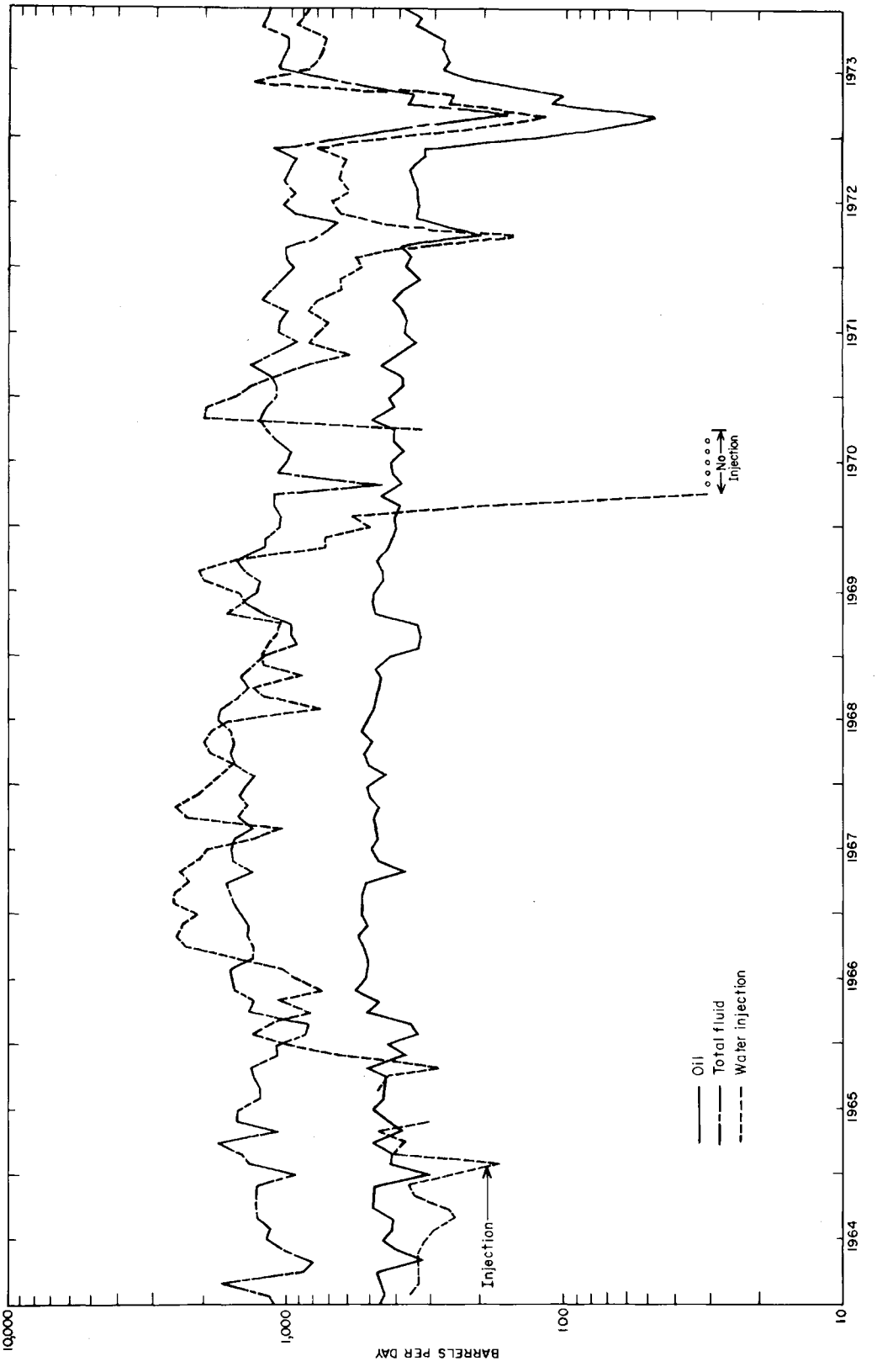

FIGURE 6. - Performance curve of Bowes field.

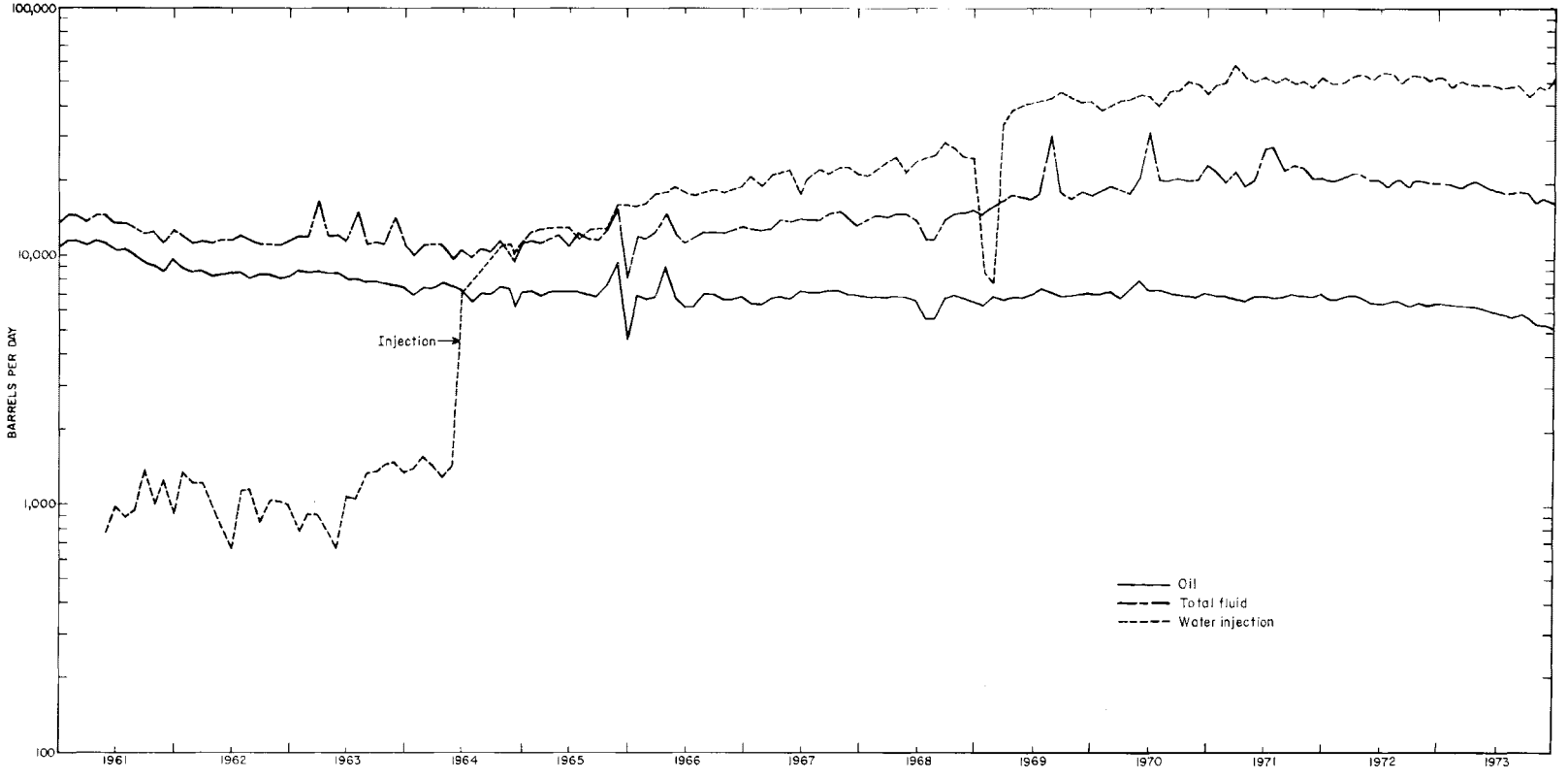

FIGURE 7. - Performance curve of Cabin Creek field.

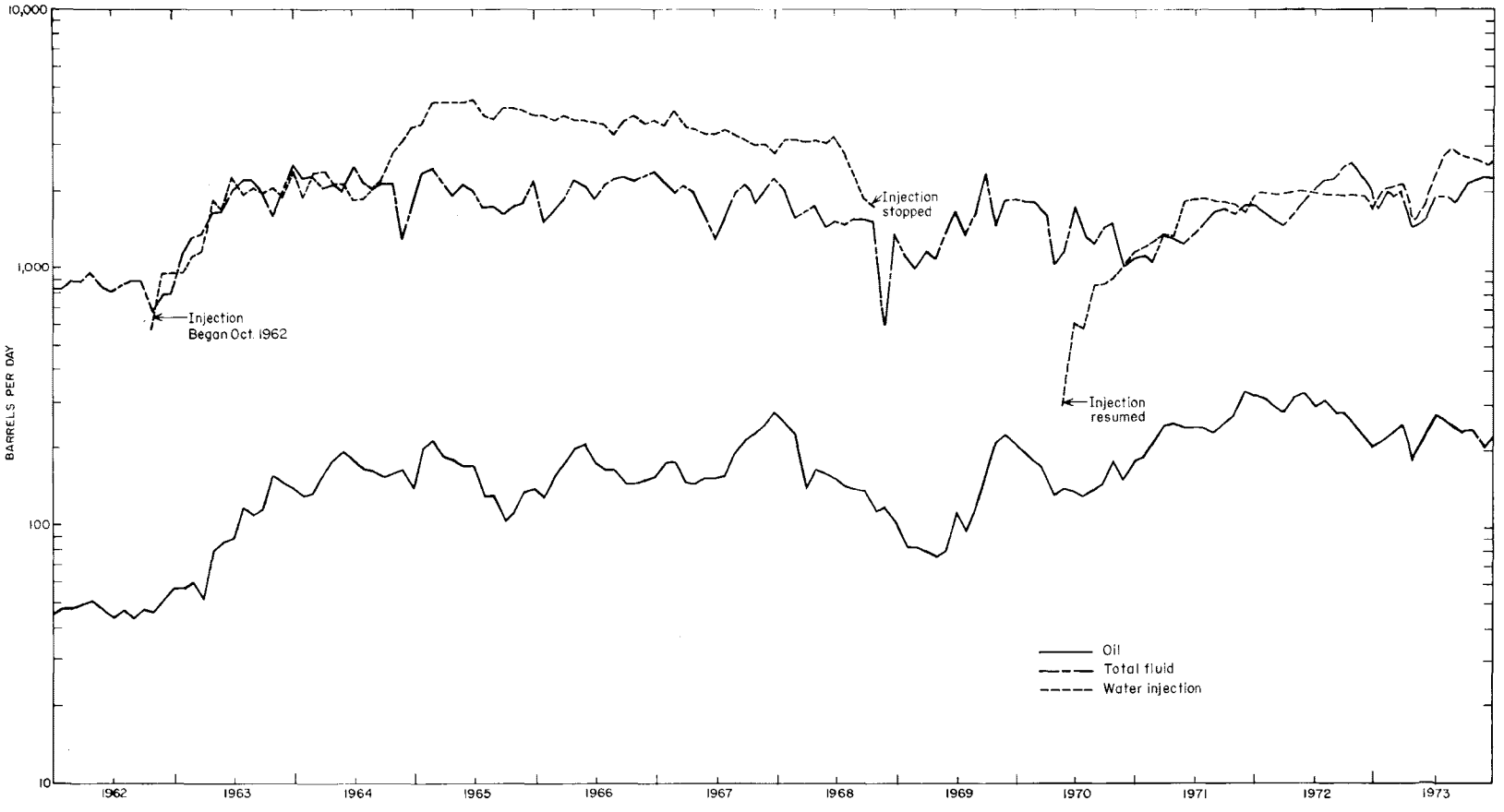

FIGURE 8. - Performance curve of Cat Creek unit No. 1.

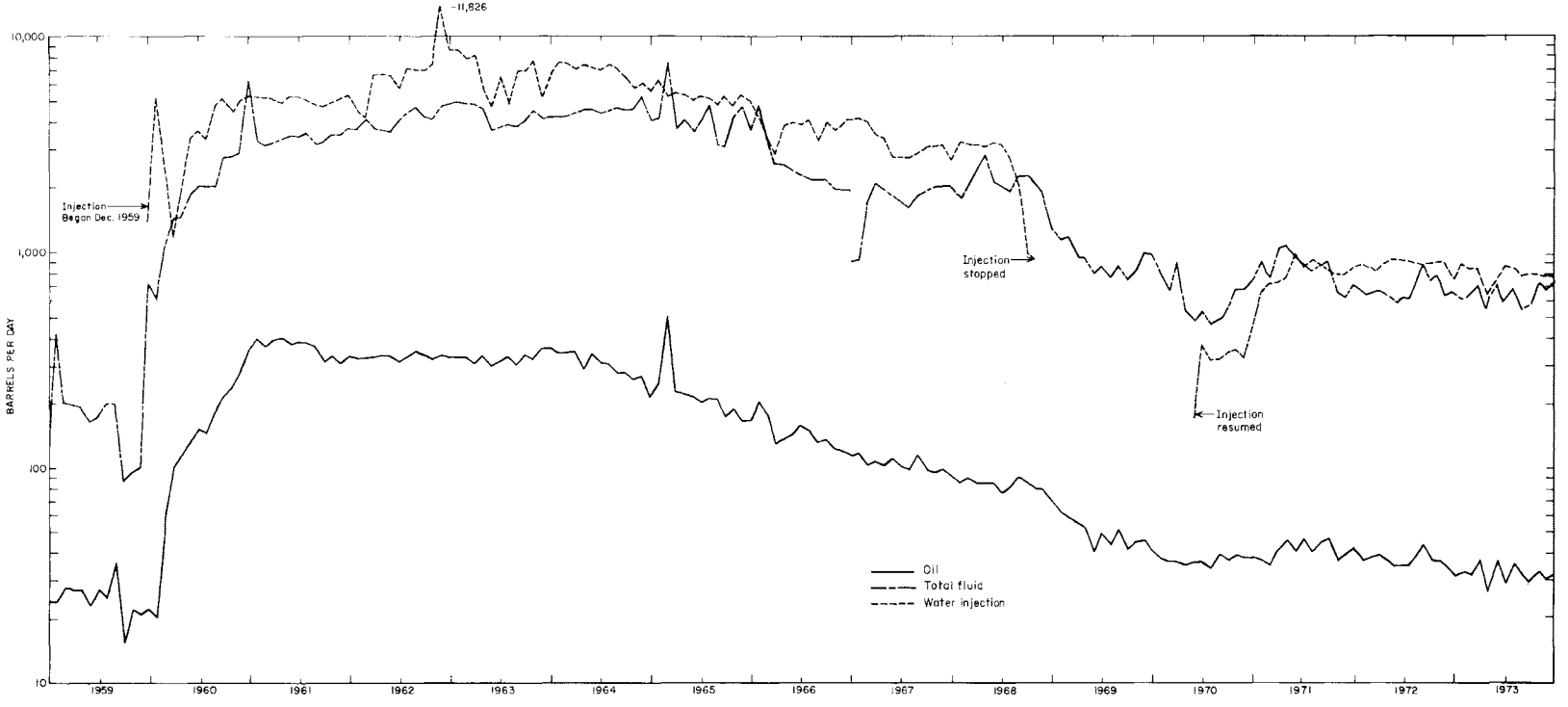

FIGURE 9. - Performance curve of Cat Creek unit No. 2.

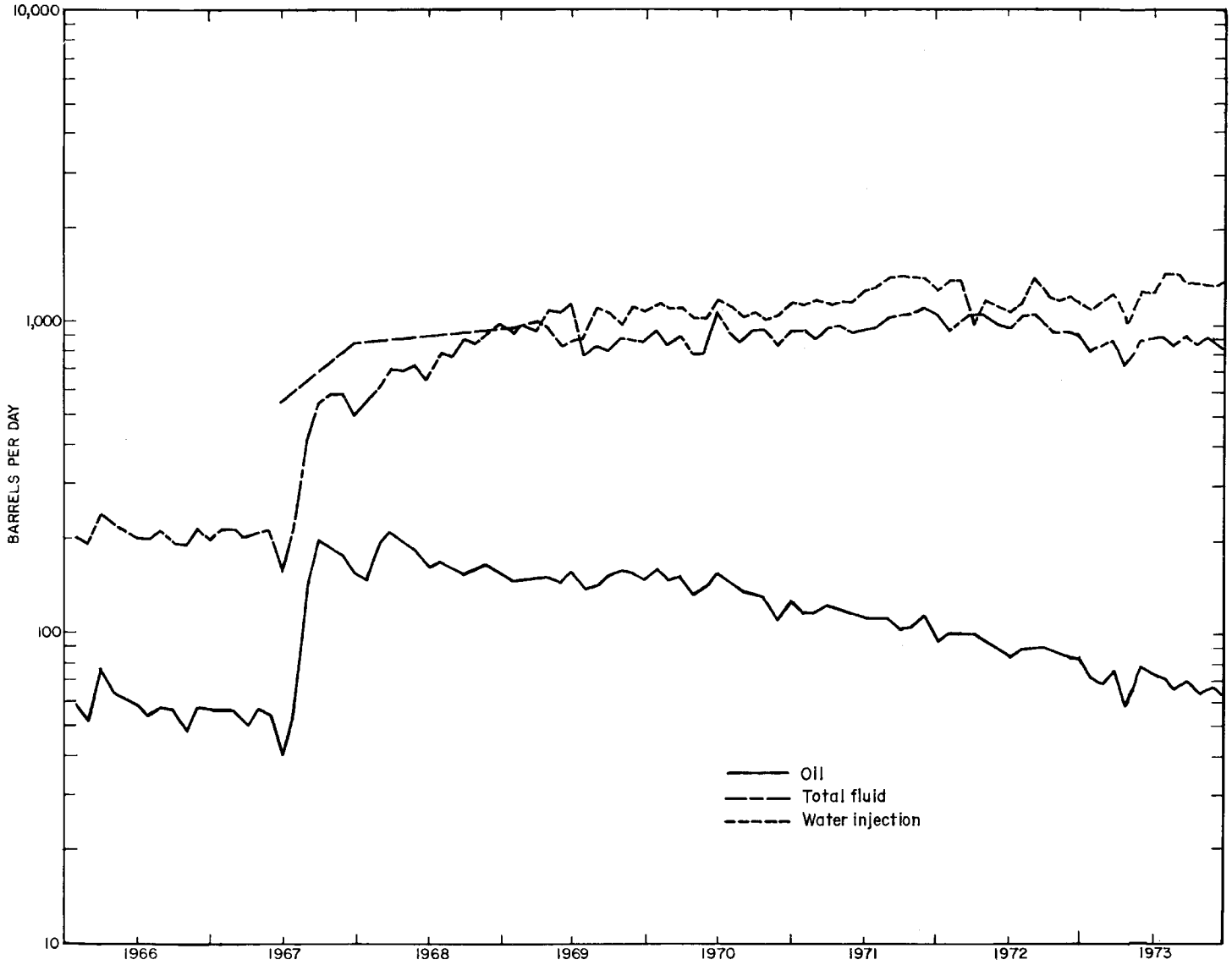

FIGURE 10. - Performance curve of Mosby Dome (Cat Creek).

Oil and total fluid production at Cat Creek unit No. 2 also increased shortly after water injection started. Injection was shut in from late 1968 to mid-1970. Reaction to the second water injection program is visible but not spectacular.

The Mosby Dome Swift sand waterflood reacted favorably. Water production increased about threefold but not enough to be a burden.

Data on the three waterfloods are presented to show definitely successful operations. The Cat Creek units were old fields before flooding began.

Cut Bank Field

Information is presented on the Northeast Cut Bank sand unit, the Northwest Cut Bank sand unit, the Texaco-Lander sand unit, and the Red Creek Cut Bank sand unit. The Red Creek unit is a relatively new part of the field, whereas the other three units are older areas.

Production curves for the Northeast Cut Bank sand unit (fig. 11) show no reaction to water injection for about 18 months. After 1965, oil production exhibits a positive flat trend. Water production did not definitely increase until early 1969 after trouble had developed in the 1967-68 winter. Water injection has been fairly uniform but was reduced in 1970-71, probably because of increased water production. Some problem caused a sharp decrease in injection in July 1971.

Production curves for Northwest Cut Bank sand unit (fig. 12) flattened out soon after water injection was started. Total fluid production gained substantially after about 30 months of water injection. A good "bank" of reservoir fluid formed in front of the injected water because water production was almost constant for 4 years. The fluid production for 1966-71 shows that injection water had reached some of the producing wells. The water injection curve shows a major problem only for a period in 1971.

The Lander sand unit curves (fig. 13) show oil production increasing after about 6 months of water injection. Water production was minor until early 1968 when it advanced sharply and then continued to gain while oil production declined. The water injection curve shows nothing unusual.

The Red Creek unit, youngest of the unit areas shown (fig. 14), had the least reaction to water injection. There was no significant increase in either oil or water production. Of the four Cut Bank units illustrated, the Red Creek unit was the least successful.

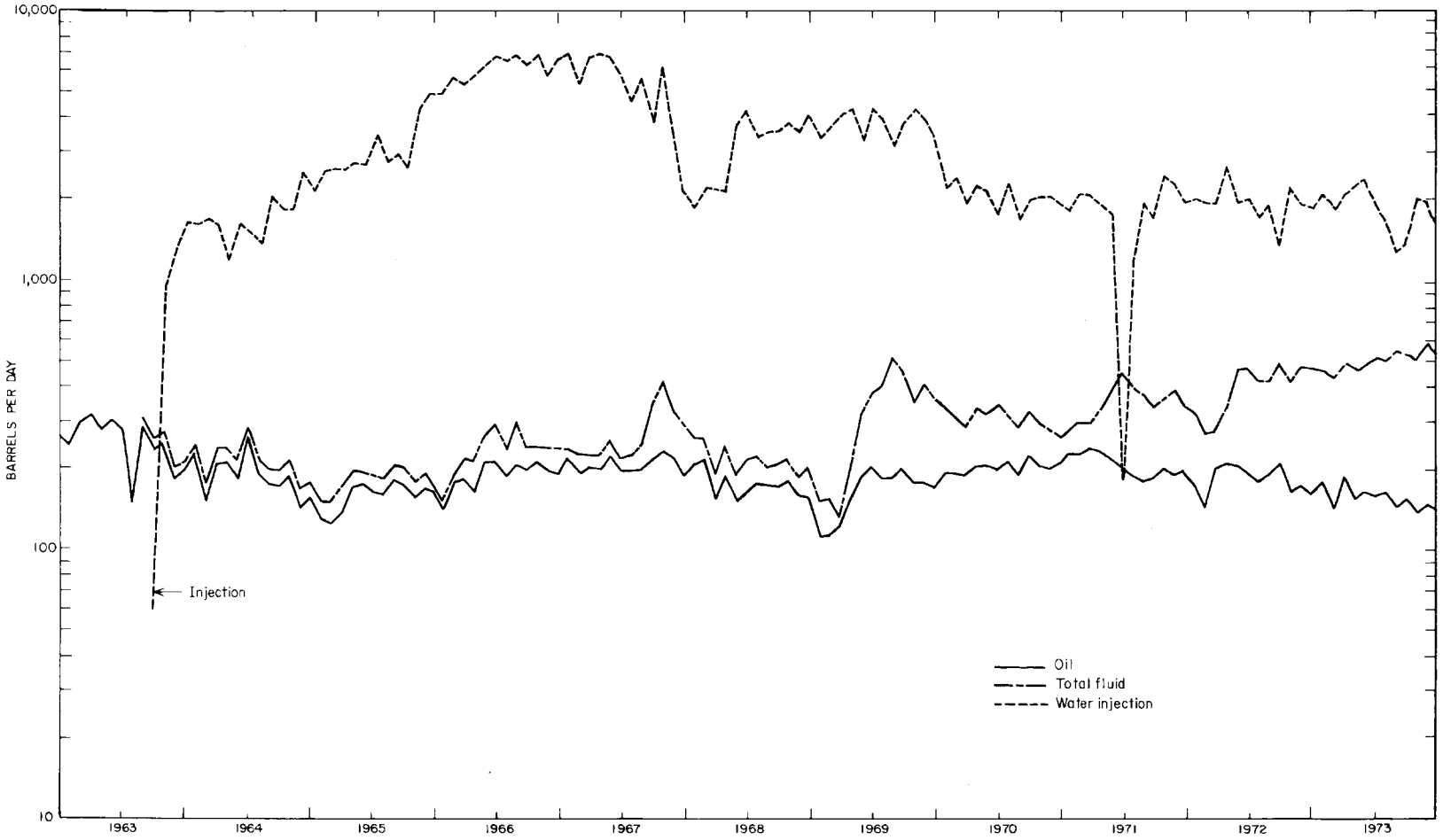

FIGURE 11. - Performance curve of Cut Bank, Northeast.

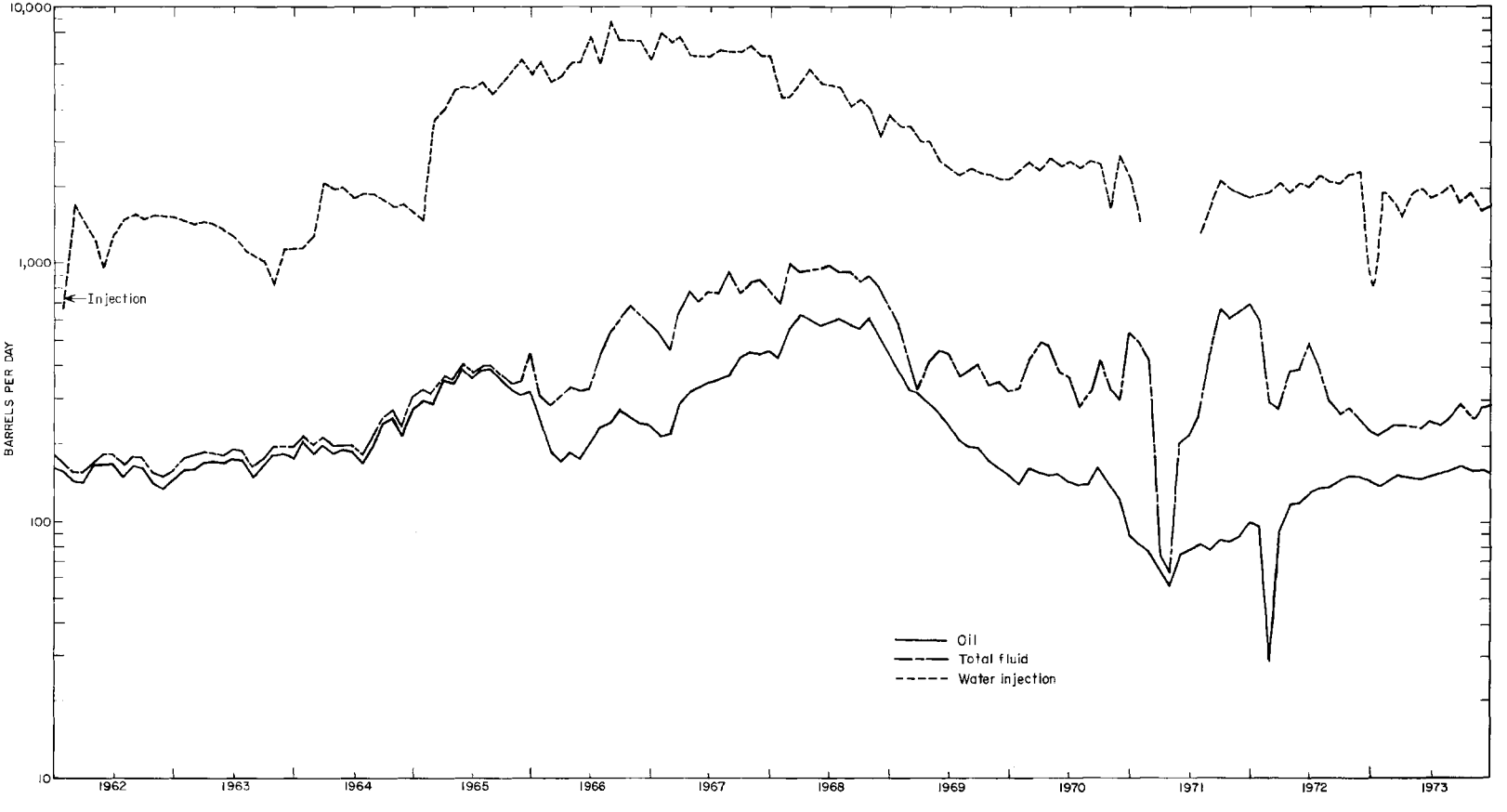

FIGURE 12. - Performance curve of Cut Bank, Northwest.

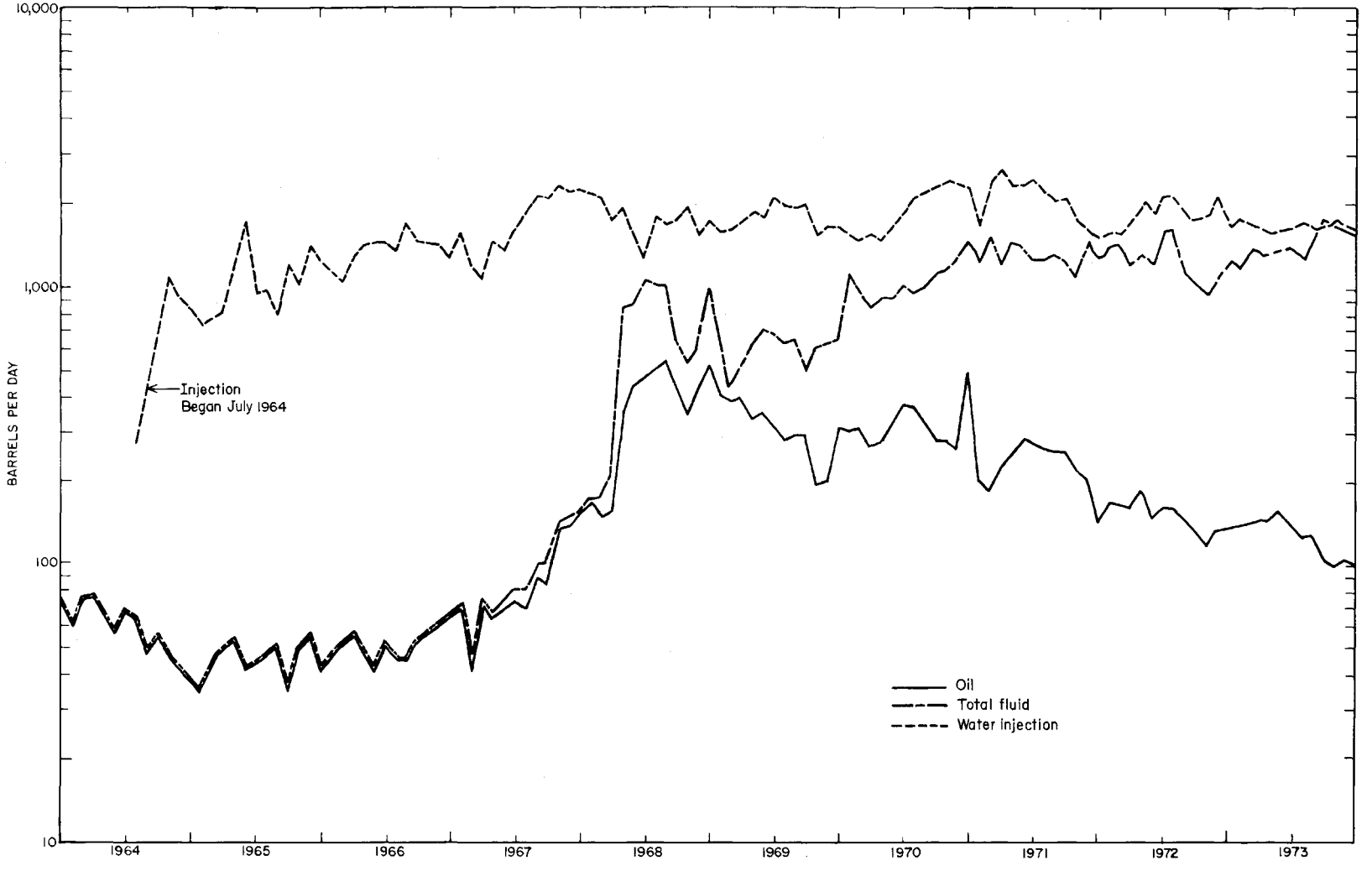

FIGURE 13. - Performance curve of Cut Bank, Lander sand unit.

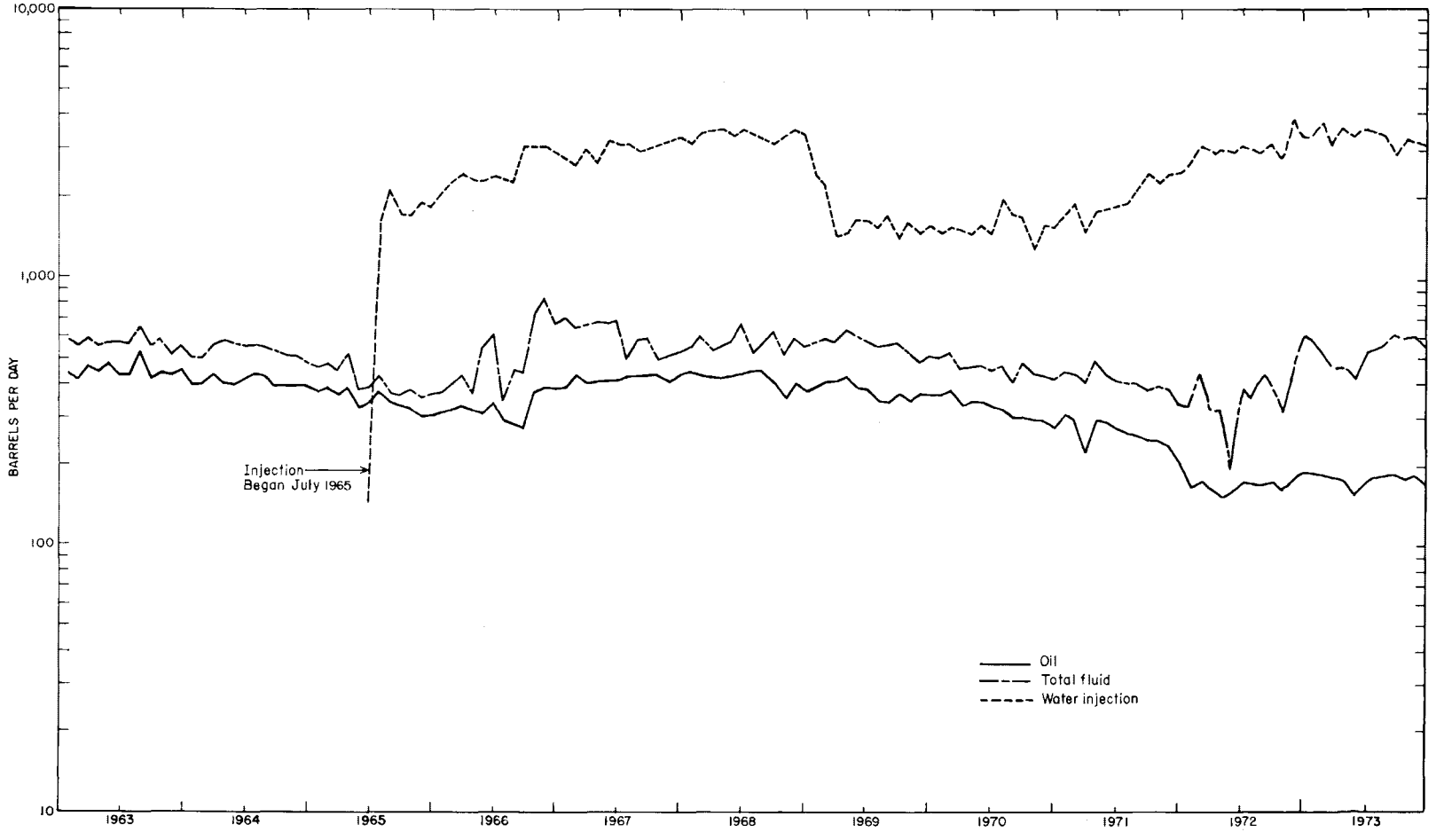

FIGURE 14. - Performance curve of Cut Bank-Red Creek unit.

SUMMARY

This Bureau of Mines report covers 77 waterflood projects in 31 Montana oilfields. The purposes of the study are to show the locations of the projects, the sources and amounts of injection water, and the results in oil produced.

Primary sources of information were the reports and records of the Board of Oil and Gas Conservation, Department of Natural Resources and Conservation, State of Montana. Previous Bureau of Mines reports also were freely used.

Waterflooding, a secondary recovery technique, did not really begin in Montana until about 40 years after the initial oil discovery at the Cat Creek oilfield in 1920. In some instances, waterflood projects apparently have stemmed from an initial need to dispose of saltwater by injection. Occasionally, too, the difference between water disposal by injection and pressure maintenance operations is not clearly evident.

In 1973, the 31 fields having waterflood projects produced 28.3 million barrels of oil valued at $88.4 million. In that year, water injected at the projects covered by this report was 157.7 million barrels. Both in volume and value, the figures constituted more than 80 percent of Montana's petroleum production in 1973. The waterflood projects are making possible the recovery of additional oil, thus contributing to conserving petroleum and lessening the impact of the current oil shortage.

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