Subsea Flowline System Lateral Buckling Design and Startup/Operational Performance

Tullow TEN Project

Speakers and Presentation Overview

Speakers:

Dr Mehrdad Mansour (Tullow)
Subsea Engineering Manager

Robert Hayes (Wood)
Project Engineering Manager

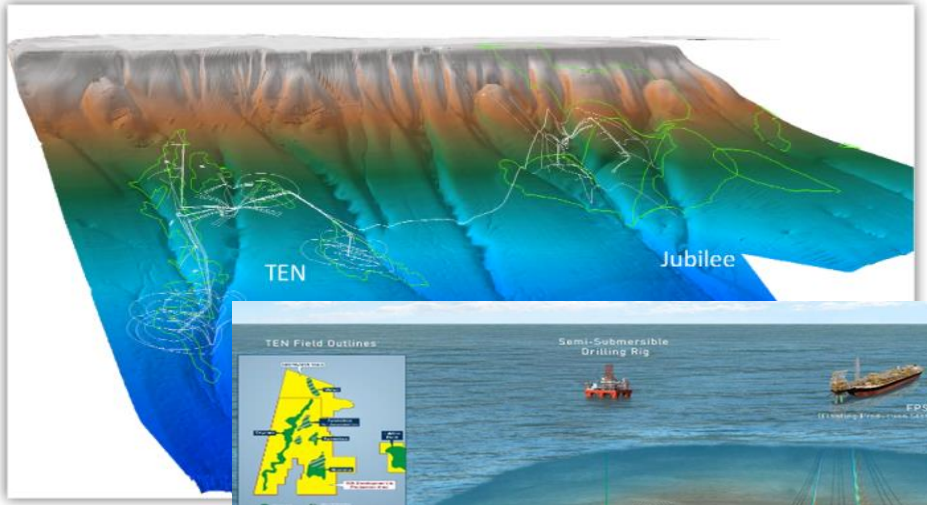
Eu Jeen Chin (Wood)
Subsea Design Engineer

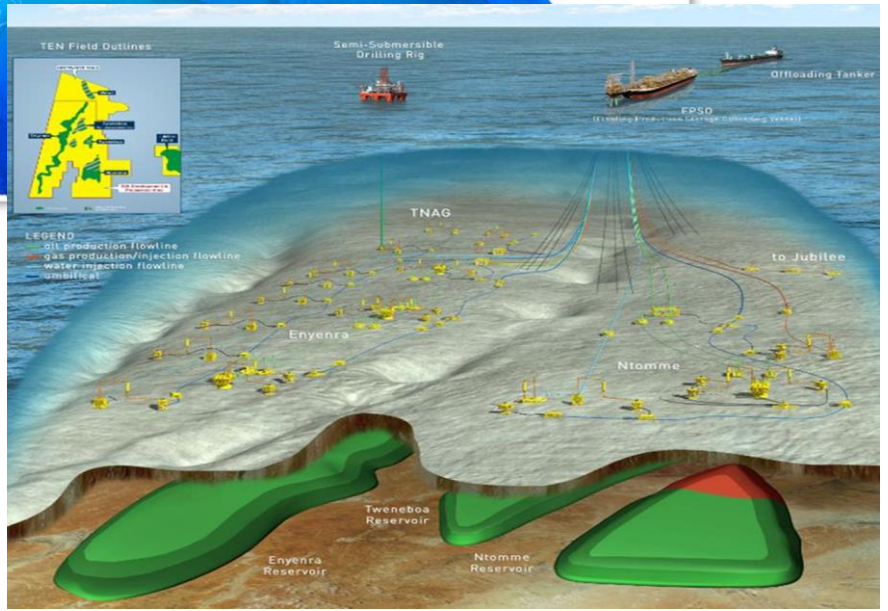
Presentation Overview:

- TEN Project Overview
  - Main Contractors, global delivery, major project milestones
- Asset Integrity and Technical Assurance(Subsea)
- Project drivers influencing the lateral buckling solution.
- Introduction to Wood and their role on the TEN project.
- Technical (Subsea) studies/independent verification
  - Lateral Buckling and walking design and post op field survey verification
- Conclusions and lateral buckling lessons learnt
  - Future improvements and recommendations

Tullow TEN Project Overview

- Tullow Oil is a leading independent oil and gas exploration and production company, with focus in Africa and South America
- TEN development is in Deepwater Tano Block Offshore Ghana,
- Tullow as the major share holder in TEN delivered the project from discovery to operation.
- Wood – Client Engineering & Technical Assurance support for Execution phase in 2013





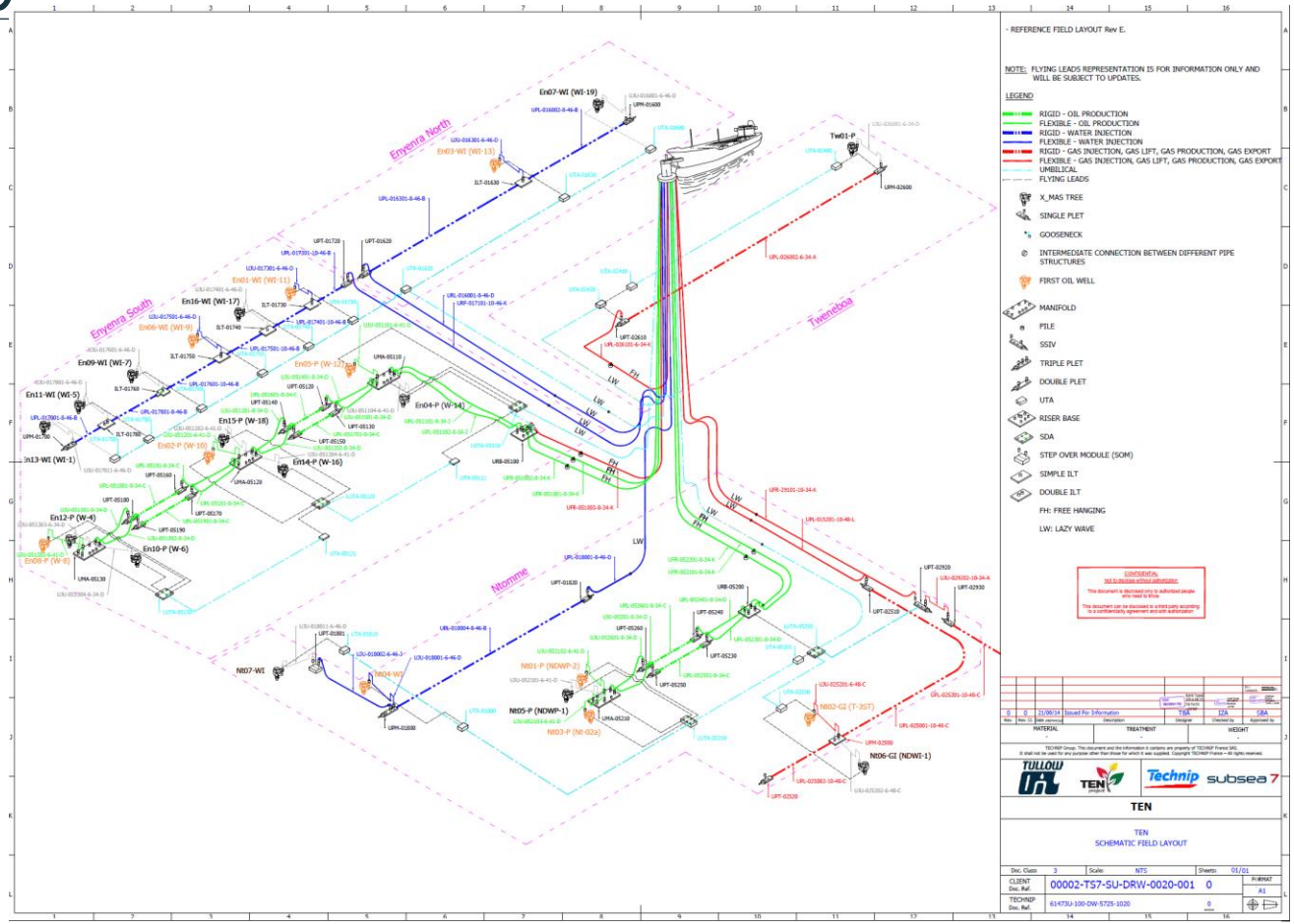
TEN Headline Statistics

- 60km from the coast, 1,250 to 2,000m WD
- Multiple and complex reservoirs
- Subsea tieback to an FPSO
- Oil production with water and gas injection support
- Fields split by subsea canyons.
- Gas exported to shore via Jubilee

TEN Field Layout

Oil Production field architecture consists of:

- Flexible riser
- Riser base
- Dual PIP flowlines
  - Enyenra: 2 x dual 5.4km
  - Ntomme: dual 7.4km
- PLETs
  - Enyenra: 8 PLETs
  - Ntomme: 4 PLETs
- Production Manifolds
  - Enyenra: 3 manifolds
  - Ntomme: 1 manifold
- Trees Tied in with rigid jumpers



Subsea Facilities and Delivery

101 km of rigid flowlines
54 km of flexible risers and flowlines
-11 dynamic risers
- 12 off flexible spools
72 km of flexible umbilicals
– 3 dynamic risers
4 off production manifolds
2 off riser bases
6 off suction piles
33 off PLETs, PLEMs and ILT's
10 off Rigid Jumpers (6 Off jumper kits)
Numerous mudmats, hold back piles and pipeline sleepers , vertical connector system and subsea tooling

A combined weight of approx 35,000 tonnes of equipment and materials installed, constructed and tested on the seabed before being hooked up to the FPSO and pre-commissioned.

Main Contractors

Modec
-
FPSO

SS7
Production Flowline System and SPS installation

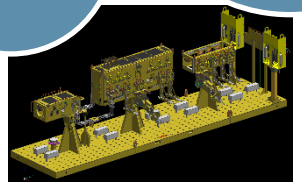
Tullow
& Partners

Aker
Umb

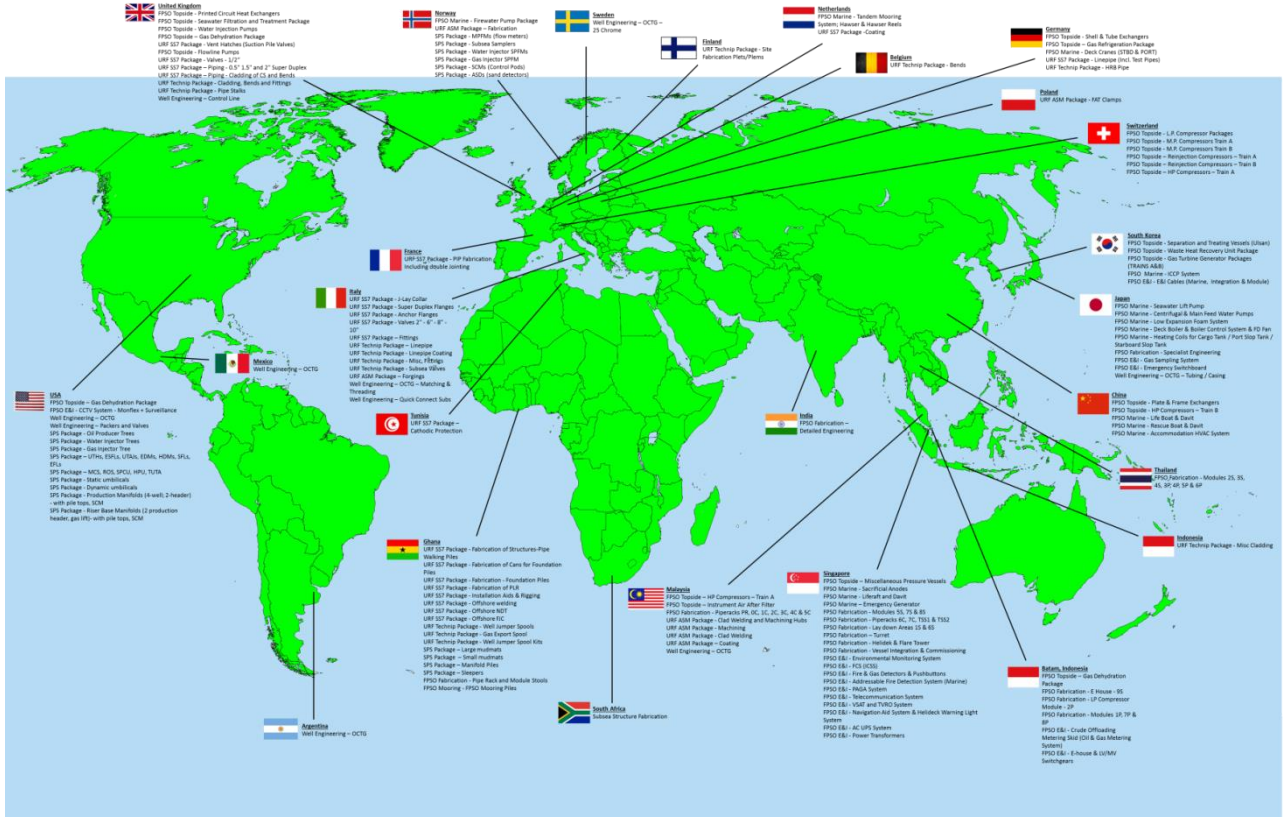
Aker
Connect ors

FMC
SPS

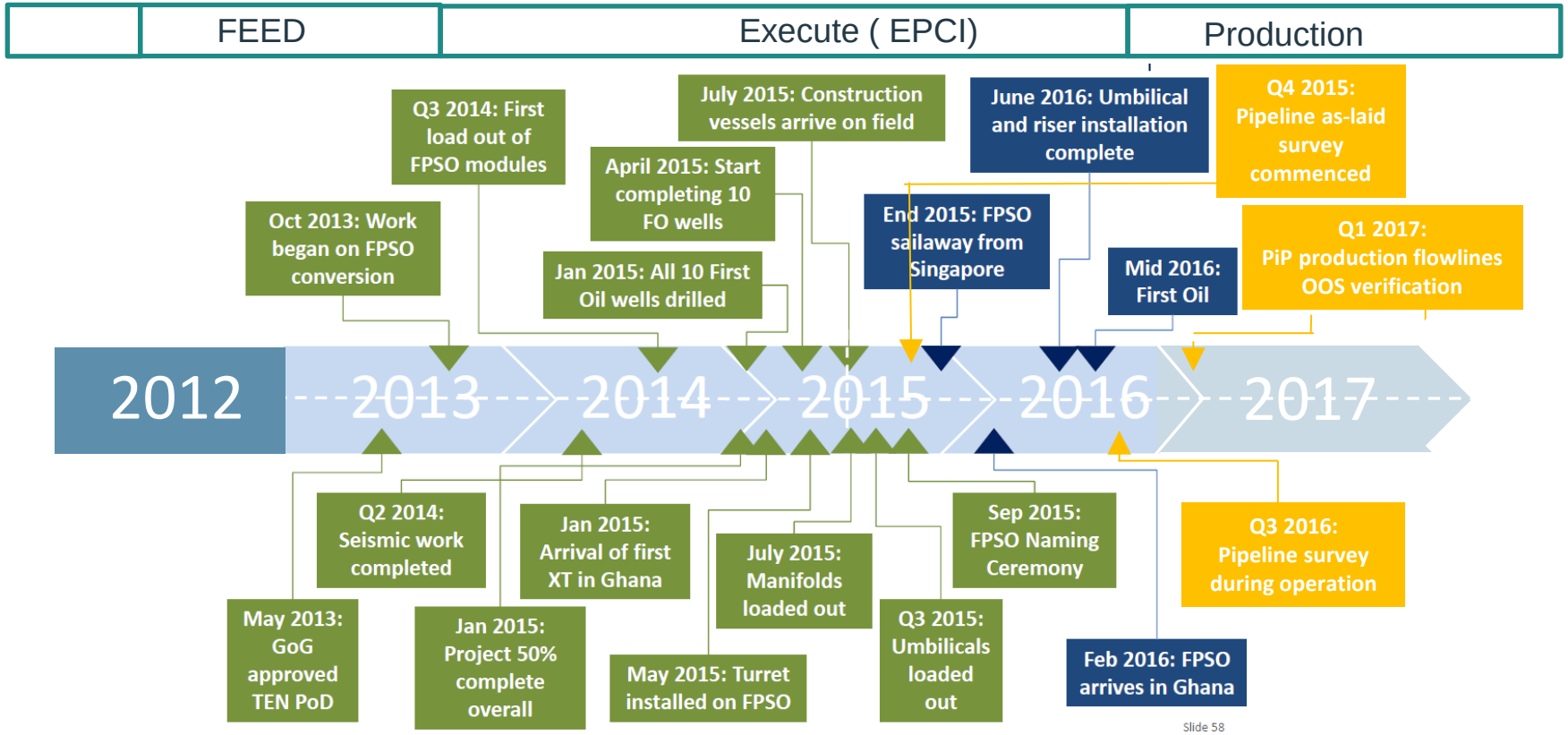
Technip
Gas and Water Injection Systems and Risers



Global Delivery



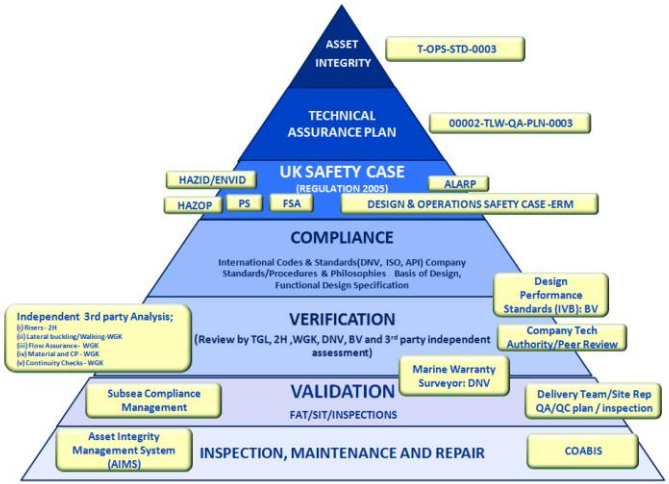
Project Timeline and Milestones



Asset Integrity and Technical Assurance

Tullow Asset Integrity Standard requires the TEN project to : -

- Develop a Technical Assurance Plan
- Develop a Safety Case inline with UK requirments;
- Assure compliance with all relevant Codes , Standards and Company requirements [Wood involvement]
- Verify that this compliance has been met [Wood involvement]



To support this process all subsea critical elements are identified and required degree of assurance and third party analysis necessary for verification put in place.

Production flowlines lateral buckling was selected for independent third party analysis and post production validation.

Project drivers influencing the lateral buckling solution

DRIVERS

- Seabed Bathymetry and routing
- Flowline lengths [on or off line Manifolds]
- Pipe/soil interaction
- Flow assurance required defining pipeline size and insulation requirement
- Installation method
- Fabrication and installation cost
- Project schedule and vessel availability/capability contractor preference.
- Construction cost
- Slugging risk
- Local content
- IMR philosophy

INFLUENCE

Lateral buckling and walking interaction.

Pipeline stiffness and level of axial force build up and feed-in.

Defined the selection of pipeline type, hence the applicable limit state

Selection of suitable mitigation solution

SOLUTION:

Production lines (Subsea7)

Most cost effective and reliable solution

- S-laid ITP PIP (double joints)
- Single buckle initiation for each flowline with 3 spaced sleepers inducing a large bending radius
- In combination with hold back anchors to manage both lateral buckling feed-in and walking .

Verification

(Wood)

Design phase

Post-Op Verification.

Wood plc

Company Structure

Specialist Technical Solutions

Asset Solutions Americas

Environmental & Infrastructure Solutions

Asset Solutions EAAA

Specialist Technical Solutions

Primary Service Lines and Sectors

Service Bundles

- Integrator Solutions
- Technology & Consulting

Primary Service Lines

Integrator Solutions

- Automation & control
- Mining & minerals
- Nuclear
- Subsea & export systems

Technology & Consulting

- Asset integrity solutions
- Clean energy
- Digital solutions
- Process technology
- Professional services
- Studies

Primary Sectors

Up/downstream oil and gas

Chemicals

Utilities

Mining

Nuclear

Manufacturing

Automotive

Mining and mineral processing

Renewables

connecting • sharing • winning •

Specialist Technical Solutions

Primary Capabilities

Primary Capabilities

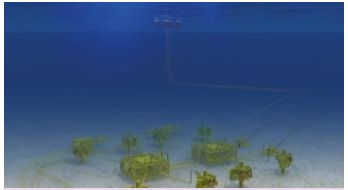
- Consulting services
- Concept to feasibility studies(mining and nuclear)
- Design
- Engineering
- Project management
- Program management
- Procurement and supply chain management
- Construction management
- Process optimisation
- Flow assurance
- Advanced applications
- Start up and commissioning
- Decommissioning
- Owner's engineer
- Control system design, configuration and testing
- Robotics
- Simulation
- Systems integration

- Consulting services
- Concept to feasibility studies
- Due diligence
- Lender's technical advisory
- Operational excellence
- Consulting and management
- Asset performance management and optimisation
- Asset integrity management
- Vibration, dynamics and noise
- Data analytics and visualisation
- Software development
- Technology development and licensing
- Virtual/augmented reality
- Operational training solutions
- Wind and solar farm engineering
- Wind and solar farm monitoring and optimisation

Subsea and Export Systems

Supporting across the subsea life cycle

Front end studies and consulting



Integrated SURF/SPS FEED and detailed design

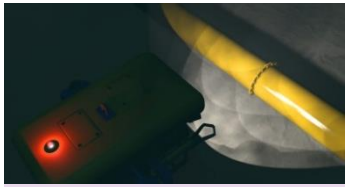
EPCm, project management services

Subsea operations support and integrity management

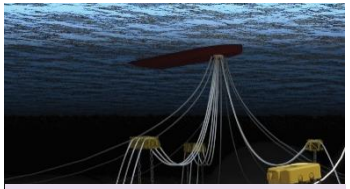
Decommissioning

Specialist services

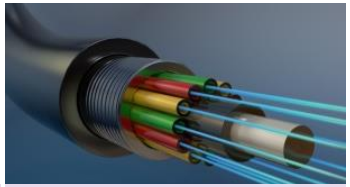
Turnkey engineering, procurement and fabrication (EPF)



Offshore and onshore pipeline and structures



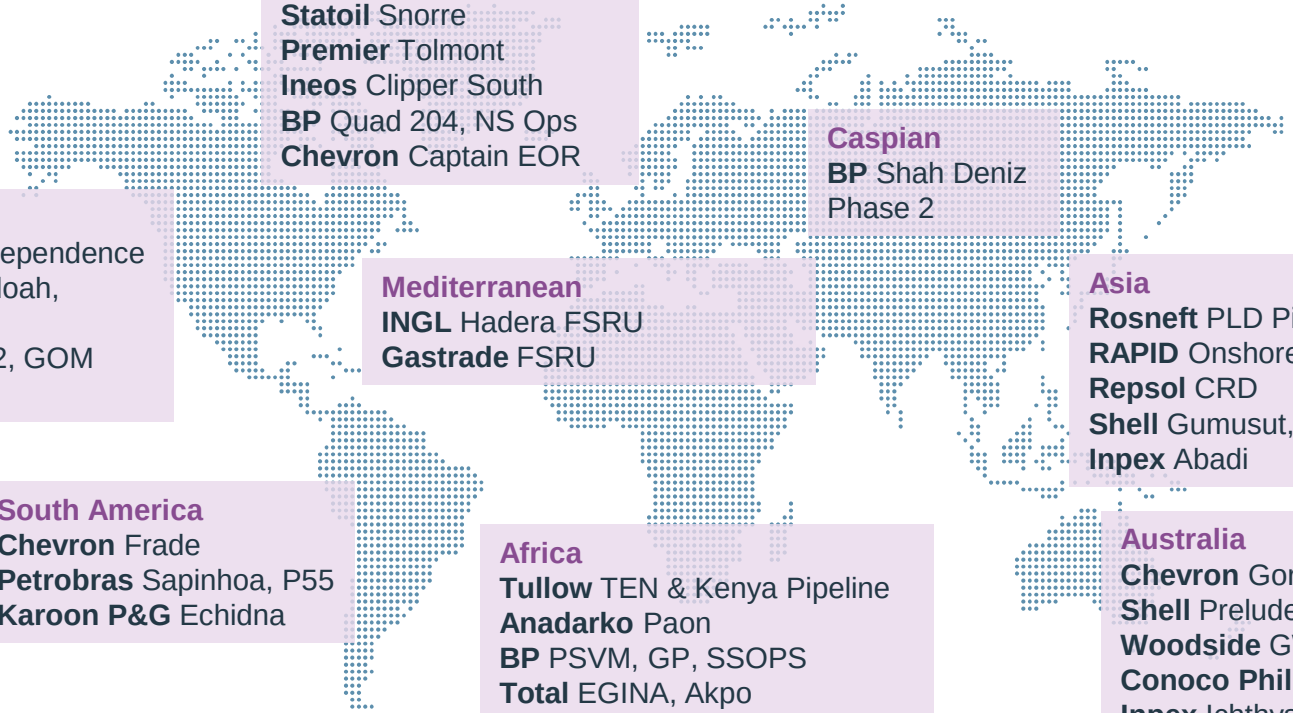
Risers, mooring and floating systems



Subsea cables and infrastructure

Flow assurance

Key projects



UK & Norway
Statoil Snorre
Premier Tolmont
Ineos Clipper South
BP Quad 204, NS Ops
Chevron Captain EOR

GOM
Anadarko Independence Hub, Shenandoah, Constellation
BP Mad Dog 2, GOM Ops

Caspian
BP Shah Deniz Phase 2

Mediterranean
INGL Hadera FSRU
Gastrade FSRU

Asia
Rosneft PLD Pipeline
RAPID Onshore Pipeline
Repsol CRD
Shell Gumusut, Waterflood
Inpex Abadi

South America
Chevron Frade
Petrobras Sapinhoa, P55
Karoon P&G Echidna

Africa
Tullow TEN & Kenya Pipeline
Anadarko Paon
BP PSVM, GP, SSOPS
Total EGINA, Akpo
Sasol Pipeline

Australia
Chevron Gorgon
Shell Prelude, Crux
Woodside GWF2, Browse
Conoco Philips Barossa
Inpex Ichthys

Buckling Experience

Wood (as J P Kenny and W G Kenny) has an extensive history of pipeline buckling mitigation expertise spanning projects across the globe. Some example projects through the years include:

- Shell Malampaya (1990s, South China Sea)
- Shell Penguins (1990-2000s, North Sea)
- Total Fina Elf Elgin Franklin (2000s, North Sea)
- Total Rosa (2000s, Angola)
- Woodside Echo Yodel / Pluto (2000s, Australia NWS)
- Total South Pars (2000s, Persian Gulf)
- BP PSVM (2010, Angola) /
- BP Shah Deniz 2 (2010s, Caspian)
- Chevron Gorgon (2010s, Australia NWS)

Wood's Role on TEN

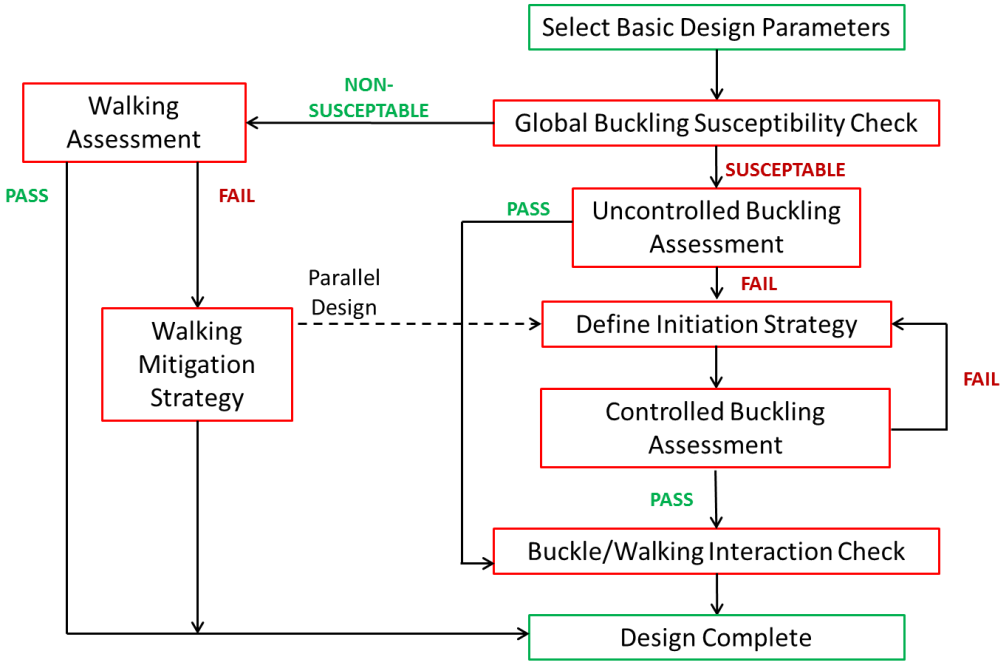
Primary Roles

- Clients Engineer/Engineering Assurance for subsea and pipelines system
- Key people integrated into Tullow delivery team
- System Process and Flow Assurance engineering
  - Full system wide transient analysis
  - Operating Guidelines for Production, Injection, Gas Lift and Export systems
- Specialist engineering studies including:
  - PSI development
  - Buckling/Walking verification

→ More details on this later…

Lateral Buckling - Design Overview

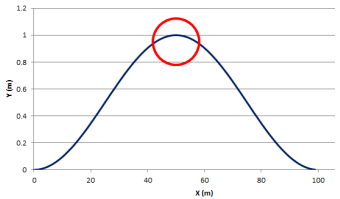
Flow chart highlighting major iteration steps:



Lateral buckling response predominantly dependent on:

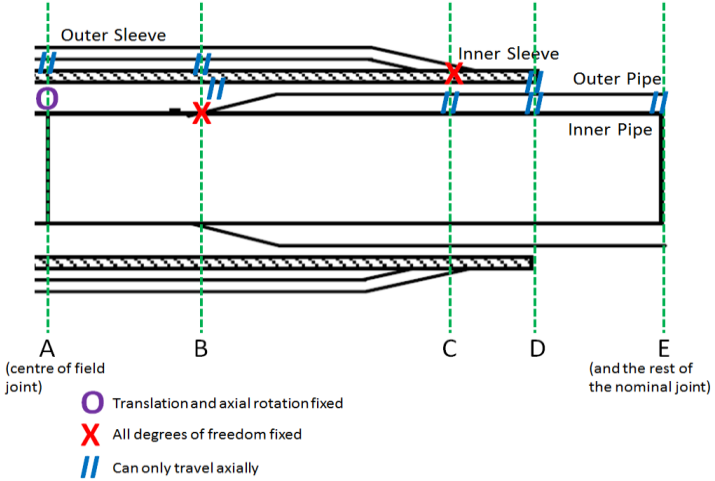
- Pipe Soil Interaction data
- Operational conditions
- Mitigation scheme to control buckle effectively to be under allowable limits

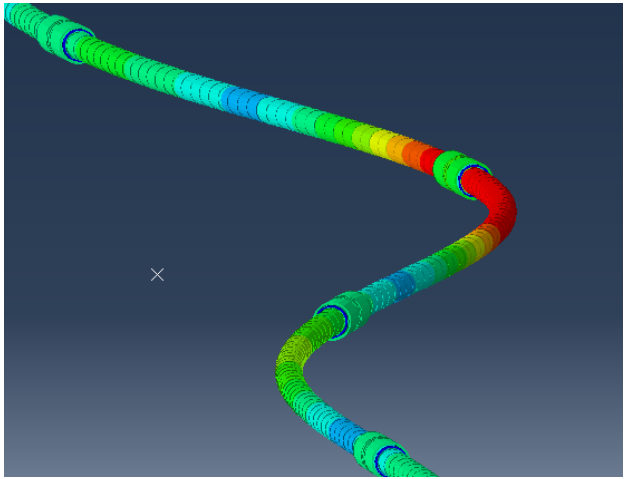
→ TEN is strain based design (DNV)

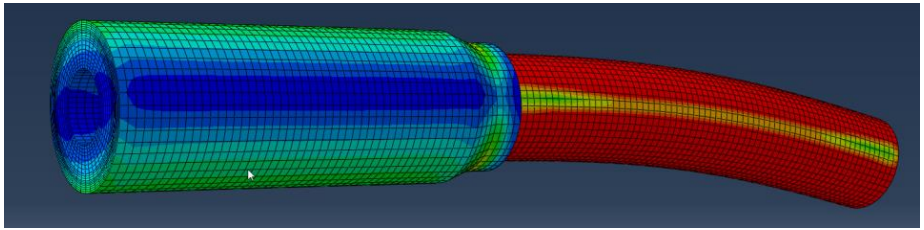


Lateral Buckling – TEN PIP System

- Production flowlines are heavy ITP patented PIP with regularly spaced FJs/bulkheads – complex modelling
- Local 3D and Global buckling models performed
  - Bulkhead modelled to determine SCF and SNCF
  - Pipeline variation of weight and stiffness modelled (including PSI)

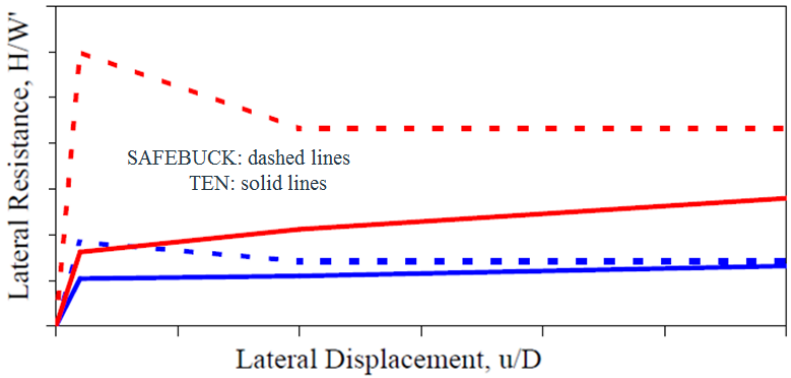


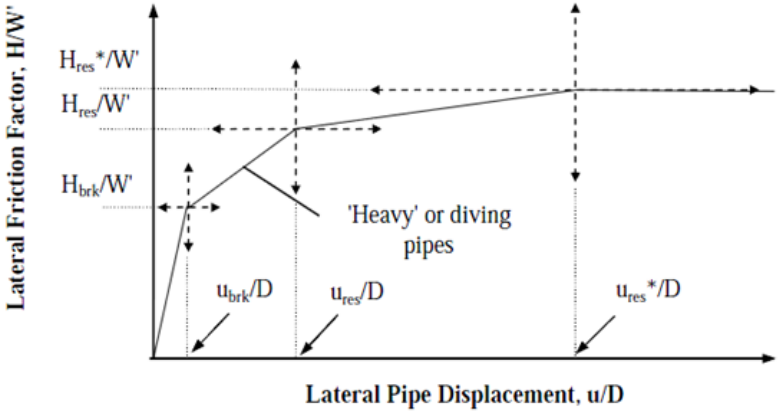




Lateral Buckling - Impact from PSI

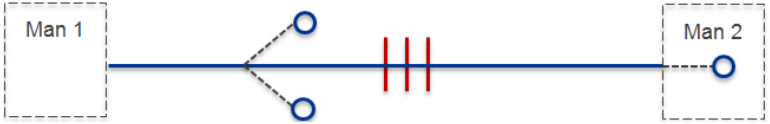
- PSI extremely important in planned lateral buckling design and will influence overall buckle shape:
  - Very soft surficial soil and uneven embedment of the heavy PIP system along its length
  - Pipeline embedment, touch down points heavily influence response
- SAFEBUCK initially used, Wood recommended specialists to obtain bespoke PSI models
  - Narrowed the range of (UB/LB) friction factors → narrow the PSI uncertainties
  - The response curve with heavy PIP is not of those typically seen:
    - Lateral - pipe tends to 'dive'
    - Axial - has breakout properties

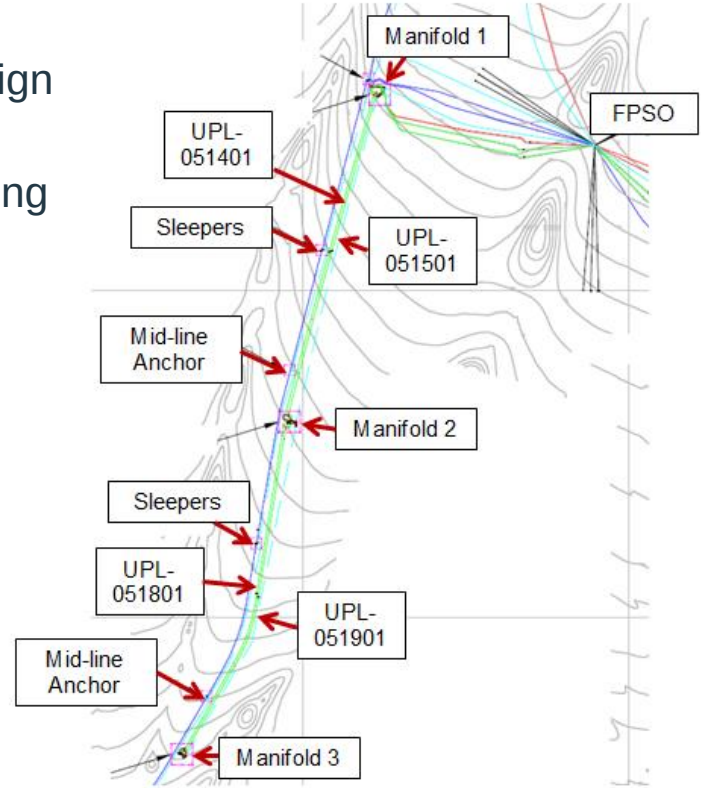




Lateral Buckling - Design Solution

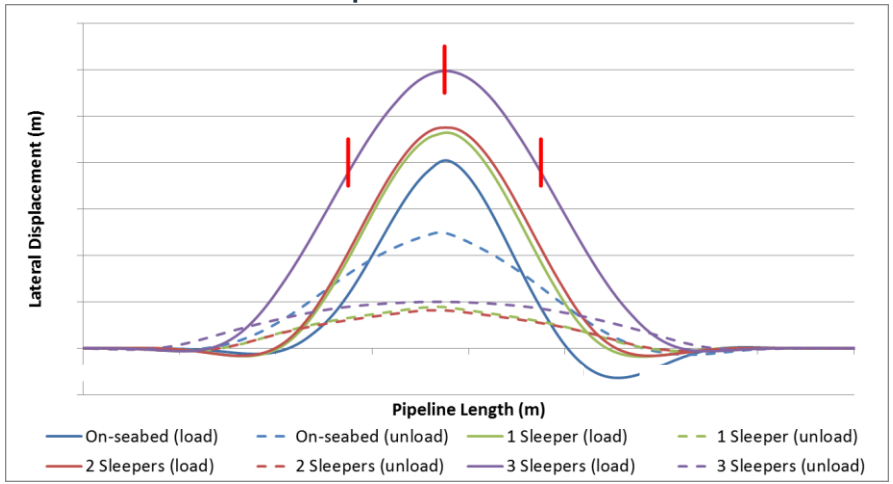
- The bespoke PSI data in general reduced the friction range → tighter parameters → tighter design
- Main contractor proposed a triple sleeper buckle mitigation solution together with anchors for walking mitigation
- Initial objective was to verify solution
- Wood also explored potential alternatives

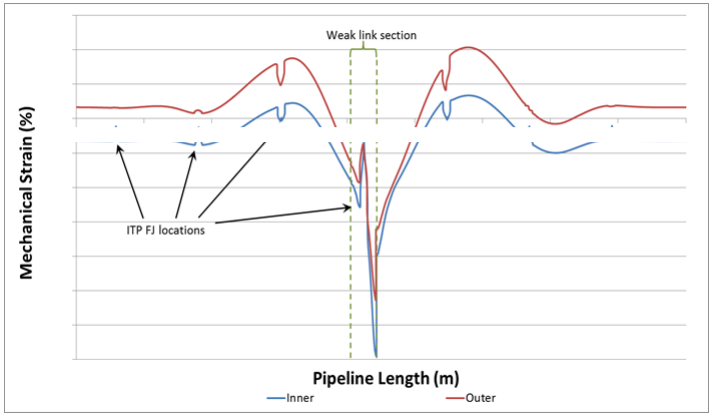


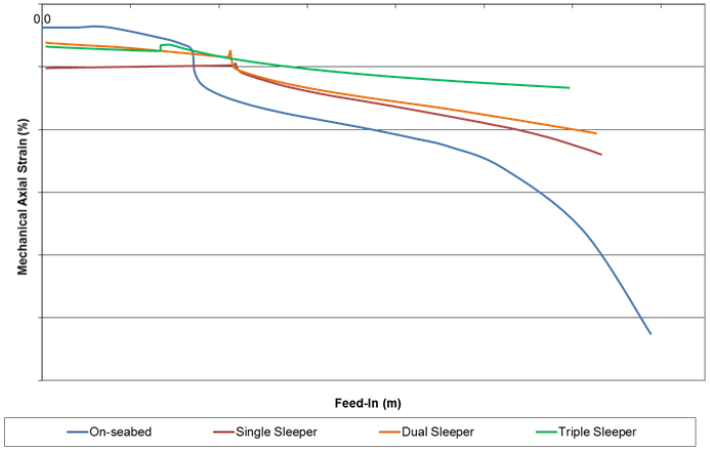


Lateral Buckling - Design Solution

- Following verification, sensitivities and other schemes were explored by Wood:
  - Main solution is acceptable and robust
  - Sensitivity in field joints relative to sleepers
  - A single double sleeper site could work, more sensitivities required







Survey and Verification – Installation/Operation Phase

Main purpose is to ensure pipelines are responding as designed

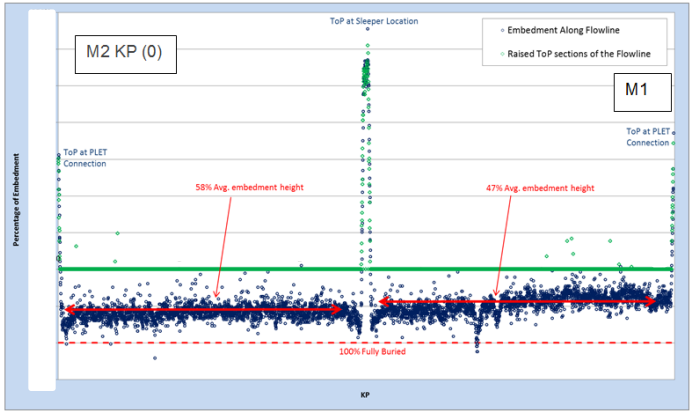
- Gain knowledge of remaining life from data records

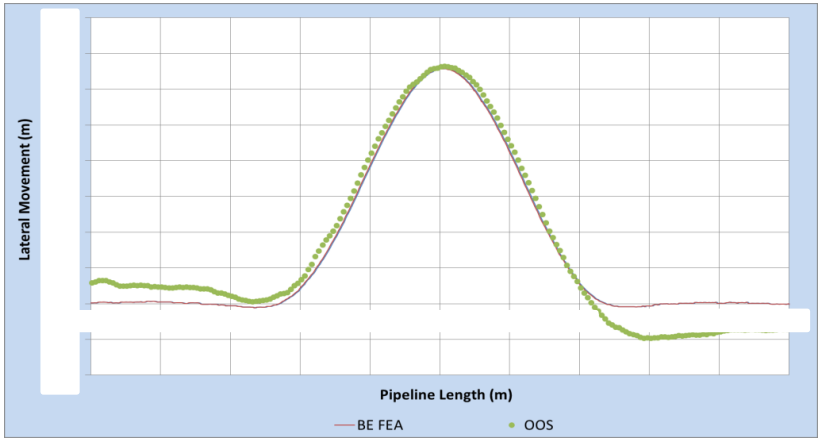
Key points to note for pipeline survey and verification works:

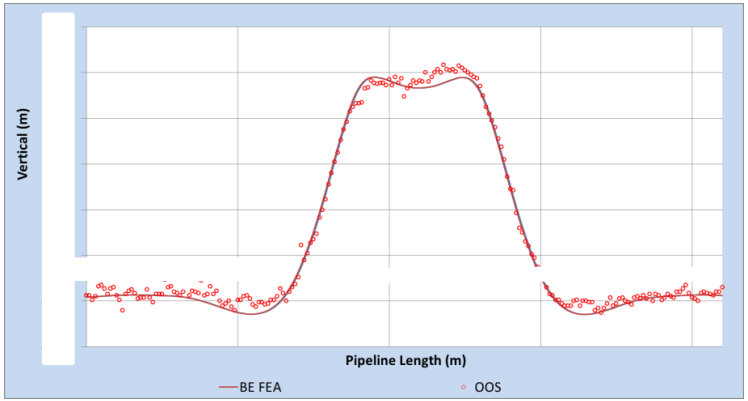
- Pipelines laid (as built survey performed, Q4 2015)
- Hydrotest, dewater
- Hot-oil cycle until operational temperature reached (wax management)
- Operation (first oil August 2016)
  - specific wells turned on (survey performed)

Lateral Buckling – Survey and Verification

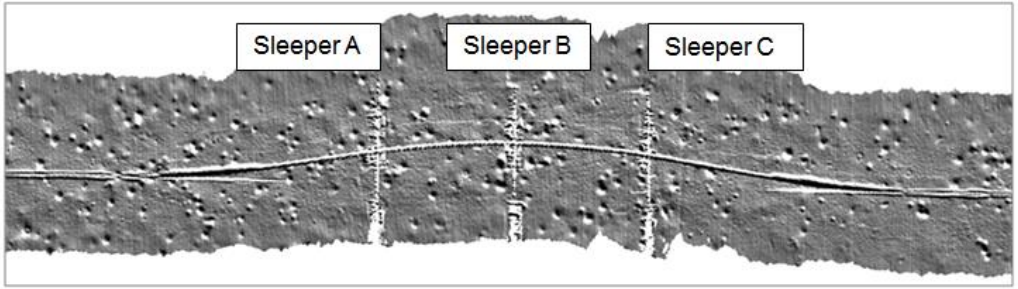
- Tasked to compare between design with ‘actual’ data
- Pipeline survey data were received at various times during operation
- Good correlation was shown in areas of:
  - Pipeline embedment with design soil data (approx. BE)
  - Process data
  - Expected buckle shape, and end expansions

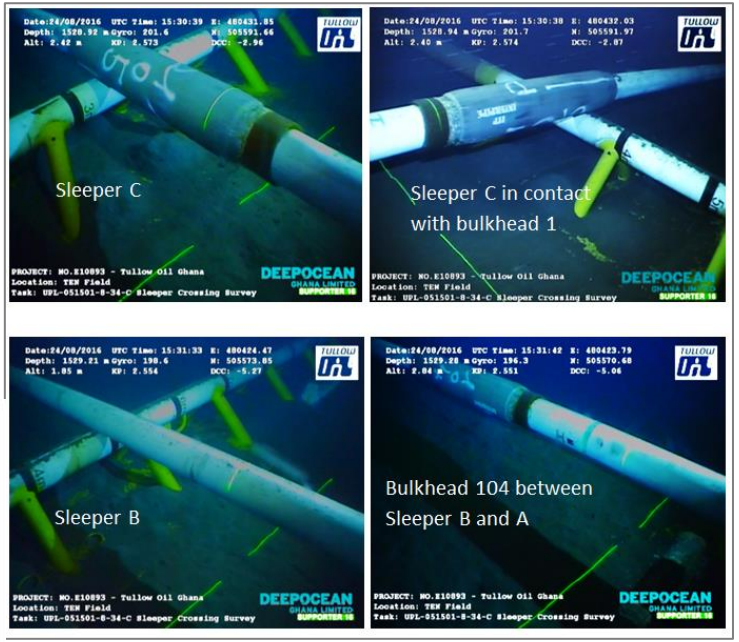




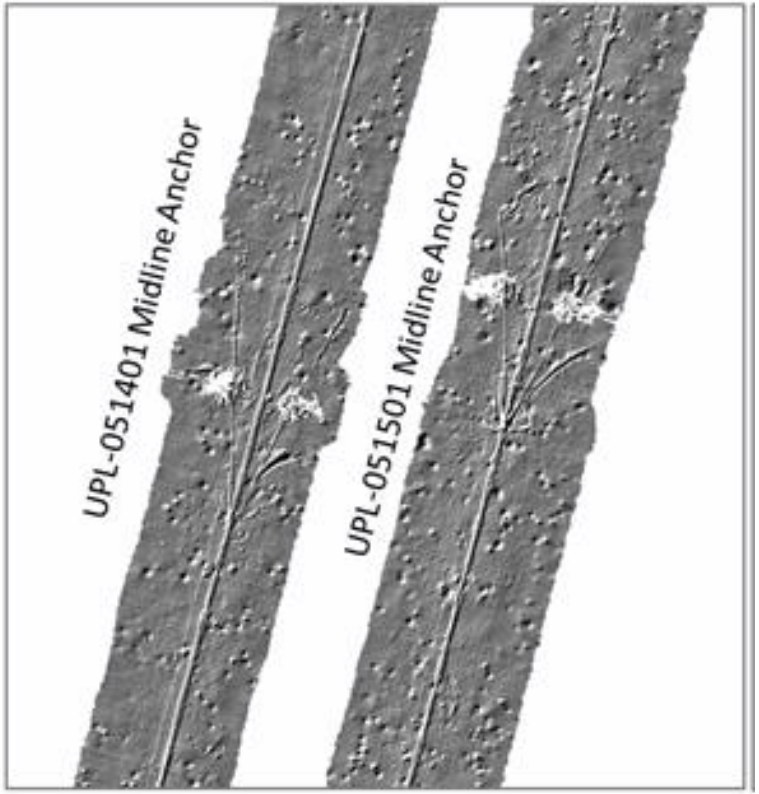


Lateral Buckling – Survey and Verification





Lateral Buckling – Survey and Verification



Conclusions

- Wood supported Tullow as client’s engineer during detailed design for subsea and pipelines
  - Proposed revised PSI data for main contractors to use in their design
  - Verified in parallel the proposed design as robust
- Wood continue to support Tullow in the operation of the TEN development as well as Jubilee including
  - Verification survey studies during operation confirm system’s integrity are currently within design limits
  - Flow assurance engineering
  - Ad hoc specialist engineering support

Lessons Learnt – Recommendations

- Bespoke PSI data one of the key drivers of mitigation solutions
  - To be developed as part of FEED (or earlier) in order to reduce risks and costs in the long term

- Independent verification type roles can encourage effective discussion between client and main contractors regarding proposed solutions

- Operation verification improvement on specifications and data collection
  - Would help in integrity assurance and monitoring works
  - Some suggestion examples:
    - Transponders installed at PLETs
    - Remote monitoring of pipeline at sleeper locations
    - Remote monitoring of pipeline walking (anchor engagement)

Wood – Questions?

Inspire with ingenuity
Partner with agility
Create new possibilities…