WIRELINE TECHNIQUES FOR MONITORING RESERVOIR FLUID MOVEMENT AND RECOMMENDATIONS FOR MALAYSIAN OIL AND GAS FIELDS

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ABSTRACT

This paper presents the wireline techniques used in reservoir monitoring and shows how the location and monitoring of variations in water, oil and gas saturations in producing wells, plays a significant role in determining the depletion profiles.

Field data from a Malaysian Oil Field is analysed to illustrate how this wireline techniques help in determining the water, oil and gas saturations and provide the information necessary to overcome well and reservoir problems.

Necessity of a systematic approach in reservoir monitoring is emphasized in order to study the movement of GOC and WOC contacts and to know the distribution of remaining oil during primary or subsequent depletions.

INTRODUCTION

Reservoir behaviour changes with time due to production of oil and gas from the reservoir. In order to achieve optimum hydrocarbon recovery, it is essential to monitor these changes in the formation at regular intervals. These important reservoir informations are accessible from cased-hole producers by using nuclear logging techniques, based on the responses to the formation close to the well bore to high-energy neutron bombardment. Wireline techniques permit evaluation of significant reservoir parameters useful at various stages of its productive life.

Type of nuclear logging wireline techniques used for monitoring reservoir fluid movements behind casing are the Thermal-Decay Time Log (TDT), the Compensated Neutron Log (CNL) and the Gamma Spectrometry Tool (GST).

From the information thus obtained, it is possible to study:

- the rise of GOC
- the rise of WOC
- the uniformity of depletion, location of water fingers and water channelling.
- the hydrocarbon recovery and residual saturation.

Reference and illustrations are at the end of paper.

Based on the data obtained, remedial action may be undertaken if necessary.

It is extremely difficult to model and predict accurately the water saturation changes. Thus, regular monitoring is necessary to check the field behaviour.

The aim of this study is to compare these different wireline methods to find the best applicable system for Malaysian Oil and Gas Fields.

FIELD DESCRIPTION

The Manggis Field located in east coast of Peninsular Malaysia is chosen as an approach to define the best monitoring system applicable in this country. Figure (1) shows the cross-section of Well M-8 penetrating reservoirs X and Y in this field. An extended shale streak separates both the reservoirs as shown. A small shale as like a sand bar is identified slightly below the original perforation depth.

PRODUCTION DATA

The reservoir total datagraph and the well performance history is shown in Figures (2) and (3).

Well M-8 started its production in late May 1978 with a watercut of about 25%.

Gas injection was initiated in this field in February 1981 with an approximate initial injection rate of 3.0 MM SCF/D. The injection rate profile as can be seen varies on monthly basis.

The watercut for this filed increases from 20% in 1978 to about 70% in 1986.

The well performance of M-8 meanwhile reveals a watercut of about almost 90% in 1984 as shown in Figure (3).

DISCUSSION OF RESULTS

TIME LAPSE TECHNIQUE

Open-hole and TDT logs were run at different times under different conditions of borehole environment. The water saturation should be seen the same by both the open-hole tools and the TDT tool (ran 3 months after completion) and therefore Sw (OH) and Sw (TDT) should overlay.

In this case, this evaluation is not possible as the TDT tool was only run 18 months after completion and production.

Thus, in this case, TDT-1 (1979) is used as base log to be compared with TDT-2 (1985) using the time-lapse technique.

Figure (4) shows the overlaying of Σ c.u. (1979) and Σ c.u. (1985).

As shown by zone A, the Σ value decreases from about 20 c.u. to 16.c.u. Further confirmation that this could be gas cap expansion is given by the N_1 - F_1 display where F_1 deflects to the left. The gas saturation computation approximately averages 60% in this zone while the ΔSw indicates no change indicates no changes in water saturation.

Excellent GOC picture is shown by the TDT log, i.e. the new GOC is now at 5682 ft. which was originally at 5640 ft.

In zone B, ΔSw indicates an increase. In the middle of the perforated zone i.e. 5750 ft., the ΔSw is about 38%, proving that depletion is taking place in this zone. The new WOC as indicated by the TDT log is now at 5776 ft., having moved up from the original WOC of 5866 ft. after a lapse of seven years.

Zone C clearly shows the depletion occuring (shaded area) where the ΔSw is 57%. The Σc.u. value has now increased from about 17 c.u. to 22 c.u. indicating presence of water in an area initial filled with oil. The drastic sharp increase in Σ c.u. value at 5780 ft. is due to the small shale bar (as shown in Figure (1)).

In zone D, no change in ΔSw is observed i.e. 0%. Originally being a water zone, the water saturation remains unchanged by the strong aquifer influx. The F_1 overlays on top of N_1, including water zone.

RESERVOIR MONITORING

Figure (5) has the two TDT's and open-hole (OH) water saturation profile plotted with GST results.

The TDT - 1 (1979) vs. TDT - 2 (1985) clearly indicates the GOC to be at 5680 ft., while the GST gives an erroneous picture in this zone A.

At zone B, the presence of oil is observed as shown in the GST vs. TDT column.

Zone C clearly shows an increase in the water saturation profile indicating that depletion of oil by water is occuring here. The GST saturation profile provides an excellent picture of this water movement where the WOC has moved up from 5866 ft. to 5760 ft. by Nov. 1985.

Zone D, meanwhile being a water zone shows a high water saturation profile. The GST saturation profile in this zone shows small portions of oil left behind by showing lower water saturation values at certain depths. The GST vs. OH water saturation plot shows how the water saturation has increased from 1978 to 1985.

WELL PROBLEM AND RECTIFICATION

One of the most significant problem in this well is water channelling due to poor cement quality as indicated by the CET log in Figure (6), which was run after the GST. Poor cement bond is encountered all the way from 5600 ft. to 5800 ft., the worst portion being directly in front of the perforation depth.

It could be said that the primary cement success in this well was low and this could not be rectified as no checking on cement quality was done after completion.

It should be stressed that hydrocarbon by passing could have occured in this well and reservoir as strong aquifer influx was evident.

The WOC has now reached 5760 ft. which is directly opposite the original perforation depth i.e. 5742 ft. - 5761 ft. Based on the monitoring with the GST, a new recompletion selection was recommended above the original perforation depth.

Thus, squeeze job was done and a good cement bond is now observed in the CBL - VDL log as shown in Figure (7). The CBL - VDL log was run in Dec. 1985. The new perforation depth is now at 5733 ft. - 5748 ft.

Table (1) clearly shows how production was improved with the watercut lowered considerably.

CONCLUSION

Consistent, with the primary objective of the paper, the analysis of the Malaysian oil field data provides an approach for proper monitoring of reservoir fluid movement by wireline techniques. The analysis addresses the following conclusions:

1) CNL gives qualitative data sufficient for accurate GOC determination, however there are limitations from the borehole (presence of gas, gas behind tail pipe, dual string where gas is present between tubing and casing.....etc) and from formation (shales).

2) The TDT log gives an excellent result in determining GOC accurately both qualitatively and quantitatively in the sense that it provides a good computation of Sg. Its main advantage over the CNL is that it is far less sensitive to borehole conditions.

3) The TDT log provides a good picture in determining the WOC and the water saturation profile. Surprisingly in this case because the salinity is about 18,000 ppm which is low enough to make the TDT log ineffective in this condition. It should be noted that the particular field presented has the highest salinity compared to all other fields in Malaysia, approximately in a range of 3000 - 18,000 ppm.

4) From the analysis and interpretation of the TDT log (based on the GOC) a proper recompletion selection if needed can be recommended.

5) The GST log provides reliable measurements of Sw in this fresh water field.

6) The GST log gives an excellent picture for the determination of WOC.

7) The GST log cannot be used to determine the GOC, (for in gas zones, it reads the carbon in gas as the carbon

in oil resulting in exaggerated values in Sw).

8) The cement quality ought to be checked and if it is of poor quality, squeeze cementing should be done prior to the running of the GST, for the water saturation profile is effected by the reinvasion of fluid which occurs due to poor cement quality behind casing.

9) From the determination of the water table movement, a safe and accurate recompletion selection can be recommended by the use of the GST log in a fresh water field. (The recommended recompletion selection in this particular well by the GST log proved successful where the watercut was lowered considerably.

Applicable System in Malaysia:

GOC	Gas saturation Profile	WOC	Water saturation Profile
CNT (borehole limitations).	-	-	-
TDT	TDT	TDT (marginal)	TDT (marginal)
-	-	GST	GST

Therefore, the best applicable system that can be used efficiently in Malaysian Oil and Gas Fields is:

TDT - for GOC and gas saturation profile.

GST - for WOC and water saturation profile.

RECOMMENDATIONS

The following recommendations are given as a method of approach for long term planning of this system throughout the life of a field in Malaysia.

1) To avoid the effects of reinvasion, a well for observatory purposes is recommended i.e. observation wells. Hence, a few observation wells around the

field ensures good depletion or drainage which increases the efficiency of the reservoir management.

2) Checking of cement quality is recommended (as seen in this well where water channelling has become a serious problem). It should be noted here that hydrocarbon bypassing or "recovery losses" most likely, could have taken place in this well and reservoir as a whole.

The following points should be considered in using the Cement Evaluation Logs:

a) Where well conditions are such that the rules of good primary cementing practices can be applied, the Cement Evaluation Logs should be not required (at least initially).

b) Where conditions make primary cementing difficult and where experience shows that primary cement success is low, the Cement Evaluation Logs can provide the keys to improve practices.

c) Where fluid movement behind the casing is suspected, the Cement Evaluation Logs may confirm the possibility and may show at the point at which remedial cementing can be effectively applied.

3) Proper planning in running the TDT (and the GST if there is no observation well) is relevant where the time-lapse technique could progress efficiently to ensure complete drainage. It is recommended that the TDT and the GST be run after 3 or 4 months after completion (as base log) where any subsequent running of the same log is compared to the base log for GOC, WOC, gas and water saturation profile monitoring purposes.

The timing of this base TDT log is important and it must be run :

- early enough that the overall conditions in the reservoir have not changed since the open-hole surveys.

- after enough time has elapsed to allow dissipation of filtrate invasion (at least in front of the perforated zones).

4) In dual completion wells, as shown in Figure (8), while workover is being done in zone (1), the GST can be run in zone (2) where in this case the water saturation profile is not affected.

5) In conditions where big or large transition zone arises in GOC as shown in Figure (9) : the TDT log is recommended where it gives a good and accurate computation of gas saturation and the GOC. This helps in avoiding recovery losses or hydrocarbon bypassing. (This is evident in this field in well M-9).

6) Figure (10) shows the well M-8 history which has taken place. Thus, a new systematized approach is proposed here. By this new system as presented in Figure (11), problems can be found and timely corrections made. Inefficient completion techniques can be spot-lighted and modified accordingly. This system gives management information that can be used to schedule remedial work on a planned basis.

This may improve the efficiency of the reservoir drainage thus assuring increased profitability.

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APPENDIX

Σ log	-	log reading (corr.) of capture cross section (c.u.).
Sw	-	water saturation
So	-	oil saturation
Sg	-	gas saturation
Ps	-	saturation pressure
Boi	-	initial oil formation volume factor
Bgi	-	initial gas formation volume factor
Rsi	-	initial solution GOR
S.G.	-	specific gravity
μo	-	oil viscosity
k avg.	-	average permeability
Ø avg.	-	average porosity
Sw avg.	-	average water saturation
Rw	-	water resistivity
GOC	-	gas-oil contact

WOC	-	water-oil contact
GOR	-	gas-oil ratio
CPI	-	Computer Processed Interpretation
SCU	-	Cyber Scan Unit
CRA	-	Cased Reservoir Analysis

CONVERSION UNITS

1)	1 (ST KL/D)	=	6.293 STB/D
2)	1 M^3/D	=	32.371 SCF/D
3)	1 psig	=	0.145 x kPa
4)	$1 \frac{\text{STD CUFT}}{\text{ST BBL}}$	=	5.615 x STD M^3/ST KL

RESERVOIR DATA

Ps	=	1725 psig
Boi	=	1.32 RB/STB
Bgi	=	1.54 RB/KSCF
Rsi	=	500 SCF/STB
^{o}AOI	=	42
S.G. gas (air = 1.0)	=	0.9368
μo	=	0.314 cp.
k avg.	=	600 md
Ø avg.	=	25%
Sw avg.	=	20%

Sw avg. connate	=	20%
Formation water	=	18,000 ppm or
salinity	=	Rw = 0.15m @ 161 ^{o}F
Original GOC	=	5640 feet MD RKB
Original WOC	=	5866 feet MD RKB
Type of completion	=	Single
Average well angle	=	58^{o}

oooOooo

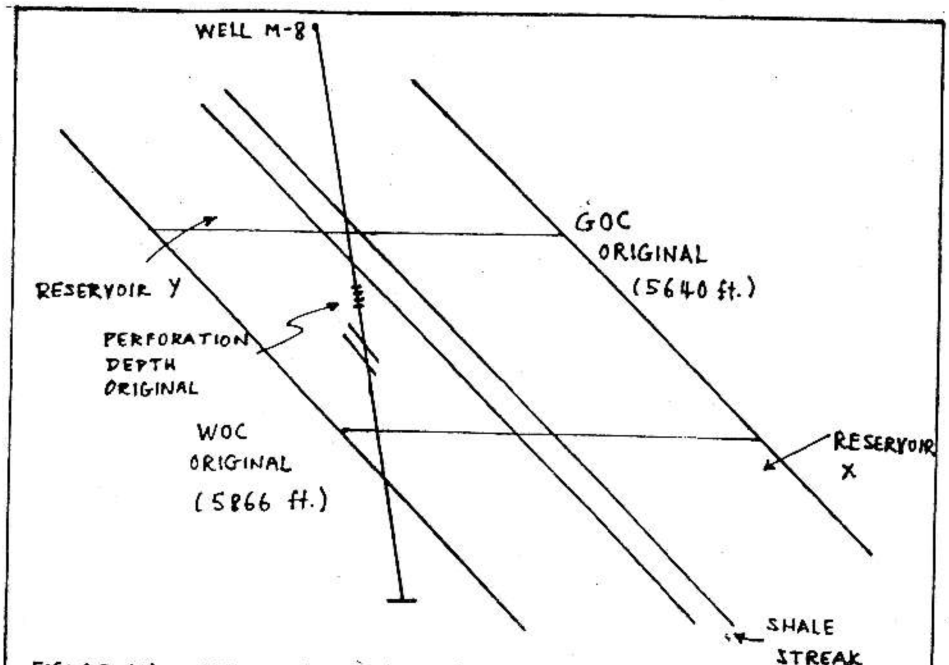


FIGURE (1) - WELL M-8 CROSS-SECTION

FIGURE (2) MANGGIS X/Y RESERVOIR TOTAL DATAGRAPH

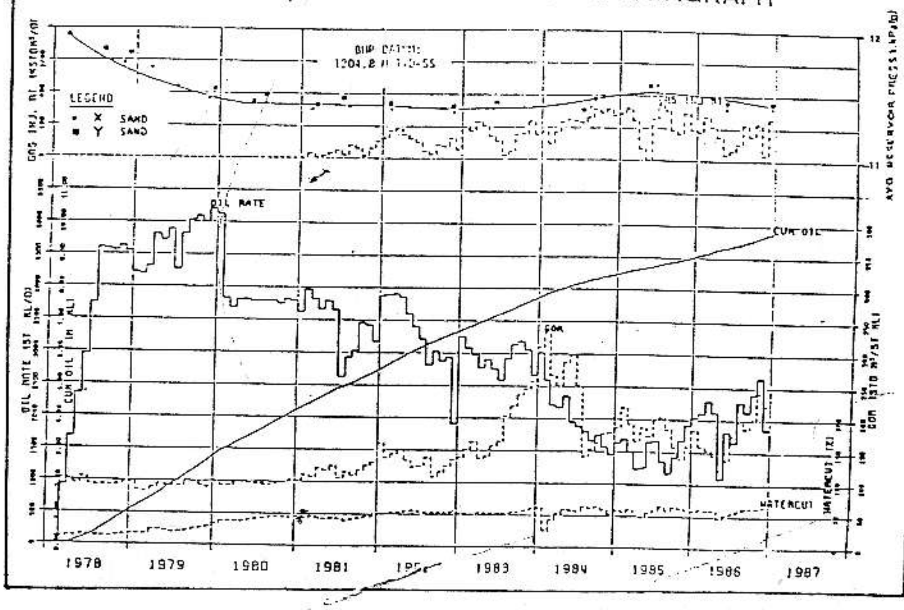
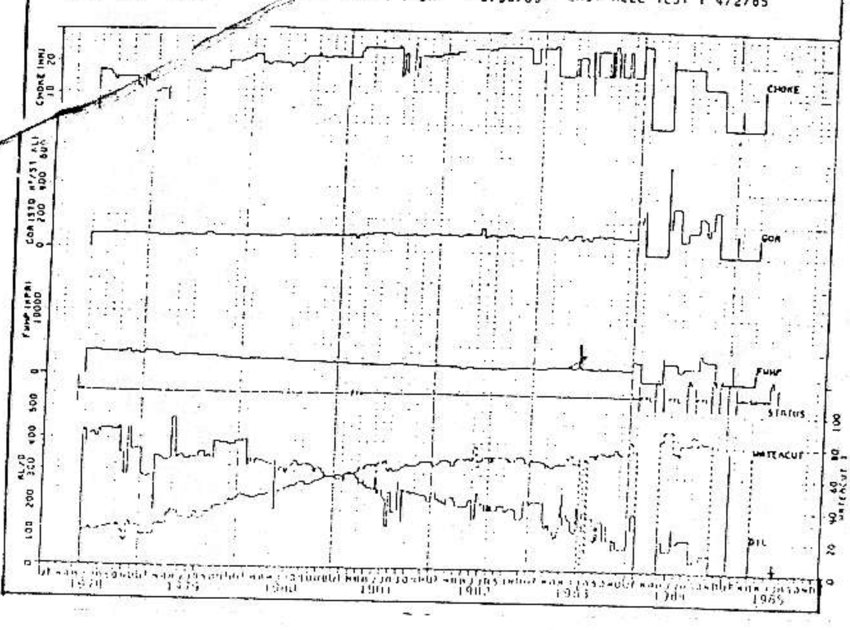
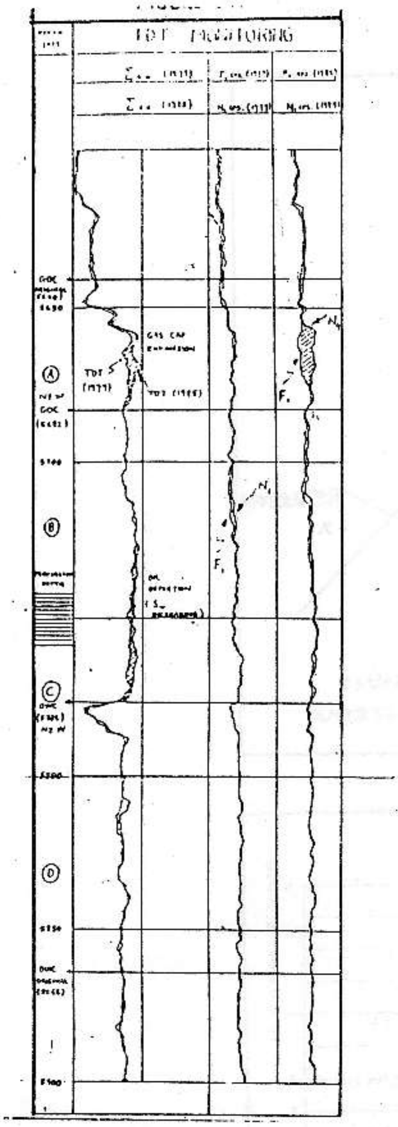


FIGURE (3)

FIELD : MANGGIS WELL PERFORMANCE HISTORY - TEST DATA @ AS AT JUNE 1985. -
WELL NO: M-8 LATEST STATUS : SN - 6/30/85- LAST WELL TEST : 4/2/85





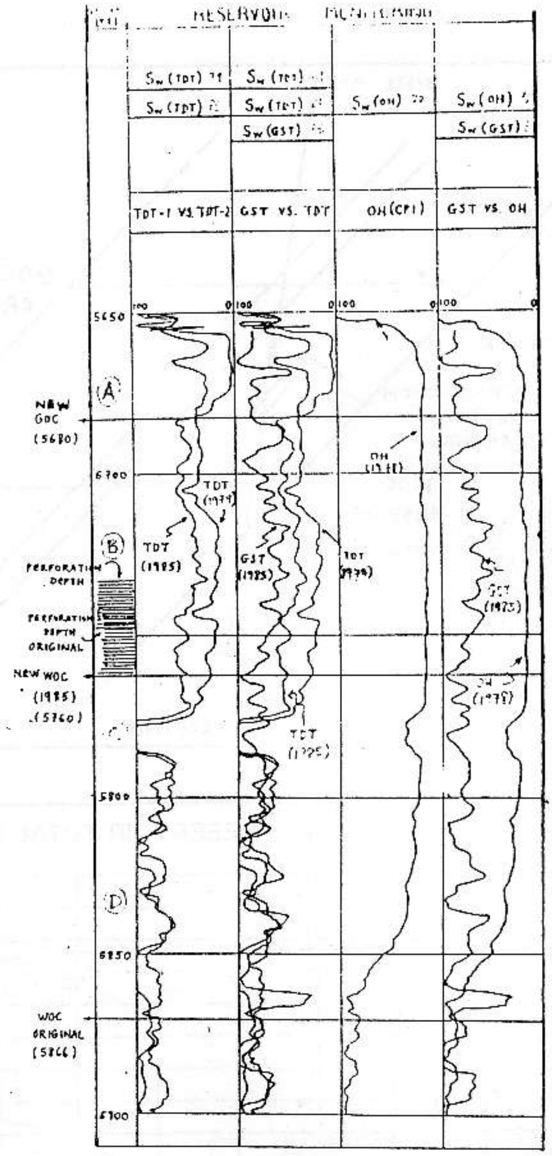


FIGURE (6) - CET LOG

(A 1)

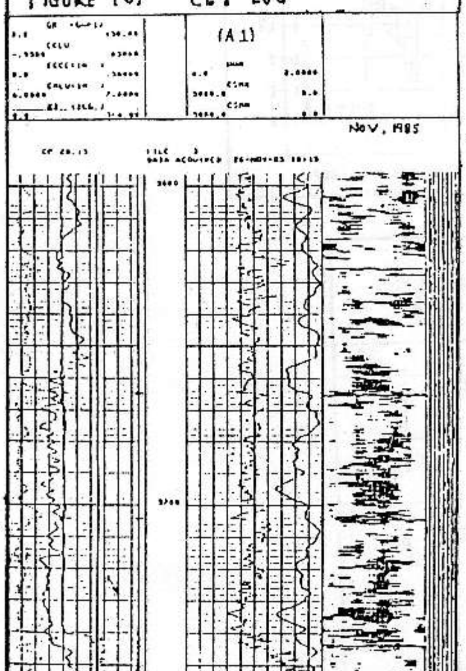
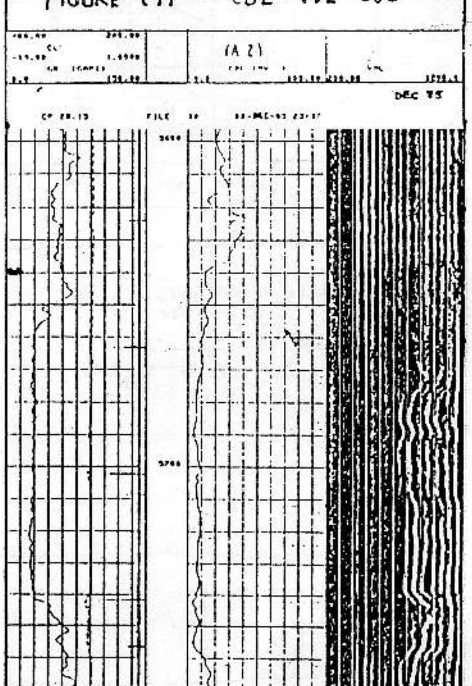


FIGURE (7) - CBL - VDL LOG

(A 2)



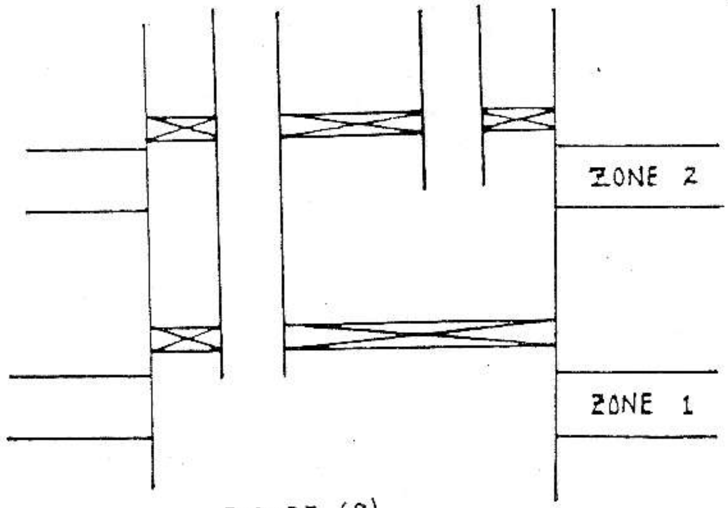


FIGURE (8)

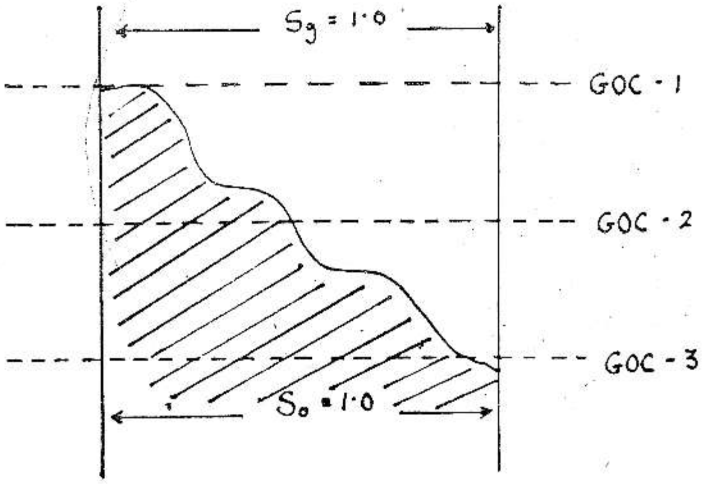


FIGURE (9)

TABLE (1)

MONTH	OIL PRODUCTION (STB/D)	GOR (CUFT/BBL)	WATERCUT (%)
NOV. 1985	SHUT - IN		
DEC. 1985	447	590	1·8
JAN. 1986	441	600	25
FEB. 1986	529	533	26
MAR. 1986	1611	573	41
APR. 1986	1209	1280	50
MAY. 1986	1536	578	51
JUN. 1986	1378	1101	53
JULY. 1986	1819	1769	58
AUG. 1986	1095	1696	62
SEP. 1986	1479	1314	64
OCT. 1986	950	2078	66
NOV. 1986	1032	1516	65
DEC. 1986	1032	1539	64

WELL - M-8 WELL PERFORMANCE

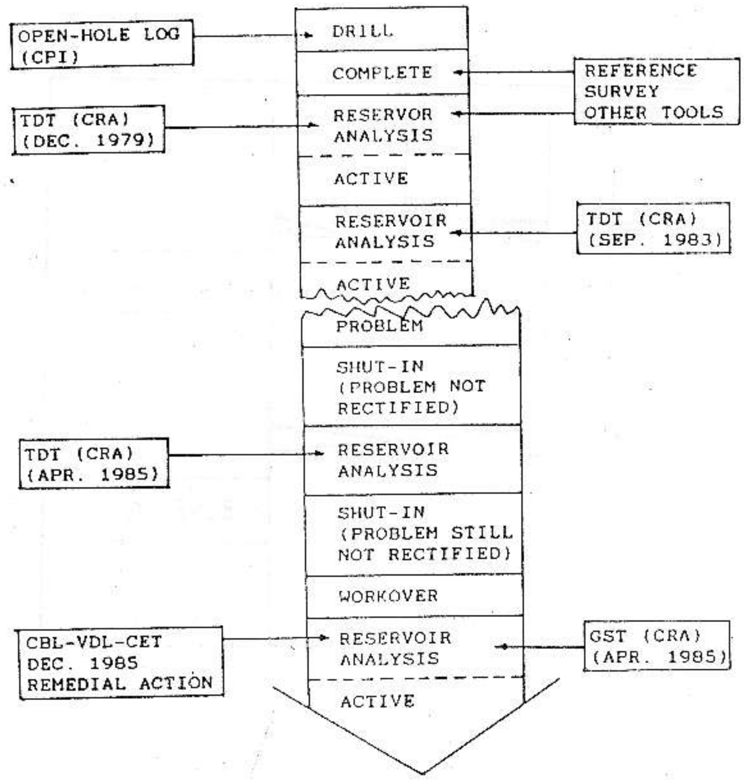


FIGURE (10) M-8 WELL HISTORY

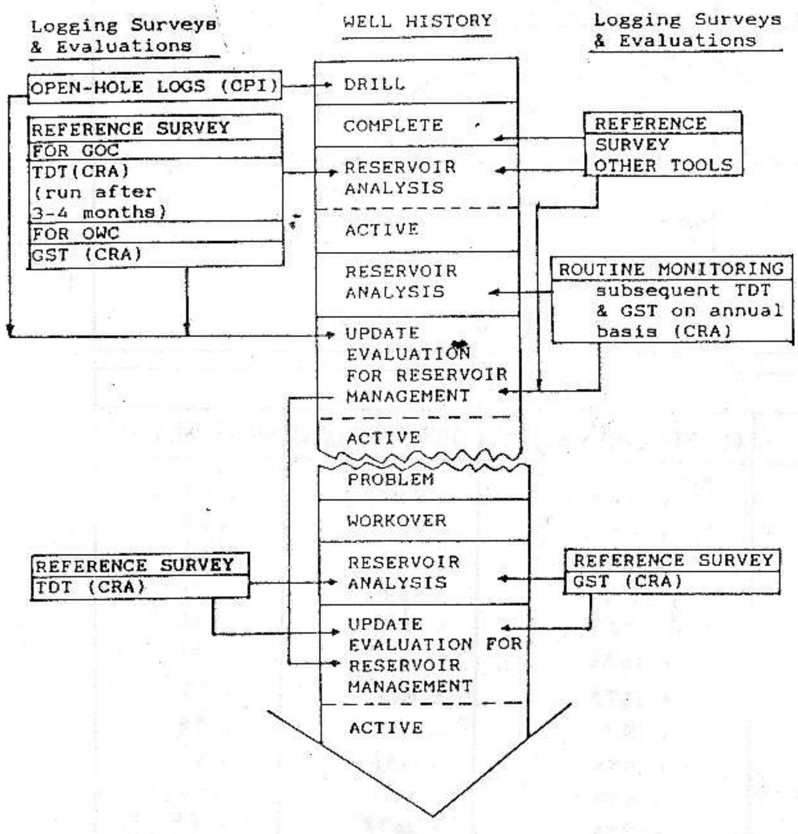


FIGURE (11)
A SYSTEMATIZED APPROACH TO RESERVOIR EVALUATION THROUGHOUT THE LIFE OF THE RESERVOIR.