CERTIFICATION OF APPROVAL

The Effect of Exclusive Drawdown To The Reservoir Productivity And Petrophysical Properties Using Numerical Study

by

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Approved by,

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TRONOH, PERAK

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

NAZATUL KHADIJAH BINTI RUZMAN

ABSTRACT

Overpressure or exclusive drawdown is one of the most common causes of failure in onshore and offshore industries. Exclusive drawdown refers to the excessive production occurred in the reservoir due to large difference of reservoir pressure and flowing bottom hole pressure. It is difficult to predict its occurrence as well as to prevent it. One of the solution is by having a good information about the well regarding the inflow pressure, outflow pressure, the expected production rate and the fluid properties of the reservoir. There are a lot of harm consequences that may happen due to exclusive drawdown that result in production decline. Thus, the projective objective is to do numerical simulation analysis as the effect of having exlusice/excessive productivity to the reservoir and petrophysical properties. The analysis will be focusing on the pressure drawdown itself. Scope of study involved conducting the simulation of software include the visual inspection and well test result by using Pansystem Software to measure the production rate and inflow performance relationship by making comparison of having optimum drawdown and exclusive drawdown. This study is very important to be conducted to ensure the reservoir can last long and meet the expected lifetime.

ACKNOWLEDGEMENT

First of all, I would like to express my upmost gratitude to my supervisor, Associate Professor Dr Muhammad Talib Shuker for being a dedicated and respectful superior. I have learnt a great deal through his effective teaching skill, solid technical knowledge and valuable experience in the oil and gas industry. I do believe I am better prepared for the challenges in industry under his guidance and advices. We discussed things regarding my topic and I learnt a lot from him.

I would also like to thank Mr Amin Shoushtari for being helpful as he also contributed in giving explanation and ideas regarding my topic. I appreciate his courage to guide students and his willingness to share knowledge and skills. Besides that, he has always been helpful whenever I have doubts and concern. Not only him, I also would like to thank Mr Ahmad Khanifar for his kindness as he is also the person I always referred to during my journey to finish this project. His passion and enthusiasm has motivated me to learn and further develop myself.

Next, I would also like to extent my gratitude to my family and friends who have been supported me and give courage to complete this project successfully. This project has taught me to be an independent person who works on my own, be a good decision maker and learn from others. I hope to cooperate from those persons in my next project again in the future.

TABLE OF CONTENTS

CHAPTER 1
INTRODUCTION

1.1 Background of Study

The title of the project is 'The Effect of Exclusive Drawdown On Reservoir Productivity and Petrophysical Properties Using Numerical Study'. This case study will cover the consequences of having excessive production due to huge drawdowns during production in terms of hydrocarbon productivity and petrophysical properties of the reservoir.

Exclusive drawdown refers to the excess of oil production due to the large difference of reservoir pressure and flowing bottom hole pressure. It is difficult to predict its occurrence as well as to prevent it. . There are a lot of harm consequences that may happen due to exclusive drawdown that result in production decline. One of the solution is by having a good information about the well regarding the inflow pressure, outflow pressure, the expected production rate and the fluid properties of the reservoir. The drawdown, and therefore the production rate, of a producing interval is typically controlled by surface chokes. Reservoir conditions, such as the tendency to produce sand may limit the drawdown that may be safely applied during production before damage or unwanted sand production occurs. [3]

During my research, I found a case study which the drawdown pressure has exceed the supposed one. The case study was in the field in Gulf Of Mexico. Marathon Oil Company has operated a certain oil field in the Gulf of Mexico for a number of years. This oilfield is over pressured and extremely unconsolidated. They produced with a drawdown pressure in excess of about 50 Psi. They are known to frequently lead to sand production and the drawdown pressures are limited accordingly. In recent years, another oil field was discovered nearby, it has the same formation rocks and at comparable depths although it is in a separate fault block. [6]

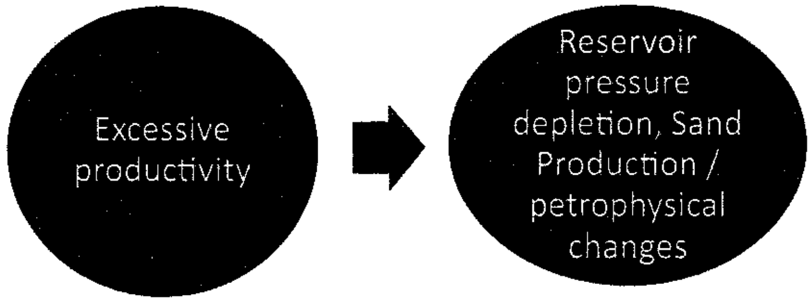
1.2 Problem Statement

The production of hydrocarbon from the well is very much depending on the pressure drawdown. From the theory we know that the larger the pressure drop of flowing bottom hole pressure, the higher the drawdown is. If the flowing bottom hole pressure is 0 psi, we will get the maximum drawdown, which lead to the maximum flowrate of the hydrocarbon. The energy produced at this time is maximum and will be drained very fast.

On the other hand, uncontrolled or excessive drawdown pressure applied will bring more harm than good to the reservoir properties and the productivity. Reservoir pressure will deplete due to very high energy level produced and with time, the reservoir cannot last long, which means it cannot produce hydrocarbon for the long term period.

From the research, it is found that the increasing of drawdown provokes sand production and formation collapse near the wellbore. Large drawdown may lead to a rapid, transient sand production once a small failure zone is developed. Not only it will effect the productivity, somehow it will also change the petrophysical properties of the reservoir.

Therefore it is crucial to study the effected aspects of having excessive pressure in order to avoid it from happen during production. [5]



1.3 Objective and Scope of Study

The objectives of the project are:

1) To study the effect of excessive productivity to the well pressure and petrophysical properties.
2) To simulate the well testing performance using PanSystem
3) To perform analysis on the changes of petrophysical properties values due to excessive productivity.
4) To compare and contrast the effect of having optimum production and excessive production.

The scope of study includes:

- Conducting research on the theory and definition of terms related to the study. The scope for the Final Year Project 2 are making more research about the importance of study of drawdown pressure to get it optimum to prevent excessive production. When excessive production occurred, the study of the effect to the reservoir characteristics and petrophysical properties are needed. The scope of study also includes to have deeper knowledge to get to know the petrophysical properties that might change. They are permeability, skin factor and wellbore storage. Every properties need to be studied into deeper to understand its behaviour.

- Conducting well testing performance using PanSystem to see the changes of well petrophysical properties due to optimum production and excessive production. For the scope of study for final year project 2 are conducting the lab of Pansystem for well testing software. Then the result of the simulation will be analyzed by making comparison of having optimum production and excessive production. Not only that, it is also necessary to fully understand on how to use this software by reading from the manual.

1.4 Relevancy of Study

This project is relevance to all petroleum engineers since most of major simulation tasks is to perform data gathering and analysis the effect of having excessive production in the reservoir. Without the knowledge of drawdown usage, we may not get the desired production as well as not maintain the economical production rates. Production rate is much dependant on the pressure drawdown. Besides, it is also relevant to do research regarding this subject because it is important to know about other software that will be using to simulate the well data. It is new thing which one need to explore herself/himself as well as might be an advantage for those who used it for being able to use the software.

1.5 Feasibility of Study within the Scope and Time Frame

This research is feasible to be conducted through reservoir simulation room available in Petroleum Engineering Department. The scope of study will be mainly on well testing analysis as data input for the simulation on the changes of petrophysical properties. If everything runs smooth and no facility breakdown, the project is expected to finish according to the Gantt chart schedule. The result of the project must be submitted during final report as well as the discussion and the analysis. With the help of supervisor and self-determination, it is believed that this project can be finished within the scope and time frame.

CHAPTER 2

LITERATURE REVIEW

2.1 Inflow Performance Relationship (IPR)

Oil production varies with the change of drawdown. To measure the production capabilities of well at the stage of reservoir depletion, the proposed dimensionless IPR can be used. IPR is Inflow Performance Relationship, was proposed by Vogel in 1962. An IPR relates production rate to flowing bottomhole pressure for a given reservoir pressure. This relationship is

Where J = productivity index, (STBpsi/day)

= oil flowrate at maximum drawdown ,(STB/day)

IPR is based on a wide range of rock and fluid properties. The resulting analytical above follows from a Taylor series expansion of the multiphase flow equations. It is also verified by computer simulation results.

A reservoir specific IPR can be developed by making one reservoir simulation run which covers the entire pressure range of reservoir. To develop the analytical IPR, one would follow the same procedure described in the verification of IPR. Utilizing fluid property, relative permeability and pressure data for the reservoir, one would make a single-well reservoir simulation run at a constant production rate or a constant flowing wellbore pressure. The purpose of this simulation is to develop a pressure profile in the reservoir from the average reservoir pressure towards the outer boundary of the reservoir to almost zero pressure at the wellbore.

Based on the analytical IPR, evidence has been presented that flow geometry, reservoir porosity, absolute permeability and formation thickness have no effect on the shape of the IPR curve. Error analysis of pressure-production estimates generated from the analytical IPR and reservoir simulation results indicate reliable field data for IPR generation requires pressure drawdowns greater than 20% of the average reservoir pressure.

Vogel's IPR developed shows the coefficients are dependent on the mobility function. It is also required that we investigate factors which may influence the mobility function. The mobility term is a function of pressure and saturation. They are affected by three primary factors, that are depletion, production rate and the presence of an altered permeability zone.

One of the factors that will effect the IPR curve is the depletion effect. During the research, I observe that the mobility function is affected by the stage of depletion experienced in the reservoir.

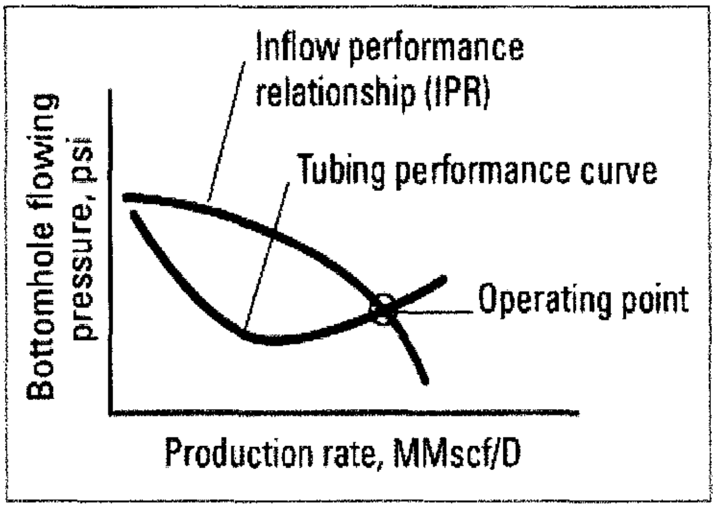


Figure 2.1 : Inflow Performance Relationship Curve (IPR)

When estimating oil well performance, engineers often assume that fluid inflow is proportional to the difference between reservoir pressure and wellbore pressure. The difference between the two pressures are called pressure drawdown. One of the first relationships to be used based on this assumption was the Productivity Index (PI).

This straight line relationship is derived from Darcy's law for the steady-state incompressible flow of a single-phase fluid and is the ratio of the producing rate to pressure difference. In equation form, the PI is defined by,

Where J = productivity index, (STBpsi/day)

q = oil flowrate,(STB/day)

However, the philosophers pointed out that a straight line relationship should not be expected when two phases, oil and gas, are flowing in the reservoir. They presented theoretical calculations that showed a curved relationship between flow rate and pressure. [4]

2.2 Sand Control

Through out my research, it is found that excessive/ overpressured production will lead to sand production. It is said that the overperessure increase of drawdown and depletion by raising the effective external stresses and the pore pressure gradient which by far exceeding the formation collapse stress, will result in productivity reductions as well as increasing sand production. This implies that a reliable sand control method must be implemented, especially in the primary completion of the well. For subsea wells or gas wells, a high level of security is required. Large drawdown may lead to a rapid, transient sand production once a small failure zone is developed.

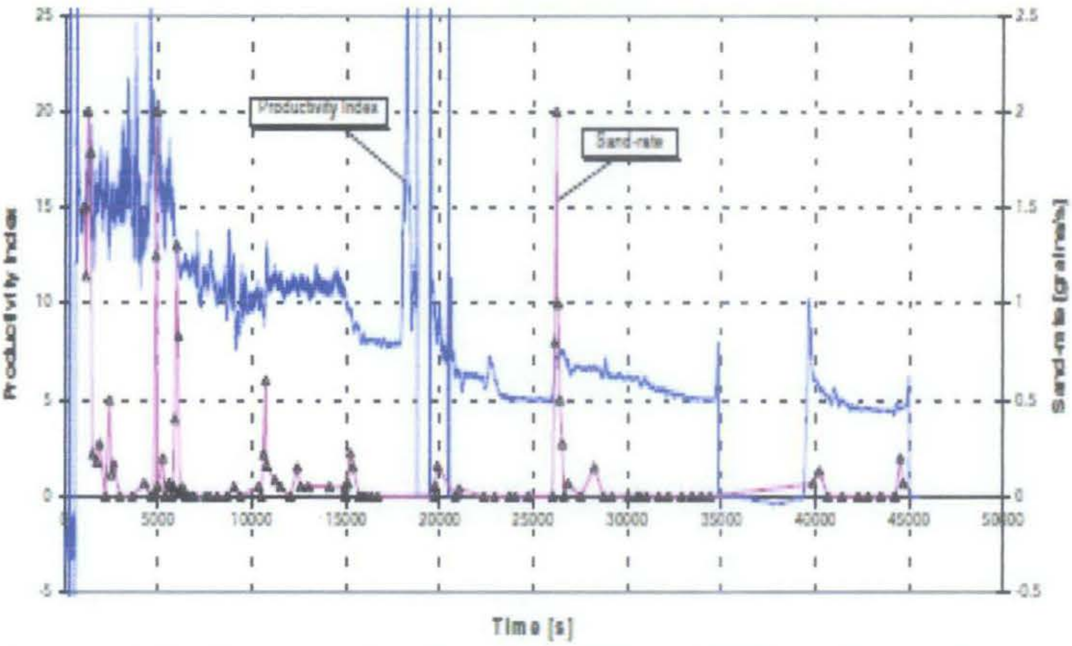


Figure 2.2 : Productivity and sand production rate as a function of time for the test on material with large annulus.

Figure 3 shows the evolution of the productivity and the manually detected sand production rate as functions of time for the test on the fire grain synthetic sandstone. It is clearly seen that the productivity is reduced with increasing confining stress level and increasing drawdown which resulted in increased depletion.

The ability to predict sand failure in producing wells is important for the economic planning of the development and management of oil and gas reservoirs. Anticipated failure of weak sands often limits the production rates from wells, perhaps unnecessarily in many cases. In terms of Gulf of Mexico case which is described previous at the background study, the overpressure lead to sand production which disappointing the production rates. Not only that, a sanding prediction study was initiated. For immediate action, they maintain a mud weight sufficient to control well, due to overpressured well. [5]

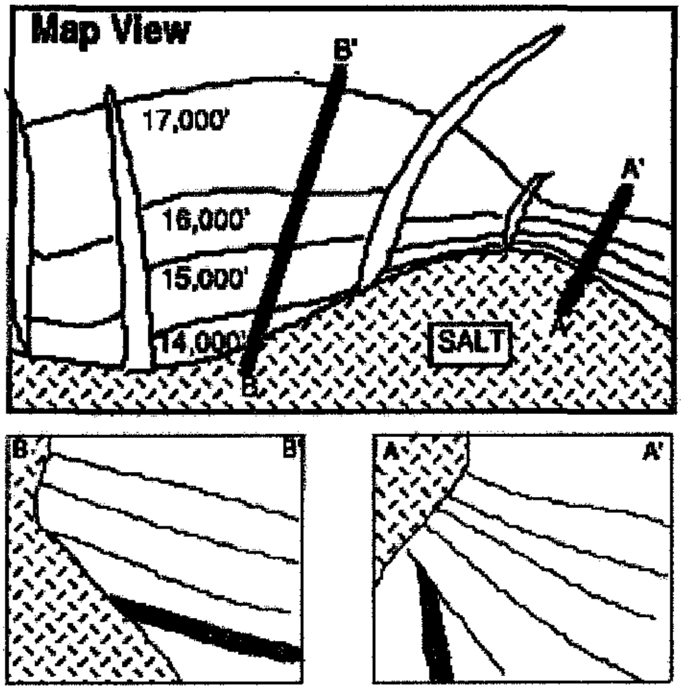


Figure 2.3: Sketches of map view and profiles along marked sections at the locations of two fields in the Gulf of Mexico. The beds containing the oil-bearing sands are shaded on the cross sections.

2.3 Petrophysical Changes

During the production of hydrocarbon at excessive drawdown, some of the petrophysical properties might have effected and changed to the other form.

The petrophysical properties are :

1) **Skin Effect**

An increase or decrease in the pressure drop predicted with Darcy's law using the value of permeability thickness, kh, determined from a buildup or drawdown test. The difference is assumed to be caused by the "skin." Skin effect can be either positive or negative. The skin effect is termed positive if there is an increase in pressure drop, and negative when there is a decrease, as compared with the predicted Darcy pressure drop. A positive skin effect indicates extra flow resistance near the wellbore, and a negative skin effect indicates flow enhancement near the wellbore. The terms skin effect and skin factor are often used interchangeably. In this glossary, the term skin effect refers to the numerical value of the skin factor.

Skin effect may be defined by :

—

The skin effect S and the external permeability Ke, can be determined from pressure build-up test. The average permeability Kavg including the altered and external permeabilities can be determined from PI tests, and may be defined approximately on the basis of steady-state flow. [8]

2) Wellbore Storage Constant

Afterflow or wellbore storage, occurs during the initial period of a shut-in. Prior to a shut-in, the rate of fluid leaving the wellbore at the wellhead is equivalent to the rate of fluid entering the wellbore at the sandface. When the well is shut in, fluid continues to enter the wellbore at the sandface, thus, compressing the fluid inside the wellbore. Until the time comes when the rate of fluid flow at the sandface is negligible, pressure data is affected by afterflow. The signature of wellbore storage on a derivative plot is a straight line with a unit slope at early time. The position of this line is used to calculate the wellbore storage constant (*C*). Note that wellbore storage 1 1ncreases as the position of this line moves to the right. [10]

	Flow Period	Wellbore Storage Constant (bbl / psi)
Oil	Drawdown $\log\left(\frac{\Delta p}{q}\right) vs \log(\Delta t)$	$C = \frac{\Delta t}{24 \cdot Der}$
	Buildup $\log(\Delta p) vs \log(\Delta t)$	$C = \frac{qB\Delta t}{24 \cdot Der}$
Gas	Drawdown $\log\left(\frac{\Delta \psi}{q}\right) vs \log(\Delta t_a)$	$C = 2348 \frac{T}{\mu_{gi} \cdot Der} \Delta t_a$
	Buildup $\log(\Delta \psi) vs \log(\Delta t_a)$	$C = 2348 \frac{qT}{\mu_{gi} \cdot Der} \Delta t_a$

Figure 2.4: Summary of Equations for Afterflow Derivative Analysis (Field Units)

CHAPTER 3
METHODOLOGY

3.1 Research Methodology

1) Gather the upper gauge data from the real well. In this project, data from Dulang platform, Offshore Terengganu is used. The data needed are time and pressure.

2) Study and understand the concept of excessive production and its behaviour. For Dulang wells, it is expected that the production rate is from 800-1000 bbl/day. Thus, I will vary the production rate and do the analysis of petrophysical changes occurred.

3) Understand the concept of Pansystem well testing analysis software and its usage in reservoir simulation. The process of understanding and mastering this software took time to ensure the efficiency of the result.

4) Create a reservoir simulation model to be used for well testing analysis. For this project, the model used are fair wellbore storage as wellbore storage model, radial homogeneous model as flow model and infinitely acting as boundary model.

5) Simulate the reservoir simulation model using different range of production rate. For this project, production rate of 400 bbl/day, 1000 bbl/day and 1800 bbl/day are used. For initial assumption, production rate of 1000 bbl/day will be the optimum production rate while production rate of 1800 bbl/day will be excessive production rate.

6) Identify the effect of having optimum production and excessive production towards well characteristics and petrophysical properties of reservoir. By using different production rates, changes of reservoir properties are identified and soon to be analysed.

7) Analyse and compare the effect of having optimum production and excessive production in the reservoir. Behind all the values obtained, there must be reasons of it. These things need to be analysed. The petrophysical properties involved are skin effect, initial pressure and permeability height.

8) Make a conclusion out of the study. Determine if the objective has been met. In the conclusion, the overall effect of having excessive production to the reservoir properties and the well lifetime need to be discussed.

9) Compilation of all research findings, literature reviews, simulation works, results and outcomes into a final report.

Preparing Data For Analysis :

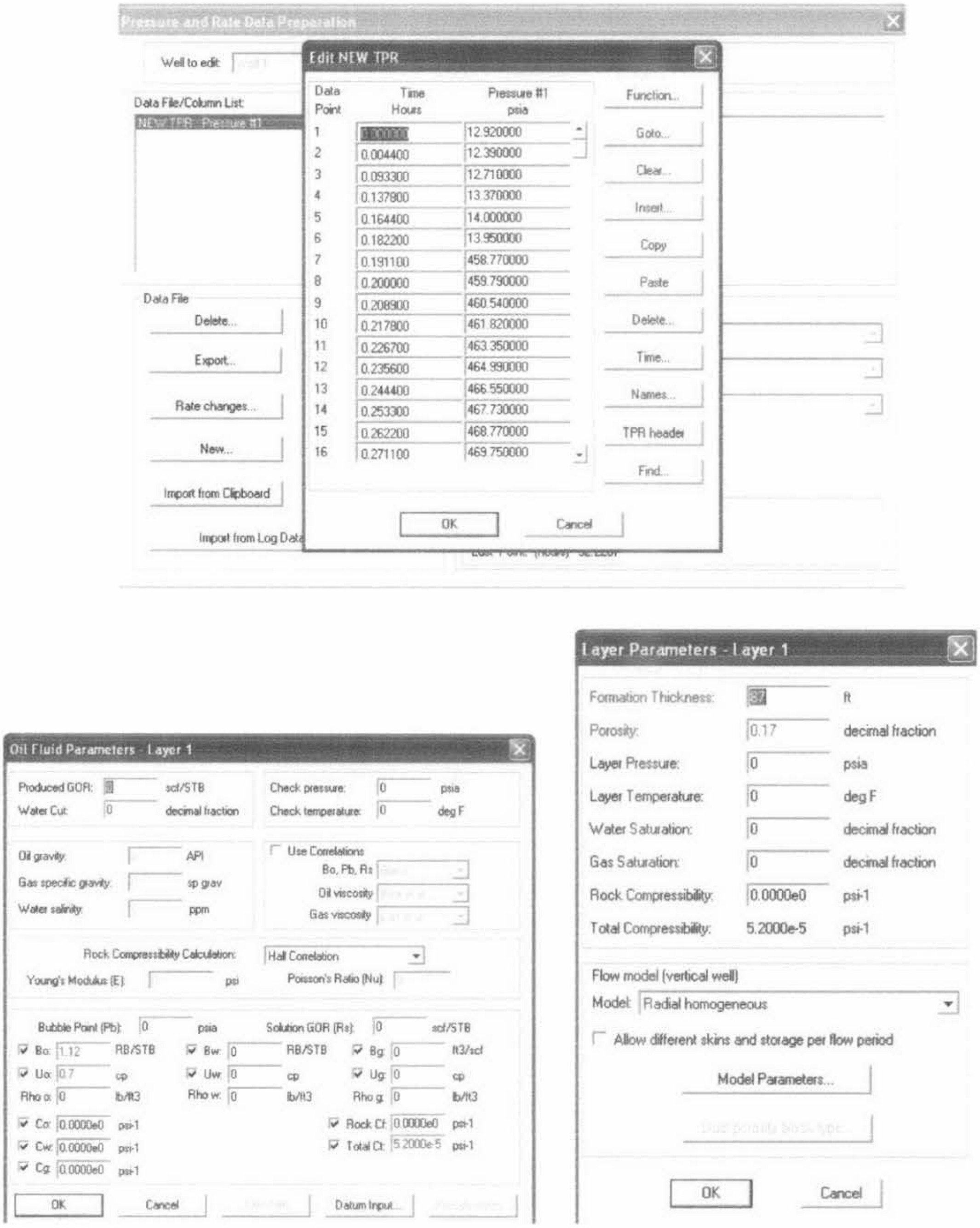


Figure 3.1 : Data needed to be filled as input values

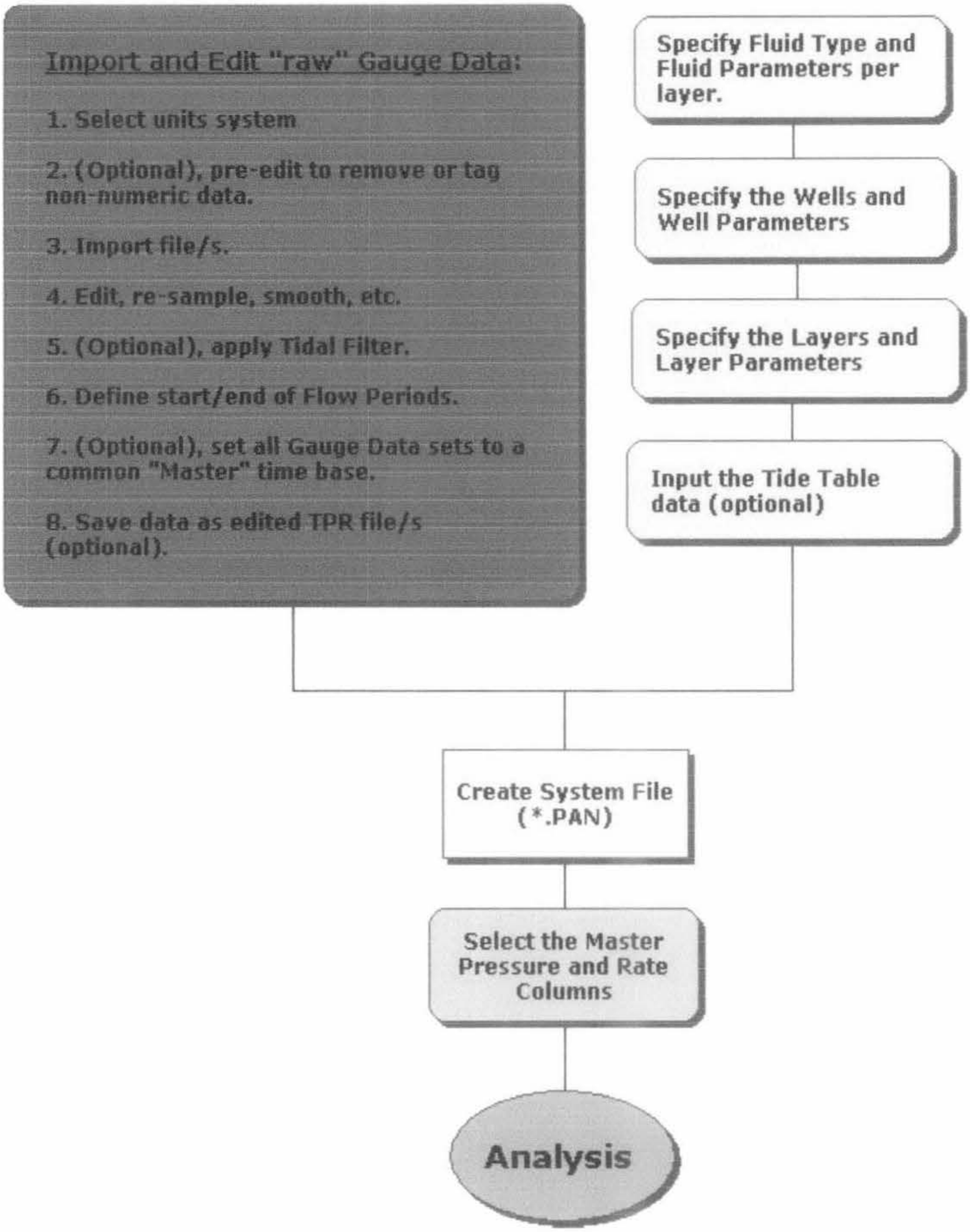


Figure 3.2 : Sequence of events users should follow to create a system files for analysis

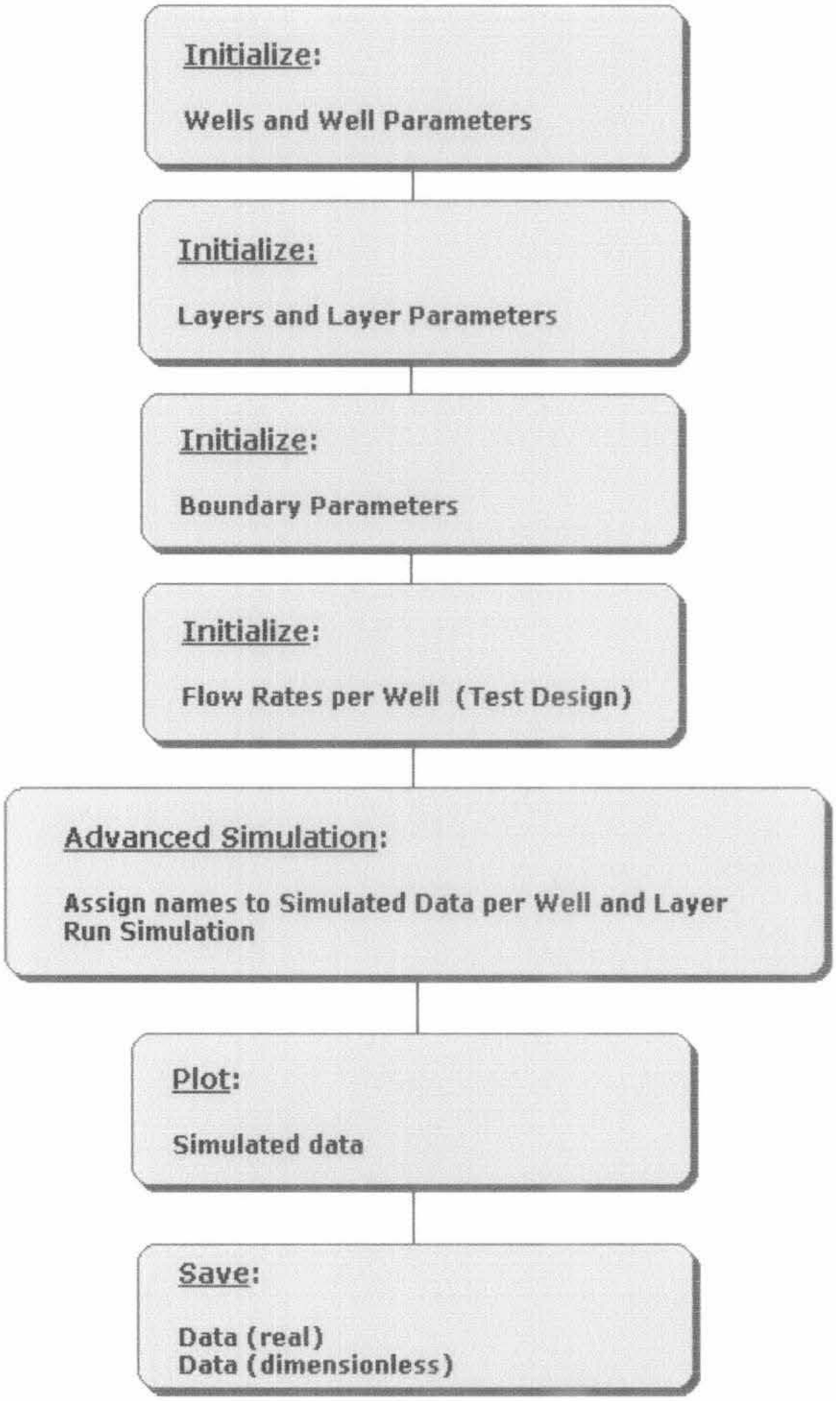
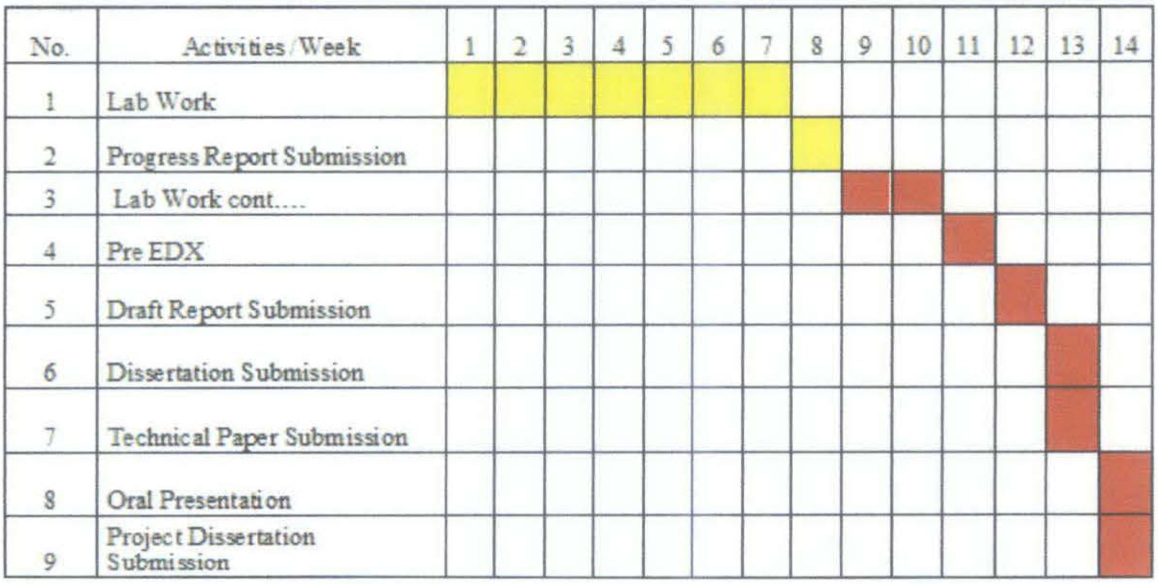


Figure 3.3 : Sequence of events for test design and advanced simulation

3.0 Key Milestone

No.	Activities	Date/Week
1.	Briefing and update on students progress	W4
2.	Project work commences	W1-W8
3.	Submission of progress report	W8
4.	PRE-EDX	W11
5.	EDX	W12
6.	Delivery of Final Report	W12
7.	Final Oral Presentation	W14
8.	Submission of hardbound copies	W16

3.3 Gantt Chart



3.4 Tools (eg. Equipment, hardware, etc.) required

Software required for the project :

1. PanSystem – The PanSystem simulator is useful when well testing analysis is required to describe reservoir productivity and petrophysical properties.

CHAPTER 4
RESULTS AND DISCUSSION

4.1 Data Gathering & Analysis

Overall, the data that will be used in this project currently is based on the data that I got from Dulang Field, Offshore Terengganu. It is based on the real data from one of its wells. Eventhough the information is private and confidential, thus I am only allowed to use it for project purpose only. The data needed are the gauge data consisting of time (T) and pressure(P), well radius (Rw), formation thickness (h), porosity , oil formation volume factor (Bo), oil viscosity (and time compressibility factor (. For my research, I am informed that for Dulang wells, the expected daily production is about 400-1000 bbl/day. Thus, for my project, I used production rates of 400 bbl/day, 1000 bbl/day and 1800 bbl/day. Production rates of 1000 bbl/day is assumed to be the opmtimum rate while 1800 bbl/day is assumed to be the excessive rate. The changes of values of reservoir properties obtained will be analysed later.

In Pansystem simulation, the data given is useful to be used in the well model. Also provided data is from the reservoir fluid data, well test data and production history data. This data is useful to design the simple well model which is without any optimisation of production. The result for the production can be obtained by knowing the oil rate which should be produced by the well. The prediction result can be done to know the value of petrophysical properties based from the assumed production rate that get from the well.

To see the changes of reservoir properties occurred, I vary the production rate from the low value to the excessive value. The values are 400 bbl/day and 1000 bbl/day, while the excessive production rate is 1800 STB/day. From that, we can see that the values of properties have changed and give different numbers.

Production rate (bbl/day)	Skin Effect,S
400	-1.1229
1000	-2.0207
1800	-1.6181

Table 4.1 : Values of Skin Effect obtained

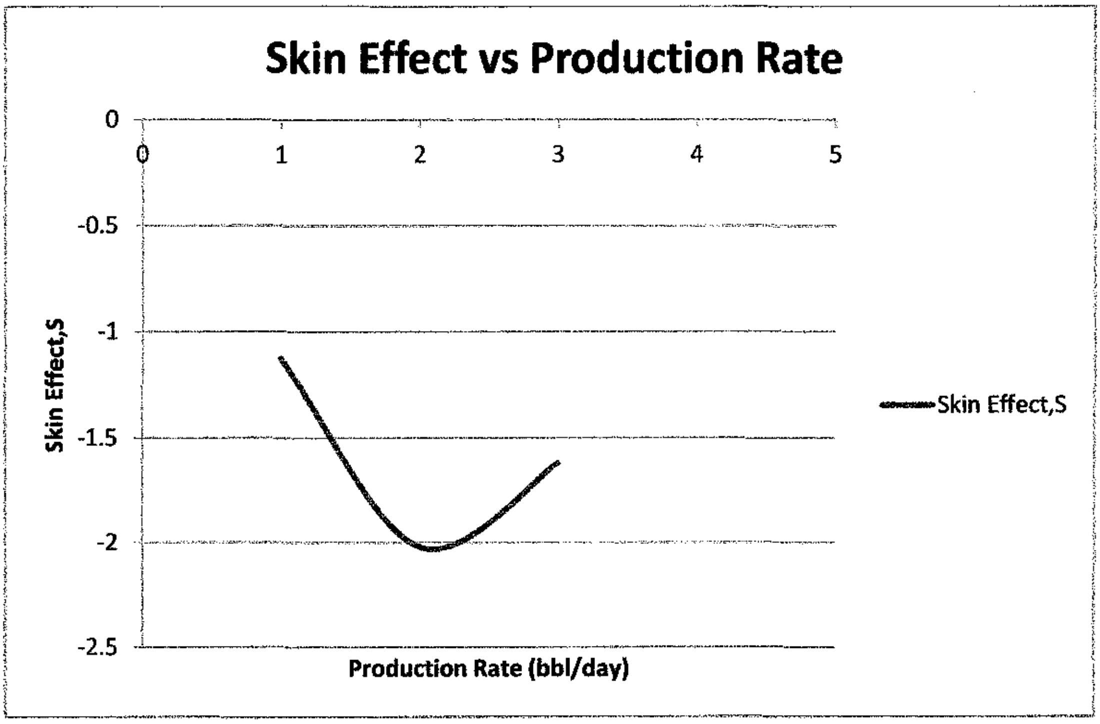


Figure 4.1: Graph of Skin Effect vs Production Rate

Production rate (bbl/day)	Initial Pressure,Pi (psia)
400	1233.9872
1000	1236.79
1800	1237.3483

Table 4.2 : Values of Initial Pressure obtained

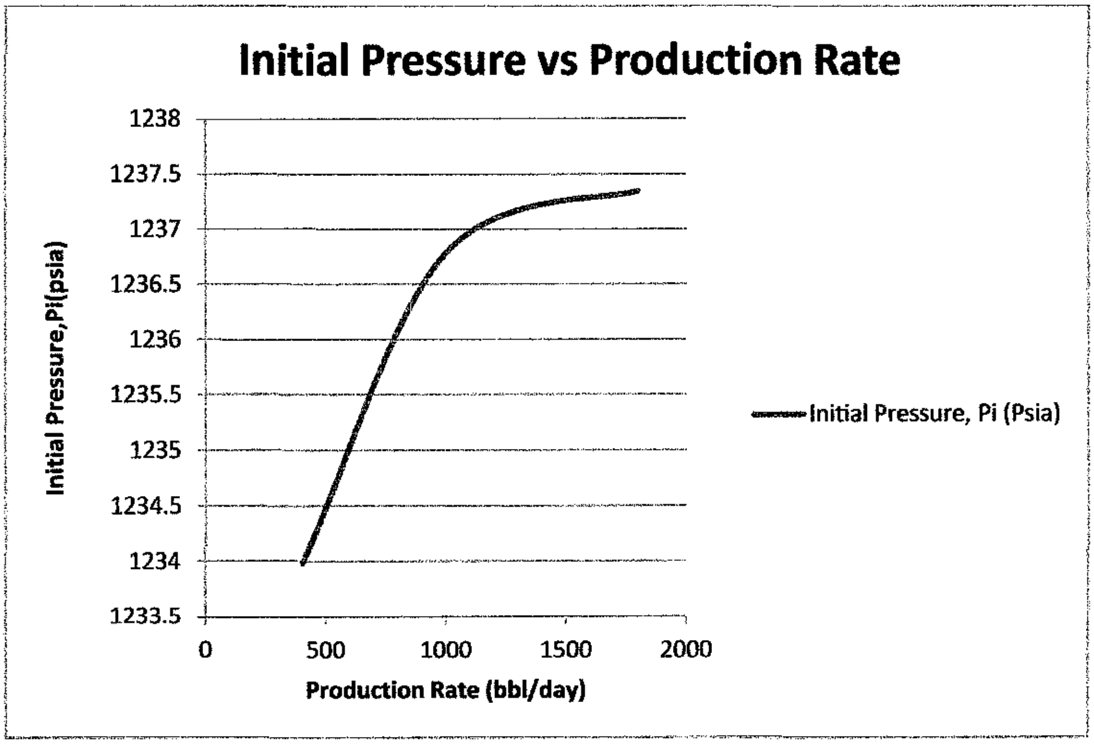


Figure 4.2: Graph of Initial Pressure vs Production Rate

Production rate (bbl/day)	Maximum Phase Redistribution Pressure, Cphi (psi)
400	3.5
1000	1.5
1800	3

Table 4.3 : Values of Maximum Phase Redistribution Pressure obtained

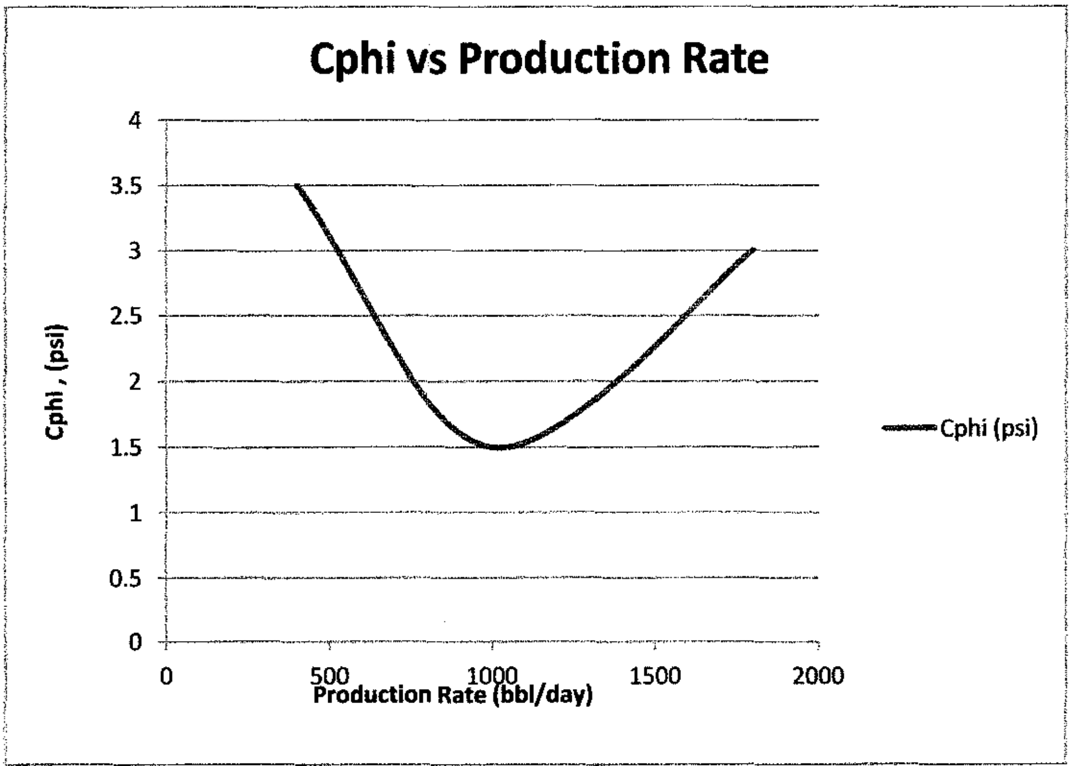


Figure 4.3: Graph of Maximum Phase Redistribution Pressure vs Production Rate

Production rate (bbl/day)	Time of Gas Segregation from Bottomhole to Surface, Tau (hr)
400	2
1000	0.46
1800	3

Table 4.4 : Values of Time of Gas Segregation from Bottomhole to Surface obtained

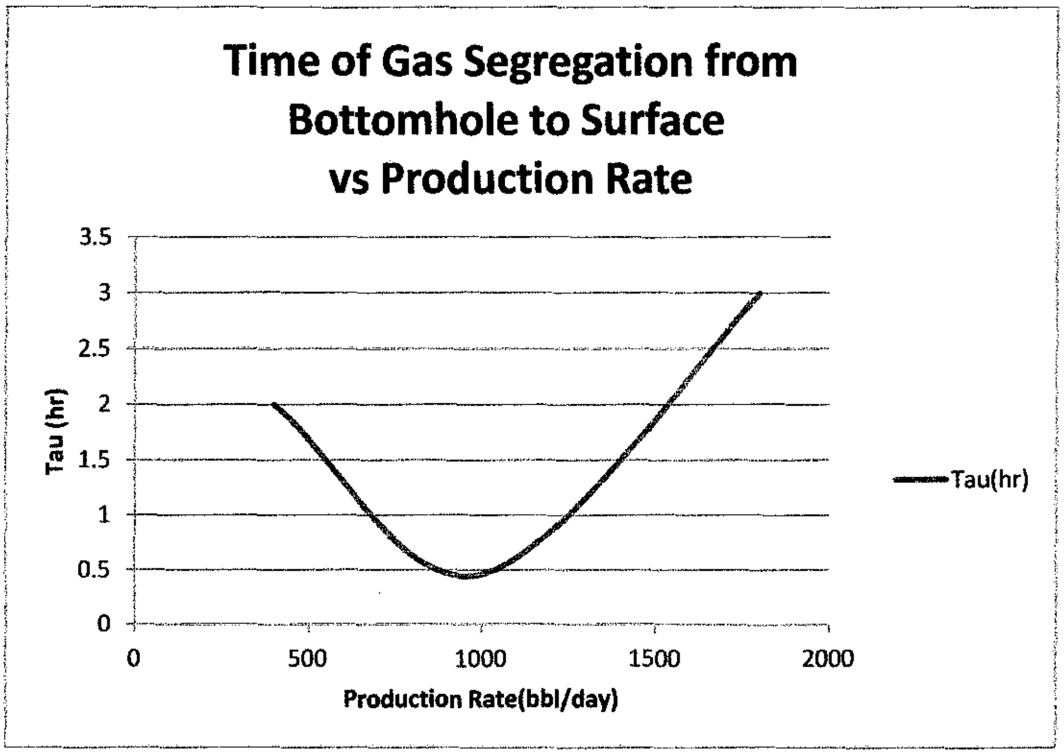


Figure 4.4: Graph of Time of Gas Segregation from Bottomhole to Surface vs Production Rate

Production rate (bbl/day)	Wellbore Storage,Cs(bbl/psi)
400	0.01237
1000	0.0365
1800	0.0556

Table 4.5 : Values of Wellbore Storage obtained

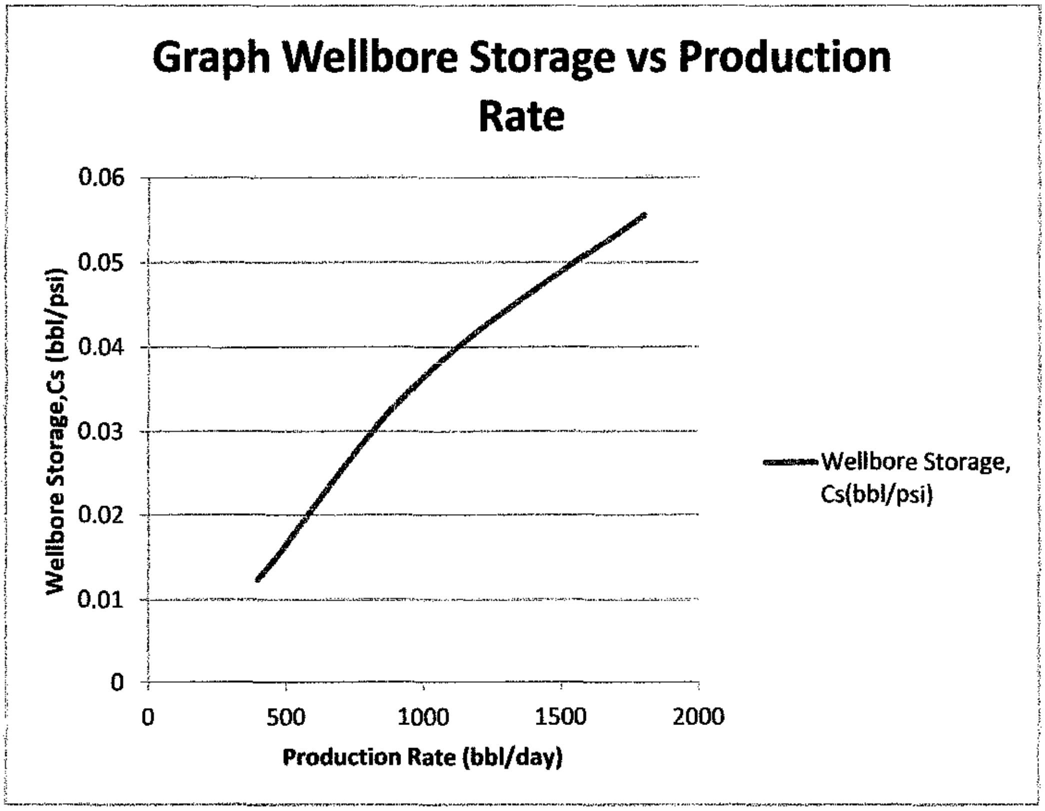


Figure 4.5: Graph of Wellbore Storage vs Production Rate

4.2 RESULTS AND DISCUSSION

4.2.1 Effect of Skin Effect

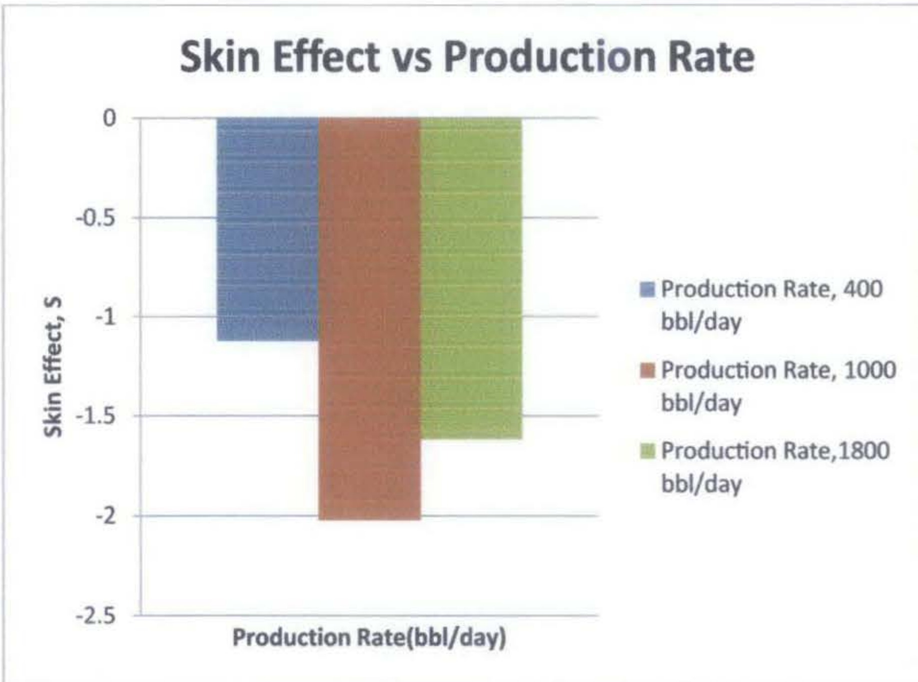


Figure 4.6: Graph of Skin Effect vs Production Rate

Based on the graph above, production rate of 1000 bbl/day gives the lowest skin effect which is the best skin effect obtained, followed by production rate of 1800 bbl/day and lastly the production rate of 400 bbl/day. Based on the values, we can say that the optimum production rate is 1000 bbl/day as it produced the least skin effect. For excessive rate, it gives quite bad skin effect and it will keep going up with the increasing of rate.

For skin effect, several possible causes exist, including flow convergence to the well, lower permeability in the gravel pack than in the formation and inertial/turbulent flow effects. The skin effect is the measure of additional pressure drop near the wellbore. With such high permeability in formation, a small additional pressure drop can easily occur, and the apparent skin factor is magnified because of the high formation permeability.

4.2.3 Effect of Initial Reservoir Pressure

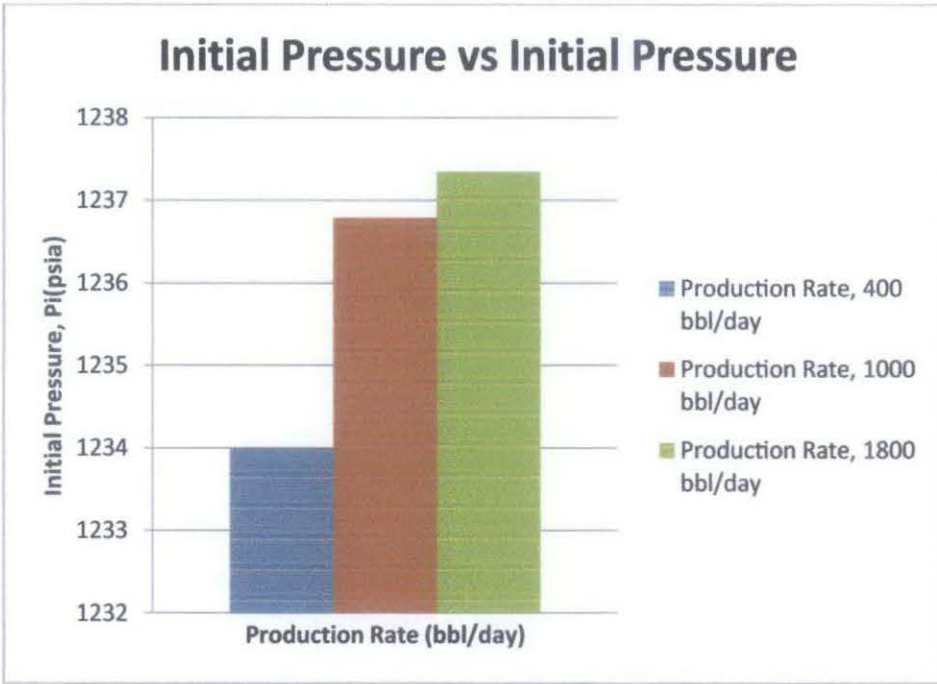


Figure 4.7: Graph of Skin Effect vs Production Rate

Based on the graph above, production rate of 1800 bbl/day gives the highest value of initial pressure that is 1237.2 psi, followed by production rate of 1000 bbl/day(1236.8 psi) and the least one is production rate of 400 bbl/day (1234 psi).

The initial pressure is the average reservoir pressure before the start of a test. For a new well, the initial pressure equals the virgin or original reservoir pressure and corresponds to the drill stem test (DST) pressure. For a well that has been on production for a long time the initial pressure may or may not be equal to the original reservoir pressure.

In this project, it is logical that the highest initial pressure is for production rate of 1800 bbl/day. The reservoir pressure provides the necessary driving energy to produce petroleum fluids. It can be inferred that a relatively high initial pressure would lead to substantially higher primary production under favorable conditions.

4.2.4 Effect of Maximum Phase Redistribution Pressure

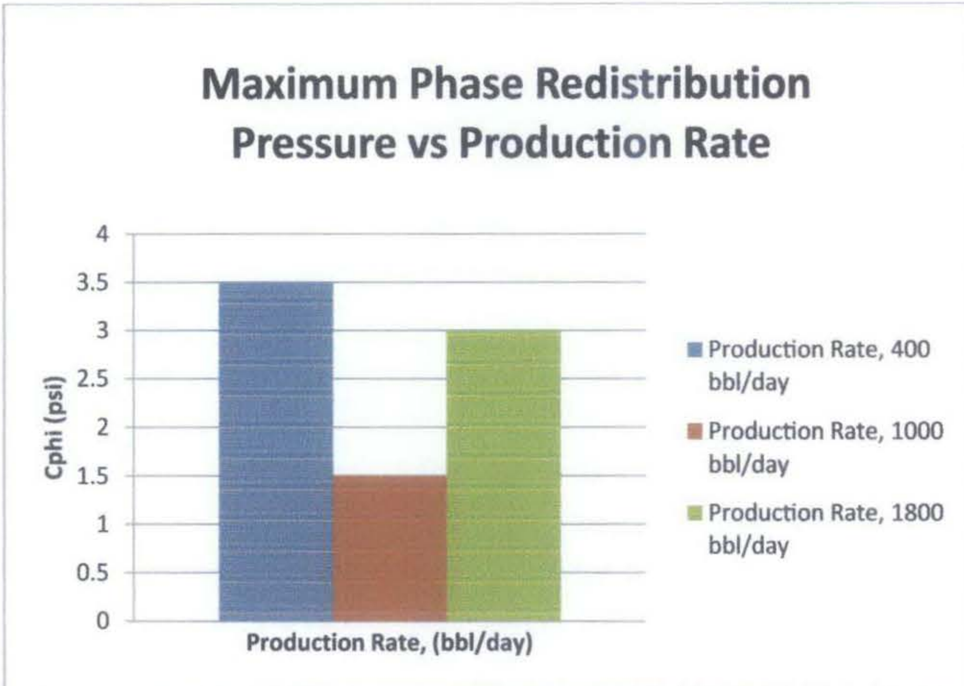


Figure 4.8: Graph of Maximum Phase Redistribution Pressure vs Production Rate

Based on the graph above, it shows that production rate of 400 bbl/day obtained the highest value of maximum phase redistribution pressure, followed by production rate of 1800bbl/day and lastly the production rate of 1000 bbl/day. The phenomenon of wellbore phase redistribution occurs in a well which is shut in with gas and liquid flowing simultaneously in the tubing.

When such well is shut in at the surface, gravity effects cause the liquid to fall and the gas to rise to the surface. If we consider a well where wellbore phase redistribution occurs, it is apparent that wellbore storage also must occur. It is expected that the phase redistribution pressure initially would rise quickly and then slowly approach its maximum value. For the above graph, the well reach its maximum phase redistribution pressure at early stage of production. This may be due to some disturbance in the well or changes in the behavior of the reservoir.

4.2.5 Effect of Time of Gas Segregation from Bottomhole to Surface

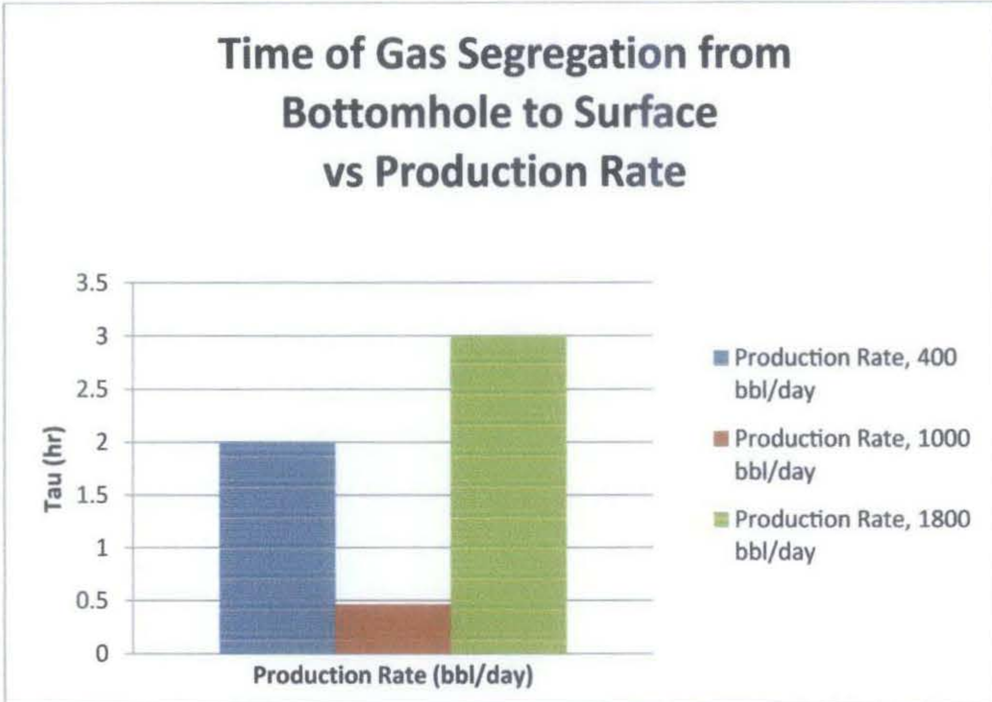


Figure 4.9: Graph of Time of Gas Segregation from Bottomhole to Surface vs Production Rate

From the graph above, the longest time of gas segregation from bottomhole to surface is contributed by the production rate of 1800 bbl/day. The second highest is from the production rate of 400 bbl/day while the lowest is the production rate of 1000 bbl/day.

As the friction force and the velocity for the production rate of 1800 bbl/day is too high, it takes time for the gas to segregate from bottomhole to surface. As production rate of 1000bbl/day is initially assumed as the optimum production, that is why it takes the least time. The gas is segregated very fast that it takes less than half an hour. For production rate, it gives quite long time for the gas to segregate is because the well is still producing in early stage, it might be the pressure has not stabilized yet.

4.2.6 Effect of Wellbore Storage

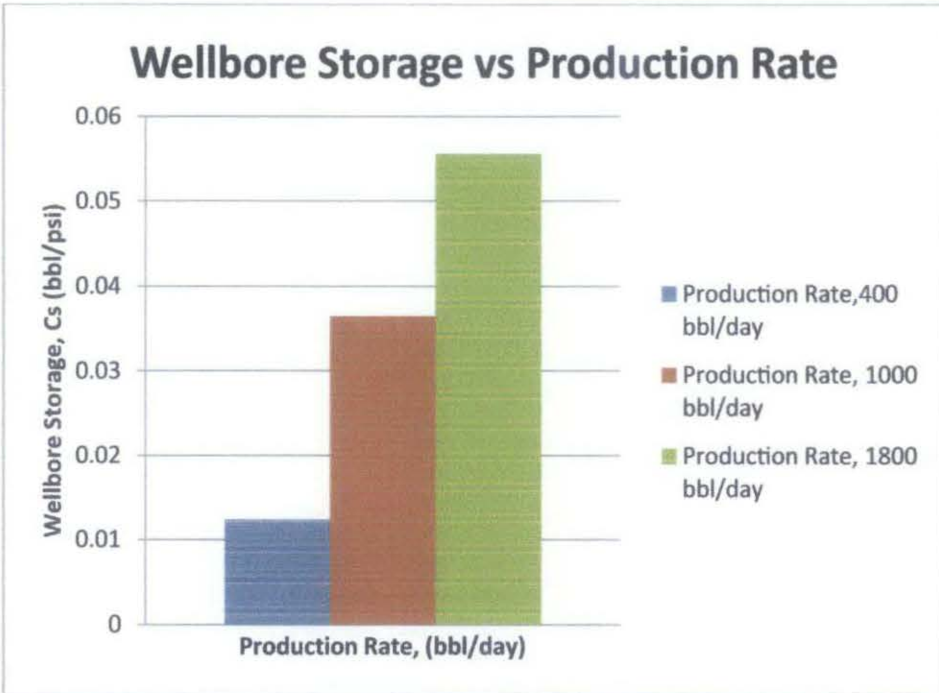


Figure 4.10: Graph of Wellbore Storage vs Production Rate

From the graph above, the highest wellbore storage is contributed by the production rate of 1800 bbl/day. The value of its wellbore storage is 0.0556 bbl/psi. The second highest is from production rate of 1000 bbl/day and the least is production rate of 400 bbl/day.

Due to excess production, that is the main reason why production of 1800 bbl/day give the highest value. Wellbore storage is caused by having a volume of compressible fluid stored in the wellbore that may include gas/liquid interface. Sudden changes in the production rate caused a significance different between the surface production and sandface flow rate.

The effect of wellbore storage is to add another flow regime to the original three, that are early time regime, intermediate time regime and late time regime. This flow regime occurs immediately following the shutting in or opening of the well.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

Based on the simulation done, the following conclusions can be made. First, the project's feasibility lies in its simplicity in implementation and the software is readily available; hence developing this project would be practical and feasible within the scope and time frame. Objectives are achieved. Second, as production rate increased, the permeability will also increased, as well as skin effect. In oil and gas industry, we are desired to get the highest productivity. However, the productivity achieved must suit our reservoir condition to ensure the durability of the well so that it can produce hydrocarbon in long period of time. Excessive production can lead to production decline and rapid depletion of reservoir pressure. Most worse, it can lead to sand production that can create corrosion to the well. From the analysis made, it also showed that for the excessive production rate, the values of petropysical properties seems to give negative impact to the reservoir. For future works, my suggestion is, we should have a good information about the well regarding the inflow pressure, outflow pressure, the expected production rate and the fluid properties of the reservoir. These study are important to protect our well from damage, therefore can produce the desired hydrocarbon throughout its lifetime.

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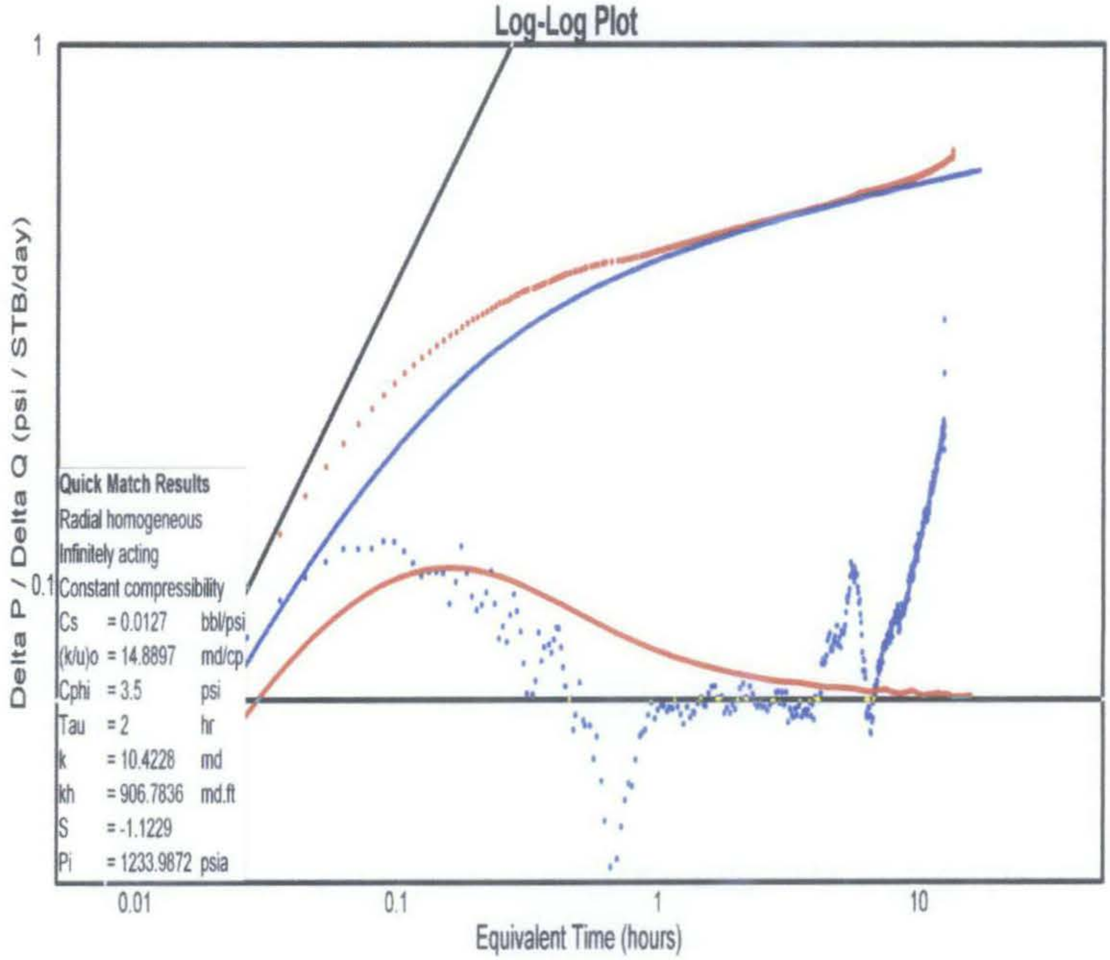
LIST OF FIGURES

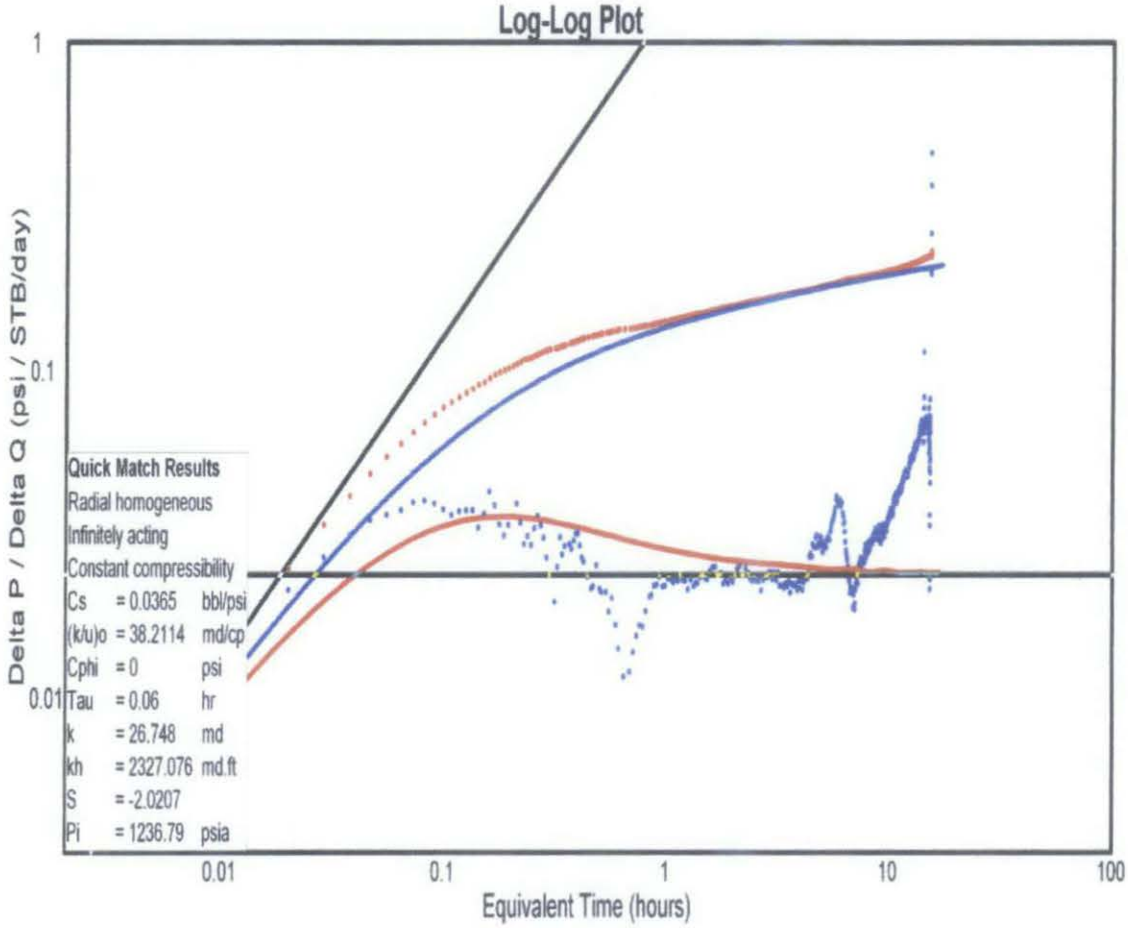
LIST OF TABLES

APPENDICES

Appendix 1 : Log Log Plot for oil production 400 bbl/day



Appendix 2 : Log Log Plot for oil production 1000 bbl/day



Appendix 3 : Log Log Plot for oil production 1800 bbl/day