Case History of the Seven Rivers Sand Waterflood Crockett County, Texas

BY E. A. "Mike" RILEY
T. P. BATES
Ambassador Oil Company

INTRODUCTION

The Noelke Field, located approximately 6-1 2 miles Southeast of Iraan in Crockett County, Texas, (Fig. 1) covers some 2760 proven productive acres with an estimated 1300 acres being oil productive and the remainder being high enough structurally to carry gas saturation. The oil productive acreage is contained in two separate "oil rings or pendants" around the gas cap (Fig. 2). Both oil segments have been waterflooded—the northern by Delhi-Taylor and the southern by Ambassador Oil Corporation, General American Oil Co. of Texas, and J. T. Holmes.

This paper will report on the southern segment only which lies in portions of Sections 20, 24, 26, 29, and 30 Blk. GG, HE&WT Railroad Survey and Sections 60 and 77 W. F. Millin Survey.

The discovery well in the southern segment, Soma Oil & Gas Syndicates' J. T. Gouras No. 1 (Ambassador Oil Corporation's W. T. Nelke "G" No. 1) was completed in April 1960 at a total depth of 1032 ft for an estimated initial potential of 10,000 BOPD flowing "wild" for approximately 19 days before being controlled. Evidence of this exists in the dry creekbed being coated with asphalt-like material for several miles into the Pecos River. Two months later when the well was settled enough for a reliable test, a potential of 775 BOPD was reported to the Raidroad Commission. Subsequent wells completed within 18 months also exhibited high potentials but due to the rapid decline in potentials and the low price of crude during early 1940-1941 (80c per bbl) many proven to semi-proven locations were not drilled. During 1940, 12 wells were completed and during 1941 17 wells were completed. In 1943 two wells extended the field to the South (Noelke "J" lease) and in 1947 one infill well was drilled. The three producers in Section 24 were drilled in the late 1950's encountering a significant section of pay sand which contained highly viscous, black crude. These wells never produced commercial primary or secondary oil.

A total of 40 wells (26 oil, seven gas and seven dry) was drilled during primary life. Development drilling during subsequent waterflood operations resulted in an additional 18 wells proving a total estimated 700 oil productive acres and 443 conformable waterflood acres in the southern segment.

Primary oil recovery to economic limit was 1,344,527 bbl for the area in discussion or 1921 bbl per acre. Secondary oil recovery to January 1, 1965 has been 2,502,789 bbl or 5650 bbl per acre.

GEOLOGY

The Noelke Field produces from the Seven Rivers Sand (Soma locally) of the Permian System. Due to the high topographical relief of the surface, the sand is found at depths ranging from 1006 to 1756 ft from the surface. Average surface elevation is 2600 ft above mean sea level and relief reaches 275-700 ft between some offset well locations. The pay zone dips approximately 40-50 ft per 660 ft location to the east and southeast.

Original gas-oil contact in the southern segment was at 1332 ft and runs diagonally across the area from southwest to northeast through Sections 29, 30, and 66 (Fig. 3).

The producing sand is most probably of lagoonal origin laid down along the southeastern edge of the Central Plains Basin Platform, a thumb-like projection extending into the old Permian Sea from southeastern New Mexico to Southern Crockett County, Texas. It was formed in early Pennsylvanian time as a series of "en echelon" mountain uplifts and thick Permian deposits were laid down atop the old eroded sur-

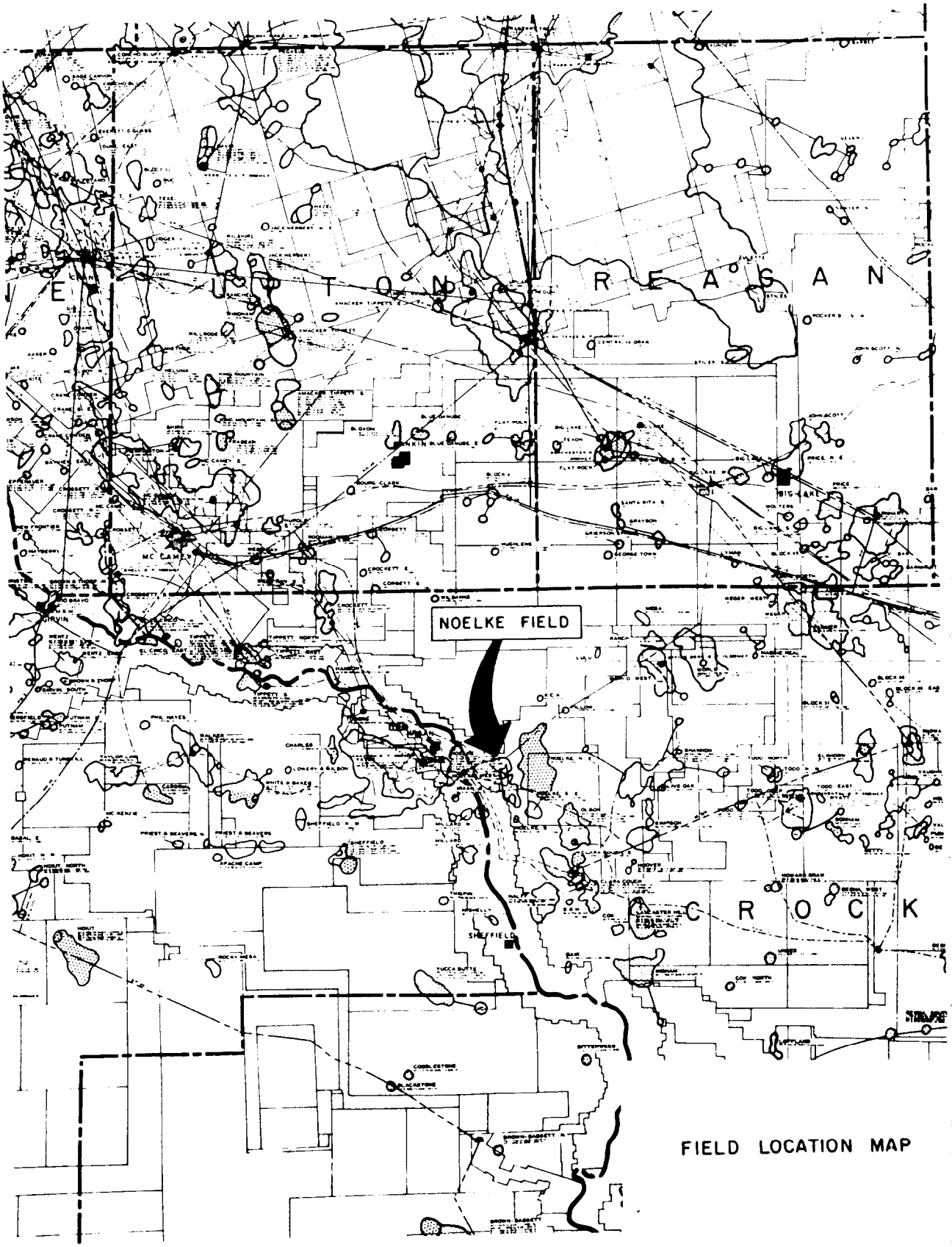

E A S T O N R E A G A N
NOELKE FIELD
C R O C K
SHEFFIELD
FIELD LOCATION MAP

FIG. 1

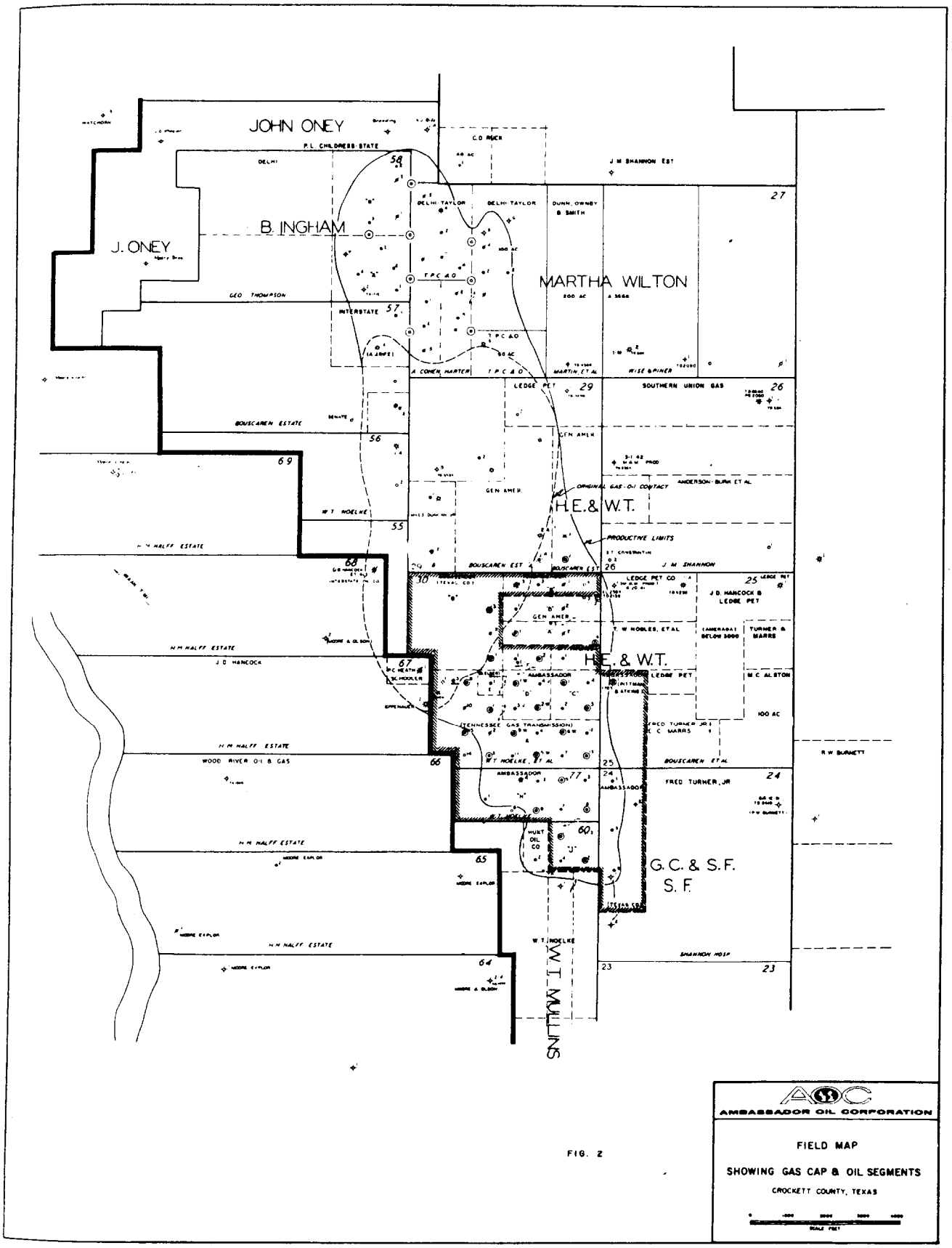
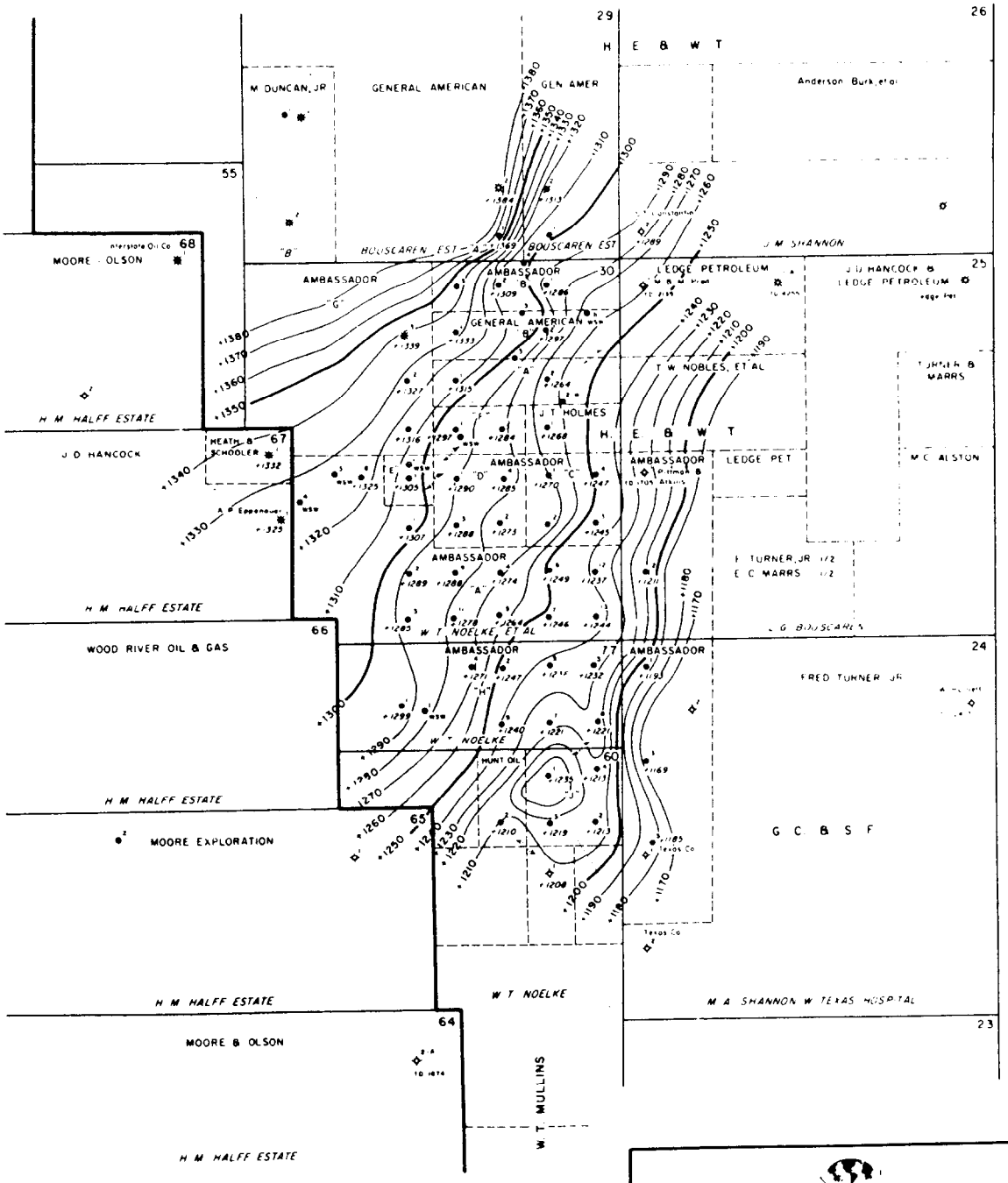

JOHN ONEY
B. INGHAM
J. ONEY
MARTHA WILTON
H.E.& W.T.
H.E. & W.T.
G.C. & S.F.
S.F.
W.T. MULLINS
AMBASSADOR OIL CORPORATION
FIELD MAP
SHOWING GAS CAP & OIL SEGMENTS
CROCKETT COUNTY, TEXAS

FIG. 2



AMBASSADOR OIL CORPORATION

STRUCTURE MAP OF
SOUTHERN SEGMENT
CROCKETT COUNTY, TEXAS
CONTOURED ON
TOP OF SOMA SAND
CONTOUR INTERVAL 10 FEET

0 1000 2000 3000 4000
SCALE FEET

FIG. 3

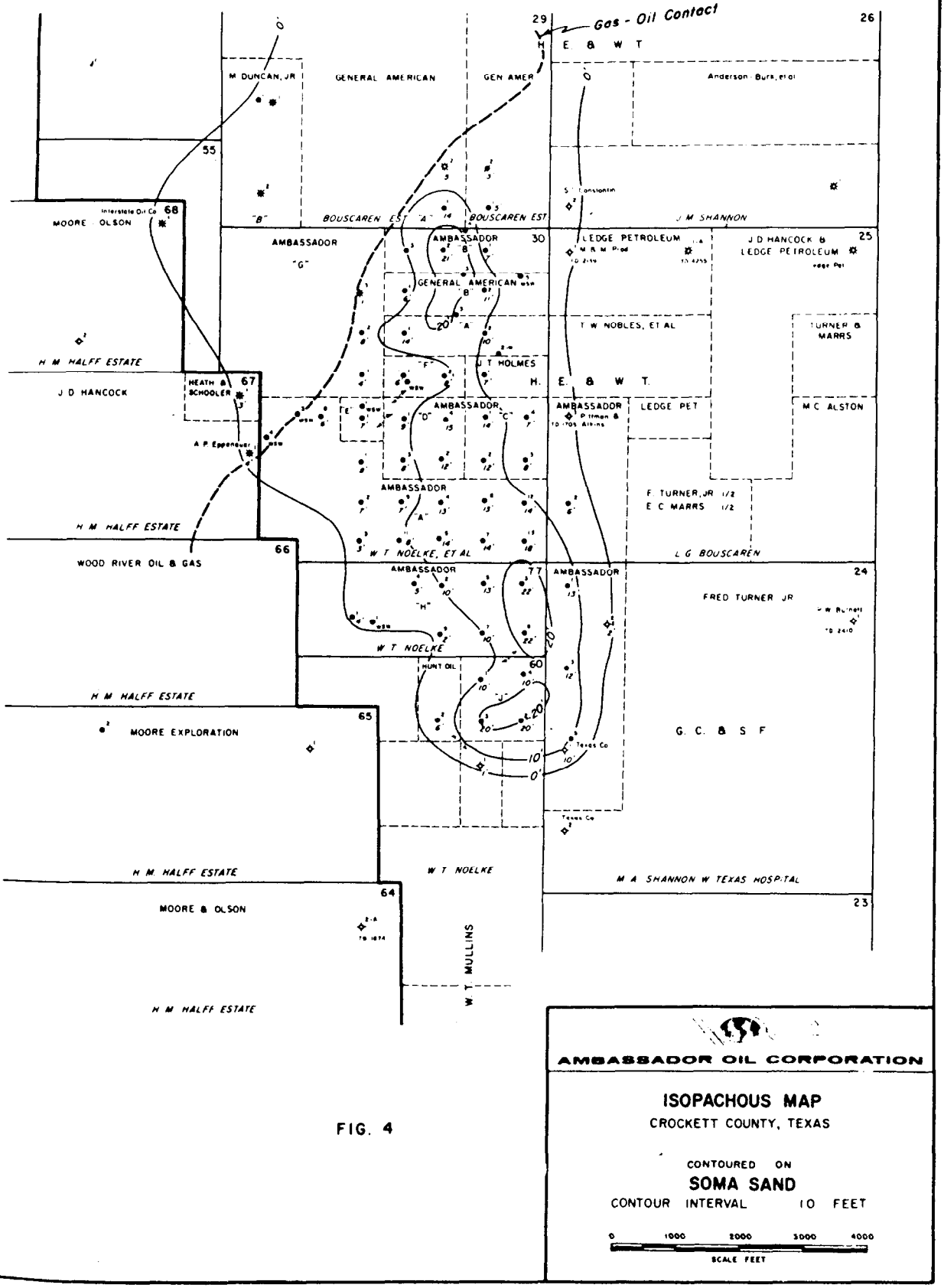

Gas - Oil Contact
M DUNCAN, JR
GENERAL AMERICAN
GEN AMER
Anderson-Burk, et al
J M SHANNON
MOORE & OLSON
BOUSCAREN EST
AMBASSADOR
LEDGE PETROLEUM
J D HANCOCK & LEDGE PETROLEUM
T W NOBLES, ET AL
TURNER & MARRS
H M HALFF ESTATE
J D HANCOCK
J T HOLMES
LEDGE PET
M C ALSTON
F TURNER, JR 1/2
E C MARRS 1/2
L G BOUSCAREN
WOOD RIVER OIL & GAS
W T NOELKE, ET AL
FRED TURNER JR
W T NOELKE
HUNT OIL
MOORE EXPLORATION
G. C. & S. F.
Texas Co
M A SHANNON W TEXAS HOSPITAL
MOORE & OLSON
W T MULLINS
AMBASSADOR OIL CORPORATION
ISOPACHOUS MAP
CROCKETT COUNTY, TEXAS
CONTOURED ON
SOMA SAND
CONTOUR INTERVAL 10 FEET
0 1000 2000 3000 4000
SCALE FEET

FIG. 4

face. Varied reef and lagoonal deposits lend evidence to this expositional history. The reef rocks are very thick dolomitic limestones of Permian age, and on the margins of the platform, elongated kidney-shaped sand bodies constitute lagoonal sand phases also of later Permian age. This appears to manifest itself in the Noelke Field.

The sand permeability pinches out around the perimeter of the field. Average sand thickness is 13 ft and ranges from 0-22 ft (Fig.4). No active water drive has been detected and the primary producing mechanism has largely been through solution gas-drive and gas cap extension energy.

ROCK PROPERTIES

The producing horizon consists of a fine-grained, subangular, partially friable sandstone, cemented rather loosely with a siliceous material. The body is well formed and possessses the following rock characteristics:

Average thickness	13 ft
Average porosity	21-23 per cent
Average permeability	300 md
Permeability range	1-990 md
Average connate water saturation	25 per cent
Average original oil saturation in the oil column	75 per cent
Average residual oil saturation after flooding	25 per cent

Original bottom hole pressure is estimated at 1500 psi. No original solution gas ratios were taken; however, it is estimated at 500 SCF/STB. Producing solution gas oil ratios were probably considerably lower since a significant volume of gas and pressure was exhausted rapidly by the discovery well blowing "wild" for several days.

FLUID PROPERTIES

The oil is a 34° API @ 60°F crude with an estimated original viscosity of 1.0 cp and 5.0 cp at deleted conditions. The oil is a black asphaltic base crude containing 20-24 per cent Italian type asphalt by analysis. It is arbitrarily classified as a "sour crude" by the pipeline because of its low gravity and salt content; however this is somewhat misleading because it contains only 1.5-1.8 per cent sulphur by ASTM 129-39 standards. Flash and pore point are below normal atmospheric condition.

PRIMARY COMPLETION AND PRODUCTION HISTORY

Completion procedure was to drill with cable tool to the bottom of the second fresh water sand at 400-500 ft, set sufficient surface casing to seal off the bed from contamination, drill into the pay zone, set and cement production string (usually seven inch O.D.) with 25-50 sacks and drill into the pay zone "barefoot". The top of the pay was easily detected by analyzing cuttings and oil-gas flow. Also, the pay zone almost uniformly occurrs 45 ft below the bottom of the Yates zone.

Initial potentials ranged from the estimated 10,000 BOPD down to 20-25 BOPD on wells dirlled up to 1942. Apparently, a number of these lower potentials were more a result of "blowing off" the reservoir energy by the discovery well than low formation capacity. A few wells were tight and were "hand shot" with nitroglycerine to stimulate production. No frac jobs were performed during this interim since the process had not been introduced to the industry.

Peak primary oil production in the southern segment reached a peak rate of 19,201 BOPM in January 1944 (Fig. 5) and declined rapidly thereafter with most wells reaching the stripper stage in 1951. Production continued at a low level until the waterflood was initiated in late 1957. Cumulative production was 1,344,527 STB by the primary recovery mechanism; this calculates to be 11.8 per cent of original oil-in-place.

PILOT WATERFLOOD DEVELOPMENT

Following a detailed engineering study which indicated that the Seven Rivers Sand (Soma) offered excellent waterflood possibilities, an application was made to, and approval given, by the Railroad Commission of Texas on September 6,1957. Immediate work was commenced to install a triple five-spot pilot flood consisting of eight injectors, W. T. Noelke A-1, A-5, A-6,A-9, C-1, D-1, D-2, F-2 and two enclosed producers, W. T. Noelke A-4 and D-4. Noelke A-9 and D-4 were newly drilled wells which were completed open hole with 5-1/2 in. O.D. casing set in the top of the pay. Core analyses showed the pay zone to have ample capacity to support desired injection rates. Noelke D-1 and F-2 were plugged back to an anhydrite stringer immediately below the pay zone. The remaining injection wells were cleaned out, logged, the casing pressure tested, and placed on injection status.

Initially only a single water supply well, WSW No. 1, located on the W. T. Noelke "F" lease was completed with 10-3/4 in. OD casing being set at 482 ft with a slotted section opposite the water sands and gravel packed behind the casing to prevent sand flow into the wellbore. An eight in. right-angle drive turbine was set at 434 ft and

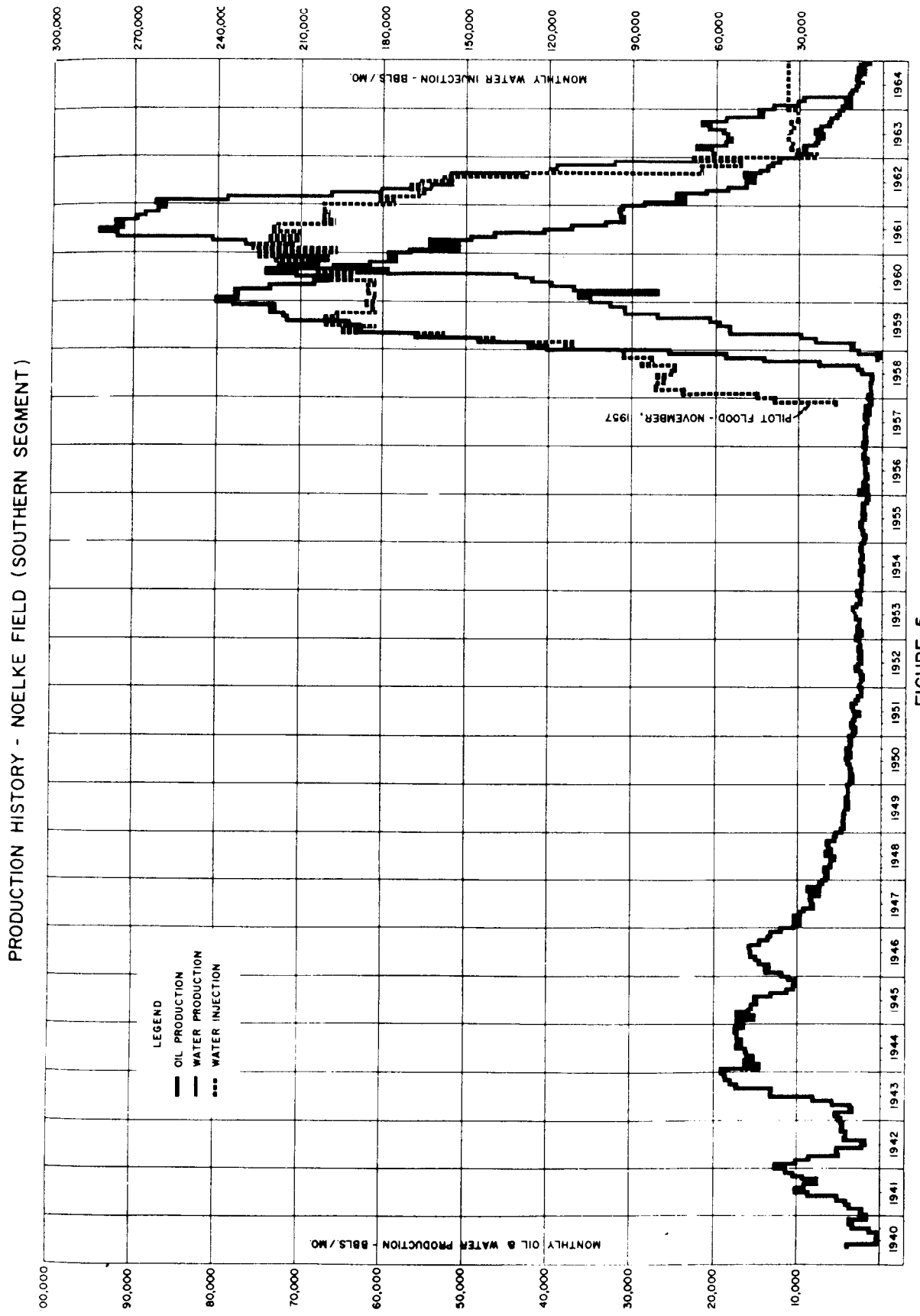

PRODUCTION HISTORY - NOELKE FIELD (SOUTHERN SEGMENT)
LEGEND
OIL PRODUCTION
WATER PRODUCTION
WATER INJECTION
MONTHLY OIL & WATER PRODUCTION - BBLS./MO.
MONTHLY WATER INJECTION - BBLS./MO.
PILOT FLOOD - NOVEMBER, 1957
10,000
20,000
30,000
40,000
50,000
60,000
70,000
80,000
90,000
100,000
30,000
60,000
90,000
120,000
150,000
180,000
210,000
240,000
270,000
300,000
1940
1941
1942
1943
1944
1945
1946
1947
1948
1949
1950
1951
1952
1953
1954
1955
1956
1957
1958
1959
1960
1961
1962
1963
1964

FIGURE 5

the well tested at 45-50 GPM. When the injection wells were capable of taking more water, a second supply well, WSW No. 2, located on the W. T. Noelke "E" lease was completed similar to WSW No. 1 and provided ample water for the pilot requirements. The water from the wells was fresh water, as from all subsequent wells, and proved to be completely compatible with formation water, presenting no treating problems, precipitatoin or corrosion.

The water plant equipment consisted of a National F-60 triplex pressure pump powered by a Buda GMO 893 gas engine. This provided a capacity of 3000 BWPD at 1200 psi. Since electricity was not immediately available in this end of the field at this time, it was decided to operate the above gas engine and the two W-226 Allis Chalmers gas engines on the supply wells with casinghead gas from the Noelke B-3, a well in the gas cap.

Initial water injection was realized on November 17, 1957 with all wells taking water readily at zero pressure. Initial flood response was detected at W. T. Noelke E-1 in July 1958 or eight months after initial injection. Although the well had only a "two way push" the response was positive and significant, reaching 75 BOPD and no water in a month.

EXPANDED WATERFLOOD DEVELOPMENT

Immediate steps were taken to initiate an expansion program to afford "backup" to W. T. Noelke E-1, thus preventing migration of oil into the gas cap and creating an intensified drive on the well. W. T. Noelke A-8 and G-1 were placed on injectoin status and the enclosed producing location, W. T. Noelke D-3 was completed and potentialed for 180 BOPD; response was anticipated at the time. The W. T. Noelke A-4 and D-4 commenced response and increased so rapidly that larger producing equipment was installed. It was also necessary to drill another water supply well, WSW No. 3, located on the W. T. Noelke "A" lease.

Expansion southward on the W. T. Noelke "A" lease and onto the "H" lease was commenced in early 1959, as production response became quite intense, reaching a level of 700 BOPD in December 1958. This necessitated larger pumping equipment and tubing on most responding wells. A unit was engineered for this particular application (see section on Problems and Solutions). Larger storage capacity and a new, more reliable source of power were necessitated since an ample gas supply was becoming non-existent from the gas cap well. This was solved by electrifying the southern portion of the flood from a REA line and equipping the northern end wells with gas engines fueled by a gas supply secured from the City of Iraan's gas line 1-1/2 miles north of the flood. Extremely rugged terrain and lighter load requirements in the south end of the flood dictated the advisability of using electricity.

Development of the W. T. Noelke "H" and "J" leases was accomplished in the second quarter of 1959 with the drilling of six new injection wells and seven new producing wells, the conversion of three wells to injectors, the extension of the water distribution trunk line, the installation of another water plant and the completion of a new water supply well, WSW No. 5, on the W. T. Noelke "H" lease. Also with the expansion of the entire project, it was necessary to drill and complete another water supply well, WSW No. 4, located on the W. T. Noelke "A" lease at water plant No. 1. This well proved the best well of the entire group, testing 148 GPM.

With the increase in the number of injection wells and the additional supply well it was necessary to enlarge Plant No. 1 output. The National F-60 pressure pump was replaced with a larger National J-125 pump. This doubled the plant's capacity. The surplus National F-60 was installed in Plant No. 2 and equipped with a 50 hp electric motor. The water supply well, WSW No. 5, was equipped with a 3 hp submersible pump run on 1-1/4 in galvanized pipe.

A Cooperative Waterflood Agreement was finalized with the offset operators, General American Oil Company of Texas and J. T. Holmes resulting in equitable and fairly efficient flood patterns on all leases. The pattern along the northern boundary of the W. T. Noelke "B" lease was not completely satisfactory; however, in view of legal difficulties preventing injection of water into the Bouscaren Estate leases, the high cost of drilling a line injection well and reduced oil recovery due to the proximimity of the gas cap, it was decided that the best possible flood coverage was afforded..

With the development of this northern section and Completion of the L. H. G. Bouscaren No. 2 in Section 25, complete field development was accomplished and resulted in the injection pattern shown in Fig. 6. A total of 25 producers and 26 injectors resulted.

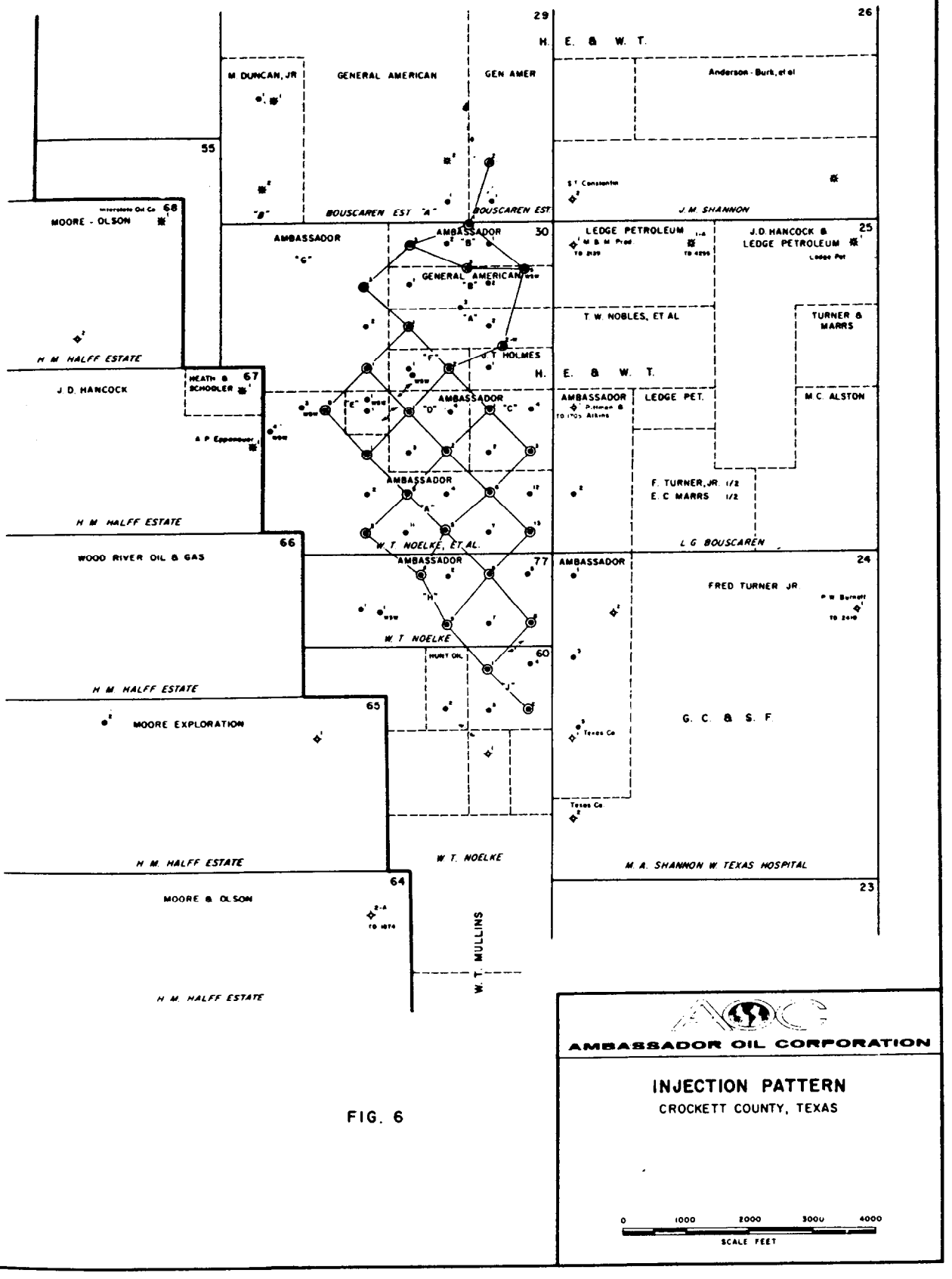

29
H. E. & W. T.
26
M DUNCAN, JR
GENERAL AMERICAN
GEN AMER
Anderson - Burk, et al
55
S T Consonlin
J M SHANNON
68
MOORE - OLSON
"B"
BOUSCAREN EST "A"
BOUSCAREN EST
AMBASSADOR
"C"
AMBASSADOR
"B"
30
LEDGE PETROLEUM
J.D. HANCOCK & LEDGE PETROLEUM
25
GENERAL AMERICAN
T W NOBLES, ET AL
TURNER & MARRS
H M HALFF ESTATE
J T HOLMES
H. E. & W. T.
J D HANCOCK
HEATH & SCHOOLER
67
AMBASSADOR
LEDGE PET.
M C ALSTON
A P Eppenauer
AMBASSADOR
F. TURNER, JR. 1/2
E. C MARRS 1/2
H M HALFF ESTATE
W T NOELKE, ET AL
L G BOUSCAREN
66
WOOD RIVER OIL & GAS
AMBASSADOR
77
AMBASSADOR
24
FRED TURNER JR
W T NOELKE
HURT OIL
60
H M HALFF ESTATE
65
MOORE EXPLORATION
G. C. & S. F.
Texas Co
Texas Co
H M HALFF ESTATE
W T NOELKE
M A SHANNON W TEXAS HOSPITAL
64
MOORE & OLSON
23
W T MULLINS
H M HALFF ESTATE
AMBASSADOR OIL CORPORATION
INJECTION PATTERN
CROCKETT COUNTY, TEXAS
0
1000
2000
3000
4000
SCALE FEET

FIG. 6

FLOOD PERFORMANCE

As previously stated, initial flood response was indicated in W. T. Noelke E-1 in July 1958. W. T. Noelke A-4 and D-4 indicated response thereafter with the completion of W. T. Noelke D-3 for 180 BOPD. Production rapidly increased during all of 1959 and reached a peak rate of 2580 BOPD in January 1960 (Fig. 5). Production declined mildly thereafter, as would be expected in a high rate flood with extremely high average permeability profile, and reached a level of 401 BOPD during December, 1962 then gradually declined thereafter through 1964 to the economic limit.

Water production commenced in late 1958 and followed an expected increase to peak at 3140 BWPD in June 1961.

Water injection reached a peak rate of 8100 BWPD in February 1961. Average per well rates were 310 BWPD with a range of 200-600 BPD.

Oil production reached economic limit on most of Ambassador Oil Corporation's leases in late 1962 and plugging operations were commenced with complete flood abandonment realized in January 1963. The W. T. Noelke F-2W and W. T. Noelke "B" leases were sold to General American so the flood operations could continue to their economic limit. This limit was later than Ambassador Oil Corporation's due to their leases being developed last. At the time of this paper their leases are at their economic limit, hence a very good picture of complete flood performance is available.

Ratio factors are: (1) secondary vs. primary 1.86 to 1, (2) water injected to secondary oil production 3.62 to 1, (3) cycle factor of 2.5 to 1, (4) total primary and secondary recovery in bbl per acre 7571 and 582 bbl per acre-foot and (5) cumulative produced water to produced secondary oil 1.13 to 1.0.

Several wells performed outstandingly, probably as a result of three factors: (1) almost complete saturation of pore space available for hydrocarbon resulting from migration of oil from the tighter flank areas into more perfeable sections in the high permeability region through the center of the oilfield and (2) very good porosity (24 - 26 per cent) around the wells and (3) some oil migration into their recovery pattern. The secondary oil recovery figures for some of the wells are given as follows:

SPECIAL PROBLEMS AND SOLUTIONS

No special problems remained critical long enough to adversely affect flood performance; however if they had remained unsolved serious impairment if recovery efficiency or significant increases in additional cost could have resulted. The most noteworthy problems and solutions were:

(1.) A serious oil sale problem was averted when negotiations with the pipeline carrier, Texas New Mexico Pipeline Co. resulted in their installing a connection to their larger "Live Oak System" to the east of the flood.

(2.) Significant savings were affected by designing a pumping unit with adequate torque rating. Since the flood depth was so shallow, standard API units had gross-excessive beam ratings but insufficient stroke length for capacities desired. The resultant has unit has now become a Standard API series.

Operator and Lease	Well	Secondary Recovery	B/A	B/A-F
Ambassador Oil Corporation				
W. T. Noelke "A"	4	246,474	11,000	768
W. T. Noelke "A"	7	237,671	11,884	811
W. T. Noelke "C"	2	325,524	16,276	1,179
W. T. Noelke "D"	4	176,343	8,817	612
W. T. Noelke "H"	2	125,814	6,990	599
W. T. Noelke "H"	3	125,379	6,599	716
W. T. Noelke "H"	7	105,980	4,999	679
General American Oil Company				
W. T. Noelke	2	121,296	5,297	354
W. T. Noelke	3	371,052	11,076	553

(3.) An adequate shallow, prolific water supply was afforded with the approval of the landowner.

(4.) Significant savings in fuel bills were afforded through the contract consummated with the City of Iraan whereby gas was made available from their supply lines to the north of the flood.

SUMMARY

This shallow waterflood project proved highly successful despite several adverse features, i.e. severe terrain, inadequate power source, very incomplete field drilling and definition and diversified field ownership. It is believed that the flood performance will rank high in any analysis and that it is near the top of the Seven Rivers reservoirs.

REFERENCES

1. Oil and Gas Journal Map of Continental United States, 1957.
2. Railroad Commission of Texas Production Records.
3. Ambassador Oil Corporation .... Secondary Recovery Division records.