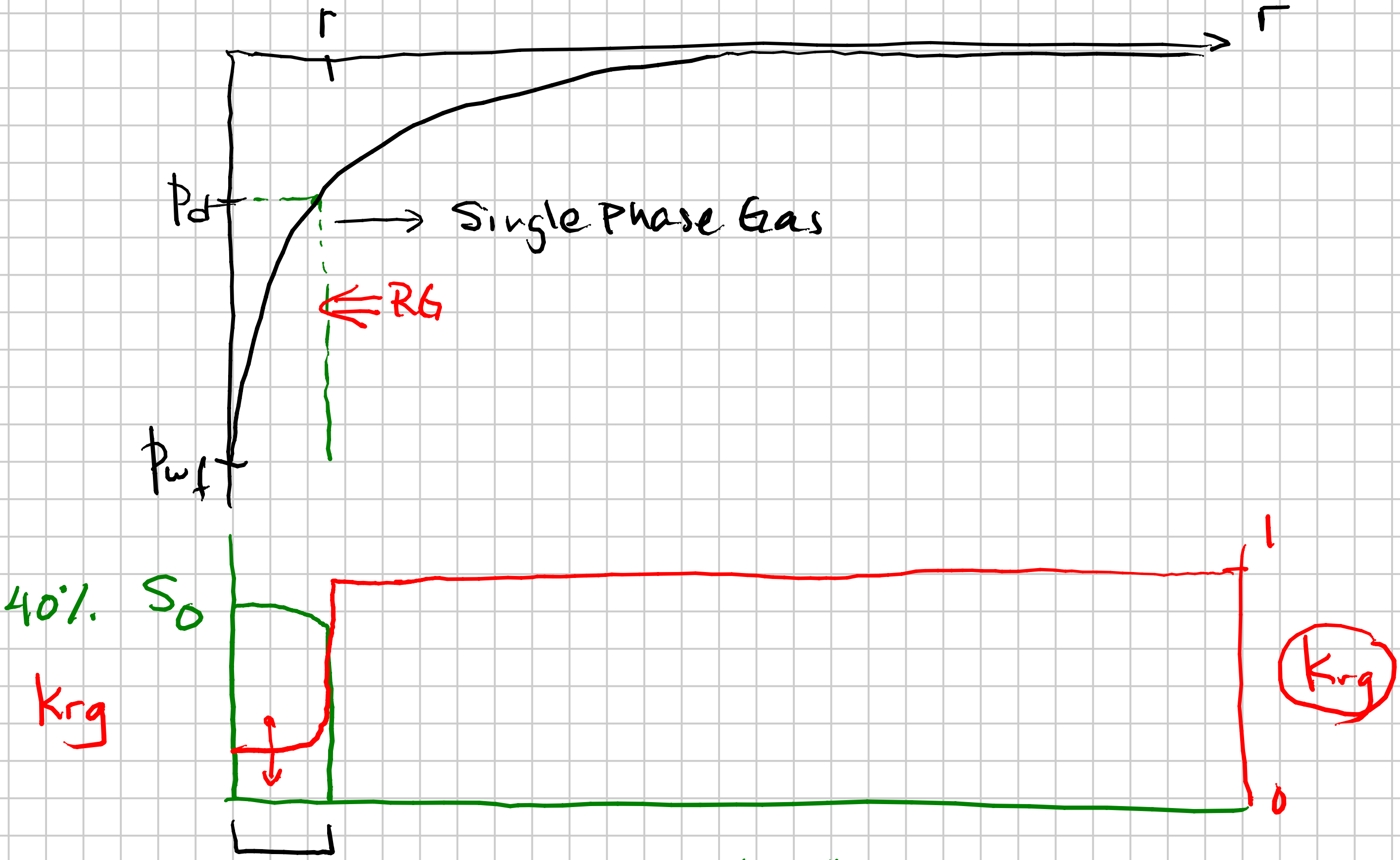
Note Title 11/20/2007

GAS CONDENSATE

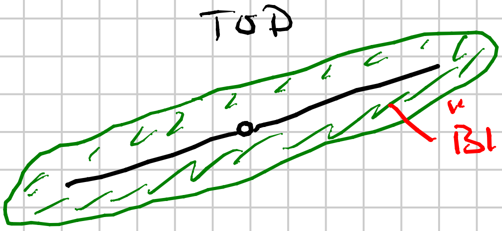
p_{wf} (BHFP) $<$ p_d



Blockage Region ⇒ "S_D" ~ +5 → +50

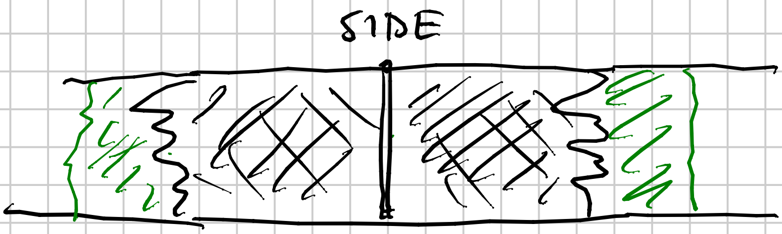
Radial, Vertical Well

Stimulation/Fracturing



+

"Blockage" → Reduced krg

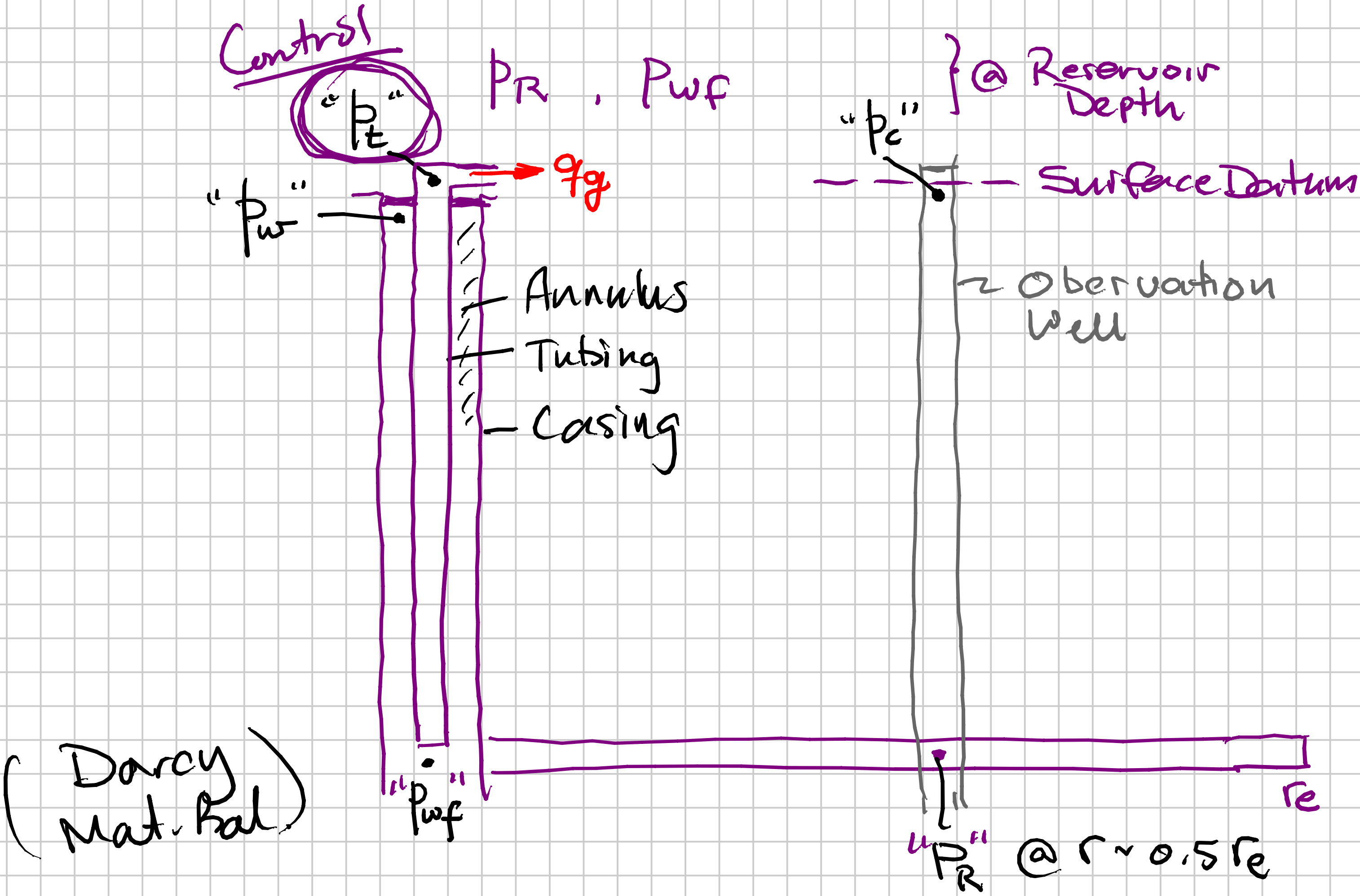


Composite Effect Stim + Blockage

$$S_t \sim 0$$

Pressures p_c, p_w, p_t } @ Surface Datum

p_R, p_{wf} } @ Reservoir Depth



Static Gas Column

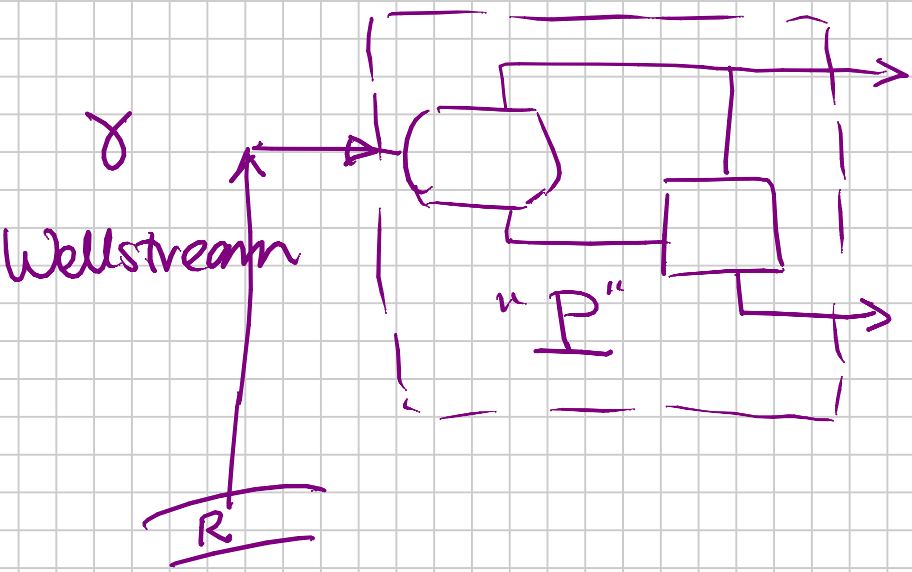
$$\frac{dp}{dz} = \rho g \Rightarrow \rho g = \underbrace{\left(\frac{M}{\bar{z}\,T\,R}\right)}_{\sim \text{const.}} \cdot p$$

$$\Rightarrow \left(\frac{p_{Reservoir}}{p_{surface}}\right)_{\text{Static Gas Column}} = \text{const} = \underbrace{e^{S/2}}_{\sim 1.1-1.4}$$

S ("static") : $\text{TVD}, \overset{\gamma_g}{M_g}, \bar{z}, \bar{T}$

$\int_0^{\text{TVD}}$ $\quad$ $\bar{T} \to$ K or R

Wellstream Specific Gravity



$(\bar{\gamma}_g)_{sp} = 0.75$

$1\ \text{MMscf} = V_{\bar{g}}$

$135\ \text{STB} = V_{\bar{o}}$

Condensate

$55\ °\text{API}$

γ_{API}

$$CGR_i = \frac{135}{10^6} = 135\ \frac{\text{STB}}{\text{MMscf}}$$

$$\gamma_o = \frac{141.5}{131.5 + \gamma_{API}}$$

Ch. 3:

$$\gamma_w = f(\bar{\gamma}_g, \underset{\to \gamma_o}{\gamma_{API}}, CGR, M_o)$$

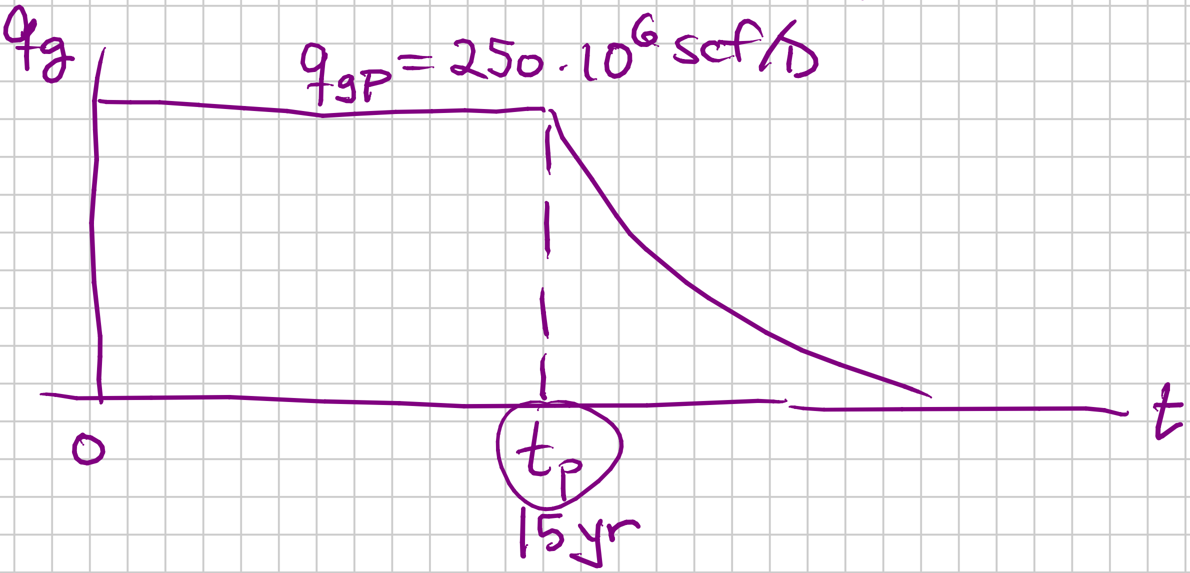
$$\gamma_w = \frac{1}{28.97} \cdot \frac{\left[10^6\,\cancel{\text{scf}} \cdot \frac{\text{lbmol}}{379\,\cancel{\text{scf}}} \cdot \overset{\text{lb}/\text{lbmol}}{28.97}(0.75)\right] + \underbrace{\left[135\,\cancel{\text{bbl}}\,\overset{\gamma_w\ \text{lb}/\cancel{\text{ft}^3}}{(62.4)}(0.759)\left(\frac{5.615\,\cancel{\text{ft}^3}}{\cancel{\text{bbl}}}\right)\right]}_{m_o}}{(10^6/379) + m_o/M_o}$$

$$C_{og} = \left(\frac{m_o}{M_o}\right) 379 \qquad \text{per bbl}$$

$$= \frac{1\ \text{bbl}\ (62.4)(0.759)(5.615)}{124} \cdot 379$$

$$= \underbrace{62.4(5.615)(379)}\ \frac{\gamma_o}{M_o}$$

End Plateau Target Recovery

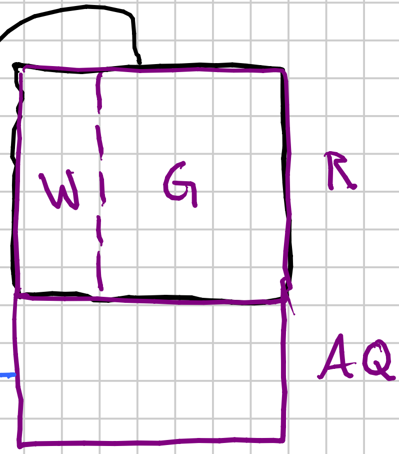


$$\left[\frac{(G_p)_{t_p}}{G}\right]_{\%} = \frac{q_{gp} \cdot t_p}{G} \cdot 100$$

G: $3 \cdot 10^{12}$ scf

$$M \equiv \frac{V_{AQ}}{V_{PR}}$$

Pore Volume of Rock
Containing Gas



Given $\frac{V_{AQ}}{HCPV} = 2 = \frac{V_{AQ}}{V_{PR}\cdot(1-S_w)}$

$$M = 2\cdot(1-S_w)$$
$$= 2(1-0.3)$$
$$= 1.4$$

Economics Issues in Project

① REVENUE (INCOME)

r – Rate q_g q_o (Annual)
R – Cumulative $\int q\,dt$
– Price P_g P_o (assuming no change in time)

$$r = q_g \cdot P_g + q_o P_o$$

$P(t)$? Forecasting $\pm$

② COSTS

c = annual (OPEX – Operating Expenses)
C = cumulative $\int c\,dt$

$$c = f(P)$$
$$c(t) = f(P(t))$$

Control Variables "V"
→ d_T
→ P_{tmin}
✓ Well type (U, S)

$C(V)$ Complex

Model is often "empirical"

! may be part of "Platform" cost

Platform
Pipeline
Wells
{ Compression
Processing P }

Taxes (Royalties)
Bank Interest

3 Net Revenue (Profit)

Sell

$$P = R - C$$

$$p = r - \{c - tr\} \quad \text{annual}$$

4 Time value of money

Discount Factor DF

~0.1 (close to business interest for loans)

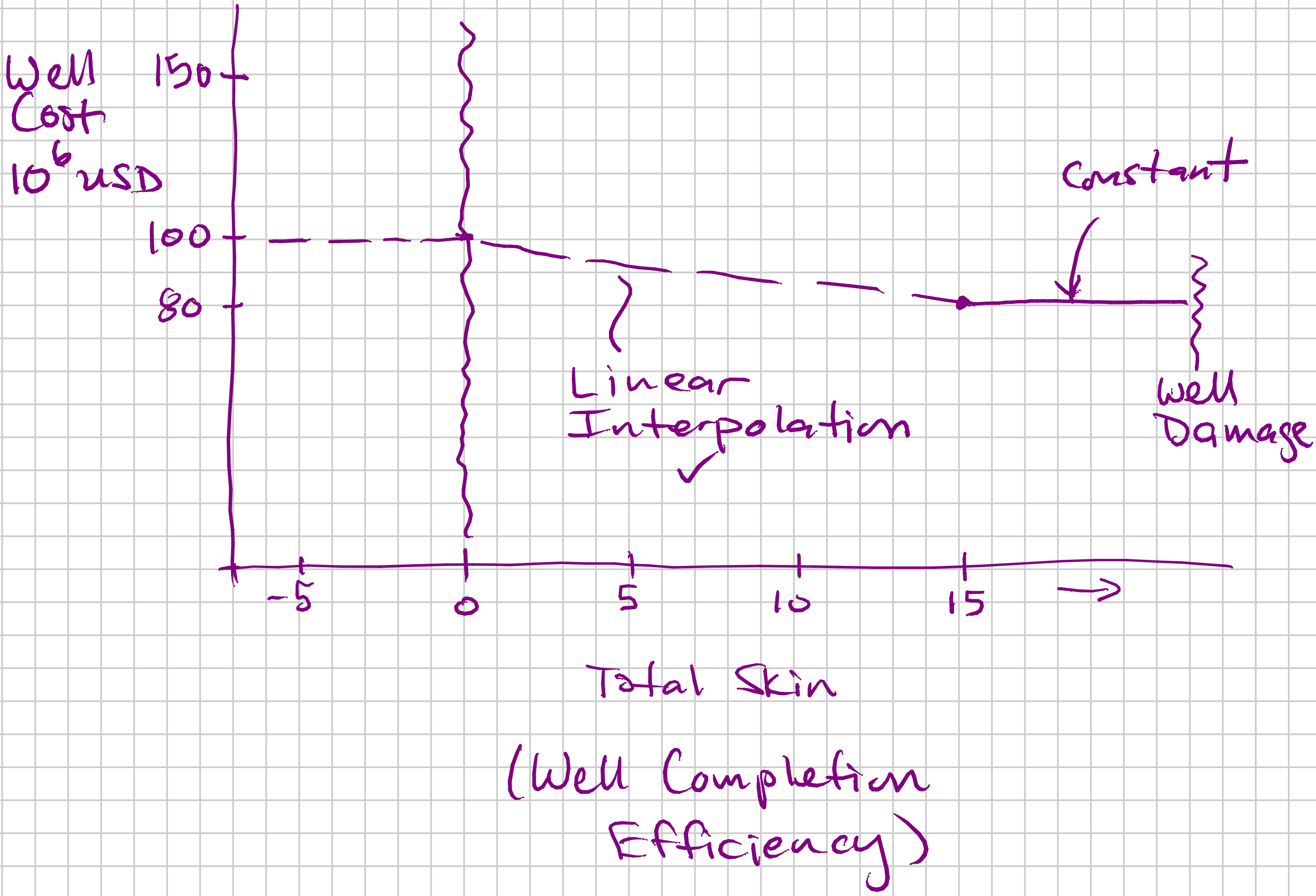
0.05–0.15

Year	Value 10^9\$ p(bUSD)	NPV p "today"
→ 0	1	
1	1	1/1.1 P/(1+DF) ~0.9
2	1	P/(1+DF)/(1+DF) ~0.8
3	1	⋮
4	1	
5	1	
⋮		
10	1	
~~20~~	~~1~~	
~~50~~	~~1/50~~	

$$\frac{P(t)}{[1+DF]^t}$$

$$\frac{10^9\ \$}{(1.1)^{50}} \simeq 10 \cdot 10^6\ \$$$

Curtis thinks it is BS



Well Cost
10^6 USD
150
100
80
Constant
Linear Interpolation
Well Damage
-5
0
5
10
15
Total Skin
(Well Completion Efficiency)

Project:

Optimize the field development strategy

Maximize NPV

Without proper NPV (V)

d_T $\quad p_{t\,min}$ $\quad$ skin

Engineering Approach

d_T selection

Minimize Δp_t : $\{p_w - p_t\}_{friction}$

$$\Delta p_t \sim \Delta p_R \qquad (p_c - p_w)$$

$p_w - p_t$

UPDATE in defining "optimal" Production Strategy:

$$\boxed{\frac{p_w - p_t}{p_c - p_t} = 0.05}$$

This condition "minimizes" to a realistic value (5%), the % of total well pressure drop $(p_c - p_t)$ in the tubing $(p_w - p_t)$.

For optimization with SOLVER, use this constraint at $t_{plateau} = 15$ yr.

Also, assume maximum $d_t = 7''$ as this is the basis for the base well cost of $\$80 \cdot 10^6$.

$d_T = 12''$ for a reservoir high (kh)

Work on a "new" well-cost model

$d_T \sim 4''$ Lower kh

NPV = 4.6 bUSD