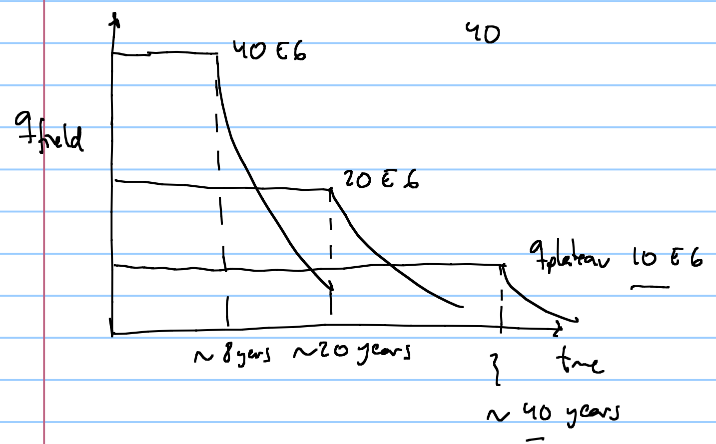
Menu : • Quick go-through exercise set "1"

• Networks (surface and downhole)

Exercise set 1

$q_{plateau}$ field $[10^6\ Sm^3/d]$	N_{well}
10	4
20	6
30	9
40	12

16 cases/combinations to run



• 15-25 years gas contract

• rule of thumb for plateau rate for gas field

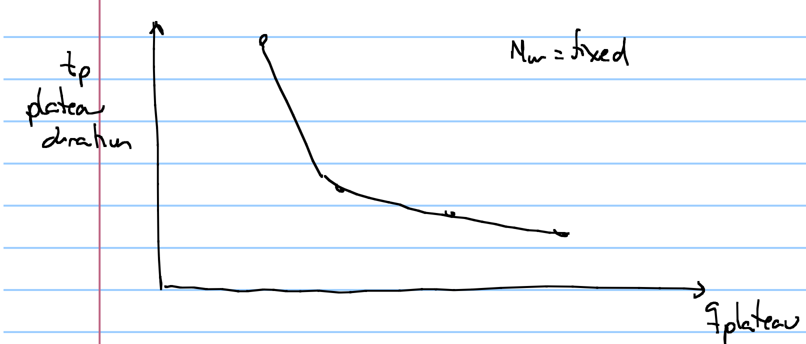
(2.5 - 5%) G_{pu} $G = 270\ E9\ Sm^3$

$RF = 0.5$

$G_{pu} = 135\ E9\ Sm^3$

$$q_{plateau\ 2.5\%} = \frac{135\ E9 \cdot 0.025}{365 \cdot 0.95} = 10\ E6\ Sm^3/d$$

$$q_{plateau\ 5\%} = 20\ E6\ Sm^3/d$$



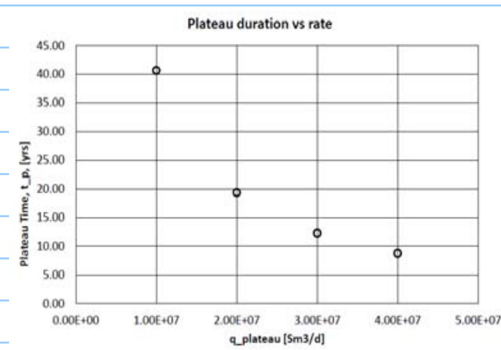
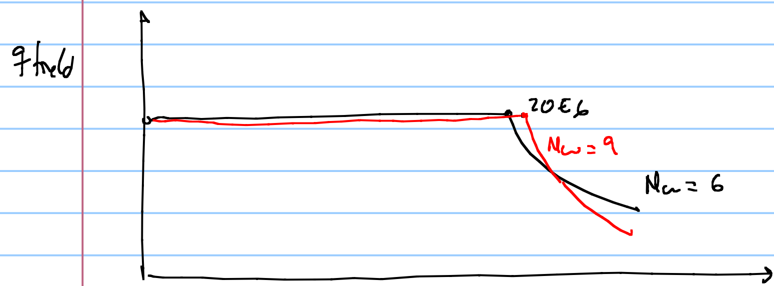
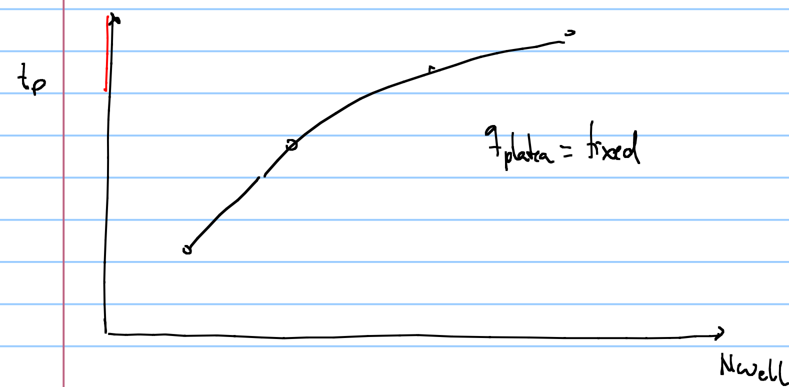
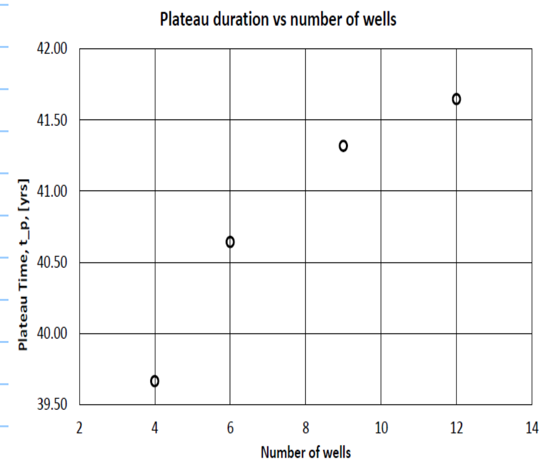


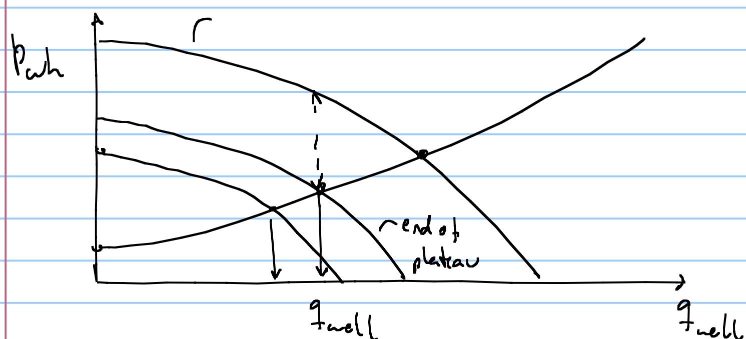
Table 1.1: Overview of simulation cases

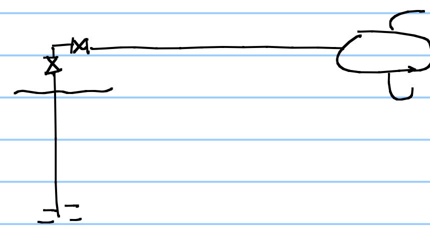
N_{wells} [-]	q_{g_field} $[E^6 \frac{Sm^3}{d}]$	t_p [years]	RF [-]	t_t [years]	$q_{g,well,max}$ $[\frac{Sm^3}{d}]$	NPV [USD]
4	10	39.66	0.528	41.46	2.5E^6	4.88E^9
4	20	18.44	0.528	21.80	5.0E^6	7.81E^9
4	30	11.43	0.528	15.65	7.5E^6	9.41E^9
4	40	7.97	0.528	12.668	1.0E^7	1.04E^{10}
6	10	40.64	0.535	41.794	1.67E^6	4.89E^9
6	20	19.36	0.535	21.525	3.33E^6	7.86E^9
6	30	12.29	0.535	14.915	5.0E^6	9.49E^9
6	40	8.78	0.535	11.765	6.67E^6	1.05E^{10}
9	10	41.315	0.539	41.978	1.11E^6	4.9E^9
9	20	19.98	0.539	20.993	2.22 E^6	7.89E^9
9	30	12.89	0.539	14.408	3.33E^6	9.55E^9
9	40	9.368	0.539	11.13	4.44 E^6	1.06E^{10}
12	10	41.645	0.542	42.27	8.33E^5	4.90E^9
12	20	20.32	0.542	21.282	1.67E^6	7.91E^9
12	30	13.222	0.542	14.294	2.50E^6	9.58E^9
12	40	9.67	0.541	10.82	3.33E^6	1.06E^{10}

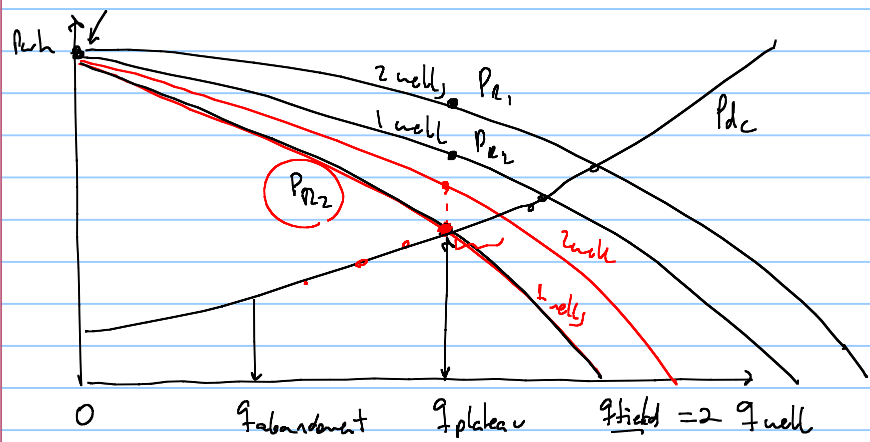


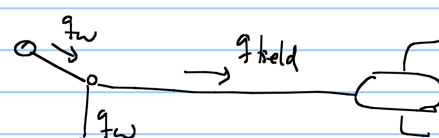










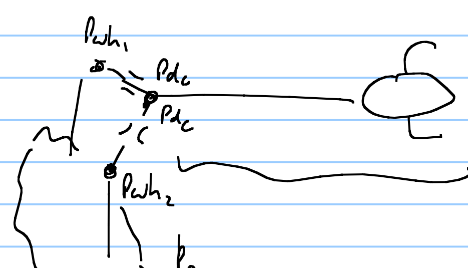


$$q_w = \frac{q_{field}}{2}$$

q_{field} = const

$$q_g = C\left(P_R^2 - P_{wf}^2\right)^n$$

$$q_g = C_T\left(\frac{P_{wf}^2}{e^s} - P_{wh}^2\right)^{0.5}$$



$$p_{wf} = \left(p_R^2 - \frac{q_{\bar{g}}}{C}^{1/n} \right)^{0.5}$$

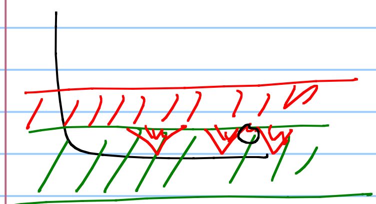
$$p_{wh} = \left[\left[p_R^2 - \left(\frac{q_{\bar{g}}}{C} \right)^{1/n} \right] \frac{1}{e^s} - \left(\frac{q_{\bar{g}}}{C_T} \right)^2 \right]^{0.5}$$

if 1 well $q_{\bar{g}} = q_{field}$ p_{wh_1}

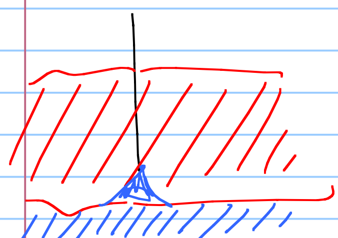
if 2 well $q_{\bar{g}} = \frac{q_{field}}{2}$ p_{wh_2}

$p_{wh_1} < p_{wh_2}$

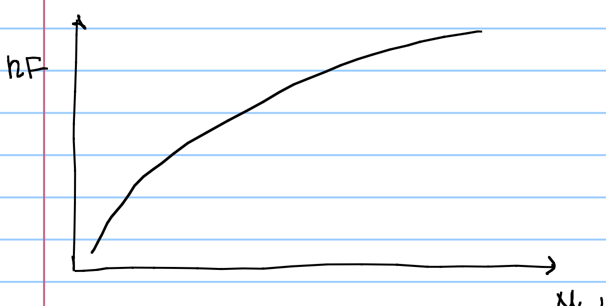
N_w is fixed, RF vs $q_{plateau}$? No change. for a fixed number of wells $q_{field} = 5\ E6\ Sm^3/d$ is reached at the same p_R^* and p_R^* for MB $f(G_p)$

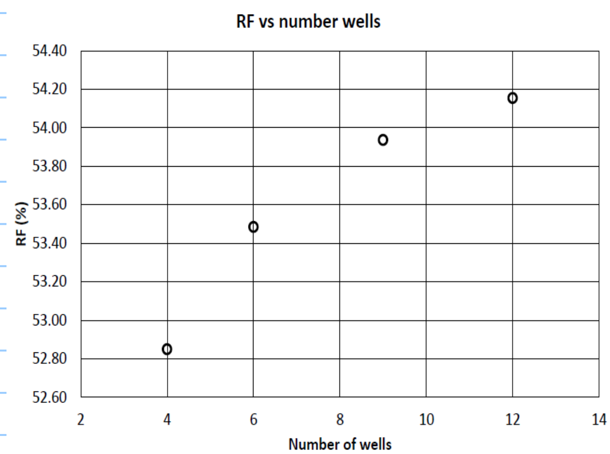


- gas coning
- reduced productivity
- water/aquifer breakthrough



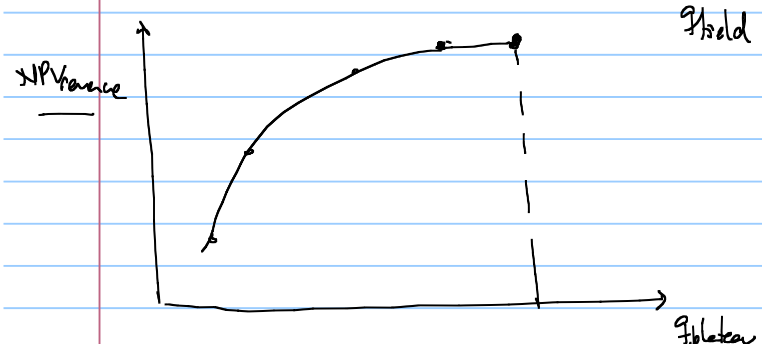
RF vs. Nw

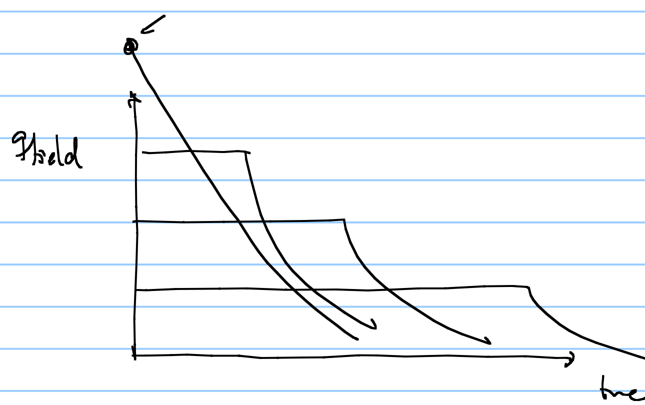




NPV

$NPV_{revenue}$ vs. plateau rate





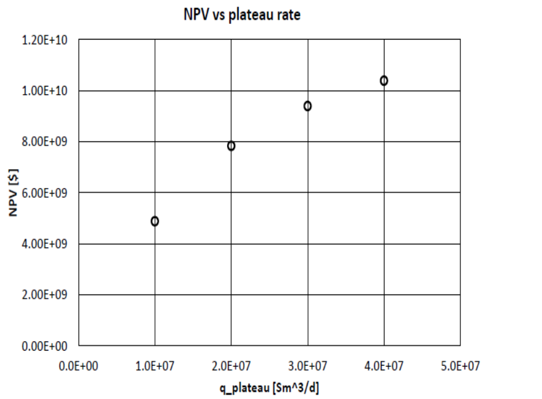


Figure 1: Economic evaluation as a function of plateau flow rates with 1E7 Sm3/d plateau rate

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NPV revenue vs Nwells

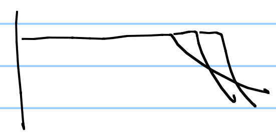
Nw	NPV [E9 USD]	
4	7.81	
6	7.86	-200 E6 = 0.2 E9 USD
9	7.89	-500 E6 = 0.5 E9 USD
12	7.91	-800 E6 = 0.8 E9 USD

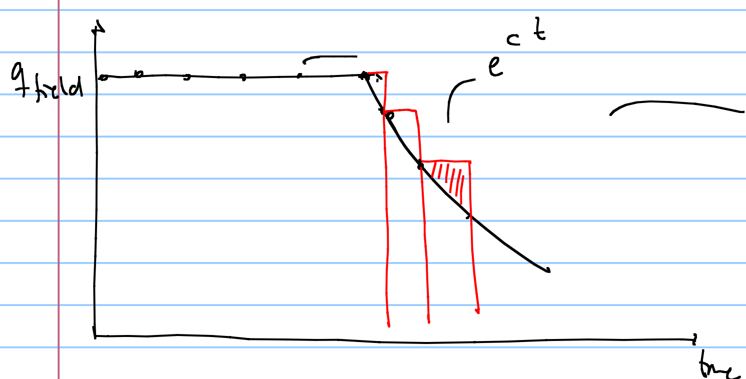
Cost per well is 100 E6 USD

Nw	NPV [E9 USD] (considering driller)
4	7.81
6	7.66
9	7.39
12	7.11

In this cases doesn't make sense to drill more wells to produce the same plateau!

the additional and early production we get does not compensate for the cost!

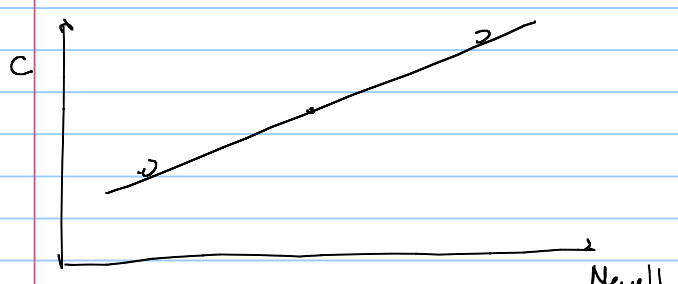




trapezoidal rule $\frac{q_{i-1}+q_i}{2}(t_i - t_{i-1})$

assume q_i → G_p → P_R → q_i^* → same → solution

not



$q_{field} = q_{plateau} \cdot e^{m(t-t_p)}$ post-plateau

$q_{field} = q_{plateau}$

$t_p = \left(\frac{q_{ppo}}{q_{plateau}} - 1 \right) \frac{1}{m}$

$m = N_w \cdot A \cdot J$

$q_{pp} = \underset{\sim}{-m}\, G_p + \underbrace{q_{ppo}}_{\sim N_w}$

$A = f\left(\frac{1}{N}\right)$

initial oil in place

this development is NOT valid for dry gas.

for dry gas:

$$p_R = \frac{Z_R \cdot p_i}{Z_i} - \frac{Z_R \cdot p_i}{Z_i \cdot G} \cdot G_p$$

Neglecting downstream bottom-hole:

Maximum field production

$$q_f = N_w \cdot C \cdot (p_R - p_{wf,min})^n$$

$$\left(\frac{q_f}{N_w \cdot C}\right)^{\frac{1}{n}} + p_{wf,min} = p_R$$

Substituting in the material balance equation

$$\left(\frac{q_f}{N_w \cdot C}\right)^{\frac{1}{n}} + p_{wf,min} = \frac{Z_R \cdot p_i}{Z_i} - \frac{Z_R \cdot p_i}{Z_i \cdot G} \cdot G_p$$

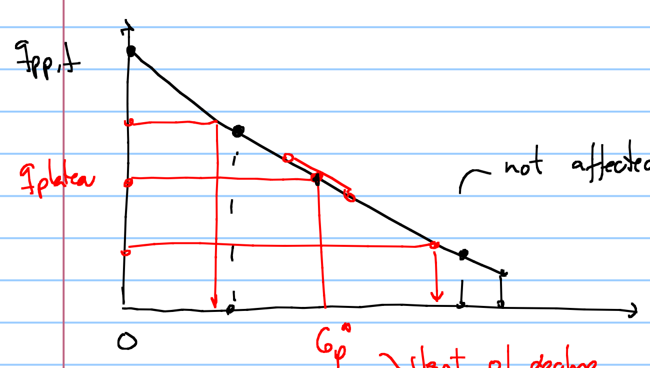
solve this!

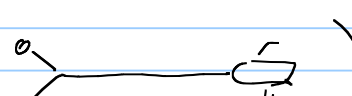
BUT surprisingly we find the decline is exponential and e^{ct} the coefficient depends on Nw

a big subsea dry gas well might produce 3E06 Sm³/d

- coning
- sand production / hole integrity
- erosion in tubing (tubing size) (9")

Using field production potential

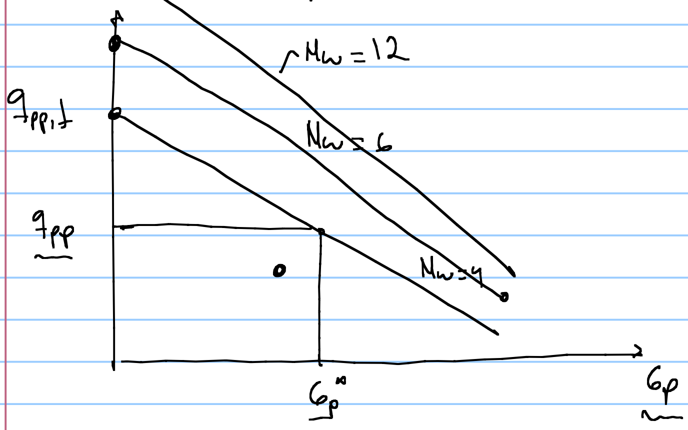


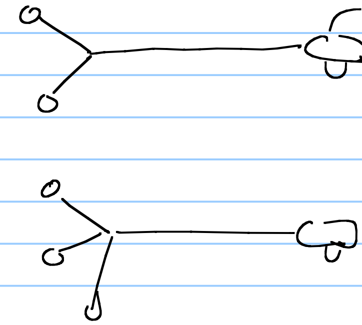


not affected by plateau rate (is the same production system)

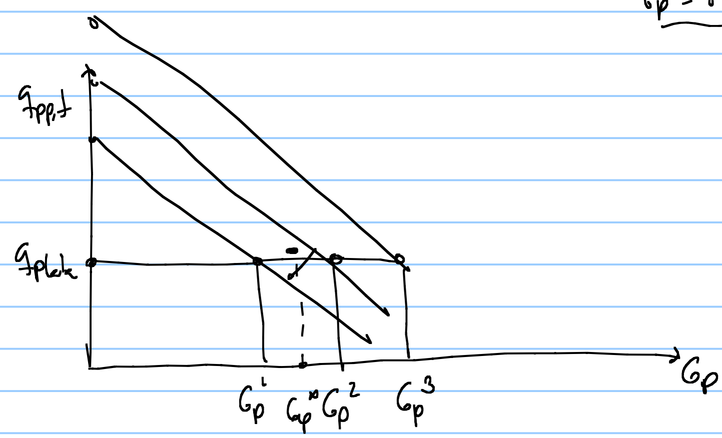
$t_p = \frac{G_p^*}{q_{plateau} \cdot \frac{N_{day}}{year}} =$

field production potential with M_w





Problem 2 of exercise set 2 $\left.\begin{array}{l} q_{plateau} \\ t_p = 8 \text{ years} \end{array}\right\}$ G_p^*



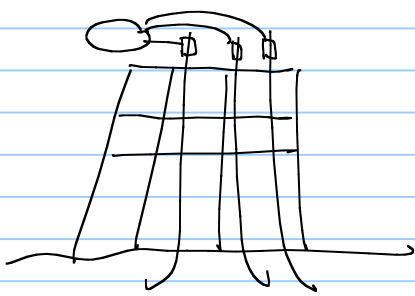
if $G_p^1 > G_p^*$

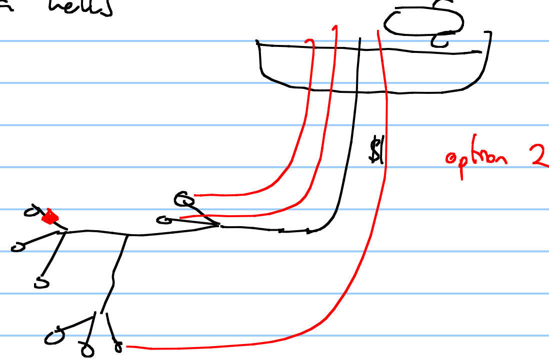
$q_{plateau} \cdot t_p > G_p^*$

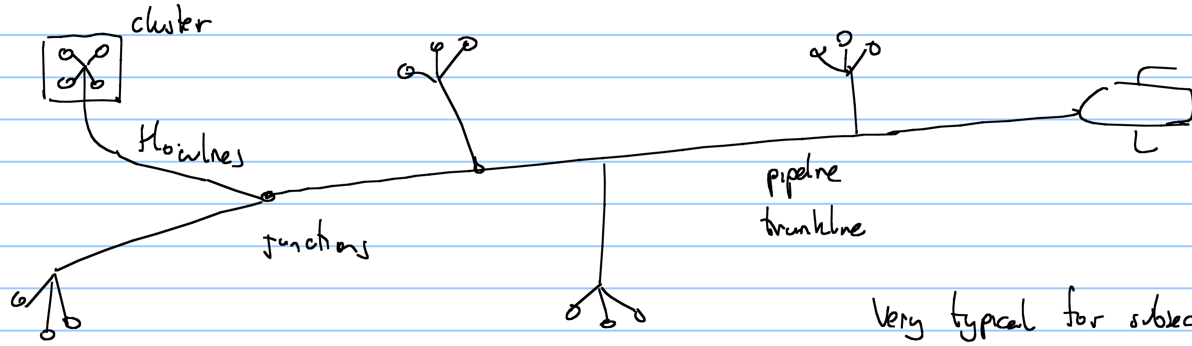
$> q_{plateau} \cdot t_p^{desired}$

Network System of pipes that commingle, gather production from several well and take it to processing facilities

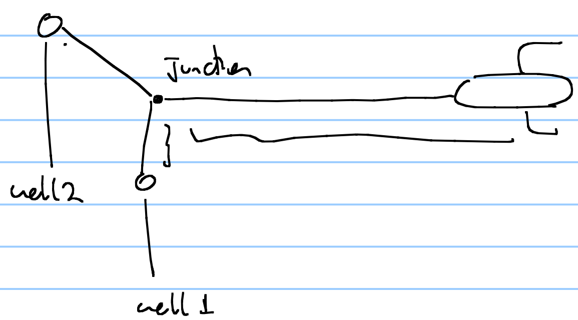
Subsea wells







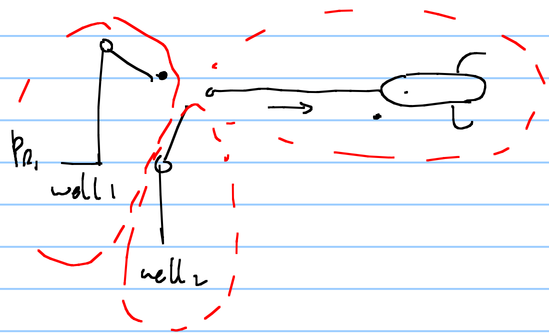
Very typical for subsea wells

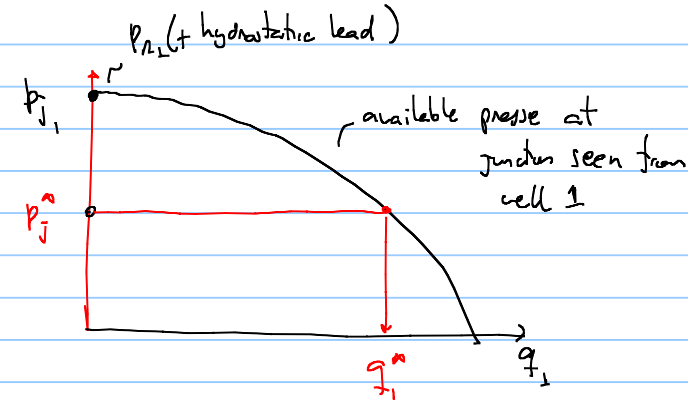


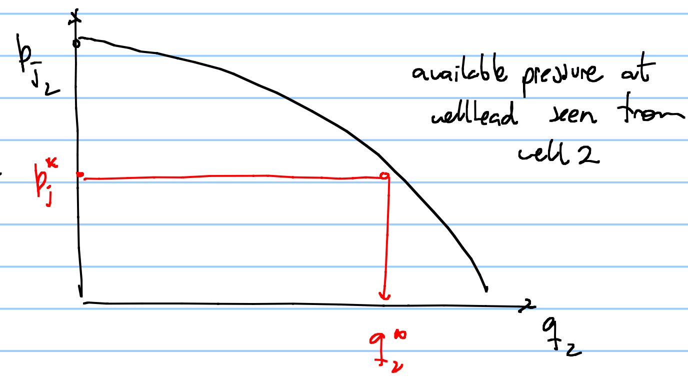
dry gas network.

X-mas trees of 1 and 2 are very close to junction

		Nr. Unknowns	Nr. equations
IPR 1	$q_1 = C_1 \left(P_{R_1}^2 - P_{wf_1}\right)^n$	2	1
TPR 1	$q_1 = C_{T_1}\left(\frac{P_{wf_1}^2}{e^{S_1}} - P_{wh_1}^2\right)^{0.5}$	1	1
IPR 2	$q_2 = C_2\left(P_{R_2}^2 - P_{wf_2}^2\right)^n$	2	1
TPR 2	$q_2 = C_{T_2}\left(\frac{P_{wf_2}^2}{e^{S_2}} - P_{wh_2}^2\right)^{0.5}$	1	1
pipeline	$q_1 + q_2 = C_{PL}\left(P_J^2 - P_{sep}^2\right)^{0.5}$	1	1
proximity	$P_{wh_1} = P_J$		1
	$P_{wh_2} = P_J$		1
		7	7







if no choke $p_{j_1} = p_{j_2} = p_j$

Assume p_j^* → read q_1^*

→ read q_2^*

→ read q_f^*

$q_1 + q_2 = q_f$ mass balance at junction

is $q_1^* + q_2^* = q_f^*$

no

yes

solution :)