PROBLEM 1 (40 POINTS): Estimation on the required number of wells for the Slagugle oil reservoir in the Norwegian Sea.

The offshore oil reservoir Slagugle consists of one main reservoir. The reservoir will be produced via a pipeline to the Heidrun TLP. The reservoir will be produced in plateau mode. The oil production potential of the reservoir can be estimated with following expression:

$$q_{pp} = e^{-5\cdot\left(\frac{N_p}{N}\right)} \cdot q_{ppo.well} \cdot N_{prod,wells}$$

- $N_{prod,wells}$ is the number of producers in the reservoir
- $q_{ppo,well}$ is the maximum rate of oil produced by one well at initial time, [Sm^3/d]
- N_p is cumulative oil production from the reservoir [Sm^3]
- N is initial oil in place in the reservoir [Sm^3]

The following data is provided:

$q_{ppo.well}$ [1E03 Sm^3/d]	6
N [1E06 Sm^3]	80

1. It is desired that the field will produce a reservoir plateau rate of 10 000 Sm3/d for at least 4 years. Determine the required number of wells needed to achieve this.
2. The values of $q_{ppo,well}$ and N are highly uncertain. Experts have estimated that they vary within the range described below.

	min	max
$q_{ppo.well}$ [1E03 Sm^3/d]	4	8
N [1E06 Sm^3]	64	96

   Considering these uncertainties, and using a conservative approach, determine the number of wells needed to ensure the reservoir delivers a reservoir plateau rate of 10 000 Sm3/d for at least 4 years.
3. Consider that the $q_{ppo.well}$ and N are normally distributed with the mean and standard deviation presented in the table below:

	mean	Standard deviation
$q_{ppo.well}$ [1E03 Sm^3/d]	6	1
N [1E06 Sm^3]	80	10

a) Considering these uncertainties, calculate the pdf and cdf of number of wells that guarantee a plateau duration of 4 years with a plateau rate of 10 000 Sm3/d.
b) Based on the results of a), Determine the number of wells for which 90% of the cases required that number of wells or less to achieve a 4 year plateau (P90 on the cdf).

Recommendations and suggestions

- Assume a year has 355 operational days
- To solve task 3, you can perform a Monte Carlo simulation with 100 iterations

- To calculate the inverse of a normal CDF, use the built-in Excel VBA function NORM.INV(probability, mean, standard_dev). Remember that to make the Monte Carlo simulations, the variable "probability" must be a random number between 0 and 1. The random number between 0 and1 can be calculated with the Excel VBA function RAND()

Solution:

Plateau ends when the production potential of the field is equal to the plateau rate

$$q_{pp} = q_{plateau} = e^{-5\cdot\left(\frac{N_p^*}{N}\right)} \cdot q_{ppo.well} \cdot N_{prod,wells}$$

Clearing out Np*

$$\frac{q_{plateau}}{q_{ppo.well} \cdot N_{prod,wells}} = e^{-5\cdot\left(\frac{N_p^*}{N}\right)}$$

$$ln\left(\frac{q_{plateau}}{q_{ppo.well} \cdot N_{prod,wells}}\right) = -5 \cdot \left(\frac{N_p^*}{N}\right)$$

$$ln\left(\frac{q_{ppo.well} \cdot N_{prod,wells}}{q_{plateau}}\right) \cdot 5 \cdot N = N_p^*$$

The plateau duration, in years, is calculated by:

$$t_{plateau} = N_p^* \cdot \frac{1}{q_{plateau}} \cdot \frac{1}{t_{uptime}}$$

$$t_{plateau} = ln\left(\frac{q_{ppo.wells} \cdot N_{prod,wells}}{q_{plateau}}\right) \cdot \frac{N}{5 \cdot q_{plateau}} \cdot \frac{1}{t_{uptime}}$$

If $t_{plateau}$ and $q_{plateau}$ are given, The number of wells required is then

$$N_{prod,wells} = \frac{q_{plateau} \cdot e^{\frac{t_{plateau}\cdot 5 \cdot q_{plateau}\cdot t_{uptime}}{N}}}{q_{ppo.wells}}$$

The number of wells should always be an integer, therefore the expression above must be always rounded up.

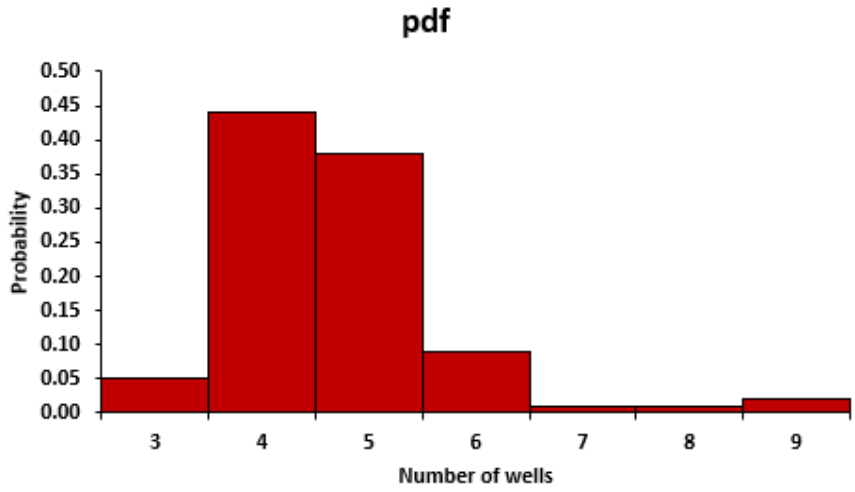
Q1:
With the input, one obtains $N_{prod,wells}$ = 4.05, i.e. at least 5 wells are needed.

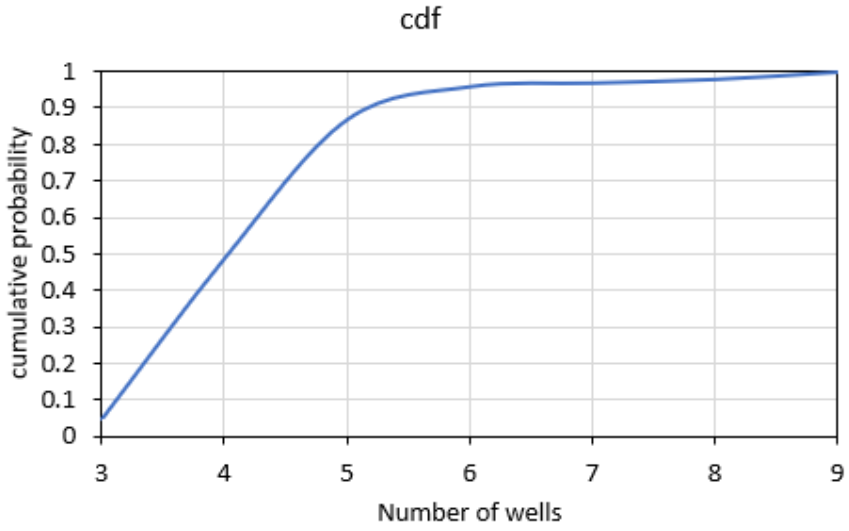
Q2:
The worst-case scenario is a small reservoir and wells with poor productivity, therefore:

$q_{ppo.well}$=4000 Sm3/d

N [1E06 Sm^3] = 64
With the input, one obtains $N_{prod,wells}$ = 7.58, i.e. at least 8 wells are needed.

Q3:
We perform a MC simulation with 100 iterations
We obtain the following pdf:





We enter in the cdf with 0.9, and read Nwells = 5.25. Rounding up, this means that 90% of the cases simulated required 6 wells or less to achieve the required plateau duration.