MES
Middle East Supplies FZC

E Lob office, Hamriyah Free Zone
PoBox 50331, Sharjah
United Arab Emirates
+971 5 62745269
info@mes-uae.com

We do - you succeed!

Reservoir Modeling & Simulation of Radial Drainage Tunnels in A **Medium Quality Reservoir**

conducted by:

NEW MEXICO TECH
SCIENCE · ENGINEERING · RESEARCH · UNIVERSITY

Outline:

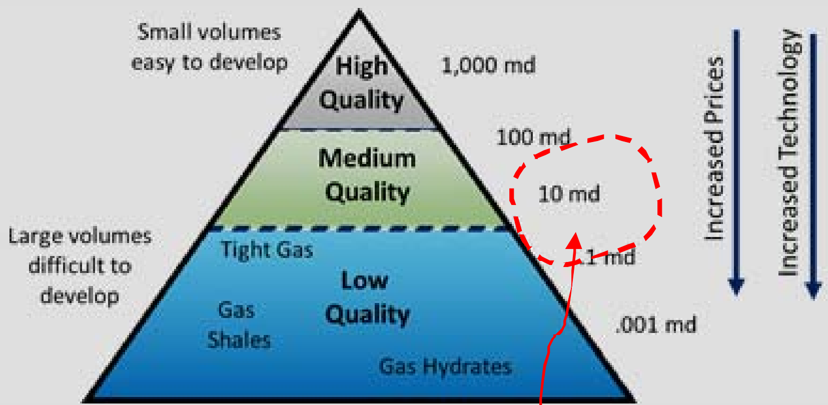
Document is divided into 3 parts

Part I: Homogeneous / Radial "Darcy" Flow

Part II: Full Reservoir Modeling / Simulation

- Who / How Study Performed?
- Reservoir Description & History-Matching
- Production Results
- Sensitivity Analysis

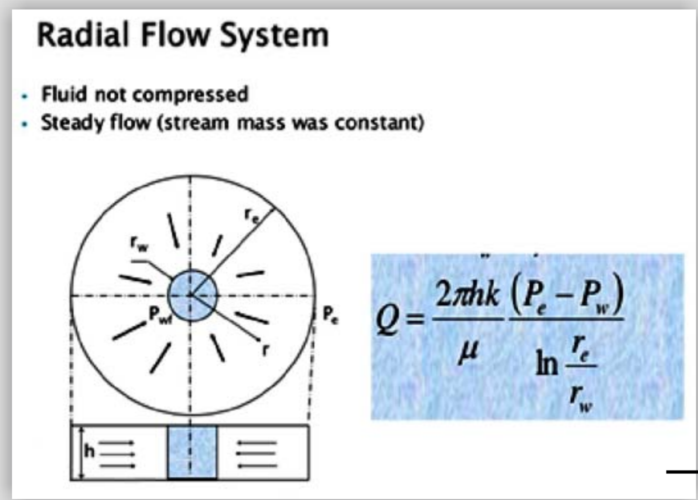
Part III: Conclusions



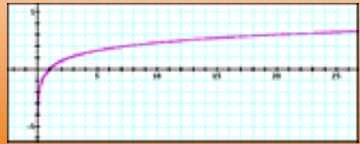
This Study is of a
Medium Quality Reservoir

Background:

The question of fluid recovery in a homogenous porous media can be derived from the Darcy Flow Formula:



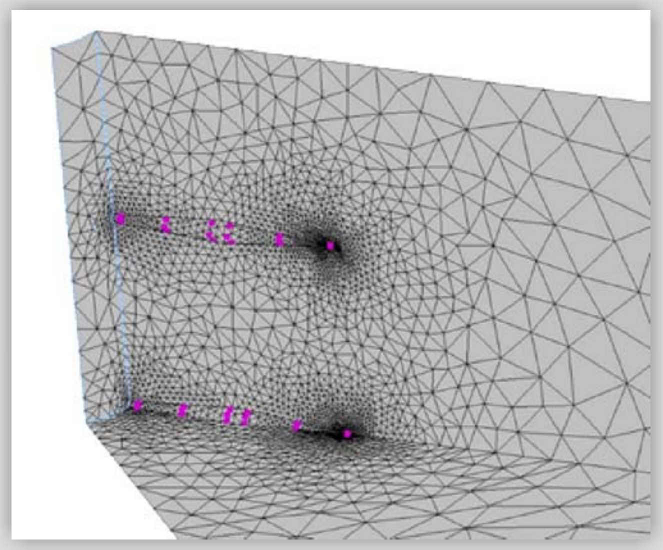
… and, flow is a Log function of distance

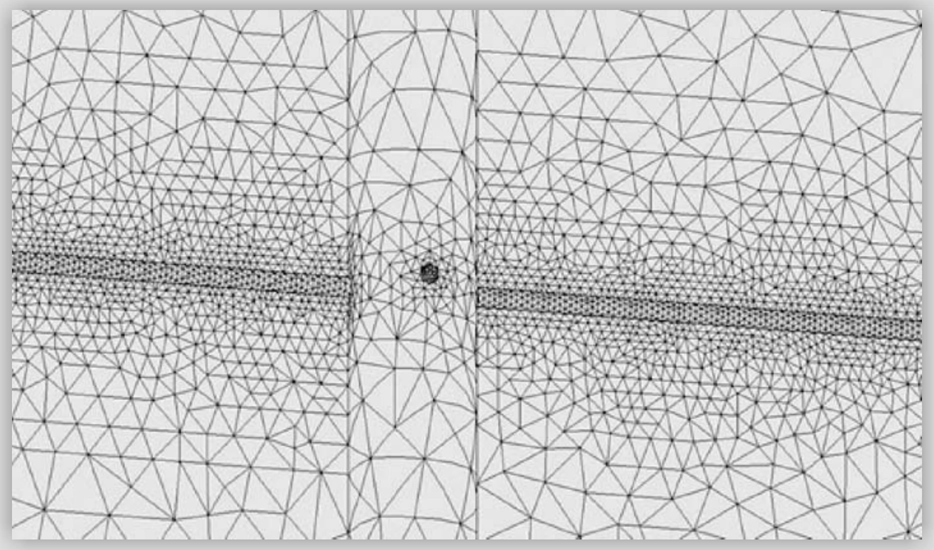


And,
Generic models (on slides immediately following), can be run to understand the potential production impact of radial drainage tunnels….

Building the Model

The process begins by building an array of cells that will be used to simulate fluid flow within a reservoir.





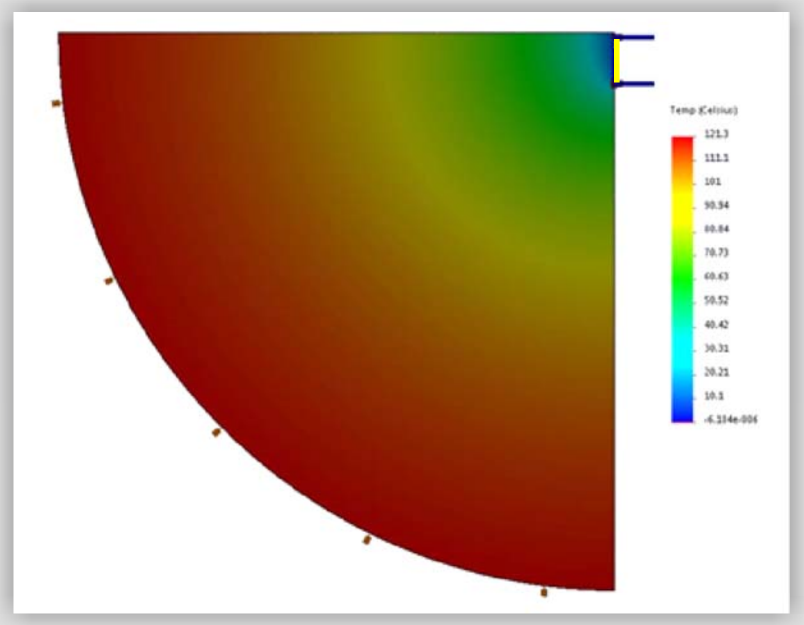
Model of Perfs

Model of MES Tunnels

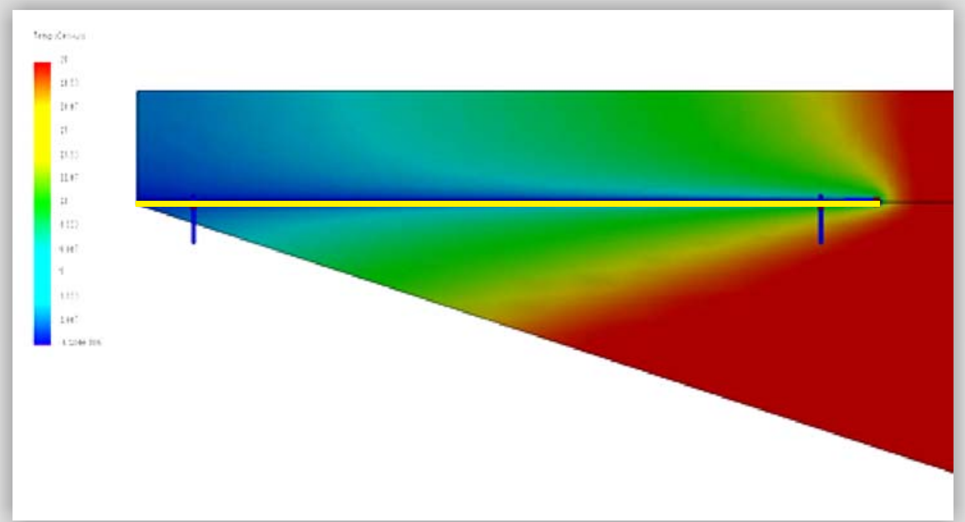
Note: Because the inter-action nearest the Perfs and Radials is the most important, the # of cells in these areas is increased.

Pressure Gradient

With a basic model built… pressure drops and hence comparative flow volumes can be calculated

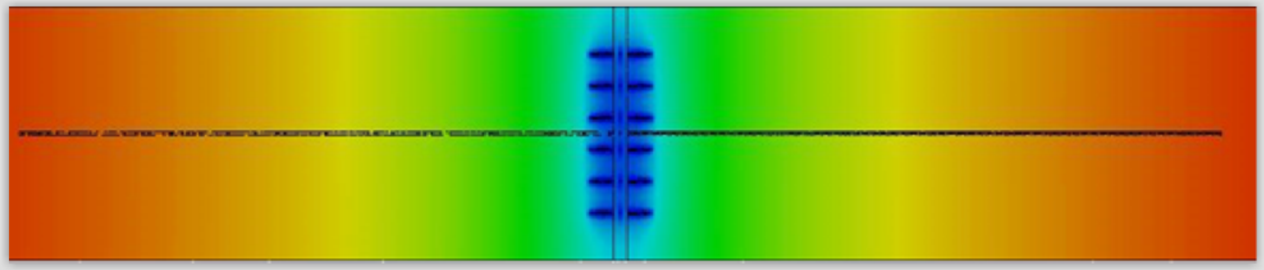


Here we see the extended radial pressure gradient of a tunnel (at top-right in yellow)

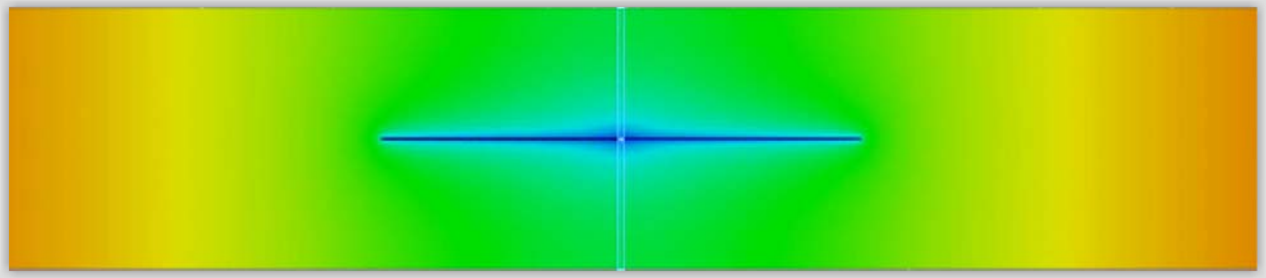


Here is a "zoomed-in" view of the vertical pressure profile around a radial (yellow)

Pressure Drop: Profile View



Here is the pressure gradient in a homogeneous zone around a set of **perforations** in a vertical well

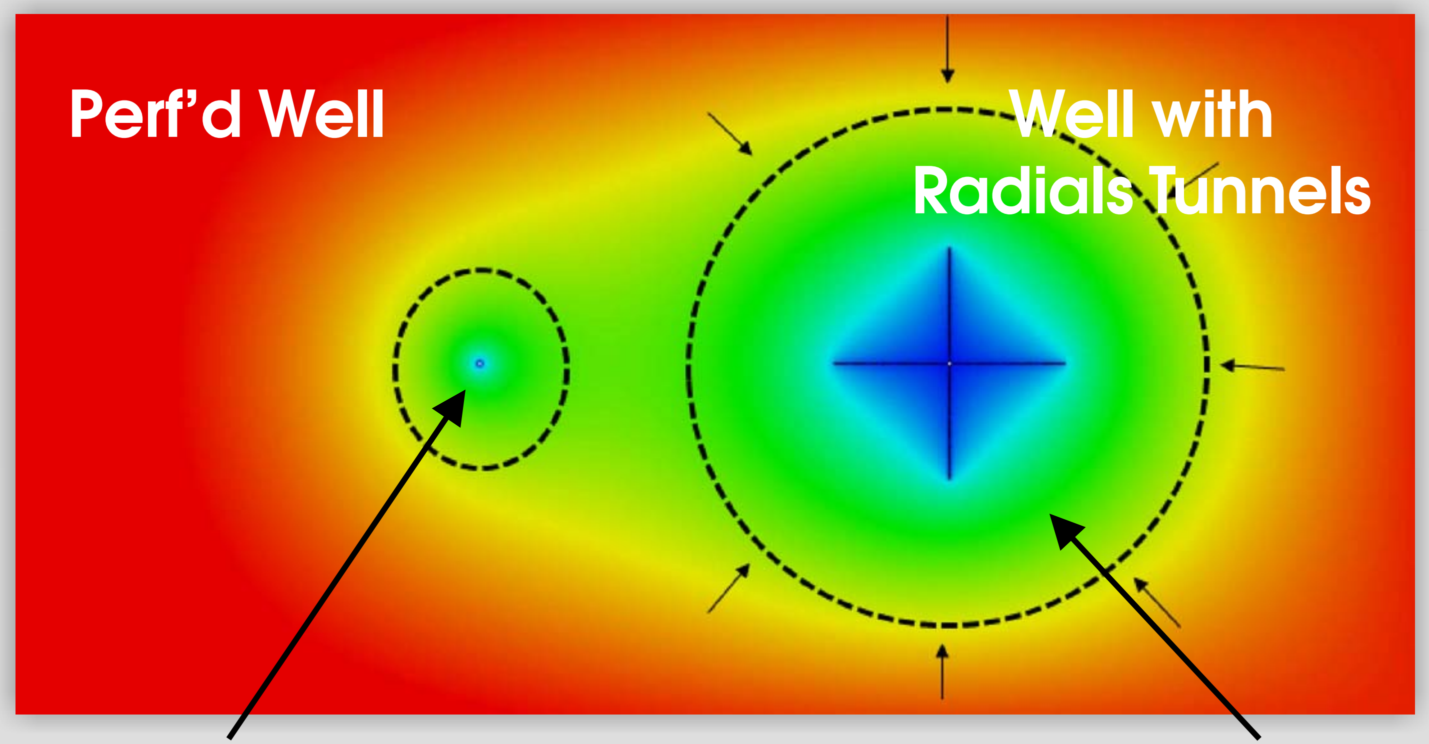


Here is the dramatically improved pressure gradient offered by **radial drainage tunnels**

Key Note:
Far more favorable gradient with radials

Pressure Drop:

Head-to-Head Comparison



Pressure loss is concentrated around the wellbore. That is, most of the reservoir's energy is lost in this area.

Here, the near wellbore pressure drop is minimal… yielding far better drainage from the extended area.

The Prior Analyses are indicative, but…

Purely "theoretical" models are too simplistic…

Reservoirs are NOT homogenous, but instead have many different characteristics – which can vary widely.

For example:

- Porosity
- X-Y-Z Permeability
- Relative Fluid Permeability
- Pressure
- Gas/Fluid Compressibility
- Rock Strength, etc.

… a Better Analysis is Needed

The Conundrum

Most operators do NOT have the resources to perform reservoir simulations that can estimate the impact of radial drilling on their wells.

…and yet, to prioritize their candidate wells, it's important to know which variables most help (or hinder) favorable outcomes.

To help answer this problem, Middle East Supplies FZC commissioned… a set of detailed reservoir models & simulation studies.

About the Study

Analysis Performed by:

- **William Ampomah, PhD**; and,
- **Robert Balch, PhD**
  - SPE Distinguished Lecturer
  - Dir. Petroleum Recovery Research Council

New Mexico Tech (NMT):

- Has offered Petroleum Engineering degrees 1930's
- Known for strong emphasis on research as well as applied skills; recognized for excellence in research.

NEW MEXICO TECH
ONE HUNDRED AND TWENTY-FIVE YEARS OF EXCELLENCE

Analysis Performed using

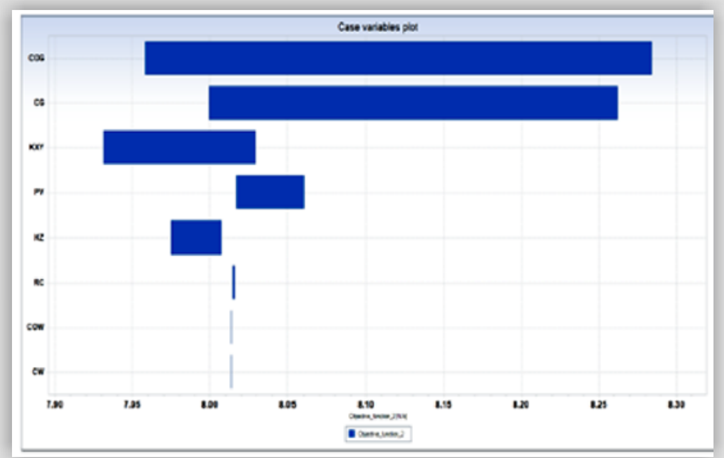
- Petrel E&P Reservoir Simulator
- Offered by Schlumberger

Petrel
Shared earth—critical insight

Schlumberger

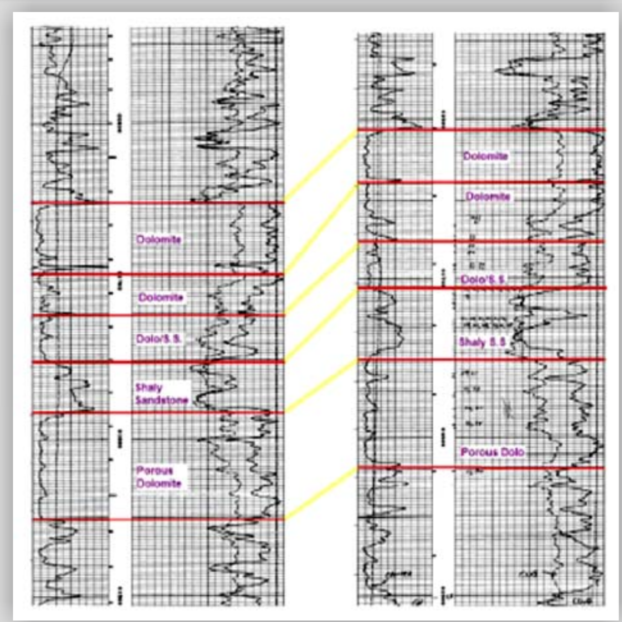
Creation of:

Model Reservoir



When defining the reservoir

- Logs from 4 adjacent wells were used
- Depth / Cross-sections were co-related
- And sensitivity of key variables were understood with the help of Tornado Plots



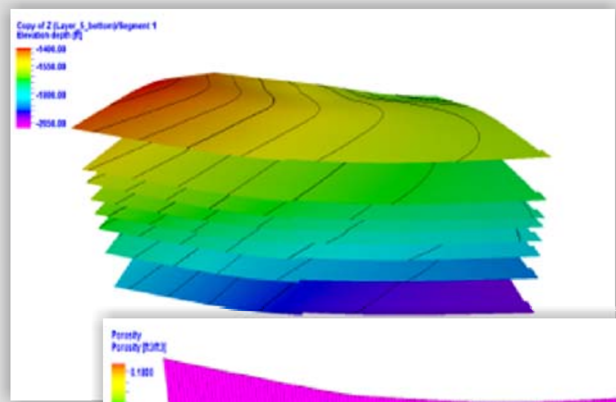
Depth(ft)

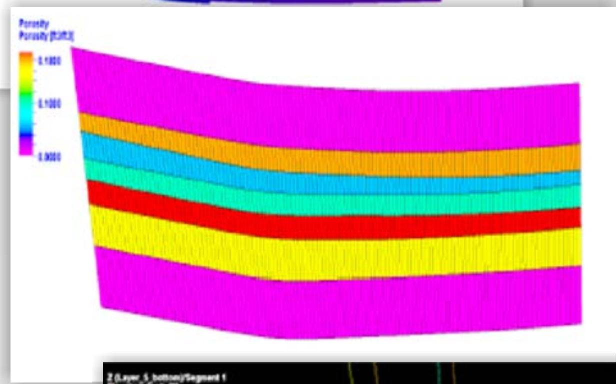
1			2			3			4			5		
h	Top	Bottom	h	Top	Bottom	h	Top	Bottom	h	Top	Bottom	h	Top	Bottom
43	1650	1693	27	1693	1720	30	1720	1750	32	1750	1782	68	1782	1850
40	1656	1696	30	1696	1726	34	1726	1760	40	1760	1800	64	1800	1864
40	1620	1660	34	1660	1694	36	1694	1730	40	1730	1770	68	1770	1838
32	1606	1638	36	1638	1674	32	1674	1706	44	1706	1750	68	1750	1818
30	1550	1580	40	1580	1620	30	1620	1650	40	1650	1690	68	1690	1758
52	1650	1702	18	1702	1720	28	1720	1748	30	1748	1778	72	1778	1850
40	1710	1750	34	1750	1784	26	1784	1810	32	1810	1842	78	1842	1920
41	1676	1717	29	1717	1746	32	1746	1778	34	1778	1812	73	1812	1885
54	1668	1722	18	1722	1740	28	1740	1768	38	1768	1806	66	1806	1872
22	1626	1648	46	1648	1694	16	1694	1710	34	1710	1744	70	1744	1814
38	1642	1680	32	1680	1712	30	1712	1742	40	1742	1782	70	1782	1852

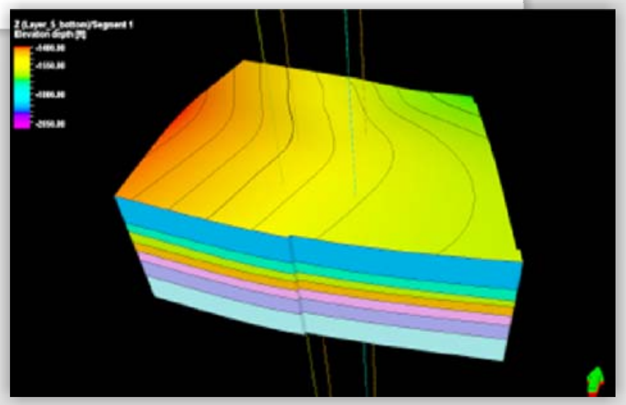
Reservoir Description:

Using the Inputs from the 4 wells

- 7 Layers were identified
- The grid array was built; and,
- The model begins taking shape







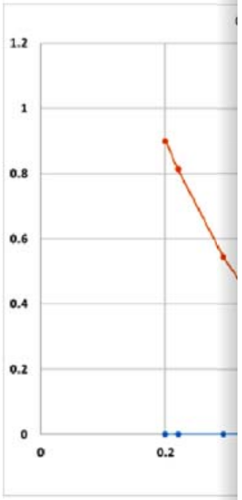
Model Parameters

Model Grid cells	131*129*7
Grid dimension	50*50
Total # of cells	118293
Total # of wells	12(4)

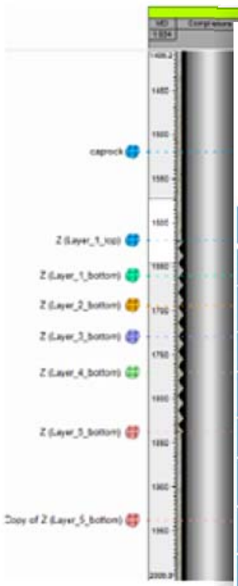
Key Parameters

Entered into the Model

Field Modeling – Model Initiation

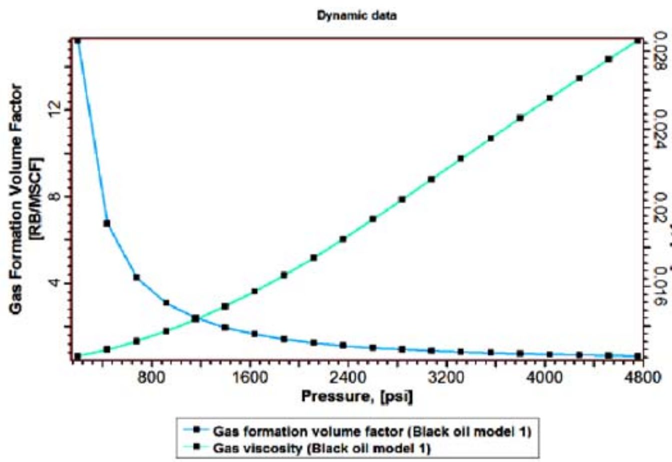


Field Modeling – Well Completions



Field Modeling – Fluid Analysis

Parameters	Unit	
Reservoir Temperature	°F	160
Oil Density	lb/ft^3	54
Gas Density/Gravity	lb/ft3(Air=1)	0.05345
Water Density	lb/ft^3	62.3664
Rsob	scf/bbl	1093.879
γ_g	-	0.7
γ_{API}	°API	31.92307
BP	psia	4814.725



A History Matching…

Was undertaken:

- That was compared to **30 yrs** of data;
- Looked at key variables; and,
- Yielded confidence in the model

History Matching Process

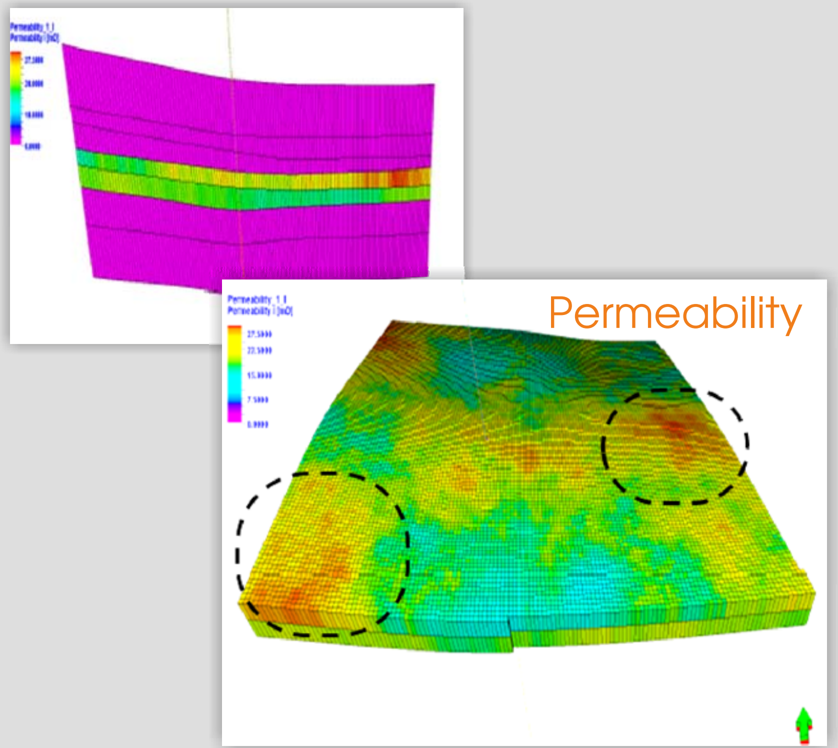
- ***High uncertainty variables***
  - Pore volume
  - permeability
  - Kv/Kh ratio
  - Relative permeability curves
  - Well inflow parameters
- ***Low uncertainty variables***
  - Porosity
  - Gross thickness
  - Net thickness
  - Structure
  - Fluid properties
  - Rock compressibility
  - Capillary pressure
  - Datum pressure
  - Production rates

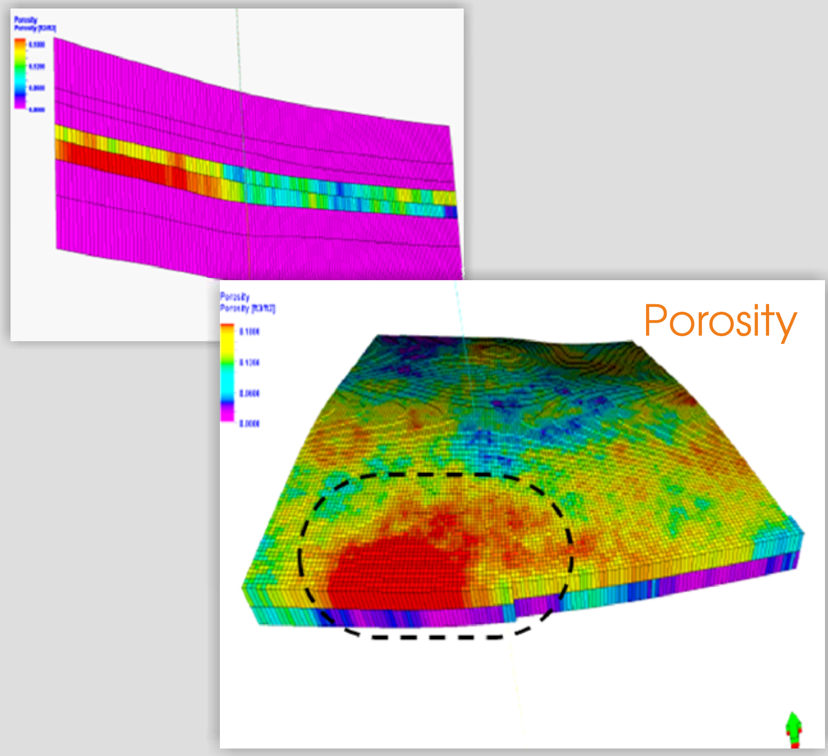
$$RMS = \sqrt{\frac{\sum_1^N (Simulated - Observed)^2}{N}}$$

Vector	RMS
Field Oil Prod.	0.002
Field Water Prod.	5
Field Gas Prod.	2
Overall RMS	7

Initial Geological Information

Distribution Profile of Certain Key Properties





Some areas better than others… so we should
expect well-to-well variability

Simulation Model

Baseline Key Values:

Case 1- Medium Quality Reservoir (MQR)

- ***Problem Description***:

- The geological surfaces created for the base case modeling (model field) was used to conduct sensitivity analysis on the performance of multi-laterals on wide range of lateral lengths, permeability, pore volume, several rock types and others.
- Multi-laterals were drilled into Well # 3 and Well #4 through layers 4 and 5.
- The rock properties were constructed stochastically
- Permeability (max = 30 mD, min = 10 mD, mean =20 mD, std =2 mD)
- Porosity (max = 0.25, min = 0.1, mean = 0.18, std = 0.100)

The Results

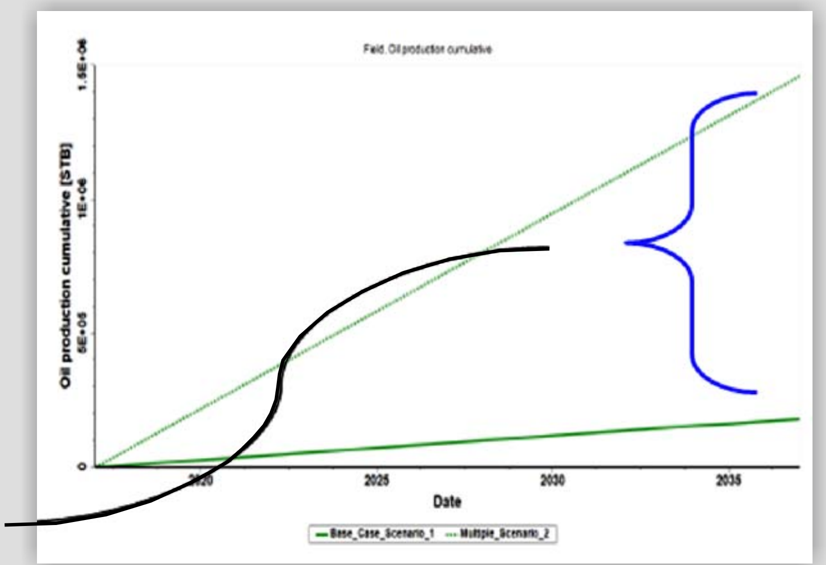
Simulation Recap:

- Comparison of baseline (vs)
  4 laterals in the wells
- Shows cum 20 Yr Oil production
- Used same reservoir model
  (identical porosity, perm, etc.)
- Model was History Matched
- Same starting BHP

Key Points:

- Dramatic increase in modeled
  Production (350+% increase)
- But remember, results can and will vary widely
  (see following slides)

Baseline vs. Radials
20 Year Cum Oil Production



MQR Simulation

Sensitivity Analysis:

A sensitivity analysis was then conducted to understand the impact of certain variables on the results.

Variables reviewed:

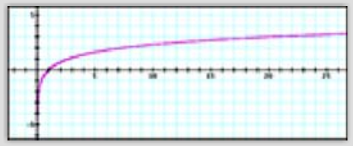
Variable	Tag	Value Range
Oil Water Contract	OWC	1600 to 4000
Laterals	L1 -L4	50 to 150
BHP	BHP	50 to 500
Pore Volume	PV	10% to 25%
Permeability XY	XY	10 to 200md
Permeability Z	Z	.2 to 200md
Rock Compressibility	CR	2.5E -05 to 5.5E -05

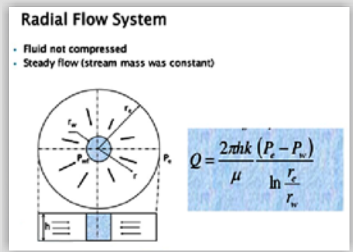
Impact of Lateral Length on Results?

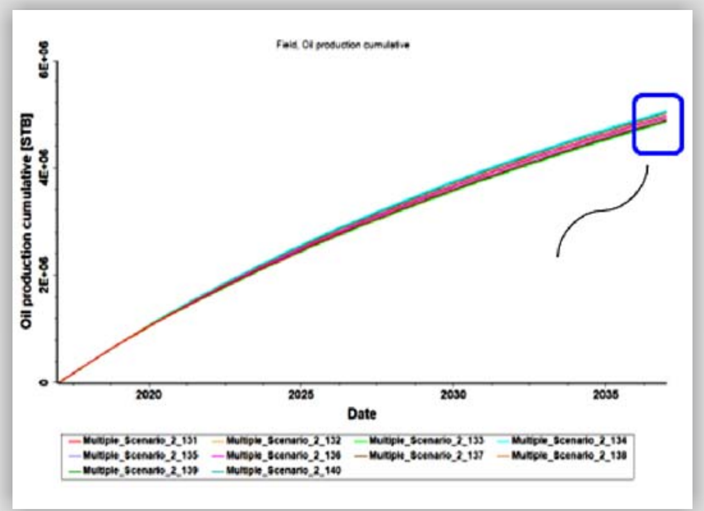
Here a total of 20 different scenarios were run, with laterals ranging from 50-150 ft…

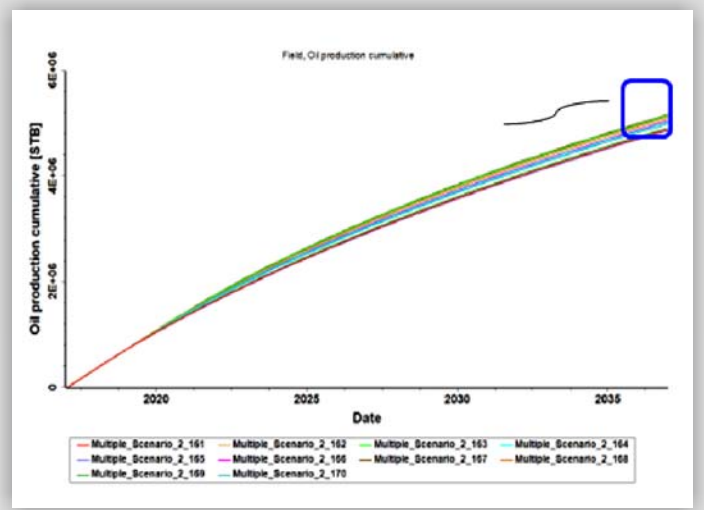
Key Lessons:

- Yes, longer radials are better, but…
- Difference not as big as one might think
- More important to get past constrictive near wellbore area (think Log function)









What About the Impact of Other Variables?

Again, 10 scenarios each were run…
based on range of values

Key Points:

- Some variable don't "move the needle"
- Meanwhile…

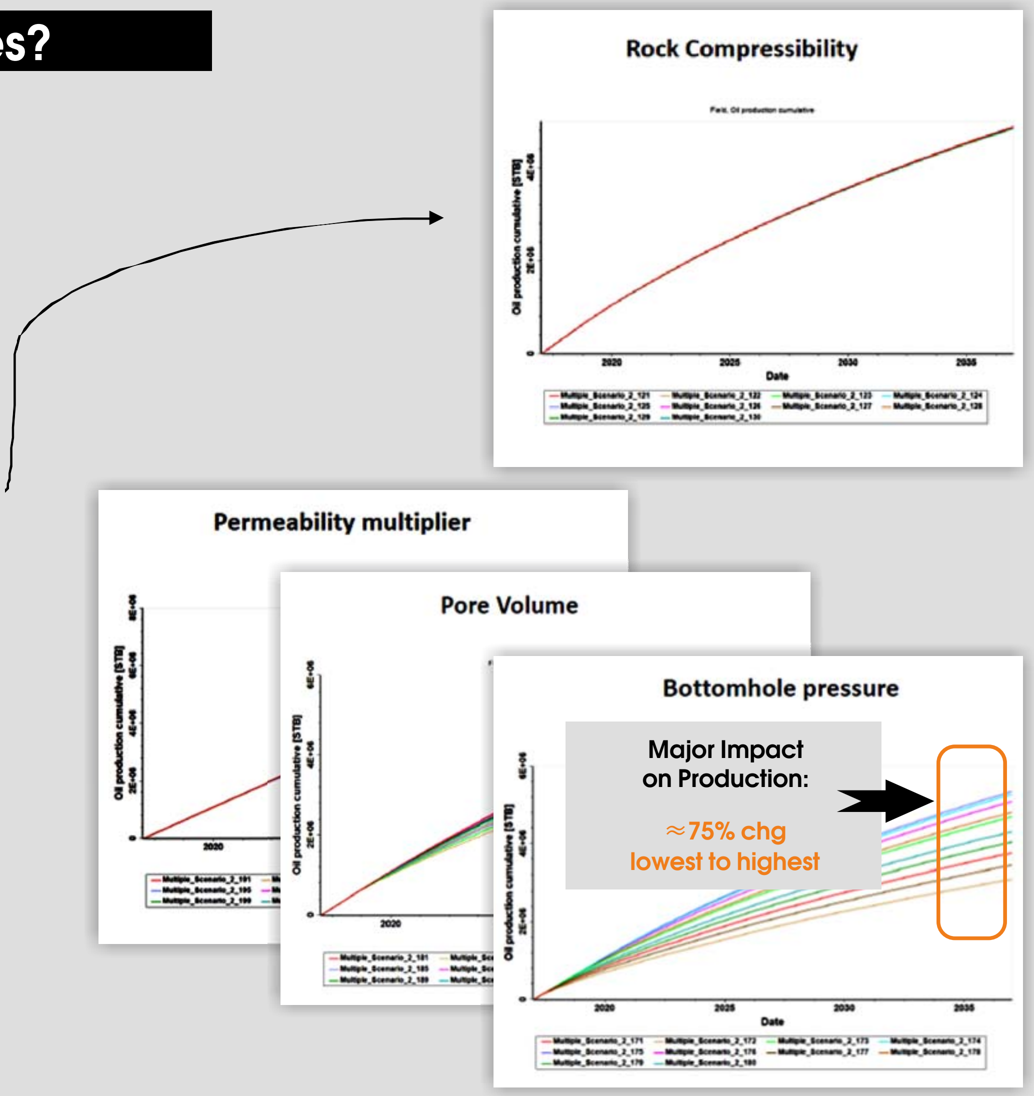
  the 3 P's make "all the difference":

  ✓ Permeability has a big impact

  ✓ Porosity even more-so; and,

  ✓ Pressure (drive) is key

  And, each one's impact far exceeds that of the lateral length (prior slide)



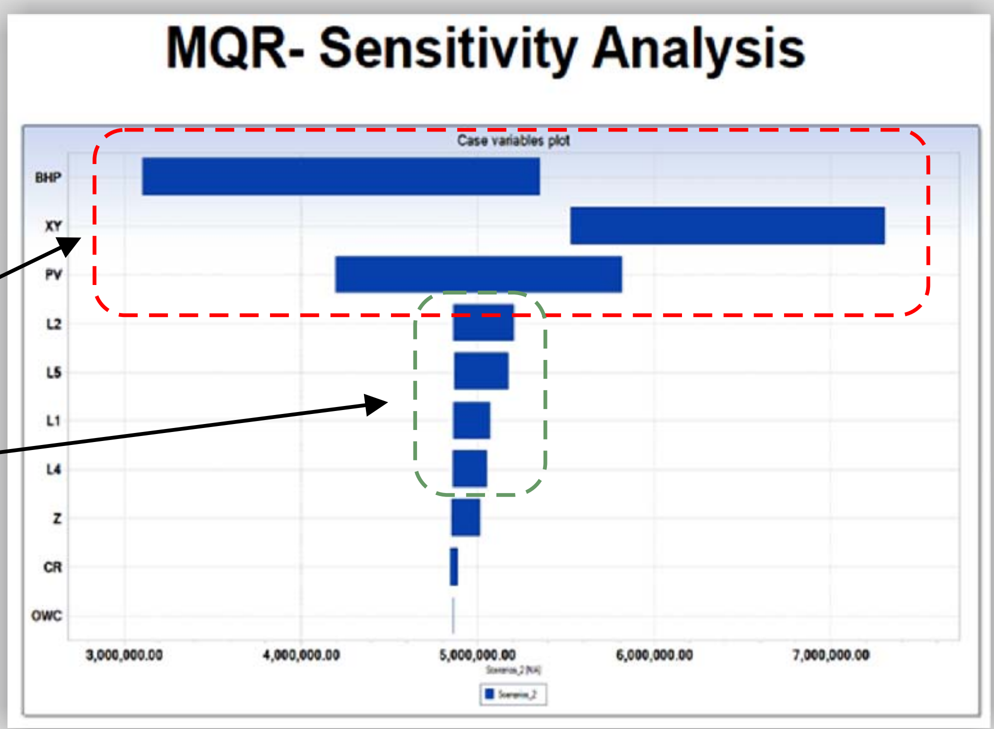
Summary:

Comparative Impact of Each Variable

Key Points:

- The "trinity" are: **Pressure, Porosity & Permeability** (**PPP**)
- Basically, they "make or break" the well
- Lateral length has an impact… but it is modest
- So, select wells with good **PPP** values, as these ultimately…

Drive the Outcome!



Conclusions

For Medium Quality Reservoirs (MQR)

- Radial Drilling can have a dramatic impact on cumulative oil production over the life of a well
- Longer radials are helpful, but not nearly as important as certain other factors
- Reservoir factors can swing results widely, with…
- Permeability, Porosity & Pressure being the key drivers.
- The success of any radial drilling program will be heavily-driven by the quality of the wells selected