NORTH DAKOTA GEOLOGICAL SURVEY

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NORTH DAKOTA CRUDE OIL INVENTORY AS OF JANUARY 1, 1967

by

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Miscellaneous Series #29

Grand Forks, North Dakota, 1967

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ABSTRACT

North Dakota's reserves of crude oil, recoverable with present technical knowledge, available equipment, and current operating practices, were 667,601,462 barrels on 1 January 1967. This figure is an increase over the 630,779,166 barrels reported for 1 January 1966.

The increase in inventory represented increased drilling activity in the state during 1966 as well as the initiation of two new energy supplementation projects.

279,637,000 barrels, or 42% of the total reserves, will be recovered by energy supplementation.

Reports of 176 well completions were received by the Geological Survey in 1966. Of these,65 were completed as producing wells while 25 previously producing wells were abandoned. About 37% of the producing wells in the state are under unit operation and 18.2% of the producing wells are considered to be marginal, or stripper wells.

Seven new pools were opened during the year but only six were credited to wildcat exploration. With permits issued for 65 wildcat prospects the success ratio was 1 in 11.

The methods used, the data sources, and the assumptions made in previous reports in this series have been followed so that the results may be compared and valid conclusions drawn therefrom.

Slope County joined the other 13 producing counties with the discovery of the Eleven Bar - Red River pool in June.

1/ Chief Petroleum Engineer, North Dakota Geological Survey

RESULTS OF THE STUDY

On 1 January 1967 the technically recoverable reserves of crude oil in North Dakota were 667,601,462 Stock Tank Barrels, of which, 279,637,000 barrels, or 42%, were second order reserves made available by the initiation of energy supplementation projects in 15 of the 114 producing pools in the state.

Cumulative production to the date of the inventory was 256,745,038 barrels of stock tank oil. Production during 1966 was 28,024,204 barrels.

The discovery of 7 new pools during 1966 added 4.9 million barrels of reserves. 21,324,000 barrels of second order reserves were added during the period by the initiation of energy supplementation projects in two pools. Revisions and extensions of previous estimates accounted for an increase of 38.6 million barrels making the total reserves added during 1966 64,846,500 barrels, or 36.8 million barrels in excess of production for the year.

Of the 2032 wells in North Dakota, capable of producing on 1 January, 1967, 745 or 36.6% were undergoing energy supplementation. 370 wells, or 18.2%, of the producing wells were considered to be marginal, or stripper, wells.

During 1966 the Geological Survey issued 192 drilling permits and received 176 reports of well completions, of which 112 were dry holes. In addition, 25 producing wells were abandoned during the year, of which 14 were marginal wells. Wildcat, or exploratory wells, accounted for 65 of the completions and 6 producing wells for a success ratio of 1 in 11. Sixteen wells were drilled as outposts, and 43 as extensions, to existing fields and resulted in 28 producers with a success ratio of 1 out of 2.

Total footage drilled during 1966 was 1,151,328 feet for an average of 6400 feet per well. While the total footage was down 10% from the previous year, the average depth per well increased from 5835 feet to 6400 feet,

indicating increased interest in the deeper geologic horizons. This was also reflected in the reserves where the Ordovician pools showed an increase of 2.3 percentage points at the expense of other producing horizons.

The results of the study have been tabulated by Marketing Districts, Counties, and Geologic horizons and the tables may be found at the end of this report as Tables IV, V, VI, VIIa, VIIb.

A WORD ABOUT CRUDE OIL RESERVE ESTIMATES

During the past year there has been much discussion about the accuracy and correlativity of various statistics concerning the oil industry. Reserve estimates were singled out for special criticism by personnel of the Federal Bureau of the Budget and academic economists who complained about the difficulties they encountered in attempting to compare reserve estimates prepared by different groups and individuals.

To those involved in the oil industry and the reserve problem, specifically, these differences are logical, and understandable, but it is possible that a layman would be confused.

Reserve estimates are made for a variety of purposes and to meet a variety of needs. Each purpose, and each need, requires a different approach, different methods, and different assumptions. Since the reserve estimate prepared by the Reserve Committee of the American Petroleum Institute is made for the use of the individuals and companies who are members of the Institute it is reasonable to suppose that the Committee has considered, and included in their estimate, the economics of production and it is easy to understand why their result would differ from that presented here.

This inventory has been prepared for use of the North Dakota Industrial Commission which is responsible for Oil and Gas Conservation. The Commission is charged with the duty of obtaining maximum ultimate recovery from the

oil and gas pools in the state. Therefore an estimate which includes all reserves technically recoverable provides a means by which the success of their programs can be measured. By technically recoverable reserves is meant that amount of oil which could be recovered using present technical knowledge, available equipment, and current operating methods. It does not take into account the economics of production since one of the objectives of the Conservation program is to improve the economics of production and thereby preclude the premature abandonment of wells which could still contribute to ultimate recovery.

Some reserve estimates include speculative reserves variously designated as "potential", "possible", or "probable" additional discoveries. Such speculation, while vital to some sectors of the industry, is not considered pertinent to the purpose of this report and no effort has been made to "gaze into the crystal ball". In accordance with this policy second order reserves are not included in the inventory until an energy supplementation program is actually initiated and fluid injection begun.[2/]

Any reserve estimate, regardless of the purpose for which it is made, should include a complete statement of the assumptions made, the sources of the data utilized, the parameters used, and the limitations, if any, that should be placed on the results. This is one of the more valid criticisms that can be made of the API figures. Since they are published with no explanation whatever, it is difficult to verify their results. For instance, the reader cannot tell whether the estimate includes second-order reserves or not; or whether speculative reserves are included.

Critics of oil industry statistics have suggested that a uniform method

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2/The terms "primary" and "secondary" have been dropped in favor of the terms "first order" and "second order" because it is felt that these programs should constitute a continuing phase of production and should not be defined by rigid time boundaries.

of calculating and presenting reserves be adopted. To do so would negate most, if not all, of the benefits of making such calculations. As pointed out above, each serves a different purpose. But more to the point is the fact that a change of method would prevent comparison with previous and subsequent estimates which is the primary value of the estimate to begin with.

The reader, by referring to previous publications in this series, can see that the figure has changed from year to year. Obviously, then none of the estimates are really correct and there is reason to believe that the figure for 1 January 1968 will be different still.

The estimate does serve a useful purpose by providing a comparison. Listed below are the various estimates of original oil in place taken from previous calculations;

TABLE I

Year	(Technically Recoverable) Original Oil in Place (STO)
1/1/62	721,856,000 barrels
1/1/63	721,695,000
1/1/64	812,673,000
1/1/65	848,852,500
1/1/66	859,500,000
1/1/67	924,346,500

The increase since 1 January 1963, following the drop in 1962, indicates renewed interest in oil development in North Dakota. The reason for this renewed interest might be better economics, a higher wildcat success ratio, improved market conditions, overall economic conditions in the industry, or a combination of circumstances.

Table II provides some interesting data.

TABLE II

Year	2nd Order Reserves Added	Production
1962	29,074,000 STO Barrels	24,854,396 STO Barrels
1963	64,427,000	26,280,379
1964	17,478,000	24,594,791
1965	-0-	26,358,388
1966	21,324,000	28,024,204

The first three years show that energy supplementation, alone, was able to offset production. Failure to initiate any additional projects in 1965 caused the Industrial Commission to adopt a policy which would establish production restrictions when it appeared that failure to initiate energy supplementation would result in loss of ultimate recovery.

If such comparisons are to be made and valid conclusions drawn therefrom it is apparent that the method must remain the same from one estimate to another.

The method used, and the assumptions made, in this study are set forth below.

EXPLANATION OF METHODS USED IN THIS STUDY

Throughout this inventory the standard volumetric method of estimating reserves has been used, according to the following formula:

$$R = 7758\ A\ h\ p\ (1-s)\ r\ /\ B$$ where

R	Recoverable reserves by presently known techniques
A	Proven acreage
h	Net average productive thickness in feet
p	Percent porosity
s	Percent water saturation
r	Recovery factor-percent
B	Reservoir volume factor - Barrels per barrel

The recovery factor used here does not take into account the economics of production. Since the study is intended to serve the same purpose as the annual inventories conducted by private business concerns, the economic situation was considered to be beyond the scope of the work.

For the purpose of this inventory a 40-acre tract was considered

proven acreage if it contained a producing well or if it offset a producing well, Credit given to offsetting 40-acre tracts was reduced if they contained dry holes or were offset in turn by dry holes.

The net average productive thickness was determined by Sidney B. Anderson, Chief Subsurface Geologist for the North Dakota Geological Survey, from mechanical logs on file in his office. Drill stem tests, core analyses and other information were considered. Additional development, particularly in relatively new pools, tended to reduce the average thicknesses used in earlier estimates.

Porosities and saturations were taken from core analyses, where available, or from log calculations. When such data was not available, values were assigned by analogy to other nearby pools producing from the same geologic intervals under similar conditions.

The formation volume factors were obtained from reservoir fluid analyses, when available, or by analogy.

The final result of the calculation was rounded off to the nearest thousand barrels, if the total was over 1 million, or to the nearest 500 barrels. The cumulative production to 1 January 1966 was then deducted to arrive at the final figure. Since the production is known to the exact barrel, this results in the final figure being shown to the single barrel.

Reserves due to supplementation of reservoir energy were added only in those cases where fluid injection was actually in progress.

DISCUSSION OF TABLES

The doubling of reserves credited to Marketing District IIIb is the outstanding feature of Table IV. This reflects the concentration of exploration efforts in the southwestern counties, and shows again in Table VI where the Ordovician horizons (the principal target of the exploratory effort) had the largest increase in reserves.

Table V shows the large increases in Billings, Bowman, and Slope counties and it also indicates a 3.3% increase in Renville County. Thus, while the southwestern counties held the spotlight, shallower drilling Renville County continued to pay off.

In Table VI the term "Permo-Pennysylvanian" has been substituted for "Pennsylvanian" on recommendation of the sub-surface geologists who feel that this is a better description of the "Heath" producing interval.

DEVELOPMENTS IN 1966

1966 was the first full year of operation without market demand restrictions. Demand in Marketing District I continued to rise but deliverability failed to keep pace and purchasers were obliged to look to other Districts for their supply.

At the end of the year oil was being trucked into District I from Districts IIa and IIIb. Purchasers in District IIa were unable to fill their needs from that source.

Price increases, averaging about 5 cents per barrel, were posted in most fields but the increase was not sufficient to meet increasing costs, particularly in the area of wages and taxes. Increases in Social Security Tax, Minimum wage, and corresponding increases in the costs of materials such as steel more than offset the crude price increase.

The Industrial Commission approved energy supplementation projects in the Charlson-Madison (North) Unit, the Antelope-Devonian Unit, and the Newburg-Spearfish-Charles Unit.

Negotiations were underway for the formation of units in the Blue Buttes-Madison Pool, Charlson-Madison (South) Pool, Lignite-Madison Pool, Black Slough-Madison Pool, and Grenora-Madison Pool.

While most of these negotiations were proceeding normally, some

difficulty was being encountered in the Blue Buttes Unit where the USGS was "studying" the proposed plan of unitization.

In the Grenora-Madison Pool the refusal of one royalty owner to ratify the proposal would appear to have halted the project which would have added about 2 1/3 million barrels of recoverable oil.

Expansion of the Williston refinery of Westland Oil Co. was begun during the year but the expanded facility was not "on stream" at year's end.

New field (or pool) discoveries are listed below.

TABLE III

North Grano - Madison	Renville County	6-14-66
Pershing - Devonian	McKenzie County	6-17-66
Eleven Bar - Red River	Slope County	7-26-66
Buffalo Creek - Red River	Stark County	10-10-66
Flat Lake (East) - Madison	Divide County	11-28-66
North Fork - Devonian	McKenzie County	11-28-66
West Dickinson - Heath	Stark County	11-28-66

STRIPPER WELL SURVEY

Table IVb from Miscellaneous Series #27 is included here as Table VIIa for the purpose of comparison. The new Table VIIb reflects the same information for 1 January 1967.

Production from marginal wells accounted for 3.14% of the total production in 1966, as compared to 2.5% in 1965. 127 wells became marginal during 1966 and 14 marginal wells were abandoned.

ACKNOWLEDGEMENTS

All of the information and data used in making this inventory was obtained from the files and records of the North Dakota State Industrial Commission, at the office of the North Dakota Geological Survey in Grand Forks.

In addition to Mr. Anderson, recognition is herewith given to the help

and assistance of Mr. Wesley D. Norton and Miss Juanita Williams, Assistant Petroleum Engineers for the Survey, and Mr. F. E. Wilborn, Jr., the Survey's Statistician.

TABLE IV

CRUDE OIL INVENTORY IN NORTH DAKOTA

	Primary Reserves STO	Secondary Reserves STO	Total Recoverable STO	Production To 1-1-67 STO	Remaining Recoverable 1-1-67 STO	% of Tot.	Fields Disc. 1-1-67	Pools Disc. 1-1-67	Fields Abandoned 1-1-67	Fields Producing 1-1-67	Pools Producing 1-1-67	Producing Acres
District I	345151500	260521000	605642500	182942562	422699938	63.3	34	51	1	33	46	165332
District IIa	68746000	2000000	70746000	21837945	48908055	7.3	21	21	4	17	17	56700
District IIb	69617500		69617500	22007651	47609849	7.1	23	29	3	20	23	44540
District IIc	50010500	12938000	62948500	14361056	48587444	7.2	18	19	2	16	17	35605
District IIIa	6364000		6364000	1813338	4550662	0.6	1	1	0	1	1	3788
District IIIb	104920000	6178000	111098000	15233866	95864134	14.5	9	13	2	7	10	36189
	644709500	279637000	924346500	256383080	667963420		106	144	12	94	114	342214
Less Gasoline Plant Recovery					361958							
					667601462							

TABLE V

CRUDE OIL INVENTORY IN NORTH DAKOTA

	Primary Reserves STO	Secondary Reserves STO	Total Recoverable STO	Production To 1-1-67 STO	Remaining Recoverable 1-1-67 STO	% of Total	Fields Disc. 1-1-67	Pools Disc. 1-1-67	Fields Abandoned 1-1-67	Fields Producing 1-1-67	Pools Producing 1-1-67	Producing Acres
illings	54972500		54972500	8088451	46884049	7.0	5	8	2	3	6	26860
ttineau	90421500	10938000	101359500	23140056	78299444	11.7	29	30	3	26	27	57005
rvman	44784500	6178000	50962500	4627763	46334737	6.9	2	3	0	2	2	7609
rke	80012000	2000000	82012000	29784817	52227185	7.8	22	22	3	19	19	60045
vide	14050000	9052500	23102500	3002703	20099797	3.0	7	7	1	6	6	8035
nn	390000		390000	262874	127126	0.1	1	1	0	1	1	360
Henry	3230000		3230000	230441	2999559	0.4	1	1	0	1	1	1000
Kenzie	138417000	53397000	191814000	63180552	128633448	19.2	15	27	1	14	22	67263
ntrail	28029000	43994000	72023000	21238865	50784135	7.6	3	3	0	3	3	15060
nville	23202500		23202500	12509166	10693334	1.6	11	11	2	9.	9	18940
pe	1713000		1713000	69589	1643411	0.2	1	1	0	1	1	720
rk	2555000		2555000	437527	2117473	0.3	4	5	1	3	3	2600
d	99000		99000	51517	47483	0.1	1	1	0	1	1	660
liams	162313500	136267950	298581250	89758759	208822491	34.10	10	15	0	10	15	76417
	644709500	279637000	924346500	256383080	667963420							342214
ss Gasoline Plant Recovery					361958							
					667601462							

TABLE VI

CRUDE OIL INVENTORY IN NORTH DAKOTA

	Primary Reserves STO	Secondary Reserves STO	Total Recoverable STO	Production To 1-1-67 STO	Remaining Recoverable 1-1-67 STO	% of Tot.	Fields Disc. 1-1-67	Pools Disc. 1-1-67	Fields Abandoned 1-1-67	Fields Producing 1-1-67	Pools Producing 1-1-67	Producing Acres
Devonian	60526000	36670000	97196000	22562564	74633436	11.1		17			13	32501
Mississipian	491000000	236189000	727189000	219616179	507572821	76.3		110			87	268813
Ordovician	48882500	6178000	55060500	5190688	49869812	7.4		7			6	16389
Permo-Penn	29254000		29254000	4883810	24370190	3.6		6			5	15380
Silurian	13913000	600000	14513000	4084558	10428442	1.5		3			2	8771
Triassic	1134000		1134000	45281	1088719	0.1		1			1	360
	644709500	279637000	924346500	256383080	667963420	100.0		144			114	342214
Less Gasoline Plant Recovery					361958							
					667601462							

TABLE VIIa

NORTH DAKOTA STRIPPER WELLS

	No. of Wells	1965 Production	Acres	Abandoned 1965	Primary Reserves 1-1-66	Secondary Reserves 1-1-66	Average daily Production Dec. 1965	Average daily Production per Well 1965
Billings	4	15510	560	0	903392		38.06	9.52
Bottineau	71	149493	5001.24	4	8134002	148300	369.22	5.20
Bowman	3	11308	480	5	592104	496800	15.67	5.22
Burke	76	184027	9200	3	5556265	779360	394	5.18
Divide	1	888	80	0	21448			
McKenzie	25	74631	2173.08	1	3010049	2689920	90.74	3.63
Mountrail	22	38111	1760	0	526189	2749440	75.96	3.45
Renville	9	27370	720	1	275943		34.64	3.85
Williams	46	141203	3791.79	4	4528221	4793880	281.70	6.12
	257	642541	23766.11	18	2354761	11657700	1299.99	5.06 B/D/well

TABLE VIIb

NORTH DAKOTA STRIPPER WELLS

	No. of Wells	1966 Prod. Bbls.	Acres	Abandoned 1966	Primary Reserves 1-1-67	Secondary Reserves 1-1-67	Average daily Production December 1966	Average daily Production per Well 1966
Billings	8	23266	2160	0	3603683		41	7.0
Bottineau	80	192078	3840	1	4056639	154500	457	6.6
Bowman	3	5188	400	0	1877074	248500	11	5.4
Burke	101	240371	13278	1	10654922	266080	476	11.5
Divide	1	1238	160	0	299881	549600	0	0.0
McKenzie	68	147870	6478	8	6496917	2570000	262	7.1
Mountrail	24	51560	1915	2	52365	3093120	93	6.7
Renville	14	30026	1120	2	1222369		72	7.1
Williams	71	187773	6438	0	7851454	7635000	324	6.5
	370	879369	35789	14	36071304	14516800	1736	6.93

APPENDIX A

MARKETING DISTRICT I

Geographical description: Township 148 North to 161 North, Ranges 94 West to 97 West, inclusive

Fields: Gros Ventre, Viking, North Tioga, Tioga, McGregor, West Tioga, East Tioga, White Earth, Beaver Lodge, Capa, Hofflund, Delta, Charlson, Blue Buttes, Antelope, Croff, Bear Den, Lost Bridge, Pershing, Camel Butte, Fancy Buttes, Dimmick Lake, Clear Creek, Keene, Sand Creek, Northwest McGregor, Stoneview, Wildrose, and Hawkeye.

MARKETING DISTRICT II

Subdistrict A

Geographical description: Township 164 North, Ranges 88 West to 103 West, inclusive, Township 163 North, Ranges 88 West to 103 West, inclusive, Township 162 North, Ranges 88 West to 103 West, inclusive, Township 161 North, Ranges 88 West to 93 West, and 98 West to 103 West, inclusive, and Township 160 North, Ranges 88 West to 93 West, and 98 West to 103 West, inclusive.

Fields: Baukol-Noonan, Noonan, Short Creek, Columbus, Portal, Rival, Black Slough, Foothills, Northeast Foothills, Rennie Lake, Lignite, Flaxton, Stony Run, Woburn, Bowbells, and Perella.

Subdistrict B

Geographical description: All of the state not included in other districts or subdistricts.

Fields: Dickinson, Haas, North Haas, Kuroki, Wayne, Wiley, Elmore, Sherwood Eden Valley, Pratt, Glenburn, Lansford, Mohall, North Maxbass, South Antler Creek, Southwest Haas, Tolley, Chola, Southwest Aurelia, and Mouse River Park.

Subdistrict C

Geographical description: Townships 160 North to 164 North, Ranges 77 West to 80 West, inclusive.

Fields: North Souris, Scandia, Northeast Landa, Roth, Starbuck, South Starbuck, North Westhope, Westhope, South Westhope, Newburg, East Newburg, West Roth, Boundary Creek, and Russell.

MARKETING DISTRICT III

Subdistrict A

Geographical description: Townships 158 North to 160 North, Ranges 98 West to 107 West, inclusive.

Fields: Grenora

Subdistrict B

Geographical description: Townships 129 North to 158 North, Ranges 98 West to 107 West, inclusive.

Fields: Little Missouri, Cedar Creek, Rocky Ridge, Fryburg, Medora, and Rough Rider