INVESTIGATION OF SLUG FLOW IN DEEPWATER ARCHITECTURES

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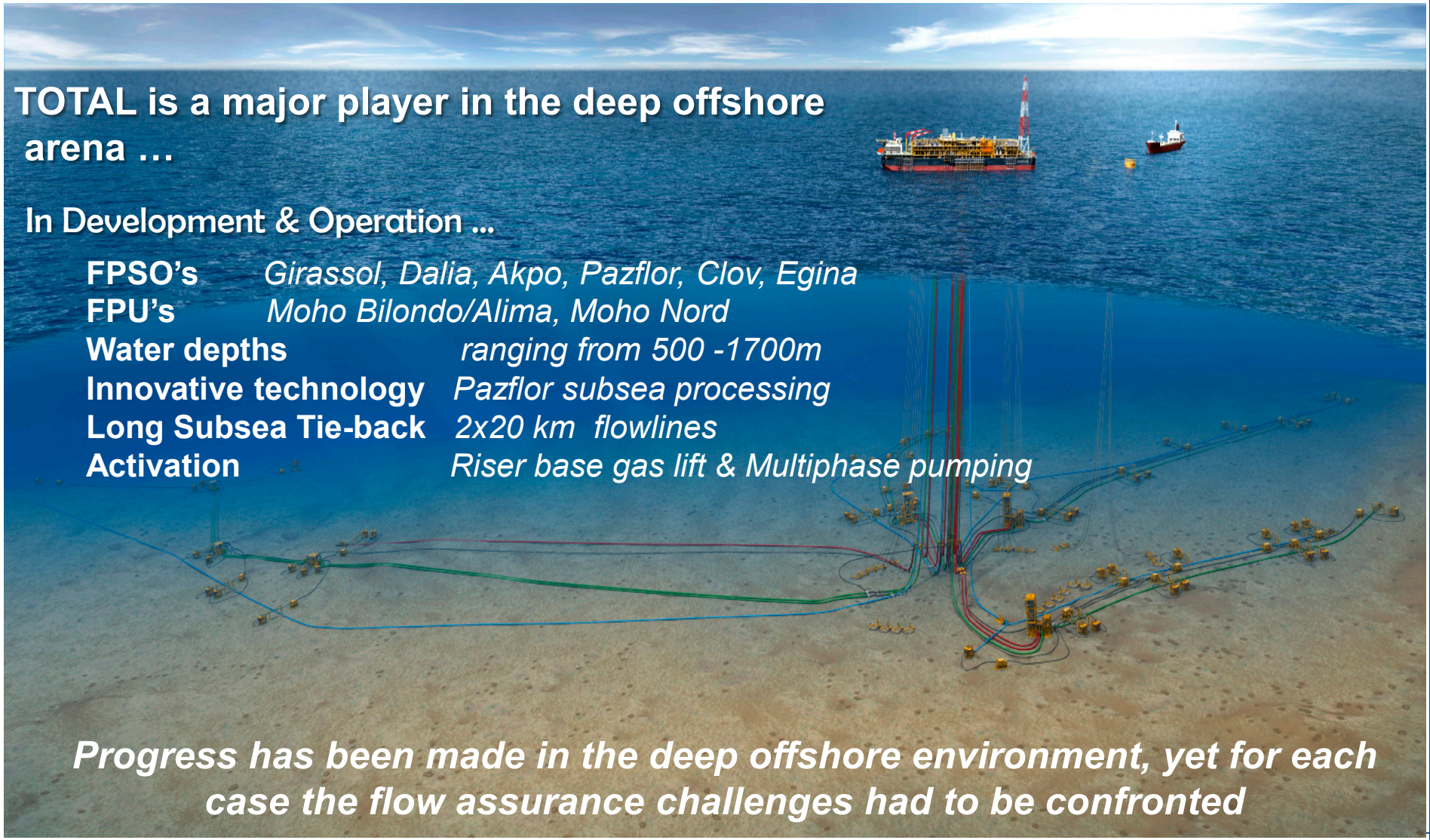
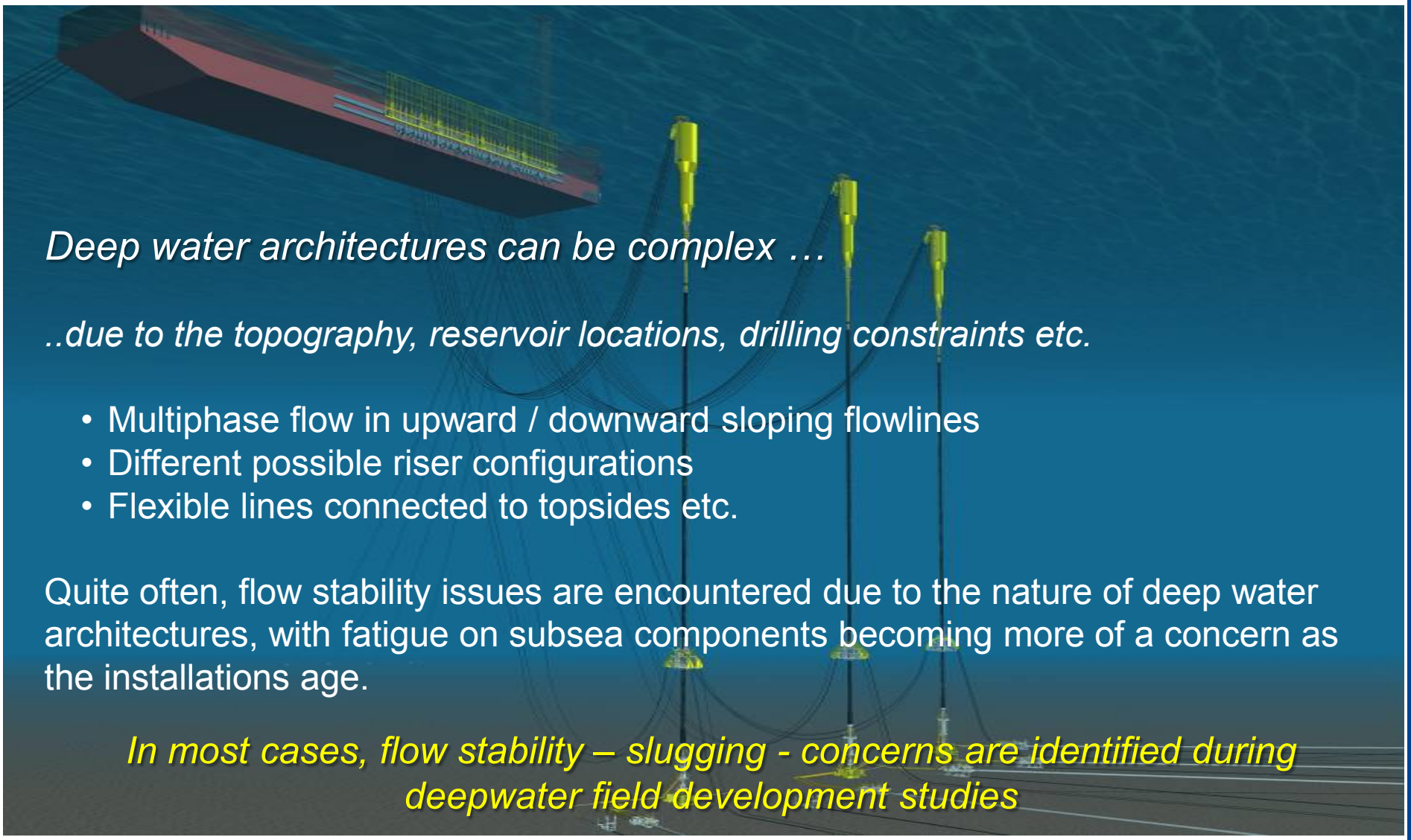


Progress has been made in the deep offshore environment, yet for each case the flow assurance challenges had to be confronted

INTRODUCTION



Deep water architectures can be complex …

..due to the topography, reservoir locations, drilling constraints etc.

- Multiphase flow in upward / downward sloping flowlines
- Different possible riser configurations
- Flexible lines connected to topsides etc.

Quite often, flow stability issues are encountered due to the nature of deep water architectures, with fatigue on subsea components becoming more of a concern as the installations age.

In most cases, flow stability – slugging - concerns are identified during deepwater field development studies

INTRODUCTION - SLUG FLOW

Three types of slugging are identified:

Hydrodynamic Slugging

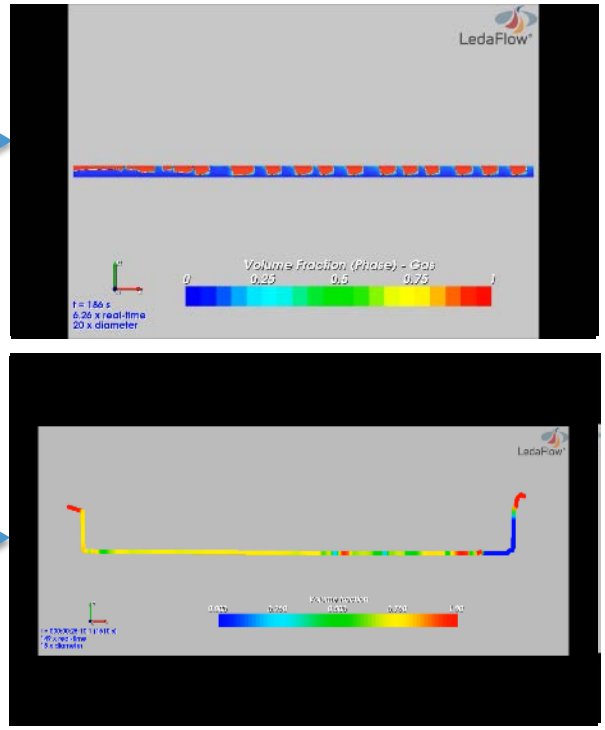
- *Instability of "waves" on gas-liquid interface …*

Terrain Slugging

- *Accumulation and periodic purging of liquid..*

Operational Slugging

- *Rate changes, pigging etc*



Main concerns of slugging:

- Instability in downstream process facilities e.g. Level control, compressor trips etc
- Un-steady back-pressure to wells – impacting production
- **Fatigue in subsea components e.g. Riser base spools**

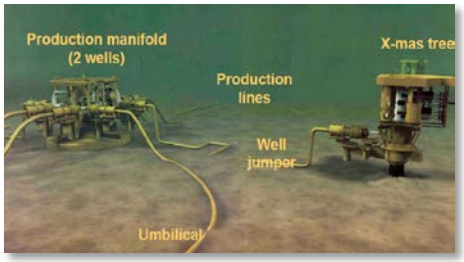
Different types of slugging exist. The industry relies on simulation tools for slug flow studies

SLUG FLOW IN FIELD DESIGN PHASE

Gas dominated systems

Study Basis

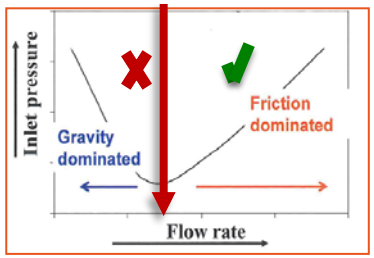
- Production profiles
- Boundary conditions (P,T..)
- Operating constraints
- Flowline/Risers definition



Oil dominated systems

Operational slugging assessment

- Separator/SC surge volume requirement
- Input to site operating philosophy for ramp up & pigging speeds/constraints



Terrain/RB slugging assessment

- Terrain slugging effect reduced to manageable limits
- Gas lift rate recommendation
- Input to site operating philosophy (choking..)

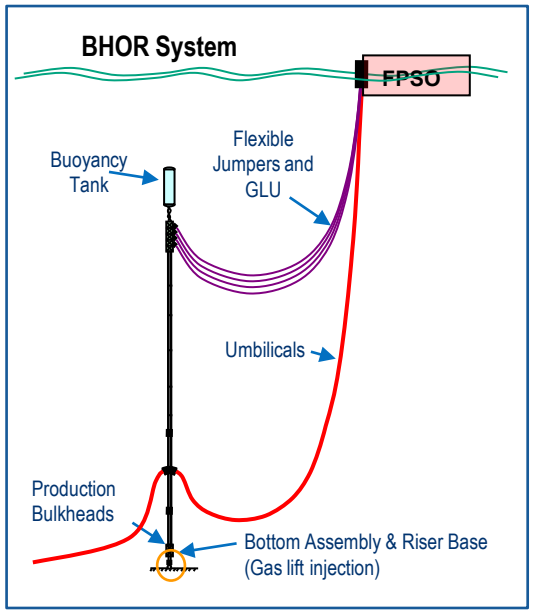
Hydrodynamic slugging assessment

- **Provide input for fatigue analysis**
- Optimum operating envelope (rate, WC, GOR)
- Proposition for wells routing
- Separator surge volume requirement

Strong reliance on the predictive ability of multiphase simulation tools & expertise of the Flow Assurance engineer

FIELD CASE STUDY

This study concerns a deepwater oilfield in the Gulf of Guinea operated by TOTAL



Key Field Characteristics:

- 30^{o} API crude & GOR ~ 100 Sm3/Sm3
- Water depth of 1400m
- ~ 19km flowlines connected to an FPSO via a Bundle Hybrid Offset Riser (BHOR) system

Video : Riser Base Spool

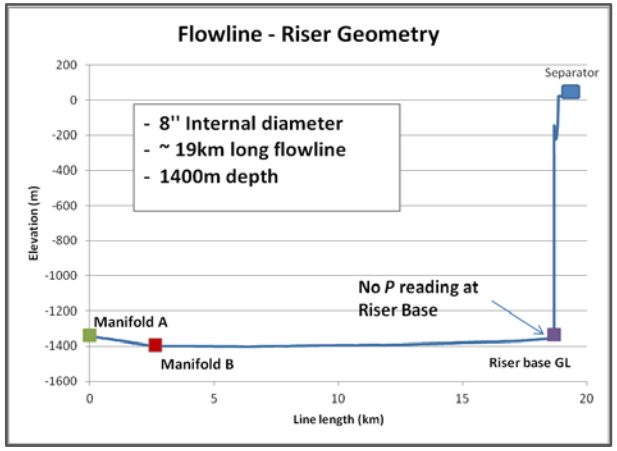
Field riser base spool has experienced oscillation and trenching with slugging suspected as a contributor

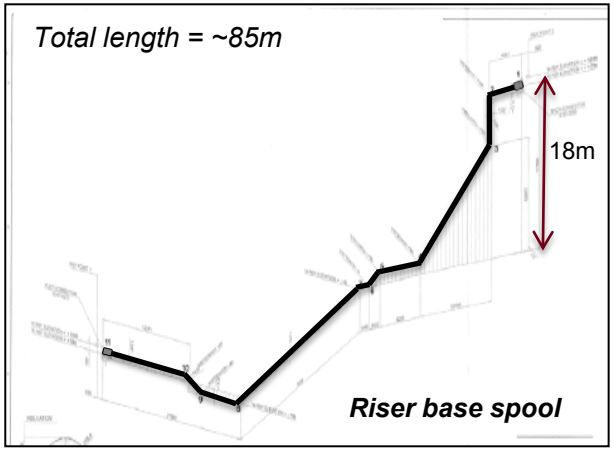
FIELD CASE STUDY

Study was performed using two commercially available multiphase flow simulators:

OLGA *v. 5.3.2.4*

LedaFlow® *v. 1.3*





Fluid description *(study base case)*:
Oil = 3117 Sm3/d, GOR = 98 Sm3/Sm3,
Water cut = 22%; Gas lift rate = 200 kSm3/d,
Arrival separator pressure at 23.6 barg

Objective → Confirm existence of slugging and determine its possible impact on the spool behaviour by:

- Matching simulation results with available field data
- Characterizing the slugs at the riser base spool for subsequent fatigue studies

FIELD CASE STUDY – GLOBAL METHODOLOGY

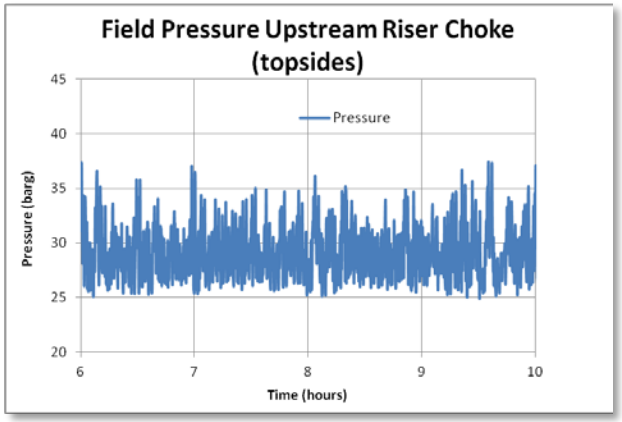
Selection of study date & field data gathering

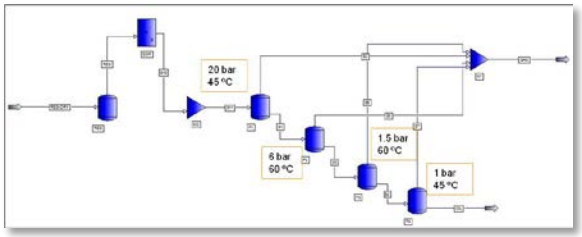
Simulation models' set up - Olga & Ledaflow

Apply specific methodology for Olga and Ledaflow

Match field data & simulation results

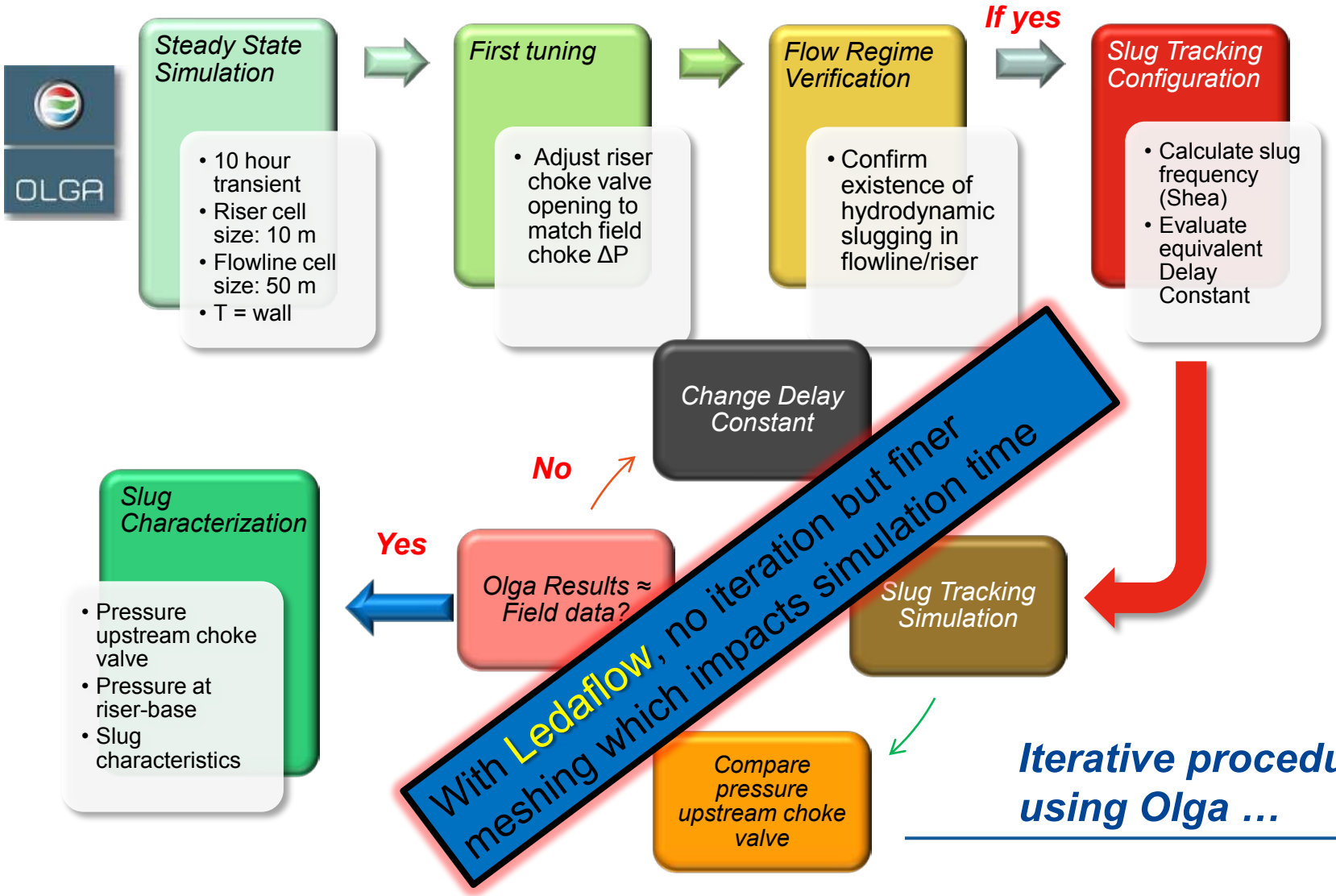
Slug characterization at riser base spool





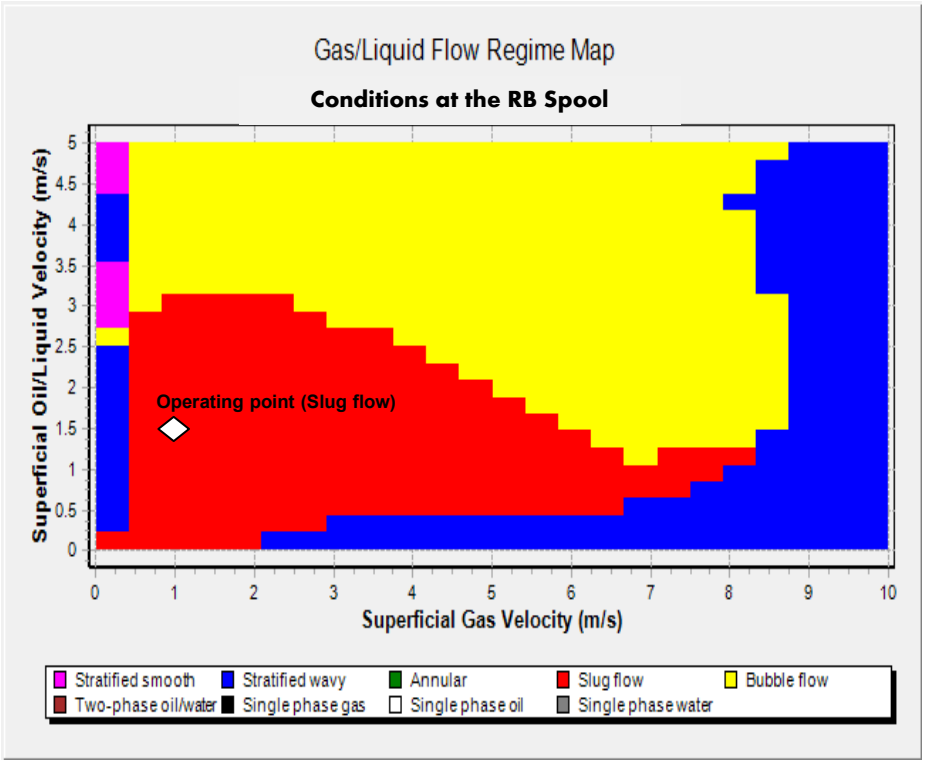
Up to 10 bar pressure variation upstream topside choke for the study base case

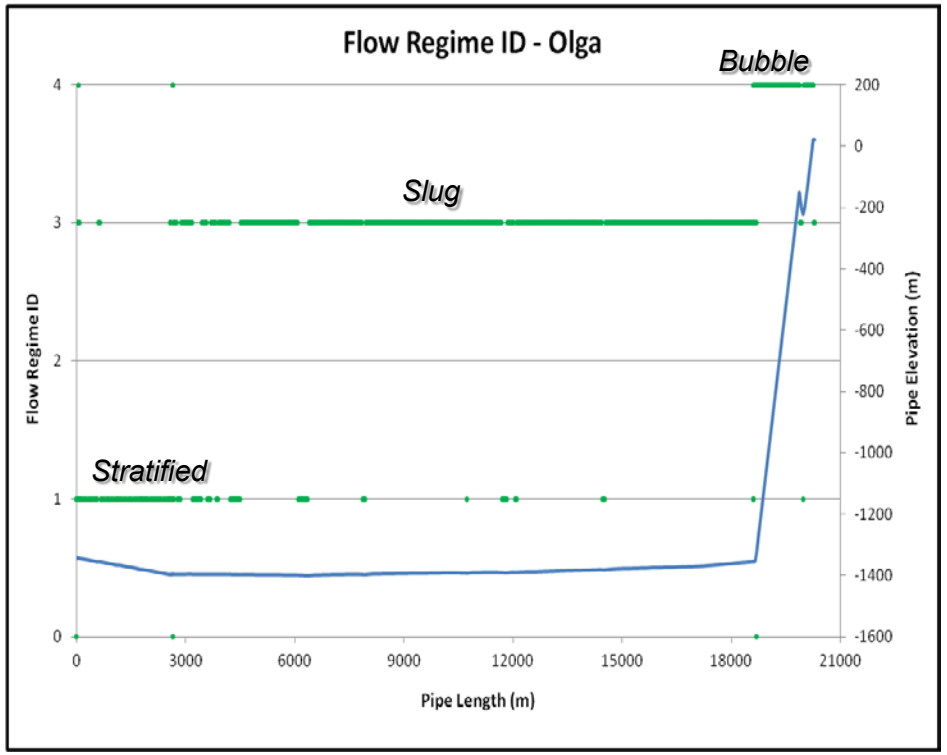
FIELD CASE STUDY – SIMULATION METHODOLOGY



FIELD CASE STUDY – RESULTS

Flow regime prediction

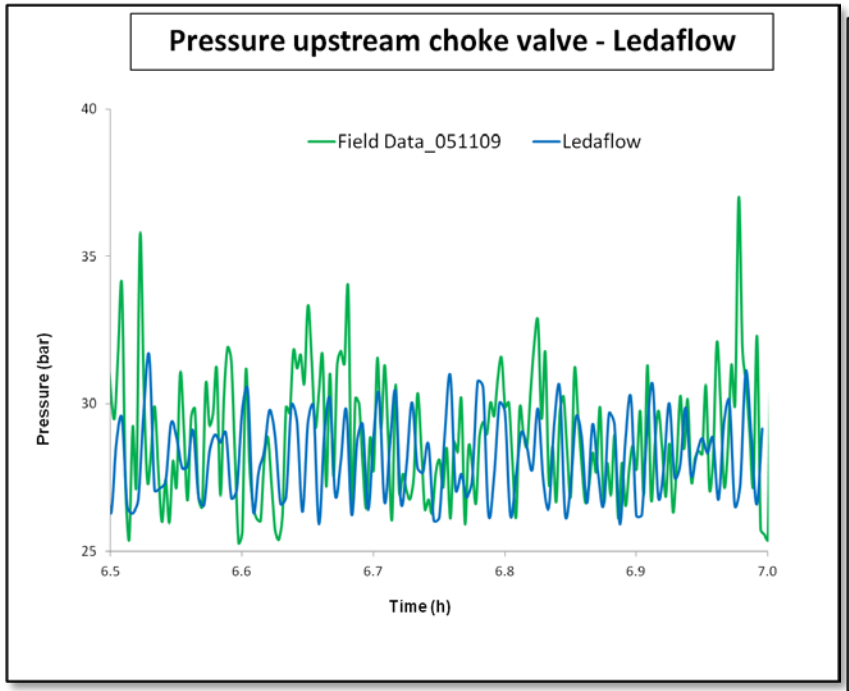


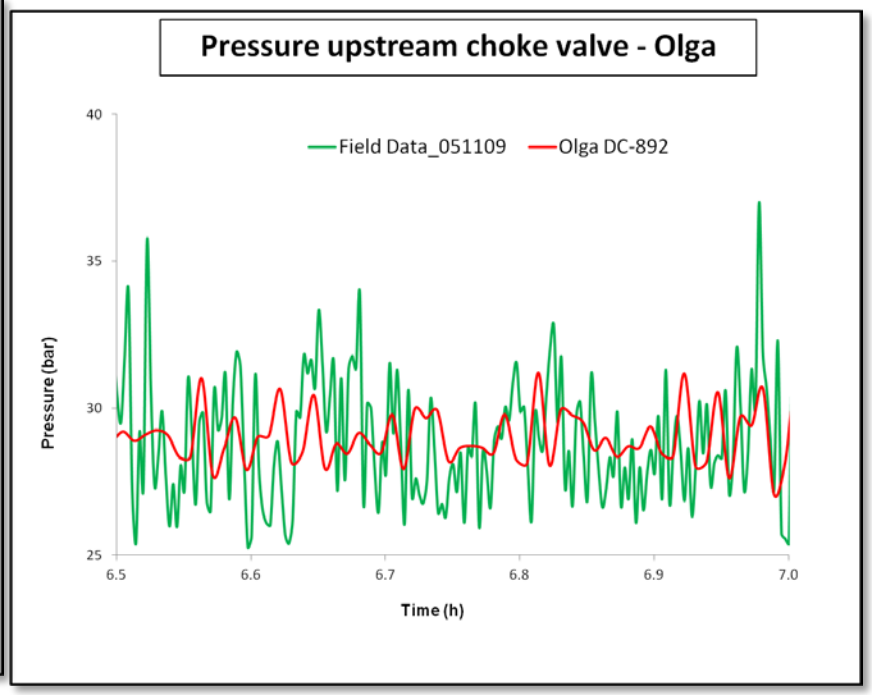


Both simulators predict hydrodynamic slug flow regime in the flowline & spool for the study cases → Further study with specialized slug modules is required

FIELD CASE STUDY – RESULTS

Matching Pressure Upstream Choke

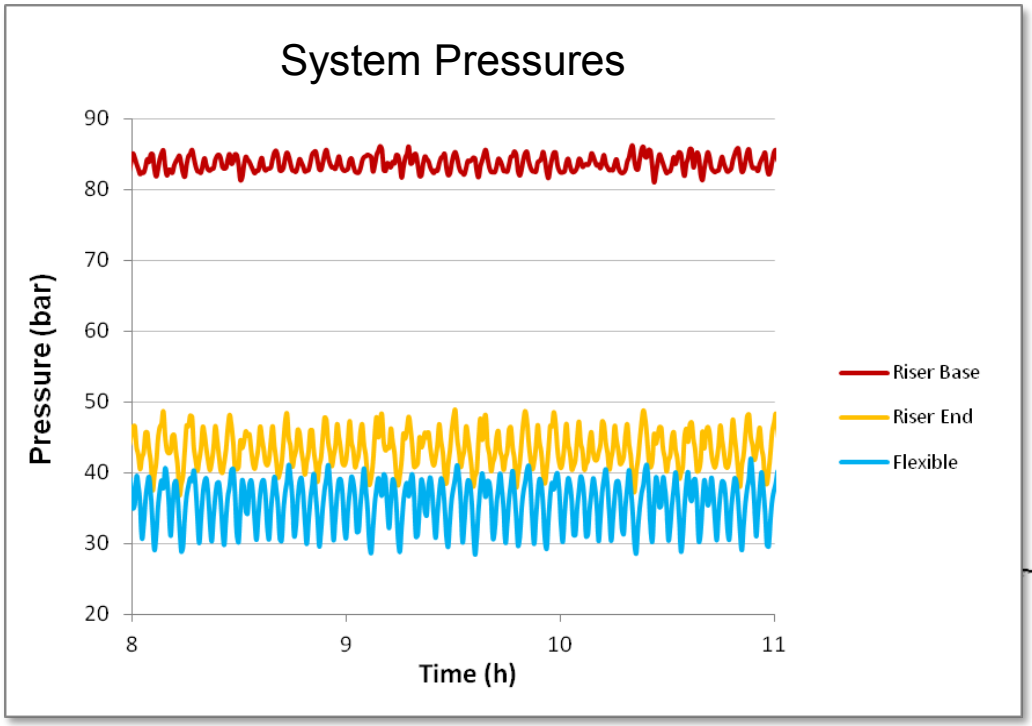


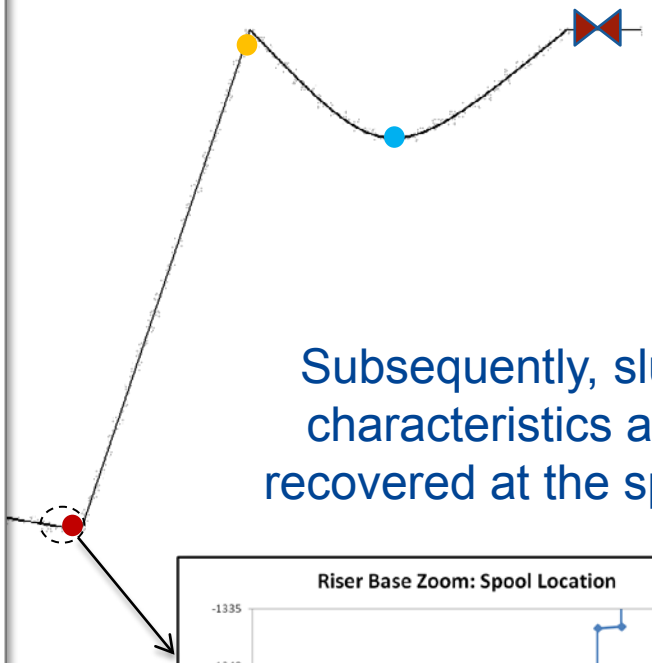


- With no need for tuning/iteration, Ledaflow matches *better* the field data frequency and amplitude (compared to Olga), although some peaks are not fully captured.
- For another study case (not shown), Olga shows a good match after several iterations highlighting the complementary nature of both simulators. In this case, Ledaflow was not used due to longer simulation time constraint.

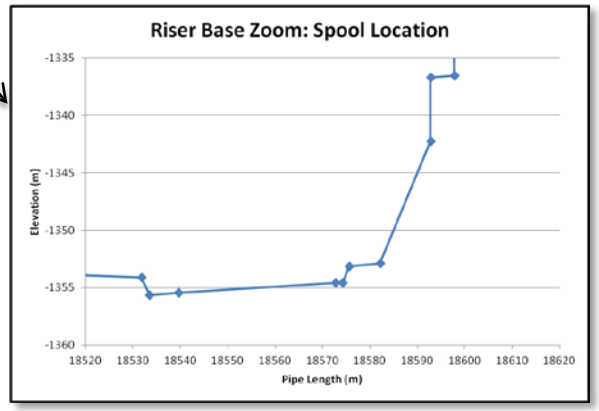
FIELD CASE STUDY – RESULTS

Riser & Flexible Pressure (after matching)





Subsequently, slug characteristics are recovered at the spool



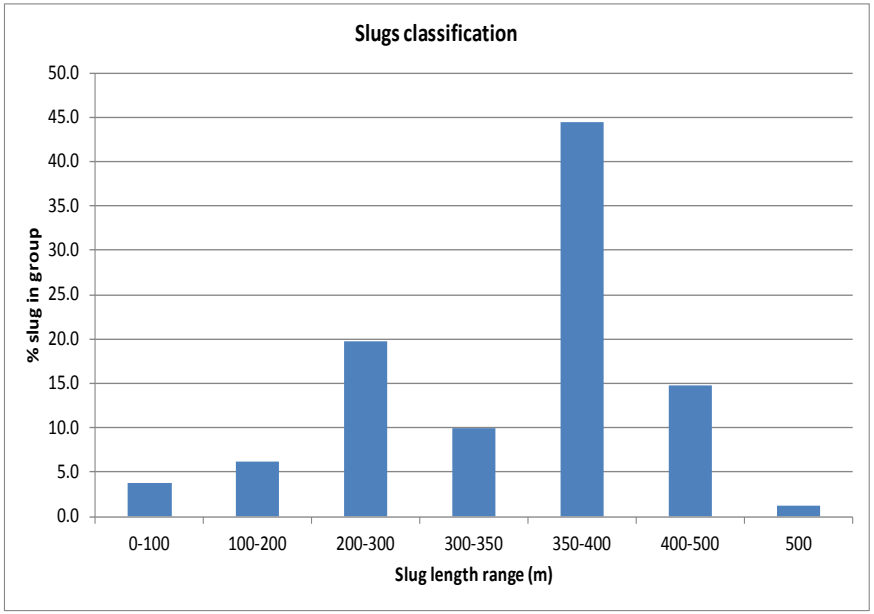
Pressure variation evolution along the line - from riser base to flexible (4 → 8 → 10 bara)

FIELD CASE STUDY – RESULTS

Slug Characteristics at Riser Base Spool

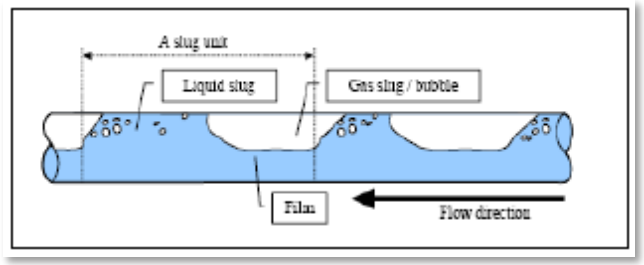
Results show significant slug characteristics at the riser base spool:

- Slug frequency ~ 20 slugs/hour
- Density variation from 310 to 854 kg/m3
- ~45% of the slugs between 350 – 400 m in length
- Slug velocity up to 11.4 m/s



Detailed data is subsequently provided to pipeline engineers for fatigue analysis:

- Slug lengths, velocities
- Slug bubble and liquid densities
- Slug frequency & Pressure variation



Pipeline engineers concluded that slugging was a contributor to the spool trenching experienced which impacts the spool life span (fatigue)

CONCLUSION

1. Slug flow can pose a problem to operations and could also generate fatigue in subsea components
2. Slug flow investigation is systematically performed for deepwater architectures during conceptual design and measures proposed to assure operations
3. There is an interest to monitor flow parameters and to also inspect lines especially at locations exposed to risk of fatigue
4. Ledaflow simulator being more predictive (does not require tuning/iterations to match field data) is a welcome tool for the F.A. engineer. Both tools (Olga & Ledaflow) are therefore complementary, enabling better study of very technical cases
5. There remains a strong reliance on the accuracy of multiphase simulation software although they have inherent limitations. Thus, there is a continuous drive to improve both the accuracy of the simulators and flow assurance engineering methodology in this domain

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