Let us speak about solid production

When a low cohesive rock is put on stream there is a high risk that solid grains are removed from the payzone and transported with the fluid to the surface. Such a process requires two main conditions. First following stress and pore pressure variations resulting from depletion, the rock damages in the vicinity of the well. This damaging phase is a necessary but insufficient condition for the well to produce solid particles. Movements of solids are triggered by hydrodynamic forces which basically depend on the fluid velocity. Therefore, this mobilisation of grains occurs almost exclusively at the borehole wall where the rock is most deteriorated and the fluid velocities are higher. The depletion level (which affects rock deterioration) but also well drawdown (which affects fluid hydrodynamics) will both play a determinant role. Solid production, even in small quantities, can generate acute operational and safety problems both in well completion and surface facilities following the rapid erosion of metal equipment such as pipes, valves or separation vessels

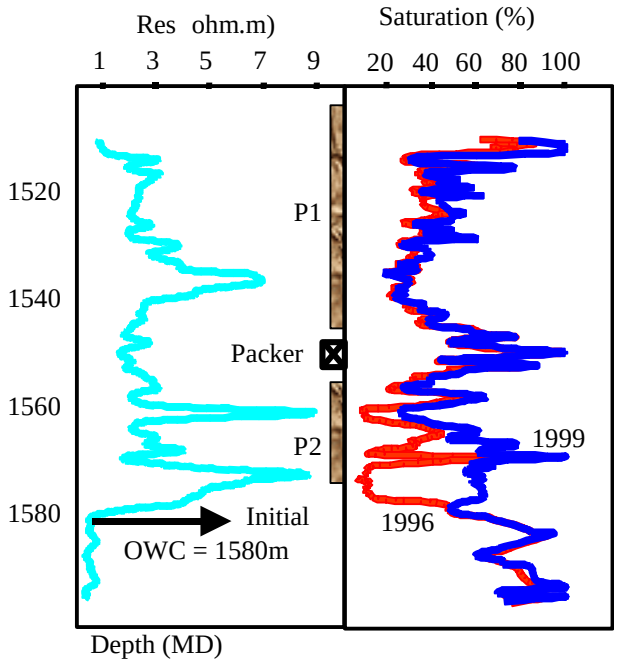

Figure 1 - Sand production and water breakthrough (North Sea)

Example: southern part of North Sea)

Although depletion and drawdown are the main driving forces of sand production, increasing water cut very often appears as a key worsening factor. Solid production just follows a water breakthrough. The weakening process is due either to rock dissolution or to capillary effects (rock cohesion resulting in small menisci between grains is destroyed when water invades the rock). Such an example is presented in **Figure 1**. The gas water contact was initially at a depth of 1580 m and three years later (1996) a saturation log showed that the water level (red line) was only a few

metres above its initial position. In contrast to this, at the beginning of 1999, a few weeks after sand production was triggered, the water level had clearly invaded the bottom perforations (blue line). Water breakthrough was therefore suspected to be a key driving force for sand production.

Mitigating solid production

There are basically two strategies for managing solid production: either implementing a downhole filter (solid control strategy) or choosing a depletion/drawdown strategy to avoid/limit solid production (solid management strategy). There are four basic types of sand control systems proposed by Service Companies: screen only in an open hole section (formation of a "natural sand pack"), open hole or cased hole gravel packs and more recently, the frac & pack system which combines gravel pack and propped fracture technologies (**Figure 2**).

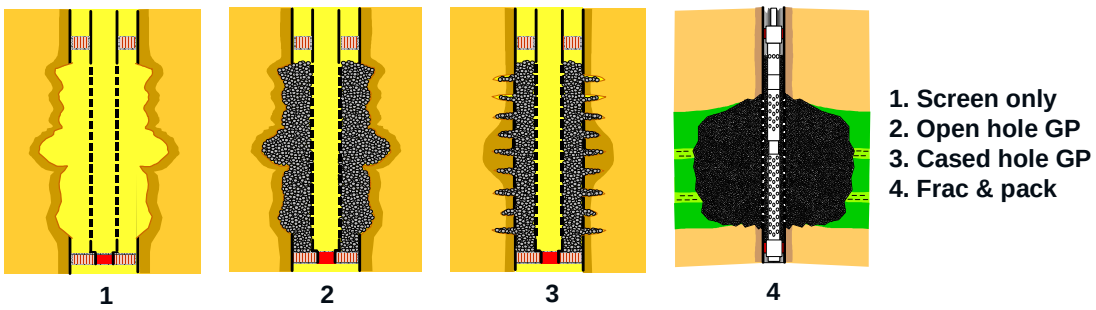

Figure 2 – Various sand control systems

It must be noted that other fairly recent technologies such as expandable sand screens (expanding a screen of smaller diameter to that of the well cumulates the dual advantages of a gravel pack and a natural sand pack), selected perforations (preferably perforating levels with better cohesion) or oriented perforations (minimising deterioration effect by orientating the perforations in a favourable stress azimuth) are now quite widely used, particularly in the North Sea.

In most cases, when a risk of sand production (even small) is suspected, the general rule consists of choosing the sand control strategy. However, although the control systems are quite powerful in stopping sand influx and avoiding erosion of completion and surface facilities, they are often very detrimental to production. Screens and gravel quickly plug after the well has been put on stream due to the effect of fines coming either from the mud cake or directly from the formation.
Accepting that sand is produced in reasonable quantities can be another option but this can quickly become catastrophic for completion and the surface facilities, especially in the case of large flow rates and nonviscous effluents (gas). The choice between sand control and sand management strategies has therefore to be carefully

analysed according to a decision tree which balances completion life, safety risk and production forecast, with and without a sand control system (**Figure 3**).

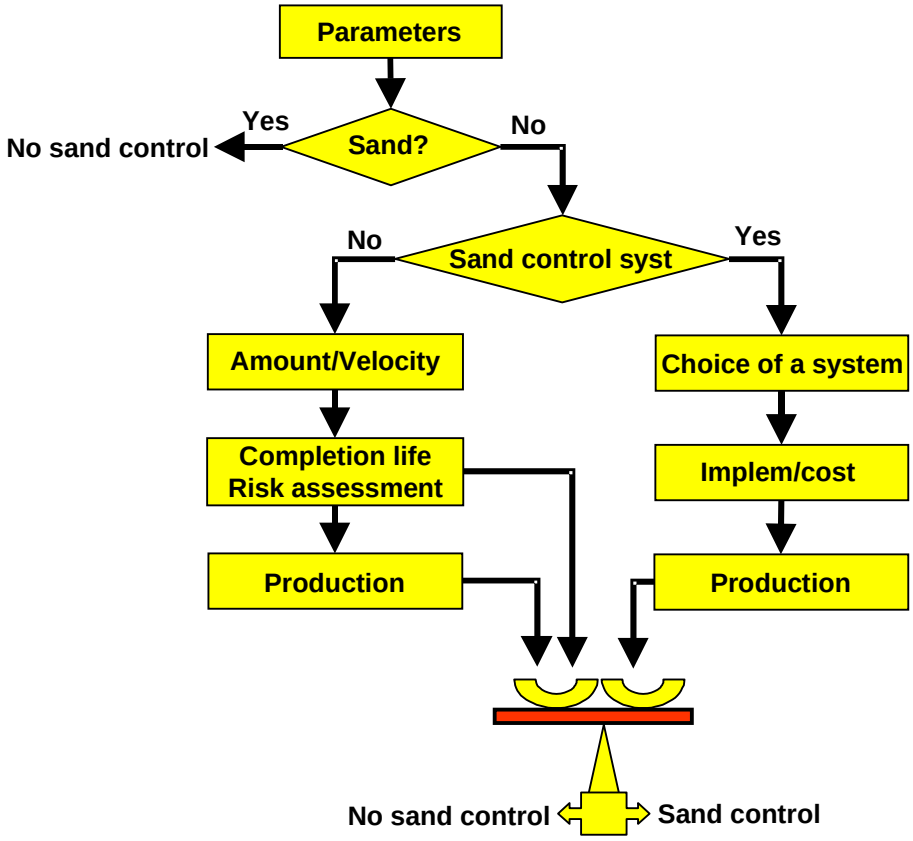

Figure 3 - Comparison of sand control and sand management strategies