PERFORMANCE PREDICTION OF WATER DRIVE RESERVOIR BY ECLIPSE SIMULATOR

Submitted to the College of Engineering

University of Petroleum and Energy Studies

in partial fulfillment of the requirements for the degree of

BACHELOR OF TECHNOLOGY
Applied Petroleum Engineering

Submitted to:

Dr. B. P. Pandey
Dean, College of Engg.

Submitted By :

UTTAM ASWAL
Enrollment No. - 0102030057
B. Tech, Applied Petroleum Engg.
Batch 2003-07

May 2007

UNIVERSITY OF PETROLEUM & ENERGY STUDIES

Certificate

This is to certify that the Project Report on " Performance Prediction of Water-drive Reservoir by Eclipse Simulator " submitted to College of Engineering, University of Petroleum & Energy Studies, by Mr. Uttam Aswal in partial fulfillment of the requirements for the degree of Bachelor of Technology in Applied Petroleum Engineering (academic session 2003-2007) is a bonafide work carried out under my supervision and guidance. This work has not been submitted anywhere else for any other degree or diploma.

Date 09.05.07

Dr. B. P. Pandey

rporate Office :
drocarbons Education & Research Society
l Floor, PHD House. 4/2, Siri Institutional Area
gust Kranti Marg, New Delhi-11001 India
+ 91-11-41730151-53 Fax : +91-11 1730154

Main Campus :
Energy Acres, PO Bidholi, Via Prem Nagar,
Dehradun-248 007 (Uttaranchal) India
Ph. : +91-135-2261090-91, 2694201/203/208
Fax : +91-135-2694204

Regional Centre (NCR)
SCO 9-12, Sector-14, Gurgaon 122 007
(Haryana), India
Ph : + 91-124-4540300
Fax : +91 124 4540 330

E-mail : info@upes.ac.in URL:www.upes.ac.in

ABSTRACT

Reservoir simulation has always been a handy tool in decision making which assists in reservoir engineering application in different phases of exploitation of petroleum reserves. With the evolution of modern age computer based commercial simulator like eclipse100 the computing speed, accuracy and reliability of results increases many folds.

For relatively high accuracy and better dependence on decision making reservoir simulation serves as a better alternative then the classical material balance approach. The new generation high speed computers making reservoir simulation very precise yielding faster outputs. Material balance works on the point function approach where lateral variation in parameters are not considered, while simulation is free from these constraints. In this project I have focused mainly on simulating results using eclipse -100 and carry out prediction for 2 different cases.

ACKNOWLEDGEMENTS

I would like to give particular thanks to Dr. B. P. Pandey, Dean college of Engg. for his patience, guidance and mentoring. I benefited from each discussion with him in the past years. Without his direction, suggestions and encouragements, this work would have been impossible.

To Dr. D. S. Bora, with whom I started working on this project for his help on the initialization of the project and giving timely good suggestions and encouragement.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1. INTRODUCTION

Prediction of oil production is an important part of reservoir development and management, and economic evaluation. The production of oil reservoirs that have associated aquifers is relatively difficult to predict and recovery efficiency is usually high. However, recovery from water-drive reservoirs may decrease because water influx may trap gas, if primary gas cap is present. Efforts to predict water-drive reservoir performance have been focused on material balances. Material balances are a fundamental reservoir engineering tool that describe and predict the relation between fluid withdrawal, expansion, influx and pressure. Material balances can predict original oil in place and oil reserves at any stage of reservoir depletion[1] (Craft and Hawkins, 1959).

This being my first attempt consideration is focused on to keep simulation simple enough and more illustrative. The scope of this study is designed such it can allow next higher level of research.

CHAPTER 2. WATER INFLUX IN RESERVOIR

Water drive reservoirs are those reservoirs in which a significant portion of volumetric withdrawals is replaced by water influx during the producing life of the reservoir.

The total influx, and influx rates, will be governed by the aquifer characteristics together with the pressure-time behavior along the original reservoir/aquifer contact. Ordinarily, few wells are drilled into the aquifer and little or no information concerning the aquifer size, geometry, or rock properties is available. However, if sufficient reservoir pressure and production history is available, the aquifer properties may be inferred from solutions of the diffusivity equation.

These inferred aquifer properties then can be used to calculate the future effect of the aquifer on the reservoir performance.

Aquifer Geometry :

- Radial-boundaries are formed by two concentric cylinders or sectors of cylinders.
- Linear-boundaries are formed by two sets of parallel planes.
- Nonsymmetrical-neither radial nor linear.

Exterior Boundary Conditions :

- Infinite-pressure disturbances do not affect the exterior boundary of the system, *during the time of inrerest.*
- *Finite closed-no* flow occurs across the exterior boundary. Pressure disturbances reach the exterior boundary, *during the time of interest.*
- *Finite* outcropping-aquifer is finite with pressure constant at exterior boundary (i.e., aquifer outcrops into lake, gulf, or other surface water source).

Aquifer Flow :

The equation we use for aquifer flow is the diffusivity equation, the same one we use in well testing theory for undersaturated oil reservoirs. Also the geometries used are the same; linear, radial and spherical flow. Although these equations are well known, I'll repeat them here for reference.

Linear Flow

$$\frac{\partial^2 p}{\partial x^2} = \frac{\phi \mu c_t}{k} \frac{\partial p}{\partial t}$$

Radial Flow

$$\frac{\partial^2 p}{\partial r^2} + \frac{1}{r} \frac{\partial p}{\partial r} = \frac{\phi \mu c_t}{k} \frac{\partial p}{\partial t}$$

In aquifer flow this problem is far simpler, for the only fluid flowing is water thus both Being μ and *ct* remain nearly constant. Usually in aquifer flow, the variation of *k*/μ with pressure is ignored, for it does not change nearly as much as it does in oil reservoirs. The effect of *k*/ μ variation was discussed in considerable detail by Samaniego *et al.* (1979).

As is done for reservoir systems, Equations are usually changed to dimensionless parameters[2]. These following equations result for linear flow,

$$\frac{\partial^2 p_D}{\partial x_D^2} = \frac{\partial p_D}{\partial t_D}$$

where the dimensionless terms used are as follows:

$$x_D = x / L$$

and

$$t_D = \frac{kt}{\phi \mu c_t L^2}$$

Where

L = The length of the linear aquifer

If a constant rate inner boundary is used, *pD* is defined as,

$$p_D = \frac{kA(p - p_i)}{q\mu L}$$

where

Pi = initial aquifer pressure

A = cross sectional area of the aquifer

If a constant pressure inner boundary is used, then the definition for P_D is,

$$p_D = \frac{p - p_i}{p_w - p_i}$$

Where , P*w* = inner boundary constant pressure

Note that the subscript, *w*, is usually used at the inner boundary just as it is in well testing, even though the inner boundary is not a well; rather, it is at the original boundary of the oil reservoir/aquifer system.

Water Influx Models :

Several models have been developed for estimating water influx that are based on assumptions that describe the characteristics of the aquifer. Due to the inherent uncertainties in the aquifer characteristics, all of the proposed models require historical reservoir performance data to evaluate constants representing aquifer property parameters since these are rarely known from exploration-development drilling with sufficient accuracy for direct application. The material balance equation can be used to determine historical water influx provided original oil-in-place is known from pore volume estimates. This permits evaluation of the constants in the influx equations so that future water influx rate can be forecasted. The mathematical water influx models that are commonly used in the petroleum industry include:

- Pot aquifer
- Schilthuis' steady-state
- Hurst's modified steady-state
- The Van Everdingen-Hurst unsteady-state
    - Edge-water drive
    - Bottom-water drive
- The Carter-Tracy unsteady-state
- Fetkovich's method
    - Radial aquifer
    - Linear aquifer

Fetkovich's Model :

Fetkovitch[3] presented a simplified approach that is based on the concept of a "stabilized" or pseudosteadystate aquifer productivity index and an aquifer material balance relating average aquifer pressure to cumulative water influx. This method is best suited for smaller aquifers, which may approach a pseudosteady condition quickly and in which the aquifer geometry and physical properties are known. In a manner similar to single-well performance, the rate of water influx is expressed by

$$e_{w'}=J_a(\bar{p}_a-p_w),$$

where

e_w = water influx rate, B/D,

Ja = aquifer productivity index, B/D-psi,

Pa = average aquifer pressure, psi, and

Pw = pressure at the original WOC, psi.

The productivity index J used in the calculation is a function of the geometry of the aquifer. Fetkovich calculated the productivity index from Darcy's equation for bounded aquifers. Lee and Wattenbarger (1996) pointed out that Fetkovich's method can be extended to infinite acting aquifers by requiring that the ratio of water influx rate to pressure drop to be approximately constant throughout the productive life of the reservoir. The productivity index J of the aquifer is given by the following expressions.

Type of Outer Aquifer Boundary	**J for Radial flow, bbl/day/psi**	**J for Linear Flow, bbl/day/psi**
Finite, no flow	$J = \frac{0.00708\,kh\,f}{\mu_w\,[\ln r_D - 0.75]}$	$J = \frac{0.003381\,kwh}{\mu_w\,L}$
Finite, constant pressure	$J = \frac{0.00708\,kh\,f}{\mu_w\,[\ln(r_D)]}$	$J = \frac{0.001127\,k\,wh}{\mu_w\,L}$
Infinite	$J = \frac{0.00708\,kh\,f}{\mu_w\ \ln(a/r_e)}$ $a = \sqrt{0.0142\,kt/(f\mu_w\,c_t)}$	$J = \frac{0.001\,k\,wh}{\mu_w\sqrt{0.0633\,kt/(f\ \mu_w c_t}}$

Table No. 01 : Aquifer Productivity Index for different cases

Where,

w = width of the linear aquifer

L = length of the linear aquifer

rD = dimensionless radius, ra/re

k = permeability of the aquifer, md

t = time, days

θ = encroachment angle

h = thickness of the aquifer

f = θ / 360

The increment of influx over a time interval t to t+Δt is given by

$$\Delta W_e = \frac{W_{et}[\bar{p}_{a(n-1)} - \bar{p}_{w_n}[1 - e^{(-J_a \Delta t_n)/(c_{wt} V_{wi})}]}{p_{ai}},$$

Where,

Wet = total aquifer expansion capacity, bbl,

Vwj, = initial water volume in the aquifer, bbl,

Pai = initial aquifer pressure, psi, and

Cwt, = total aquifer compressibility, psi -1 .

$$\bar{p}_{a_{(n-1)}} = p_{ai}\left[1 - \frac{W_{e_{(n-1)}}}{W_{et}}\right],$$

$$J_a = \frac{7.08 \times 10^{-3}\, kh}{\mu_w(\ln r_D - 0.75)} \quad \ldots$$

for a closed radial system, and

$$J_a = \frac{3(1.127 \times 10^{-3})kbh}{\mu_w L}$$

for a closed linear system.

CHAPTER 3. BASIC THEORY OF SIMULATION

Analytical and numerical solutions of simple one-dimensional, one-phase flow equations[2] :

Here we will review the simplest one-dimensional flow equations for horizontal flow of one fluid, and look at analytical and numerical solutions of pressure as function of position and time. These equations are derived using the continuity equation, Darcy's equation, and compressibility definitions for rock and fluid, assuming constant permeability and viscosity. They are the simplest equations we can have, which involve transient fluid flow inside the reservoir.

Linear flow :

Consider a simple horizontal slab of porous material, where initially the pressure everywhere is P_0 , and then at time zero, the left side pressure (at x = 0) is raised to P_L while the right side pressure (at x = L) is kept at $P_R = P_0$. The system is shown in the figure below:

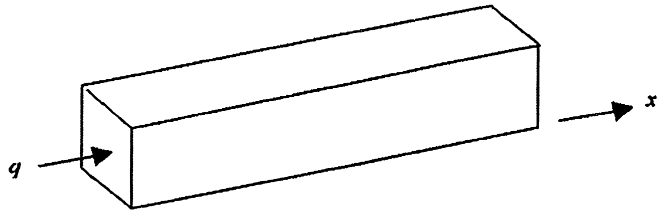


Fig 01 - Linear flow through a porous horizontal slab

Partial differential equation (PDE) :

The linear, one dimensional, horizontal, one phase, partial differential flow equation for a liquid, assuming constant permeability, viscosity and compressibility is:

$$\frac{\partial^2 P}{\partial x^2} = \left(\frac{\phi \mu c}{k}\right) \frac{\partial P}{\partial t}$$

Transient vs. steady state flow :

The equation above includes time dependency through the right hand side term. Thus, it can describe transient, or time dependent flow. If the flow reaches a state where it is no longer time dependent, we denote the flow as steady state. The equation then simplifies to:

$$\frac{d^2P}{dx^2} = 0$$

Transient and steady state pressure distributions are illustrated graphically in the figure below for a system where initial and right hand pressures are equal. As can be observed, depending on the properties of the system, the pressure will increase in all parts of the system (transient solution), for then to approach a final distribution (steady state), described by a straight line between the end pressures.

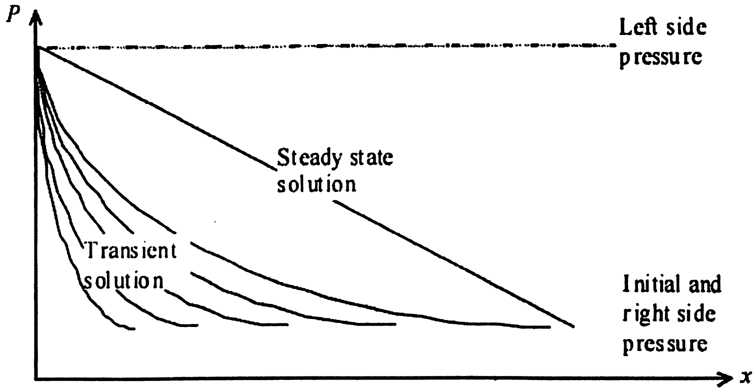


Fig. 02 - Transient and steady state pressure distributions [4]

Analytical solution to the linear PDE :

The analytical solution of the transient pressure development in the slab is then given by:

$$P(x,t) = P_L + (P_R - P_L)\left[\frac{x}{L} + \frac{2}{\pi}\sum_{n=1}^{\infty}\frac{1}{n}\exp\left(-\frac{n^2\pi^2}{L^2}\frac{k}{\phi\mu c}t\right)\sin\left(\frac{n\pi x}{L}\right)\right]$$

It may be seen from the solution that as time becomes large, the exponential term approaches zero, and the solution becomes:

$$P(x,t) = P_L + (P_R - P_L)\frac{x}{L}.$$

This is, of course, the solution to the steady state equation above.

Radial flow (Well test equation):

An alternative form of the simple one dimensional, horizontal flow equation for a liquid, is the radial equation that frequently is used for well test interpretation. In this case the flow area is proportional to r^2, as shown in the following figure:

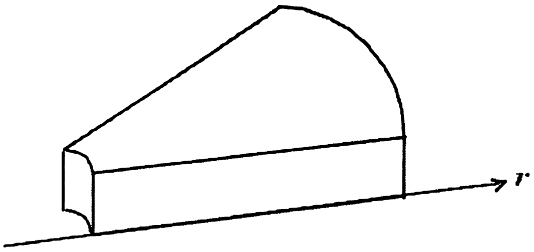


Fig. 03 – One dimensional radial flow through 1-D segment

The one-dimensional (radial) flow equation in this coordinate system becomes

$$\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial P}{\partial r}\right)=\frac{\phi\mu c}{k}\frac{\partial P}{\partial t}$$

A steady state solution does not exist for an infinite system, since the pressure will continue to decrease as long as we produce from the center. However, if we use a different set of boundary conditions, so that $P(r = r_w) = P_w$ and $P(r = r_e) = P_e$, we can solve the steady state form of the equation

$$\frac{1}{r}\frac{d}{dr}\left(r\frac{dP}{dr}\right)=0$$

Numerical solution :

Generally speaking, analytical solutions to reservoir flow equations are only obtainable after making simplifying assumptions in regard to geometry, properties and boundary conditions that severely restrict the applicability of the solution. For most real reservoir fluid flow problems, such simplifications are not valid. Hence, we need to solve the equations numerically.

Discretization :

In the following we will, as a simple example, solve the linear flow equation above numerically by using standard finite difference approximations for the two derivative terms ($\delta^2P/\delta x^2$) and ($\delta P/\delta t$) . First, the x-coordinate must be subdivided into a number of discrete grid blocks, and the time coordinate must be divided into discrete time steps. Then, the pressure in each block can be solved for numerically for each time step. For our simple one dimensional, horizontal porous slab, we thus define the following grid block system with N grid blocks, each of length Δx.

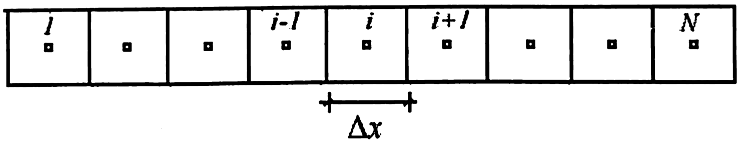


Fig. 04 – One dimensional block centered grid block arrangement

This is called a block-centered grid, and the grid blocks are assigned indices, i, referring to the mid-point of each block, representing the average property of the block.

Taylor series approximations [5] :

A so-called Taylor series approximation of a function f(x+ h) expressed in terms of f(x)and its derivatives f ' (x) may be written:

$$f(x+h) = f(x) + \frac{h}{1!}f'(x) + \frac{h^2}{2!}f''(x) + \frac{h^3}{3!}f'''(x) + \ldots..$$

Applying Taylor series to our pressure function, we may write expansions in a variety of ways in order to obtain approximations to the derivatives in the linear flow equation.

Approximation of the second order space derivative :

At constant time, t, the pressure function may be expanded forward and backwards:

$$P(x+\Delta x,t)=P(x,t)+\frac{\Delta x}{1!}P'(x,t)+\frac{(\Delta x)^2}{2!}P''(x,t)+\frac{(\Delta x)^3}{3!}P'''(x,t)+\ldots..$$

$$P(x-\Delta x,t)=P(x,t)+\frac{(-\Delta x)}{1!}P'(x,t)+\frac{(-\Delta x)^2}{2!}P''(x,t)+\frac{(-\Delta x)^3}{3!}P'''(x,t)+\ldots..$$

By adding these two expressions, and solving for the second derivative, we get the following approximation:

$$P''(x,t)=\frac{P(x+\Delta x,t)-2P(x,t)+P(x+\Delta x,t)}{(\Delta x)^2}+\frac{(\Delta x)^2}{12}P''''(x,t)+\ldots..$$

or, by employing the grid index system, and using superscript to indicate time level:

$$(\frac{\partial^2 P}{\partial x^2})_i^t=\frac{P_{i+1}^t-2P_i^t+P_{i-1}^t}{(\Delta x)^2}+O(\Delta x^2).$$

This is called a central approximation of the second derivative. Here, the rest of the terms from the Taylor series expansion are collectively denoted $O(\Delta x^2)$, thus denoting that they are in order of, or proportional in size to Δx^2 . This error term, sometimes called discretization error, which in this case is of second order, is neglected in the numerical solution. The smaller the grid blocks used, the smaller will be the error involved.

Any time level could be used in the expansions above. Thus, we may for instance write the following approximations at time levels $t + \Delta t$ and $t + \Delta t/2$:

$$\left(\frac{\partial^2 P}{\partial x^2}\right)_i^{t+\Delta t} = \frac{P_{i+1}^{t+\Delta t} - 2P_i^{t+\Delta t} + P_{i-1}^{t+\Delta t}}{(\Delta x)^2} + O(\Delta x^2)$$

$$\left(\frac{\partial^2 P}{\partial x^2}\right)_i^{t+\frac{\Delta t}{2}} = \frac{P_{i+1}^{t+\frac{\Delta t}{2}} - 2P_i^{t+\frac{\Delta t}{2}} + P_{i-1}^{t+\frac{\Delta t}{2}}}{(\Delta x)^2} + O(\Delta x^2)$$

Approximation of the time derivative :

At constant position, x, the pressure function may be expanded in forward direction in regard to time:

$$P(x, t + \Delta t) = P(x, t) + \frac{\Delta t}{1!} P'(x, t) + \frac{(\Delta t)^2}{2!} P''(x, t) + \frac{(\Delta t)^3}{3!} P'''(x, t) + \ldots..$$

By solving for the first derivative, we get the following approximation:

$$P'(x,t) = \frac{P(x,t + \Delta t) - P(x,t)}{\Delta t} + \frac{(\Delta t)}{2} P''(x,t) + \ldots..$$

or, employing the index system:

$$\left(\frac{\partial P}{\partial t}\right)_i^t = \frac{P_i^{t+\Delta t} - P_i^t}{\Delta t} + O(\Delta t).$$

While from the central approximation, we obtain the following central approximation of the time derivative, with a second order error term:

$$\left(\frac{\partial P}{\partial t}\right)_i^{t+\frac{\Delta t}{2}} = \frac{P_i^{t+\Delta t} - P_i^t}{\Delta t} + O(\Delta t)$$

Explicit difference equation :

First, we will use the approximations above at time level t and substitute them into the linear flow equation. The following difference equation is obtained:

$$\frac{P_{i+1}^t - 2P_i^t + P_{i-1}^t}{\Delta x^2} \approx (\frac{\phi\mu c}{k})\frac{P_i^{t+\Delta t} - P_i^t}{\Delta t}, \quad i = 1,\ldots,N$$

For convenience, the error terms are dropped in the equation above, and the equality sign is replaced by an approximation sign. It is important to keep in mind, however, that the errors involved in this numerical form of the flow equation, are proportional to Δt and Δx^2, respectively. Boundary conditions (BC's). The driving force for flow arises from the BC's. Basically, we have two types of BC's, the pressure condition, and the flow rate condition.

- Pressure Boundary Conditions:

  When pressure boundaries are to be specified, we normally, specify the pressure at the end faces of the system in question. Applied to the simple linear system described above, we may have the following two BC's:

$$P(x = 0, t > 0) = P_L$$

$$P(x = L, t > 0) = P_R$$

or, using the index system:

$$P_{i=1/2}^{t>0} = P_L$$

$$P_{N+1/2}^{t>0} = P_R$$

The reason we here use indices i = 1/2 and N+1/2 is that the BC's are applied to the ends of the first and the last blocks, respectively.

- Flow rate Boundary Conditions:

Alternatively, we would specify the flow rate, Q, into or out of an end face of the system in question, for instance into the left end of the system above. Making use of the fact that the flow rate may be expressed by Darcy's law, as follows:

$$Q_L = -\frac{kA}{\mu}\left(\frac{\partial P}{\partial x}\right)_{x=0}.$$

Similarly, a constant rate Q_R, would result in the following expression:

$$\left(\frac{\partial^2 P}{\partial x^2}\right)_N^t = \frac{P_N^t - P_{N-1}^t}{(\Delta x)^2} - Q_R\frac{\mu}{\Delta x A k} + O(\Delta x)$$

- Initial condition (IC) :

The initial condition (initial pressures) for our horizontal system may be specified as:

$$P_i^{t=0} = P_0, i = 1,\ldots,N.$$

For non-horizontal systems, hydrostatic pressures are normally computed based on a reference pressure and fluid densities.

Solution of the difference equation :

Having derived the difference equation above, and specified the grid system, the BC's and the IC, we can solve for pressures. However, one issue of importance needs to be discussed first. In deriving the difference approximations, t we assigned a time level of to the terms in the Taylor series. Obviously, we could as well assigned a time level t of $t + \Delta t$ with equivalent generality. Or we could assign a time level of $t+ \Delta t/2$. following formulations are used for solving the above differential equations. For convenience, error terms are not included below.

- Explicit formulation
- Implicit formulation
- Crank-Nicholson formulation / Semi- Implicit formulation

Discussion of the formulations[6] :

Obviously, the explicit formulation is simpler to use than the implicit formulation, as explicit expressions for pressures are obtained directly. Discretization errors are the same for the two formulations. The amount of work involved is less for the explicit case. In one-dimensional solutions, this may not have any importance, however, in two and three dimensional cases with large numbers of grid blocks, the difference in computational time per time step will become large. However, the explicit formulation is seldom used. As it turns out, it becomes unstable for large time steps.

Application of von Neumann stability analysis to the implicit formulation, shows that it is unconditionally stable for all time step sizes. Practice shows that the additional computational work per time step involved in the implicit method, generally is compensated for by permitting much larger time step. Larger time steps lead to larger numerical errors, so it is important in any numerical solution application to check that the errors are within acceptable limits.

The Crank-Nicholson formulation has less discretization error than the two others, since the central approximation of the time derivative has a second order error term. The solution of the set of equations is similar to the implicit case. However, the Crank-Nicholson method often results in oscillations in the solved pressures, and is therefore seldom used.

Implicit formulation :

In this case, all time levels in the approximations are changed to t+Δt, except for in the time derivative approximation, which now will be of the backward type.

$$\frac{P_2^{t+\Delta t} - 3P_1^{t+\Delta t} + 2P_L}{\frac{3}{4}\Delta x^2} = \left(\frac{\phi\mu c}{k}\right)\frac{P_i^{t+\Delta t} - P_i^t}{\Delta t} \quad (i=1)$$

$$\frac{P_{i+1}^{t+\Delta t} - 2P_i^{t+\Delta t} + P_{i-1}^{t+\Delta t}}{\Delta x^2} = \left(\frac{\phi\mu c}{k}\right)\frac{P_i^{t+\Delta t} - P_i^t}{\Delta t}, \quad i = 2,\ldots,N-1$$

$$\frac{2P_R^{t+\Delta t} - 3P_N^{t+\Delta t} + P_{N-1}^{t+\Delta t}}{\frac{3}{4}\Delta x^2} = \left(\frac{\phi\mu c}{k}\right)\frac{P_i^{t+\Delta t} - P_i^t}{\Delta t} \quad (i=N)$$

Now we have a set of N equations with N unknowns, which must be solved simultaneously with the help of appropriate numerical technique.

Oil Water Simulation – IMPES Approach

Multiphase flow equations for one-dimensional, horizontal flow in a layer of

constant cross sectional area as consisting of a continuity equation for each fluid phase flowing:

$$-\frac{\partial}{\partial x}(\rho_l u_l) = \frac{\partial}{\partial t}(\phi\rho_l S_l), \quad l = o,w,g,$$

and corresponding Darcy equations for each phase:

$$u_l = -\frac{k k_{rl}}{\mu_l}\frac{\partial P_l}{\partial x}, \quad l = o,w,g,$$

where

$$P_{cow} = P_o - P_w$$

$$P_{cog} = P_g - P_o$$

$$\sum_{l=o,w,g} S_l = 1 .$$

Considering the fluid phases of oil and water only, and substituting Darcy's equations and standard Black Oil fluid descriptions into the continuity equations, and including production/injection terms in the equations, will result in the following flow equations for the two phases:

$$\frac{\partial}{\partial x}\left(\frac{kk_{ro}}{\mu_o B_o}\frac{\partial P_o}{\partial x}\right) - q_o' = \frac{\partial}{\partial t}\left(\frac{\phi S_o}{B_o}\right)$$

and

$$\frac{\partial}{\partial x}\left(\frac{kk_{rw}}{\mu_w B_w}\frac{\partial P_w}{\partial x}\right) - q_w' = \frac{\partial}{\partial t}\left(\frac{\phi S_w}{B_w}\right),$$

where

$$Pw - Po = Pcow$$

and

$$So + Sw = 1$$

Relative permeabilities and capillary pressures are functions of water saturation, and formation volume factors, viscosities and porosity are functions of pressures.

Fluid properties as considered as they are defined in a standard Black Oil model.

Discretization of flow equations :

We will use similar approximations for the two-phase equations as we did for one phase flow.

Left side flow terms :

$$\frac{\partial}{\partial x}\left(\frac{kk_{ro}}{\mu_o B_o}\frac{\partial P_o}{\partial x}\right)_i \approx T_{xoi+1/2}(P_{oi+1} - P_{oi}) + T_{xoi-1/2}(P_{oi-1} - P_{oi})$$

and

$$\frac{\partial}{\partial x}\left(\frac{kk_{rw}}{\mu_w B_w}\frac{\partial P_w}{\partial x}\right)_i \approx T_{xwi+1/2}(P_{wi+1} - P_{wi}) + T_{xwi-1/2}(P_{wi-1} - P_{wi}),$$

where, using oil term and plus direction as example, oil transmissibility is defined as

$$T_{xoi+1/2} = \frac{2\lambda_{oi+1/2}}{\Delta x_i\left(\frac{\Delta x_{i+1}}{k_{i+1}} + \frac{\Delta x_i}{k_i}\right)}$$

and the oil mobility term is defined as

$$\lambda_o = \frac{k_{ro}}{\mu_o B_o}.$$

The mobility term is now a function of saturation in addition to pressure. This will have significance for the evaluation of the term in discrete form.

upstream election of mobility :

$$\lambda_{o_{i+1/2}} = \begin{cases} \lambda_{o_{i+1}} & \text{if } P_{o_{i+1}} \geq P_{o_i} \\ \lambda_{o_i} & \text{if } P_{o_{i+1}} < P_{o_i} \end{cases}$$

$$\lambda_{w_{i+1/2}} = \begin{cases} \lambda_{w_{i+1}} & \text{if } P_{w_{i+1}} \geq P_{w_i} \\ \lambda_{w_i} & \text{if } P_{w_{i+1}} < P_{w_i} \end{cases}$$

Right side terms :

The right hand side of the oil equation may be expanded as follows:

$$\frac{\partial}{\partial t}\left(\frac{\phi S_o}{B_o}\right) = \frac{\phi}{B_o}\frac{\partial S_o}{\partial t} + S_o\frac{\partial}{\partial t}\left(\frac{\phi}{B_o}\right).$$

The complete difference form of the right hand side of the oil equation may be written as:

$$\frac{\partial}{\partial t}\left(\frac{\phi S_o}{B_o}\right)_i \approx C_{poo_i}(P_{o_i} - P_{o_i}^t) + C_{swo_i}(S_{w_i} - S_{w_i}^t),$$

where

$$C_{poo_i} = \frac{\phi_i(1 - S_{w_i})}{\Delta t}\left[\frac{c_r}{B_o} + \frac{d(1/B_o)}{dP_o}\right]_i,$$

and

$$C_{swo_i} = -\frac{\phi_i}{B_{o_i}\Delta t_i}.$$

Similarly using the one phase terms and standard difference approximations for the derivatives, the right side of the water equation becomes:

$$\frac{\partial}{\partial t}\left(\frac{\phi S_w}{B_w}\right)_i \approx Cpow_i(Po_i - Po_i^t) + Csww_i(Sw_i - Sw_i^t),$$

where

$$Cpow_i = \frac{\phi_i Sw_i}{\Delta t}\left[\frac{c_r}{B_o} + \frac{d(1/B_w)}{dP_w}\right]_i,$$

and

$$Csww_i = \frac{\phi_i}{B_{wi}\Delta t_i} - \left(\frac{dP_{cow}}{dSw}\right)_i Cpow_i .$$

The discrete forms of the oil and water equations may now be written as:

$$\begin{aligned} &Txo_{i+1/2}\left(Po_{i+1} - Po_i\right) + Txo_{i-1/2}\left(Po_{i-1} - Po_i\right) - q'_{oi} \\ &\qquad = Cpoo_i\left(Po_i - Po_i^t\right) + Cswo_i\left(Sw_i - Sw_i^t\right), \qquad i = 1, N \end{aligned}$$

$$\begin{aligned} &Txw_{i+1/2}\left[\left(Po_{i+1} - Po_i\right) - \left(Pcow_{i+1} - Pcow_i\right)\right] + Txw_{i-1/2}\left[\left(Po_{i-1} - Po_i\right) - \left(Pcow_{i-1} - Pcow_i\right)\right] - q'_{wi} \\ &\qquad = Cpow_i\left(Po_i - Po_i^t\right) + Csww_i\left(Sw_i - Sw_i^t\right), \qquad i = 1, N \end{aligned}$$

where

$$Txo_{i+1/2} = \frac{2\lambda o_{i+1/2}}{\Delta x_i\left(\frac{\Delta x_{i+1}}{k_{i+1}} + \frac{\Delta x_i}{k_i}\right)}$$

$$Txo_{i-1/2} = \frac{2\lambda o_{i-1/2}}{\Delta x_i\left(\frac{\Delta x_{i-1}}{k_{i-1}} + \frac{\Delta x_i}{k_i}\right)}$$

$$Txw_{i+1/2} = \frac{2\lambda w_{i+1/2}}{\Delta x_i\left(\frac{\Delta x_{i+1}}{k_{i+1}} + \frac{\Delta x_i}{k_i}\right)}$$

$$Txw_{i-1/2} = \frac{2\lambda w_{i-1/2}}{\Delta x_i\left(\frac{\Delta x_{i-1}}{k_{i-1}} + \frac{\Delta x_i}{k_i}\right)}$$

The three derivative terms appearing in the expressions above:

$$\left[\frac{d(1/Bo)}{dPo}\right]_i, \left[\frac{d(1/Bw)}{dPw}\right]_i \text{ and } \left(\frac{dPc}{dSw}\right)_i$$

are all computed numerically for each time step based on the respective PVT and capillary pressure input tables to the model.

Boundary conditions[7] :

The boundary conditions for multiphase are as for one phase flow, but rates and pressures can be specified for each of the phases. Normally, we inject water in a grid block at constant surface rate or at constant bottom hole pressure, and produce oil and water from a grid block at constant bottom hole pressure, or at constant surface oil rate, or at a constant surface liquid rate. Sometimes we may want to specify constant reservoir voidage rate, where either the rate of injection of water is to match a specified rate of liquid production, so that average reservoir pressure remains constant, or the liquid production rate is to match a specified water injection rate.

Constant water injection rate :

This is the simplest condition to handle, as a water rate term is already included in the water equation. Thus, for a constant surface water injection rate of Qwi (negative) in a well in grid block i:

$$Q_{wi} = WC_i \lambda_{oi} (Pw_i - Pbh_i).$$

The well constant is defined as for one phase flow:

$$WC_i = \frac{2\pi k_i h}{ln(\frac{r_e}{r_w})},$$

where rw is the well radius and the drainage radius is theoretically defined as:

$$r_e = \sqrt{\frac{\Delta y \Delta x_i}{\pi}}\ .$$

However, the fluid injected in a well meets resistance from the fluids it displaces also. Therefore, as a better approximation, it is normally accepted to use the sum of the mobilities of the fluids present in the injection block in the well equation. Thus, the following well equation is often used for the injection of water in an oil-water system:

$$Q_{wi} B_{wi} = WC_i \left(\frac{kro_i}{\mu_{oi}} + \frac{krw_i}{\mu_{oi}} \right) (Pw_i - Pbh_i)\,,$$

Or,

$$Q_{wi} = WC_i \left(\frac{B_{oi}}{B_{wi}} \lambda_{oi} + \lambda_{wi} \right) (Pw_i - Pbh_i)$$

Frequently, capillary pressure is neglected in the well equation, particularly in the case of field scale simulation, so that the well equation becomes:

$$Q_{wi} = WC_i \left(\frac{B_{oi}}{B_{wi}} \lambda_{oi} + \lambda_{wi} \right) (Po_i - Pbh_i)\,.$$

Constant oil production rate :

For the oil equation, this condition is handled as for the constant water injection rate. Thus, for a constant

surface oil production rate of Qoi (positive) in a well in grid block i :

$$q'_{oi} = Q_{oi} / (A \Delta x_i)\,.$$

However, in this case oil production will generally be accompanied by water production, so that the water

equation will have a water production term given by:

$$q'_{wi} = q'_{oi} \frac{\lambda_{wi}(Pw_i - Pbh_i)}{\lambda_{oi}(Po_i - Pbh_i)} .$$

In case the capillary pressure is neglected around the production well, the expression simply becomes:

$$q'_{wi} = q'_{oi} \frac{\lambda w_i}{\lambda o_i} .$$

At the end of a time step, after having solved the equations, the bottom hole production pressure for the well may be calculated using the well equation for oil:

$$Q_{oi} = WC_i \lambda_{oi} (Po_i - Pbh_i) .$$

Production wells are normally constrained by a minimum bottom hole pressure, for lifting purposes in the well.

If this is reached, the well should be converted to a constant bottom hole pressure well.

Solution by IMPES method :

In the equations above, oil pressure, Poi , and water saturation, Swi , are the primary variables, and unknowns to be solved for. All the coefficients in the equations, transmissibilities as well as storage coefficients, are functions of these unknowns. In addition, the capillary pressures on the left side of the water equation are functions of saturation. Thus, we cannot solve the equations before the coefficients and the capillary pressures are calculated, and we cannot calculate the coefficients and the capillary pressures before the unknown pressures and saturations have been solved for. Obviously, a solution method is needed that either iterates on the solution and updates coefficients and capillary pressures until convergence is reached, or some other method for estimating the coefficients and the capillary pressures. IMPES is a simple method, but one that is still being used quite extensively today, although in decreasing extent. The acronym IMPES stands for IMplicit Pressure, Explicit Saturation method, and we will describe this method in detail in the following.

In the IMPES method, the key lies in the approximation of coefficients and capillary pressures. It simply evaluates these at time level t , and thus enable us to solve for pressures and saturations without having to iterate on the solution. Thus, the following assumptions are made:

Txo^t, Txw^t

Cpo^t, Cpw^t

Cso^t, Csw^t

$Pcow^t$

Having made these approximations, the equations become:

$$\begin{aligned} &Txo^t_{i+1/2}\left(Po_{i+1} - Po_i\right) + Txo^t_{i-1/2}\left(Po_{i-1} - Po_i\right) - q'_{oi} \\ &\qquad = Cpoo^t_i\left(Po_i - Po^t_i\right) + Cswo^t_i\left(Sw_i - Sw^t_i\right), \qquad i = 1, N \end{aligned}$$

$$\begin{aligned} &Txw^t_{i+1/2}\left[\left(Po_{i+1} - Po_i\right) - \left(Pcow_{i+1} - Pcow_i\right)^t\right] \\ &+Txw^t_{i-1/2}\left[\left(Po_{i-1} - Po_i\right) - \left(Pcow_{i-1} - Pcow_i\right)^t\right] - q'_{wi} \\ &\qquad = Cpow^t_i\left(Po_i - Po^t_i\right) + Csww^t_i\left(Sw_i - Sw^t_i\right), \qquad i = 1, N \end{aligned}$$

IMPES pressure solution :

Since water saturation only appear as Swi on the right sides of the two equations, they may be combined to eliminate water saturation completely as an unknown from the equations. Thus, we may obtain a pressure equation as:

$$\left(Txo_{i+1/2}^{t} + \alpha_i Txw_{i+1/2}^{t}\right)\left(Po_{i+1} - Po_i\right) + \left(Txo_{i-1/2}^{t} + \alpha_i Txw_{i-1/2}^{t}\right)\left(Po_{i-1} - Po_i\right)$$
$$-\alpha_i Txw_{i+1/2}^{t}\left(Pcow_{i+1} - Pcow_i\right)^{t} - \alpha_i Txw_{i-1/2}^{t}\left(Pcow_{i-1} - Pcow_i\right) - q'_{oi} - \alpha_i q'_{wi} =$$
$$\left(Cpoo_i^{t} + \alpha_i Cpwo_i^{t}\right)\left(Po_i - Po_i^{t}\right), \qquad i = 1, N$$

Where

$$\alpha_i = -Csww_i^{t} / Cswo_i^{t} .$$

The pressure equation may now be rewritten in the following form as:

$$a_i Po_{i-1} + b_i Po_i + c_i Po_{i+1} = d_i, \quad i = 1, N$$

IMPES saturation solution :

Having obtained the oil pressures above, we need to solve for water saturations using either the oil equation or the water equation. In the following we will use the oil equation for this purpose:

$$Txo_{i+1/2}^{t}\left(Po_{i+1} - Po_i\right) + Txo_{i-1/2}^{t}\left(Po_{i-1} - Po_i\right) - q'_{oi}$$
$$= Cpoo_i^{t}\left(Po_i - Po_i^{t}\right) + Cswo_i^{t}\left(Sw_i - Sw_i^{t}\right), \qquad i = 1, N$$

Since water saturation only appears as an unknown in the last term on the right side of the oil equation, we may solve for it explicitly:

$$Sw_i = Sw_i^{t} + \frac{1}{Cswo_i^{t}}\left[Txo_{i+1/2}^{t}\left(Po_{i+1} - Po_i\right) + Txo_{i-1/2}^{t}\left(Po_{i-1} - Po_i\right) - q'_{oi} - Cpoo_i^{t}\left(Po_i - Po_i^{t}\right)\right] \quad , \quad i = 1, N$$

CHAPTER 4. SIMULATION REVIEW

A comprehensive study may take a year or more to complete and, for a time, may place intense demands on computer hardware and skilled personnel depending on the intensity of work required to achieve the desired results. Less-comprehensive studies require fewer resources but usually must be conducted under severe time constraints. Both types of studies should follow clear, practical plans to ensure that they supply the correct information to the reservoir management team in appropriate detail and, above all, in time to be used effectively. Most studies involve essentially the same kinds of activities, although the distribution of effort among the activities will vary from project to project depending upon the objectives.

4.1 Problem Definition.

The scope and objective of this study is to define the performance of water drive reservoir and the associated operating parameters. More detailed effects such as water coning, skin effect and individual well behavior will not be taken care of as they require more detailed approach and proper licensing of eclipse simulator. The performance prediction will be based upon the reservoir parameters such as aquifer water influx, recovery, FOIP, formation pressure, water cut and formation water saturation.

4.2 Data Review.

Data usually must be reviewed and reorganized once they have been collected because they will have been obtained for a number of loosely related reasons and normally will not have been screened or organized well enough to be of immediate use. Review of the available data will almost always reveal gaps and inconsistencies that need to be resolved.

The data on which this study is based fulfills the minimum required level and is gathered from different sources and may lead certain contradiction and inconsistency regarding reliability of data. however, that many objectives can be met even with poor data by evaluation of the sensitivity of reservoir performance to reservoir description or other parameters over a range of values believed to encompass the actual values .But these kinds of sensitivity analysis itself comes out as a detailed analysis which itself requires serious amount of effort.

TABLE NO. 02 - INPUT DATA FOR SIMULATION

Phase present	Oil, Water
No. of grid blocks	400
Grid block type	Block Centered
Horizontal Dimensions of grid blocks (ft.)	1000 * 1000
Height of Grid Blocks	Variable
Period of simulation	1Jan 05' to July 21'
Depth of reservoir (ft.)	variable
Permeability in X-direction (md.)	variable
Permeability in Y-direction (md.)	variable
Permeability in Z direction (md.)	50
Aquifer type	Fetkovitch
Aquifer size (MM bbl)	2000
API Gravity of oil	34.2
Specific Gravity of water	1.07
Specific Gravity of gas	0.7
Rock compressibility	5.0 * 10^-6
water compressibility	3.0 * 10^-6
Oil viscicity@1200 psi (cp.)	1.164
water viscicity@1200 psi (cp.)	0.70
Bo @ 1200 psi	1.004

The detailed data used in this study can be reviewed from the data files of the simulation run. (CASE_1_INPUT.DATA and CASE_1_INPUT.DATA)

4.3 Model Description

The design of a simulation model will be influenced by the type of process to be modeled and the level of complexity of the process. The process of oil swepting in the drive as occurring in the reservoir can be illustrated by a 2-D areal model. The reservoir can be divided into two regions, the oil zone and the aquifer. The water volume change in the region aquifer is calculated with the production of oil. With no real data provided for this simulation study, a 2000 ft. * 2000 ft reservoir model with single layer is created with an Eclipse 100.

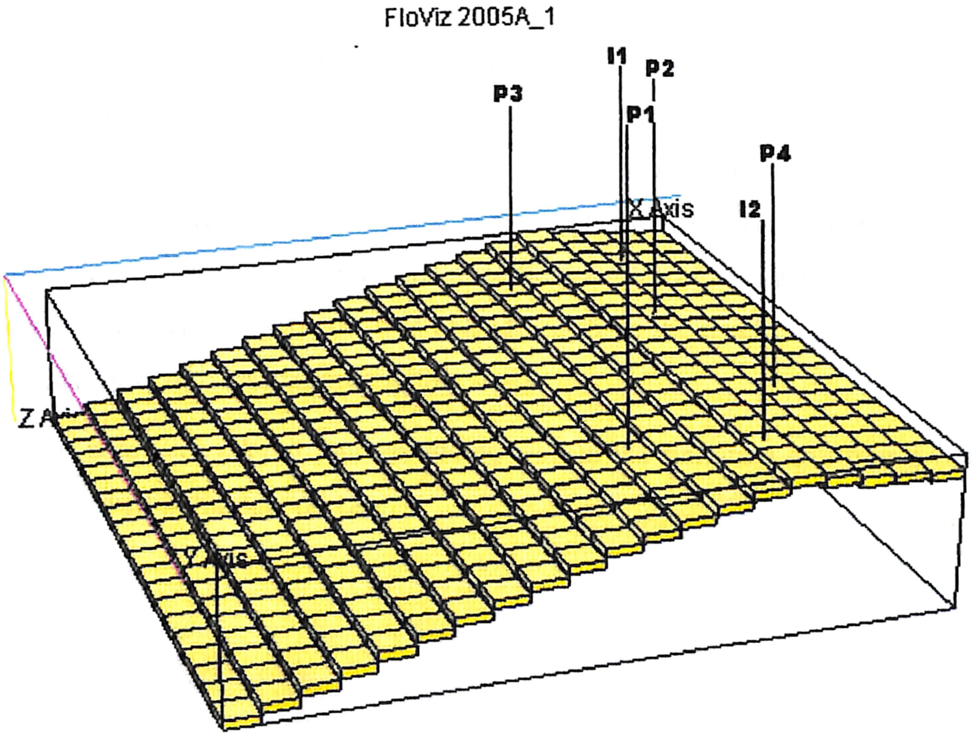


Fig. 05 - **Sketch of Reservoir Model**

simulator. For Case 1 and 2 models, the grids consisted of 40 blocks. The length and the width of the model is 2000 ft divided into 20 grid blocks, which makes the length and width of the single grid block of 1000 ft, and the height of the model is taken to be variable.

4.4 Reservoir Geometry and Properties

In this study, a simple rectangular reservoir model is used. The reservoir length, width and thickness can be varied to different levels for the simulation designs. In this study, the reservoir depth varies from 7500 to 6880 ft., keeping the reservoir thickness variable. The water oil contact was found to be at 7000 ft. and reservoir pressure was measured 3000 psi at a reference depth of 6900 ft. The aquifer selected was fetkovich type connected to reservoir in j+ direction.

The ground surface temperature was set to 60°F and the temperature gradient was set to 1.2°F per 100 feet. The reservoir temperature is 120°F, although this value of reservoir temperature was not required in the simulation.

The porosity was taken as variable in range of 9% to 16%. The irreducible water saturation was set to 20% and the residual oil saturation was set to 25%. The vertical permeability was set to a constant value of 50 md while the horizontal permeabilities Kx and Ky are variable with gridblocks and values are illustrated in the input data file.. The gas and water properties were estimated using PVT data gathered. The specific gravities of oil, water and gas were set to 34.2, 1.07 and 0.7 respectively. The oil was considered to be the dead oil having negligible dissolved gas. Capillary pressure was ignored in this study.

This study considered four producing well in the first case and four producing well with two injection well in the second case.

4.5 Grid Description

Although corner point geometry have excellence in simulation but as this is a preliminary exercise block-centered grid are good enough. This approach will have very less level of complexity, less data requirement and fair amount of reliability of results The thickness of the grid blocks were taken variable varying in range of 35-45 ft approx and NTG ratio was taken as default.

4.6 Simulation Period

The time period of the simulation was taken from Jan 2005 to July 2021. The time period was chosen arbitrarily as it does not have any impact on output produced. The reservoir was expected to be in initial phase having no development done.

CHAPTER 5. SIMULATED RESULTS AND PREDICTIONS

The results were obtained from eclipse -100 for 2 different cases

- CASE 1 – 4 wells producing at constant oil production rate
- CASE 2 – 4 wells producing at constant oil production rate with 2 injection wells with constant water injection rate.

The parameters selected for representing the performance of reservoir are chosen as [7]:

- Total Oil Production (FOPT)
- Total Water Injection (FWIT)
- Field Water Cut (FWCT)
- Avg. Reservoir Pressure (FPR)
- Formation Oil in Place (FOIP)
- Formation Water Saturation (FWSAT)
- Oil Recovery (FOE)
- Total Water production (FWPT)

Also indivisual well parameters such as well BHP, water cut, oil PI are also obtained for the simulation runs for both the cases.

Following results are obtained for the simulation run for both cases.

TABLE. NO. 03 SIMULATED RESULTS FOR CASE-1 IN TABULATED FORM

DATE	FAQT(Average) STB	FOE(Average)	FOIP(Average) STB	FOPT(Avg) STB	FPR(Average) PSIA	FWCT(Average) STB	FWPT(Average) RB	FWPV(Average)	FWSAT(Avg)
JAN 2005	+6.19033e+05	+2.25334e-03	+1.56641e+08	+7.17225e+05	+3.13575e+003	+1.18899e-006	+8.66968e-001	+1.64435e+008	+5.15908e-001
JUL 2005	+1.41400e+06	+6.82178e-03	+1.55923e+08	+1.43445e+06	+3.16464e+003	+1.17633e-006	+1.70919e+000	+1.65248e+008	+5.18332e-001
JAN 2006	+2.08015e+06	+1.13900e-02	+1.55206e+08	+2.15167e+06	+3.15810e+003	+1.36223e-006	+2.71371e+000	+1.65946e+008	+5.20501e-001
JUL 2006	+2.69253e+06	+1.59581e-02	+1.54489e+08	+2.86890e+06	+3.13798e+003	+2.12381e-006	+4.30387e+000	+1.66597e+008	+5.22573e-001
JAN 2007	+3.27849e+06	+2.05263e-02	+1.53772e+08	+3.58612e+06	+3.11128e+003	+3.71429e-006	+7.10515e+000	+1.67225e+008	+5.24600e-001
JUL 2007	+3.85141e+06	+2.50947e-02	+1.53055e+08	+4.30335e+06	+3.08131e+003	+6.71666e-006	+1.21645e+001	+1.67842e+008	+5.26606e-001
JAN 2008	+4.41723e+06	+2.96755e-02	+1.52336e+08	+5.02058e+06	+3.04884e+003	+1.18579e-005	+2.10721e+001	+1.68453e+008	+5.28602e-001
JUL 2008	+4.97587e+06	+3.42562e-02	+1.51616e+08	+5.73780e+06	+3.01420e+003	+1.99315e-005	+3.59718e+001	+1.69057e+008	+5.30585e-001
JAN 2009	+5.52653e+06	+3.88244e-02	+1.50899e+08	+6.45503e+06	+2.97766e+003	+3.18837e-005	+5.97353e+001	+1.69655e+008	+5.32550e-001
JUL 2009	+6.07301e+06	+4.33926e-02	+1.50182e+08	+7.17225e+06	+2.93986e+003	+4.92286e-005	+9.63115e+001	+1.70249e+008	+5.34508e-001
JAN 2010	+6.61842e+06	+4.79608e-02	+1.49465e+08	+7.88948e+06	+2.90175e+003	+7.31661e-005	+1.50523e+002	+1.70842e+008	+5.36467e-001
JUL 2010	+7.16489e+06	+5.25290e-02	+1.48748e+08	+8.60670e+06	+2.86396e+003	+1.06814e-004	+2.29634e+002	+1.71436e+008	+5.38430e-001
JAN 2011	+7.71244e+06	+5.70972e-02	+1.48030e+08	+9.32393e+06	+2.82641e+003	+1.55029e-004	+3.44415e+002	+1.72031e+008	+5.40397e-001
JUL 2011	+8.26102e+06	+6.16654e-02	+1.47313e+08	+1.00412e+07	+2.78904e+003	+3.11657e-004	+5.86411e+002	+1.72628e+008	+5.42367e-001
JAN 2012	+8.81091e+06	+6.62461e-02	+1.46594e+08	+1.07584e+07	+2.75129e+003	+6.91062e-004	+1.10985e+003	+1.73226e+008	+5.44343e-001
JUL 2012	+9.36062e+06	+7.08268e-02	+1.45875e+08	+1.14756e+07	+2.71326e+003	+1.21405e-003	+2.02038e+003	+1.73823e+008	+5.46319e-001
JAN 2013	+9.90887e+06	+7.53950e-02	+1.45158e+08	+1.21928e+07	+2.67506e+003	+2.36197e-003	+3.84127e+003	+1.74419e+008	+5.48291e-001
JUL 2013	+1.04585e+07	+7.99632e-02	+1.44441e+08	+1.29101e+07	+2.63677e+003	+5.28485e-003	+7.92761e+003	+1.75015e+008	+5.50264e-001
JAN 2014	+1.10109e+07	+8.45313e-02	+1.43723e+08	+1.36273e+07	+2.59811e+003	+1.19085e-002	+1.72035e+004	+1.75610e+008	+5.52236e-001
JUL 2014	+1.15683e+07	+8.90994e-02	+1.43006e+08	+1.43445e+07	+2.55833e+003	+2.72944e-002	+3.88297e+004	+1.76203e+008	+5.54204e-001
JAN 2015	+1.21350e+07	+9.36676e-02	+1.42289e+08	+1.50617e+07	+2.51563e+003	+5.62944e-002	+8.41172e+004	+1.76788e+008	+5.56154e-001
JUL 2015	+1.27170e+07	+9.82357e-02	+1.41572e+08	+1.57790e+07	+2.46860e+003	+9.46624e-002	+1.62290e+005	+1.77361e+008	+5.58079e-001
JAN 2016	+1.33217e+07	+1.02816e-01	+1.40853e+08	+1.64962e+07	+2.41705e+003	+1.34028e-001	+2.76633e+005	+1.77923e+008	+5.59982e-001
JUL 2016	+1.39509e+07	+1.07397e-01	+1.40134e+08	+1.72134e+07	+2.36148e+003	+1.71905e-001	+4.28941e+005	+1.78474e+008	+5.61861e-001
JAN 2017	+1.46059e+07	+1.11965e-01	+1.39417e+08	+1.79306e+07	+2.30295e+003	+2.05971e-001	+6.18234e+005	+1.79015e+008	+5.63719e-001
JUL 2017	+1.52902e+07	+1.16532e-01	+1.38699e+08	+1.86479e+07	+2.24227e+003	+2.36109e-001	+8.43056e+005	+1.79550e+008	+5.65565e-001
JAN 2018	+1.60042e+07	+1.21100e-01	+1.37982e+08	+1.93651e+07	+2.17993e+003	+2.63090e-001	+1.10213e+006	+1.80080e+008	+5.67406e-001
JUL 2018	+1.67481e+07	+1.25667e-01	+1.37265e+08	+2.00807e+07	+2.11628e+003	+2.87551e-001	+1.39358e+006	+1.80608e+008	+5.69241e-001
JAN 2019	+1.75159e+07	+1.30178e-01	+1.36557e+08	+2.07793e+07	+2.05500e+003	+3.04581e-001	+1.70144e+006	+1.81134e+008	+5.71069e-001
JUL 2019	+1.82948e+07	+1.34569e-01	+1.35868e+08	+2.14603e+07	+1.99814e+003	+3.20306e-001	+2.02439e+006	+1.81654e+008	+5.72870e-001
JAN 2020	+1.90851e+07	+1.38868e-01	+1.35193e+08	+2.21258e+07	+1.94382e+003	+3.35754e-001	+2.36273e+006	+1.82169e+008	+5.74645e-001
JUL 2020	+1.98839e+07	+1.43071e-01	+1.34533e+08	+2.27764e+07	+1.89168e+003	+3.50682e-001	+2.71610e+006	+1.82674e+008	+5.76389e-001
JAN 2021	+2.06873e+07	+1.47171e-01	+1.33889e+08	+2.34134e+07	+1.84122e+003	+3.64794e-001	+3.08372e+006	+1.83170e+008	+5.78097e-001
JUL 2021	+2.14870e+07	+1.51143e-01	+1.33266e+08	+2.40379e+07	+1.79233e+003	+3.77714e-001	+3.46450e+006	+1.83651e+008	+5.79754e-001

TABLE. NO. 04. SIMULATED RESULTS FOR CASE-2 IN TABULATED FORM

DATE	FAQT(Average) STB	FOE(Average)	FOIP(Average) STB	FOPT(Avg) STB	FPR(Average) PSIA	FWCT(Average)	FWIT(Average) STB	FWPT(Avg) STB	FWSAT (Average)
JAN 2005	+6.01642e+05	+2.25337e-03	+1.56641e+08	+7.17225e+05	+3.15138e+03	+9.85777e-07	+1.27750e+05	+7.03502e-01	5.16E-01
JUL 2005	+1.34459e+06	+6.82190e-03	+1.55923e+08	+1.43445e+06	+3.20347e+03	+6.98535e-07	+2.55500e+05	+1.18516e+00	5.19E-01
JAN 2006	+1.94672e+06	+1.13903e-02	+1.55206e+08	+2.15167e+06	+3.21569e+03	+5.78217e-07	+3.83250e+05	+1.60693e+00	5.21E-01
JUL 2006	+2.48548e+06	+1.59587e-02	+1.54489e+08	+2.86890e+06	+3.21154e+03	+9.52489e-07	+5.11000e+05	+2.32913e+00	5.23E-01
JAN 2007	+2.98905e+06	+2.05269e-02	+1.53772e+08	+3.58612e+06	+3.19821e+03	+1.80817e-06	+6.38750e+05	+3.69907e+00	5.25E-01
JUL 2007	+3.47276e+06	+2.50951e-02	+1.53055e+08	+4.30335e+06	+3.17974e+03	+3.56552e-06	+7.66500e+05	+6.40201e+00	5.27E-01
JAN 2008	+3.94547e+06	+2.96760e-02	+1.52335e+08	+5.02058e+06	+3.15787e+03	+6.53487e-06	+8.94250e+05	+1.13158e+01	5.29E-01
JUL 2008	+4.40933e+06	+3.42568e-02	+1.51616e+08	+5.73780e+06	+3.13349e+03	+1.12215e-05	+1.02200e+06	+1.97257e+01	5.31E-01
JAN 2009	+4.86497e+06	+3.88250e-02	+1.50899e+08	+6.45503e+06	+3.10711e+03	+1.82376e-05	+1.14975e+06	+3.33193e+01	5.33E-01
JUL 2009	+5.31508e+06	+4.33933e-02	+1.50182e+08	+7.17225e+06	+3.07904e+03	+2.82072e-05	+1.27750e+06	+5.42868e+01	5.35E-01
JAN 2010	+5.76110e+06	+4.79615e-02	+1.49465e+08	+7.88948e+06	+3.04971e+03	+4.21983e-05	+1.40525e+06	+8.55598e+01	5.37E-01
JUL 2010	+6.20455e+06	+5.25297e-02	+1.48748e+08	+8.60670e+06	+3.01956e+03	+6.11977e-05	+1.53300e+06	+1.30814e+02	5.40E-01
JAN 2011	+6.64711e+06	+5.70979e-02	+1.48030e+08	+9.32393e+06	+2.98912e+03	+8.65468e-05	+1.66075e+06	+1.94700e+02	5.42E-01
JUL 2011	+7.08922e+06	+6.16661e-02	+1.47313e+08	+1.00412e+07	+2.95849e+03	+1.21101e-04	+1.78850e+06	+2.84084e+02	5.44E-01
JAN 2012	+7.53279e+06	+6.62469e-02	+1.46594e+08	+1.07584e+07	+2.92780e+03	+1.69815e-04	+1.91625e+06	+4.10294e+02	5.46E-01
JUL 2012	+7.97651e+06	+7.08276e-02	+1.45875e+08	+1.14756e+07	+2.89705e+03	+3.55544e-04	+2.04400e+06	+6.84123e+02	5.48E-01
JAN 2013	+8.41891e+06	+7.53959e-02	+1.45158e+08	+1.21928e+07	+2.86620e+03	+6.98257e-04	+2.17175e+06	+1.20937e+03	5.50E-01
JUL 2013	+8.86106e+06	+7.99641e-02	+1.44441e+08	+1.29101e+07	+2.83509e+03	+1.14834e-03	+2.29950e+06	+2.06627e+03	5.52E-01
JAN 2014	+9.30332e+06	+8.45323e-02	+1.43723e+08	+1.36273e+07	+2.80381e+03	+1.92269e-03	+2.42725e+06	+3.53105e+03	5.54E-01
JUL 2014	+9.74619e+06	+8.91005e-02	+1.43006e+08	+1.43445e+07	+2.77230e+03	+3.93764e-03	+2.55500e+06	+6.53424e+03	5.56E-01
JAN 2015	+1.01905e+07	+9.36687e-02	+1.42289e+08	+1.50617e+07	+2.74045e+03	+8.07380e-03	+2.68275e+06	+1.27423e+04	5.58E-01
JUL 2015	+1.06375e+07	+9.82369e-02	+1.41572e+08	+1.57790e+07	+2.70783e+03	+1.68772e-02	+2.81050e+06	+2.59069e+04	5.60E-01
JAN 2016	+1.10913e+07	+1.02818e-01	+1.40853e+08	+1.64962e+07	+2.67338e+03	+3.56037e-02	+2.93825e+06	+5.41205e+04	5.62E-01
JUL 2016	+1.15556e+07	+1.07398e-01	+1.40134e+08	+1.72134e+07	+2.63575e+03	+6.61637e-02	+3.06600e+06	+1.07525e+05	5.64E-01
JAN 2017	+1.20351e+07	+1.11966e-01	+1.39416e+08	+1.79306e+07	+2.59430e+03	+1.02233e-01	+3.19375e+06	+1.92025e+05	5.66E-01
JUL 2017	+1.25353e+07	+1.16534e-01	+1.38699e+08	+1.86479e+07	+2.54939e+03	+1.36767e-01	+3.32150e+06	+3.08581e+05	5.68E-01
JAN 2018	+1.30585e+07	+1.21102e-01	+1.37982e+08	+1.93651e+07	+2.50154e+03	+1.69449e-01	+3.44925e+06	+4.57792e+05	5.69E-01
JUL 2018	+1.36063e+07	+1.25670e-01	+1.37265e+08	+2.00823e+07	+2.45125e+03	+1.99066e-01	+3.57700e+06	+6.38873e+05	5.71E-01
JAN 2019	+1.41797e+07	+1.30238e-01	+1.36548e+08	+2.07995e+07	+2.39932e+03	+2.25634e-01	+3.70475e+06	+8.50517e+05	5.73E-01
JUL 2019	+1.47799e+07	+1.34806e-01	+1.35831e+08	+2.15168e+07	+2.34629e+03	+2.49860e-01	+3.83250e+06	+1.09208e+06	5.75E-01
JAN 2020	+1.54089e+07	+1.39387e-01	+1.35111e+08	+2.22340e+07	+2.29219e+03	+2.72874e-01	+3.96025e+06	+1.36398e+06	5.77E-01
JUL 2020	+1.60664e+07	+1.43966e-01	+1.34393e+08	+2.29496e+07	+2.23725e+03	+2.95501e-01	+4.08800e+06	+1.66674e+06	5.79E-01
JAN 2021	+1.67454e+07	+1.48479e-01	+1.33684e+08	+2.36490e+07	+2.18467e+03	+3.12313e-01	+4.21575e+06	+1.98636e+06	5.81E-01
JUL 2021	+1.74291e+07	+1.52830e-01	+1.33001e+08	+2.43313e+07	+2.13666e+03	+3.28959e-01	+4.34350e+06	+2.32311e+06	5.83E-01

5.1 Total Oil Production (FOPT)

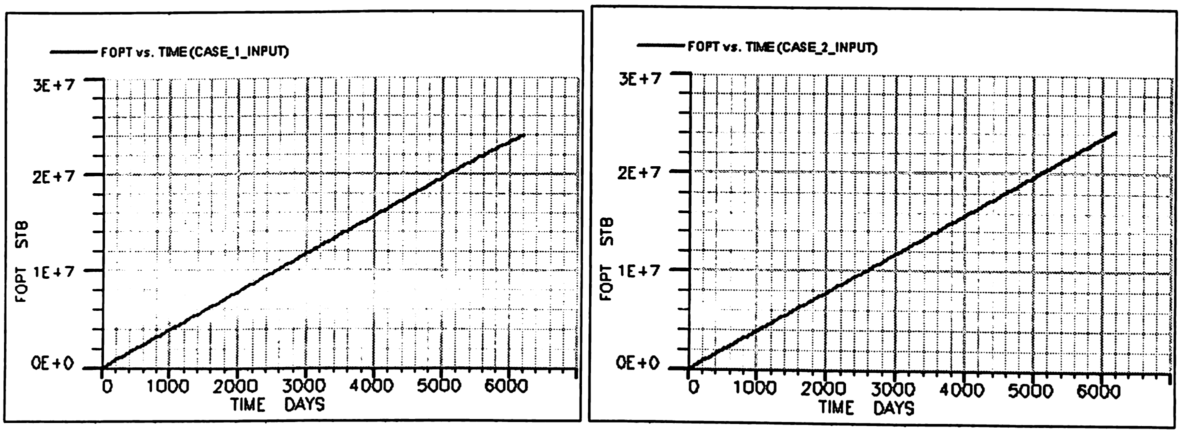


Fig. 06 - FOPT vs. time curve

At the end of july 2021 a oil total production of 24 MM STB was obtained and it increases linearly as oil production rate was kept constant due to supply constraints.

Both cases shows similar results as production constraints were same as in case 1.

5.2 Total Water Injection (FWIT)

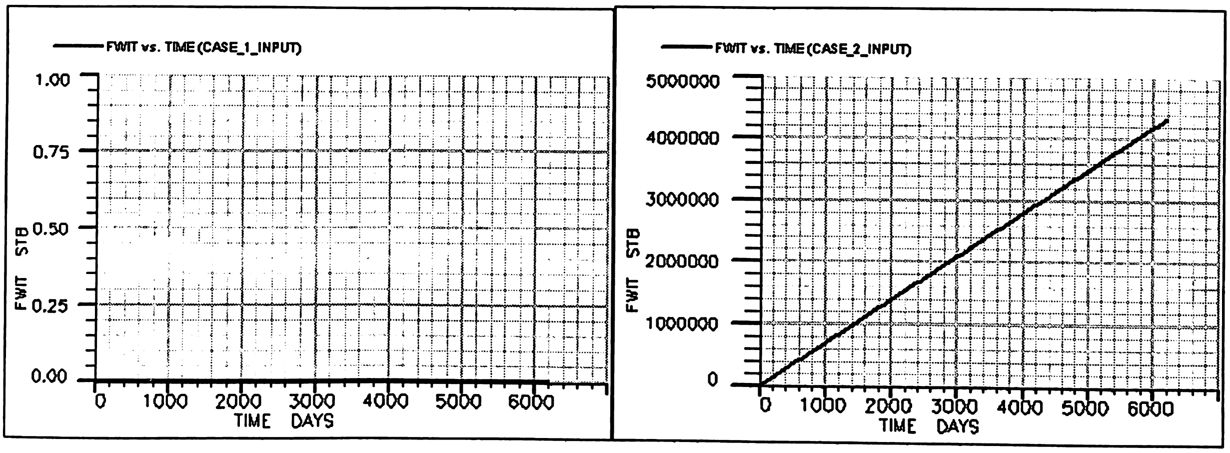


Fig. 07 – FWIT vs. time curve

Case 1 does not contain any water injection so there will be no response in FWIT curve

Whereas in case 2 total water injection increases linearly as injection rate was kept constant at 350 bpd. This injection will not affect total oil production or overall recovery as oil rate target is kept constant but result in maintenance of reservoir pressure which can be shown under FPR curve.

5.3 Field Water Cut (FWCT)

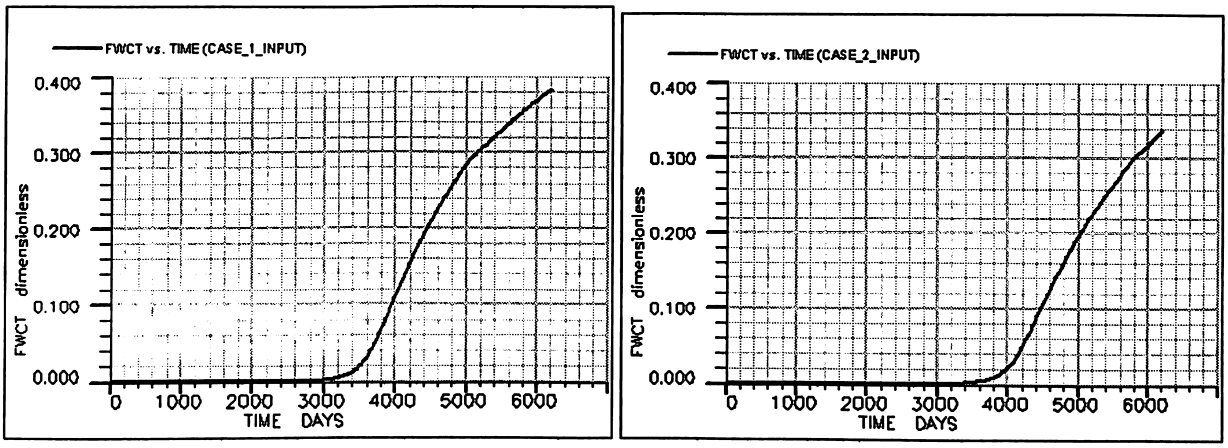


Fig. 08 – FWCT vs. time curve

In case 1 water cut starts early around 3000 days and increases very rapidly to attain a value just above 0.38 in next 3200 days. Such behaviour of water cut may be resulting due to water coning as the well production rate is kept quite high.

While in case 2 water cut starts little late at around 3500 days and increases rapidly to a value of 0.34 at the end of June 2021. The reason behind late water conning may be a result of maintained pressure in the reservoir which is more favorable case then case 1.

5.4 Avg. Reservoir Pressure (FPR)

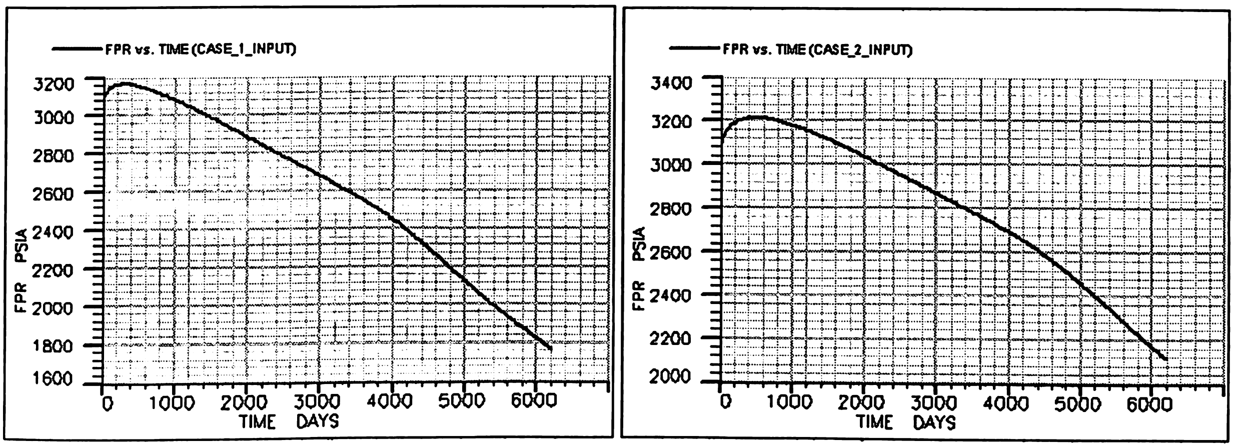


Fig. 09 – FPR vs. time curve

In this section avg. reservoir pressure is discussed which decrease with production life of reservoir and attain a value of 1792 psi at the end Jul 2021.

While in case 2 due to water injection we are able to reduce the depletion of pressure from 1792 to 2136 psi , which will result in longer production life and ultimately increased overall recovery from the field.

5.5 Formation Oil in Place (FOIP)

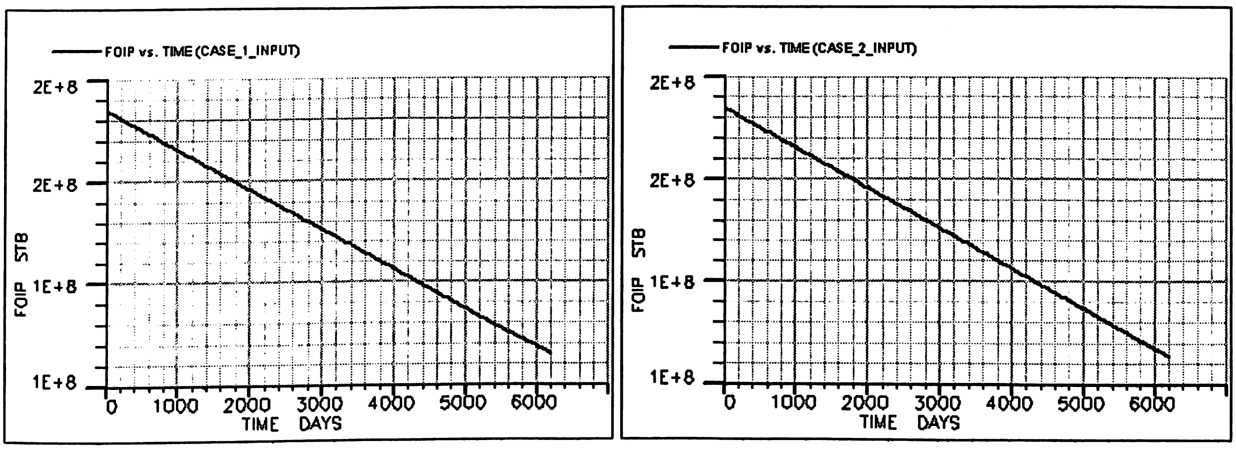


Fig. 10 – FOIP vs. time curve

The formation oil in place does not change as initial FOIP and total oil production from the reservoir is same in both cases. Case 2 may result less FOIP if production constraints for wells is changed from ORAT to BHP or liquid production rate. The remaining FOIP at the end of July 2021 was found to be 133 MM STB.

5.6 Formation Water Saturation (FWSAT)

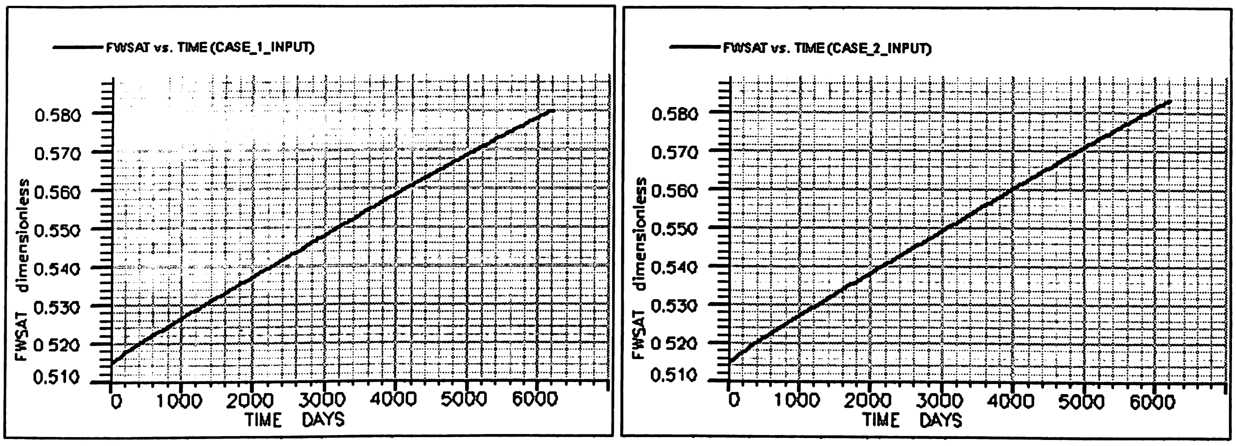


Fig. 11 – FWSAT vs. time curve

The nature of formation water saturation remains same for both cases as exploitation scheme for both cases are same excluding the injection wells. Case 1 results into FWSAT value of 0.579 while case 2 results value as 0.583 for a period upto June 2021.

5.7 Oil Recovery (FOE)

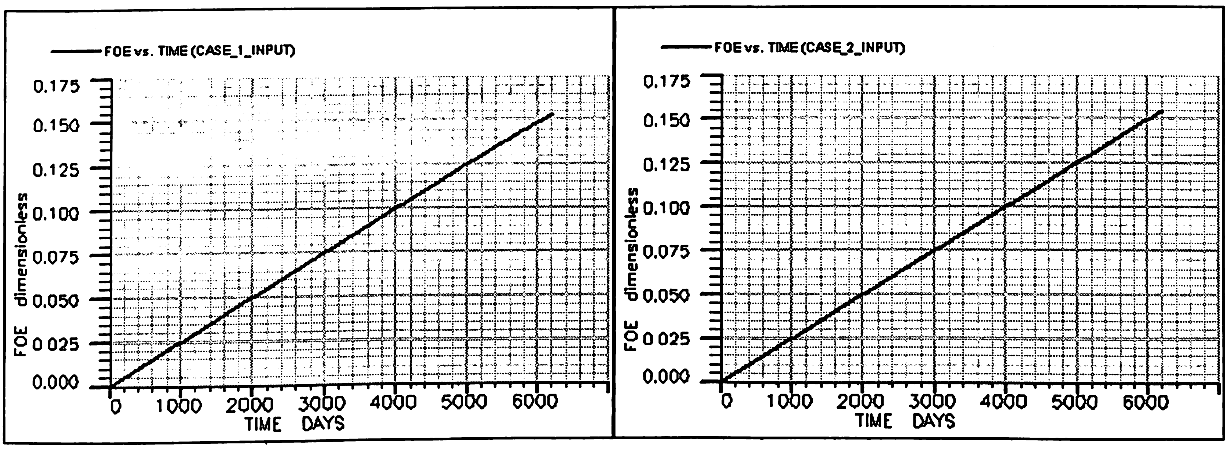


Fig. 12 – FOE vs. time curve

The total oil recovery remains same for both the cases as the initial oil saturation and total oil production from reservoir remains same. The overall oil recovery at the end of July 2021 was found to be just above 15 % and change was found to be linear as exploitation scheme was kept same throughout the production life.

Now similar recovery does not suggests that both cases are same in terms of ultimate recovery as case 2 definitely have larger production life and less residual oil in place and thus more ultimate recovery can be obtained.

5.8 Total Water production (FWPT)

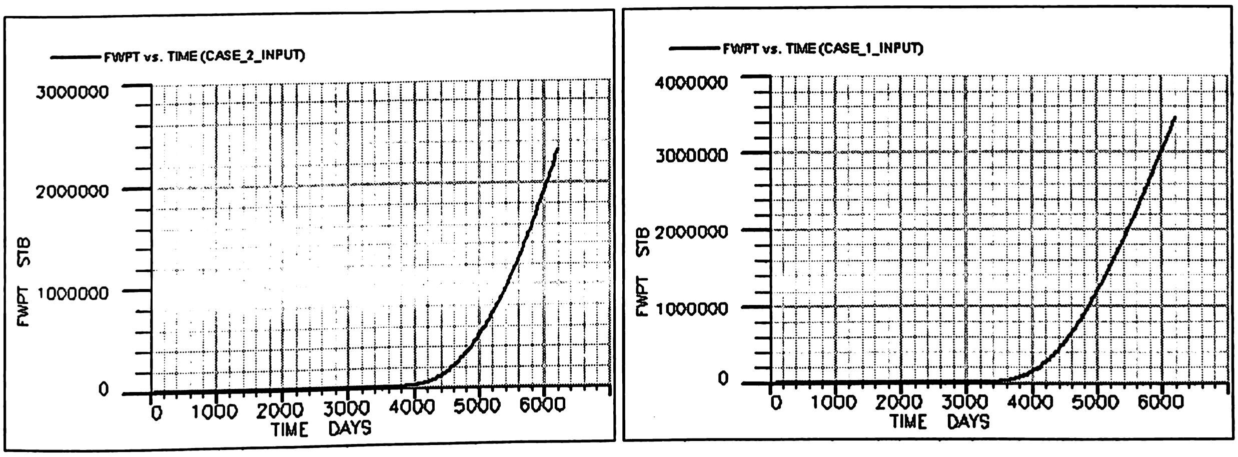


Fig. 13 – FWPT vs. time curve

The water production in case 2 started little early around 3500 days in comparison to case 1 where water production started around 4000 days. Case 2 shows premature and high water production due to presence of water injection wells. At the end of simulation study case 1 results into total water production of 2.3 MM STB and case 2 same was 3.4 MM STB approx. Even though the total water production in case 2 is higher but it shows much stable reservoir pressure and if this excess amount of produced water can be handled case 2 comes as a better exploitation scheme.

CHAPTER 6. - CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The objective of the study was to predict the performance of a model water drive reservoir based on the simulated results in eclipse 100 simulator. The prediction was given on the basis of 2 different cases representing two different exploitation scheme for the same reservoir under similar production constraints. The effort was to generate the simulated data for both cases to predict the favorable case in terms of different performance parameters. On the basis of the simulated results the case-2 found out to be more favorable as it increases the production life of reservoir and thus a higher total recovery can be expected before abandonment of reservoir is done. Also if production rate from field is to be increased it is obvious that it will be more easier and economically profitable in case-2 as it runs on a higher avg. reservoir pressure.

6.2 Recommendations

This being a preliminary exercise and availability of data it was not possible to simulate more practical case where no. of wells and production figures are more realistic. Also if actual set of reservoir data including production data is available and operating license permits history match should be practiced for validating the simulated results. Eclipse simulator provides more in depth reach to the reservoir by means of dynamic modeling, front tracking, flow grid, well test data handling etc. which can be used only after achieving proper license. Along with this same reservoir model can be used to study the water flooding performance only by aligning the wells in appropriate way.

NOMENCLATURE

Bg = gas formation volume factor, Rcf/scf
Bo = oil formation volume factor, RB/STB
Bw = water formation volume factor, RB/STB
h = height, ft
iw = water injected, STB/D
k = permeability, md
L = length, ft
n = number of time steps
N = original oil in place, STB
Np = cumulative oil produced, RB
So = oil saturation, fraction
Sw = water saturation, fraction
Sg = gas saturation, fraction
Soi = initial oil saturation, fraction
Swc = connate water saturation, fraction
Swi = initial water saturation, fraction
tf = time of complete fill up
w = width, ft
Wi = cumulative water injected, RB
Δp = pressure change, fraction
φ = porosity, %
μo = oil viscosity, cp
μw = water viscosity, cp
A = cross sectional area of the aquifer
Pw = inner boundary constant pressure
e_w = water influx rate, B/D,
Ja = aquifer productivity index, B/D-psi,
Pa = average aquifer pressure, psi, and
Pw = pressure at the original WOC, psi.
w = width of the linear aquifer
rD = dimensionless radius, ra/re
t = time, days
θ = encroachment angle
h = thickness of the aquifer
f = θ / 360
Wet = total aquifer expansion capacity, bbl,
Vwj, = initial water volume in the aquifer, bbl,
Pai = initial aquifer pressure, psi, and
Cwt, = total aquifer compressibility, psi -1 .

REFERENCES

1. Craft, B.C. and Hawkins, M.: *Applied Reservoir Engineering,* second edition, Prentice-Hall Inc

2. William E. Brigham, "Water Influx, and Its Effect on Oil Recovery", pg. no. 2- 6

3. Fetkovich. M.J.: "A Simplified Approach to Water lntlux Calculations-Finite Aquifer Systems." *J. Pet. Tech.* (July 1971)

4 Professor Jon Kleppe, Norwegian University of Science and Technology, SIG4042 Reservoir Simulation 2001 Lecture note 2

5. B. S. Grewal, "*Applied Numerical Methods",* S. Chand publication.

6. Anar Etibar Azimov, Thesis on "*Comparative Analysis of remaining oil saturation in waterflood patterns based on analytical modeling and simulation*", Office of Graduate Studies of Texas A&M University.

7. Eclipse reference manual 2001

APPENDIX

1. Simulator Input Data File for Case 1

```
RUNSPEC

TITLE
PERFORMANCE PREDICTION CASE 1

DIMENS
20    20    1     /

OIL

WATER

FIELD

AQUDIMS
0 0 0 0 1 20 /


WELLDIMS
4 1   4 /

START
1 'JAN' 2005 /

UNIFOUT

--

GRID

BOX
1     20    1     20    1     1     /

DXV
20*1000  /

DYV
20*1000 /

DZ
38.2  37.4  36.6  36.0  35.8  36.0  36.6   37.3  38.0  38.5  38.7   38.7  38.6
38.6  37.6  36.7  36.2   36.3  37.0  37.9
39.1  40.1  41.0  41.2  41.1  40.8  38.5   37.5   36.5  35.8  36.4   37.5
38.9  40.4  41.9  43.2  43.4  43.1  42.6  38.1
37.3  36.4  35.8  36.6   38.0  39.5  41.1  42.8   44.3   44.6  44.3   44.0
37.3  37.0  36.6  36.6  37.3  38.4  39.7  41.1
42.5  43.8   44.5 44.8  45.0 36.2  36.6  37.0  37.4   38.1  38.8  39.7   40.6
41.7   42.8  43.8  44.8  45.6  34.8  36.0
```

```
37.1  38.0  38.6  39.0  39.3  39.7 40.4  41.4  42.8  44.4  46.0  32.9   35.1
37.1   38.5   39.1   39.0  38.7  38.6  38.8
39.7  41.4   43.7  46.2  30.6  33.8 36.7 38.7  39.1  38.5  37.8   37.3   37.1
37.7   39.8   42.9   46.0  28.7  32.1   35.3
37.7  38.0   37.3  36.6  36.0  35.7  36.2  38.6  42.0 45.3 27.3   30.1   32.7
34.7   35.4   35.2   34.9   34.8   35.0  36.0
38.2  41.1  44.2   25.8  27.8   29.8   31.3  32.3  32.8  33.1  33.6  34.4
35.7  37.8  40.2  42.7  24.0  25.5  27.0  28.2
38.2  37.4  36.6  36.0  35.8  36.0  36.6   37.3  38.0  38.5  38.7   38.7  38.6
38.6  37.6  36.7  36.2   36.3  37.0  37.9
39.1  40.1  41.0  41.2  41.1  40.8  38.5   37.5   36.5  35.8  36.4   37.5
38.9  40.4  41.9  43.2  43.4  43.1  42.6  38.1
37.3  36.4  35.8  36.6   38.0  39.5  41.1  42.8   44.3   44.6  44.3   44.0
37.3  37.0  36.6  36.6  37.3  38.4  39.7  41.1
42.5  43.8   44.5 44.8  45.0 36.2  36.6  37.0  37.4   38.1  38.8  39.7   40.6
41.7   42.8  43.8  44.8  45.6  34.8  36.0
37.1  38.0  38.6  39.0  39.3  39.7 40.4  41.4  42.8  44.4  46.0  32.9   35.1
37.1   38.5   39.1   39.0  38.7  38.6  38.8
39.7  41.4   43.7  46.2  30.6  33.8 36.7 38.7  39.1  38.5  37.8   37.3   37.1
37.7   39.8   42.9   46.0  28.7  32.1   35.3
37.7  38.0   37.3  36.6  36.0  35.7  36.2  38.6  42.0 45.3 27.3   30.1   32.7
34.7   35.4   35.2   34.9   34.8   35.0  36.0
38.2  41.1  44.2   25.8  27.8   29.8   31.3  32.3  32.8  33.1  33.6  34.4
35.7  37.8  40.2  42.7  24.0  25.5  27.0  28.2
38.2  37.4  36.6  36.0  35.8  36.0  36.6   37.3  38.0  38.5  38.7   38.7  38.6
38.6  37.6  36.7  36.2   36.3  37.0  37.9
39.1  40.1  41.0  41.2  41.1  40.8  38.5   37.5   36.5  35.8  36.4   37.5
38.9  40.4  41.9  43.2  43.4  43.1  42.6  38.1
37.3  36.4  35.8  36.6   38.0  39.5  41.1  42.8   44.3   44.6  44.3   44.0
37.3  37.0  36.6  36.6  37.3  38.4  39.7  41.1
42.5  43.8   44.5 44.8  45.0 36.2  36.6  37.0  37.4   38.1  38.8  39.7   40.6
41.7   42.8  43.8  44.8  45.6  34.8  36.0

/

PORO

0.16 0.14 0.12 0.1 0.08 0.09 0.1 0.11 0.12 0.13 0.16 0.14 0.12 0.1 0.08 0.09
0.1 0.11 0.12 0.13
0.16 0.14 0.12 0.1 0.09 0.09 0.1 0.11 0.12 0.13 0.16 0.14 0.12 0.1 0.09 0.09
0.1 0.11 0.12 0.13
0.15 0.14 0.12 0.1 0.10 0.09 0.1 0.11 0.12 0.13 0.15 0.14 0.12 0.1 0.10 0.09
0.1 0.11 0.12 0.13
0.15 0.14 0.12 0.1 0.10 0.09 0.1 0.11 0.12 0.13 0.15 0.14 0.12 0.1 0.10 0.09
0.1 0.11 0.12 0.13
0.14 0.14 0.12 0.1 0.09 0.09 0.1 0.11 0.12 0.13 0.14 0.14 0.12 0.1 0.09 0.09
0.1 0.11 0.12 0.13
0.14 0.14 0.12 0.1 0.08 0.09 0.1 0.11 0.12 0.13 0.14 0.14 0.12 0.1 0.08 0.09
0.1 0.11 0.12 0.13
0.16 0.14 0.12 0.1 0.08 0.09 0.1 0.11 0.12 0.13 0.16 0.14 0.12 0.1 0.08 0.09
0.1 0.11 0.12 0.13
0.16 0.14 0.12 0.1 0.09 0.09 0.1 0.11 0.12 0.13 0.16 0.14 0.12 0.1 0.09 0.09
0.1 0.11 0.12 0.13
0.15 0.14 0.12 0.1 0.10 0.09 0.1 0.11 0.12 0.13 .15 0.14 0.12 0.1 0.10 0.09
0.1 0.11 0.12 0.13
0.15 0.14 0.12 0.1 0.10 0.09 0.1 0.11 0.12 0.13 0.15 0.14 0.12 0.1 0.10 0.09
0.1 0.11 0.12 0.13
0.16 0.14 0.12 0.1 0.08 0.09 0.1 0.11 0.12 0.13 0.16 0.14 0.12 0.1 0.08 0.09
0.1 0.11 0.12 0.13
0.16 0.14 0.12 0.1 0.09 0.09 0.1 0.11 0.12 0.13 0.16 0.14 0.12 0.1 0.09 0.09
0.1 0.11 0.12 0.13
```

```
0.15 0.14 0.12 0.1 0.10 0.09 0.1 0.11 0.12 0.13 0.15 0.14 0.12 0.1 0.10 0.09
0.1 0.11 0.12 0.13
0.15 0.14 0.12 0.1 0.10 0.09 0.1 0.11 0.12 0.13 0.15 0.14 0.12 0.1 0.10 0.09
0.1 0.11 0.12 0.13
0.14 0.14 0.12 0.1 0.09 0.09 0.1 0.11 0.12 0.13 0.14 0.14 0.12 0.1 0.09 0.09
0.1 0.11 0.12 0.13
0.14 0.14 0.12 0.1 0.08 0.09 0.1 0.11 0.12 0.13 0.14 0.14 0.12 0.1 0.08 0.09
0.1 0.11 0.12 0.13
0.16 0.14 0.12 0.1 0.08 0.09 0.1 0.11 0.12 0.13 0.16 0.14 0.12 0.1 0.08 0.09
0.1 0.11 0.12 0.13
0.16 0.14 0.12 0.1 0.09 0.09 0.1 0.11 0.12 0.13 0.16 0.14 0.12 0.1 0.09 0.09
0.1 0.11 0.12 0.13
0.15 0.14 0.12 0.1 0.10 0.09 0.1 0.11 0.12 0.13 .15 0.14 0.12 0.1 0.10 0.09
0.1 0.11 0.12 0.13
0.15 0.14 0.12 0.1 0.10 0.09 0.1 0.11 0.12 0.13 0.15 0.14 0.12 0.1 0.10 0.09
0.1 0.11 0.12 0.13
/

PERMX

250 250 8*260 3*240 4*260 2*180 246
240 250 8*260 3*250 4*234 2*168 247
230 250 8*265 3*240 4*242 2*175 249
220 250 8*270 3*255 4*260 2*177 257
210 250 8*275 3*240 4*232 2*164 252
200 250 8*275 3*234 4*235 2*158 256
190 250 8*260 3*247 4*244 2*174 233
180 250 8*260 3*254 4*254 2*186 233
160 250 8*275 3*270 4*260 2*169 262
150 250 8*275 3*230 4*250 2*180 246
250 250 8*260 3*240 4*260 2*180 246
240 250 8*260 3*250 4*234 2*168 247
230 250 8*265 3*240 4*242 2*175 249
220 250 8*270 3*255 4*260 2*177 257
210 250 8*275 3*240 4*232 2*164 252
200 250 8*275 3*234 4*235 2*158 256
190 250 8*260 3*247 4*244 2*174 233
80  150 8*60  3*54  4*154 2*86  33
60  150 8*75  3*70  4*160 2*69  62
50  150 8*75  3*30  4*150 2*80  46
/

PERMY

150 150 8*160 3*140 4*160 2*180 146
140 150 8*160 3*150 4*134 2*168 147
130 150 8*165 3*140 4*142 2*175 149
120 150 8*170 3*155 4*160 2*177 157
110 150 8*175 3*140 4*132 2*164 152
100 150 8*175 3*134 4*135 2*158 156
150  150 8*160 3*147 4*144 2*174 133
180  150 8*160 3*154 4*154 2*186 133
160  150 8*175 3*170 4*160 2*169 162
150  150 8*175 3*130 4*150 2*180 146
150 150 8*160 3*140 4*160 2*180 146
140 150 8*160 3*150 4*134 2*168 147
130 150 8*165 3*140 4*142 2*175 149
120 150 8*170 3*155 4*160 2*177 157
110 150 8*175 3*140 4*132 2*164 152
100 150 8*175 3*134 4*135 2*158 156
90  150 8*160 3*147 4*144 2*174 133
```

```
120  150 8*160 3*154 4*154 2*186 133
130  150 8*175 3*170 4*160 2*169 162
150  150 8*175 3*130 4*150 2*180 146
/
PERMZ

400*50 /

ENDBOX



TOPS

7500 7450 7400 7350 7300 7250 7200 7150 7100 7050 7000 6960 6920 6880 6840
6800 6825 6850 6865 6880
7500 7450 7400 7350 7300 7250 7200 7150 7100 7050 7000 6960 6920 6880 6840
6800 6825 6850 6865 6880
7500 7450 7400 7350 7300 7250 7200 7150 7100 7050 7000 6960 6920 6880 6840
6800 6825 6850 6865 6880
7500 7450 7400 7350 7300 7250 7200 7150 7100 7050 7000 6960 6920 6880 6840
6800 6825 6850 6865 6880
7500 7450 7400 7350 7300 7250 7200 7150 7100 7050 7000 6960 6920 6880 6840
6800 6825 6850 6865 6880
7500 7450 7400 7350 7300 7250 7200 7150 7100 7050 7000 6960 6920 6880 6840
6800 6825 6850 6865 6880
7500 7450 7400 7350 7300 7250 7200 7150 7100 7050 7000 6960 6920 6880 6840
6800 6825 6850 6865 6880
7500 7450 7400 7350 7300 7250 7200 7150 7100 7050 7000 6960 6920 6880 6840
6800 6825 6850 6865 6880
7500 7450 7400 7350 7300 7250 7200 7150 7100 7050 7000 6960 6920 6880 6840
6800 6825 6850 6865 6880
7500 7450 7400 7350 7300 7250 7200 7150 7100 7050 7000 6960 6920 6880 6840
6800 6825 6850 6865 6880
7500 7450 7400 7350 7300 7250 7200 7150 7100 7050 7000 6960 6920 6880 6840
6800 6825 6850 6865 6880
7500 7450 7400 7350 7300 7250 7200 7150 7100 7050 7000 6960 6920 6880 6840
6800 6825 6850 6865 6880
7500 7450 7400 7350 7300 7250 7200 7150 7100 7050 7000 6960 6920 6880 6840
6800 6825 6850 6865 6880
7500 7450 7400 7350 7300 7250 7200 7150 7100 7050 7000 6960 6920 6880 6840
6800 6825 6850 6865 6880
7500 7450 7400 7350 7300 7250 7200 7150 7100 7050 7000 6960 6920 6880 6840
6800 6825 6850 6865 6880
7500 7450 7400 7350 7300 7250 7200 7150 7100 7050 7000 6960 6920 6880 6840
6800 6825 6850 6865 6880
7500 7450 7400 7350 7300 7250 7200 7150 7100 7050 7000 6960 6920 6880 6840
6800 6825 6850 6865 6880
7500 7450 7400 7350 7300 7250 7200 7150 7100 7050 7000 6960 6920 6880 6840
6800 6825 6850 6865 6880
7500 7450 7400 7350 7300 7250 7200 7150 7100 7050 7000 6960 6920 6880 6840
6800 6825 6850 6865 6880
7500 7450 7400 7350 7300 7250 7200 7150 7100 7050 7000 6960 6920 6880 6840
6800 6825 6850 6865 6880

/

INIT

__*********************************************

EDIT
```

```
--******************************************
PROPS

SWOF
-- Sw krw kro Pcow
0.20 0.000000 0.900000 0
0.25 0.000364 0.709187 0
0.30 0.002536 0.544963 0
0.35 0.007892 0.405962 0
0.40 0.017660 0.290741 0
0.45 0.032987 0.197760 0
0.50 0.054960 0.125368 0
0.55 0.084625 0.071765 0
0.60 0.122991 0.034959 0
0.65 0.171041 0.012686 0
0.70 0.229732 0.002243 0
0.75 0.300000 0.000000 0
/

-- Specifies PVT properties of OIL
PVDO
400  1.012  1.16
1200 1.0040 1.164
2000 0.9960 1.167
2800 0.9880 1.172
3600 0.9802 1.177
4400 0.9724 1.181
5200 0.9646 1.185
5600 0.9607 1.19
/

PVTW
1025  1.06  3.03E-06  .7  0.0 /

GRAVITY
34.2 1.07 0.7  /

ROCK
525.0       5.0E-06 /

--******************************************
REGIONS

--******************************************
SOLUTION

EQUIL
6900  3000  6900  0    4*    0     /



AQUFETP
1 7400.0 4000.0 2.0E9 1.0E-5 50.0 1 /


AQUANCON
-- Aquifer 1
1 10 20 20 20 1 1 'J+' /

/
```

```
--*********************************************
SUMMARY



-- Average pressure for field.
FPR

-- Oil production total
FOPT

-- Water injection total of field
FWIT

--Water cut
FWCT

--WELL BHP
WBHP
P1 P2 P3 P4/

--OIL PI
WPIO
P1 P2 P3 P4/

--WELL PR
WWPR
P1 P2 P3 P4/

--WELL WATER CUT
WWCT
P1 P2 P3 P4 /

--OIL IN PLACE
FOIP

-- FORMATION WATER SATURATION
FWSAT

--Water Reservoir Volume in Place
FWIPR

--Fraction of total oil produced by water influx
FORFW

--FORM OIL PORE VOL
FOPV

--FORM WATER PORE VOL
FWPV

--OIL RECOVERY
FOE

--CUMM AQUIFER INFLUX
FAQT

--Water production
FWPT

EXCEL
```

```
--*******************************************
SCHEDULE

WELSPECS
P1 G1   13   5  6940       OIL   0     1* STOP /
P2 G2   17   14 6840       OIL   0     1* STOP /
P3 G3   14   17 6900       OIL   0     1* STOP /
P4 G4   18   7  6870       OIL   0     1* STOP /
/

COMPDAT
P1     13     5      1 1 OPEN    0     0.0    0.40   0 /
P2     17     14     1 1 OPEN    0     0.0    0.40   0 /
P3     14     17     1 1 OPEN    0     0.0    0.40   0 /
P4     18     7      1 1 OPEN    0     0.0    0.40   0 /
/

WCONPROD
P1     OPEN   ORAT   850    /
P2     OPEN   ORAT   1080   /
P3     OPEN   ORAT   950    /
P4     OPEN   ORAT   1050   /

/


TSTEP
31     28     31     30     31     30     31     31     30     31     30     31
31     28     31     30     31     30     31     31     30     31     30     31
31     28     31     30     31     30     31     31     30     31     30     31
31     28     31     30     31     30     31     31     30     31     30     31
31     28     31     30     31     30     31     31     30     31     30     31
31     28     31     30     31     30     31     31     30     31     30     31
31     28     31     30     31     30     31     31     30     31     30     31
31     28     31     30     31     30     31     31     30     31     30     31
31     28     31     30     31     30     31     31     30     31     30     31
31     28     31     30     31     30     31     31     30     31     30     31
31     28     31     30     31     30     31     31     30     31     30     31
31     28     31     30     31     30     31     31     30     31     30     31
31     28     31     30     31     30     31     31     30     31     30     31
31     28     31     30     31     30     31     31     30     31     30     31
31     28     31     30     31     30     31     31     30     31     30     31
31     28     31     30     31     30     31     31     30     31     30     31
31     28     31     30     31     30     31     31     30     31     30     31
/

END
```

2. Simulator Input Data File for Case 2

```
RUNSPEC

TITLE
PERFORMANCE PREDICTION CASE 1

DIMENS
20    20    1     /

OIL

WATER

FIELD

AQUDIMS
0 0 0 0 1 20 /


WELLDIMS
6 1   6 /

START
1 'JAN' 2005 /

UNIFOUT

--

GRID

BOX
1     20    1     20    1     1     /

DXV
20*1000  /

DYV
20*1000 /

DZ
38.2  37.4  36.6  36.0  35.8  36.0  36.6   37.3  38.0  38.5  38.7   38.7  38.6
38.6  37.6  36.7  36.2   36.3  37.0  37.9
39.1  40.1  41.0  41.2  41.1  40.8  38.5   37.5   36.5  35.8  36.4   37.5
38.9  40.4  41.9  43.2  43.4  43.1  42.6  38.1
37.3  36.4  35.8  36.6   38.0  39.5  41.1  42.8   44.3   44.6  44.3   44.0
37.3  37.0  36.6  36.6  37.3  38.4  39.7  41.1
42.5  43.8   44.5 44.8  45.0 36.2  36.6  37.0  37.4   38.1  38.8  39.7   40.6
41.7   42.8  43.8  44.8  45.6  34.8  36.0
37.1  38.0  38.6  39.0  39.3  39.7 40.4  41.4  42.8  44.4  46.0  32.9   35.1
37.1   38.5   39.1   39.0  38.7  38.6  38.8
39.7  41.4   43.7  46.2  30.6  33.8 36.7 38.7  39.1  38.5  37.8   37.3   37.1
37.7   39.8   42.9   46.0  28.7  32.1   35.3
```

```
37.7  38.0   37.3  36.6  36.0  35.7  36.2  38.6  42.0 45.3 27.3   30.1   32.7
34.7   35.4   35.2   34.9   34.8   35.0  36.0
38.2  41.1  44.2   25.8  27.8   29.8   31.3  32.3  32.8  33.1  33.6  34.4
35.7  37.8  40.2  42.7  24.0  25.5  27.0  28.2
38.2  37.4  36.6  36.0  35.8  36.0  36.6   37.3  38.0  38.5  38.7   38.7  38.6
38.6  37.6  36.7  36.2   36.3  37.0  37.9
39.1  40.1  41.0  41.2  41.1  40.8  38.5   37.5   36.5  35.8  36.4   37.5
38.9  40.4  41.9  43.2  43.4  43.1  42.6  38.1
37.3  36.4  35.8  36.6   38.0  39.5  41.1  42.8   44.3   44.6  44.3   44.0
37.3  37.0  36.6  36.6  37.3  38.4  39.7  41.1
42.5  43.8   44.5 44.8  45.0 36.2  36.6  37.0  37.4   38.1  38.8  39.7   40.6
41.7   42.8  43.8  44.8  45.6  34.8  36.0
37.1  38.0  38.6  39.0  39.3  39.7 40.4  41.4  42.8  44.4  46.0  32.9   35.1
37.1   38.5   39.1   39.0  38.7  38.6  38.8
39.7  41.4   43.7  46.2  30.6  33.8 36.7 38.7  39.1  38.5  37.8   37.3   37.1
37.7   39.8   42.9   46.0  28.7  32.1   35.3
37.7  38.0   37.3  36.6  36.0  35.7  36.2  38.6  42.0 45.3 27.3   30.1   32.7
34.7   35.4   35.2   34.9   34.8   35.0  36.0
38.2  41.1  44.2   25.8  27.8   29.8   31.3  32.3  32.8  33.1  33.6  34.4
35.7  37.8  40.2  42.7  24.0  25.5  27.0  28.2
38.2  37.4  36.6  36.0  35.8  36.0  36.6   37.3  38.0  38.5  38.7   38.7  38.6
38.6  37.6  36.7  36.2   36.3  37.0  37.9
39.1  40.1  41.0  41.2  41.1  40.8  38.5   37.5   36.5  35.8  36.4   37.5
38.9  40.4  41.9  43.2  43.4  43.1  42.6  38.1
37.3  36.4  35.8  36.6   38.0  39.5  41.1  42.8   44.3   44.6  44.3   44.0
37.3  37.0  36.6  36.6  37.3  38.4  39.7  41.1
42.5  43.8   44.5 44.8  45.0 36.2  36.6  37.0  37.4   38.1  38.8  39.7   40.6
41.7   42.8  43.8  44.8  45.6  34.8  36.0

/

PORO

0.16 0.14 0.12 0.1  0.08 0.09 0.1 0.11 0.12 0.13 0.16 0.14 0.12 0.1 0.08 0.09
0.1 0.11 0.12 0.13
0.16 0.14 0.12 0.1  0.09 0.09 0.1 0.11 0.12 0.13 0.16 0.14 0.12 0.1 0.09 0.09
0.1 0.11 0.12 0.13
0.15 0.14 0.12 0.1  0.10 0.09 0.1 0.11 0.12 0.13 0.15 0.14 0.12 0.1 0.10 0.09
0.1 0.11 0.12 0.13
0.15 0.14 0.12 0.1  0.10 0.09 0.1 0.11 0.12 0.13 0.15 0.14 0.12 0.1 0.10 0.09
0.1 0.11 0.12 0.13
0.14 0.14 0.12 0.1  0.09 0.09 0.1 0.11 0.12 0.13 0.14 0.14 0.12 0.1 0.09 0.09
0.1 0.11 0.12 0.13
0.14 0.14 0.12 0.1  0.08 0.09 0.1 0.11 0.12 0.13 0.14 0.14 0.12 0.1 0.08 0.09
0.1 0.11 0.12 0.13
0.16 0.14 0.12 0.1  0.08 0.09 0.1 0.11 0.12 0.13 0.16 0.14 0.12 0.1 0.08 0.09
0.1 0.11 0.12 0.13
0.16 0.14 0.12 0.1  0.09 0.09 0.1 0.11 0.12 0.13 0.16 0.14 0.12 0.1 0.09 0.09
0.1 0.11 0.12 0.13
0.15 0.14 0.12 0.1  0.10 0.09 0.1 0.11 0.12 0.13 .15 0.14 0.12 0.1 0.10 0.09
0.1 0.11 0.12 0.13
0.15 0.14 0.12 0.1  0.10 0.09 0.1 0.11 0.12 0.13 0.15 0.14 0.12 0.1 0.10 0.09
0.1 0.11 0.12 0.13
0.16 0.14 0.12 0.1  0.08 0.09 0.1 0.11 0.12 0.13 0.16 0.14 0.12 0.1 0.08 0.09
0.1 0.11 0.12 0.13
0.16 0.14 0.12 0.1  0.09 0.09 0.1 0.11 0.12 0.13 0.16 0.14 0.12 0.1 0.09 0.09
0.1 0.11 0.12 0.13
0.15 0.14 0.12 0.1  0.10 0.09 0.1 0.11 0.12 0.13 0.15 0.14 0.12 0.1 0.10 0.09
0.1 0.11 0.12 0.13
0.15 0.14 0.12 0.1  0.10 0.09 0.1 0.11 0.12 0.13 0.15 0.14 0.12 0.1 0.10 0.09
0.1 0.11 0.12 0.13
```

```
0.14 0.14 0.12 0.1 0.09 0.09 0.1 0.11 0.12 0.13 0.14 0.14 0.12 0.1 0.09 0.09
0.1 0.11 0.12 0.13
0.14 0.14 0.12 0.1 0.08 0.09 0.1 0.11 0.12 0.13 0.14 0.14 0.12 0.1 0.08 0.09
0.1 0.11 0.12 0.13
0.16 0.14 0.12 0.1 0.08 0.09 0.1 0.11 0.12 0.13 0.16 0.14 0.12 0.1 0.08 0.09
0.1 0.11 0.12 0.13
0.16 0.14 0.12 0.1 0.09 0.09 0.1 0.11 0.12 0.13 0.16 0.14 0.12 0.1 0.09 0.09
0.1 0.11 0.12 0.13
0.15 0.14 0.12 0.1 0.10 0.09 0.1 0.11 0.12 0.13 .15 0.14 0.12 0.1 0.10 0.09
0.1 0.11 0.12 0.13
0.15 0.14 0.12 0.1 0.10 0.09 0.1 0.11 0.12 0.13 0.15 0.14 0.12 0.1 0.10 0.09
0.1 0.11 0.12 0.13
/

PERMX

250 250 8*260 3*240 4*260 2*180 246
240 250 8*260 3*250 4*234 2*168 247
230 250 8*265 3*240 4*242 2*175 249
220 250 8*270 3*255 4*260 2*177 257
210 250 8*275 3*240 4*232 2*164 252
200 250 8*275 3*234 4*235 2*158 256
190  250 8*260 3*247 4*244 2*174 233
180  250 8*260 3*254 4*254 2*186 233
160  250 8*275 3*270 4*260 2*169 262
150  250 8*275 3*230 4*250 2*180 246
250 250 8*260 3*240 4*260 2*180 246
240 250 8*260 3*250 4*234 2*168 247
230 250 8*265 3*240 4*242 2*175 249
220 250 8*270 3*255 4*260 2*177 257
210 250 8*275 3*240 4*232 2*164 252
200 250 8*275 3*234 4*235 2*158 256
190  250 8*260 3*247 4*244 2*174 233
80  150 8*60 3*54 4*154 2*86 33
60  150 8*75 3*70 4*160 2*69 62
50  150 8*75 3*30 4*150 2*80 46
/

PERMY

150 150 8*160 3*140 4*160 2*180 146
140 150 8*160 3*150 4*134 2*168 147
130 150 8*165 3*140 4*142 2*175 149
120 150 8*170 3*155 4*160 2*177 157
110 150 8*175 3*140 4*132 2*164 152
100 150 8*175 3*134 4*135 2*158 156
150  150 8*160 3*147 4*144 2*174 133
180  150 8*160 3*154 4*154 2*186 133
160  150 8*175 3*170 4*160 2*169 162
150  150 8*175 3*130 4*150 2*180 146
150 150 8*160 3*140 4*160 2*180 146
140 150 8*160 3*150 4*134 2*168 147
130 150 8*165 3*140 4*142 2*175 149
120 150 8*170 3*155 4*160 2*177 157
110 150 8*175 3*140 4*132 2*164 152
100 150 8*175 3*134 4*135 2*158 156
90  150 8*160 3*147 4*144 2*174 133
120  150 8*160 3*154 4*154 2*186 133
130  150 8*175 3*170 4*160 2*169 162
150  150 8*175 3*130 4*150 2*180 146
/
```

```
PERMZ

400*50 /

ENDBOX



TOPS

7500 7450 7400 7350 7300 7250 7200 7150 7100 7050 7000 6960 6920 6880 6840
6800 6825 6850 6865 6880
7500 7450 7400 7350 7300 7250 7200 7150 7100 7050 7000 6960 6920 6880 6840
6800 6825 6850 6865 6880
7500 7450 7400 7350 7300 7250 7200 7150 7100 7050 7000 6960 6920 6880 6840
6800 6825 6850 6865 6880
7500 7450 7400 7350 7300 7250 7200 7150 7100 7050 7000 6960 6920 6880 6840
6800 6825 6850 6865 6880
7500 7450 7400 7350 7300 7250 7200 7150 7100 7050 7000 6960 6920 6880 6840
6800 6825 6850 6865 6880
7500 7450 7400 7350 7300 7250 7200 7150 7100 7050 7000 6960 6920 6880 6840
6800 6825 6850 6865 6880
7500 7450 7400 7350 7300 7250 7200 7150 7100 7050 7000 6960 6920 6880 6840
6800 6825 6850 6865 6880
7500 7450 7400 7350 7300 7250 7200 7150 7100 7050 7000 6960 6920 6880 6840
6800 6825 6850 6865 6880
7500 7450 7400 7350 7300 7250 7200 7150 7100 7050 7000 6960 6920 6880 6840
6800 6825 6850 6865 6880
7500 7450 7400 7350 7300 7250 7200 7150 7100 7050 7000 6960 6920 6880 6840
6800 6825 6850 6865 6880
7500 7450 7400 7350 7300 7250 7200 7150 7100 7050 7000 6960 6920 6880 6840
6800 6825 6850 6865 6880
7500 7450 7400 7350 7300 7250 7200 7150 7100 7050 7000 6960 6920 6880 6840
6800 6825 6850 6865 6880
7500 7450 7400 7350 7300 7250 7200 7150 7100 7050 7000 6960 6920 6880 6840
6800 6825 6850 6865 6880
7500 7450 7400 7350 7300 7250 7200 7150 7100 7050 7000 6960 6920 6880 6840
6800 6825 6850 6865 6880
7500 7450 7400 7350 7300 7250 7200 7150 7100 7050 7000 6960 6920 6880 6840
6800 6825 6850 6865 6880
7500 7450 7400 7350 7300 7250 7200 7150 7100 7050 7000 6960 6920 6880 6840
6800 6825 6850 6865 6880
7500 7450 7400 7350 7300 7250 7200 7150 7100 7050 7000 6960 6920 6880 6840
6800 6825 6850 6865 6880
7500 7450 7400 7350 7300 7250 7200 7150 7100 7050 7000 6960 6920 6880 6840
6800 6825 6850 6865 6880
7500 7450 7400 7350 7300 7250 7200 7150 7100 7050 7000 6960 6920 6880 6840
6800 6825 6850 6865 6880
7500 7450 7400 7350 7300 7250 7200 7150 7100 7050 7000 6960 6920 6880 6840
6800 6825 6850 6865 6880

/

INIT

--********************************************
EDIT

--********************************************
PROPS
```

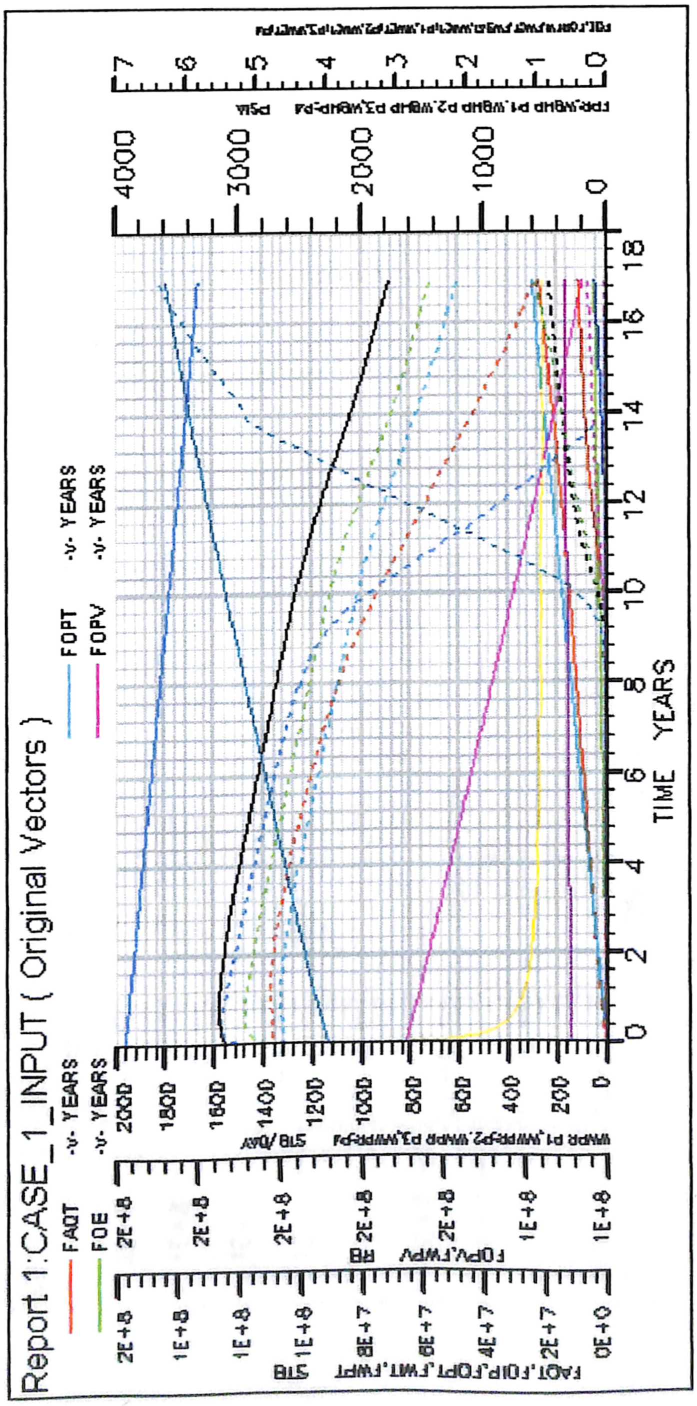
```
SWOF
-- Sw krw kro Pcow
0.20 0.000000 0.900000 0
0.25 0.000364 0.709187 0
0.30 0.002536 0.544963 0
0.35 0.007892 0.405962 0
0.40 0.017660 0.290741 0
0.45 0.032987 0.197760 0
0.50 0.054960 0.125368 0
0.55 0.084625 0.071765 0
0.60 0.122991 0.034959 0
0.65 0.171041 0.012686 0
0.70 0.229732 0.002243 0
0.75 0.300000 0.000000 0
/

-- Specifies PVT properties of OIL
PVDO
400  1.012  1.16
1200 1.0040 1.164
2000 0.9960 1.167
2800 0.9880 1.172
3600 0.9802 1.177
4400 0.9724 1.181
5200 0.9646 1.185
5600 0.9607 1.19
/

PVTW
1025  1.06  3.03E-06  .7  0.0 /

GRAVITY
34.2 1.07 0.7  /

ROCK
525.0       5.0E-06 /

--*******************************************
REGIONS

--*******************************************
SOLUTION

EQUIL
6900  3000  6900  0     4*    0     /



AQUFETP
1 7400.0 4000.0 2.0E9 1.0E-5 50.0 1 /


AQUANCON
-- Aquifer 1
1 10 20 20 20 1 1 'J+' /

/
--*******************************************
SUMMARY
```

```
-- Average pressure for field.
FPR

-- Oil production total
FOPT

-- Water injection total of field
FWIT

--Water cut
FWCT

--WELL BHP
WBHP
P1 P2 P3 P4/

--OIL PI
WPIO
P1 P2 P3 P4/

--WELL PR
WWPR
P1 P2 P3 P4/

--WELL WATER CUT
WWCT
P1 P2 P3 P4 /

--OIL IN PLACE
FOIP

-- FORMATION WATER SATURATION
FWSAT

--Water Reservoir Volume in Place
FWIPR

--Fraction of total oil produced by water influx
FORFW

--FORM OIL PORE VOL
FOPV

--FORM WATER PORE VOL
FWPV

--OIL RECOVERY
FOE

--CUMM AQUIFER INFLUX
FAQT

--Water production
FWPT

EXCEL

--*********************************************
SCHEDULE
```

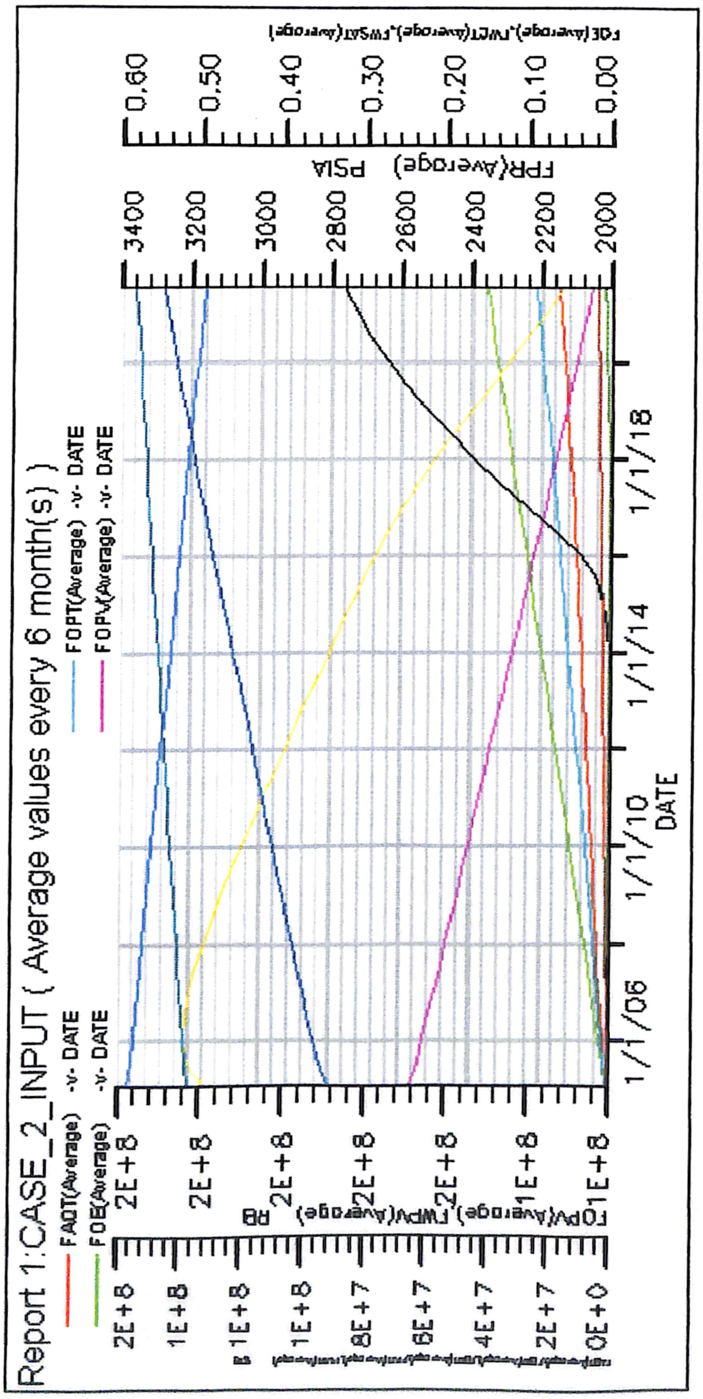
```
WELSPECS
P1 G1   13   5  6940       OIL   0      1* STOP /
P2 G2   17   14 6840       OIL   0      1* STOP /
P3 G3   14   17 6900       OIL   0      1* STOP /
P4 G4   18   7  6870       OIL   0      1* STOP /
I1 G5   18   17 6870       WATER 0      1* STOP /
I2 G6   16   3  6855       WATER 0      1* STOP /
/

COMPDAT
P1     13     5     1 1 OPEN     0     0.0    0.40   0 /
P2     17     14    1 1 OPEN     0     0.0    0.40   0 /
P3     14     17    1 1 OPEN     0     0.0    0.40   0 /
P4     18     7     1 1 OPEN     0     0.0    0.40   0 /
I1     18     17    1 1 OPEN     0     0.0    0.40   0 /
I2     16     3     1 1 OPEN     0     0.0    0.40   0 /

/

WCONPROD
P1     OPEN   ORAT   850    /
P2     OPEN   ORAT   1080   /
P3     OPEN   ORAT   950    /
P4     OPEN   ORAT   1050   /
/

WCONINJE
I1 WATER OPEN RATE 350 /
I2 WATER OPEN RATE 350 /
/

TSTEP
31     28     31     30     31     30     31     31     30     31     30     31
31     28     31     30     31     30     31     31     30     31     30     31
31     28     31     30     31     30     31     31     30     31     30     31
31     28     31     30     31     30     31     31     30     31     30     31
31     28     31     30     31     30     31     31     30     31     30     31
31     28     31     30     31     30     31     31     30     31     30     31
31     28     31     30     31     30     31     31     30     31     30     31
31     28     31     30     31     30     31     31     30     31     30     31
31     28     31     30     31     30     31     31     30     31     30     31
31     28     31     30     31     30     31     31     30     31     30     31
31     28     31     30     31     30     31     31     30     31     30     31
31     28     31     30     31     30     31     31     30     31     30     31
31     28     31     30     31     30     31     31     30     31     30     31
31     28     31     30     31     30     31     31     30     31     30     31
31     28     31     30     31     30     31     31     30     31     30     31
31     28     31     30     31     30     31     31     30     31     30     31
31     28     31     30     31     30     31     31     30     31     30     31
/

END
```

3. SIMULAED RESULTS IN GRAPHICAL FORM SHOWING KEY PARAMETERS

CASE 1 :



CASE 2 :


Report 1:CASE_2_INPUT (Average values every 6 month(s))
FAQT(Average) -v- DATE
FOE(Average) -v- DATE
FOPT(Average) -v- DATE
FOPV(Average) -v- DATE
2E+8
1E+8
1E+8
1E+8
8E+7
6E+7
4E+7
2E+7
0E+0
2E+8
2E+8
2E+8
2E+8
2E+8
1E+8
1E+8
FOPV(Average),FWPV(Average) RB
3400
3200
3000
2800
2600
2400
2200
2000
FPR(Average) PSIA
0.60
0.50
0.40
0.30
0.20
0.10
0.00
FOE(Average),FWCT(Average),FWSAT(Average)
1/1/06
1/1/10
1/1/14
1/1/18
DATE