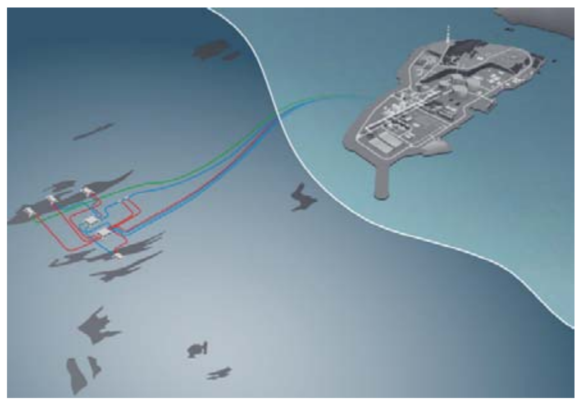
Exercise set 02 (DRAFT)

PROBLEM 1: Production scheduling calculations for the Snøhvit field

Snøhvit is an offshore gas field located in the Barents Sea 158 km from Hammerfest. The field will be developed with the "subsea to beach" concept. The gas production will be processed in a LNG plant on Melkøya (a nearby island) and transported further in LNG carrier to customers in US and Spain.

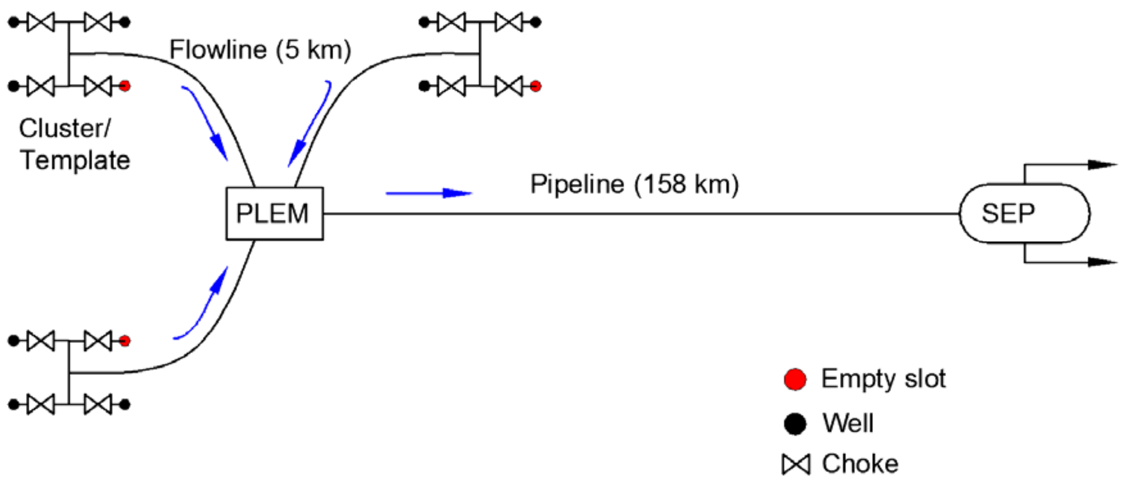


According to the base case Scenario (BCS) selected for the study, the field is completed subsea with subsea templates, each with 4-well slots. Typically, only three wells are completed in each template (there is one slot is for redundancy). The templates will be symmetrically positioned at 5 km away from the subsea Pipeline Entry Module (PLEM). Each template is connected by flow line to the PLEM where the production streams of all the templates are commingled (combined and mixed). The PLEM is on the seabed approximately 158 km from shore and is connected by the main field export pipeline to the slug catcher (separator) on shore.

Assume all the wells are identical (in completion, depth and productivity and all other design and operation parameters) and produce from the same reservoir (tank model).

Your main task is to determine the number of wells and field plateau rate that give maximum economic value. To decide, you have to compute the net present value of the project at abandonment.

For the best case, you should make a sensitivity analysis on the gas price (+-20%), the CAPEX of the LNG plant (+-20%). Present your results in a tornado chart or using a spider plot.



Field layout when using 9 wells.

Guidelines, requirements and useful information

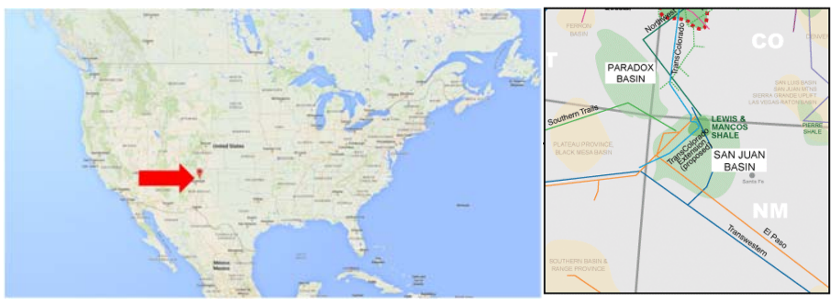
- To calculate revenue, you should compute the production profile until abandonment (field rate of 5 E06 Sm^3/d). To compute the production profile you have to use flow equilibrium calculations. Due to the fact that wells are identical, and if the system is symmetric, it is possible to perform flow equilibrium by looking at the path: well (formation), well (tubing), flowline and pipeline, but using different rates (i.e., well rate, template rate, and field rate, correspondingly). The recommended equilibrium point is the wellhead. (upstream and downstream the choke).
- Use the pre-programmed VBA functions to calculate flow in tubing, pipeline and flowline (VBA function linep1 or line p2), for the dry gas material balance, for the Z factor and for the IPR.
- It is recommended for you to test at least 9 cases, for example number of wells between 6-15 and plateau rates 20-35 E06 Sm^3/d. When presenting your results be crystal clear about what cases were tested.
- To avoid sand production, wells shouldn't produce more than 3 E06 Sm^3/d.
- When varying the number of wells, there should be always the same number of wells in each template (to take advantage of symmetry when doing flow equilibrium). Add and remove templates as needed.
- All wells must be drilled before production startup. The average time required to drill a well is 3 months (4 wells per year). The average cost per well (including perforating, completing, tree and well equipment) is 100 E6 USD. **Note that the number of wells affects the production startup.**
- The cost of a single subsea manifold is 20 E06 USD (to be paid during the first year of the project).
- The cost of the main transportation pipeline and umbilicals is 500 E06 USD (to be paid evenly during the first two years of the project).
- The cost of the LNG plant is a linear function of the field gas rate, expressed by $CAPEX_{LNG} = 160 \cdot q_{g,field}$ where $CAPEX_{LNG}$ is in USD and $q_{g,field}$ is the maximum rate of the field in Sm^3/d. (to be paid evenly during the first two years of the project).
- LNG carriers are needed to take the LNG production from Hammerfest to customers in Spain. Each LNG carrier has a capacity of 145,000 m^3 of LNG (equivalent to 86 E06 Sm^3 of produced gas) and can make 22 trips per year. The cost of each LNG carrier is

200 E06 USD. (to be paid evenly during the first two years of the project). Estimate the number of carriers needed depending on annual production during the plateau period.

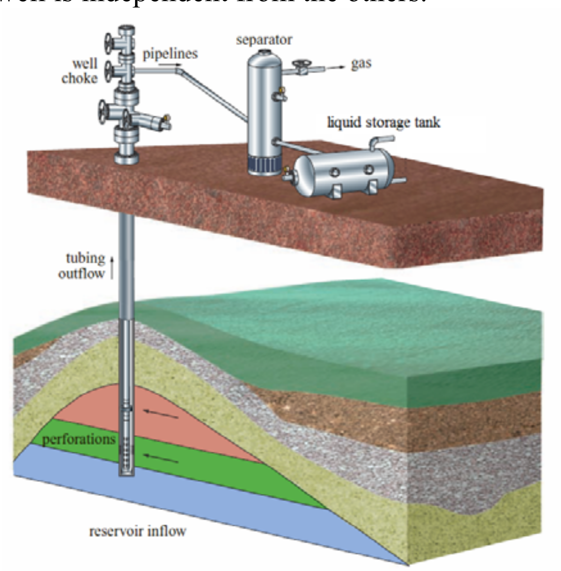
- Neglect tax and depreciation, OPEX (operational expenditures) and ABEX (abandonment expenditures).
- It is recommended you plot project NPV versus field plateau rate, for a fixed number of wells.
- It is recommended you plot project NPV versus number of wells, for a fixed field plateau.
- It is estimated you compute and report plateau duration and ultimate recovery factor for all alternatives.

PROBLEM 2: Estimation of number of wells required to meet gas contract

A family-owned company has found a small dry gas reservoir in a farm plot they own in the San Juan Basin (onshore USA). They would like to sell the gas to a local 10 MW power station located a few kilometers away. The power plant requires 80 E3 Sm^3/d of gas and at least a 5-year delivery guarantee to evaluate the proposal.



The company is planning to develop the field using multiple systems of well-choke-pipeline-separator as indicated in the figure below. The pressure of the separators is typically 4 bara. In this arrangement, each well is independent from the others.



You are the youngest son of the owner of the company currently studying a year abroad at IGP-NTNU and taking TPG4230. Your father **has asked you to estimate how many wells will they need to meet the 5 year delivery guarantee of 80E3 Sm^3/d of gas**.

The following information is available:

-Mathematical expression for single well gas production potential as a field cumulative gas production:

$$q_{pp} = -2.5320 \cdot 10^{-4} \cdot G_p + 7.0752 \cdot 10^4$$

Your tasks are:
-Estimate the minimum number of wells that have to be drilled to guarantee the supply of 80E3 Sm^3/d of gas for at least 5 years.
-Using the number of wells estimated above, calculate the full production profile (plateau+decline period) until field gas rate reaches 3E4 Sm^3/d. Plot your results.

Assumptions:
-Assume that a "year" consists of 355 operational days.
-Assume that each well behaves independently from the others.
-The field production potential can be predicted as

$$q_{pp,f} = N_w \cdot \left(-2.5320 \cdot 10^{-4} \cdot G_p + 7.0752 \cdot 10^4\right)$$