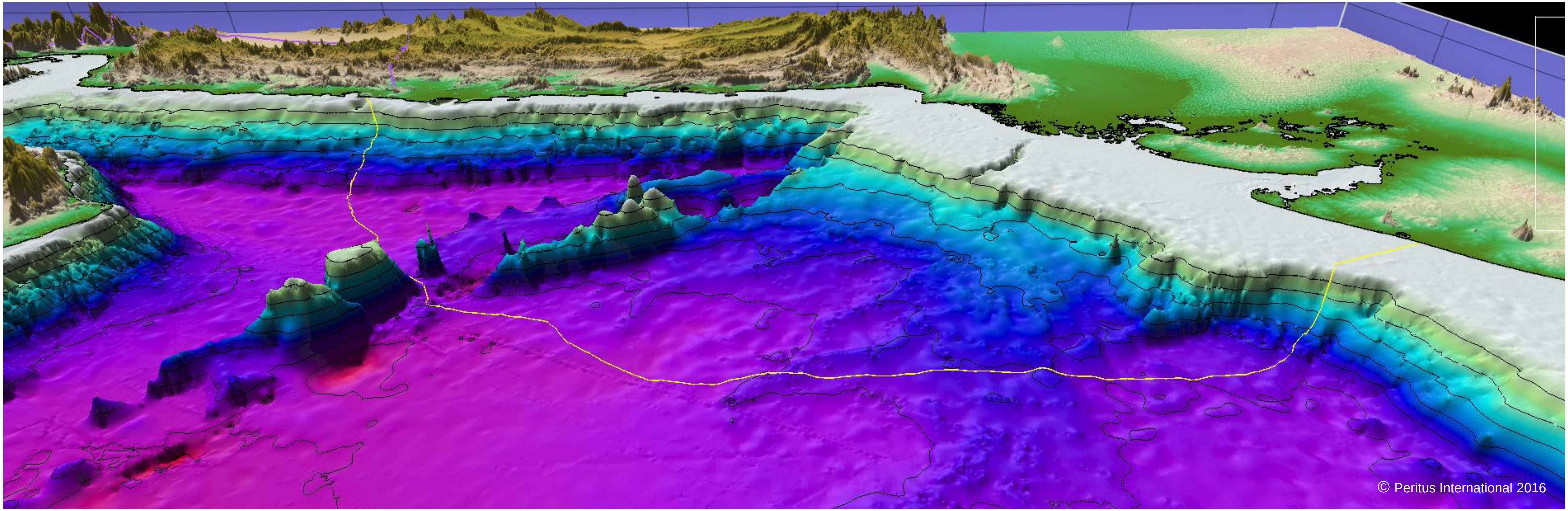
Middle East to India Deepwater Pipeline



MEIDP Presentation to DNVGL

17th October 2016

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Peritus International Limited.
Woking, Surrey, UK

Overview

- Introduction
- Design Basis
- Executive Summary
- Review of Potential Route options
- New MEIDP “Extended Route”
- Implications on Flow Assurance
- Mechanical Design of Extended Route
- Latest Mill testing and Mill capacity
- Vessel Status and Installability
- Cost Estimate update
- Summary and Conclusions

Introduction

SAGE

- South Asia Gas Enterprise Pvt Ltd (SAGE), a consortium lead by the Indian Siddhomal group, is actively considering building a deepwater, transnational, natural gas pipeline system from the Middle East to India

Base Case design

- SAGE has been developing the MEIDP project since 2008 and has established the technical viability of the pipeline between potential source countries Oman and Iran
- The technical issues associated with the Oman-India Pipeline of mid 90's have been solved
- The cost of MEIDP has shown it is an economically viable and safe way to import significant Gas into the West coast of India
- The base case route was designed to avoid Pakistan EEZ, passing to the south in international waters.

Design Basis (1)

SAGE

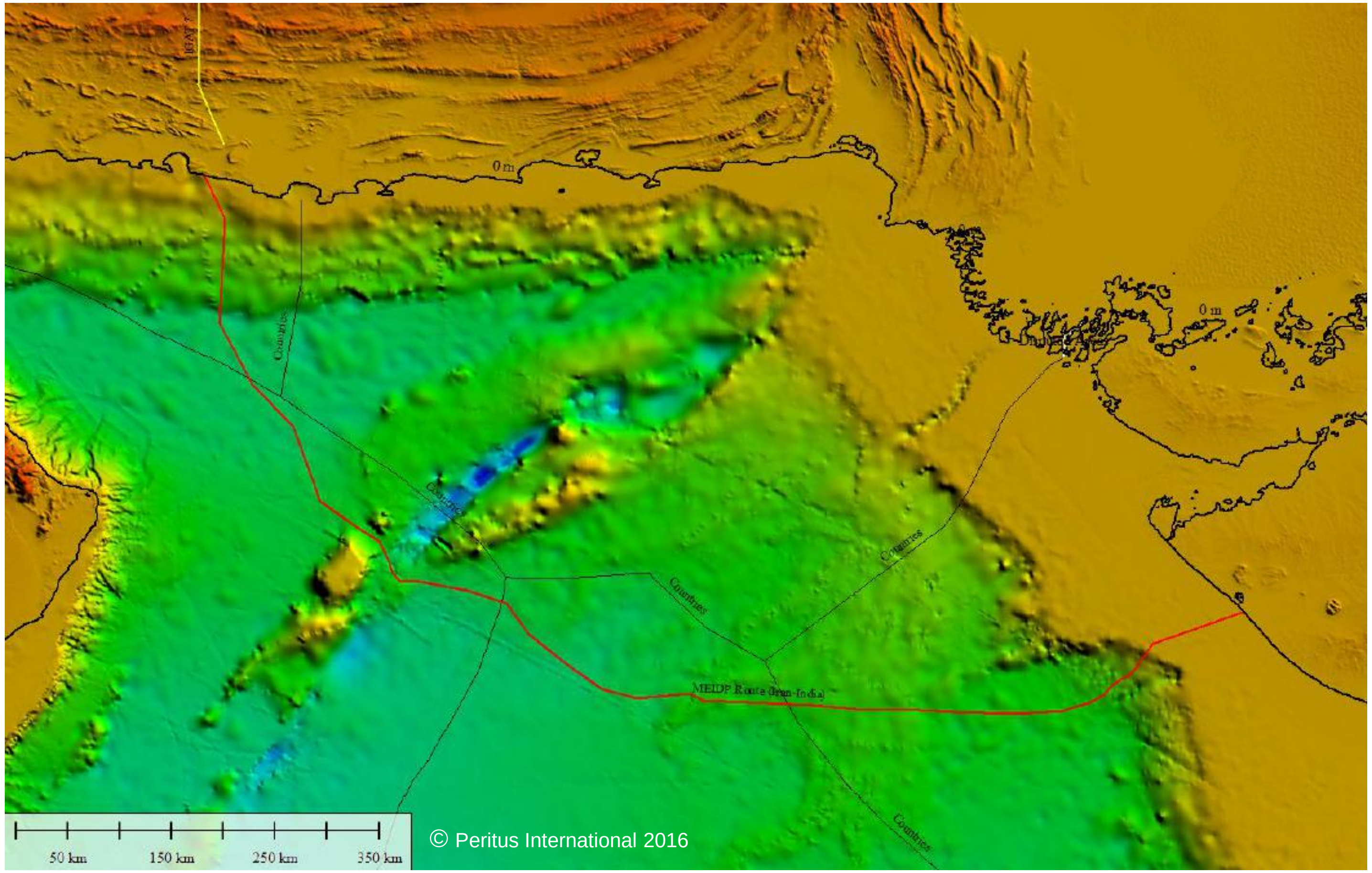
- MECS
  - 1.0BSCFD (annual Average)
  - 1.1BSCFD Nominal flowrate
  - Sales Quality Natural Gas
  - Dehydrated at MECS (<47mg/Sm³)
  - Inlet pressure 50 – 100 Barg
  - Outlet pressure 400 Barg
  - Cooling
- GPRT
  - 1.0BSCFD (annual Average)
  - Inlet at 50 Barg
  - Compression to 90 Barg
  - Heating/Cooling

Parameter	Unit	Average	Min	Max
C1	mol%	84.00	79.00	96.41
C2	mol%	9.21	2.01	10.20
C3	mol%	2.24	0.48	2.90
iC4	mol%	0.26	0.00	0.30
nC4	mol%	0.35	0.15	1.19
iC5	mol%	0.06	0.00	0.10
nC5	mol%	0.05	0.03	0.34
C6+	mol%	0.04	0.02	0.29
N2	mol%	2.57	0.45	5.42
Hemium	mol%	0.10	0.00	0.30
Hydrogen	mol%	0.00	0.00	0.10
CO2	mol%	1.13	0.19	3.23
	mol%	100.00		
Molecular Weight	kg/kmol	18.92		
Standard	kg/Sm3 (1bara@15C)	0.80		
Gross Calorific Value	Kcal/Sm3 (1bara@15C)		9000	10000
Wobbe	Kcal/Nm3 (1bara@0C)		9860	13850
Water	ppm	40	0	80

Peritus

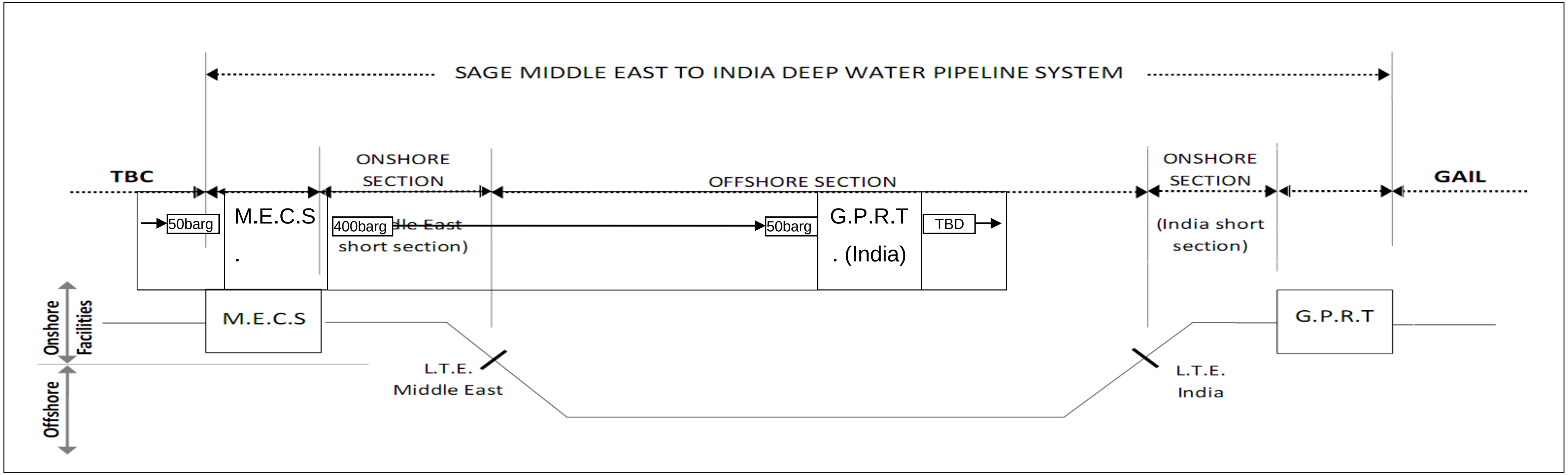
Project Executive summary

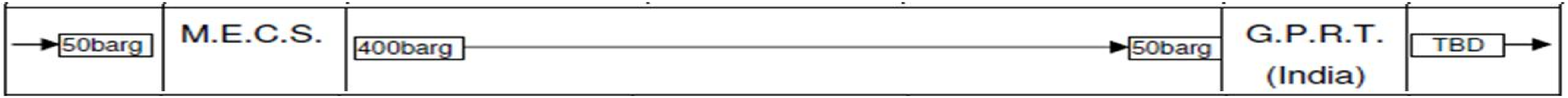
- **Start Point:** - Chabahar, Iran (IGAT 7)
- **End Point:** - Near Porbandar (South Gujarat), India
- **Flowrate:** - 1.1BSCFD (31.1mmscmd)
- **Inlet Pressure:** - 400barg
- **Diameter:** - 24” I.D. (27.2” O.D.)
- **Steel Grade:** - DNV SAWL485 FDU
- **Maximum Depth:** - 3,420 meters
- **Length:** - 1,278 kilometers
- **Project Duration:** - 7yrs (5yrs as Fast Track Project)
- **Pipeline Construction:** - 2 yrs



Design Basis (1)

- Battery Limits of MEIDP (Direct Option)





Design Basis (2)

Pipeline Design Codes
Onshore Iran - IPS-E-PI-140:2004
Offshore - DNV, Offshore Standard DNV-OS-F101, Submarine Pipeline System :2013
Onshore India - IS 15663 : 2006 (P1/2/3)

Description	Location Class	
	1	2
	All Offshore Sections Between Class 2 Locations	Shore termination to 500m Offshore
Installation / Hydrotest	Low	Low
Commissioning / Operation	Medium	High

Linepipe Data		
Description	Value	Unit
Corrosion Allowance	0	mm
Steel Density	7850	kg/m^3
Young's Modulus	207,000	MPa
Poisson's Ratio	0.3	-
Pipe Type	DSAW	-
Material Grade	DNV 485 Steel	-
SMYS	485	MPa
SMTS	570	MPa
Wall Thickness Negative Fabrication Tolerance	1.0	mm
Ovality	0.5	%

Project Executive summary (1)

- Project Definition and preliminary technical studies were carried out in 2010-2013
- Confirmed Technical Viability 2013
- Reconnaissance survey performed in 2013 on Oman to India route. Base case route reviewed and optimised
- Review of project economics and legal project framework 2014
- Route options defined to avoid Pakistan ECS and updated flow assurance mechanical design performed 2015/2016
- Updated Cost Estimate and schedule 2016

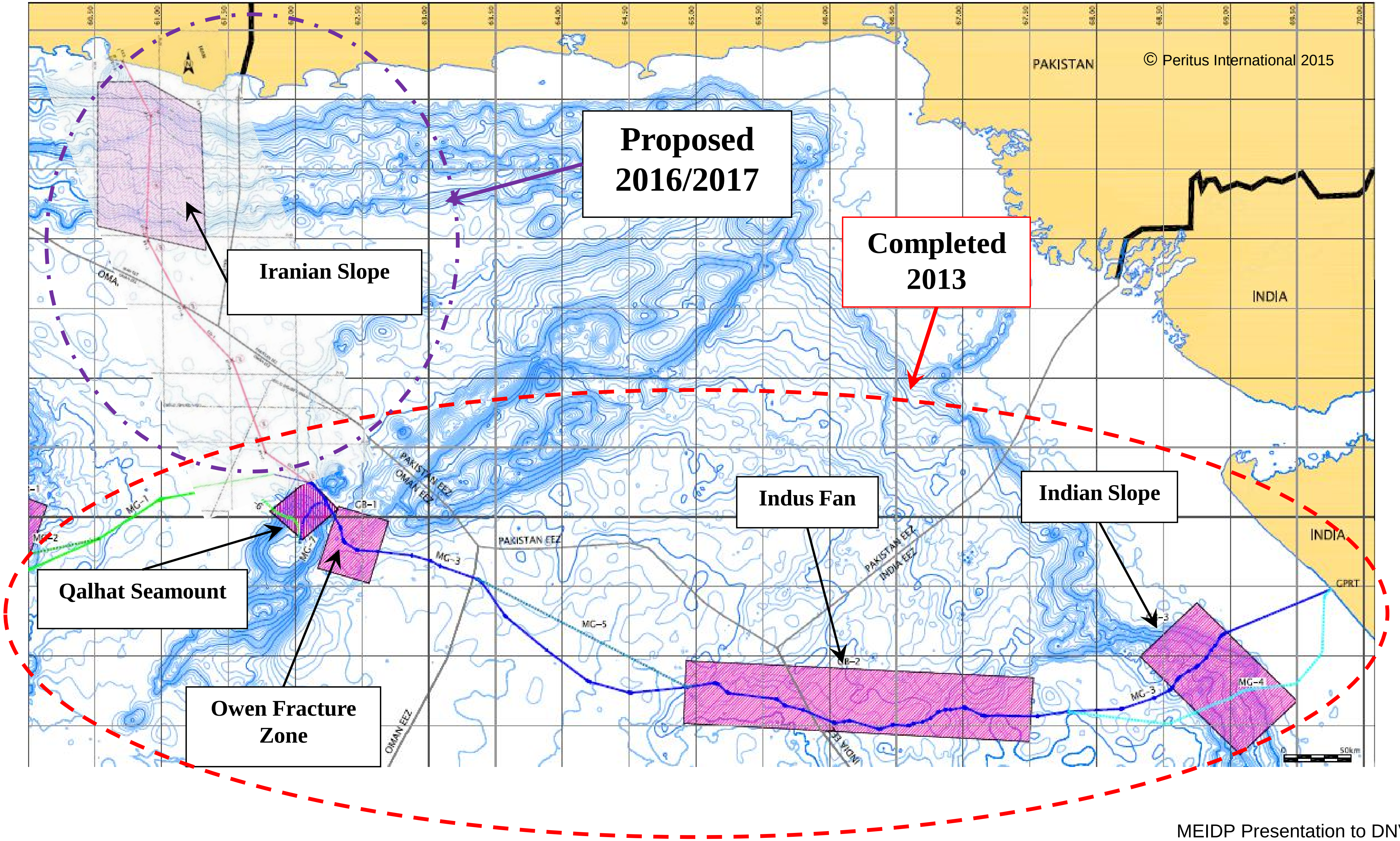
Project Executive summary (2)

- Design Basis definition (Peritus 2010)
- Flow Assurance Studies (Peritus 2011)
- Mechanical Design (Peritus 2011)
- Metocean desk top study (Fugro 2011)
- Geohazard and Fault Crossing Assessment Oman – India (Fugro 2011)
- Onshore Compression Station (WorelyParsons 2011, Petrofac 2012)
- Offshore Compression Station Definition (WorelyParsons 2011, Petrofac 2012)
- Receiving Terminal Definition (Petrofac 2012)
- Quantified Risk Assessment - OIP Update (Peritus 2012)
- Geohazard and Fault Crossing Assessment Iran (D’Appolonia 2012)
- GIS Data collection (Fugro/D’Appolonia 2012)
- Riser and Subsea By-Pass definition (Peritus 2012)

Project Executive summary (3)

- Reconnaissance Survey definition and scope of work (Peritus 2012)
- Emergency Repair and Intervention Equipment Review (Peritus 2013)
- Indian Mill pre-qualification and ring testing program (Peritus/EIL 2013-2014)
- Vessel & Equipment Capabilities review (Peritus 2012 & 2015)
- Alternative Integrity Verification Phase 1 (Establish no hydrotest principle) (Peritus 2015)
- Reconnaissance Survey Completed (Fugro OSAE 2013)
- Landfall point identification in India (EIL 2014)
- Preliminary Owen Fracture Zone and Indus Fan Assessments (Peritus 2014)
- Route options, Flow Assurance and Mechanical Design Update (Peritus 2015)
- Chinese Mill pre-qualification and ring testing program (Peritus/EIL 2015-2016)
- Cost Estimate and Schedule Update (Peritus 2016)

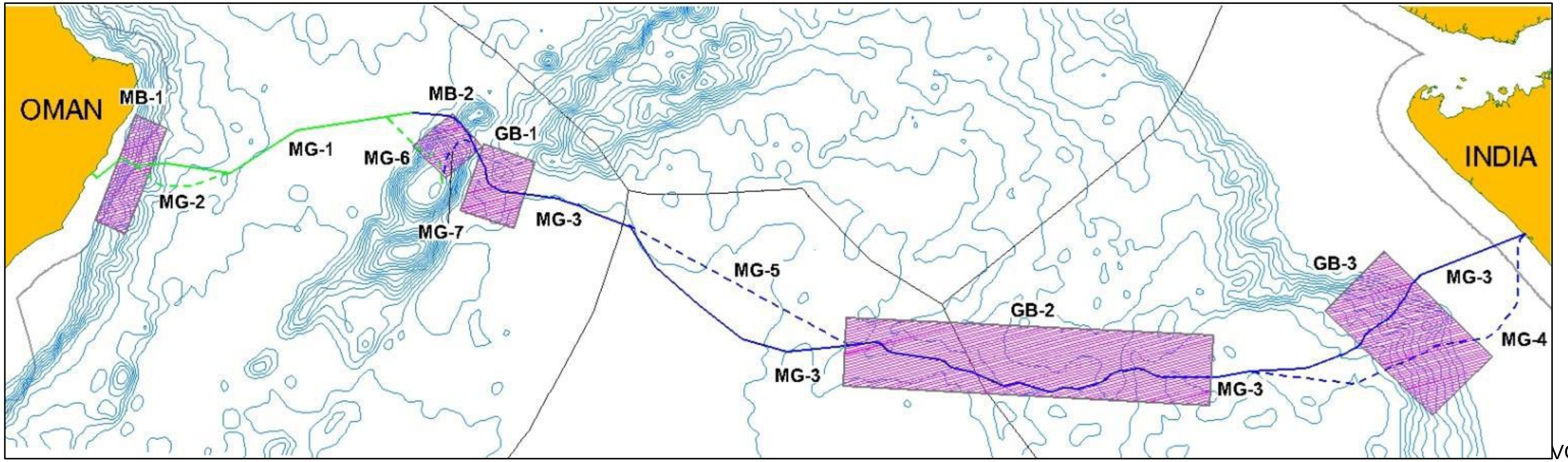
MEIDP 2013 Reconnaissance Survey (1)



MEIDP 2013 Reconnaissance Survey (2)

Objectives of Survey

- Omani Continental Shelf and slope
- Owen Fracture Zone
- Indus Fan
- Indian Continental shelf and slope.
- Potential compression Site on Qalhat Seamount



MEIDP2013 Reconnaissance Survey (3)

SAGE

- MV Fugro Gauss
- Hull mounted systems
  - Multi beam echo sounders (MBES)
    - Kongsberg EM122
    - Kongsberg EM710
  - Sub Bottom Profiler
    - Innomar SES-2000
- 18 April to 21 June 2013

Peritus

MEIDP 2013 Reconnaissance Survey (4)

Survey included the acquisition, processing, interpretation and reporting of appropriate hydrographic, geophysical, geological and geotechnical data as required to:

- Establish seabed topography
- Evaluation of seabed and shallow sub-seabed geological and geotechnical parameters
- Identify and map potential geological features, geotechnical phenomena and environmental constraints that may have the potential to influence the pipeline routing, construction or operation of the proposed pipeline development.

Task		Water Depth	Survey Scope
Block:	Reconnaissance Surveys	100m-3500m	Swath bathymetry, sub-bottom profiler
Corridor:	Reconnaissance Surveys	20m-200m	Swath bathymetry, sub-bottom, backscatter. Minimum corridor width 1 km (Bathy)
		200m-500m	Swath bathymetry, sub-bottom, backscatter. Minimum corridor width 2 km (bathy)
		500m-2000m	Swath bathymetry, sub-bottom, backscatter. Minimum corridor width 5 km (bathy)
		2000m-3500m	Swath bathymetry, sub-bottom, backscatter. Minimum corridor width 7 km (bathy)

MEIDP 2013 Reconnaissance (5)

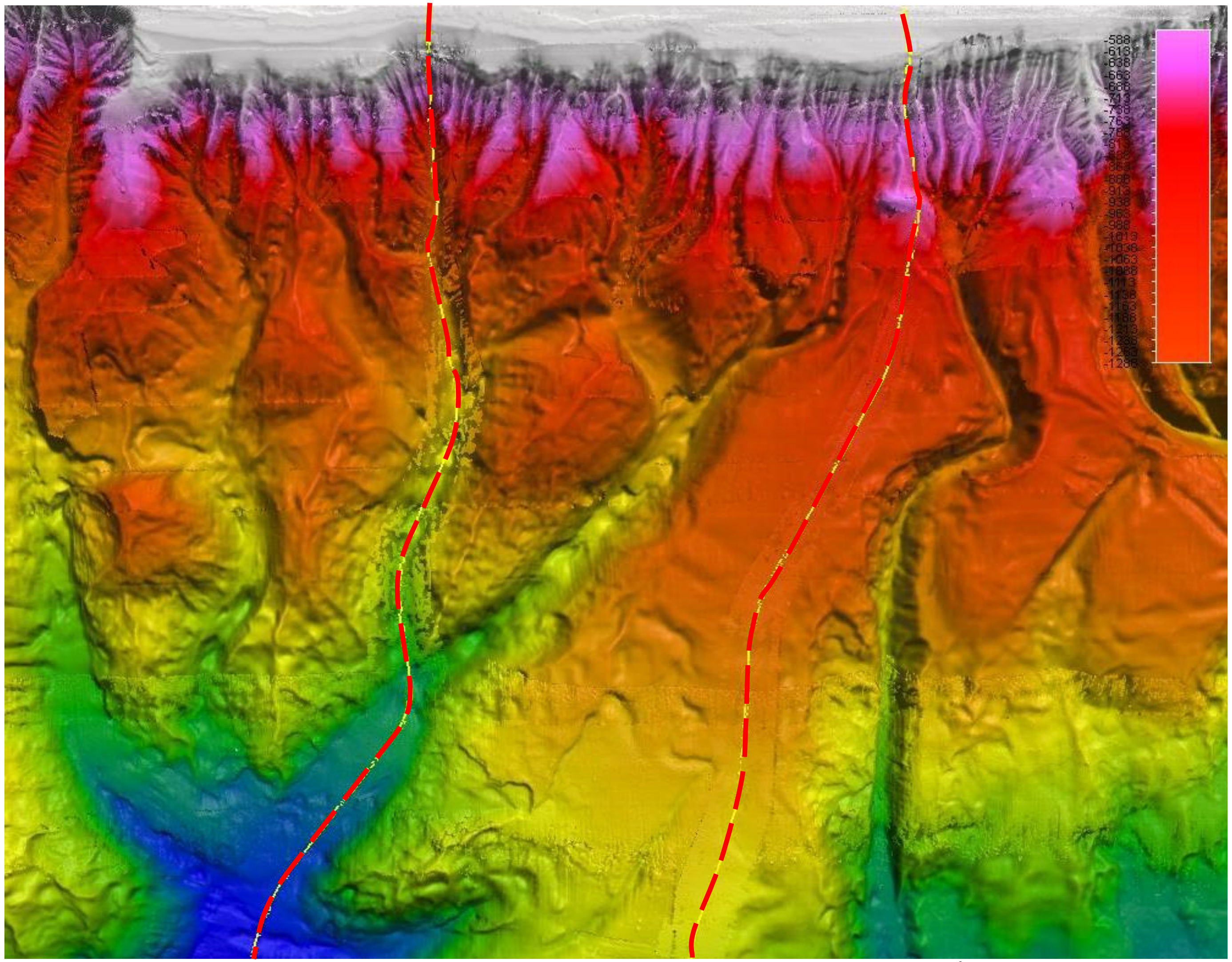
- Oman Continental Slope
- Route to Owen Fracture Zone
- Qalhat Seamount

MEIDP 2013 Reconnaissance (6)

Oman Continental Slope

The slope is dominated by large canyons and channels descending the slope seawards from the shelf.

- Water depth at the shelf break is approx. 100m with many small channels
- Channels merge to form canyons and at the foot of the slope (4 major canyons)
- Largest canyon complex, three large tributaries (almost 6km wide @2900m WD)
- There is evidence of slumping and sliding mainly within the channel walls
- The shelf and slope show homogeneous sediments between canyons which contain various amounts of coarser sediment
- On the shelf, there are outcropping rock and hard ground (sediments < 2m)

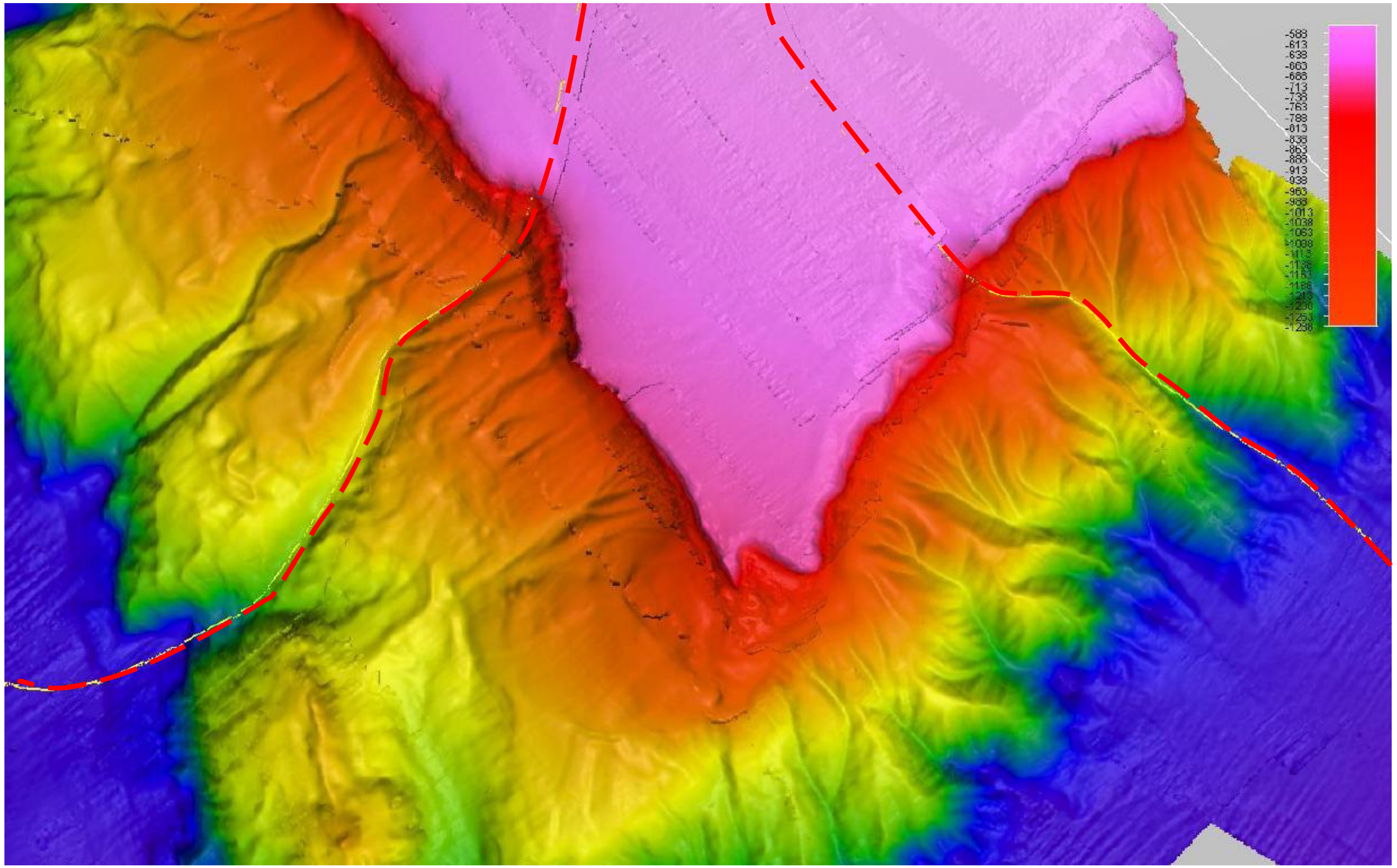


MEIDP 2013 Reconnaissance Survey (7)

Qalhat Seamount

Only the Northern corner of the plateau was covered by this survey,

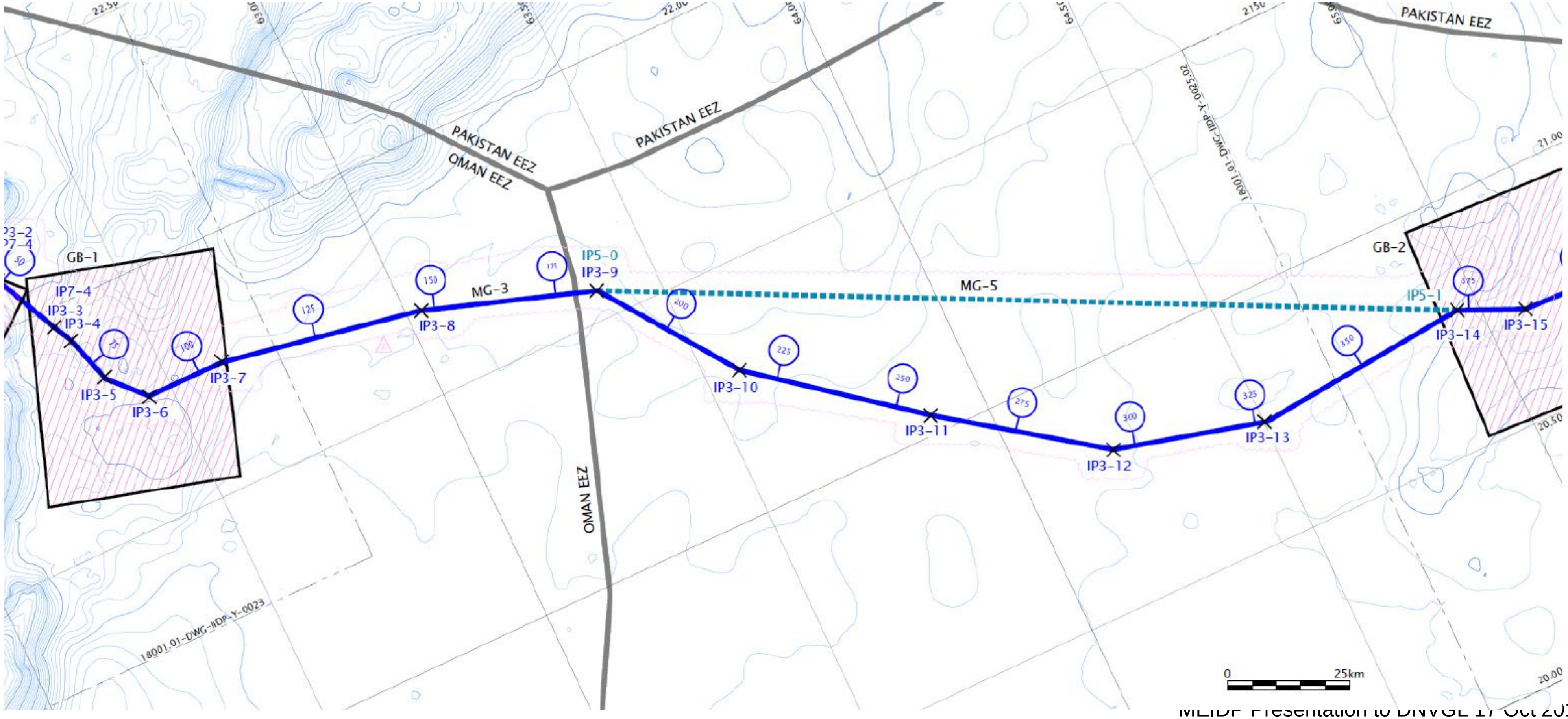
- Shallowest part of the Plateau is around 350m
- Plateau dips slightly towards the north with the plateau break occurring at between 650m and 700m water depth.
- Gradients are around 20° in the lower part
- Gradients between 25° and 29° in the upper slope area
- Deep canyons and gullies dissect the slopes containing courser materials
- There is some evidence of slumping and sliding along the slopes



MEIDP 2013 Reconnaissance (8)

SAGE

- Owen Fracture Zone
- Dalrymple Trough
- Lower Indus Fan



Peritus

MEIDP 2013 Reconnaissance (9)

Owen Fracture Zone

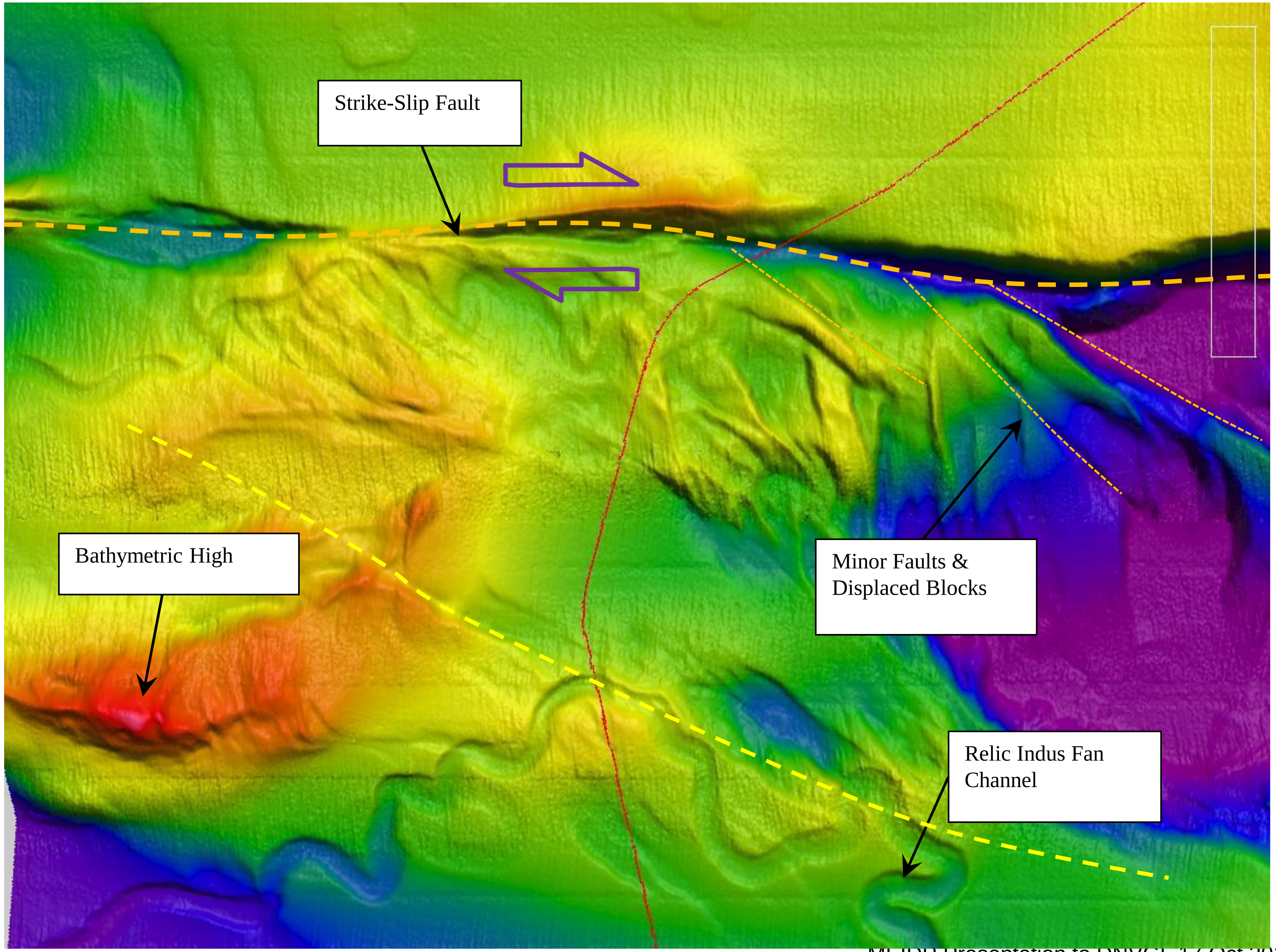
Block GB-1 block is characterized by two main structures:

- The deep basins of the Dalrymple Trough and horsetail in the north
- An arch formed bathymetrical high in the south

This fault is the tectonic plate boundary of the Indian and Arabian plates.

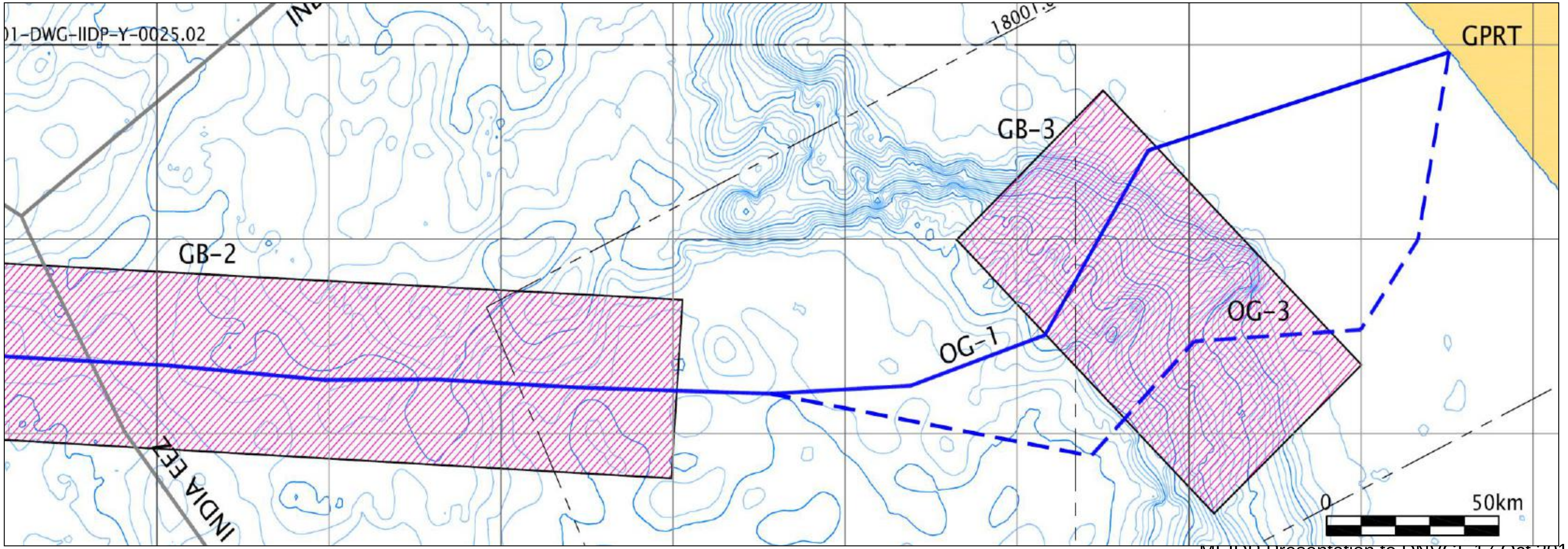
- A strike-slip right lateral fault
- Moving at a slip rate of 2mm/year (7mm/yr max).
- Fault forms a 200m deep canyon 1.3km wide at MEIDP crossing

The bathymetric high is about 6km wide and approx 19km long, rising to 2630m water depth at its shallowest part.



MEIDP 2013 Reconnaissance (10)

- Middle Indus Fan
- Indian Continental Slope
- Route to Gujarat Landfall



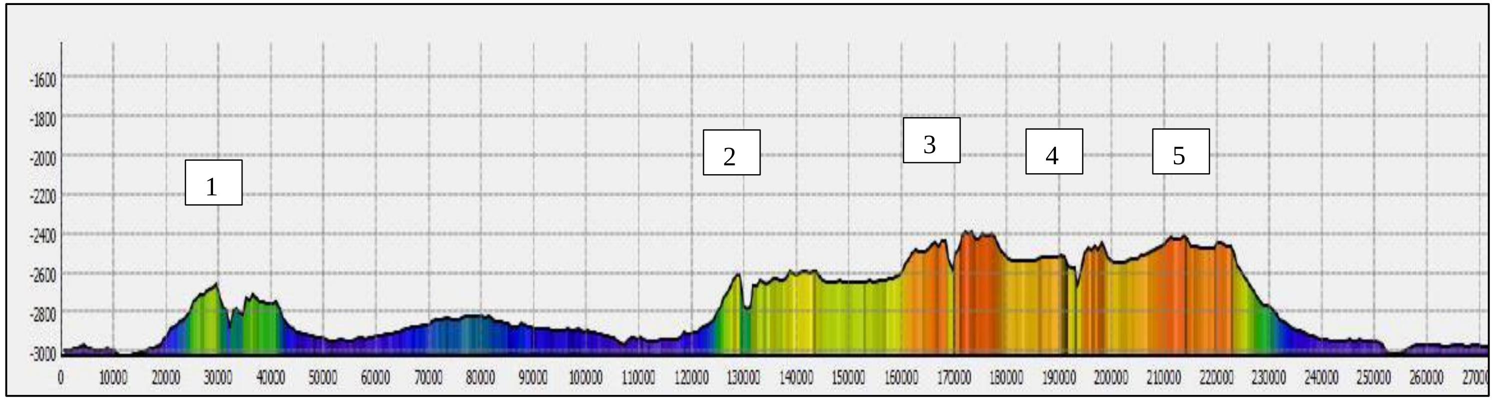
MEIDP 2013 Reconnaissance (11)

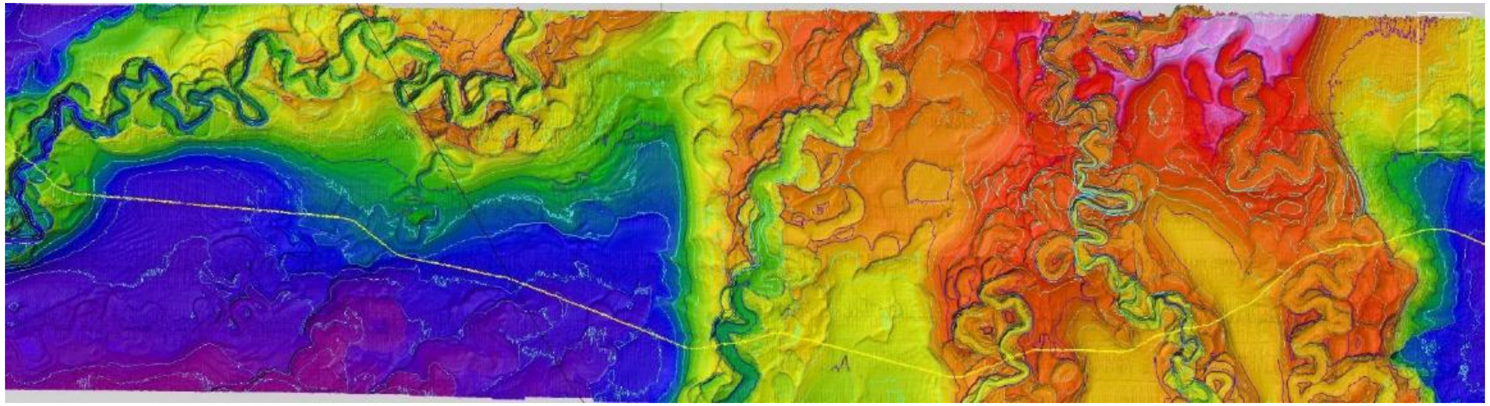
Block GB-2 is characterized by two topographical main structures in water depths between 2100m – 3200m:

- Channel/levee systems dominating the central part
- Deep sea basins in the easterly and westerly sections

The channel/levee system is characterized by central channels with a series of adjacent terraces and numerous abandoned channel loops

- The pipeline route crosses five turbidity current Channels
- up to 200m high with up to 25˚ side slopes
- Generally in a meandering flow pattern with general N-S direction
- Generally covered by a fine grained soft to very soft clay

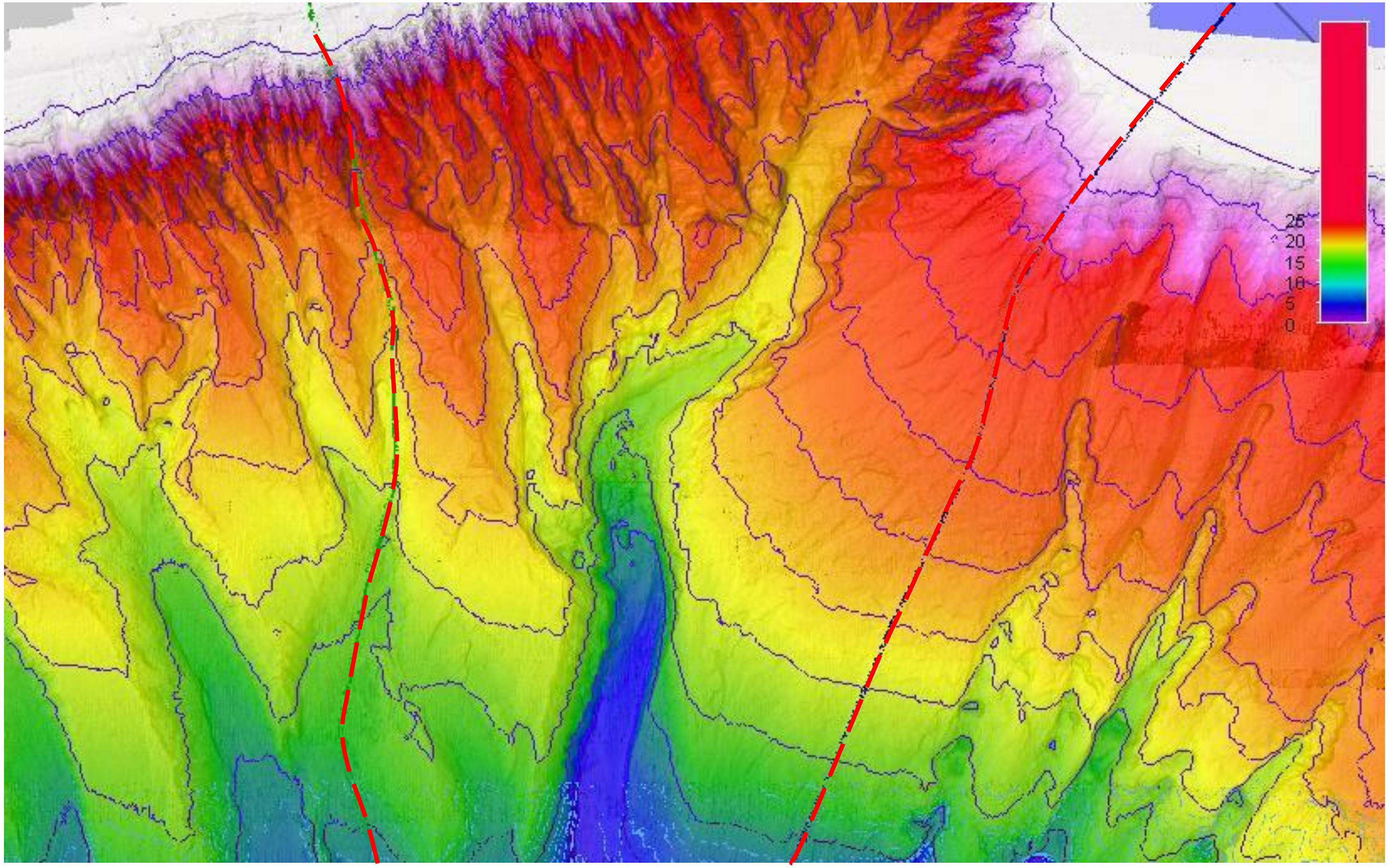




MEIDP 2013 Reconnaissance (12)

The Indian shelf break occurs between 100m to 150m water depth with the slope decending to 2500m at its base. The upper slope area is dominated by numerous steep incised gullies

- Slopes of up to 30 ˚ observed near the shelf break
- Gullies join to form smaller then large canyons
- Between the canyons sediment ridges/mounts are developed
- Slump deposits are evident especially at the base of the slope (within canyon walls)



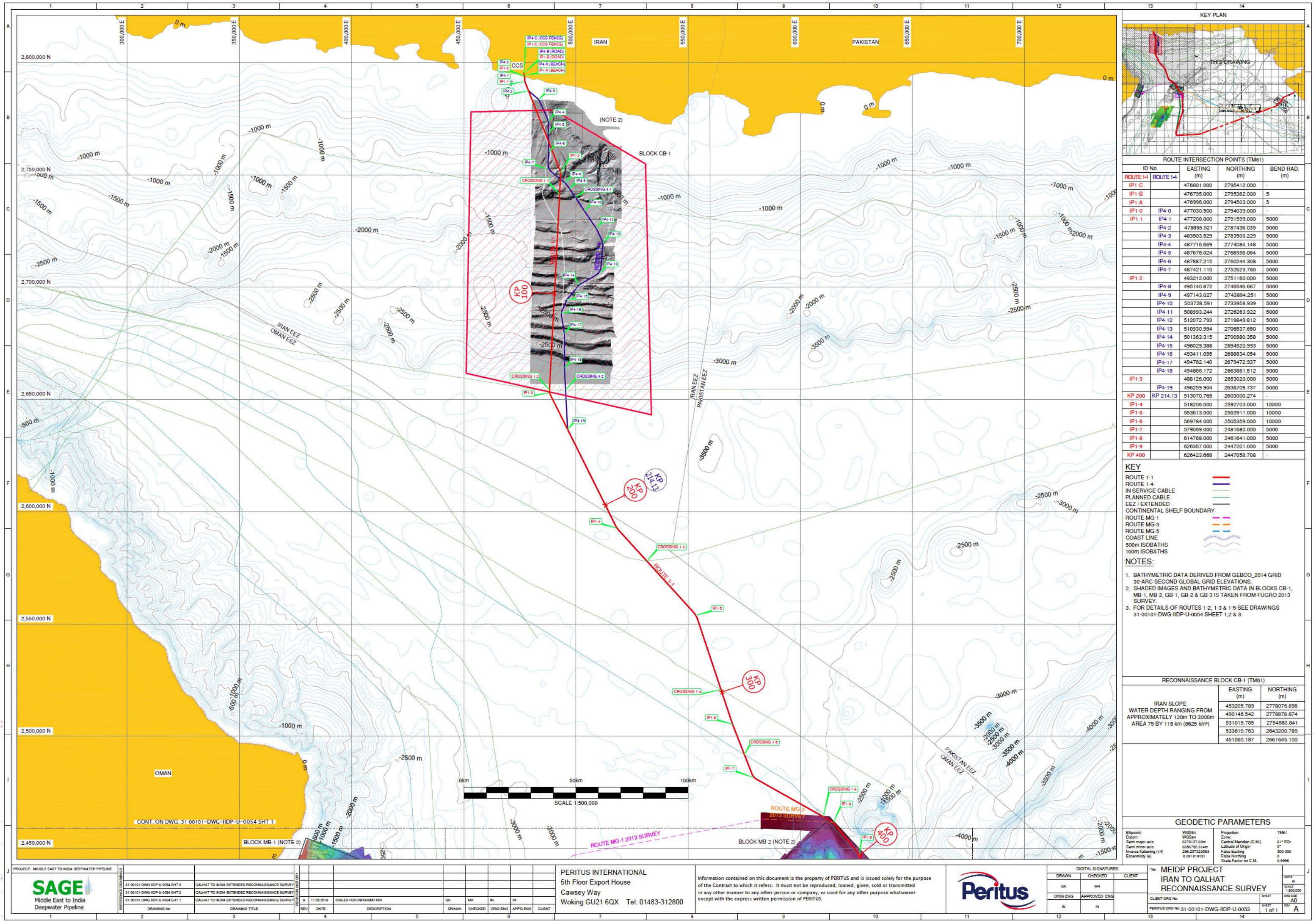
MEIDP 2013 Reconnaissance (13)

Geological Hazard	Survey Block				
	MB-1	MB-2	GB-1	GB-2	GB-3
Faults	✓	✓	✓		✓
Slope instability	✓	✓	✓	✓	✓
Debris Flows	✓	✓	✓		✓
Slumps/Slides	✓	✓	✓		✓
Turbidity Currents			✓	✓	
Scour	✓				✓
Rock Outcrop	✓	✓	✓		✓
Hardground	✓	✓			
Corals	✓				✓
Shallow Gas					✓
Variable Soil Conditions	✓	✓	✓		✓

Future & Detailed Surveys (1)

- Reconnaissance Surveys (Planned Jan 2017) – Hull mounted Geophysical with limited Piston Cores and current metering at seabed
  I. Iran Qalhat (Iran Slope Block, 2 Route Corridors)
  II. Qalhat – Indian slope (Qalhat South Block, Extended route (ECS), Indus South Block)
- Metocean Survey (Planned Dec 2016) – Seabed current metering throughout route. Full profile metering selected locations, wave recording selected locations
- Detailed Geotechnical (Planned Nov 2017) – CPT's and Piston Cores throughout route, limited box cores.
- Detailed Geophysical (Planned Nov 2017) – AUV survey of base and alternate routes
- 2DUHR Surveys (Planned Nov 2017) – At key features
- Environmental Survey (Planned TBD) – Survey of Base and Alternate routes

Future & Detailed Surveys (2)



ID No. ROUTE 1-1	ID No. ROUTE 1-4	EASTING (m)	NORTHING (m)	BEND RAD. (m)
IP1-C		476801.000	2795412.000	-
IP1-B		476795.000	2795362.000	5
IP1-A		476996.000	2794503.000	5
IP1-0	IP4-0	477030.500	2794039.000	-
IP1-1	IP4-1	477208.000	2791599.000	5000
	IP4-2	478855.521	2787436.035	5000
	IP4-3	483503.529	2783500.229	5000
	IP4-4	487716.669	2774084.148	5000
	IP4-5	487678.024	2768556.064	5000
	IP4-6	487887.215	2760244.308	5000
	IP4-7	487421.110	2752623.760	5000
IP1-2		493212.000	2751160.000	5000
	IP4-8	495140.872	2746546.667	5000
	IP4-9	497143.027	2743894.251	5000
	IP4-10	503728.591	2733958.939	5000
	IP4-11	508993.244	2726263.922	5000
	IP4-12	512072.793	2719849.812	5000
	IP4-13	510930.994	2706537.650	5000
	IP4-14	501363.315	2700980.358	5000
	IP4-15	496029.388	2694520.993	5000
	IP4-16	493411.095	2688634.054	5000
	IP4-17	494782.140	2679472.937	5000
	IP4-18	494866.172	2663881.512	5000
IP1-3		488126.000	2653020.000	5000
	IP4-19	496259.904	2636709.737	5000
KP 200	KP 214.13	513070.765	2603000.274	-
IP1-4		518206.000	2592703.000	10000
IP1-5		553613.000	2553911.000	10000
IP1-6		569784.000	2505359.000	10000
IP1-7		579069.000	2481680.000	5000
IP1-8		614768.000	2461641.000	5000
IP1-9		626357.000	2447201.000	5000
KP 400		626423.668	2447058.708	-

KEY

ROUTE 1-1
ROUTE 1-4
IN SERVICE CABLE
PLANNED CABLE
EEZ / EXTENDED CONTINENTAL SHELF BOUNDARY
ROUTE MG-1
ROUTE MG-3
ROUTE MG-5
COAST LINE
500m ISOBATHS
100m ISOBATHS

NOTES:

1. BATHYMETRIC DATA DERIVED FROM GEBCO_2014 GRID 30-ARC SECOND GLOBAL GRID ELEVATIONS.
2. SHADED IMAGES AND BATHYMETRIC DATA IN BLOCKS CB-1, MB-1, MB-2, GB-1, GB-2 & GB-3 IS TAKEN FROM FUGRO 2013 SURVEY.
3. FOR DETAILS OF ROUTES 1-2, 1-3 & 1-5 SEE DRAWINGS 31-00101-DWG-IIDP-U-0054 SHEET 1,2 & 3.

RECONNAISSANCE BLOCK CB-1 (TM61)

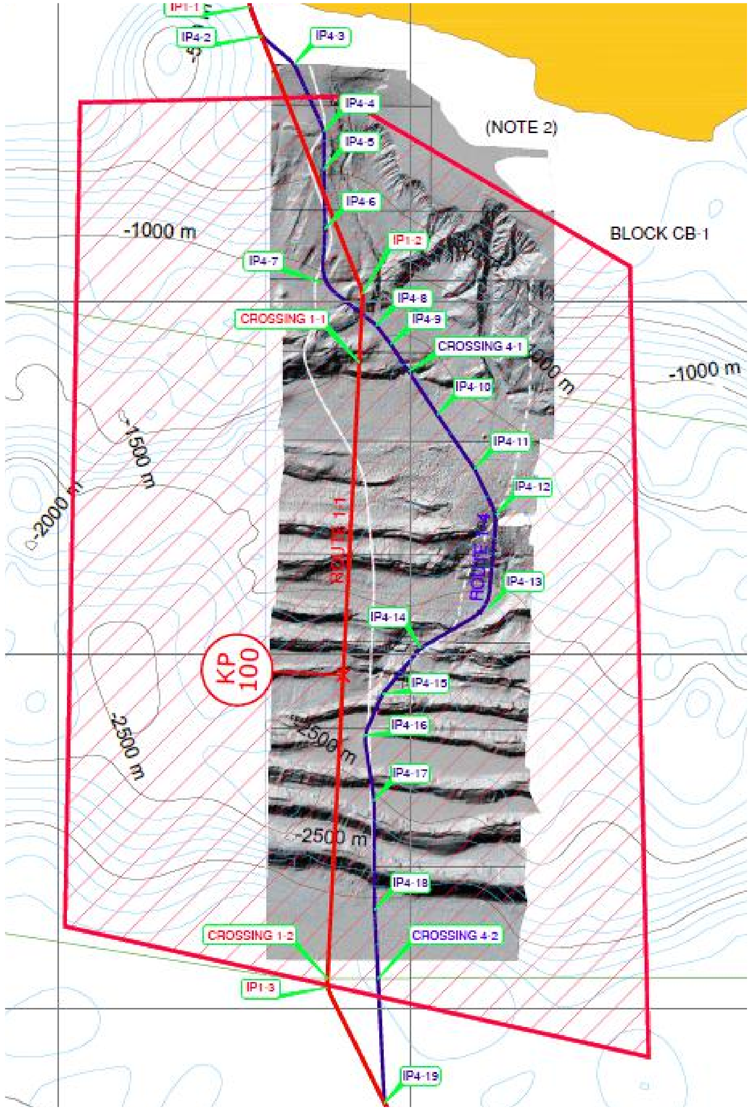
	EASTING (m)	NORTHING (m)
IRAN SLOPE WATER DEPTH RANGING FROM APPROXIMATELY 120m TO 3000m AREA 75 BY 115 km (8625 km²)	453205.789	2778076.898
	490146.542	2778878.874
	531019.785	2754880.841
	533619.763	2643200.789
	451060.187	2661645.100

GEODETIC PARAMETERS

PERITUS INTERNATIONAL
5th Floor Export House
Cawsey Way
Woking GU21 6QX Tel: 01483-312800

MEIDP PROJECT
IRAN TO QALHAT
RECONNAISSANCE SURVEY

31-00101-DWG-IIDP-U-0053



Summary and Conclusions

- The Technical Feasibility of MEIDP is proven
- Design methods for ultra deepwater pipeline and pipelines in seismic zones are well established
- Mills can and have made pipe to meet MEIDP Requirements
- Vessels are available in the market that can install the pipeline and more are due soon
- Intervention tools to avoid flooding and effect pipeline repair are available

MEIDP Current and Planned work

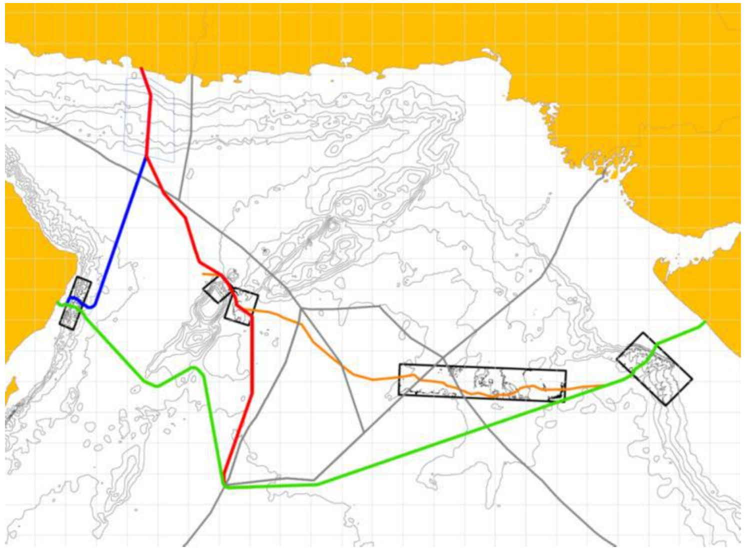
Planned Work

- Iran Leg Reconnaissance Survey
- Extended Route Reconnaissance Survey
- Intervention optimization at the Continental Slopes, Owen Fracture Zone and Indus Fan
- Commence Offshore Pipeline FEED (lite)
- Onshore Facilities' FEED (lite)
- Environmental Statement & Survey
- Metocean Data Collection on Site
- Detailed Geophysical & Geotechnical Surveys

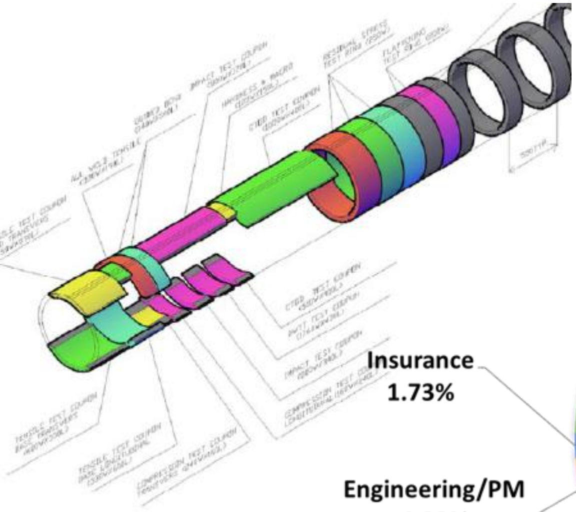
Highlighted Technical Challenges

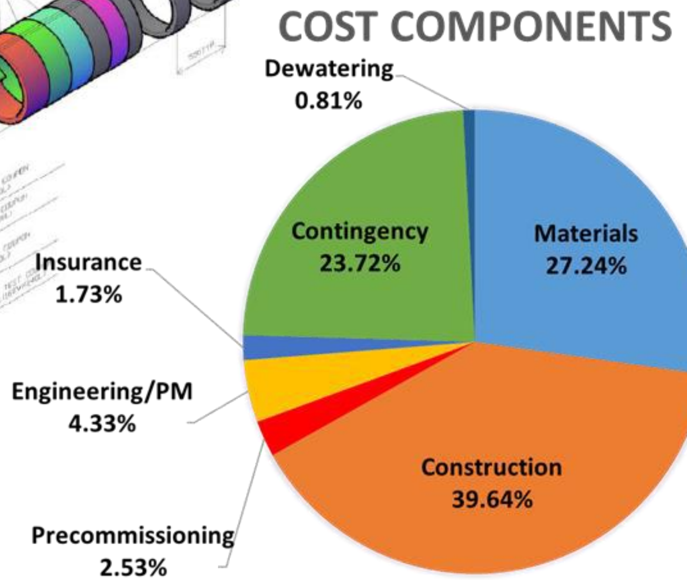
- Ultra Deep Water 3400m - 3600m depending on Route
- Wall Thickness on limit of Mill Capacity
- Mill Qualification
- Active Fault crossing (Seismic Design)
- Indus Fan channel crossings up to 200m deep and 30 degree slopes
- High pressure 400barg system
- Anti Flooding system required for Installation
- Hydrotest dispensation required
- Steep Slopes and geohazards on shelf breaks in Iran and India (Seismic Design)

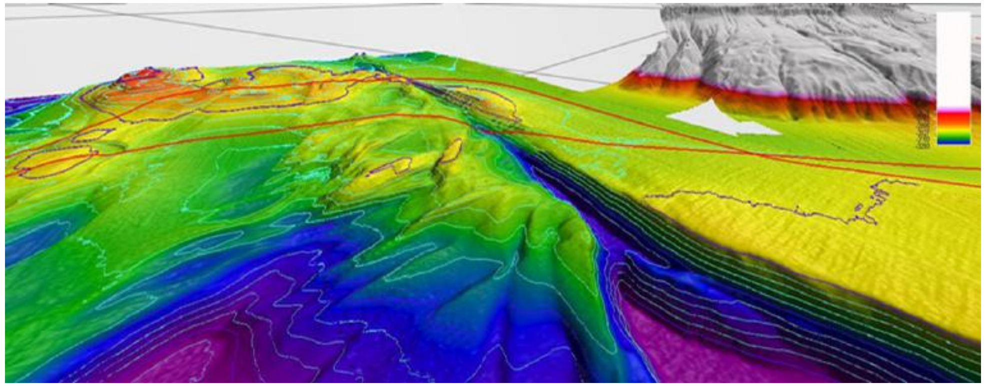
Other Interesting Bits!!

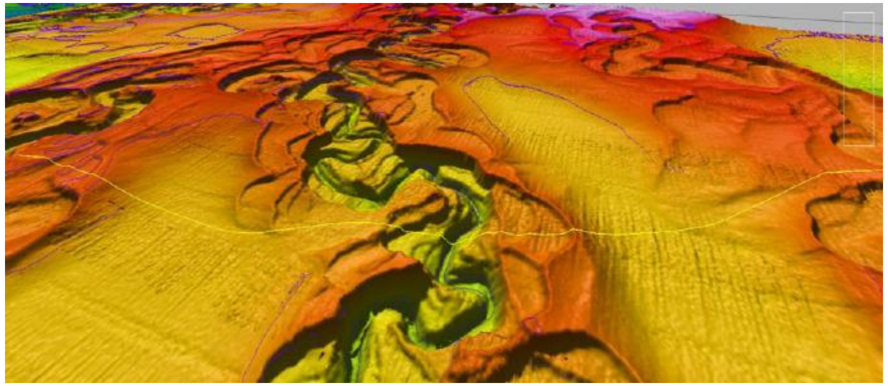


- 2015 Route Issues (UNCLOS)
- Project Linepipe Requirements
- Mill Capacity and Testing
- Vessel Status and Installability
- Project Cost Estimate
- Initial Review of Owen Fracture Zone
- Initial Review of Indus Fan Crossing









Route Issues

UNCLOS Decision April 2015

- In April 2015 UNCLOS made a decision to allow Pakistan an extension to its Continental Shelf to 350Nm. This decision was made **without prejudice to Oman's counter claim** covering much of the same seabed.
- Under UNCLOS the Continental Shelf and EEZ have different Status
- The coastal state **Cannot stop** or **hinder** the installation of a submarine pipeline of Cable across its Continental Shelf.
- The coastal state does however have the **right to be consulted** on the route of a pipeline crossing its continental shelf.

Review of Base Case design

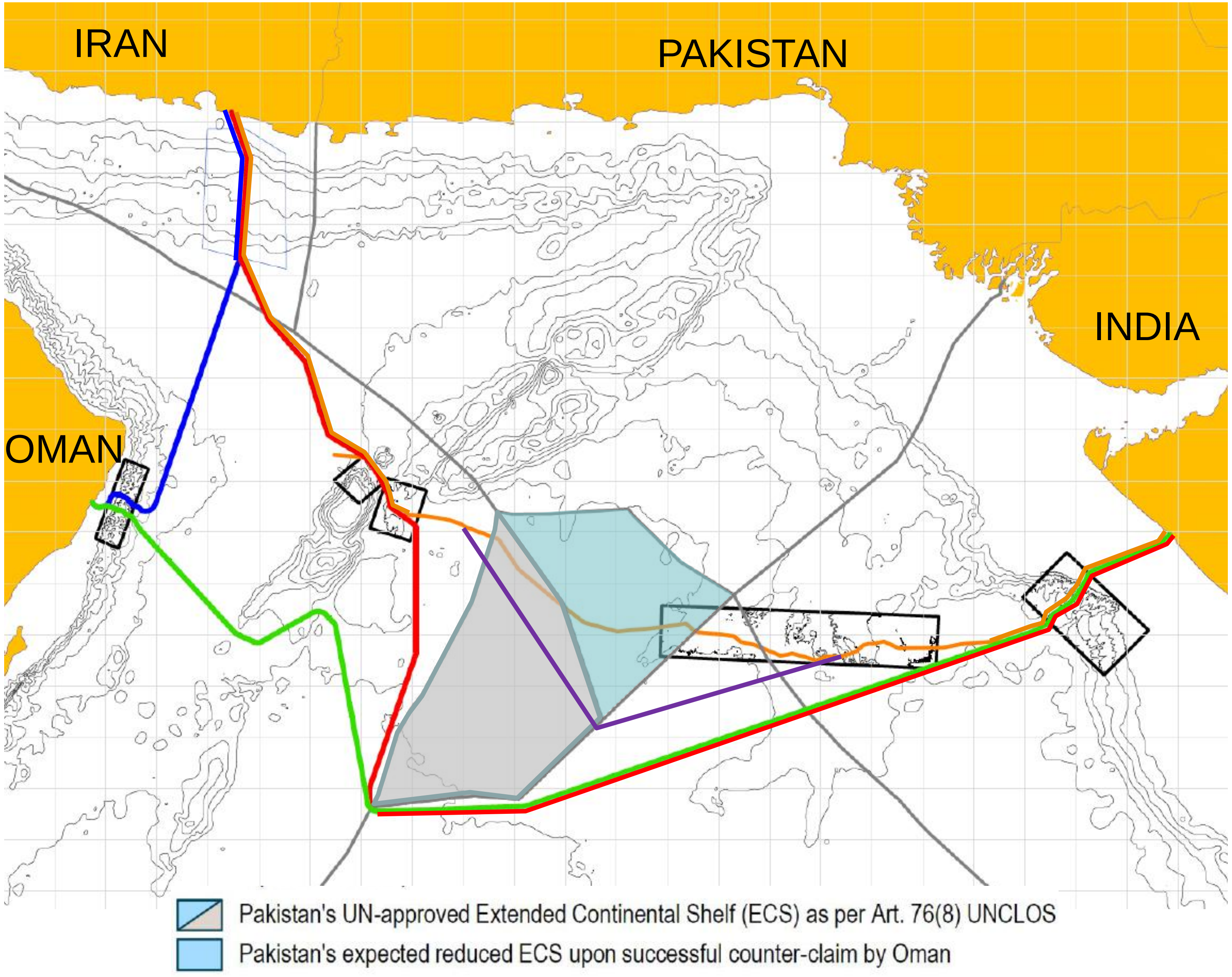
- The Base Case MEIDP route was designed to avoid Pakistan EEZ and pass through international water to the south.
- The Extended Continental Shelf (ECS) means the Base Case route now passes through Pakistans ECS.
- SAGE has performed an assessment to determine the potential options and implications of new route options that avoid the new ECS of Pakistan

Review of Potential Route Options

Four routes have been considered

- Base Route has been updated based on 2013 Reconnaissance Survey results.
- Deviated Route which avoids the undisputed part of Pakistan's ECS (Oman Counter claim), but maintains most of the Base Route.
- Extended Route which avoids the ECS awarded to Pakistan (UNCLOS April 2015) but maintains a direct route from Iran to India.
- Alternative Route which avoids the ECS awarded to Pakistan (UNCLOS April 2015) but takes an indirect route from Iran to Oman then Oman to India.

Review of Potential Route Options



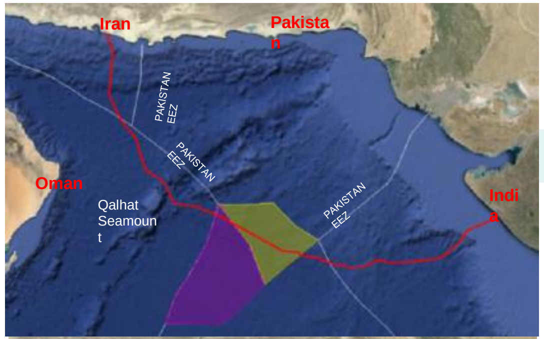
Base Route

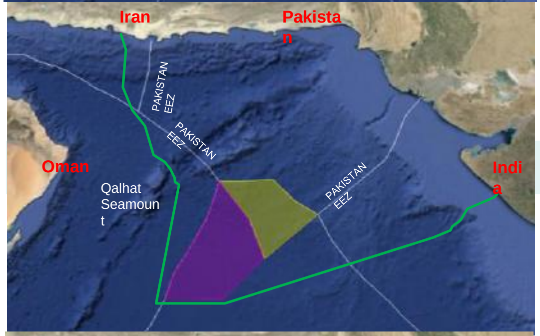
Deviated Route

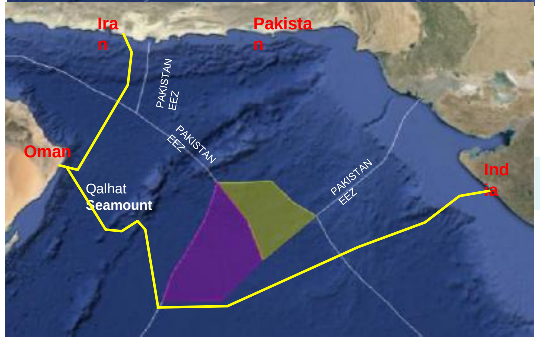
Extended Route

Alternative Route

Review of Potential Route Options







Route Options & Implications

	Route Length (km)	Internal Diameter (mm)	Maximum Water Depth (m)	Maximum Wall Thickness (mm)
Base Case Route	1277	610	3380	40.3
Extended Route	1596	711 & 610	3600	42.3 (610 ID)
Alternative Route	1816	610	3600	42.3

4.2 Linepipe (4) – Project Requirements

Base Route Linepipe tonnages

KP Start (km)	KP End (km)	Length (km)	Pipe ID (mm)	Pipe OD (mm)	Pipe WT (mm)	Concrete Thickness (mm)	Buckle Arrestor Thickness (mm)	Pipe Steel Required (Tonnes)	Concrete Required (km)	Buckle Arrestor Quantity	Buckle Arrestor Steel Required (Tonnes)(1)	SG
0	10	10	610.0	685.6	37.8	90.0	-	6,039	10	-	-	1.8
10	30	20	610.0	675.8	32.9	50.0	-	10,433	20	-	-	1.6
30	70	40	610.0	675.8	32.9	-	53.1	20,865	-	20	76	1.4
70	105	35	610.0	675.8	32.9	-	60.5	18,257	-	18	79	1.4
105	130	25	610.0	683.6	36.8	-	65.9	20,865	-	13	63	1.6
130	742	612	610.0	690.6	40.3	-	70.3	18,257	-	306	1,615	1.7
742	1,130	388	610.0	683.6	36.8	-	65.9	14,675	-	194	945	1.6
1,130	1,157	27	610.0	675.8	32.9	-	60.5	395,539	-	14	62	1.4
1,157	1,178	21	610.0	675.8	32.9	-	53.1	227,756	-	11	42	1.4
1,178	1,248	70	610.0	675.8	32.9	50.0	-	36,514	70	-	-	1.6
1,248	1,268	20	610.0	675.8	32.9	90.0	-	10,433	20	-	-	1.7
1,268	1,278	10	610.0	685.6	37.8	90.0	-	6,039	10	-	-	1.8
							TOTAL	**771,586**	**130**	**576**	**2,882**	

Latest Mill testing and Mill capacity

- Six pipe Mills have responded to budget queries about the production of MEIDP linepipe of these three have stated they can produce the full range.
- Two pipe Mills (JindalSAW, PCK) have manufactured linepipe specifically for SAGE to MEIDP Dimensions and Specification.
- JFE is about to embark on a similar production and testing trial.
- PCK (China) are currently undergoing a “Ring Collapse” test program, witness by SAGE. Preliminary results are successful.

Latest Mill testing and Mill capacity

Mills capable of making MEIDP Linepipe

Pipe ID (mm)	Wall Thickness (mm)	Tata Steel	Jindal SAW	Metal One	Europipe	PCK	Welspun
610	32.9	✓	✓	✓	✓	✓	TBA (HOLD 1)
	34.5	✓	✓	✓	✓	✓	
	36.8	✓	✓	✓	✓	✓	
	37.8	✓	✓	✓	✓	✓	
	40.3	✗	✓	✓	✓	✓	
	42.3	✗	✓	✗	✓	✓	
711	38.7	✗	✓	✗	✓	✓	
	43.9	✗	✓	✗	✓	✓	

Linepipe – Ring Collapse Testing (1)

SAGE

Testing program including Ring collapse testing has been performed at 3 pipe mils

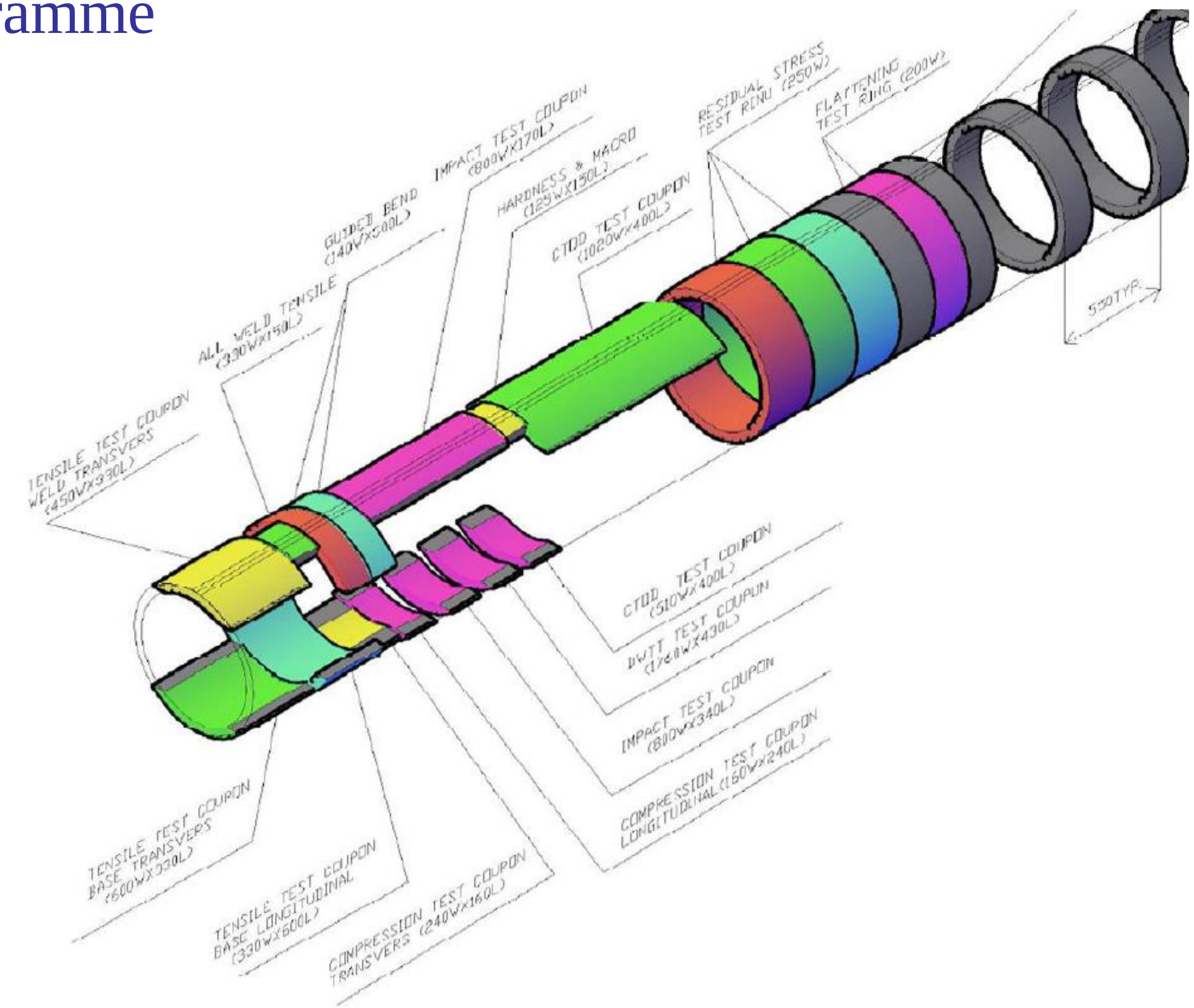
- JindalSAW (India) 4 Joints 32 Rings
- Welspun (India) 4 Joints 24 Rings
- PCK (China) – 10 Joints 72 Rings

In addition JFE (Japan) has undergone internal trials on the production of MEIDP linepipe and has just commenced a formal testing program.

Peritus

Linepipe – Ring Collapse Testing (2)

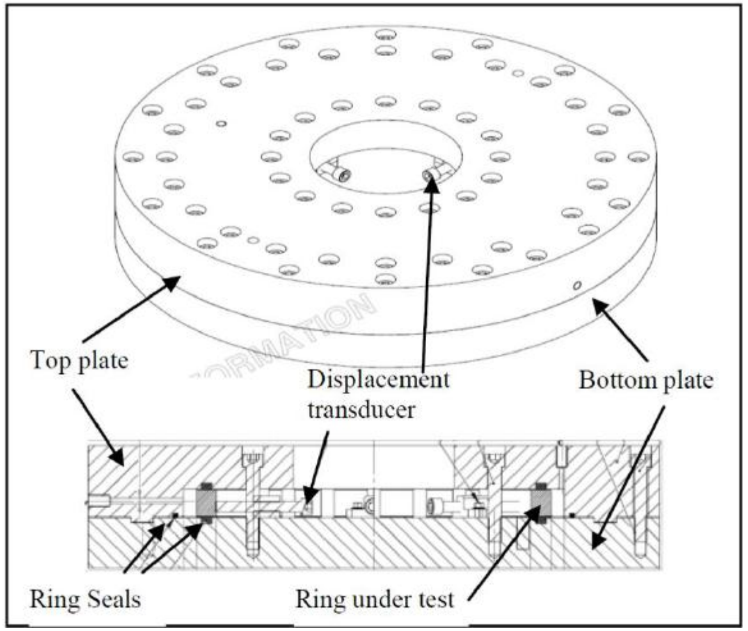
Testing Programme

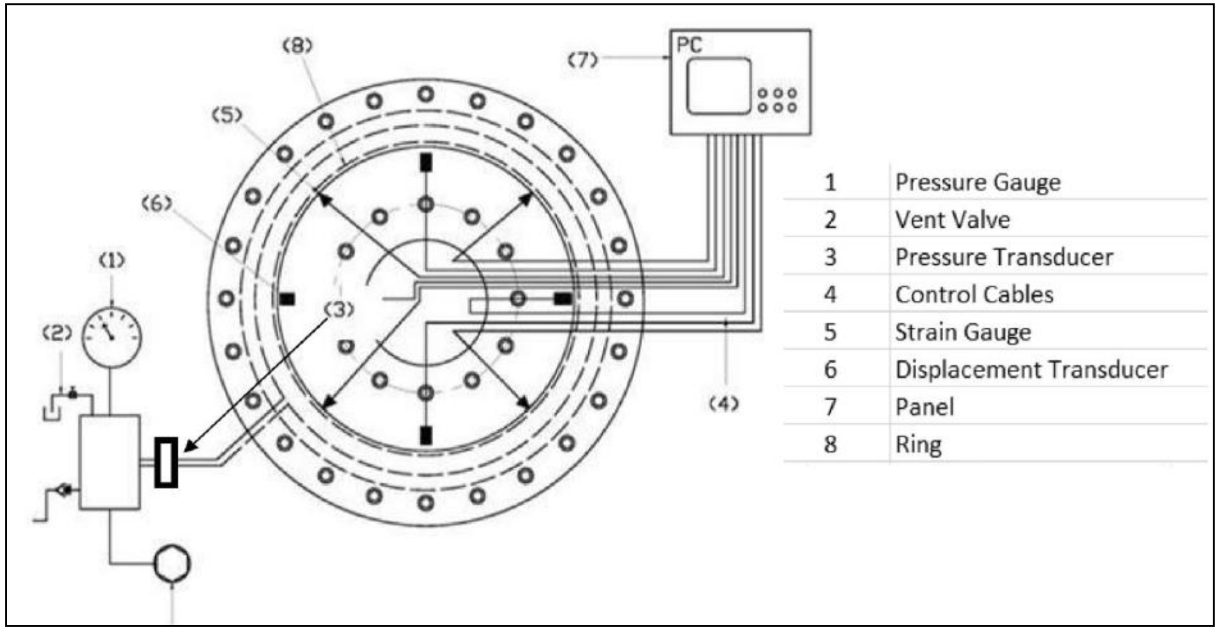


- Tensile & Compression Testing
  - Longitudinal
  - Transverse
    - Plate
    - “J”-ing
    - “O”-ing
    - Expansion
    - After heat soaking
- Guided Bend
- Impact DWTT
- Hardness & Macro
- Residual Stress
- CTOD
- Flattening
- Weldability
- Ring Collapse Testing
  - Expansion
  - After heat soaking

Linepipe (3) – Ring Collapse Testing

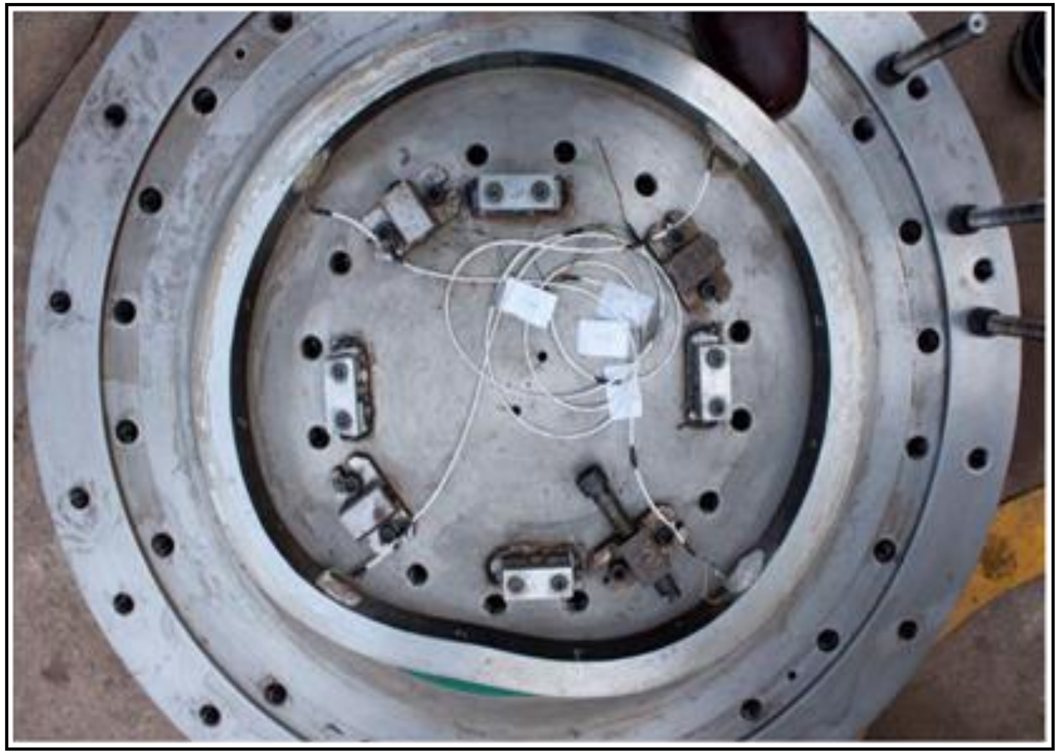
Ring Test Equipment

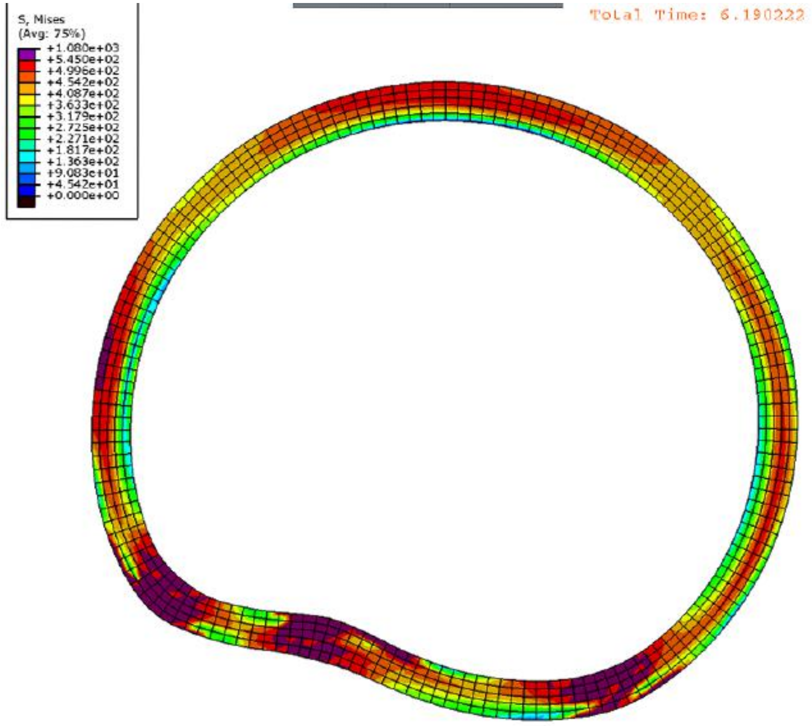




- 50mm long ring cold cut from a pipe joint
- Ring is instrumented for strain and displacement
- Sandwiched between a top and bottom plate with seal rings
- Roberts P, Walker A, Method and apparatus for pipe testing. United States Patent No. 20100212405:2010

Linepipe – Ring Collapse Testing (4)



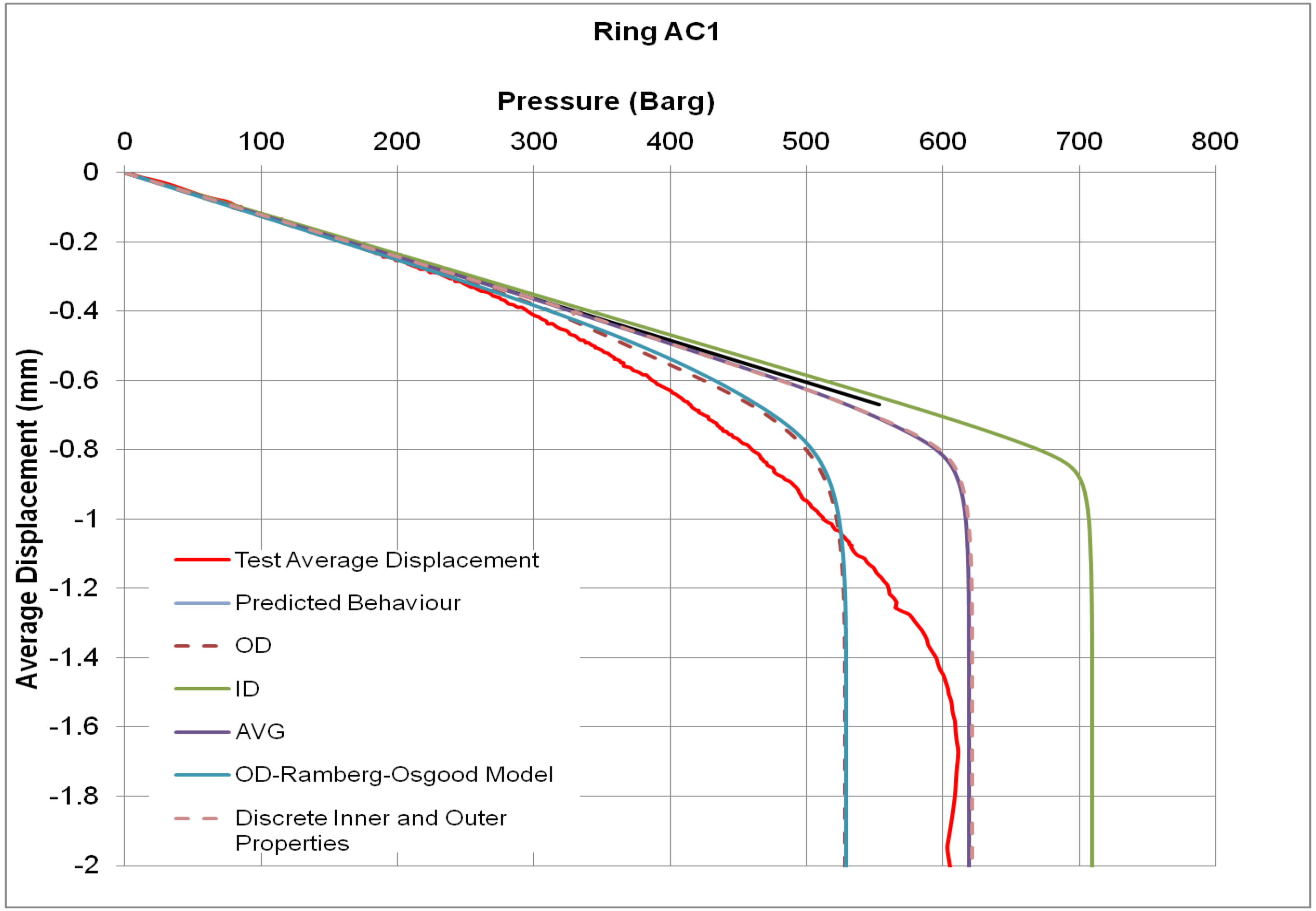


Actual Collapsed shape	FE Predicted Collapse Shape

Example of Real Collapse V's FE Prediction

Linepipe – Ring Collapse Testing (5)

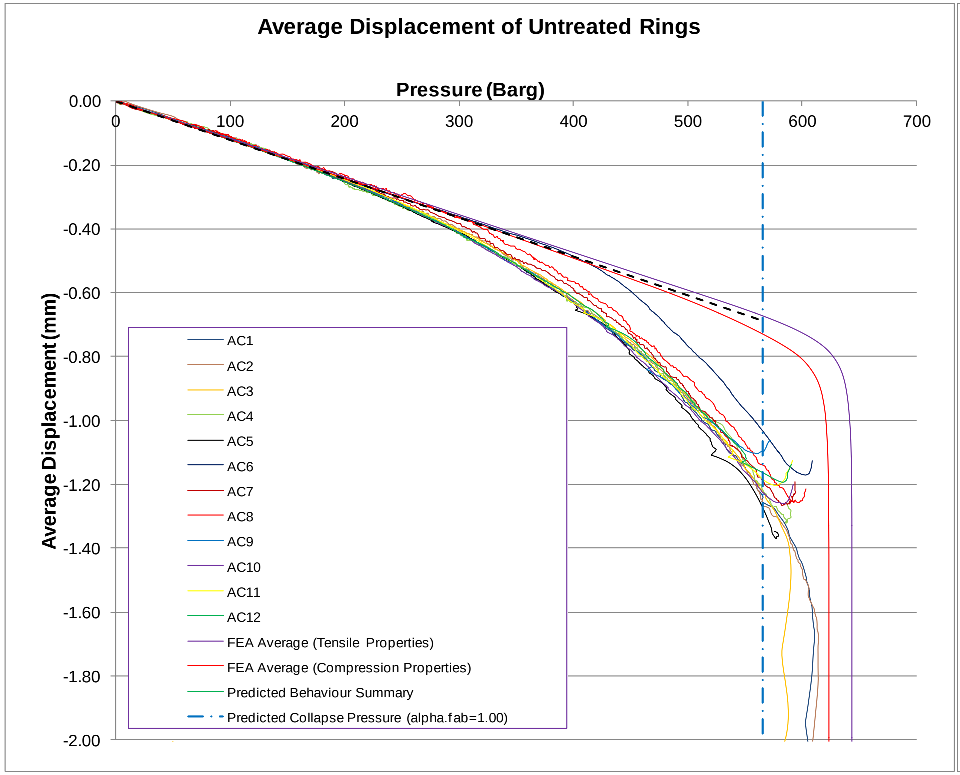
Average displacement development in ring during pressure loading

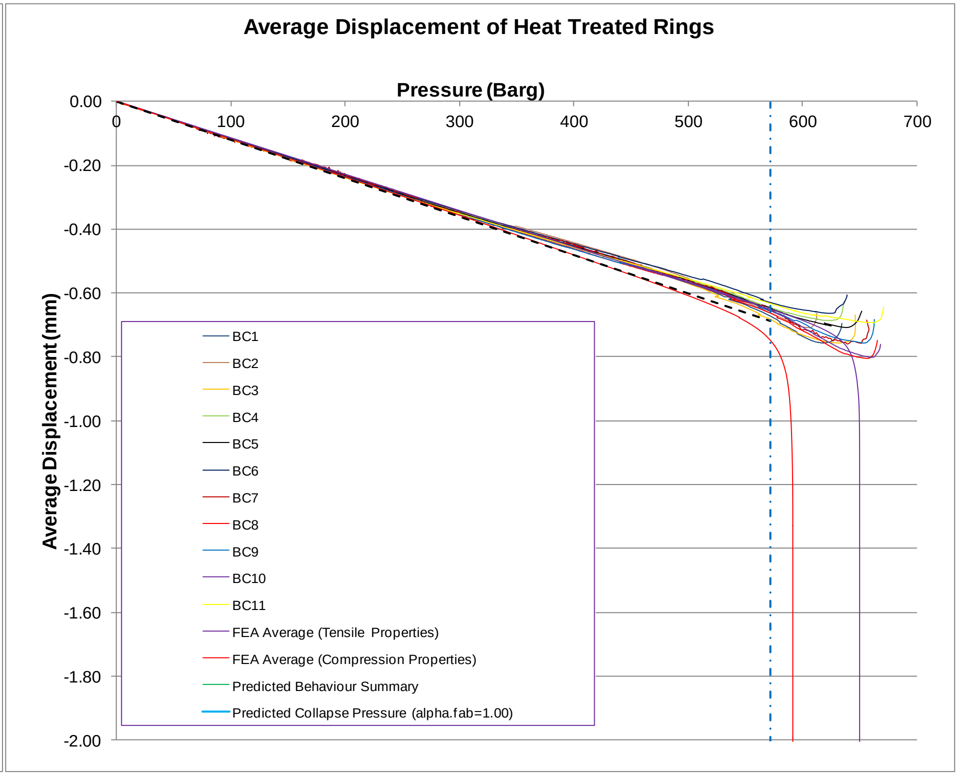


- Actual pipe failure occurs close to the average of inner and outer transverse compressive properties
- Outer pipe properties most closely reflect the movement away from the predicted line
- Modelling actual inner and outer transverse compressive properties at respective locations yielded similar results to the average value applied over the whole section
- From FE modelling the RO stress-strain curve yields similar results to the actual stress strain curves

Linepipe – Ring Collapse Testing (6)

Average Displacement curves for Welspun





- Noticeable difference between untreated and heat soaked rings
- Heat Soaked rings followed predicted path almost to failure
- All rings failed at pressure higher than predicted by DnV
- Untreated rings failed at pressures lower than predicted by FEA

Linepipe – Full Scale Collapse Testing

Currently no full scale testing has been performed on MEIDP linepipe due to inability of CFER to collapse the pipe.

- 1 Joint of pipe manufactured by JindalSAW has been set aside for full scale testing
- Welspun has tested full scale its submitted pipe however this was performed under GALSI program and results have not been made available
- JFE has agreed a programme of full scale testing of 32” x 39mm pipe for the end of the 2016

Linepipe – Production Testing Requirements (1)

In addition to OS-F101 normal requirements for SAWL FDU linepipe the following are also included in Production testing:

- Compression testing in Transverse and Axial directions (Same frequency as for tensile testing using the same pipe for sampling)
- Ring collapse testing (3 pipes per shift 3 samples per pipe)

Linepipe – Production Testing Requirements (2)

Manufacturing summary

- It has been possible to successfully deploy heat soaking equipment at the end of the production line at the mills and this **heat soaking can be included in the production process**.
- **Ring testing equipment has been successfully deployed at the pipe mills** and it is possible to successfully conduct ring collapse testing as part of the production testing process.
- Through Wall and Around circumference strain history varies significantly
- The **pipe through wall temperatures vary significantly** as the pipe passes through the induction heating and quenching process.
- Whilst the use of installed thermocouples in the pipe joint is a good mechanism for determining the heat history of pipe joints during prequalification testing it will not be possible to use this method during the pipe production. **Alternative methods to confirm the heating history of each pipe joint need to be investigated**.
- The **dimension of the rings need to be taken as radii rather than diameters** a method of defining the ovality based on radius measurements as part of the production process needs to be developed.

Linepipe– Production Testing Requirements (3)

Technical summary

- For the JCOE Process **marked differences** were observed between internal and external wall samples during transverse compression testing with and without heat soaking
- Further testing to **establish heat treatment parameters** and their effect on internal and external wall locations is clearly required.
- Ring collapse tests performed at Welspun showed a **noticeable increase in the collapse pressure** of samples that passed through a heat soaking process (Expansion 0.9%).
- Ring collapse tests performed at JindalSAW however, show only slight improvement in collapse pressure (Expansion 0.5%).
- Ring collapse test and FEA modeling of pipe rings shows **consistently higher collapse pressures than predicted by DNV OS-F101** based on actual Young's modulus and yield strength (R_{TCt05}) pipe properties.
- This indicates that if minimum **transverse compressive yield strength criterion is specified** in linepipe specifications and used in calculation of predicted collapse then a fabrication factor **α_{fab} = 1.0** can be used in DNV formulation of collapse pressure.

Vessel Status and Installability

- The requirements to install MEIDP along the Route options has been assessed
- Contact has been made with vessel owners to get confirmation of MEIDP installability. (Allseas, HMC, Saipem).
- Allseas, HMC and Saipem have all confirmed there vessels can install the pipeline

Company	Pipelay Vessel	Tension Capacity (tonnes)	
		J-Lay Mode	S-Lay Mode
Allseas	Pioneering Spirit	n/a	2000
	Solitaire		1050
Saipem	S 7000	750 with tensioners 2000 with friction clamps	n/a
	Castorone	2500	750 tonnes upgradeable to 1050
Heerema Marine Contractors	Aegir	1500 static 2000 dynamic	n/a
	Balder	1210 static 1270 dynamic	
Petrofac	JSD 6000	2000	750

Installation - Project Requirements (1)

SAGE

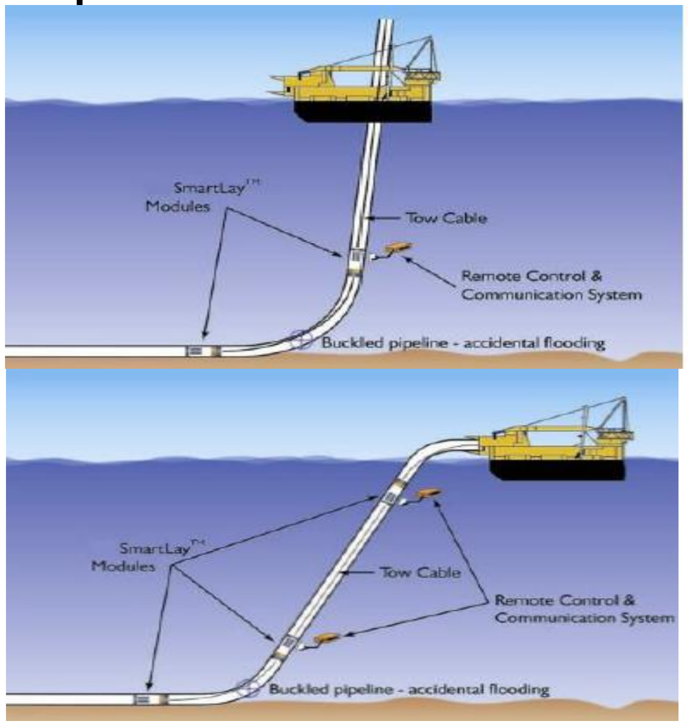
Vessel Requirements

- for Base Route
  - 933 tonne normal laying Demand
  - 1180 tonne Dynamic Capacity
  - 1994 tonne Flooded Abandonment
- for Extended Route
  - 1110 tonne normal laying Demand
  - 1404 tonne Dynamic Capacity
  - 2230 tonne Flooded Abandonment
- Alternate Route
  - 1110 tonne normal laying Demand
  - 1404 tonne Dynamic Capacity
  - 2230 tonne Flooded Abandonment

Inside Diameter (mm)	Wall Thickness (mm)	Stinger Radius (m)	Water Depth (m)	Top Tension (tonne)	Top Tension (tonne)
610.0	40.3	120	500	158	157
			1,000	288	285
			1,500	419	420
			2,000	552	553
			2,500	687	686
			3,000	819	820
			3,420	933	936
610.0	42.3	120	500	177	174
			1,000	322	322
			1,500	468	469
			2,000	615	617
			2,500	763	764
			3,000	913	912
			3,650	1,110	1,113
711.1	38.7	120	500	128	129
			1,000	235	238
			1,500	344	347
			2,000	456	458
			2,500	567	569

Inside Diameter (mm)	Wall Thickness (mm)	Water Depth (m)	Weight of Flooded Vertical Pipe String (tonnes)	Static Top Lay Tension Flooded (tonne)	
				S-Lay	J-Lay
610.0	40.3	3,420	1922	1991	1994
610.0	42.3	3,650	2159	2233	2236
711.1	38.7	2,500	1517	1647	1651

Flooding Prevention Tool will be required



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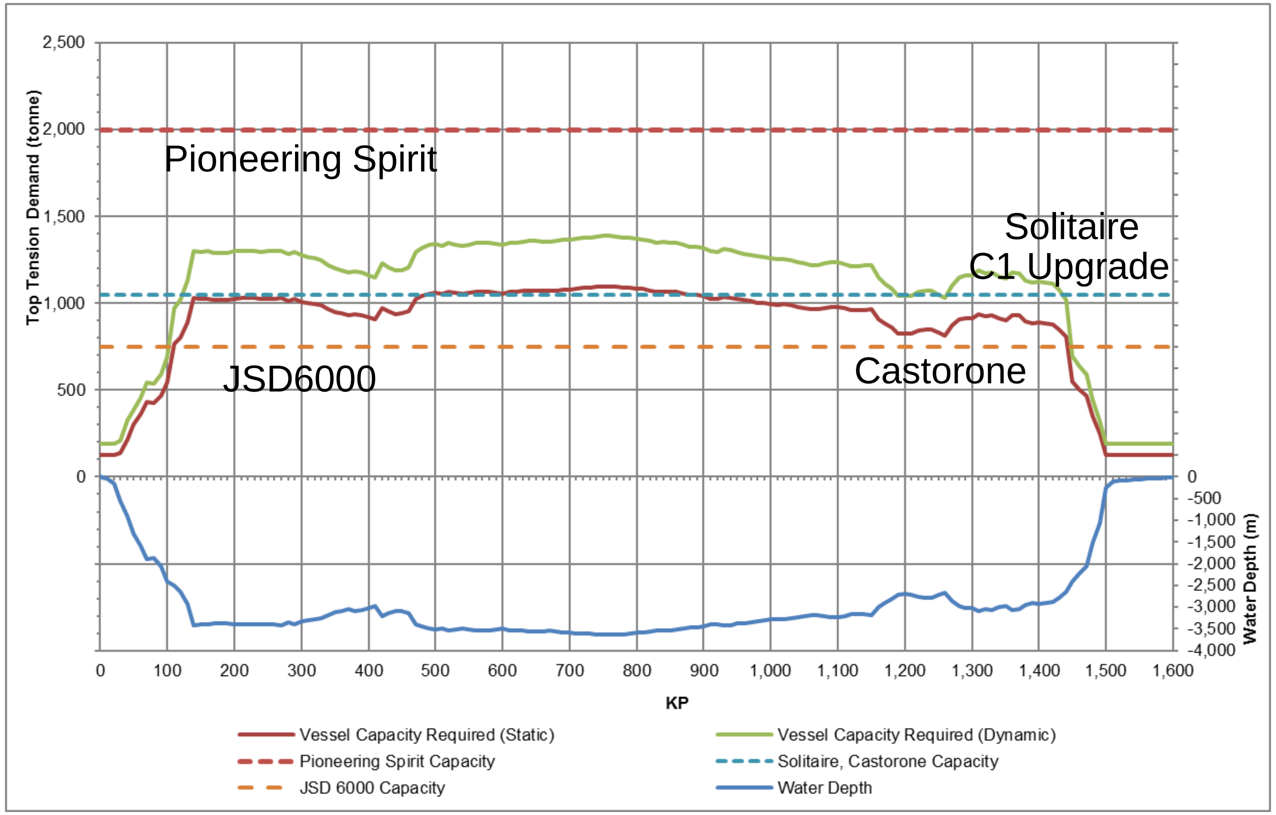
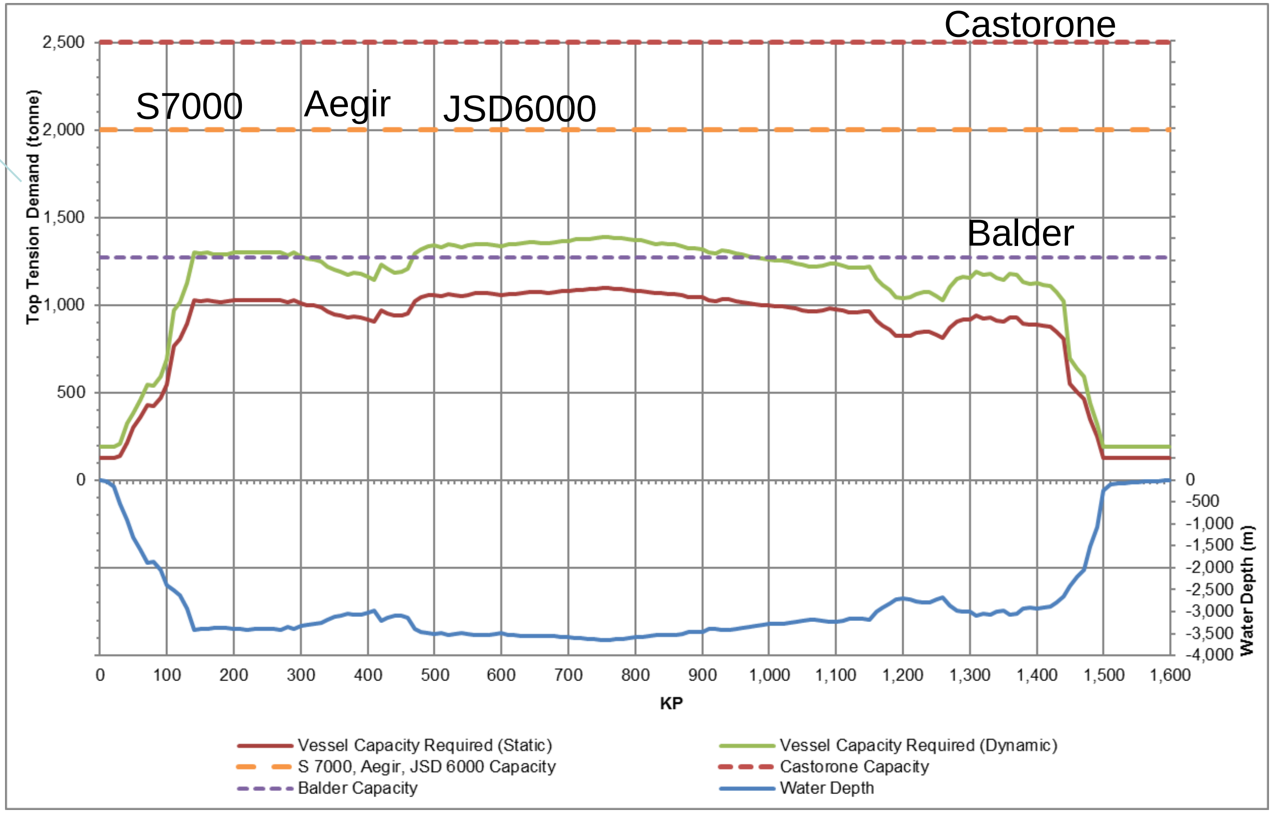
Installation S-Lay Installation (2)

- Extended Route S-Lay



Installation J-Lay Installation (3)

- Extended Route J-Lay



Installation - Requirements for Equipment Upgrade (1)

SAGE

- The requirements to install MEIDP along the Route options has been assessed
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- Allseas, HMC and Saipem have all confirmed there vessels can install the pipeline

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Saipem	S 7000	750 with tensioners 2000 with friction clamps	n/a
	Castorone	2500	750 tonnes upgradeable to 1050
Heerema Marine Contractors	Aegir	1500 static 2000 dynamic	n/a
	Balder	1210 static 1270 dynamic	
Petrofac	JSD 6000	2000	750

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Installation - Requirements for Equipment Upgrade (6)

Five vessels are capable of installing the MEIDP empty in the maximum water depth of the Base Case,
extended and alternative routes. Of these vessels :

- Saipem's S 7000 and HMC's Balder and Aegir are currently available. S7000 Needs to be upgraded
- Allseas' Pioneering Spirit will be operational in 2017 and therefore is available when required in 2020
- Saipem's Castorone is available, and the planned J-lay facility could be fabricated and installed by 2020
- If Petrofac decides to construct the JSD 6000 in another shipyard then a sixth vessel capable of installing the MEIDP will be available by 2020.
- All the available pipelay vessels, with the exception of Saipem's Castorone in J-lay mode, will require flood prevention plugs during pipelay to prevent the pipeline flooding in the event of a buckle and subsequent rupture.

Cost Estimate update

The project cost estimate has been updated to account for:

- 2016 linepipe prices
- 2016 turbo compressor prices
- 2016 vessel prices
- 2016 oil and gas construction indices

Budgetary cost estimates have been received from:

- 5 pipe mills
- 2 installation Contractors
- 1 Turbo Compressor-Generator supplier

Cost Estimate update

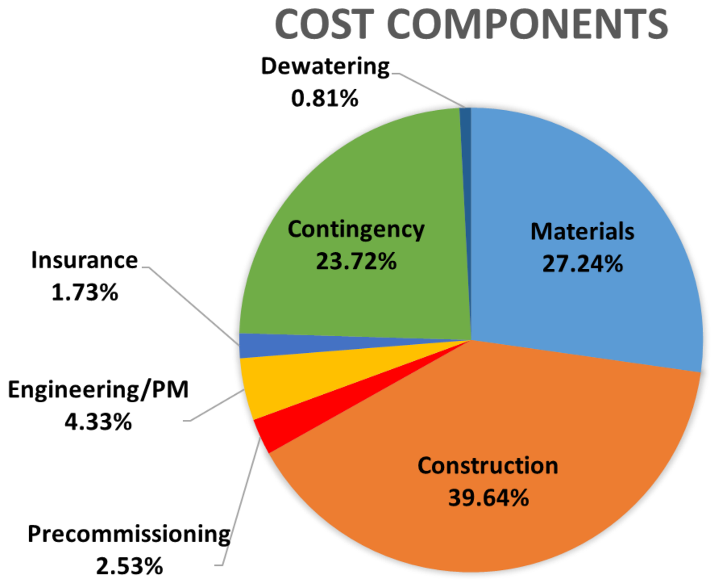
Indicative Project Costs for considered routes

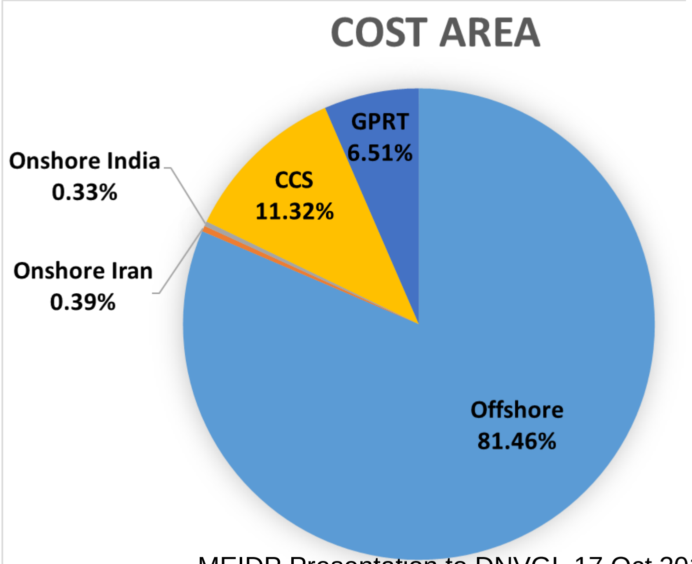
	Base Case Route ($billion)	Extended Route ($billion)	Alternative Route ($billion)
CCS	0.665		
Iran Onshore Pipeline	0.023		
Offshore Pipeline Iran to India	3.869	4.785	
Offshore Pipeline Iran to Oman			1.840
Oman Onshore Pipeline			0.020
MECS			0.665
Oman Onshore Pipeline			0.020
Offshore Pipeline Oman to India			3.457
Indian Onshore Pipeline	0.019		
GPRT	0.382		
Total Cost ($billion)	**4.957**	**5.874**	**7.091**

CCS Chabahar Compression Station
MECS Middle East Compression Station
GPRT Gujarat Pipeline Receiving Terminal

Validity of CAPEX of the subsea line at present date.

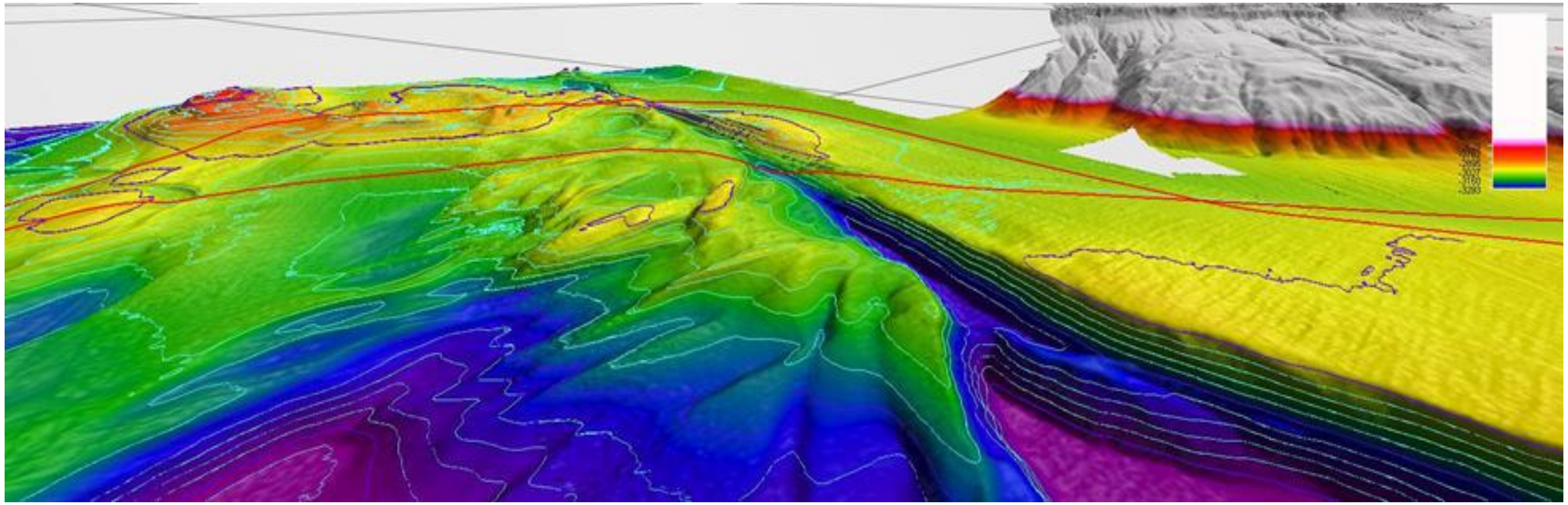
- SAGE has just issued an update of the Cost estimate to bring it up to date for 2016 and account for:
  - linepipe prices
  - turbo compressor prices
  - vessel prices
  - oil and gas construction indices
- Budgetary cost estimates have been received from:
  - 5 pipe mills
  - 2 installation Contractors
  - 1 Turbo Compressor-Generator supplier
- Budget Estimate for Extended Route is $4.9b
  - Indicative offshore pipeline installation cost $1.25m/km is consistent with recent ultra deepwater pipelines





Initial review of Owen Fracture Zone (1)

Owen Fracture Zone Characteristics



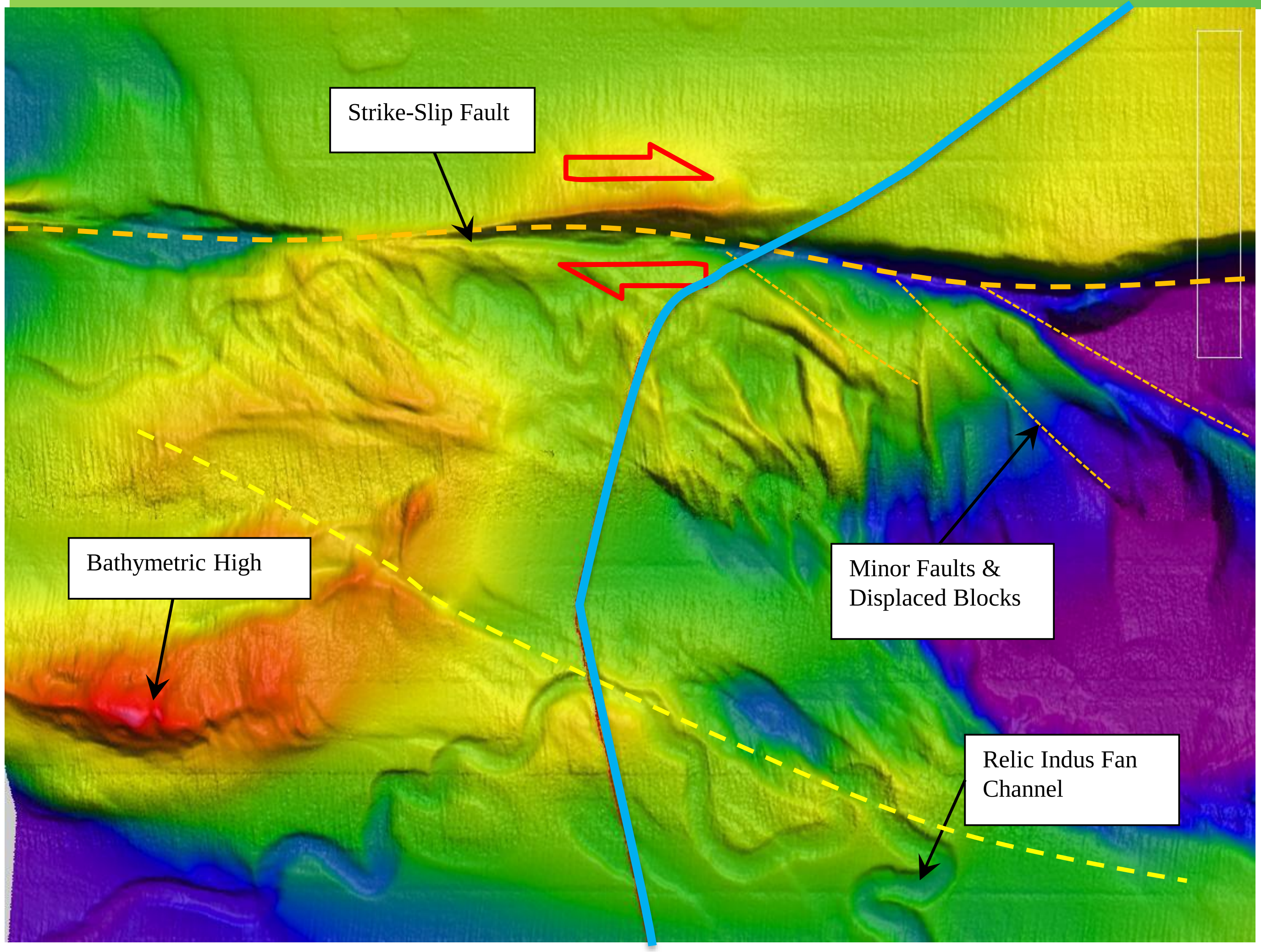
At the MEIDP Crossing the Owen Fracture Zone is characterized by two main structures:

- The deep basins of the Dalrymple Trough and horsetail in the North
- An arch formed bathymetrical high in the South

The Owen Fracture zone stretches for more than 1200km with the Dalrymple Trough forming the last 350km at its Northeastern end and reaching a depth in excess of 4000m.

The bathymetric high is about 6km wide and approx. 19km long, rising to 2630m water depth at its shallowest part.

Initial review of Owen Fracture Zone (2)



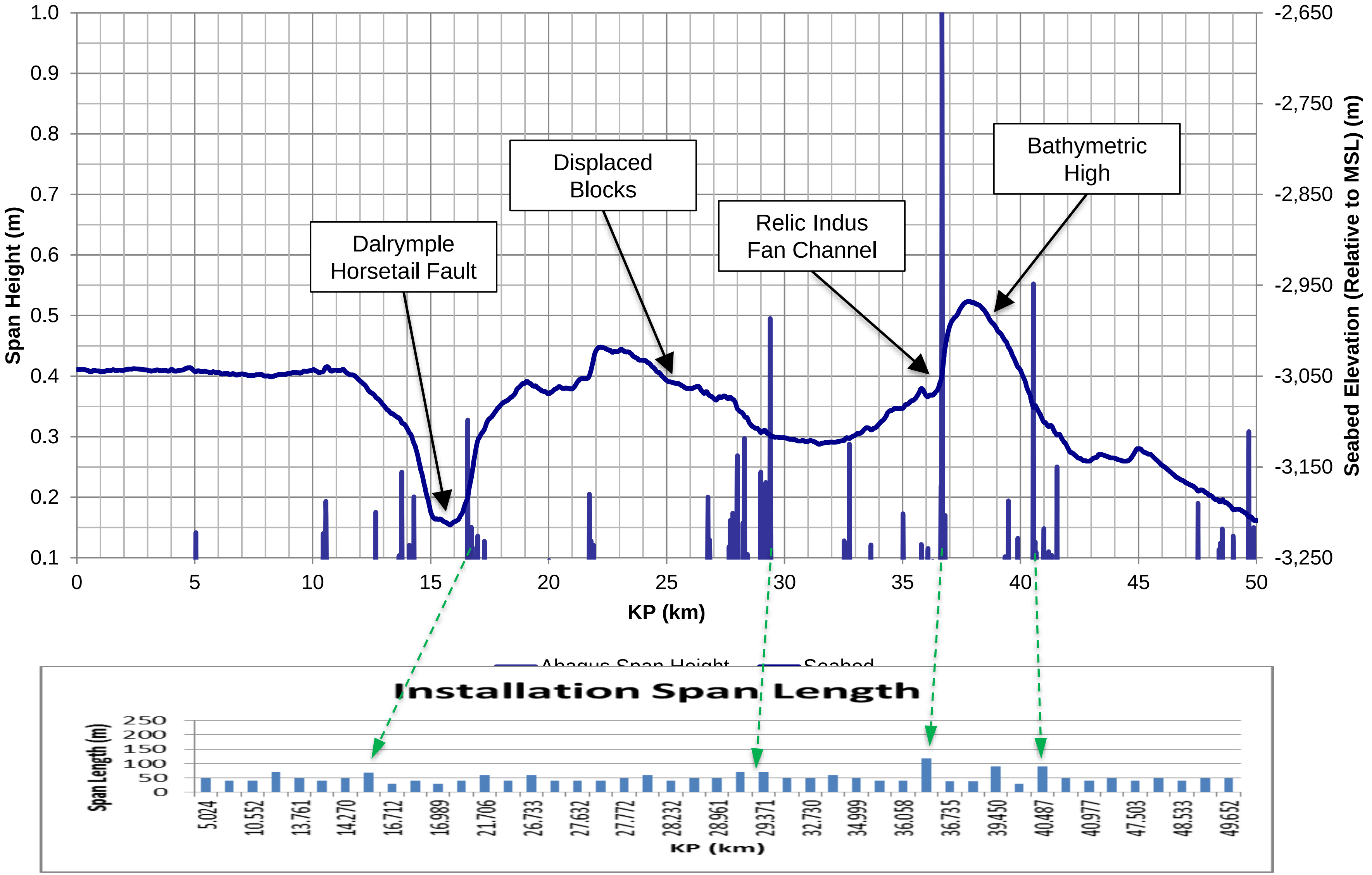
3D Bathymetry from Survey

This fault is the tectonic plate boundary of the Indian and Arabian plates.

- A strike-slip right lateral fault
- Moving at a slip rate of 3mm/year (7mm/yr max).
- Fault forms a 200m deep canyon 1.3km wide at MEIDP crossing

Initial review of Owen Fracture Zone (3)

Span Assessment overview



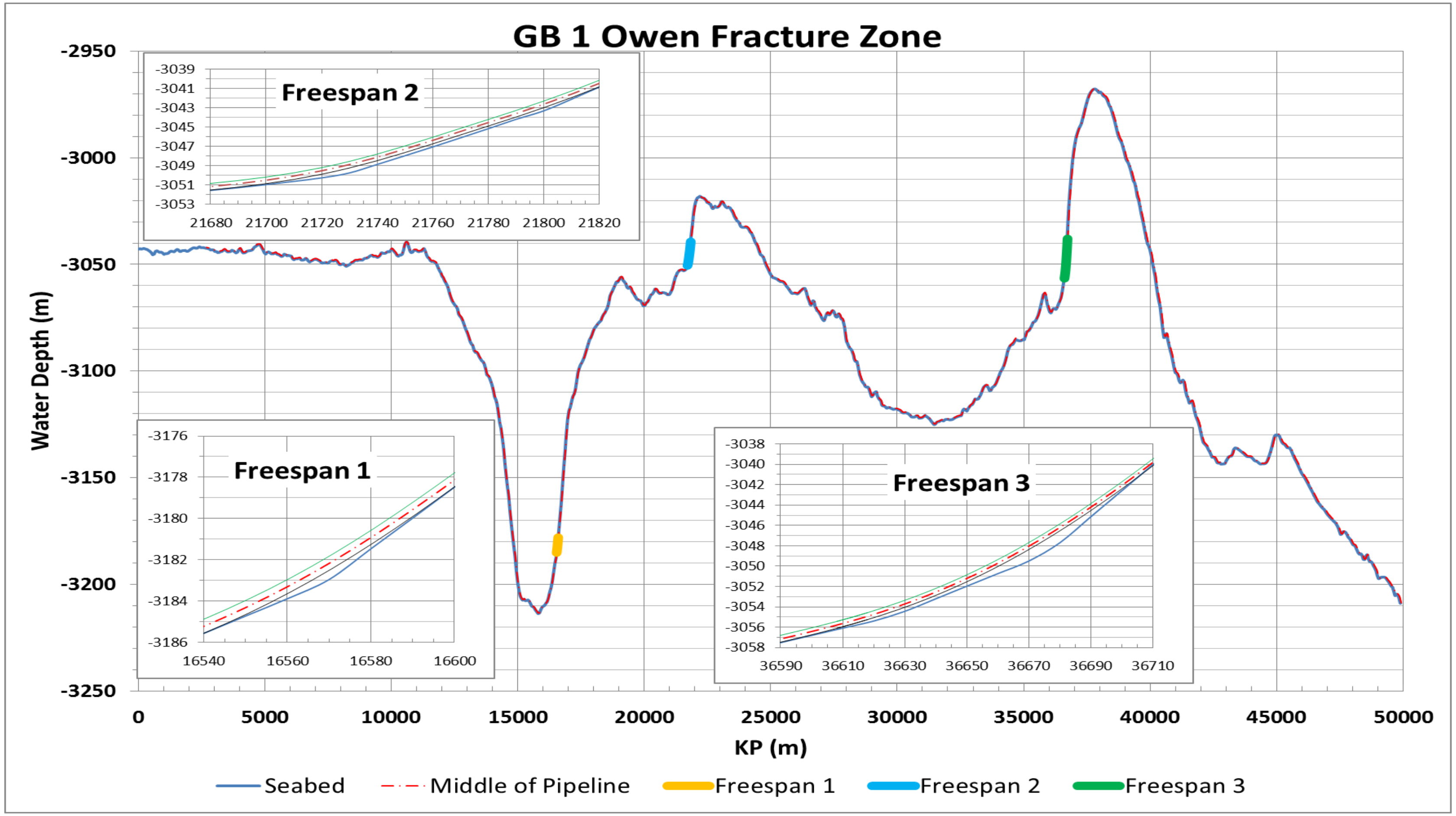
OTC-24958, MEIDP Crossing of the Owen Fracture Zone, Ian Nash

Initial review of Owen Fracture Zone (4)

Spans of Note

There were 3 spans of note observed in the OFZ.

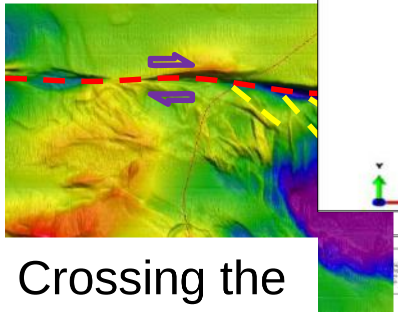
- Maximum Span Lengths approx. 130m
- Maximum Span Heights approximately 1.2m

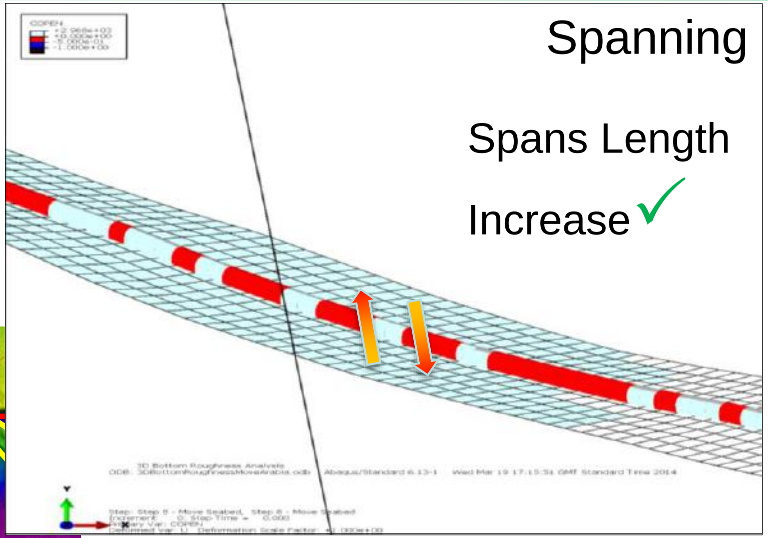


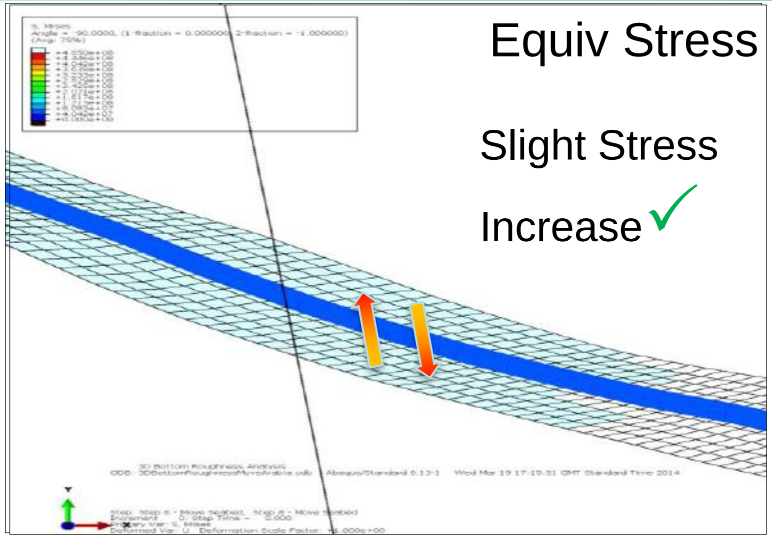
Initial review of Owen Fracture Zone (5)

3D Analysis of Effects of 1000yr - 7m Fault movement on MEIDP during Operation using 200m corridor of 3D Seabed

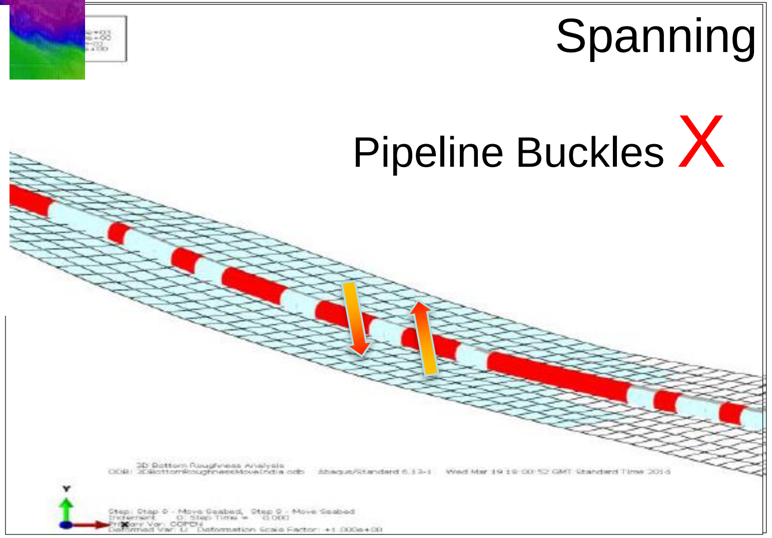
Crossing the Fault in direction of Strike-Slip Movement

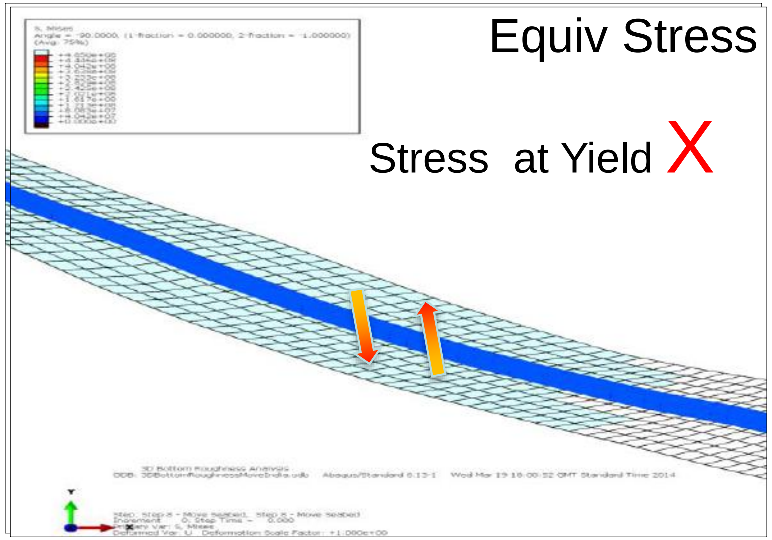






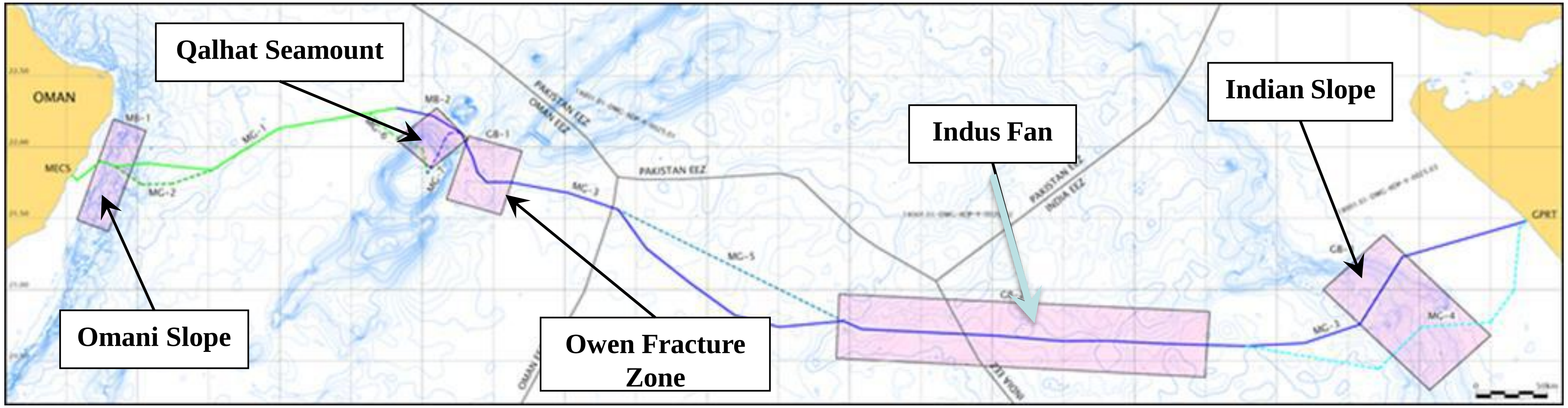
Crossing the Fault against the direction of Strike-Slip Movement

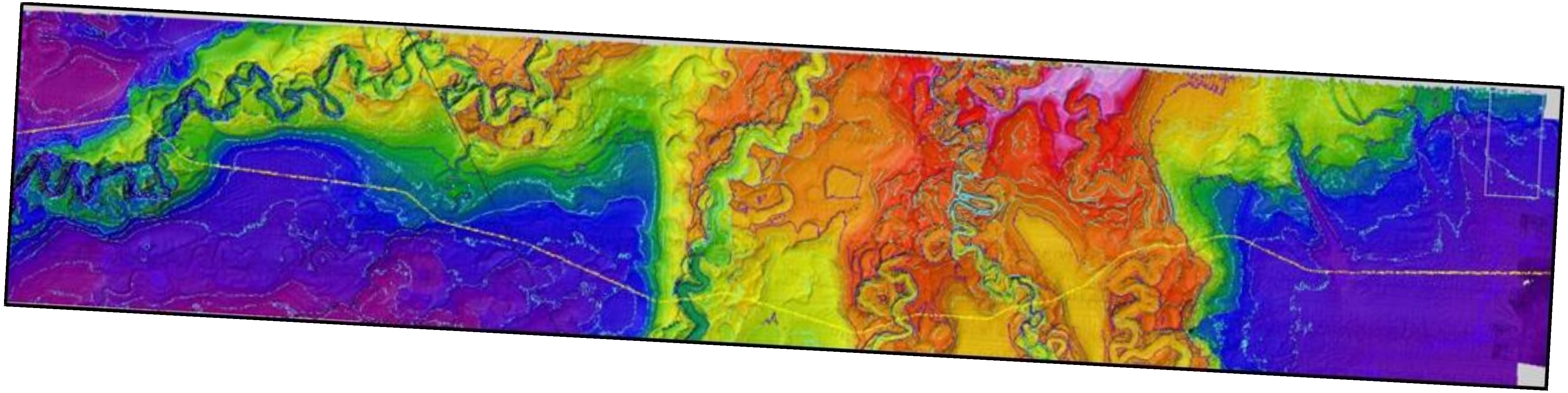




Initial review of Indus Fan Crossing (1)

Indus Fan Block Survey

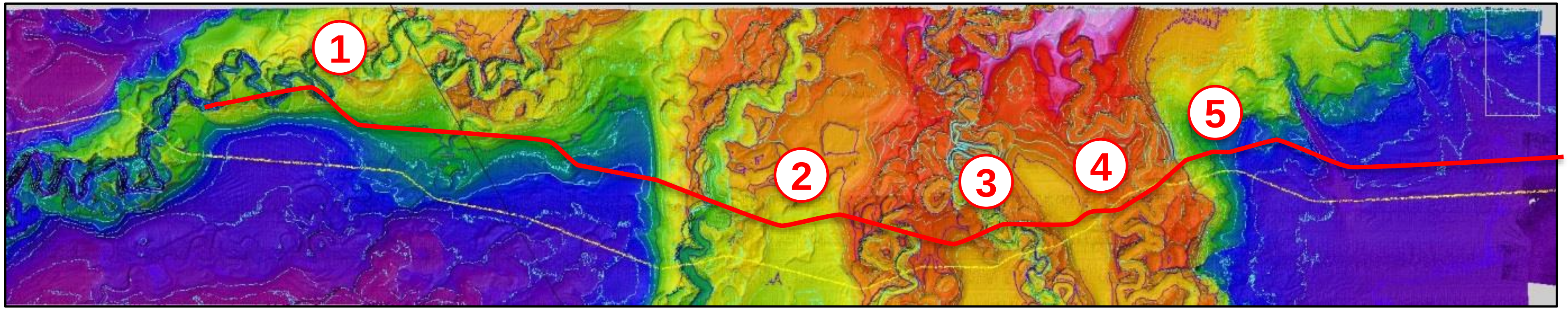


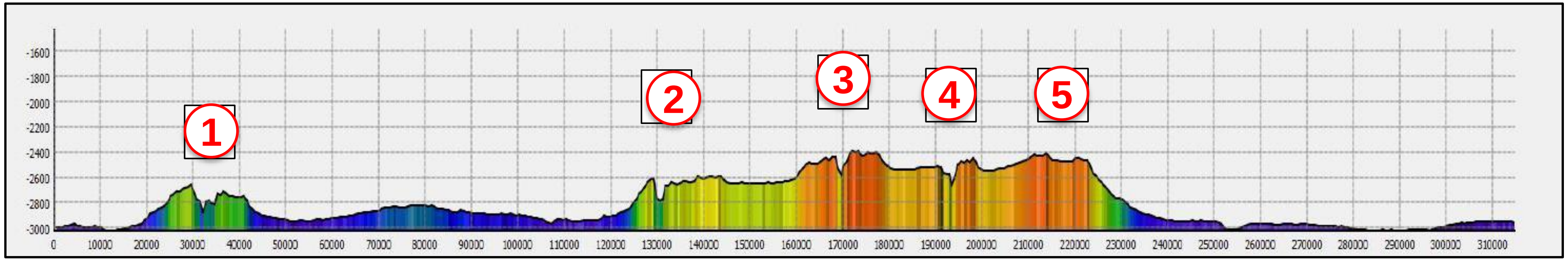


OTC-25175-MS, MEIDP Crossing of the Indus Fan, Ian Nash

Initial review of Indus Fan Crossing (2)

Indus Fan Characteristics



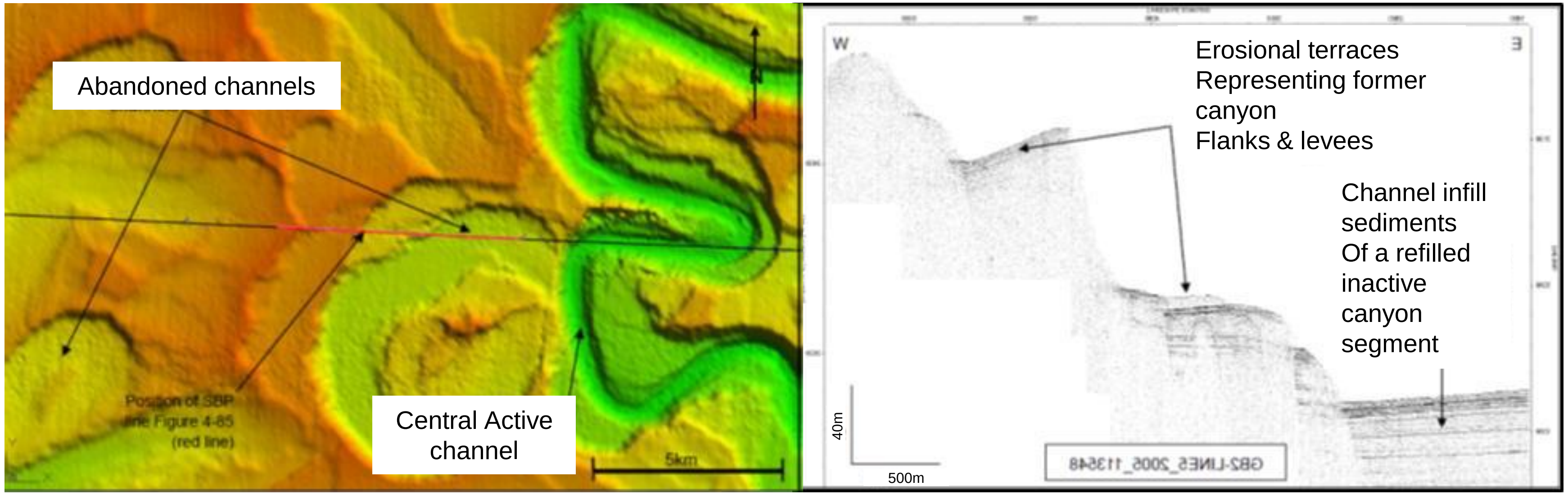


Indus River Abyssal Fan Route:-

- water depths between 2100m - 3200m
- crosses five turbidity current Channels
- Channels up to 200m deep with side slopes up to 35°
- channels follow a meandering flow pattern in N-S direction

OTC-25175-MS, MEIDP Crossing of the Indus Fan, Ian Nash

Indus Fan Characteristics

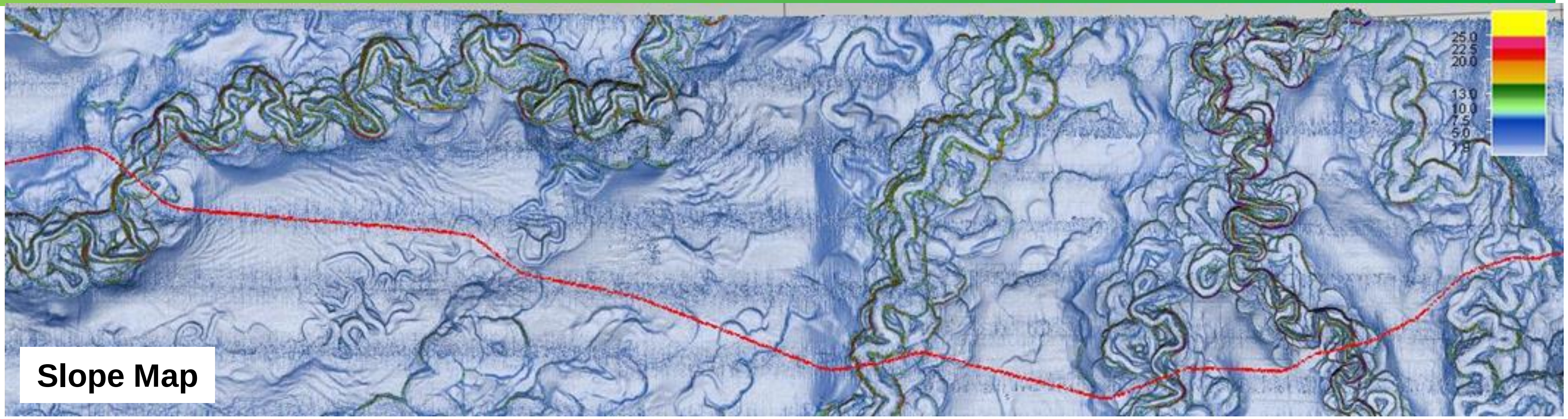


- generally the seabed is covered by a fine grained soft to very soft clay
- deposited by turbidity currents and mass wasting events.
- the sedimentary levees are a result of overspill sediments and deposits on both sides of the canyon/channels.

OTC-25175-MS, MEIDP Crossing of the Indus Fan, Ian Nash

Initial review of Indus Fan Crossing (4)

Channel Characteristics



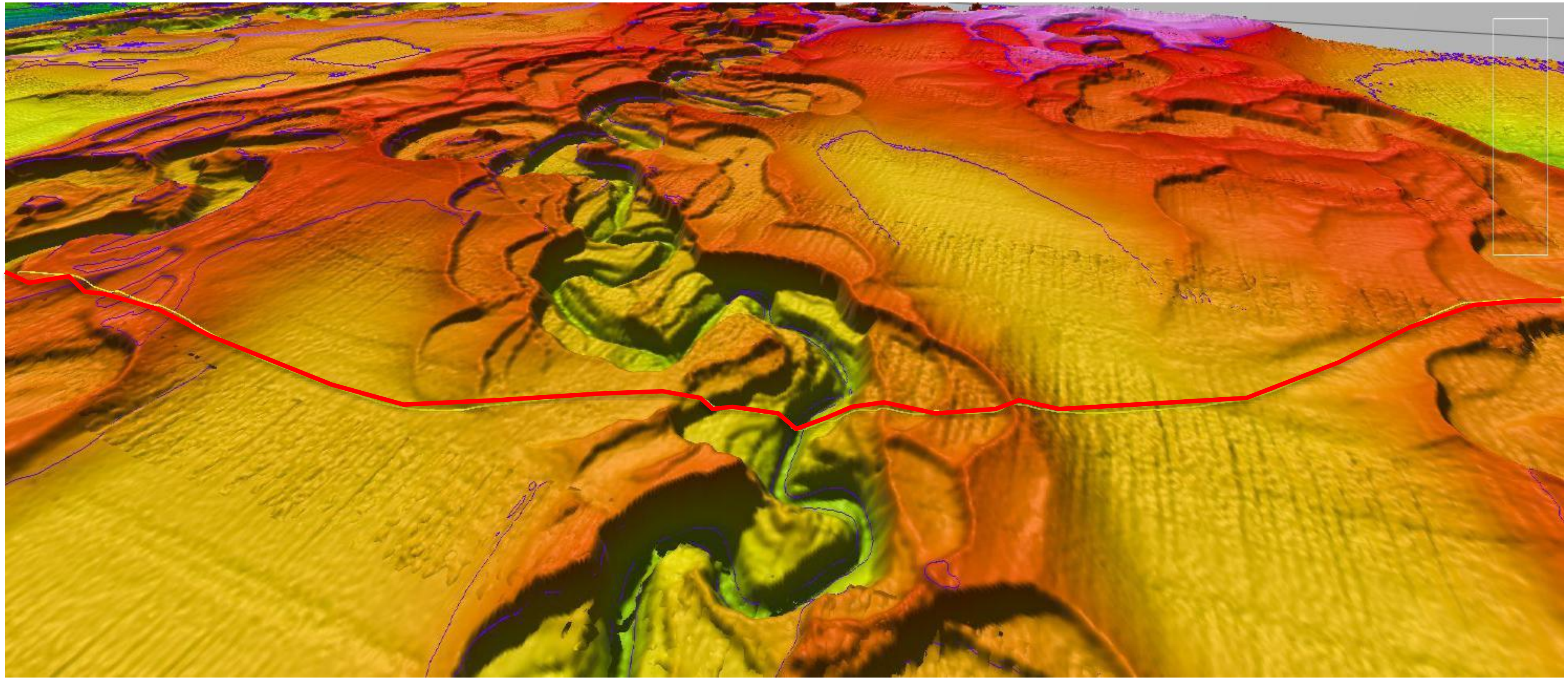
Feature	General Heading of Channel (deg)	Elevation		Channel characteristic at MEIDP Crossing			Inter Channel Depth (m)
		Maximum Elevation (m)	Minimum Elevation (m)	Depth (m)	Main Channel Approximate Top(Base) width (m)	Channel crossing maximum slope (deg)	
Channel 1	255	-2780	-2865	85	1300(600)	17	-2960
Channel 2	205	-2590	-2780	190	2700 (1500)	24	-2640
Channel 3	190	-2430	-2580	150	2100 (500)	14	-2535
Channel 4	160	-2460	-2660	200	2300 (180)	18	-2545
Channel 5	170	-2380	-2470	90	5900(800)	12	

OTC-25175-MS, MEIDP Crossing of the Indus Fan, Ian Nash

Initial review of Indus Fan Crossing (5)

SAGE

3D Seabed from survey across Indus Fan Channel 4



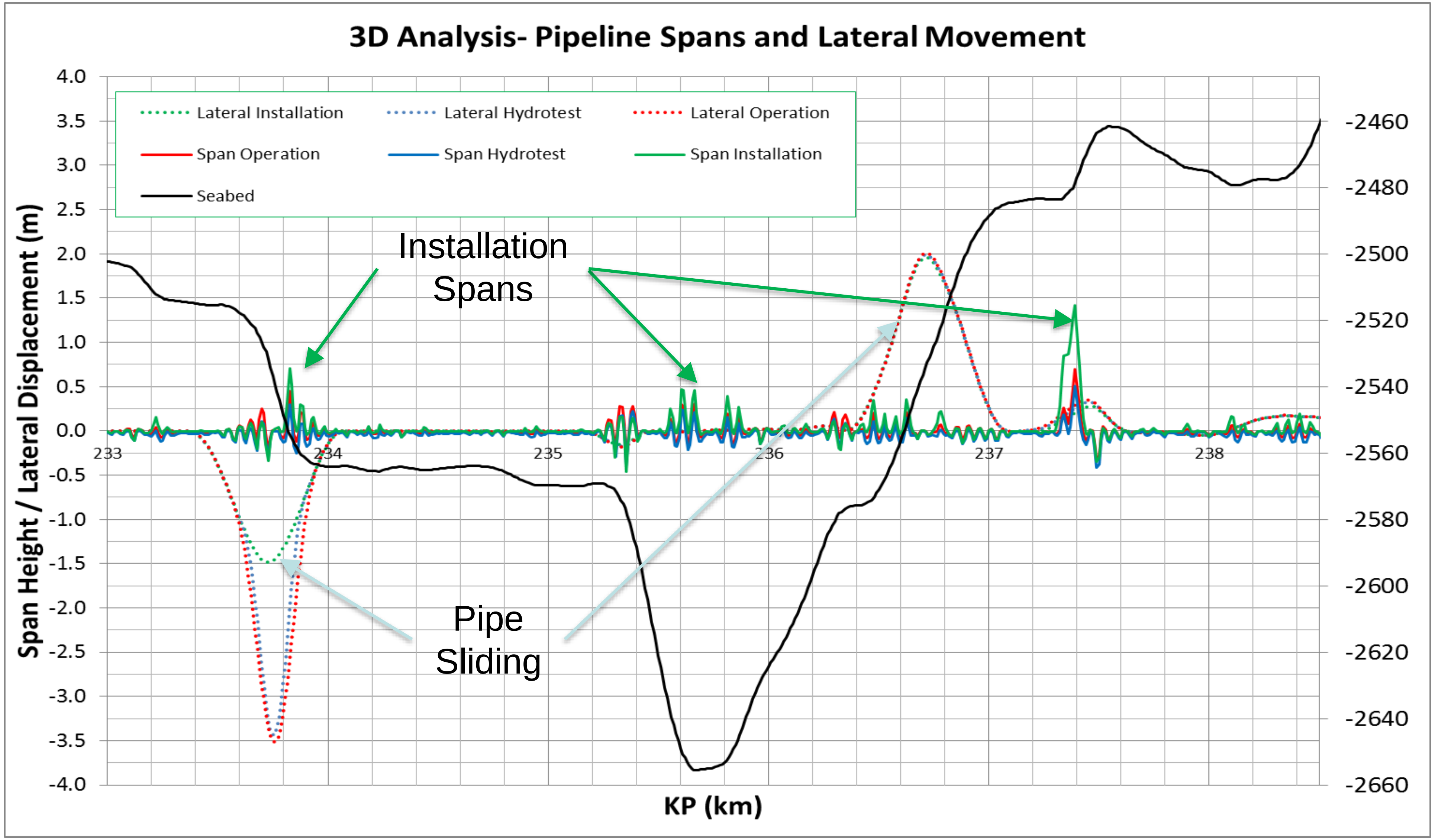
Of the four channels crossed:-

- only channel 4 that appears to be recently active in geological time,
- potential activity date around the last sea level low (20,000 years ago)
- Current activity is unknown

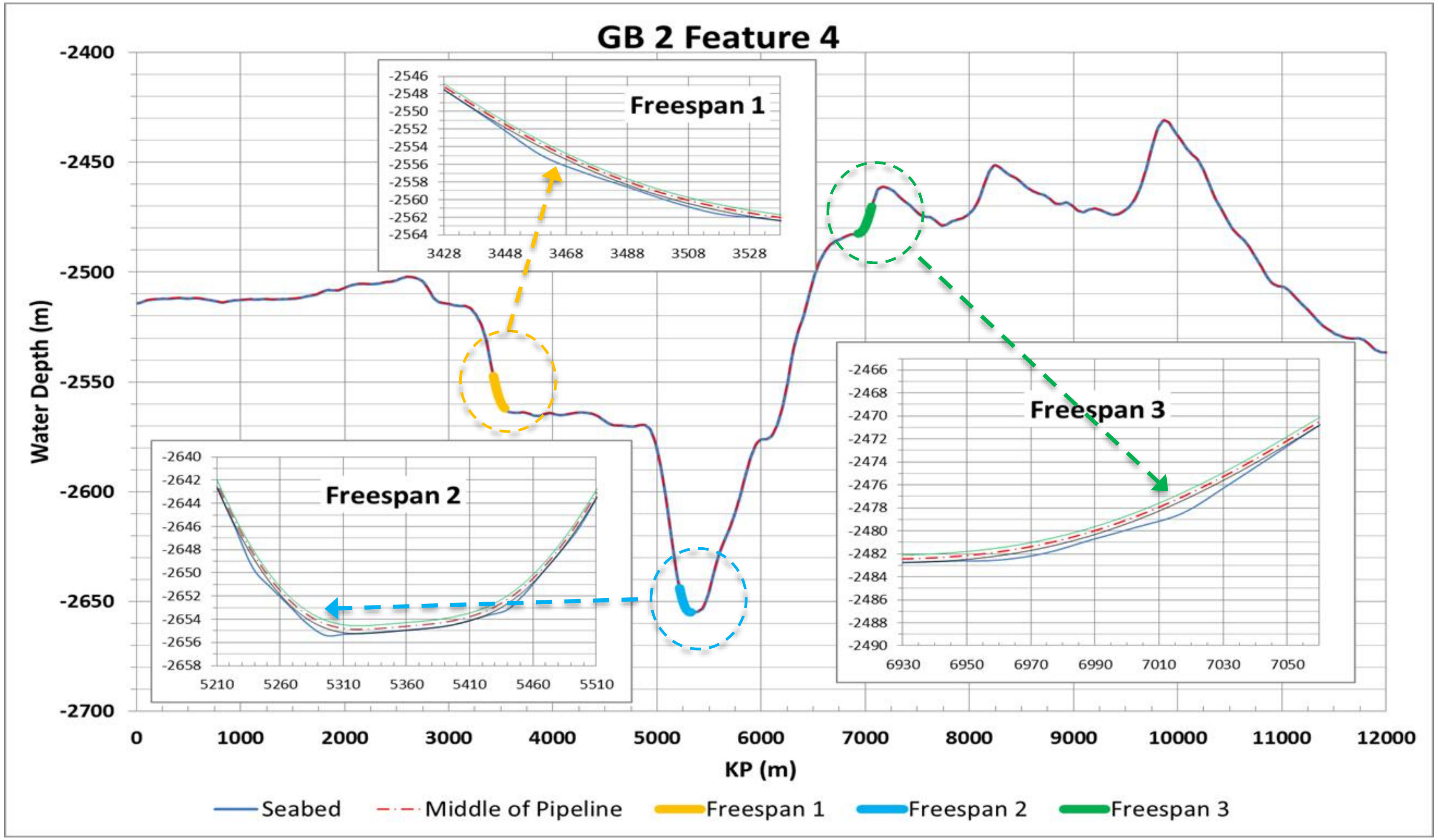
Peritus

Initial review of Indus Fan Crossing (6)

Channel #4 Assessment Overview



Initial review of Indus Fan Crossing (7)



Spans of Note during Installation

There were 3 spans of note observed in Channel #4.

- Maximum Span Lengths approx. 90m
- Maximum Span Heights approximately 1.75m

Thank You

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Bedtime Reading!

- Middle East India Deepwater Pipeline (MEIDP) – Geohazard Features Assessment and Intervention, Ian Nash and Christopher Burnett ISOPE 2014 – Proceedings
- Middle East India Deepwater Pipeline (MEIDP) crossing of the Indus Fan, Ian Nash, Christopher Burnett and Russell Smith, Peritus International Ltd. Offshore Technology Conference (OTC), May 2014, (OTC 25175)
- Middle East to India Deepwater Pipeline (MEIDP) Crossing of the Owen Fracture Zone, Ian Nash, Christopher Burnett and Simon Parry, Peritus International Ltd, Offshore Technology Conference Asia (OTC-ASIA), March 2014 (OTC 24958)
- Middle East India Deepwater Pipeline (MEIDP) – findings and implications of the 2013 reconnaissance survey, I. Nash, Petrotech 2014 Conference, New Delhi, India, Feb 2014.
- Bringing the Middle East India Deepwater Pipeline (MEIDP) closer to reality – findings of the 2013 reconnaissance survey. Ian Nash, Peritus International & Robert Hawkins, Fugro. Offshore Pipeline Technology (OPT) Conference, Amsterdam, Feb 2014.
- The Production and testing of JCOE Linepipe for the Middle East to India Deepwater Pipeline's 3500m Application, I Nash & P Carr, Offshore Pipeline Technology (OPT) Conference, Amsterdam, Feb 2013
- The Production and Testing of MEIDP Line-Pipe for 3500m Application, I Nash & P Carr, International Society or Offshore and Polar Engineers (ISOPE), Anchorage, Alaska, USA, June 2013
- Middle East to India, Deepwater Pipeline: Challenges and Opportunities, I Nash, Presentation given at 2nd World Energy Policy Summit (WEPS), New Delhi, India, November 2012
- MEIDP The Deepwater Route to India, I Nash, Presentation at Offshore Pipeline Technology (OPT) Conference, Amsterdam, Feb 2011
- MEIDP The Deepwater Route to India, I Nash, Presentation at Offshore Technology Conference (OTC),Houston, May 2011
- Inspection Maintenance and Repair of Deepwater Pipelines, I Nash, Presentation at Deepwater and Ultra-deepwater Pipelines Conference, Paris, Sept 2011
- Middle East to India, Deepwater Pipeline (MEIDP) requirements for Installation, Intervention and Emergency Repair, I Nash, Presentation at Deepwater and Ultra-deepwater Pipelines Conference, Paris, Sept 2011
- MEIDP The Deepwater Route to India, I Nash & P Roberts, Offshore Pipeline Technology (OPT) Conference, Amsterdam, Feb 2011
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