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INJECTION OF WATER INTO UNDERGROUND RESERVOIRS IN THE STATE OF MICHIGAN

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ABSTRACT

Injection of water in Michigan has been solely for the purpose of disposal, but regulations have been such that in excess of 90 per cent of oil-field waters are returned underground. The paper discusses the types of equipment used in injection wells and disposal systems, as well as describing the injection characteristics of each of the seven different formations employed for disposal purposes. Statistics on injection wells by years and by formations are detailed and summarized.

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INTRODUCTION

This study of water injection into underground reservoirs in the state of Michigan is made by the author as a member of the API Eastern District Production Technology Committee. It is stated at the outset that, with one exception, there is no record of water injection in the state of Michigan having been performed for the expressed purpose of secondary recovery of oil but, rather, that the primary purpose of all wells and projects investigated has been for the disposition of water into underground reservoirs in order to prevent pollution of lands, surface waters, and shallow-water wells. The sole exception was the periodic injection of small quantities of water in conjunction with a gas-injection program in the Greendale Field. This was done in one well for a period of approximately 3 weeks in 1932.

The source of information for this study has been semi-annual and special reports of the Oil and Gas Division of the Michigan Department of Conservation, from personal contact with the employees of this department and with the personnel of operating companies, and from general experience in this state.

Purpose

The purpose of this study is to compile all the available statistical information pertinent to water injection in Michigan, to analyze these data in order that significant conclusions might be reached, to describe sufficiently the physical injection and its inherent problems, in order that all such facts will be available for the use of Michigan oil operators and the industry as a whole.

History of Water Injection.

The tourist trade is the second largest industry in the state of Michigan, and for that reason the Department of Conservation in this state has paid particular attention to the matter of prevention of stream pollution resulting from the disposition of oil-field wastes into surface waters. An excerpt from the "general rules and regulations" governing oil and gas operations in the state of Michigan, effective May 1, 1941, best explains the attitude of this department, and is as follows:

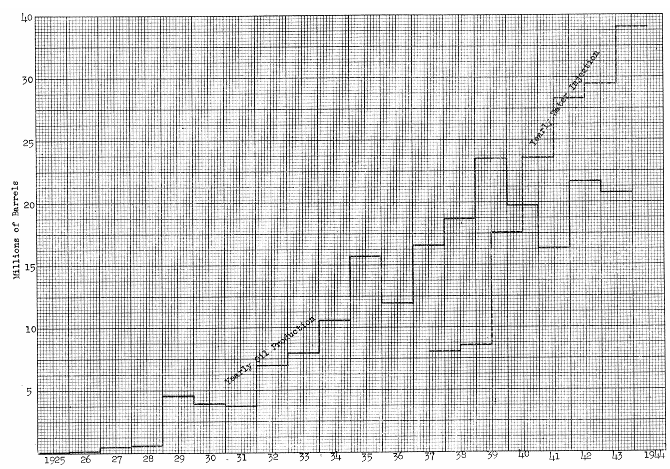
"Brine or salt water produced in the drilling for, or the production of, oil shall not be run to earthen reservoirs or ponds, except for such reasonable time and under conditions as may be approved by the supervisor, or his authorized representative, after which it must be returned to some underground formation or otherwise disposed of as approved by the supervisor where it cannot do damage to any fresh water, oil, gas, or other minerals."

It is for this reason that the oil and gas industry in the state of Michigan in recent years has had such an enviable record in returning underground in excess of 90 per cent of the oil-field water produced, the balance going to ponds constructed for storage. Reference is made to Fig. 1 which illustrates graphically total oil production in the state by years from 1925 through 1944, together with the total yearly water injected during this period. It is noteworthy that during 1937 and 1938 the total water injected was equal to half the total oil produced, whereas currently total water injected is equal to 1½ times the oil produced. Total water injected underground to midyear 1944 is in excess of 150,000,000 bbl.

Fig. 2 is a generalized transverse section of the Michigan synclinal basin from which area the majority of the oil is produced and into which area all of the water is injected. This figure illustrates the approximate thickness and depth of the formations which are used for water disposal, viz., the Drift, the Parma, the Marshall, the Coldwater, the Traverse, the Dundee-Monroe, and the Sylvania. Fig. 3, which is included for reference, shows the location of principal Michigan oil fields.

Table 1 lists water-injection wells by fields and indicates: the formation or formations into which each well is opened, the type well, the estimated cumulative injection to June 30, 1944, the 1944 approximate daily rate of injection, and whether or not the well operates on a pressure or vacuum. A search of the records reveals that there was little information available on water injection previous to 1937, notwithstanding the fact that there were probably a few water-injection wells in existence previous to that time. Therefore, the total cumulative injected barrels contained in this report include no water previous to 1937. It is to be appreciated that the water-injection volumes were prepared from semi-annual estimates of the daily average injection as of July 1 and January 1. Naturally, a change in method of operation would involve errors in the calculation of these total quantities, but it is believed that these errors are sufficiently compensating to make the totals a reliable estimate.

Table 2 is a summary of statistical data revealing by years: the number of wells, the daily average rate of injection, and the yearly total injection in the different types of wells used for water disposal. Table 3 is an analysis of 1944 injection, showing for each injection formation: the number of wells, and the total yearly injection for 1944, with a breakdown as to the wells operating by pressure or by gravity. Further analysis reveals the percentage of the total number of wells and percentage of the total water injected, as well as the average rate of injection for each respective formation.



Michigan Yearly Oil Production and Water Injection.

FIG. 1

Description of Operations

Well Completion and Operation

There are 3 general classifications of disposal wells insofar as the mechanics of completion and operation are concerned: 1, wells which inject water into the annular space between casing strings; 2, wells which were originally dug in search for or were used for production of oil and gas and were later converted to water-disposal wells; 3, wells which were dug for the specific purpose of water injection.

Table 2 illustrates that, although there have been 316 wells which injected water between the casings and 120 which have been completely converted to water disposal, the former type wells have contributed a total of approximately 50,000,000 bbl of water injected as compared to a total of 97,000,000 bbl for converted wells. There have been only 18 wells dug specifically for the purpose of water disposal, and the total water injection into this type of well has been less than 3,000,000 bbl to date. In view of the fact that there are so many disposal wells in the state injecting water between strings of casing, it would be helpful perhaps to mention briefly the method of well drilling and the casing program in order that this type of injection may be more understandable.

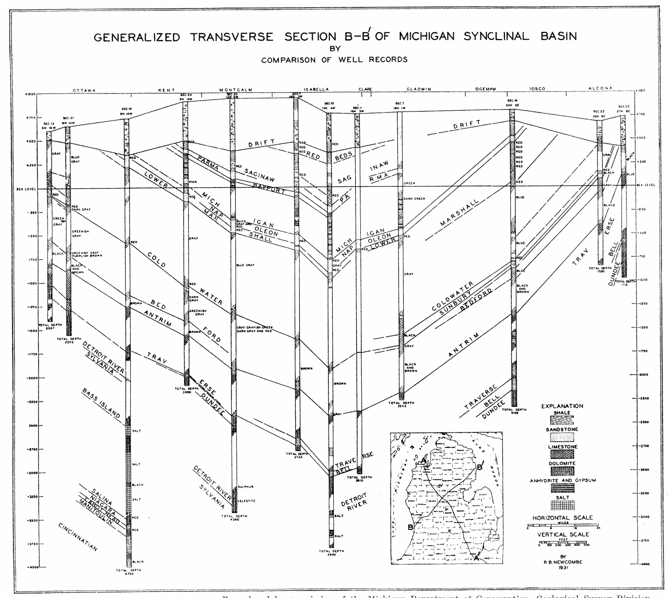


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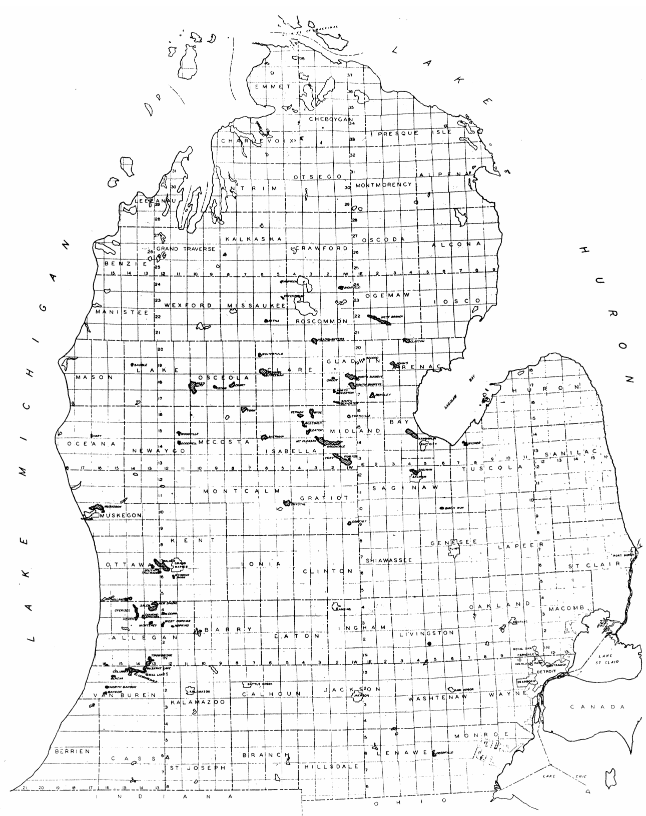
FIG. 2



Map of Michigan Oil Fields.

FIG. 3

The thickness of the glacial drift in Michigan varies from 100 ft to 1,100 ft. A great percentage of the wells are drilled with cable tools, and in such cases surface casing is generally driven completely through the Drift. Many, although not all, of the cable-tool wells, set a permanent intermediate casing string. Most production strings are set on a shoulder with a packer, and without the use of cement. Surface casing in rotary-drilled holes is set from 100 ft in the Drift to the base of the Drift. Both intermediate strings, when used, and production casing strings are cemented in the rotary holes. The resulting casing programs in both cable-tool and rotary wells make available the annular spaces between the surface casing, the intermediate casing, and the production casing, for water disposal to any of the several formations which are usable for this purpose.

Wells converted for salt-water disposal may use the formation in which they were originally completed, may have been deepened to other horizons, or may have been perforated in shallower permeable zones. Wells dug specifically for the purpose of salt-water injection have been dug to the Drift, to the Parma, but no deeper than to the Marshall formation.

TABLE 1

Tabulation of Water-Injection Wells

STATE OF MICHIGAN

Operator	Well	Formation	Type Well *	Barrels Per Day Injected (P=Pressure G=Gravity) 12-31-43	Cumulative Injection to 6-30-44 (Barrels)	1944 Injection Data Not Included in Summary, Analysis, or Manuscript: Barrels Per Day Injected 12-31-44	1944 Injection Data Not Included in Summary, Analysis, or Manuscript: Cumulative Injection to 6-30-45 (Barrels)	Remarks
ALLEGAN COUNTY								
Fillmore Field:								
Carl E. Grimes	Wilterdink No. 1	Traverse				45	16,425	
Michigan Development and J. W. Lang	Dozeman-Schaap No. B-1	Traverse				48	17,520	
						93	33,945	
New Salem Field:								
American Drilling Co.	Loew No. 1	Coldwater	A		14,600		14,600	
Borough and Fleming	Fein 2	Coldwater	A	200 G	379,600	130	427,050	
Chapman Oil Co.	Weber 3	Traverse	C	135 G	116,800	97	152,205	
Gordon Oil and Basin Oil	Weber 2	Traverse	C	30 G	82,125	12	86,505	
Gordon Oil and Basin Oil	Weber A-2	Coldwater	A		36,500		36,500	
Gordon Oil and Wilson	Miller 2	Coldwater	A	60 G	22,630	60	44,530	
Muskegon Oil Corp.	Sutter 2	Coldwater	A	30 P	87,600	35	100,375	
Socony-Vacuum	Loew 3	Traverse	C	315 G	320,470	343	445,665	
Vorhees Drilling Co.	Loew 1	Coldwater	A	40 G	14,600	40	29,200	
				810	1,074,925	717	1,336,630	
Otsego Field:								
Robert B. Patrick	Zierle and Stone 1 and 2	Coldwater	A	153 PP	55,845		55,845	
				153	55,845		55,845	
Salem Field:								
Socony-Vacuum	Thomas 2	Traverse	C	75 G	98,550	23	106,945	
				75	98,550	23	106,945	
Trowbridge Field:								
P. S. Anheuser	Tripp 1	Coldwater	A	125 P	69,350	60	91,250	
F. T. Canon	Dickinson 1	Coldwater	A	60 P	21,900		21,900	
F. T. Canon	Morgan 1	Coldwater	A	30 P	10,950		10,950	
F. T. Canon	Woodham 1	Coldwater	A			40	14,600	
Clapsaddle and Harris	Beldon 1	Coldwater	A		27,375		27,375	
Dreiske and Bridgeman	Dreiske and Bridgeman 1	Coldwater	A	50 G P	29,200	40	43,800	
J. E. Flanigan	Brown 1 and No. 2	Coldwater	A	200 G	229,950	150	284,700	
J. E. Flanigan	Clair 1 and 2	Coldwater	A		109,500	75	136,875	
H. L. Gentry Engineering Co.	Keene 1	Coldwater	A		10,950		10,950	
Hardy	Bridgeman 1	Coldwater	A	60 P	71,175	40	85,775	
E. G. Hartman	Marble and Parks 1	Coldwater	A	125 P	118,625	100	155,125	
E. G. Hartman	Waterman 1	Coldwater	A	195 P	195,275		195,275	
E. G. Hartman	Waterman- 1 / Lindsley 2	Coldwater / Traverse	A / C	G Traverse 200 P Cold-water	164,250	100	200,750	Waterman-Lindsley No. 2 Traverse in 1942.
Haynes Oil and Gas	Hadden 1	Coldwater	A		18,250		18,250	
Herz	Shafer 1	Coldwater	A	60 G	73,000		73,000	
R. D. Malcolm	Graves 1	Coldwater	A		25,550		25,550	
J. W. McIntosh	Darby 1	Coldwater	A	20 G P	29,200	20	36,500	
Miller Brothers	Foster 1	Coldwater	A	27 G	91,980	20	99,280	
Roth and Banierla	Brown 1	Coldwater	A	32 P	20,805	30	31,755	
Roth and Banierla	O'Dell 1	Coldwater	A	45 P	45,625	140	96,725	
Roth and Banierla	Wilson 1	Coldwater	A	20 G	10,950		10,950	
Schrauben	Wilson 1	Coldwater	A	15 P	10,950		10,950	
L. Sleep	Bridgeman 1	Coldwater	A	75 G	136,145		136,145	
H. C. Williams	Wilson 1	Coldwater	A	80 P	65,700		65,700	
A. W. Winchester	Russell 1	Coldwater	A		21,900		21,900	
				1,419	1,608,555	815	1,906,030	

TABLE 1—Continued

Operator	Well	Formation	Type Well *	Barrels Per Day Injected (P=Pressure G=Gravity) 12-31-43	Cumulative Injection to 6-30-44 (Barrels)	1944 Injection Data Not Included in Summary, Analysis, or Manuscript: Barrels Per Day Injected 12-31-44	1944 Injection Data Not Included in Summary, Analysis, or Manuscript: Cumulative Injection to 6-30-45 (Barrels)	Remarks
ALLEGAN COUNTY—Continued								
West Hopkins Field:								
Muskegon Development Co.	Knorr 1	Traverse	C	20 G	23,725	60	45,625	
Muskegon Development Co.	Pauschel 2	Traverse	C		7,300		7,300	
C. A. Perry	McDermott 1	Coldwater	A		5,475		5,475	
Perry, Gould and Cross	Nicolai 2	Coldwater	A	50 P	29,200	50	47,450	
Perry, Gould and Cross	Shafer 4	Coldwater	A	50 G	47,450	50	65,700	
Sprenger Bros.	Wamhoff 1	Coldwater	A	70 P	45,625		45,625	
				190	158,775	160	217,175	
ARENAC COUNTY								
Adams Field:								
Basin Oil Co.	Templin 1	Marshall	A	12 P	11,680	10	15,330	
Ingram-Rodgers	Ames 1	Parma				50	18,250	
E. Major	Bryan 2	Traverse	C	400 P	435,810	625	663,935	
E. Major	Collins 1	Traverse	A		7,300		7,300	
E. Major	Dubey 1	Marshall	A		5,475		5,475	
E. Major	Moore 1	Marshall	A		14,235		14,235	
E. Major	Shearer 2	Marshall	A	49 P	40,880	51	59,495	
E. Major	Solomon 1	Marshall	A		5,840		5,840	
The Pure Oil Co.	McTaggert 4	Traverse	C	684 P	249,660	684	499,320	
The Pure Oil Co.	Yenoir 1	Traverse	A		449,315		449,315	
Don Rayburn	Marsh 1	Marshall	A	2 G	1,460	2	2,190	
Don Rayburn	Milne 1	Marshall	A	40 G	14,600		14,600	
Don Rayburn	Milne 2	Marshall	A		24,455	45	40,880	
Don Rayburn	White 1	Marshall	A		5,475		5,475	
Rayburn and Major	Collins 2	Traverse				20	7,300	
				1,187	1,266,185	1,487	1,808,940	
Clayton Field:								
McClanahan Oil Co.	Buffalo Land	Traverse	C		25,550		25,550	
McClanahan Oil Co.	Seignious 2	Traverse	C	257 P	93,805	282	196,735	
Swanson Oil Co.	Shepard 5	Traverse	C	1,150 P	1,412,550	1,200	1,850,550	
The Ohio Oil Co.	Berry 3	Traverse	C	70 P	226,300	75	253,675	
The Ohio Oil Co.	Mills A-3	Traverse	A			100	36,500	
The Ohio Oil Co.	Mills 2	Traverse	A			300	109,500	
The Ohio Oil Co.	Whiting 5	Traverse	C	900 P	1,177,125	900	1,505,625	
				2,377	2,935,330	2,857	3,978,135	

TABLE 1—Continued

Operator	Well	Formation	Type Well *	Barrels Per Day Injected (P=Pressure G=Gravity) 12-31-43	Cumulative Injection to 6-30-44 (Barrels)	1944 Injection Data Not Included in Summary, Analysis, or Manuscript: Barrels Per Day Injected 12-31-44	1944 Injection Data Not Included in Summary, Analysis, or Manuscript: Cumulative Injection to 6-30-45 (Barrels)	Remarks
CLARE COUNTY								
Freeman-Redding Field:								
American Drilling Co.	Newcomer 8	Monroe	C					Newcomer No. 8 abandoned in 1944.
	State "K" 2	Monroe	C	3,600 G	3,661,315		3,661,315	
American Drilling Co.	State "K" 1 and 2 and Newcomer 8	Parma and Marshall	C			3,400	1,241,000	
American Drilling Co.	State "X" 32	Parma	A	40 P	29,200	40	43,800	
Basin Oil Co.	Van Horn 2	Dundee	C	2,620 G	1,505,260		1,505,260	
Daily Crude Oil	Van Horn 2	Monroe	C		328,500		328,500	
Freeman Oil Co.	Bicknell 1	Parma	A	85 P	31,025	330	151,475	
Freeman Oil Co.	Christensen 1	Parma	A		48,180		48,180	
Freeman Oil Co.	Redding-State 1	Parma	A	260 P	94,900		94,900	
Freeman Oil Co.	Redding-State 2	Dundee	A			300	109,500	
		Parma	A			350	127,750	
Freeman Oil Co.	Van Horn 2	Monroe	C			300	109,500	
Gulf Refining Co.	Arthur 1	Monroe	C	3,500 G	7,486,150	3,600	8,800,150	
Gulf Refining Co.	Van Horn 2	Monroe	C		511,000	1,500	1,058,500	
S. J. Higelmire	Van Horn 4	Parma	A		693,500		693,500	
S. J. Higelmire	Van Horn 2	Monroe	C		611,740		611,740	
S. J. Higelmire	Williams 1	Parma	A		142,350		142,350	
C. L. Maguire	Barlow 2	Dundee	C	310 G	665,760	300	775,260	Disposal in Parma until 1941.
C. L. Maguire	Coyne 4	Parma	A	640 P	779,275	400	925,275	
C. L. Maguire	Goldsmith-Wine 2	Dundee	C	145 G	190,165	145	243,090	
C. L. Maguire	Russell-Tope 1	Parma	A	35 P	49,275	50	67,525	
Mammoth Producing and Refining Co.	Van Horn 1 and 2	Parma	A		454,790		454,790	
McClanahan Oil Co.	Clare-State 2	Parma	A	10 P	636,925	100	673,425	
McClanahan Oil Co.	Redding-State 1	Parma	A	70 P	38,325	80	67,525	
The Pure Oil Co.	Douglas 1 and 2	Monroe	C	10,476 G	17,838,645	9,576	21,333,885	
Rowmar Oil Corp.	Silvernail 1	Parma	A	35 P	24,455	60	46,355	
Socony-Vacuum	Fell A-2	Monroe	C		3,613,500	300	3,723,000	
Socony-Vacuum	Fell 2	Monroe	C	350 G	894,250		894,250	
Socony-Vacuum	Fell B-4	Dundee				200	73,000	
Socony-Vacuum	Van Horn 8	Monroe	C	1,000 G	365,000	700	620,500	
Talbot Oil Co.	State B-2	Parma	A	850 P	739,125	1,005	1,105,950	
Talbot Oil Co.	State C-2	Parma	A	5 G	4,015		4,015	
Talbot Oil Co.	State-Redding 1	Parma	A		91,250		91,250	
Talbot Oil Co.	State-Redding C-2A	Parma	D					Well never used. Required too much pressure for injection.
C. W. Teater	Van Horn 8	Parma	A		401,500		401,500	
	Van Horn 2	Dundee	C		563,195	350	690,945	
Turner Petroleum	State F-1	Parma	A		17,155		17,155	
Turner Petroleum	Wheeler 1 and 3	Parma	A		256,230		256,230	
Wicklund Development Co.	Fell 1 and 2	Parma	A	500 G	697,150	500	879,650	
Wicklund Development Co.	Fell 2	Parma	A		10,950		10,950	
				24,531	43,474,055	23,586	52,082,945	
East Winterfield Field:								
Sun Oil Co.	State A-4	Dundee	C	1,660 G	1,611,840	2,848	2,651,360	
				1,660	1,611,840	2,848	2,651,360	

TABLE 1—Continued

Operator	Well	Formation	Type Well *	Barrels Per Day Injected (P=Pressure G=Gravity) 12-31-43	Cumulative Injection to 6-30-44 (Barrels)	1944 Injection Data Not Included in Summary, Analysis, or Manuscript: Barrels Per Day Injected 12-31-44	1944 Injection Data Not Included in Summary, Analysis, or Manuscript: Cumulative Injection to 6-30-45 (Barrels)	Remarks
CLARE COUNTY—Continued								
West Winterfield Field:								
Daily Crude	Schuett 2	Parma	C	130 G	51,830	140	102,930	
Pure Oil and Cities Service	Tope 1	Monroe	C	1,548 G	1,078,210	1,402	1,589,940	
Rowmar Corp.	Wyman 1	Parma	D	1,228 P	684,740	1,012	1,054,120	
Sun Oil Co.	Goodrich 1	Dundee	C	474 G	367,555	541	565,020	
				3,380	2,182,335	3,095	3,312,010	
GLADWIN COUNTY								
Buckeye Field:								
American Drilling Co.	Soldan 7	Parma	A	62 G	309,155	75	336,530	
T. F. Caldwell	Emmott 1	Parma	A		98,550		98,550	
T. F. Caldwell	Palmer 1	Parma	A	6 G	31,390		31,390	
H. H. Hart	Soldan 2	Parma	A		93,805		93,805	
Ralph LaBlanc	Campbell 3	Parma	A		30,295		30,295	
Mammoth Producing and Refining Corp.	State B-4	Parma				150	54,750	
Rex Oil and Gas	McKinney 3	Parma	A	175 G	63,875	150	118,625	
Rex Oil and Gas	McKinney 1 and 4	Parma	A		131,400		131,400	
Rex Oil and Gas	State "A"-2	Parma	A	60 G	21,900	50	40,150	
Rowmar-Cryden	Schaeffer 2 and 6	Parma	A		49,275		49,275	
Rowmar-Cryden	Schaeffer 5	Parma	A	192 G	70,080	300	179,580	
Socony-Vacuum	Dalley 4	Dundee	C		7,300		7,300	
Sun Oil Co.	Strohkirch 3	Dundee	C	165 G	89,425		89,425	
Sun Oil Co.	Strohkirch 9	Dundee	C		36,500	228	119,720	
C. W. Teater	Ademetes 5	Parma	A	10 G	10,950	10	14,600	
Wicklund Development Co.	State "A"-4	Parma	A		71,175		71,175	State A-1 and A-3 used in 1940 only.
Wicklund Development Co.	State "C"-4	Parma	A	20 G	16,060	25	25,185	State K-4 used in 1940 only.
Wicklund Development Co.	State "K"-3	Parma	A	12 G	37,595	15	43,070	
				702	1,168,730	1,003	1,534,825	
North Beaverton Field:								
M. F. Whitehill	W. Bell 1	Parma	A	88 G	130,670	85	161,695	
M. F. Whitehill	T. Bell 1	Parma	A		5,840		5,840	
M. F. Whitehill	Dell 1	Parma	A		9,855		9,855	
M. F. Whitehill	King 3	Parma	A	62 G	122,640	64	146,000	
M. F. Whitehill	Welker 1	Parma	A		5,110		5,110	
				150	274,115	149	328,500	
ISABELLA COUNTY								
Broomfield Field:								
R. Leuder	Bantlett 1	Parma	A		12,775		12,775	
McClanahan Oil Co.	Beutler 2	Parma	A		29,200		29,200	
The Pure Oil Co.	Embray 4	Parma	A	156 G	302,220	164	362,080	
The Pure Oil Co.	Latham Heirs 2	Parma	A		325,215		325,215	
The Pure Oil Co.	McClintic B-4	Monroe	C	891 G	210,970	974	566,480	
The Pure Oil Co.	Skarritt No. 3 and Willie 11	Parma	A		62,050		62,050	
The Pure Oil Co.	Willie 6 and 7	Parma	A		791,685		791,685	
The Pure Oil Co.	Willie 10 and 11	Monroe	C		542,025		542,025	
				1,047	2,276,140	1,138	2,691,510	

TABLE 1—Continued

Operator	Well	Formation	Type Well *	Barrels Per Day Injected (P=Pressure G=Gravity) 12-31-43	Cumulative Injection to 6-30-44 (Barrels)	1944 Injection Data Not Included in Summary, Analysis, or Manuscript: Barrels Per Day Injected 12-31-44	1944 Injection Data Not Included in Summary, Analysis, or Manuscript: Cumulative Injection to 6-30-45 (Barrels)	Remarks
ISABELLA COUNTY—Continued								
Denver Field:								
Atha and Atha	Demski 2	Parma	A		73,000		73,000	
Chartiers Oil Co.	Graham 1	Parma	A		67,525		67,525	
Gordon Oil Co.	Prout 1	Parma	A	100 G	82,125	100	118,625	
Turner Petroleum Co.	Wegensky 1	Parma	A	25 G	93,075	40	107,675	
Whittmer Co.	Cashen 1	Dundee	C			40	14,600	
	Cashen 2	Parma	A	46 G	43,800		43,800	
Whittmer Co.	Smith 2	Parma		G		30	10,950	
				171	359,525	210	436,175	
Isabella Field:								
Chartiers Oil Co.	Prout 1	Parma				2	730	
Chartiers Oil Co.	West 2	Parma				10	3,650	
Whittmer Oil Co.	McKenzie 1	Parma	A		24,820	20	32,120	
Whittmer Oil Co.	McLachlen 1	Parma	A		2,190	2	2,920	
Whittmer Oil Co.	Phillips 1	Parma	A		2,190	5	4,015	
					29,200	39	43,435	
Sherman Field:								
McClanahan Oil Co.	Beutler 2	Parma	A		63,875		63,875	
McClanahan Oil Co.	Embray 3	Parma	A	150 G	461,725	150	516,475	
McClanahan Oil Co.	Terry 1	Parma	A	20 G	18,250	20	25,550	
The Pure Oil Co.	Baker 4	Parma	A		471,580		471,580	
The Pure Oil Co.	Beutler 1, Dell 1, Leiter 1	Parma	A		200,385		200,385	
The Pure Oil Co.	Cornell 1	Parma	A		6,205		6,205	
The Pure Oil Co.	Doyle A-3	Parma	A	50 G	240,900		240,900	
The Pure Oil Co.	Doyle 1 and 2	Parma	A		293,825		293,825	
The Pure Oil Co.	J. W. Embray 1	Monroe	C	1,120 G	1,540,665	789	1,828,650	
The Pure Oil Co.	J. W. Embray 3	Parma	A	50 G	314,265		314,265	
The Pure Oil Co.	Embray A-1	Parma				81	29,565	
The Pure Oil Co.	Embray A-3	Parma	A	414 G	576,700		576,700	
The Pure Oil Co.	Goodenough 1	Parma	A	24 G	37,960	24	46,720	
The Pure Oil Co.	Latham 6	Parma	C		428,510		428,510	Ryckman No. 5 also used in 1940.
The Pure Oil Co.	Latham Heirs No. 4 and Doyle A-2	Parma	A		663,935		663,935	
The Pure Oil Co.	McClintic 1	Parma	A		324,120		324,120	
The Pure Oil Co.	McClintic B-4	Monroe	C	2,523 G	920,895	1,441	1,446,860	
The Pure Oil Co.	McClintic B-9	Monroe	C	2,493 G	4,255,535	1,694	4,873,845	
The Pure Oil Co.	Willie 10	Monroe	C	364 G	6,364,870	330	6,485,320	Embray B-1 (Parma) also used in 1940.
				7,208	17,184,200	4,529	18,837,285	

TABLE 1—Continued

Operator	Well	Formation	Type Well *	Barrels Per Day Injected (P = Pressure G = Gravity) 12-31-43	Cumulative Injection to 6-30-44 (Barrels)	1944 Injection Data Not Included in Summary, Analysis, or Manuscript: Barrels Per Day Injected 12-31-44	1944 Injection Data Not Included in Summary, Analysis, or Manuscript: Cumulative Injection to 6-30-45 (Barrels)	Remarks
ISABELLA COUNTY—Continued								
Vernon Field:								
Mammoth Producing and Refining Co.	Verrette 1	Dundee	C		109,500		109,500	
Mammoth Producing and Refining Co.	Thayer 6	Monroe	C	1,680 G	2,894,450	1,380	3,398,150	Disposal in Parma during 1937.
Mammoth Producing and Refining Co.	Schug 3	Parma	A		803,000		803,000	
J. W. McIntosh	A. Thayer 2	Parma	A	100 P	593,125	200	666,125	
Nollem Oil and Gas Co.	Bowman 2	Parma	A	150 P	332,150	150	386,900	
Nollem Oil and Gas Co.	Brief 2	Parma	A	600 P	894,250	600	1,113,250	
Nollem Oil and Gas Co.	Brief 3	Parma	A		711,750		711,750	
Nollem Oil and Gas Co.	Crowley 2	Parma	A	225 P	177,025		177,025	
Nollem Oil and Gas Co.	Crowley 4	Parma	A			288	105,120	
Nollem Oil and Gas Co.	House 4	Dundee	C	200 G	547,500	700	803,000	Disposal in Parma in 1944.
Nollem Oil and Gas Co.	Slentz 1	Dundee	C	550 G	1,093,175	550	1,293,925	
Nollem Oil and Gas Co.	Slentz 1 and 2	Dundee	C		1,022,000		1,022,000	
Nollem Oil and Gas Co.	Smock 3	Dundee	C	1,4[illegible]0 G	1,852,375	1,000	2,217,375	
Nollem Oil and Gas Co.	Stough 1	Dundee	C		584,000		584,000	
Nollem Oil and Gas Co.	Thayer 3	Parma	A	625 P	1,368,750	625	1,596,875	
Templemayr and Tope	Reake 1	Parma	A		109,500		109,500	
Wicklund Development Co.	Durwin 3A	Parma	A	1,065 P	3,185,720	1,104	3,588,680	
F. O. Wilkins	Herring 1 and 2	Parma	A	680 P	248,200	350	375,950	
F. O. Wilkins	Herring 1	Parma	A		350,400		350,400	
				7,275	16,876,870	6,947	19,412,525	
Wise Field:								
American Drilling Co.	Smith 1	Parma	A	G		10	3,650	
Cities Service Oil Co.	Lennox 1	Parma	A	20 G	74,460	40	89,060	
Cities Service Oil Co.	McDonald 1	Parma	A	8 G	9,855	10	13,505	
Cities Service Oil Co.	Ramey 1	Parma	A	56 G	58,035	49	75,920	
Cities Service Oil Co.	Smith 1	Parma	A	402 G	382,885	20	390,185	
Cities Service Oil Co.	Smith 1 and Lennox 1	Parma	A			390	142,350	
Cities Service Oil Co.	Tice 1	Parma	A	77 G	70,080	50	88,330	
Turner Petroleum Co.	Dennis 1	Parma	A	20 G	24,455	35	37,230	
Turner Petroleum Co.	Jones 1	Parma	A	10 G	16,060	10	19,710	
Turner Petroleum Co.	McNernery 1	Parma	A	129 G	139,795	76	167,535	
Turner Petroleum Co.	Menery 1	Parma	A	20 G	24,455	15	29,930	
				742	800,080	705	1,057,405	
KENT COUNTY								
Walker Field:								
Fisher-McCall	Newhouser BD1	Marshall	D	10 G	20,440	8	23,360	
Gordon Oil Co.	Smith-Dayton 1	Marshall	A	25 G	66,430		66,430	
Hilliard	Coeling BD1	Marshall	D	16 G	112,055	11	116,070	
Lenoran Petroleum Co.	Mason BD1	Marshall	D		24,455		24,455	
Smith Petroleum Co.	VanPortvliet BD1	Marshall	D	20 G	31,390	50	49,640	
				71	254,770	69	279,955	
LAKE COUNTY								
Sauble Field:								
Gordon Oil Co.	Myers Estate 2	Marshall	A	380 P	222,650	350	350,400	
Shoemaker	Mateson 1	Marshall	A	600 P	474,500	1,000	839,500	
Swanson Oil Co.	Myers Estate 1	Marshall	A	300 G	284,700	350	412,450	
				1,280	981,850	1,700	1,602,350	

TABLE 1—Continued

Operator	Well	Formation	Type Well *	Barrels Per Day Injected (P = Pressure G = Gravity) 12-31-43	Cumulative Injection to 6-30-44 (Barrels)	1944 Injection Data Not Included in Summary, Analysis, or Manuscript: Barrels Per Day Injected 12-31-44	1944 Injection Data Not Included in Summary, Analysis, or Manuscript: Cumulative Injection to 6-30-45 (Barrels)	Remarks
MECOSTA COUNTY								
Fork Field:								
Sun Oil Co.	Murray 2	Dundee	C	913	333,245	1,103	735,840	
Gulf Refining Co.	E. Van Syckle 2	Dundee				1,202	438,730	
Mogul Oil Co.	Murray 1	Parma				208	75,920	
Smith Petroleum Co.	Plummer A-1	Monroe				993	362,445	
				913	333,245	3,506	1,612,935	
MIDLAND COUNTY								
Edenville Field:								
Mammoth Producing and Refining Co.	Rickett 1	Parma	A	8 G	2,920		2,920	
				8	2,920		2,920	
Greendale Field:								
Atha Supply Co.	Stapleton 2	Parma	A		328,500		328,500	
The Pure Oil Co.	Bernard B-5	Parma	A	51 G	74,095	44	90,155	
The Pure Oil Co.	Reed A-3	Parma	A	39 G	137,240	44	153,300	
The Pure Oil Co.	Reed C-6	Parma	A		8,395		8,395	
The Pure Oil Co.	Reem C-2	Parma	A	57 G	134,320	54	154,030	
The Pure Oil Co.	Yost A and B-1	Parma	A		172,280		172,280	
				147	854,830	142	906,660	
Lee Field:								
Atha and Atha	Faulker 1 and 2	Parma	A		365,000		365,000	
Atha and Atha	Faulker 3	Parma	A	300 P	109,500	275	209,875	
Atha and Atha	State 1	Parma	A	250 P	529,250	225	611,375	
Atha and Gordon	Atha 1	Parma	A		29,200		29,200	
Atha and Gordon	Faulker 1	Parma	A	100 P	140,525		140,525	
				650	1,173,475	500	1,355,975	
Porter Field:								
Bauman and Shine	Long 2	Parma	A	75 G	76,650	50	94,900	
Bauman and Shine	Long 1	Parma	A		75,190		75,190	
Burnstein	Webster and McCallum 2	Parma	A		127,750		127,750	
Carter Lease, Inc.	Carter 6	Parma	A	45 G	372,300	45	388,725	
Columbia Oil and Gas Co.	Hale 1 and 4	Parma	A		384,710		384,710	
W. E. Dotson	Forbes 1	Parma	A		5,475		5,475	
Goll, Graves and Mechling	Otway 1	Parma	A	20 G	19,710	20	27,010	
Gordon and Stewart	Richmond 3 and 4	Parma	A	140 G	131,765	130	179,215	
Globe	Hill 1	Parma	A		21,900		21,900	
Gordon Oil Co.	Diebel 1	Parma	A	49 G	59,860	40	74,460	
Gordon Oil Co.	Finch 2	Parma	A	150 G	217,175	100	253,675	
Gordon Oil Co.	Good 2	Parma	A	8 G	8,760	2½	9,672½	
Gordon Oil Co.	Hale 1	Parma	A	200 G	146,000	150	200,750	
Gordon Oil Co.	Muscott 4	Parma	A	20 G	31,025	20	38,325	
Hall Lumber Co.	Harris Bond 1	Parma	A		18,250		18,250	
Hall Lumber Co.	Rayner 1	Parma	A	26 G	27,375	26	36,865	
Lang and McClure	Hill 1	Parma	A		45,990		45,990	
Mead (Stork)	Town Hall 1	Parma	A	15 G	32,120	16	37,960	
McClanahan Oil Co.	Breu 3	Parma	A	40 G	73,000		73,000	
McClanahan Oil Co.	Densmore 4	Parma	A		186,150		186,150	
McClanahan Oil Co.	Hoyt 1	Base of Drift	A		32,850		32,850	

TABLE 1—Continued

Operator	Well	Formation	Type Well *	Barrels Per Day Injected (P = Pressure G = Gravity) 12-31-43	Cumulative Injection to 6-30-44 (Barrels)	1944 Injection Data Not Included in Summary, Analysis, or Manuscript: Barrels Per Day Injected 12-31-44	1944 Injection Data Not Included in Summary, Analysis, or Manuscript: Cumulative Injection to 6-30-45 (Barrels)	Remarks
MIDLAND COUNTY—Continued								
Porter Field—Continued								
The Pure Oil Co.	Bond "A"	Parma	A	16 G	5,840	10	9,490	
The Pure Oil Co.	Clark 1	Parma	A	10 G	14,600	10	18,250	
The Pure Oil Co.	Crandell 2	Parma	A	126 G	219,365	144	271,925	
The Pure Oil Co.	Eldredge 1	Parma	A	1 G	1,825	1	2,190	
The Pure Oil Co.	Hicks 3	Parma	A	20 G	24,090	23	32,485	
The Pure Oil Co.	Howland 2	Parma	A	111 G	173,010	78	201,480	
The Pure Oil Co.	Hoyt 1	Parma	A		17,155		17,155	
The Pure Oil Co.	Mates 1	Parma	A		10,220		10,220	
The Pure Oil Co.	Miller B	Parma	A		86,870		86,870	
The Pure Oil Co.	Mitchell 1	Parma	A	5 G	3,650	5	5,475	
The Pure Oil Co.	H. Neitzke 1	Parma	A	96 G	225,205	96	260,245	
The Pure Oil Co.	Raynor B-2	Parma	A	8 G	19,710	8	22,630	
The Pure Oil Co.	Root C-1	Parma	A		227,030		227,030	
The Pure Oil Co.	Root E-4	Parma	A	23 G	39,420	23	47,815	
Pyramid Oil	Wayne 1	Parma	A		1,095		1,095	
Rex Oil and Gas Co.	Howland 1 and 2	Parma	A		40,150		40,150	
Roosevelt Oil Co.	Campbell 11	Parma	A			150	54,750	
Smith Petroleum Co.	Bushre 2	Parma	A		10,950		10,950	
Smith Petroleum Co.	Teeter-Otway 3	Parma	A			50	18,250	
Stewart-Gordon	Carter 2, 3 and 4	Parma	A	285 G	337,625	200	410,625	
Stork Oil Co.	Baxter 3	Parma	A	165 G	323,025	100	359,525	
Stork Oil Co.	Campbell 2 and 3	Parma	A			45	16,425	
Stork Oil Co.	Richmond 2	Parma	A		43,800		43,800	
Stork Oil Co.	Richmond 3	Parma	A	65 G	23,725		23,725	
Strange and Fortney	Campbell 3	Parma	A		109,500		109,500	
Strange and Fortney	Campbell 5	Parma	A	400 G	509,175		509,175	
Strange and Fortney	Campbell 7	Monroe	A			500	182,500	
Strange Oil and Gas	Walley 6 and 7	Parma	A	50 G	282,875	40	297,475	
Sun Oil Co.	Miller 4	Parma	A		58,400		58,400	
C. W. Teater	Emery 2	Parma	A	150 G	222,650	50	240,900	
C. W. Teater	Otway 2 and 3	Parma	A	125 G	164,250	75	191,625	
C. W. Teater	Wale 2	Dundee	C	125 G	240,900	70	266,450	Disposal in Parma until 1942.
Theodore Oil Co.	Campbell 11	Parma	A	125 G	82,125		82,125	
Fred W. Turner	Baxter 3	Parma				150	54,750	
Fred W. Turner	Hock 2	Parma	A	150 G	141,255	150	196,005	
Fred W. Turner	Magill 1	Parma	A	10 G	7,665		7,665	
Fred W. Turner	St. John A2	Parma and Dundee	A and C	950 G	1,770,250	950	2,117,000	Root B-1 (Parma) also used in 1939.
Wayne Well, Inc.	Wayne 1	Parma				5	1,825	
				3,804	7,531,410	3,532½	8,820,772½	

TABLE 1—Continued

Operator	Well	Formation	Type Well *	Barrels Per Day Injected (P = Pressure G = Gravity) 12-31-43	Cumulative Injection to 6-30-44 (Barrels)	1944 Injection Data Not Included in Summary, Analysis, or Manuscript: Barrels Per Day Injected 12-31-44	1944 Injection Data Not Included in Summary, Analysis, or Manuscript: Cumulative Injection to 6-30-45 (Barrels)	Remarks
MIDLAND COUNTY—Continued								
Yost-Jasper Field:								
Gordon Oil Co.	Greene 2	Parma	A	25 G	27,375	25	36,500	
The Pure Oil Co.	Alspaugh 2	Dundee	C	31 G	24,090	49	41,975	
The Pure Oil Co.	Alspaugh 3	Parma	A	86 G	193,815	89	226,300	
The Pure Oil Co.	Balch 1	Parma	A		7,665		7,665	
The Pure Oil Co.	Bond B-4	Parma	A	30 G	59,495	26	68,985	
The Pure Oil Co.	Bond C3 and 10	Parma	A	69 G	86,870	94	121,180	
The Pure Oil Co.	Bond-Root 14	Dundee and Parma	C	821 G	1,248,303	791	1,537,015	Dundee disposal only since 1943.
The Pure Oil Co.	Clark Heirs 1	Parma	A		31,025		31,025	
The Pure Oil Co.	Corning A1	Parma	A	39 G	82,125	43	97,820	
The Pure Oil Co.	Corning B1	Parma	A	47 G	31,390	74	58,400	
The Pure Oil Co.	Haynes D3	Parma	A		13,140		13,140	
The Pure Oil Co.	Rayner D5	Parma	A	49 G	37,960	50	56,210	
The Pure Oil Co.	Root B2	Parma	A		5,840		5,840	
The Pure Oil Co.	Root D1	Parma	A	27 G	22,630	33	34,675	
The Pure Oil Co.	Sinif 2	Parma	A	68 G	130,305	64	153,665	
The Pure Oil Co.	Yahs 1	Parma	A	102 G	254,040	102	291,270	
				1,394	2,256,065	1,440	2,781,665	
MISSAUKEE COUNTY								
Prosper Field:								
Cities Service	State-APPs 1	Drift	C	9 G	3,280	16	9,120	
Gordon Oil Co.	Blue 2	Dundee	C	1,457 G	531,805	1,990	1,258,155	
				1,466	535,085	2,006	1,267,275	
MONTCALM COUNTY								
Bellyachers Field:								
Socony-Vacuum	Dickinson 1	Parma				100	36,500	
Socony-Vacuum	Haynes 1	Parma				1	365	
Socony-Vacuum	Jergenson 1	Parma				150	54,750	
Socony-Vacuum	Nisonger 1	Parma				70	25,550	
						321	117,165	
Bloomer Field:								
C. L. Maguire	Blackmere 1 and 2	Parma				98	35,770	
						98	35,770	

TABLE 1—Continued

Operator	Well	Formation	Type Well *	Barrels Per Day Injected (P = Pressure G = Gravity) 12-31-43	Cumulative Injection to 6-30-44 (Barrels)	1944 Injection Data Not Included in Summary, Analysis, or Manuscript: Barrels Per Day Injected 12-31-44	1944 Injection Data Not Included in Summary, Analysis, or Manuscript: Cumulative Injection to 6-30-45 (Barrels)	Remarks
MONTCALM COUNTY—Continued								
Crystal Field:								
Atha and Atha	Cryden 2	Dundee	C	600 G	2,135,250	600	2,354,250	
Cryden	Husted 2	Monroe	C		1,178,950		1,178,950	
Crystal Syndicate	Drake 2	Parma	A	300 G	2,372,500	255	2,465,575	
Daily Crude Oil Co.	Flint 1	Parma	A		91,250		91,250	
Daily Crude Oil Co.	Fulford A and B	Parma	A		191,625		191,625	
Daily Crude Oil Co.	Robbins 4	Monroe	C		1,569,500		1,569,500	
Daily Crude Oil Co.	Tow 2	Parma	A		16,425		16,425	
Duck Lake Oil	Fee 1	Parma	A		447,125		447,125	
Gordon Oil Co.	Strait 1	Parma	A		73,000		73,000	
Gulf Refining Co.	Eastman 1	Monroe	C		39,420		39,420	
Gulf Refining Co.	Fisher 1	Monroe	C		117,895		117,895	
Gulf Refining Co.	Rule 1	Monroe	C		93,805		93,805	
Leonard Oil Co.	Durbin 2	Dundee	C	875 G	2,530,180	848	2,839,700	
Leonard Oil Co.	Tow 1 and 2	Dundee	C		1,796,530		1,796,530	
Leonard Oil Co.	Tow 4	Dundee and Parma	A and C	1,100 G	832,200	1,192	1,267,780	Disposal in Parma in 1944.
Mammoth Producing and Refining Corp.	Strait "B"	Parma	A		73,000		73,000	
McClanahan	Flint 2	Parma	A	1,500 P	3,923,750	1,500	4,471,250	
McClanahan	Frost 1	Parma	A	40 P	43,800	45	60,225	
McClanahan Oil	Lamphier 1	Parma	A		127,750		127,750	
Morris	Pugsley 1	Parma	A		146,000		146,000	
The Pure Oil Co.	Preston 4	Monroe	C		1,823,905		1,823,905	
The Pure Oil Co.	Stedman 1	Parma	A		155,125		155,125	
Roosevelt (Atha)	Flint 1	Monroe	C		310,250		310,250	
Snowden and McSweeney	Wight 1	Parma	A		12,045		12,045	
Stork Oil Co.	Dickenson 7	Dundee	C	1,150 G	3,206,160	1,150	3,625,910	
Strange and Fortney	Rockleman 1	Traverse	C		20,805		20,805	
Townline	Fisher and Rule	Parma	A		47,085		47,085	
United Producing and Refining	Connor	Parma	A		194,545		194,545	
Warren Oil Co.	Warren	Parma	A		377,775		377,775	
				5,565	23,947,650	5,590	25,988,000	
NEWAYGO COUNTY								
Goodwell Field:								
The Pure Oil Co.	Hull 1	Drift	D	182 G	66,430	671	311,345	
				182	66,430	671	311,345	
OGEMAW COUNTY								
Mills Field:								
The Ohio Oil Co.	Mills 2A and 3A	Traverse	C	975 P	812,125	975	1,168,000	
				975	812,125	975	1,168,000	
OSCEOLA COUNTY								
Cedar Field:								
The Ohio Oil Co.	Boettcher 3	Traverse	C	776 G	283,240	784	569,400	
Sun Oil Co.	Beardsley 1	Traverse	C	241 G	87,965	209	164,250	
				1,017	371,205	993	733,650	
Evart Field:								
Sun Oil Co.	Wirth B-1	Dundee	C	974 G	370,110	2,976	1,456,350	
				974	370,110	2,976	1,456,350	

TABLE 1—Continued

Operator	Well	Formation	Type Well *	Barrels Per Day Injected (P = Pressure G = Gravity) 12-31-43	Cumulative Injection to 6-30-44 (Barrels)	1944 Injection Data Not Included in Summary, Analysis, or Manuscript: Barrels Per Day Injected 12-31-44	1944 Injection Data Not Included in Summary, Analysis, or Manuscript: Cumulative Injection to 6-30-45 (Barrels)	Remarks
OSCEOLA COUNTY—Continued								
Reed City Field:								
E. L. Bennight	Beecher BD-1	Parma				105	38,325	
E. L. Bennight	Howe 1	Drift	A	150 G	54,750	95	89,425	Disposal in Parma and Drift during 1944.
Gordon Oil Co.	State 1	Parma	D	320 P	116,800	755	392,375	
Gulf Refining Co.	Fulmerhouser 1	Parma	C	154 G	56,210	183	123,005	
Gulf Refining Co.	Maxine 1	Monroe-Traverse	C	1,968 G	718,320	2,061	1,470,585	
The Pure Oil Co.	Campbell BD-1	Parma	D					Used for short time only.
The Pure Oil Co.	Carney 1	Parma and Drift	D	133 P	89,060	952	436,540	
The Pure Oil Co.	Dan Richards BD-1	Drift	A	1,921 P	701,165	1,758	1,342,835	Parma plugged 6-13-44.
The Pure Oil Co.	Small 4	Parma and Drift	A	406 P	148,190	427	304,045	
The Pure Oil Co.	State 1	Traverse	C	1,666 G	831,835	174	894,250	Disposal in Traverse and Monroe during 1944. Monroe disposal in 1942 and 1943.
Louis Rose	Pfuhl 1	Parma and Drift	D	105 P	100,375	166	160,965	
C. W. Teater	Baderschneider BD-1	Parma and Drift	D	92 P	33,580	264	128,845	
The Ohio Oil Co.	Auten BD-1	Parma and Drift	D	386 P	140,890	485	317,915	
The Ohio Oil Co.	Gingrich 1	Monroe	C	749 G	382,885	817	681,090	
The Ohio Oil Co.	Heilman 4	Drift	C			1,100	401,500	Converted to brine-disposal June 24, 1944.
The Ohio Oil Co.	Homan 1	Drift	D			170	62,050	
The Ohio Oil Co.	Johnson BD-1	Parma and Drift	D	407 P	148,555	645	383,980	Injection began in July 1944.
The Ohio Oil Co.	Johnson BD-2	Drift	D			351	128,115	
The Ohio Oil Co.	Ritter BD-1	Parma and Drift	D	110 D	40,150	183	106,945	
				8,567	3,562,765	10,685	7,462,790	
Rose Lake Field:								
Sun Oil Co.	Bowman 2	Dundee	C	87 G	31,755	763	310,250	
The Ohio Oil Co.	Howe BD-1	Drift	D	12 G	4,380	32	16,060	
				99	36,135	795	326,310	
OTTAWA COUNTY								
Holland Field:								
Regal Dutch	Bosch-Walters 1	Coldwater	A	90 P	32,850		32,850	
Regal Dutch	Petroelje, et al. 1	Coldwater	A	35 P	12,775		12,775	
E. L. Bourret	Verhoeven, et al.	Traverse				174	63,510	
				125	45,625	174	109,135	
Zeeland Field:								
H. E. Fowler	Geerling-Baron 1	Coldwater	A	30 G	10,950		10,950	
Perry, Gould, Cross	Baron-Nykamp 1	Coldwater	A	10 P	18,250	10	21,900	
Perry, Gould, Cross	Mast, et al. 1	Marshall	A	6 P	16,790	5	18,615	
				46	45,990	15	51,465	

TABLE 1—Continued

Operator	Well	Formation	Type Well *	Barrels Per Day Injected (P = Pressure G = Gravity) 12-31-43	Cumulative Injection to 6-30-44 (Barrels)	1944 Injection Data Not Included in Summary, Analysis, or Manuscript: Barrels Per Day Injected 12-31-44	1944 Injection Data Not Included in Summary, Analysis, or Manuscript: Cumulative Injection to 6-30-45 (Barrels)	Remarks
ROSCOMMON COUNTY								
Headquarters Field:								
E. Hilliard	State 4	Marshall	A	297 G	108,405	500	290,905	
E. Hilliard	State W-1	Dundee	C	142 G	51,830	180	117,530	
Marshall Oil	State A-2	Marshall	A	316 G	115,340	240	202,940	
The Pure Oil Co.	State B-4	Monroe	C	2,453 G	895,345	2,092	1,658,925	
Sun Oil Co.	State M-5	Monroe	C	260 G	94,900	375	231,775	
The Ohio Oil Co.	State M-1	Dundee	C	435 G	158,775	437	318,280	
American Drilling	State L-2	Dundee				64	23,360	
Freeman Oil Co.	State 2	Marshall				235	85,775	
				3,903	1,424,595	4,123	2,929,490	
Richfield Field:								
The Ohio Oil Co.	VanWagoner 1	Traverse	A	6 P	2,190	5	4,015	
				6	2,190	5	4,015	
VAN BUREN COUNTY								
Bangor Field:								
Clapsaddle Drilling Co.	Sheldon 1	Traverse / Coldwater	C	80 G / P	29,200	100	65,700	Coldwater disposal until 1944.
W. H. Clock	A. Overton 2	Traverse				15	5,475	
Fisher-McCall	Dillman, et al. 3	Traverse				1,225	447,125	
Fisher-McCall	Sznepkowski 1	Traverse	C	620 G	281,050		281,050	
Hartman Oil Co.	Piefer 1 and 3	Coldwater	C	400 P	146,000	300	255,500	
Henrich and Kendall	Ulrath 1	Coldwater	C	65 P	23,725	500	206,225	
A. S. Hoyt, Agent	Drake 2	Coldwater	A	500 P	419,750	350	547,500	
A. S. Hoyt, Agent	Nutting 2	Coldwater	A	200 P	160,600	250	251,850	
A. S. Hoyt, Agent	Shugars 1 and 3	Coldwater	A	250 P	182,500	500	365,000	
John H. McClean	Ulrath 3	Traverse			11,315		11,315	
Michahoma Oil Co.	Austin 3	Coldwater	C			75	27,375	Injection began in 1944. (F. R. Zook in 1941 and Shelburn Oil in 1940.)
Michahoma Oil Co.	Jackson 1 and 2	Traverse	C	406 G	657,000	135	706,275	
Roung and Clark	Allers 1	Coldwater	A	80 P	29,200		29,200	
Socony-Vacuum	Merrian 1	Traverse	C	300 G	109,500	200	182,500	
Socony-Vacuum	Adaskevich and Madsen 1	Coldwater				175	63,875	
Weinberg	Minshall 2	Traverse				20	7,300	
				2,895	2,049,840	3,845	3,453,265	

TABLE 1—Continued

Operator	Well	Formation	Type Well *	Barrels Per Day Injected (P = Pressure G = Gravity) 12-31-43	Cumulative Injection to 6-30-44 (Barrels)	1944 Injection Data Not Included in Summary, Analysis, or Manuscript: Barrels Per Day Injected 12-31-44	1944 Injection Data Not Included in Summary, Analysis, or Manuscript: Cumulative Injection to 6-30-45 (Barrels)	Remarks
VAN BUREN COUNTY—Continued								
Bloomingdale Field:								
Bauman	Rogers 1 and 5	Traverse	C	200 G	237,250	240	324,850	
Bloomingdale Development Co.	Decker 3	Traverse	C	150 G	93,075	150	147,825	
Bloomingdale Development Co.	West B-1	Traverse	C		18,250		18,250	
W. R. Borough	S. Wait 1	Traverse	C	150 G	63,875		63,875	
Cooper and Shakespeare	Harpman 2	Traverse	C	200 G	132,495	200	205,495	
Fisher-McCall	Wiggins D-1 and B-3	Traverse	C	493 G	674,520	400	820,520	
J. H. Fitchett	Stewart 6	Traverse	C	350 P	616,850	300	726,350	Well deepened to Sylvania. Sylvania no aid as disposal formation.
Tr. Fitchett	West 2	Coldwater	A	90 P	60,225	150	114,975	
H. E. Fowler	Melvin J-2	Traverse	C	100 G	163,520	205	238,345	
Fredenhagen and Henigman	A. Schock 1	Coldwater	A	25 P	18,250		18,250	
Harris Oil Co.	Peavy 1	Coldwater				120	43,800	
Harris Oil Co.	Remington 2	Traverse	C	145 G	195,275	225	277,400	
Harris Oil Co.	Canute 1	Coldwater	A	100 G	98,915		98,915	
D. F. Jones	Melvin 2	Coldwater	A	125 P	136,875		136,875	
McIntosh	Merrifield 1	Traverse	C	225 G	428,875		428,875	
Alton C. Murray	Merrifield 1	Traverse	C	30 G	10,950		10,950	
Nelson	Williams 1	Traverse	C	605 G	664,300	680	912,500	
R. T. and E. and T. F. Caldwell	Clinkenbeard 5	Traverse	C	225 G	182,500	185	250,025	
W. H. Thourlby	Bell 1	Coldwater	A		3,650		3,650	
Vanco	Comisky 2	Traverse	C	295 G	178,850	305	290,175	
Voorhees Drilling Co.	Melvin 1	Traverse	C	180 G	370,475	160	428,875	
Wiser Oil Company	Boyers 6	Traverse	C	370 G	233,600	315	348,575	
				4,058	4,582,575	3,635	5,909,350	
Columbia Field:								
O. O. Borden	Parisian 7	Traverse	C		273,750		273,750	
Clapsaddle and Harris	Locker 4	Traverse and Sylvania	C		870,525		870,525	
Daily Crude	Potter 1	Traverse	C		18,250		18,250	
Dotson	Stockton A-1	Traverse	C		410,625		410,625	
Universal	Poth 2	Traverse	C					
Harris Oil Co.	Locker 7 and 8	Traverse	C	150 G	439,825	150	494,575	
Hartman Oil Co.	Pepper 1 and Pepper No. 6	Coldwater	A			500	719,050	
		Traverse	C	560 G	344,925	525		
Reed, Whitney and Whitney	Cooley 2	Traverse	C		16,425		16,425	
				710	2,374,325	1,175	2,803,200	
Geneva Field:								
W. H. Clock	Wood 1	Coldwater	A			20	7,300	
W. H. Clock	A. D. Marr 1	Coldwater	A			40	14,600	
A. S. Hoyt	Lynch and Phol 1	Coldwater				50	18,250	
Michahoma Oil Co.	Abfall 1	Coldwater				325	118,625	
	Rapson-Myers 1	Coldwater						
Michahoma Oil Co.	Thomas-Myers 1	Traverse	C	126 P	45,990	300	155,490	
Rex Oil and Gas	N. Johnson 1	Coldwater	A	300 P	109,500		109,500	
Smith Petroleum Co.	Fellows 1	Coldwater	A		56,575		56,575	
Socony-Vacuum	Marr and Hills 1	Coldwater	A	75 P	27,375	185	94,900	
Socony-Vacuum	Smith 1	Coldwater	A	50 P	18,250	65	41,975	
				551	257,690	985	617,215	
Gobles Field:								
Albert Schiller	Miller 4	Traverse	C		365,000		365,000	
					365,000		365,000	
Mill Lake Field:								
W. H. Clock	Sage 1	Traverse	C			20	7,300	
						20	7,300	
Muskrat Lake Field:								
Borough and Fox	G. Bell 2	Coldwater	A	152 P	70,080		70,080	
Bridges Basin Oil Corp.	Melching 1	Coldwater	A		89,425		89,425	
Bridges Basin Oil Corp.	Munn 1	Coldwater	A	5 P	1,825		1,825	
Clapsaddle and Harris	Allen 1	Coldwater	A		100,375		100,375	
Clapsaddle and Harris	Huntsburger 1	Coldwater	A		18,250		18,250	
N. R. Dodd	Bell 1	Coldwater	A		155,125		155,125	
N. R. Dodd	Helms 1	Coldwater	A		109,500		109,500	
N. R. Dodd	Keene 1	Coldwater	A		10,950		10,950	
Muskrat Lake Field:								
W. E. Dotson	Holdeman 1	Coldwater	A	50 G	54,750	40	69,350	
Fortney-Broughton	Pullin 1	Coldwater	A	153 P	347,845		347,845	
Fortney-Broughton	Reed 1	Traverse	C	110 G	40,150		40,150	
Fortney-Broughton	Reed 2	Coldwater	A		69,350		69,350	
Fortney-Broughton	Truax 1	Coldwater	A	2 G P	161,330		161,330	
Globe Drilling Co.	Healey 1	Coldwater	A		54,750		54,750	
C. C. Goff	Galicki 1	Coldwater	A		3,650		3,650	
Harris Oil Co.	Hayes 1	Coldwater	A	125 P	91,250	155	147,825	
E. G. Hartman	Ampey 1	Coldwater	A	20 G	83,950	50	102,200	
Jetter and DeKrafft	Munn 1	Coldwater	A	120 P	89,425	40	104,025	
E. W. Leeder	Ampey 1	Coldwater	A		12,775		12,775	
Rae Lewis	Munn 1	Coldwater	A	55 G P	107,675	15	113,150	
R. D. Malcolm	Allen 1	Coldwater	A		109,500		109,500	
R. D. Malcolm	Dvorak 1	Coldwater	A		63,875		63,875	
R. D. Malcolm	Truax 1	Coldwater	A		54,750	3	55,845	
L. C. Sleep	Bell 3	Coldwater	A			100	36,500	
L. C. Sleep	Reed 3	Coldwater	A			50	18,250	
L. C. Sleep	Truax 1	Coldwater	A			3	1,095	
C. J. Stevens	Schindler 1	Coldwater	A		18,250		18,250	
H. L. Wheeler	Pullin 1	Coldwater	A	100 P	164,250		164,250	
H. L. Wheeler	Stadler 1	Coldwater	A		197,100		197,100	
H. C. Williams	Gelden 1	Coldwater	A	175 G	164,250	160	222,650	
				1,067	2,444,405	616	2,669,245	

* A—Disposes in annular space between casing.
C—Converted to a disposal well.
D—Drilled for disposal.

Injection Equipment

There is no record of either chemical or physical water treatment in disposal plants other than the use of sufficient skimming tanks to separate oil from water, and the use of oil seals to prevent the contact with air from the time of production to the time of injection. Steel pipe, either new or used, is employed in gathering lines for the transportation of salt water in the vast majority of cases. This does not mean to imply that the Michigan salt water, or brines as they are commonly termed, are non-corrosive; for there is evidence of corrosion in all types of equipment associated with saltwater disposal. However, the life of the properties has been relatively short, and apparently operators have not taken pains to install non-ferruginous materials. In later years there have been several installations of Transite lines to eliminate the corrosion problem.

Referring to Table 3, of the total of 279 wells in operation during 1944, 194 took water by gravity and 85 required pressure for the disposal of water. In the majority of the cases pressure is furnished by pumps connected to the walking beam of the producing wells. This is particularly true in the case of scattered operations or small volumes of water. A larger concentration of operations, or larger quantities of water, are generally served by separately-powered and centrally-located pumps installed for use in conjunction with a disposal pipe-line system.

TABLE 2

Summary of Statistical Data on Salt-Water Injection

(Quantities of Water Shown in Barrels)

	July 1937 to July 1938	July 1938 to July 1939	July 1939 to July 1940	July 1940 to July 1941	July 1941 to July 1942	July 1942 to July 1943	July 1943 to July 1944	Totals for 1937-1944 Inclusive
WELLS USING ANNULAR SPACE BETWEEN CASINGS:								
Number of wells	61	57	81	124	186	185	178	316
Daily rate	12,392	11,873	19,326	20,921	24,112	25,876	22,248	
Yearly total	4,523,080	4,333,645	7,053,990	7,636,165	8,800,880	9,444,740	8,120,520	49,913,020
WELLS CONVERTED FOR DISPOSAL:								
Number of wells	20	15	41	54	62	74	86	120
Daily rate	9,594	11,808	29,004	44,097	53,485	54,083	64,962	
Yearly total	3,501,810	4,309,920	10,586,460	16,095,405	19,522,025	19,740,295	23,711,130	97,467,045
WELLS DRILLED FOR DISPOSAL:								
Number of wells				4	4	6	15	18
Daily rate	0	0	0	283	116	830	6,332	
Yearly total				103,295	42,340	302,950	2,311,180	2,759,765
TOTALS:								
Number of wells	81	72	122	182	252	265	279	454
Daily rate	21,986	23,681	48,330	65,301	77,713	80,789	93,542	
Yearly total	8,024,890	8,643,565	17,640,450	23,834,865	28,365,245	29,487,985	34,142,830	150,139,830

Well Treatment

The contaminating materials resulting from inadequate physical or chemical treatment of the water which cause the plugging of injection wells are principally carbonates, iron oxide, salts, and paraffin. There has been an appreciable amount of trouble from these several contaminating agents which periodically reduce the ability of injection wells to take water. However, it is generally believed in Michigan disposal operations that, considering the overall picture, it is cheaper to treat wells after they have become partly contaminated than it is to prevent contamination by the installation of complex and comparatively expensive water-treating equipment.

There are four different methods of well treatment or repair which are generally applied to water-injection wells in this state. They are, in order of their general importance: acid treatment, application of pressure, fresh-water injection, and lye-solution injection.

Acid treatments, varying in concentration of hydrogen chloride from 15 to 30 per cent, have been extremely successful in increasing the effective permeability of limestone-injection wells by either dissolving the reservoir rock, dissolving the contaminating material, or both. No accurate records of the frequency of this type treatment are available, but the acid service company most generally employed for this work in the state reports in excess of 30 acid treatments per year from 1940 through 1944. In addition to these treatments, a considerable quantity of bulk acid has been sold to operators injecting their own acid with lease equipment. In many cases it is the practice to repeat acid treatments on certain wells at not infrequent intervals, thereby periodically increasing the capacity of the well to meet requirements.

Pressures, generally not in excess of 1,000 psi at the surface, are applied to wells which have experienced a decline in injection rate, and results have been sometimes quite successful. Pressures so applied to limestones and the unconsolidated sands of the Drift break down any film of contaminating materials that may be against the permeable portion of the formation.

TABLE 3

Analysis of 1944 Injection

(Quantities of Water Shown in Barrels)

Injection Formation	Wells Injecting by Gravity	Wells Injecting by Pressure	Totals	Per Cent of Total Wells	Per Cent of Total Injection	Average Rate of Injection (Barrels Per Well Per Day)
DRIFT:						324
Number of wells	5	2	7	2.5		
Yearly total	128,845	701,165	830,010		2.4	
PARMA:						149
Number of wells	84	24	108	38.7		
Yearly total	2,527,625	3,360,920	5,888,545		17.2	
MARSHALL:						148
Number of wells	9	5	14	5.0		
Yearly total	374,490	382,155	756,645		2.2	
COLDWATER:						96
Number of wells	23	38	61	21.9		
Yearly total	607,360	1,540,300	2,147,660		6.3	
TRAVERSE:						317
Number of wells	32	10	42	15.1		
Yearly total	3,071,840	1,795,070	4,866,910		14.3	
DUNDEE-MONROE:						1,320
Number of wells	38	0	38	13.6		
Yearly total	18,306,575	0	18,306,575		53.6	
DUNDEE AND PARMA:						1,025
Number of wells	2	0	2	0.7		
Yearly total	748,250	0	748,250		2.2	
PARMA AND DRIFT:						234
Number of wells	1	6	7	2.5		
Yearly total	40,150	558,085	598,235		1.8	
TOTALS:						335
Number of wells	194	85	279	100.0	100.0	
Total injection	25,805,135	8,337,695	34,142,830			

The injection of fresh water to dissolve water-soluble salts has been used with some success, and is often done just previous to an acid treatment.

It is reported that well treatments have been effected by the injection of a solution of ordinary lye, but little is known of the results.

Description of Disposal Formations

Glacial Drift

The Glacial Drift covers practically all of the state in which there exists the problem of salt-water disposal. The Drift is an unconsolidated formation varying in thickness from 100 ft to 1,100 ft containing sands, gravel beds, boulders, and clay. This formation generally contains water which may be potable at any depth, although normally it has sufficiently high salinity at its base to be unsuitable for domestic or commercial uses, and it is, therefore, sometimes employed for water disposal. The unconsolidated nature of this formation makes well completion for disposal a relatively difficult procedure, but the method of setting casing through the Drift and gun-perforating have proved relatively successful. Perforating with ⅓-in.-diameter bullets has recently been tried to prevent sanding-up of these wells. When disposal is effected into this formation between strings of casing, it is always unknown as to just how much of the formation might be exposed or, rather, how much of the formation has caved or bridged.

Parma

Notwithstanding the current use of the Parma formation in 108 disposal wells, a limited number of cores from this formation do not indicate that it would lend itself readily to water injection. This formation is generally a relatively impermeable sandstone with some carbonate cementing material which responds to acid treatment in some areas. The number of disposal wells in this formation is 38.7 per cent of the current total in operation, but these wells contribute only 17.2 per cent to the total injection of water—which fact would tend to confirm the mediocrity of this formation for injection.

Marshall

The Marshall formation consists of relatively thick sands interbedded with shale. This formation has not been used a great deal because of its relative depth and its proximity to the Michigan Stray gas sand which it immediately underlies; i.e., sufficient protective measures for the Michigan Stray must of necessity be taken where it is gas-bearing, and the use of the Marshall for water disposal has been generally precluded in such areas.

Coldwater

There are a total of 61 disposal wells which inject water into the Coldwater lime, the porous lime member in the basal part of the Coldwater shale formation. All of these wells are located in southwestern Michigan, and all water disposal into this formation is in the annular space between casings. These wells represent 21.9 per cent of the current total number of wells, but contribute only 6.3 per cent to the total water injected. Disposal into the Coldwater formation has been by gravity when quantities less than 100 bbl per day are injected; whereas pressure is generally required for quantities in excess of 100 bbl per day. Acid has been used in most of these wells with good results. Some of these wells have required pressure during the initial period of injection, later breaking down and taking water by gravity. Water in the Coldwater formation has been found to be fresh in some areas in southwestern Michigan.

Because of the setting of surface casing above the base of the Drift in some wells, and the destruction of drive-pipe casing seats at the base of the Drift as a result of injection breakdown pressures as high as 600 psi, there is the probability that at least a portion of the water allocated to the Parma, Marshall, and Coldwater formations is actually going into the base of the Drift formation. Just what percentage of this water finds its way to the Drift is naturally unknown, but mention is made of the fact in order that the quantities allocated to these other three formations might be qualified to forestall any misrepresentation of the ability of these formations to take water.

Traverse

The available permeable lime members of the Traverse formation readily lend themselves to water disposal. Generally, there exists a lime bed in the upper portion of the formation which may or may not be sufficiently permeable for water injection. At greater depths in this section the limes may or may not be present. It should be noted that the ability to find a permeable lime in the Traverse formation will not only vary from field to field, but from location to location—which fact distinctly lowers the desirability of this formation as a potential water-disposal horizon. Notwithstanding, in fields where the permeable zones have been found, they have a great potential capacity for disposal. There are, as of mid-1944, 42 Traverse disposal wells in the state which are returning during the year 4,800,000 bbl, or 14.3 per cent, of the total water. It is to be noted that of the total of 42 wells presently in operation, 32 take water by gravity. The significance of this is that Traverse wells are used for disposal principally in fields which have Traverse production, and most generally there will be some degree of pressure decline within these reservoirs. This results in a progressively lowering static fluid level in injection wells, affording a greater height to the injected column of water, with the resulting advantage that there is available for injection increased pressure at the formation.

Dundee-Monroe

The Dundee and Monroe formations have been grouped together, and include the porous members of the limestones and dolomites below the base of the Bell Shale. The Monroe formation is designated on the generalized transverse section, as the upper part of the Detroit River formation. These zones are presently being used in 38 water-injection wells (13.6 per cent of the total), and have contributed 18,000,000 bbl injected, which represents 53.6 per cent of the total for 1944. As in the case of the Traverse formation, the wells which are used for disposal in the Dundee-Monroe exist in fields which are producing from these formations and enjoy the same benefits of declining reservoir pressures. All of these 38 wells are operated by gravity.

Sylvania

Only two wells are known to have been open to the Sylvania formation for water injection and, therefore, adequate information on this horizon is lacking.

SUMMARY

The unavailable portion of the early history of water injection in the state of Michigan does not represent a sufficiently high percentage of the data to make an appreciable difference in the total picture presented herewith. Water has been injected in sufficient volumes, and with sufficient variance of attendant conditions, to conclude that the information available can be a guide to future operations in Michigan, as well as an addition to the general information available on the subject of water injection.

Formations available for water injection in the state are numerous, and have proved adequate (with a minimum of expense) to dispose of the vast majority of the water incidental to the production of oil. It is noteworthy that, currently, half of the total number of wells in operation inject into a limestone, and that these wells contribute three-quarters of the present water injected. Attention is again called to the fact that the best available wells for injection are those completed in the same horizons as the oil-producing wells because of the advantage resulting from declining reservoir pressures. Capital cost of accessory equipment for injection has been comparatively low in the state, as has been the cost of equipment, maintenance, and well repair.

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