

DEPARTMENT OF NATURAL RESOURCES
GEOLOGICAL SURVEY DIVISION
PRODUCTION AND PRORATION UNIT
SECONDARY RECOVERY REPORT NO. 7

Columbus 3 Unit

**ENHANCED OIL & GAS RECOVERY IN
MICHIGAN**

by

Arthur D. Matzkanin, Floyd L. Layton, James S. Lorenz,
Ronald J. Pollom, and Rex A. Tefertiller, Jr.

Lansing, Michigan 1978

series on Salina-Niagaran reservoirs. The Onondaga 10 Unit report (Number 5 in series), Aurelius 35 Unit report (Number 6 in series), and this report demonstrate the advantages to be gained by implementing either pressure maintenance or secondary recovery projects in Salina-Niagaran reefs. Like the Onondaga 10 Unit and the Aurelius 35 Unit, this project is a pressure maintenance operation and is to be distinguished from a secondary recovery project. The advantage to be gained by initiating a pressure maintenance project rather than utilizing secondary recovery methods is the resultant greater ultimate oil recovery. Secondary recovery methods are initiated after primary production has been depleted. Pressure maintenance operations are begun while primary production remains in the reservoir.

ABSTRACT

The Columbus 3 Unit located in St. Clair County is an example of a successful pressure maintenance project. The success of such a project most often is realized through the maintenance of reservoir pressure by the injection of gas and/or water into the reservoir. However, in the case of the Columbus 3 Unit, the incremental gain of 64 percent in excess of anticipated primary production is generally the result of more efficient production of the field, achieved through selective production of the best wells as permitted through the unitization agreement.

INTRODUCTION

Wildcat drilling by Sun Oil Company led to the discovery of the Columbus 3 field in December 1968 through the application of the most modern geophysical technology available at the time. The risks associated with the application of gravity anomaly data to the discovery of oil and gas are illustrated by the fact that two dry holes were drilled into the perceived Columbus 3 structure prior to the actual discovery of the field. The field spans approximately 460 reservoir acres and is located in Sections 3 and 10 of Columbus Township, T5N, R15E, and Section 34 of Wales Township, T6N, R15E, in St. Clair County.

The Columbus 3 field, now unitized, produces from a Niagaran reef developed during Silurian time. The reef extends in a north-south direction and contains a structural saddle in the southern portion which results in two gas caps in the reservoir. The gas-oil contact in the northern gas cap is located at 2352 feet subsea level, while in the southern gas cap it is located at 2390 feet subsea level. The oil-water contact is constant throughout the reservoir with a subsea elevation of 246A feet. The average reservoir oil pay per well is approximately 51 feet. At the present time the gas being injected into the reservoir is that gas which is produced with the oil.

Contents

PREFACE	1
ABSTRACT.....	1
INTRODUCTION.....	1
SALINA AND NIAGARAN RESERVOIR ROCKS	2
GENERAL HISTORY OF THE COLUMBUS 3 UNIT	2
REFERENCES.....	5

Figures

Figure 1. <i>Principal oil and gas pays and informal terms used in petroleum exploration applied to parts of formations or groups of formations in the subsurface of the Michigan Basin.</i>	3
Figure 2. <i>Structure of the Columbus 3 Unit.</i>	4
Figure 3. <i>Oil and water production from the Columbus 3 Unit.</i>	5
Figure 4. <i>Water and gas injected into the Columbus 3 Unit.</i>	5
Figure 5. <i>Bottom-hole pressure drop versus reservoir cumulative oil production for the Columbus 3 Unit.</i>	5

Data Sheets

Data Sheet No. 1. <i>Columbus 3 Unit, Niagaran Waterflood Project</i>	4
---	---

Tables

Table 1. <i>Oil, gas, and water production from the Columbus 3 Unit</i>	6
Table 2. <i>Water and gas injection data for the Columbus 3 Unit.</i>	6

PREFACE

The Columbus 3 Unit report is the third report in this

SALINA AND NIAGARAN RESERVOIR ROCKS

In the Michigan Basin, Salina and Niagaran rocks of the Silurian period contain highly productive oil and gas reservoirs in reef and associated structures.

Niagara rocks in the subsurface are predominantly dolomites and limestones with scattered regional occurrences of cherty zones and thin shale beds. These rocks range in thickness from less than 100 feet in the basin interior to more than 1000 feet at the basin margin. Oil, condensate, and gas production are found primarily in pinnacle reef complexes a few miles basinward from the thick carbonate bank.

Reefs, reef associated sediments, and biostromes occur at various stratigraphic levels within the Salina-Niagara Group. Reefs range in size from small isolated masses 10 feet in diameter to large complexes several hundred acres in extent and vary in height from a few feet to more than 500 feet. Most reefs in the subsurface appear to be coral-algal-stromatoporoid mounds with occurrences of brecciation and a variety of fossil debris from shelly organisms. "Pay zone" porosity appears to be developed by preferential solution of coral skeletons and invertebrate remains from the fossiliferous rock by groundwaters. Dolomitization of limestone reefs frequently plays an important role in the development of porosity. Occasionally evaporite infilling destroys potentially productive porosity.

The Salina Group contains evaporite, carbonate, and shale stratigraphic units. The A-1 Evaporite, A-1 Carbonate, A-2 Evaporite, and A-2 Carbonate units are of particular interest where Niagaran reefs are present. While the A-1 Evaporite is a clean salt over most of the Michigan basin interior, the unit grades laterally into an anhydrite that thins and pinches out against the flanks of reef complexes. The A-1 Carbonate is essentially a dark colored limestone, dolomite, or both in non-reef locations. In the vicinity of reefs, the A-1 Carbonate may be completely or partially dolomitized and exhibits depositional thinning over the reef and margin reef complexes. The A-2 Evaporite is nearly a pure salt in the deeper parts of the basin, while near reefs the unit is generally represented entirely by anhydrite. Partial dolomitization and some depositional thinning occur in the A-2 Carbonate where it overlays reef complexes.

Other Salina Group units have been shown to be capable of oil and gas production in limited areas of Michigan. For example, small anticlinal structures where the A-1 and A-2 Carbonates are draped over Niagaran reefs have been known to produce oil and gas when porosity in these units is sufficiently developed.

GENERAL HISTORY OF THE COLUMBUS 3 UNIT

The Columbus 3 field was discovered on December 11,

1968, with the completion of the H. H. Winn #1 located in the NE $\frac{1}{4}$ NE $\frac{1}{4}$ SW $\frac{1}{4}$ of Section 3, T5N, R15E, Columbus Township, St. Clair County. By April 1970 the entire extent of the field had been delineated with the completion of 22 additional productive wells. Since that date no other wells have been drilled in the reservoir.

A spacing order dated December 19, 1968, was adopted to establish 20-acre drilling units and well spacing patterns for the Columbus Section 3 Salina-Niagaran Formation Pool. The drilling units, rectangular in shape, are formed by dividing a governmental surveyed quarter-quarter section of land into an east half and a west half. This spacing order designated the Columbus 3 Pool to span a tract of 1360 acres. An amended spacing order was issued on May 22, 1969, to include an additional 360 acres. A Proration Order was issued, effective February 1, 1970, which established an allowable of 75 barrels of oil and/or 100,000 cubic feet of gas per day per well.

Early in the production history of the Columbus 3 field, Sun Oil Company conducted a pressure maintenance feasibility study and summarized the findings in a November 1971 report. The report contained the recommendation that a gas-plus-water pressure maintenance project be initiated for the field to include the injection of approximately 200 Mcf gas per day or approximately 80% of the produced gas plus about 500 barrels of water per day. This decision was based upon the fact that an incremental gain of 2,100,000 barrels of additional oil was forecast if the proposed pressure maintenance project was implemented.

To process the gas a 2500 MCF/GPD refrigeration-type gas processing plant with a suction pressure of 300 psig and a discharge pressure of 1600 psig was recommended. The reservoir was evaluated by means of two computerized simulation models that matched historical performance of the field with model parameters and accordingly projected future recovery. By using the models, future performance was evaluated through analysis of bottom-hole pressure data, production data, isopach information, reservoir geometry, and physical properties of the oil and gas. From this data the determination was made that the reservoir contained an estimated original stock tank volume of 11,375,000 barrels of oil with 7,055 MMcf of solution gas plus a gas cap containing 3,623 MMcf of gas.

Much of the original porosity has been destroyed by the presence of salt throughout the reservoir. Salt-filled porosity is especially present in the top of the reservoir structure and in the west flank of the reef, and, to a lesser extent the upper portion of the reef along the eastern flank is salt plugged. Porosity in the remainder of the reef was found to depend upon the degree of dolomitization caused by the movement of formation waters during lithification.

An initial attempt at the unitization was made on March 20, 1973, when the Sun Oil Company filed a petition with the Supervisor of Wells requesting an order providing for

the unitized management, operation, and pressure maintenance of the Columbus 3 Field. The findings, as a result of a hearing held May 15, 1973, specified approval of the plan on June 20, 1973, contingent upon Sun Oil Company obtaining written approval of 75 percent of the interests which are free of costs, as stipulated in Act 197, Public Acts of 1959 (Unitization Act). The unitization agreement did not take effect as scheduled and the gas, which was produced from the field in excess of that used for lease fuel requirements, continued to be flared.

This gas flaring led to a show cause hearing held on March 20, 1974, to explore the opinion of the Supervisor of Wells issued on February 22, 1974, that "... based on the data of record, the opinion that the venting and flaring of gas without beneficial use is unnecessary and unwarranted waste and that a gas gathering system and facilities should be installed capable of processing and marketing all gas produced." At this time estimated volumes of gas being vented and flared totaled approximately 500 Mcf per day. At the time of the March hearing, unitization of the field had not yet been accomplished because 75% of the interests which are free of costs had not approved the plan. The determination of the Supervisor of Wells dated April 13, 1974, stated that in the interest of maximum hydrocarbon production from the reservoir all produced gas from the Columbus 3 field should be recycled "... for pressure maintenance or marketed prior to July 1, 1974" or that "... all wells in the pool are to be immediately closed in and remain closed in until such time the gas is either utilized in pressure maintenance of the reservoir or gas connections and market facilities have been achieved."

In response to this action, the necessary 75% of the interests which are free of costs signed the unitization agreement and a supplemental hearing was held on June 25, 1974, on which date the unitization order was issued for the Columbus 3 Unit. The order became effective June 30, 1974, and supersedes the proration order for the field. At the time of unitization, two gas wells in the field were converted into gas injection wells and an oil well was converted into a water injection well. The source of gas and water injected into the field is that gas and brine associated with the production of oil from the field.

Through June 30, 1978, a total of 4,360,000 barrels of oil has been produced, with no gas sales from the field. Estimated primary production of 3,275,000 barrels of oil was exceeded in the third quarter of 1976. As of May 1978 the Columbus 3 Unit has 10 pumping wells, 6 flowing wells, one temporarily abandoned well, 3 wells shut-in for high gas-oil ratios, 1 water injection well (brine disposal well), and 2 gas injection wells. Most of the wells in the field could be flowed without the use of a pump, but to minimize paraffin problems pumping units with scrapers on the pump rods have been installed. At the present time a vapor recovery unit recovers approximately 60 to 100 Mcf of gas per day, which is

reinjecting into the field.

With the unitization of the field, the Columbus 3 Unit has been produced with greater efficiency than when the wells were produced at the prorated allowables. Without unitization all high GOR and gas wells would be produced with a loss of ultimate oil recovery from the reservoir. This results from the fact that energy contained within the reservoir which could have been used to produce oil would have imprudently been used to produce gas from the reservoir. Production efficiency was increased by the selective production of the best oil wells as permitted in the unitization order. This fact, more than any other, has led to the projected incremental gain of 2,100,000 barrels of oil for the project.

STRATIGRAPHIC POSITION	INFORMAL TERMS	PAYS
Basal sandstones of Saginaw Fm.	Parma sandstone	
In lower part of Michigan	triple gyp brown lime gray-stay ss gray dol gray ss	Gas Gas & Oil
Marshall Ss.		Gas & Oil
Coldwater Sh.	Coldwater lime Weir sand Coldwater red-rock	Gas
In upper part of Ellsworth Sh.	"Berea" (Western Michigan)	Oil & Gas
Berea Ss.	Berea sand (Eastern Michigan)	Oil & Gas
Squaw Bay Ls.	Squaw Bay	Oil & Gas
Upper part of Traverse Group in Western Michigan	Traverse formation Traverse lime Stoney Lake zone	Oil & Gas Oil & Gas
Rogers City Ls.		Oil & Gas
Dundee Ls.		Oil & Gas
Dundee Ls. (?), Upper part of Lucas Fm. (?)	Reed City zone	Oil & Gas
In Lucas Fm.	massive salt big salt sour zone massive anhydrite big anhydrite Richfield zone	Oil & Gas Oil & Gas
Amherstburg Fm.	black lime	
Part of Salina Group E Unit	E zone (or Kintigh zone)	Oil
Divisions of A-2 Carbonate in Western Michigan	A-2 dolomite A-2 lime	Gas
A-1 Carbonate	A-1 dolomite	Oil & Gas
Upper part of Niagara Series	brown Niagara gray Niagara white Niagara	Oil & Gas
Part of Niagara Series	Clinton shale (Eastern Michigan)	
Trenton Group		Oil & Gas
Black River Group	Black River formation Black River shale Van Wert zone	Oil & Gas
Oneota Dol.		Oil

Figure 1. Principal oil and gas pays and informal terms used in

petroleum exploration applied to parts of formations or groups of formations in the subsurface of the Michigan Basin.

A summary of field data is presented in Data Sheet No. 1. Historical oil production is listed in Table 1, with gas and water injection data listed in Table 2. Figure 5 illustrates bottom-hole pressure drop versus reservoir cumulative oil production for the Columbus 3 Unit. As of May 1978 the field is producing at a bottom-hole pressure of 1020 psig with a 20 psig pressure decline for the last twelve months. Total field production per 1 psig pressure drop has been 10,300 barrels of oil.

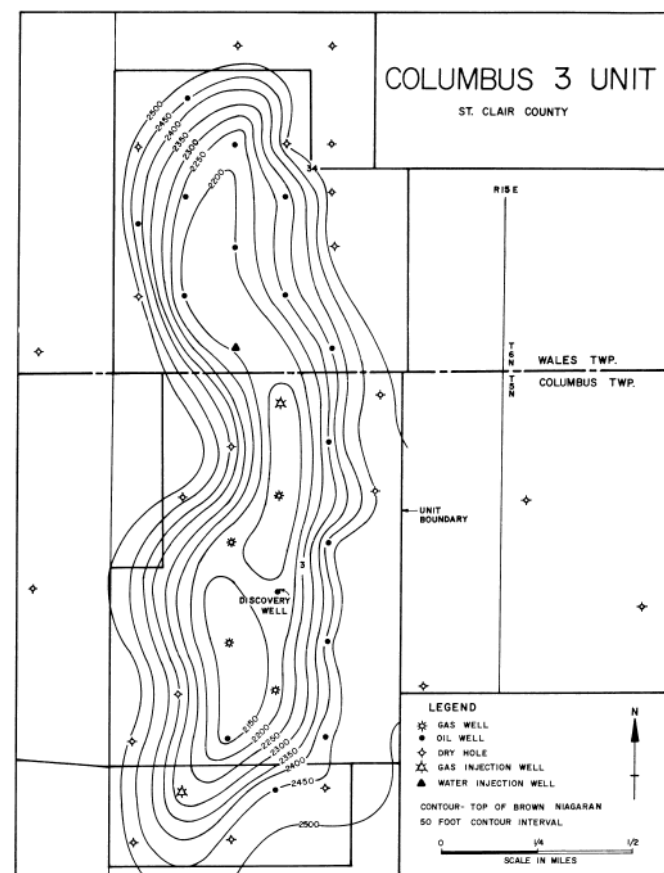


Figure 2. Structure of the Columbus 3 Unit.

Data Sheet No. 1

Columbus 3 Unit

Salina-Niagaran Pressure Maintenance Gas Injection and Waterflood Project

GENERAL POOL DATA

Location St. Clair County, Columbus Township (T5N, R15E), Sec. 3, 10, Wales Twp. (T6N, R15E), Sec. 34

Date of pool discovery December 11, 1968
Discovery well Sun Oil Company, H. H. Winn #1 Permit No 27691
Producing formation Salina-Niagaran
Pay lithology Brown dolomite, dolomitized carbonate
Type of trap Reef
Drilled acres 460
Unit acres 860
Reservoir area, estimated acres 460

ENGINEERING DATA

Type of reservoir energy Gas cap
Original reservoir pressure 1447 psia
Reservoir temperature 72°F
Viscosity of original reservoir oil .95 cp
Bubble point pressure 1447 psia
Formation volume factor 1.281 Reserve bbl./stock tank bbl.
API oil gravity 40.2°
Original solution gas-oil ratio 615 c.f.p.b.
Average porosity 10% gas zone, 12% oil zone
Average permeability 80 md. gas zone, 150 md. oil zone
Connate water, estimated 12% gas zone, 14% oil zone
Net oil pay thickness 51 feet* (estimated)
Acre feet of oil pay 23460*

RECOVERABLE HYDROCARBON DATA*

Estimated original stock tank oil in place 11,375,000 bbls.
Est. original recoverable stock tank oil 3,275,000 bbls.
Calculated recoverable stock tank oil per acre foot 140 bbls. primary; 229 bbls. primary and secondary
Original gas in solution 7055 MMcf, 3623 MMcf gas cap
Est. additional recoverable oil due to secondary recovery methods 2,100,000 bbls.

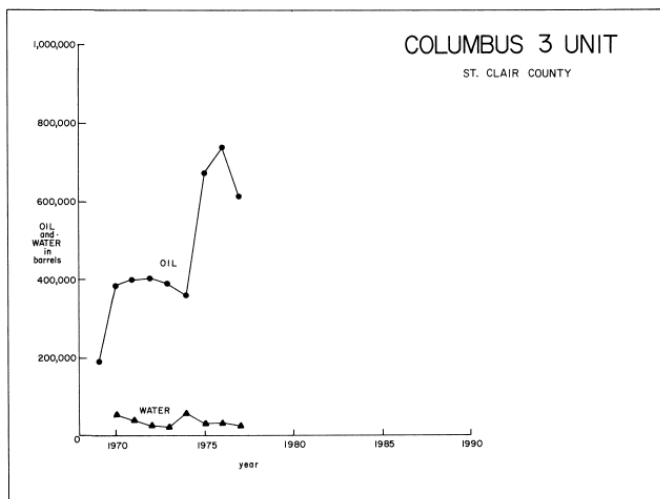


Figure 3. Oil and water production from the Columbus 3 Unit.

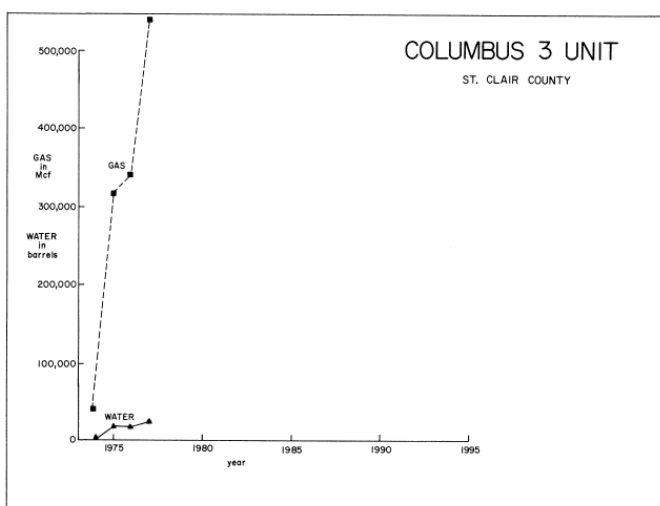


Figure 4. Water and gas injected into the Columbus 3 Unit.

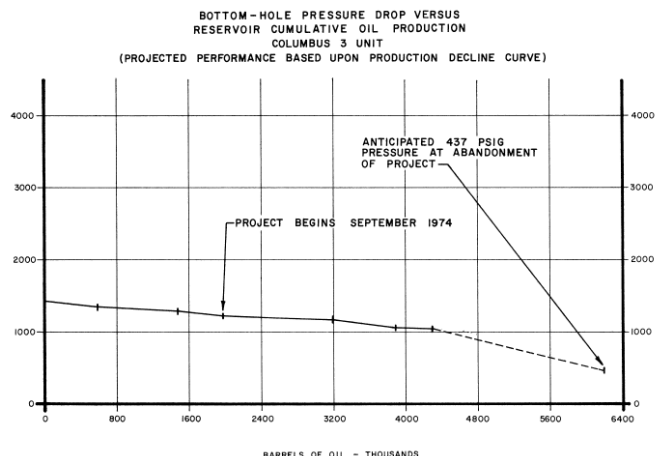


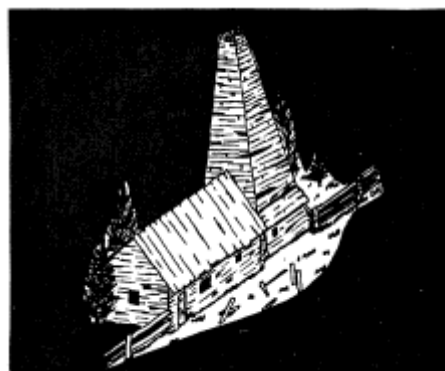
Figure 5. Bottom-hole pressure drop versus reservoir cumulative oil production for the Columbus 3 Unit.

REFERENCES

- Cohee, George V., (1948), Thickness and Lithology of Upper Ordovician, and Lower and Middle Silurian Rocks in the Michigan Basin. U.S. Geological Survey Oil and Gas Investigation, Preliminary Chart No. 33.
- Ells, Garland D., (1967), Michigan's Silurian Oil and Gas Pools. Michigan Geological Survey Publication.
- Mantek, W., (1973), Niagaran Pinnacle Reefs in Michigan, Michigan Basin Geological Society, Annual Field Conference.
- Mesolella, K. J., Robinson, J. D., McCormick, L. M., and Ormiston, A. R., (1974), Cyclic Deposition of Silurian Carbonates in the Michigan Basin. Bulletin American Association of Petroleum Geologists, Volume 58, No. 1, (January, 1974).
- Michigan Basin Geological Society, 1968, Symposium on Michigan Oil & Gas Fields: 199 pages.
- Michigan Geological Survey, Michigan's Oil and Gas Fields: Annual Statistical Summaries 2 thru 22 (even numbered issues only).
- Sun Oil Company, Feasibility Study of Pressure Maintenance, Niagaran Brown Dolomite Reservoir, Columbus Section "3" Field, November, 1971.

Other publications available in this series:

- #1 HAMILTON FIELD, RICHFIELD OIL POOL, 1976 Wilson, S. E., F. L. Layton, J. S. Lorenz, A. D. Matzkanin, and R. J. Pollom
- #2 BEAVER CREEK FIELD, 1976 Pollom, R. J., F. L. Layton, J. S. Lorenz, A. D. Matzkanin, and S. E. Wilson
- #3 CRANBERRY LAKE FIELD, RICHFIELD OIL POOL, 1976 Wilson, S. E., F. L. Layton, J. S. Lorenz, A. D. Matzkanin, and R. J. Pollom
- #4 ENTERPRISE FIELD, 1977 Matzkanin, A. D., F. L. Layton, J. S. Lorenz, R. J. Pollom, and R. A. Tefertiller, Jr.
- #5 ONONDAGA 10 UNIT, 1977 Pollom, R. J., F. L. Layton, J. S. Lorenz, A. D. Matzkanin, and R. A. Tefertiller, Jr.
- #6 AURELIUS 35 UNIT, 1977 Matzkanin, A. D., F. L. Layton, J. S. Lorenz, R. J. Pollom, and R. A. Tefertiller, Jr.



Columbus 3 Unit, St. Clair County							
Year	Production Data						Remarks
	Gas		Oil		Water (estimated)		
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	
1969			180,820	180,820			Unitization effective June 30, 1974
1970			382,202	563,022	53,655	53,655	
1971			398,152	961,174	40,880	94,535	
1972			401,631	1,362,805	24,455	118,990	
1973			387,750	1,750,555	19,710	138,700	
1974			360,473	2,111,028	55,480	194,180	
1975			669,880	2,780,908	29,930	224,110	
1976			737,938	3,518,846	30,660	254,770	
1977			612,163	4,131,009	26,100	280,870	

Table 1. Oil, gas, and water production from the Columbus 3 Unit. Oil and water production figures are shown in barrels. Gas production figures are shown in thousand cubic feet (Mcf).

Columbus 3 Unit, St. Clair County								
Year	Injection Data							
	Gas			Water			Pressure	
	No. Wells	Annual	Cumulative	No. Wells	Annual	Cumulative	Gas	Water
1974	2	40,414	40,414	1	559	559	1070	Vacuum
1975	2	318,263	358,677	1	18,382	18,941	1100	Vacuum
1976	2	340,759	706,264	1	18,677	37,618	1100	Vacuum
1977	2	580,638	1,286,902	1	25,906	63,524	1100	Vacuum

Table 2. Water and gas injection data for the Columbus 3 Unit. Water figures are in barrels

STATE OF MICHIGAN
 William G. Milliken, *Governor*
 DEPARTMENT OF NATURAL RESOURCES
 Howard A. Tanner, *Director*
 GEOLOGICAL SURVEY DIVISION
 Arthur E. Slaughter, *Chief and State Geologist*
 NATURAL RESOURCES COMMISSION
 Hilary F. Snell, *Chairman*, Grand Rapids, 1971
 E. M. Laitala, Hancock, 1961
 (Mrs.) Joan L. Wolfe, Belmont, 1973
 Harry H. Whiteley, Rogers City, 1961
 Carl T. Johnson, Cadillac, 1963
 Charles G. Younglove, Allen Park, 1972
 Jacob A. Hoefer, East Lansing, 1979
 John M. Robertson, *Executive Assistant*

Published by authority of State of Michigan CL '70 s.321.6 Printed by Reproduction Services Section, Office Services Division, Department of Management and Budget Available for \$.50 per copy from the Information Services Center, Department of Natural Resources, Box 30028, Lansing, Michigan 48909.

On deposit in public libraries, state libraries, and university libraries in Michigan and other selected localities.