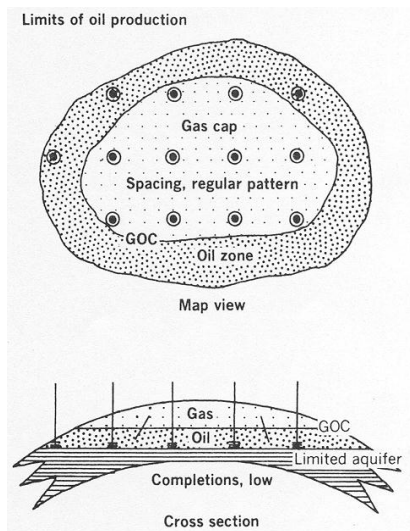


# ***Chapter 3***

## ***Reserve Estimation***



Lecture notes for PET 370

Spring 2012

Prepared by: Thomas W. Engler,  
Ph.D., P.E.

## Reserve Estimation

OIP

### Parameters

Area = 640 acres

Boi = 1.2 rb/stb

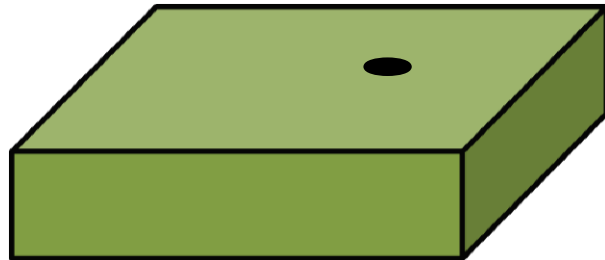
Calculated from log

h = 20 ft

$\phi_{ave} = 10\%$

$Sw_{ave} = 30\%$

One well



H=20 ft

What is the OIP in MSTB?

OOIP = 5,793 MSTB

# Reserve Estimation

OIP

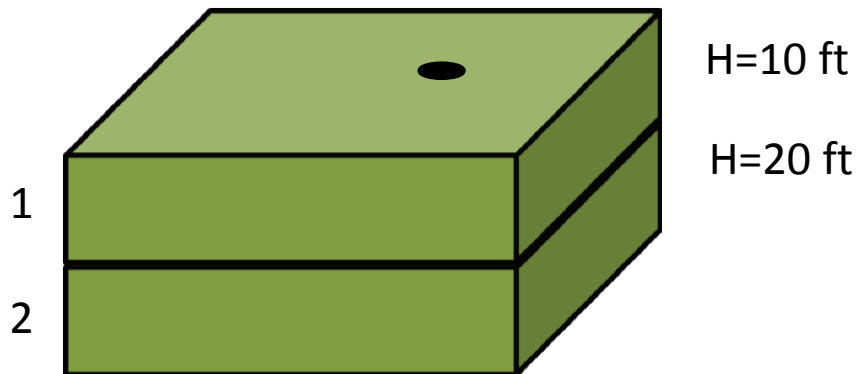
## Parameters

Area = 640 acres

Boi = 1.2 rb/stb

Calculated from log

One well



	Zone 1	Zone 2
H, ft	10	20
$\Phi$ , %	10	15
Sw, %	30	50

What is the HCPV? **2.2 ft**

What is the OIP? **9,102** MSTB

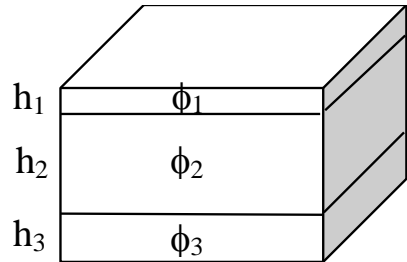
What is the average porosity? **13.3%**

What is the ave. Sw? **45.0%**

What is the OIP using  
The ave values?

Porosity – thickness weighted average

$$\bar{\phi} = \frac{\sum_{i=1}^n \phi_i \cdot h_i}{\sum_{i=1}^n h_i}$$



Water saturation – volume weighted average

$$\overline{S_w} = \frac{\sum_{i=1}^n S_{wi} \phi_i \cdot h_i}{\sum_{i=1}^n \phi_i \cdot h_i}$$

# Reserve Estimation

OIP

two wells

## Parameters

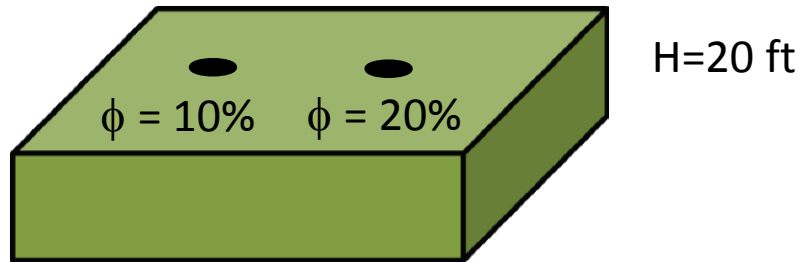
Area = 640 acres

Boi = 1.2 rb/stb

Calculated from log

$h = 20 \text{ ft}$

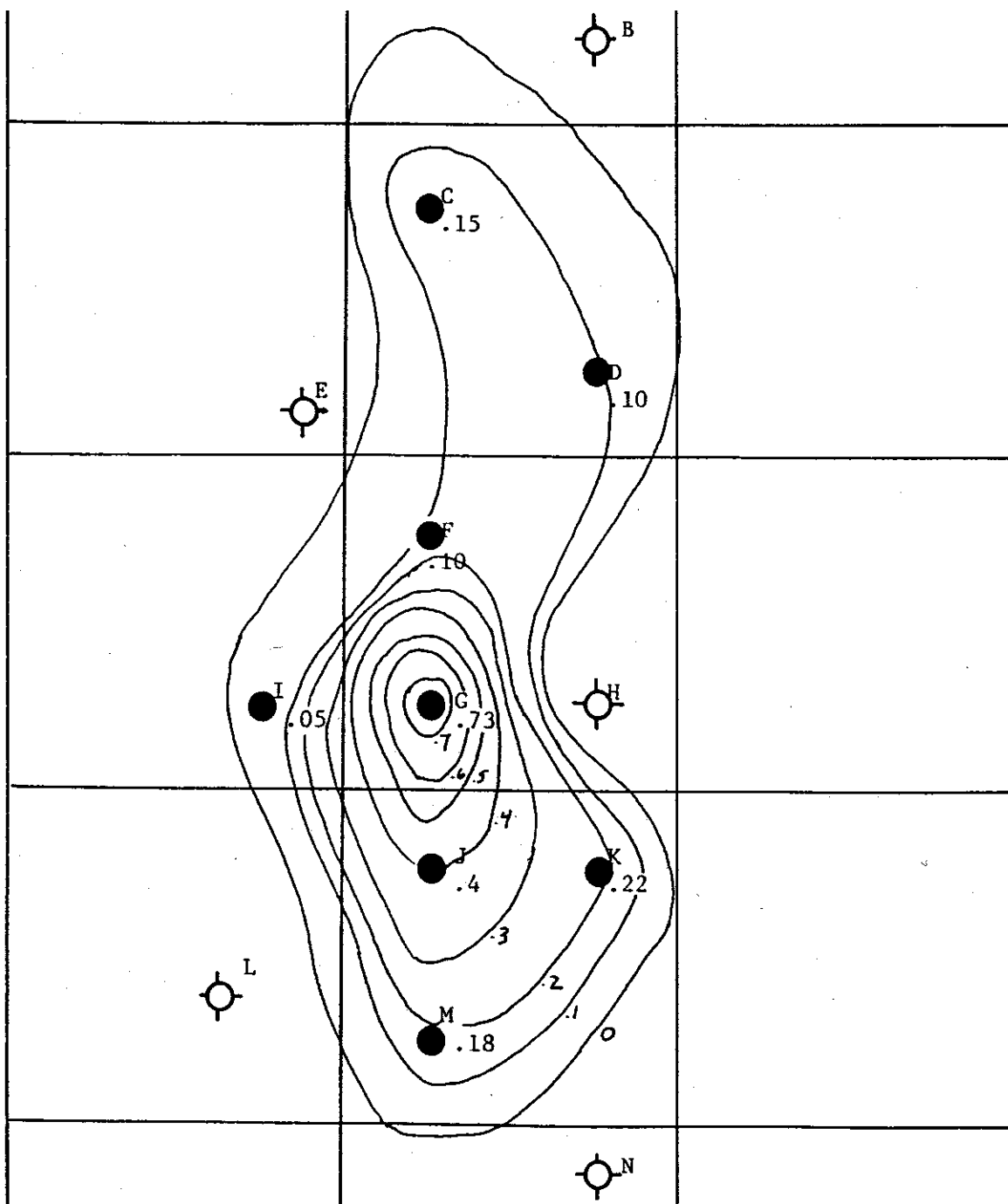
$Sw_{ave} = 30\%$



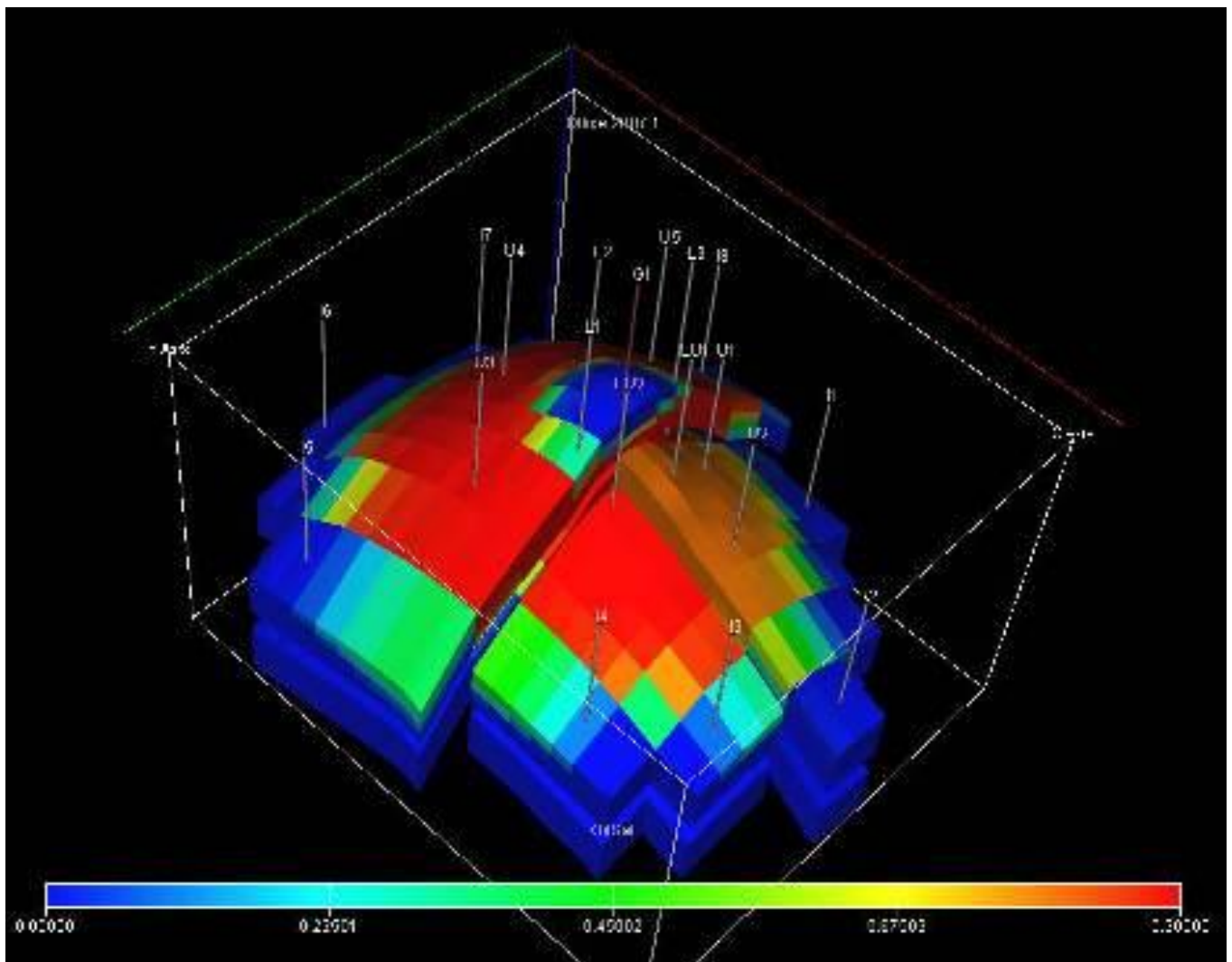
What is the average porosity?

$$\text{OOIP} = \underline{\underline{8,689}} \text{ MSTB if } A_1 = A_2$$

Example of a HCPV map



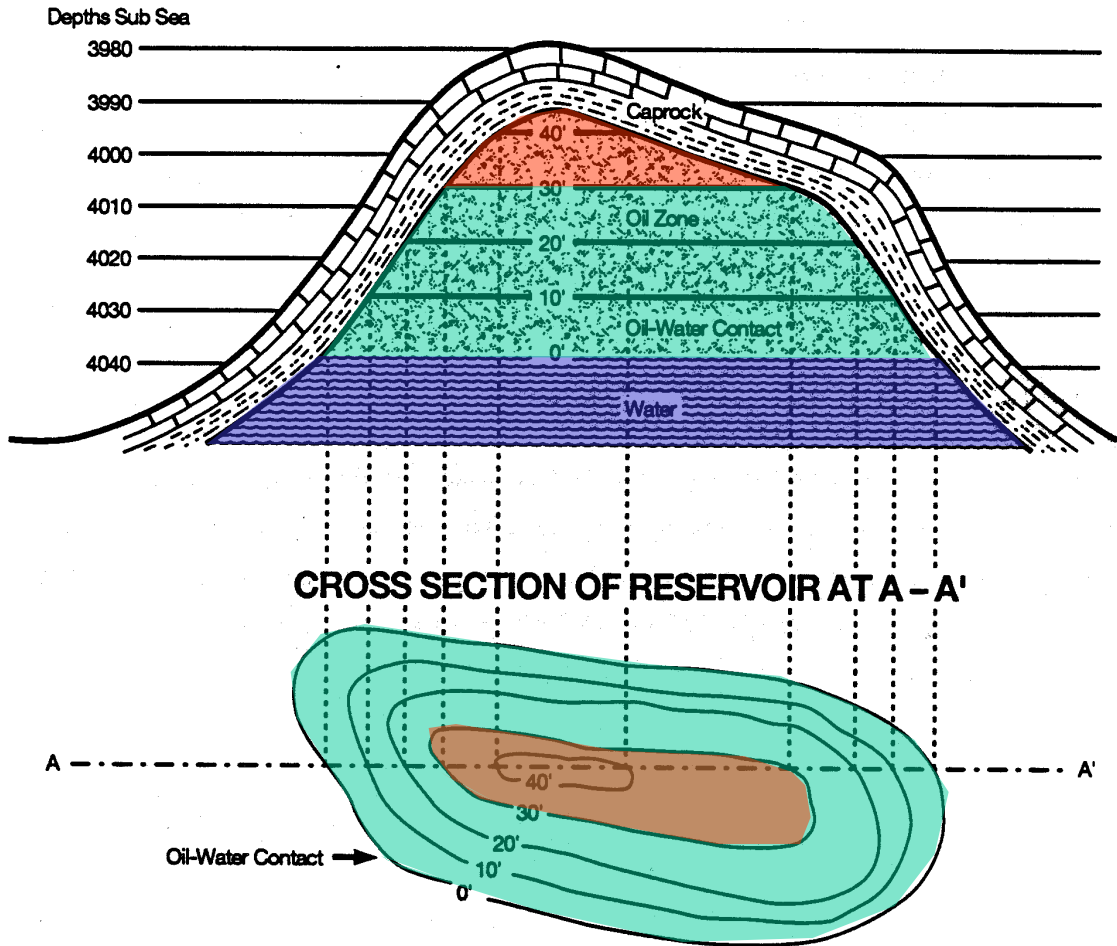
Graduate students only....what is the OIP for the system below?



3D view of a multilayered reservoir, colors show oil saturation

# Reserve Estimation

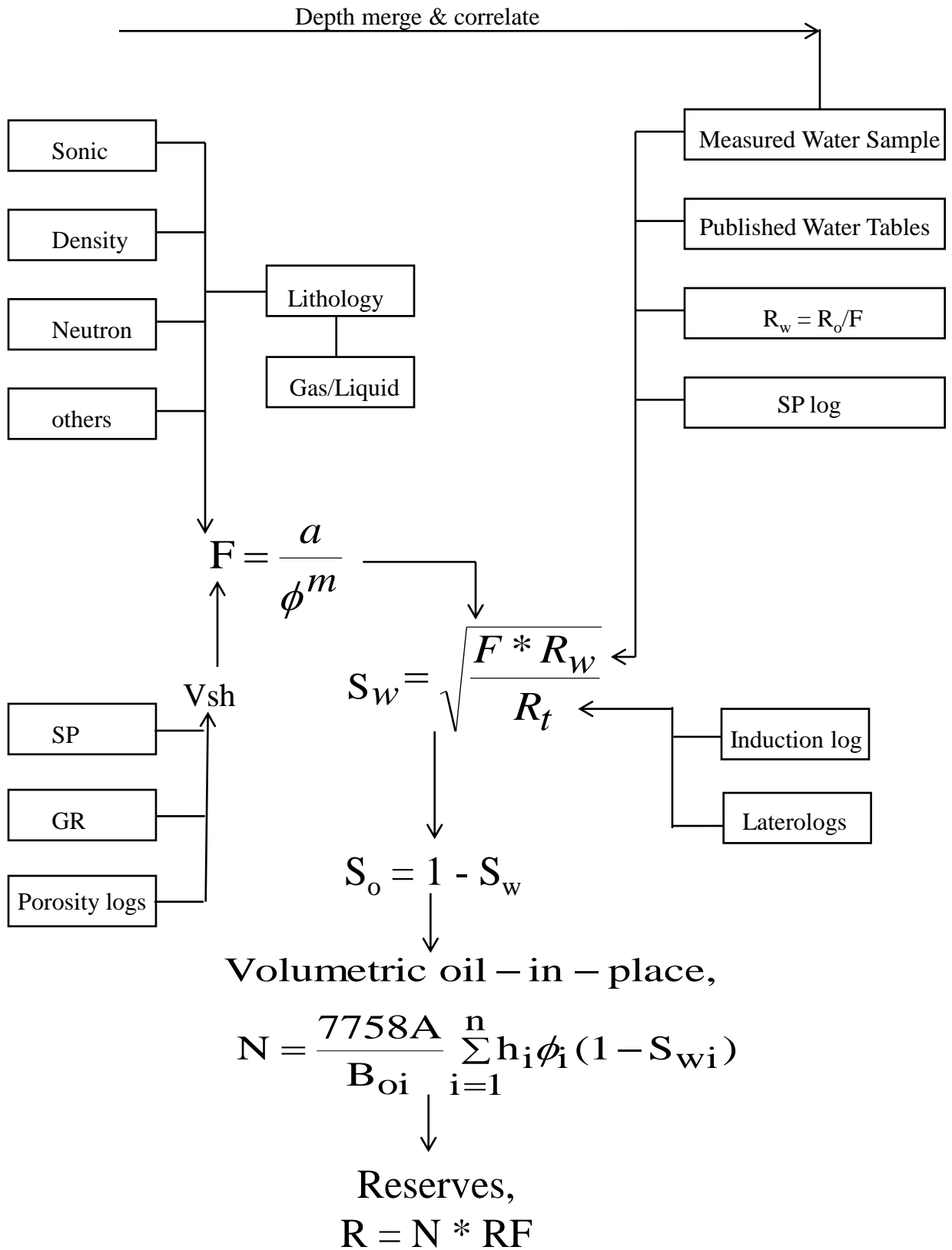
# Reservoir Volume



$$V_b = \frac{h}{3} \left( A_n + A_{n+1} + \sqrt{A_n * A_{n+1}} \right)$$

or

$$V_b = \frac{h}{2} \left( A_n + A_{n+1} \right)$$



Flowchart for Well Log Interpretation

## Reserve Estimation

## Cutoff Values

1. Shale content ( $V_{sh}$ ) – eliminate the portion of the formation which contains large quantities of shale.

$V_{shcutoff} \approx 20$  to  $30\%$

*(Note: shale plays up to 40 to 50%)*

**GROSS SAND**

# Reserve Estimation

How much gross sand in this well?

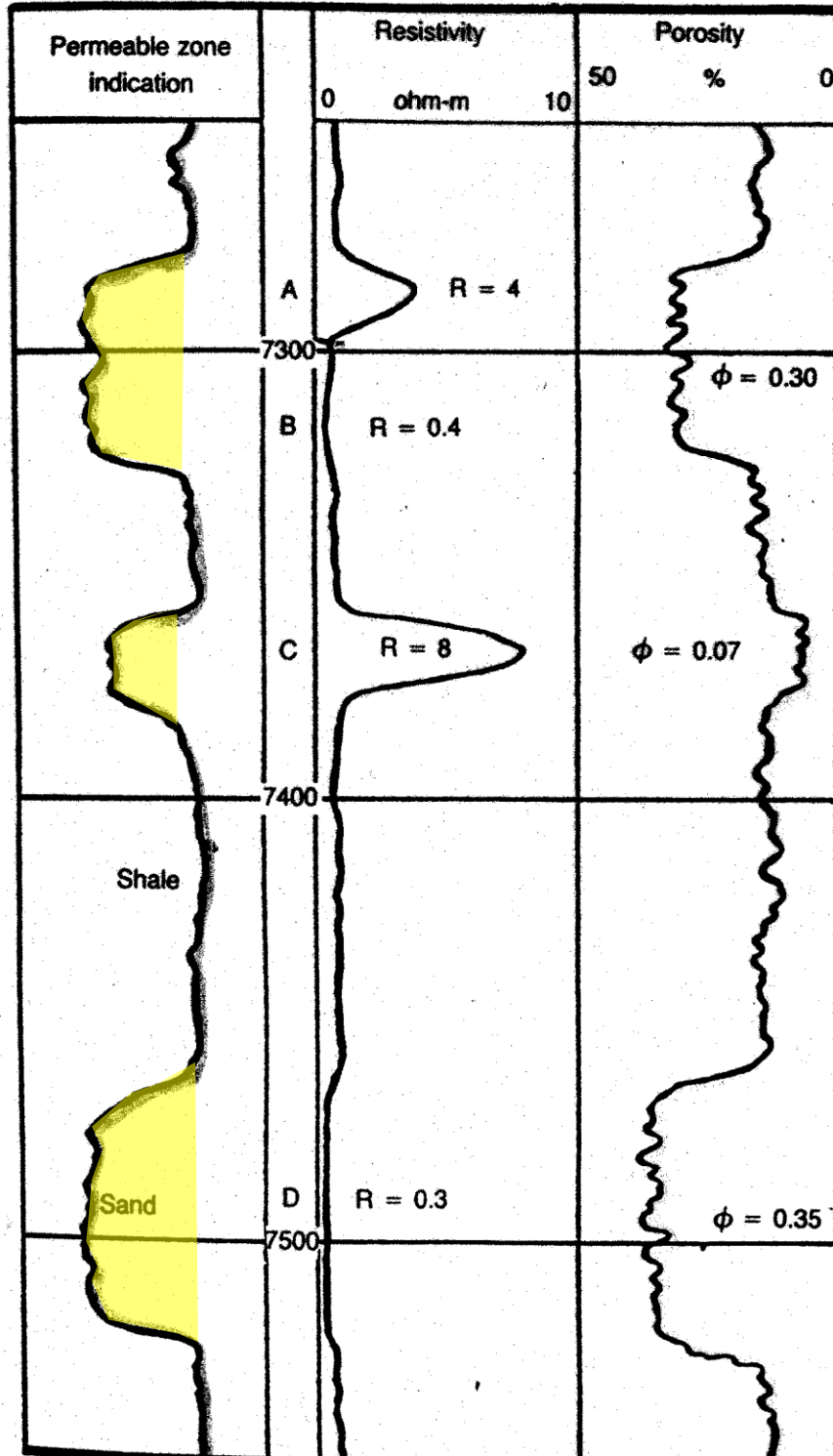
Gross Sand

50 ft

15 ft

50 ft

Total=115ft



## Reserve Estimation

## Cutoff Values

1. Shale content ( $V_{sh}$ ) – eliminate the portion of the formation which contains large quantities of shale.

$V_{sh\text{cutoff}} \approx 20 \text{ to } 30 \%$

*(Note: shale plays up to 40 to 50%)*

**GROSS SAND**

2. Porosity – eliminate the portion of the formation which is low porosity (and low permeability) and therefore would be non-productive.

Sandstones

$\phi_{\text{cutoff}} \approx 5\% \text{ to } 15\%$

consolidated → friable, unconsolidated

Carbonates

$\phi_{\text{cutoff}} \approx 4\%$

*(Note: shale plays ~ 3 to 4%)*

**NET SAND**

# Reserve Estimation

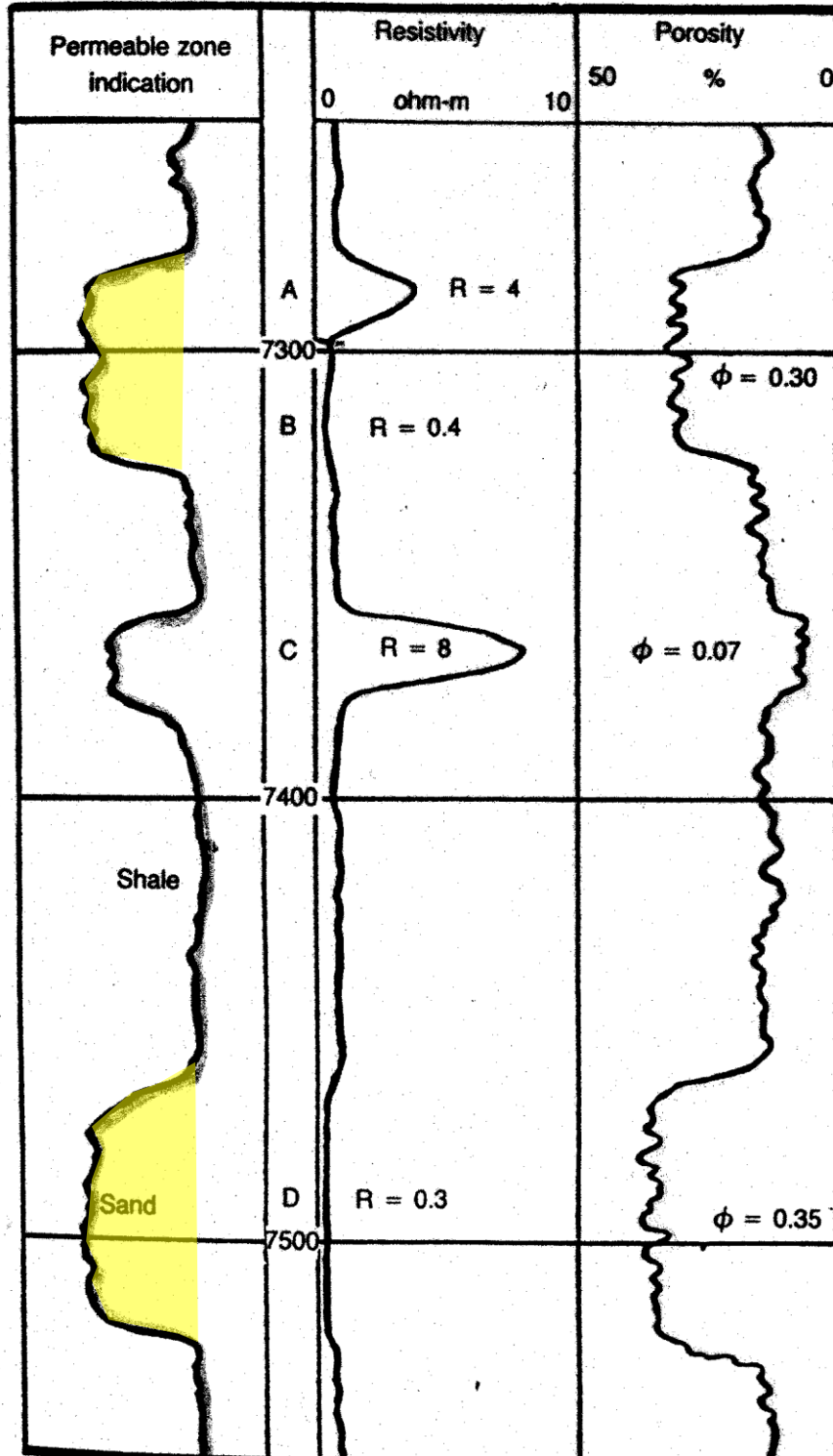
How much net sand in this well?

Net Sand

50 ft

50 ft

Total=100ft



## Reserve Estimation

## Cutoff Values

1. Shale content ( $V_{sh}$ ) – eliminate the portion of the formation which contains large quantities of shale.

$V_{sh\text{cutoff}} \approx 20$  to  $30\%$

*(Note: shale plays up to 40 to 50%)*

**GROSS SAND**

2. Porosity – eliminate the portion of the formation which is low porosity (and low permeability) and therefore would be non-productive.

Sandstones

$\phi_{\text{cutoff}} \approx 5\%$  to  $15\%$

consolidated → friable, unconsolidated

Carbonates

$\phi_{\text{cutoff}} \approx 4\%$

*(Note: shale plays ~ 3 to 4%)*

**NET SAND**

3. Water saturation – eliminate the portion of the formation which contains large volumes of water in the pore space.

Sandstones

$S_{w\text{cutoff}} \approx 60\%$

Carbonates

$S_{w\text{cutoff}} \approx 50\%$

**NET PAY**

# Reserve Estimation

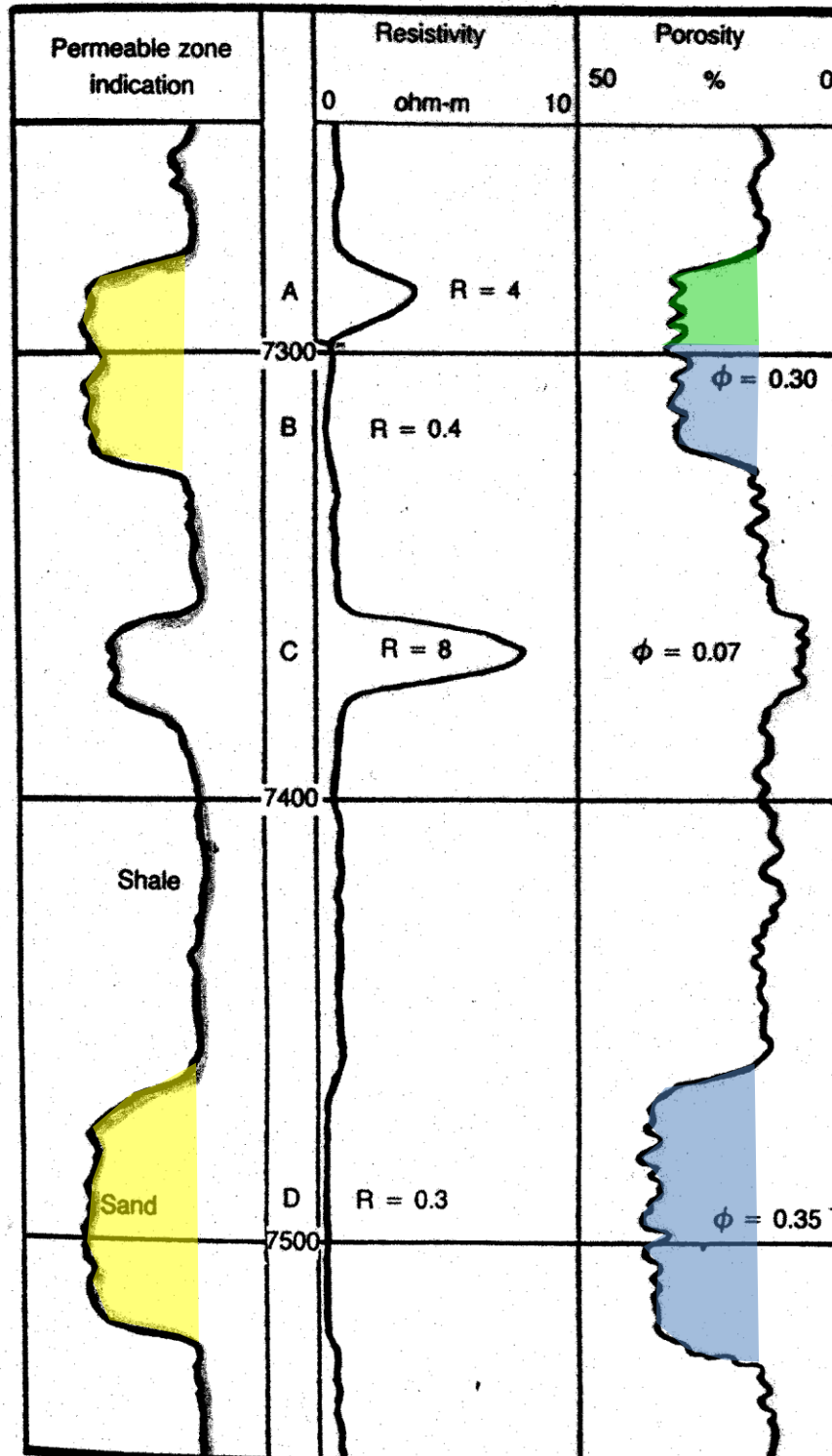
How much net pay in this well?

Net Sand

50 ft

Net pay

20 ft



50 ft

Total=100ft

## Parameters

Area = 40 acres

Boi = 1.5 rb/stb

Calculated from log

h = 20 ft

$\phi_{ave} = 30\%$

$Sw_{ave} = 30\%$



**OOIP = 869 Mstb**

Recovery Factor can be estimated by:

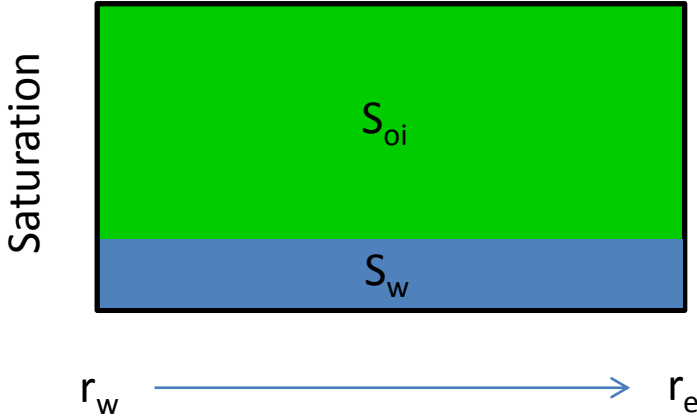
- A. displacement efficiency studies
- B. correlations based on statistical studies of particular types of reservoir mechanisms
- C. All of the above
- D. None of the above
- E. I don't know I slept through Reservoir Engineering class

Recovery Factor can be estimated by:

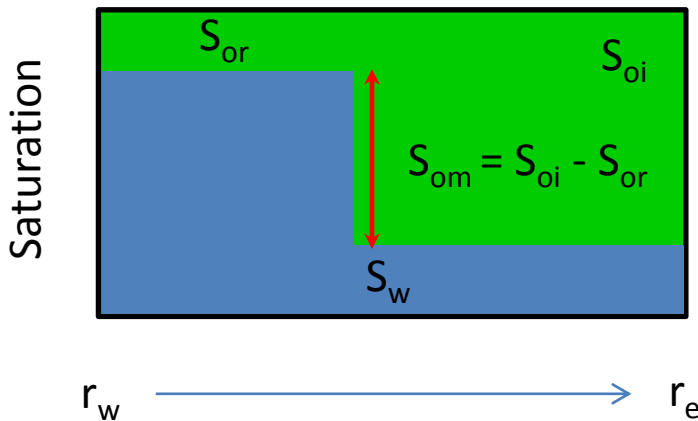
- A. displacement efficiency studies
- B. correlations based on statistical studies of particular types of reservoir mechanisms
- C. All of the above
- D. None of the above
- E. I don't know I slept through Reservoir Engineering class**

# Reserve Estimation

# Recovery Factor

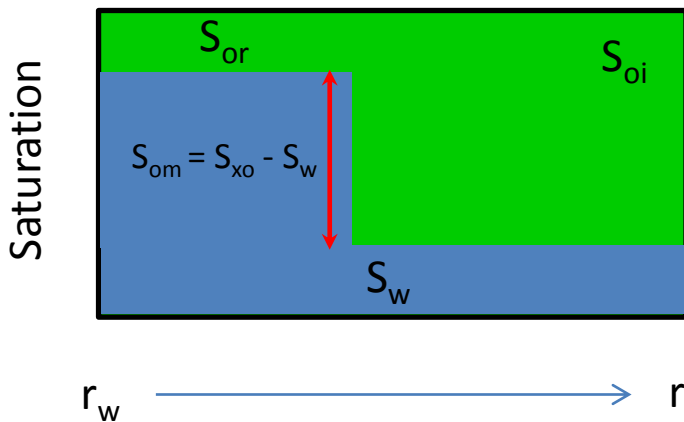


From displacement of reservoir fluids (invasion) using well logs



Difference between initial oil saturation,  $S_{oi}$  and the residual oil saturation,  $S_{or}$ , that remains after the formation is invaded by water.

or



Infer mud filtrate invasion as an efficient displacement mechanism, recovery factor is:

$$(E_r)_{wd} = \frac{S_{xo} - S_w}{1 - S_w}$$

....for depletion drive, use *rule of thumb* of 1/2 of  $(RF)_{wd}$

# Reserve Estimation

# Recovery Factor

## Statistical Performance

Soln Gor	Oil gravity	Sandstones			Carbonates		
		maximum	average	minimum	maximum	average	minimum
60	15	12.8	8.6	2.6	28.0	4.4	0.6
	30	21.3	15.2	8.7	32.8	9.9	2.9
	50	34.2	24.8	16.9	39.0	18.6	8.0
200	15	13.3	8.8	3.3	27.5	4.5	0.9
	30	22.2	15.2	8.4	32.3	9.8	2.6
	50	37.4	26.4	17.6	39.8	19.3	7.4
600	15	18.0	11.3	6.0	26.6	6.9	1.9
	30	24.3	15.1	8.4	30.0	9.6	2.5
	50	35.6	23.0	13.8	36.1	15.1	4.3
1000	15	-	-	-	-	-	-
	30	34.4	21.2	12.6	32.6	13.2	4.0
	50	33.7	20.2	11.6	31.8	12.0	3.1
2000	15	-	-	-	-	-	-
	30	-	-	-	-	-	-
	50	40.7	24.8	15.6	32.8	14.5	5.0

## Solution Gas Drive Reservoirs (Arps, 1962)

Drive	Sandstones			Carbonates		
	minimum	average	maximum	minimum	average	maximum
Water drive	27.8	51.1	86.7	6.3	43.6	80.5
Solution gas drive without supplemental drives	9.5	21.3	46.0	15.5	17.6	20.7
Solution gas drive with supplemental drives	13.1	28.4	57.9	9.0	21.8	48.1
Gas cap drive	15.8	32.5	67.0	Combined with sandstone Data not available		
Gravity drainage	16.0	57.2	63.8			
Gas depletion	75.0	85.0	95.0			
Gas water drive	50.0	70.0	80.0			

Recovery factor for different drive mechanisms

## Electrical Properties of Rocks

## Example

### Parameters

Area = 40 acres

Boi = 1.5 rb/stb

Calculated from log

h = 20 ft

$\phi_{ave} = 30\%$

$Sw_{ave} = 30\%$

**OOIP = 869 Mstb**

### Recovery Factor

Assume sandstone reservoir, water drive.

**RF = 51.1%**

What is the R.F.?

Reserves (R) = ?

**R = 444 Mstb**

Assume  $S_{xo} = 70\%$  What is the R.F.?

**RF = 57 %**

Reserves (R) = ?

**R = 496 Mstb**

**Chapter 11, Sec 11.4-11.7**, Bassiouni, Z: Theory, Measurement, and Interpretation of Well Logs, SPE Textbook Series, Vol. 4, (1994)

Corelab, Fundamentals of Core Analysis, Houston, TX (1983), Chapter 7