University of Mosul

College of Petroleum and Mining Engineering

Department of Petroleum Reservoir Engineering

Applied Reservoir Engineering II

Third Year

Lecture 3

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Water Influx:

Nearly all hydrocarbon reservoirs are surrounded by water-bearing rocks called aquifers. These aquifers may be larger than the oil or gas reservoirs they adjoin, as to appear infinite in size, or they may be so small in size as to be negligible in their effect on reservoir performance.

The active system is the reservoir-aquifer system in which the size of the aquifer is large enough and the permeability of the rock is high enough that water influx occurs as the reservoir is depleted.

Classification of Aquifers

Many gas and oil reservoirs produced by a mechanism termed water drive. Often this is called natural water drive to distinguish it from artificial water drive that involves the injection of water into the formation. Hydrocarbon production from the reservoir and the subsequent pressure drop prompt a response from the aquifer to offset the pressure decline. This response comes in a form of water influx, commonly called water encroachment, which is attributed to:

a- Expansion of the water in the aquifer
b- Compressibility of the aquifer rock
c- Artesian flow where the water-bearing formation outcrop is located structurally higher than the pay zone

Reservoir-aquifer systems are commonly classified on the basis of:

a- Degree of pressure maintenance
b- Outer boundary conditions
c- Flow regimes
d- Flow geometries

Degree of Pressure Maintenance

Based on the degree of the reservoir pressure maintenance provided by the aquifer, the natural water drive is often qualitatively described as:

a- Active water drive
b- Partial water drive
c- Limited water drive

The term active water drive refers to the water encroachment mechanism in which the rate of water influx equals the reservoir total production rate. Active water-drive reservoirs are typically characterized by a gradual and slow reservoir pressure decline. If, during any long period, the production rate and reservoir pressure remain reasonably constant, the reservoir voidage rate must be equal to the water influx rate.

$$\begin{bmatrix}\text{water influx}\\ \text{rate}\end{bmatrix} = \begin{bmatrix}\text{oil flow}\\ \text{rate}\end{bmatrix} + \begin{bmatrix}\text{free gas}\\ \text{flowrate}\end{bmatrix} + \begin{bmatrix}\text{water production}\\ \text{rate}\end{bmatrix}$$

or

$$e_w = Q_o\ B_o + Q_g\ B_g + Q_w\ B_w \tag{10-1}$$

where

e_w = water influx rate, bbl/day
Q_o = oil flow rate, STB/day
B_o = oil formation volume factor, bbl/STB
Q_g = **free** gas flow rate, scf/day
B_g = gas formation volume factor, bbl/scf
Q_w = water flow rate, STB/day
B_w = water formation volume factor, bbl/STB

Equation 10-1 can be equivalently expressed in terms of cumulative production by introducing the following derivative terms:

$$e_w = \frac{dW_e}{dt} = B_o \frac{dN_p}{dt} + (GOR - R_s)\frac{dN_p}{dt} B_g + \frac{dW_p}{dt} B_w \tag{10-2}$$

where

W_e = cumulative water influx, bbl
t = time, days
N_p = cumulative oil production, STB
GOR = current gas-oil ratio, scf/STB
R_s = current gas solubility, scf/STB
B_g = gas formation volume factor, bbl/scf
W_p = cumulative water production, STB
dN_p/dt = daily oil flow rate Q_o, STB/day
dW_p/dt = daily water flow rate Q_w, STB/day
dW_g/dt = daily water influx rate e_w, bbl/day
$(GOR - R_s)\ dN_p/dt$ = daily free gas flow rate, scf/day

Outer Boundary Conditions

The aquifer can be classified as infinite or finite (bounded). Geologically all formations are finite, but may act as infinite if the changes in the pressure at the oil-water contact are not “felt” at the aquifer boundary. Some aquifers outcrop and are infinite acting because of surface replenishment. In general, the outer boundary governs the behavior of the aquifer and, therefore:

a. Infinite system indicates that the effect of the pressure changes at the oil/ aquifer boundary can never be felt at the outer boundary. This boundary is for all intents and purposes at a constant pressure equal to initial reservoir pressure.
b. Finite system indicates that the aquifer outer limit is affected by the influx into the oil zone and that the pressure at this outer limit changes with time.

Flow Regimes

There are basically three flow regimes that influence the rate of water influx into the reservoir. As previously described in Chapter 6, those flow regimes are:

a. Steady-state
b. Semisteady (pseudosteady)-state
c. Unsteady-state

Flow Geometries

Reservoir-aquifer systems can be classified on the basis of flow geometry as:

a. Edge-water drive
b. Bottom-water drive
c. Linear-water drive

In edge-water drive, as shown in Figure 10-1, water moves into the flanks of the reservoir as a result of hydrocarbon production and pressure drop at the reservoir-aquifer boundary. The flow is essentially radial with negligible flow in the vertical direction.
Bottom-water drive occurs in reservoirs with large areal extent and gentle dip where the reservoir-water contact completely underlies the reservoir. The flow is essentially radial and, in contrast to the edge-water drive, the bottomwater drive has significant vertical flow.
In linear-water drive, the influx is from one flank of the reservoir. The flow is strictly linear with a constant cross-sectional area.

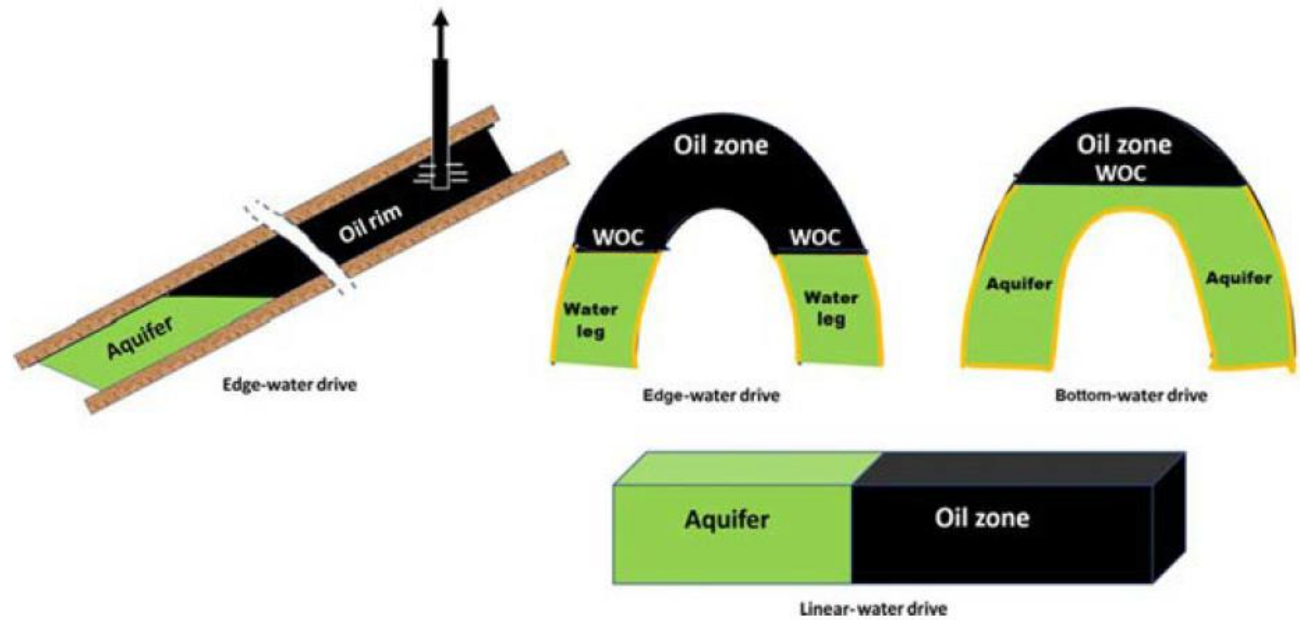

FIGURE 10-1 Flow geometries.