Engineering 'Lunch & Learn' Series

"An overview of Typical and Non-typical Seabed Intervention Methodologies"

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Purpose for Seabed Intervention

Seabed intervention refers to physical intervention of the seabed through seabed modification or placement of objects, etc.

Seabed intervention is carried out for several purposes, including but not limited to:

- Preventing excessive spans during pipelaying
- Correcting excessive spans after pipelaying
- Allowing for crossing of new pipeline/cable over existing infrastructure (i.e. pipeline, cable, etc.)
- Protection of infrastructure (e.g. burial of pipelines & cables)
- Levelling of seabed (e.g. prior to subsea structure installation), and so on

Seabed intervention for pipeline span correction is most common & may take place by prevention (pre-lay) or by correction (post-lay). Span correction methods may be categorized as those which:

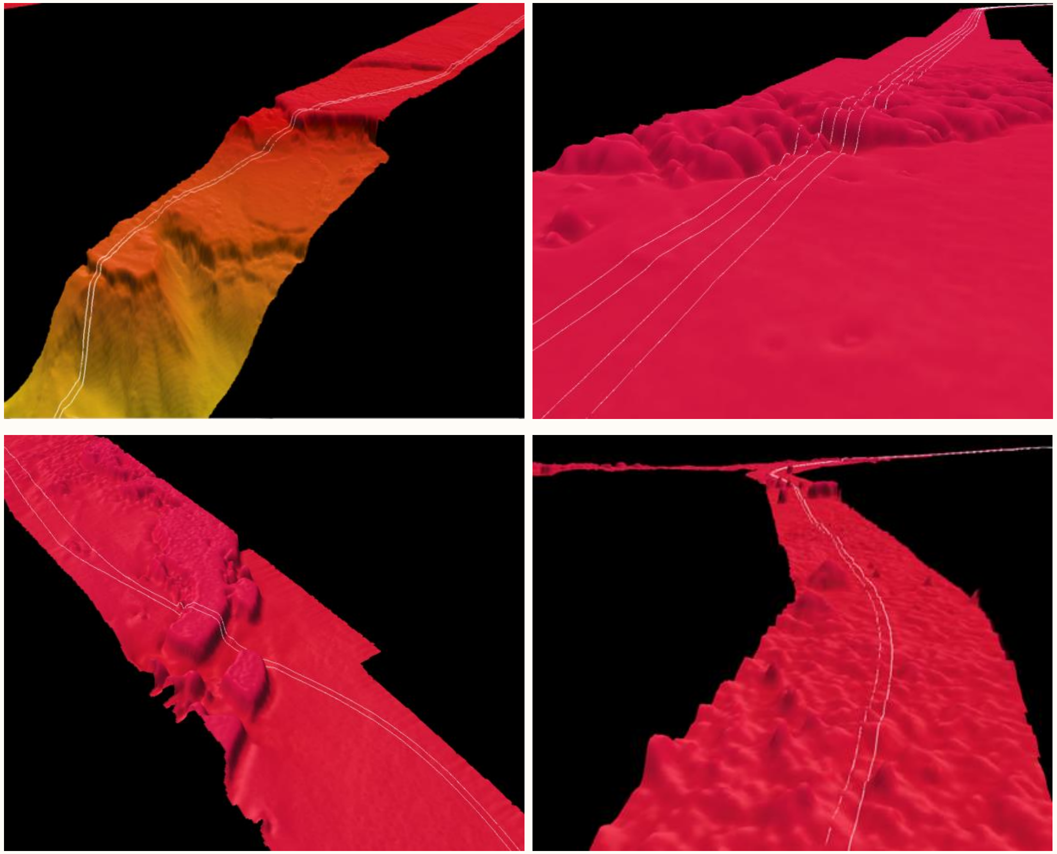
- Provide support to the pipe
- Modify the seabed
- Modify the behavior of the pipe.

The first two methods are the most frequently adopted ones.

Challenges along pipeline routes

Even after route optimization, the lay corridor may still contain bathymetric features which result in unavoidable spans that need seabed intervention for mitigation. These include:

- Reef and carbonate complexes/ outcrops
- Growth faults
- Steep terrain at shelf break
- Irregular or undulating seabed
- Pinnacles
- Landslide complexes
- Channels
- Gullies
- Sand waves / ripples
- Pockmarks (seabed craters)



Pre-lay Seabed Intervention

Pre-lay Seabed Intervention by dredging

- Pre-lay seabed intervention by dredging is relatively common.
- For shallow water up to 30m depth, it is generally felt that cutter suction dredger, backhoe dredger and Trailing Suction Hopper Dredger (TSHD) are most appropriate for soil of varying conditions (soft to hard).
- For seabed intervention in deep water beyond the reach of TSHD, bucket dredger could still be used.

Dredging Equipment	Suitable Soil Condition	Depth Limitation
Cutter Suction Dredger	Soft to hard soil	35m
Backhoe Dredger	Soft to hard soil	30m
Bucket Dredger	Soft soil	1000m
Trailing Suction Hopper Dredger	Soft soil (without draghead) Hard soil up to 1MPa (Tideway) or 30 MPa (Boskalis) with Draghead c/w teeth	100m (Tideway/ Dredging International) – 250m [(1)] (Boskalis)

(1) Boskalis' brochure shows 90m but they claim 250m during face to face discussion

Near shore dredging

Geocean’s Marine Autonomous Excavator

Shore approach / mangrove swamp dredging using ‘march buggy’

Shallow water cutter suction dredger

Cutter Suction Dredger

Tideway Cutter Suction Dredger “d’Artagnan”
(dredging up to 30m depth)

Dredging of Channel along Pipeline Route to obtain Required Seabed Design Profile

Van Oord's Backhoe Dredger "Ave Caesar" dredging rocky seabed in Singapore
& 2 no. hopper barges for disposal of spoils

Seabed Intervention by Excavation (Bucket Dredger)

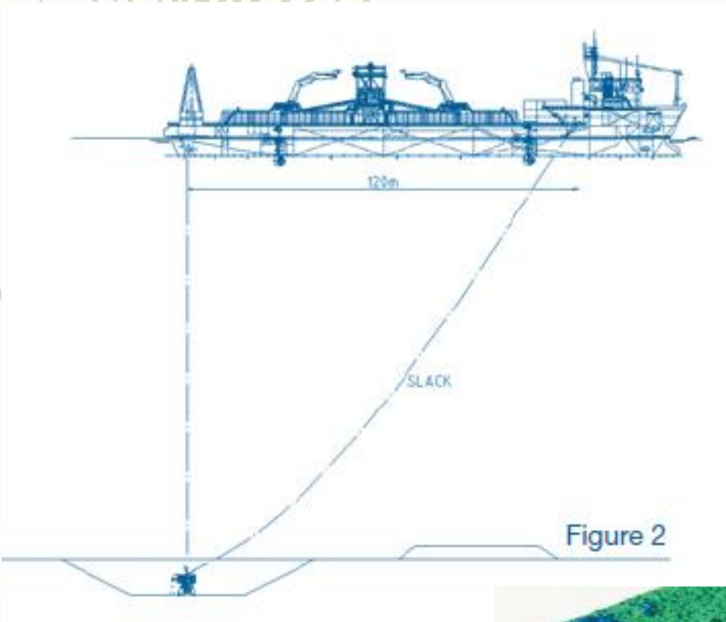


Figure 2

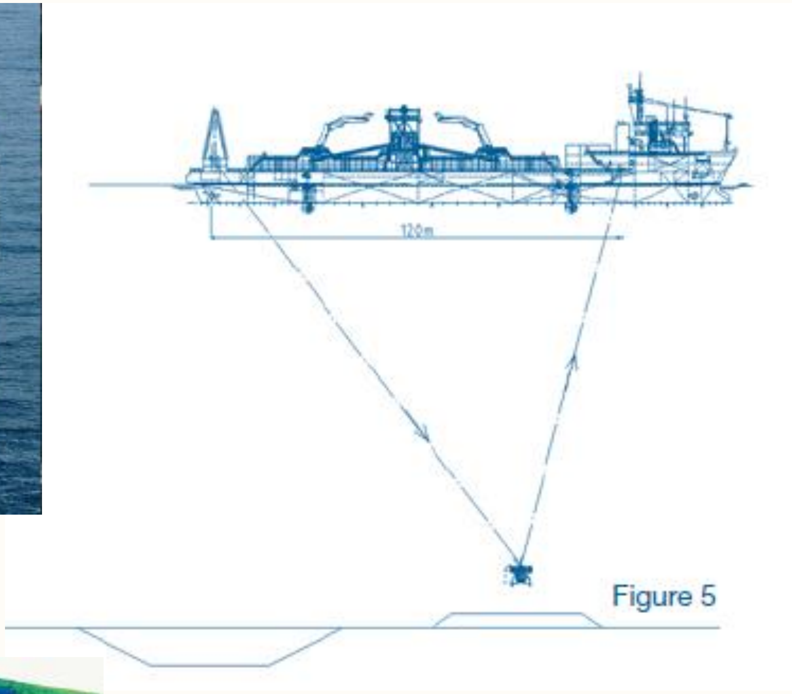
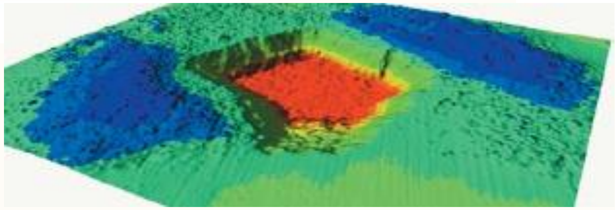
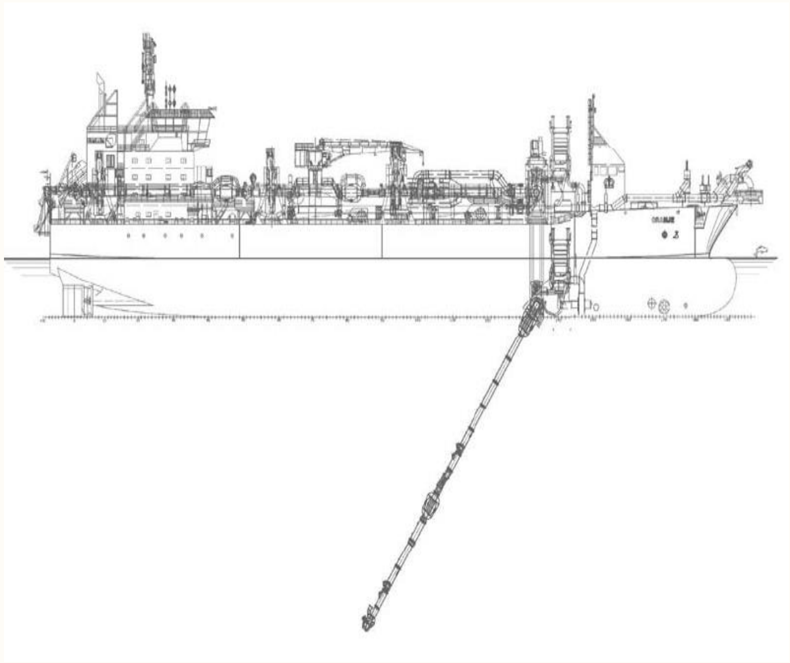


Figure 5



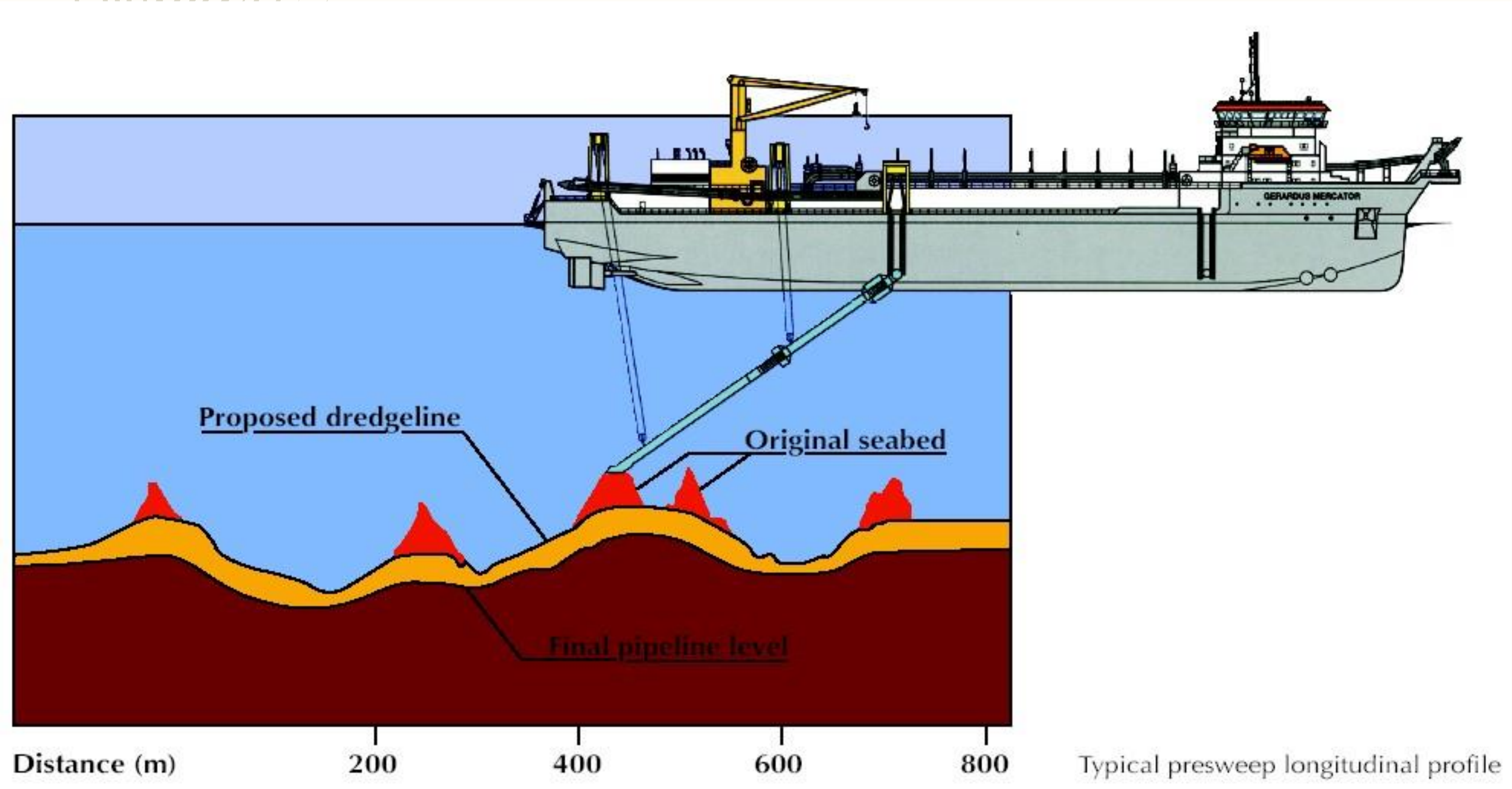
Schematic Showing a typical Boskalis Bucket Dredger at Work

Pre-Pipelay Dredging: Trailing Suction Hopper Dredger (TSHD)



Boskalis' Trailing Suction Hopper Dredger Prins der Nederlanden

Peak Shaving with TSHD



Mass Flow Excavator (MFE)

SeaVator Mass Flow Excavator with V-jet system (left)

SeaVator MFE coupled with ClayCutter X

- For trenching of pipelines & cables from 4” to 50” OD
- No contact with pipeline/cable
- Trench depth up to 5m
- Water depth from 5m onwards (max depth limited by hose handling)

- Can be used for deburial and rock dump removal
- Seabed levelling
- Sandwave clearance
- Span rectification even on live pipelines

ClayCutterX can cut 5m wide trench in soils up to 500kPa

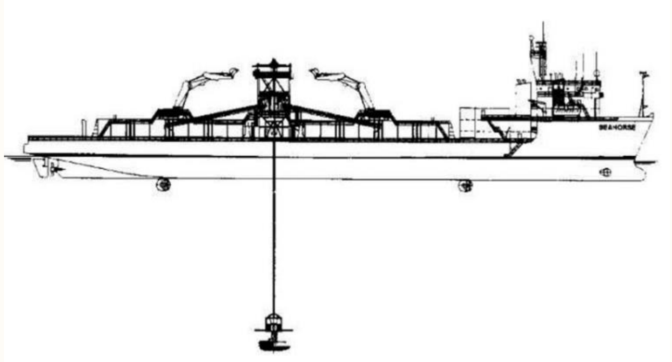
Dredgers (e.g. TSHD) can be adapted to perform MFE functions

Pre-Lay Seabed Preparation by Rock Dumping

Dredging itself may not be sufficient, and rock dumping may be required as supplementary means of span mitigation.

The recommended equipment are:

- Buckets for shallow water and deep water but is slow.
- Side stone dumping vessels are efficient for shallow water rock dumping.
- Fall pipe rock dumping vessels can operate to 1000m and new builds can operate up to 2000m



(L&C) : Van Oord's Rock dumping using Side Stone Dumping Vessel, Jan Steen

Drilling & Blasting Works along Pipeline Route to Shatter the Rocks where dredger was unable to dredge



Drilling & Blasting Works along Pipeline Route (2nd vessel – same project; very slow process)

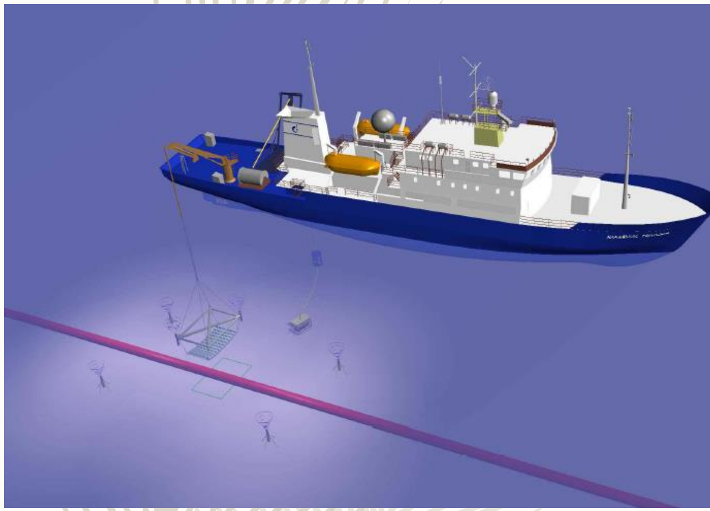
View of drilling machine in operation (from another project)

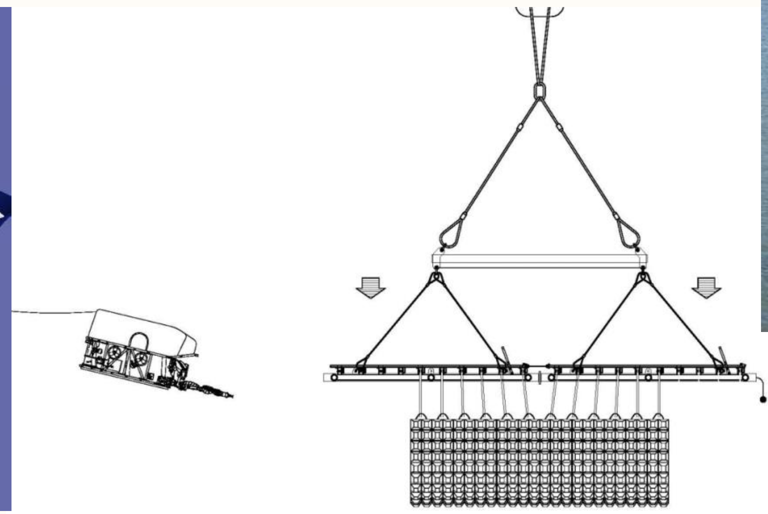
Note cables hanging from drilling m/cs to sea. Those are detonation control cables to initiate the detonation.

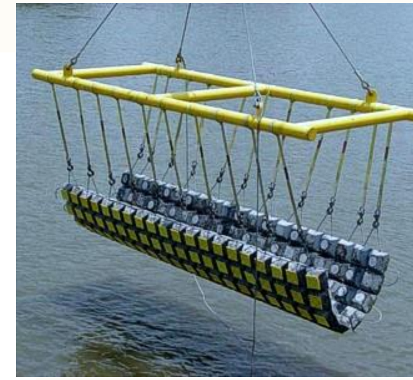
Dredger and D&B Vessel Working Side by Side –
D&B vessel shatters rock & dredger removes shattered rock

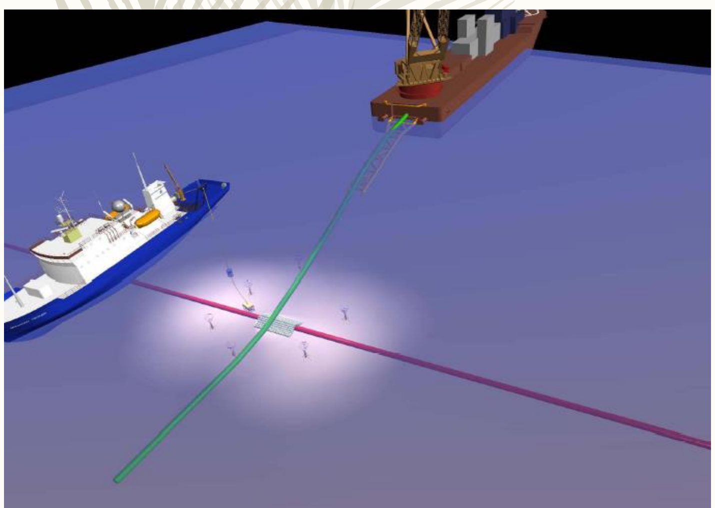
Seabed intervention through Placement of ‘structures’ on seafloor

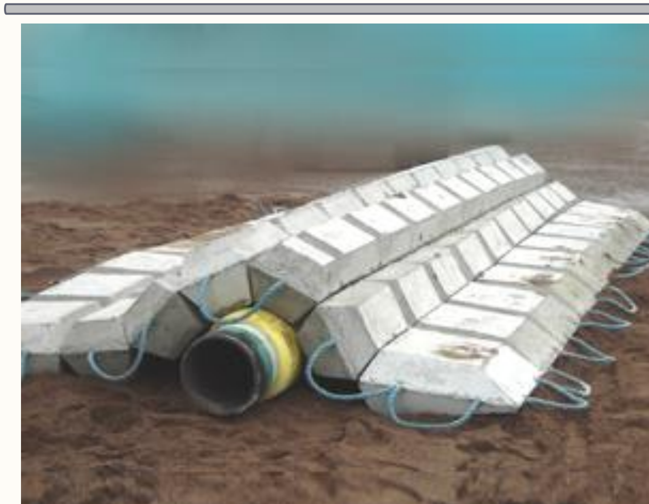
Concrete mattresses are used to provide separation between existing infrastructure and newbuilds





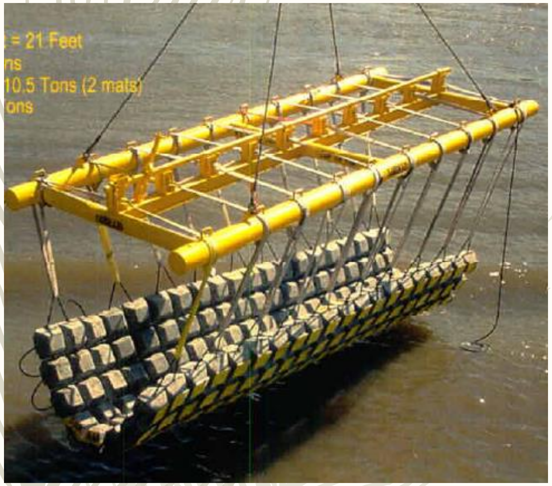






Picking up of Mattress from material barge & subsea deployment via Lifting Frame

Mattresses can be installed single, dual or triple layers



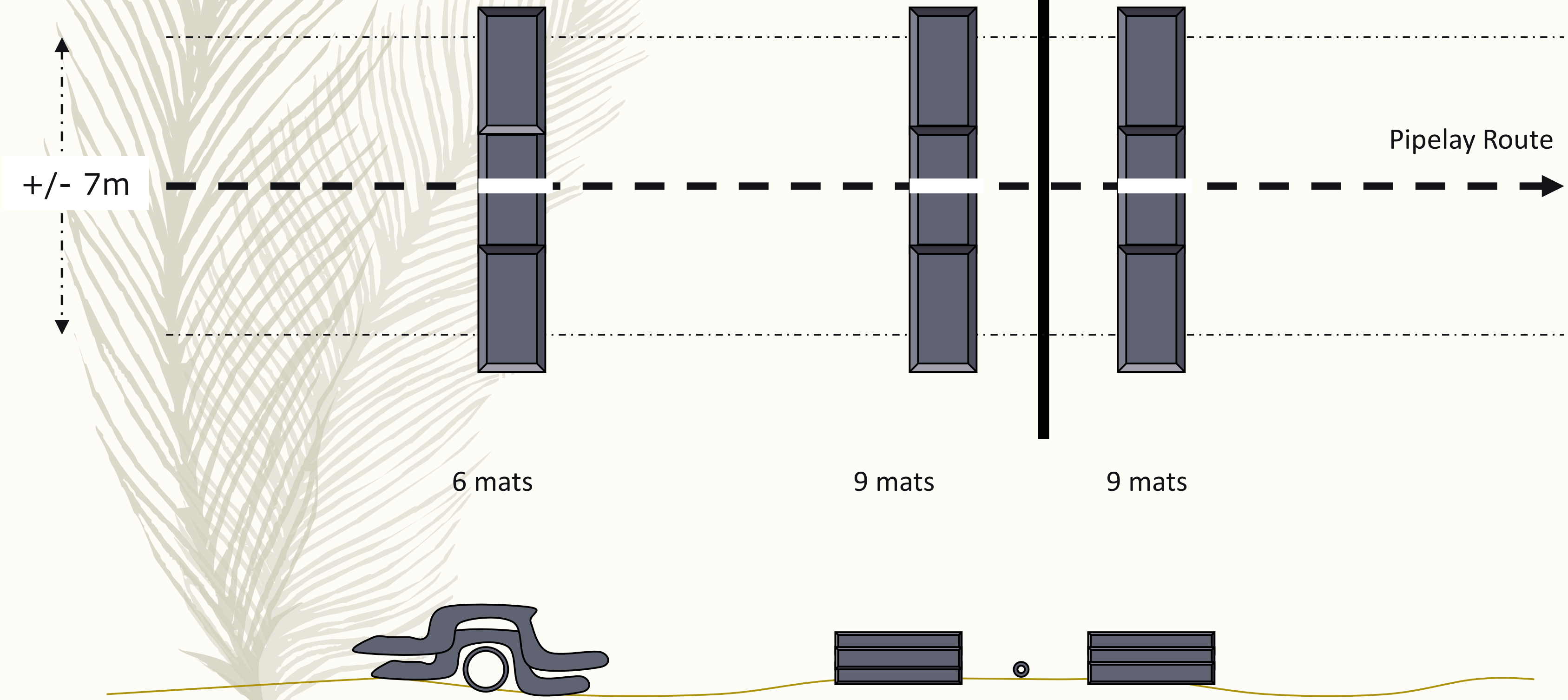
Single

All ROV Releasable

Triple

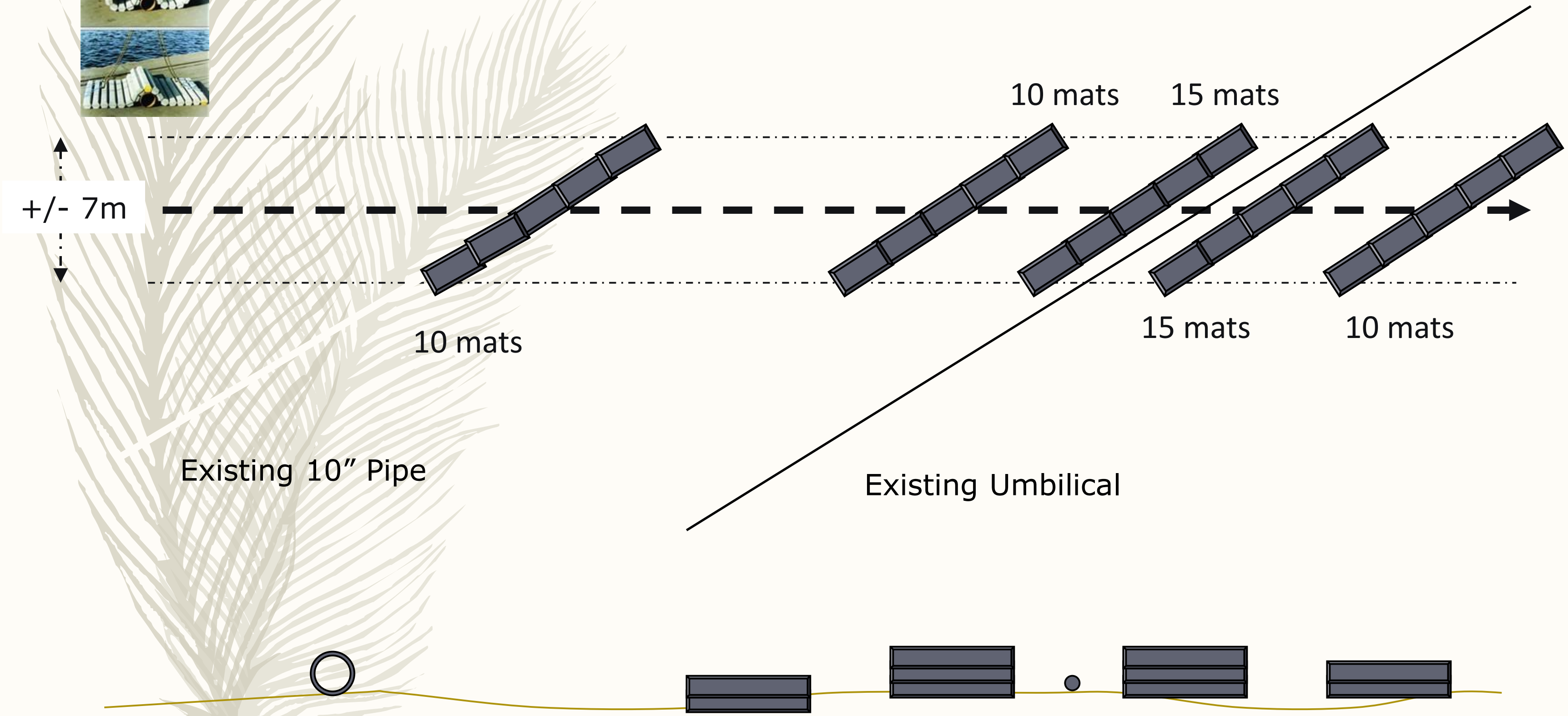
Dual

Right angle crossing

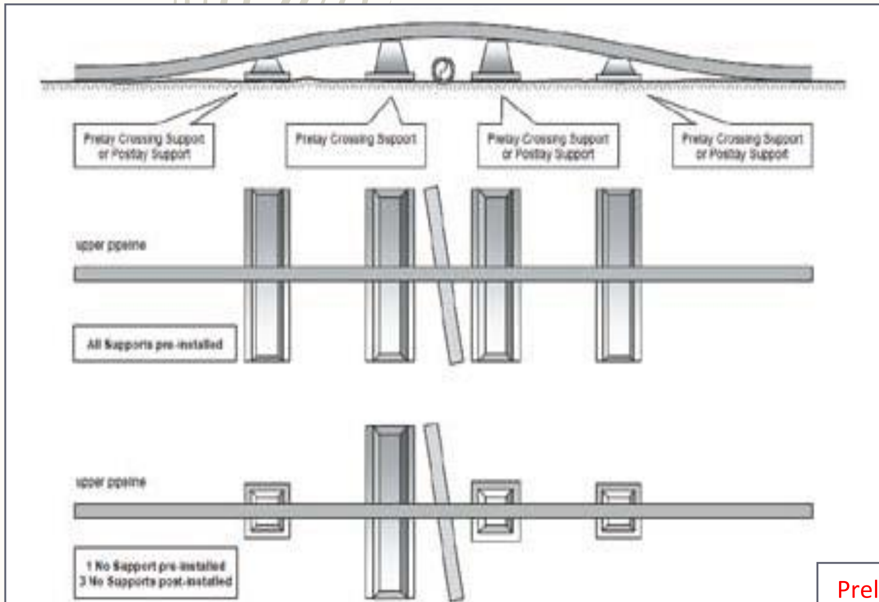


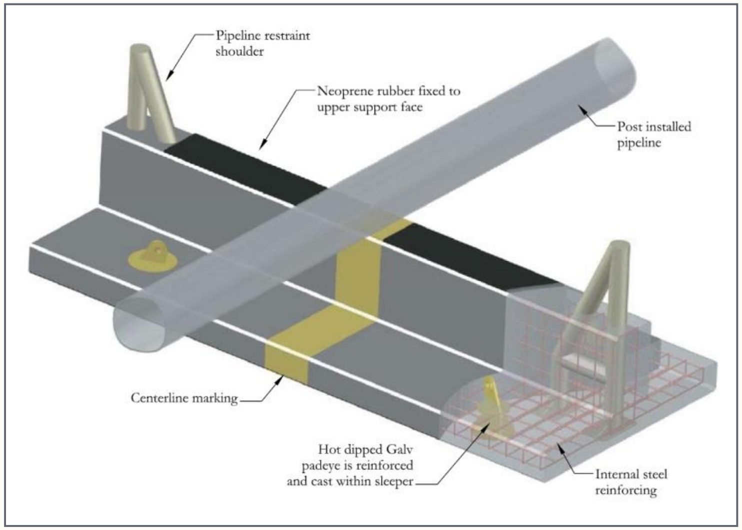
Assume ½ mat to 1 mat sinking into seabed

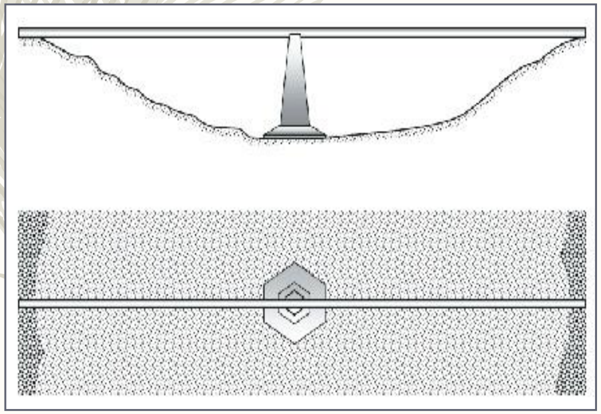
Shallow angle crossing



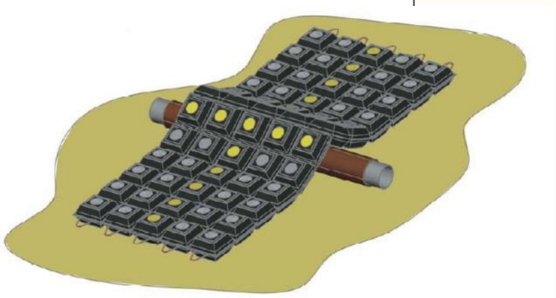
Typical Crossing Supports (ULO Products)



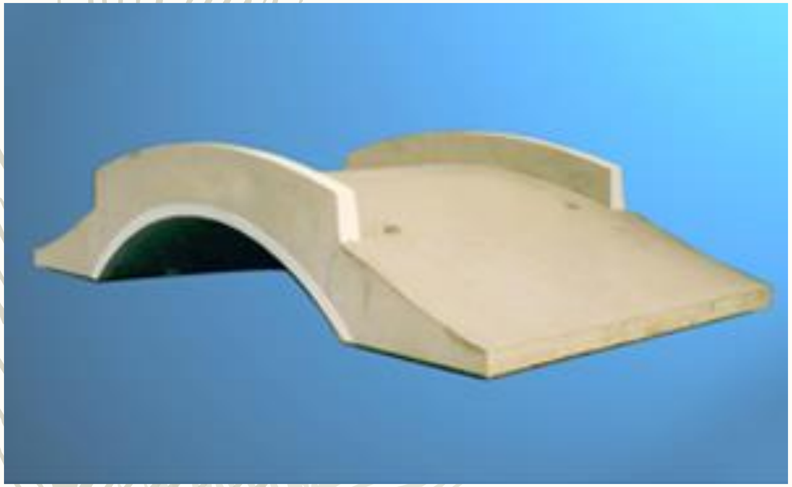




Prelay Crossing Support
Standard and Large Base Pipeline Supports
Wedge Cable / Umbilical / Flexible Pipeline Crossing Support
Jacking Supports
Mono Crossing Support
Pillar Supports
Cable Crossing Supports
Dome Support
J-Tube Support
Pipeline Stabilisation



Crossing Bridges

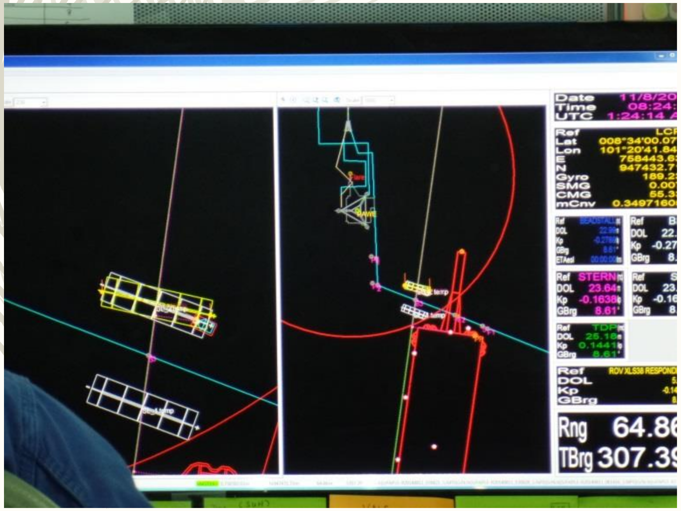


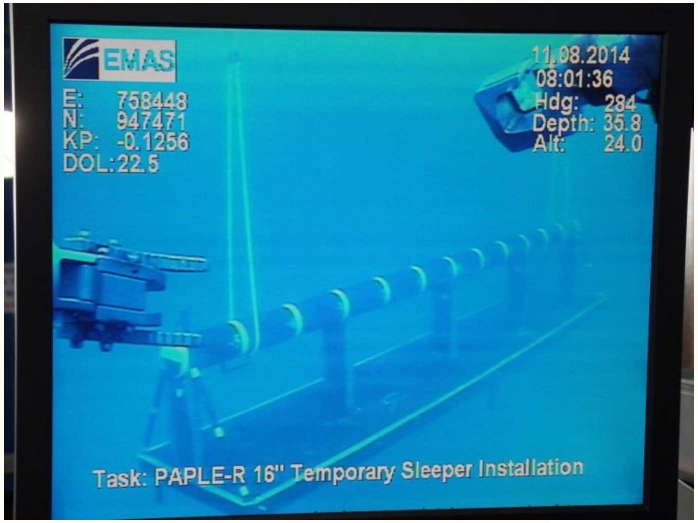
SPS Crossing Bridges are an ideal solution for crossing an existing pipeline with a pipeline or cable in a single unit installation. These can be manufactured to:

- Standard Design
- Client Design
- Client/Manufacturer Joint Design

As for all products, due consideration is given to all issues around handling, installation and certification.

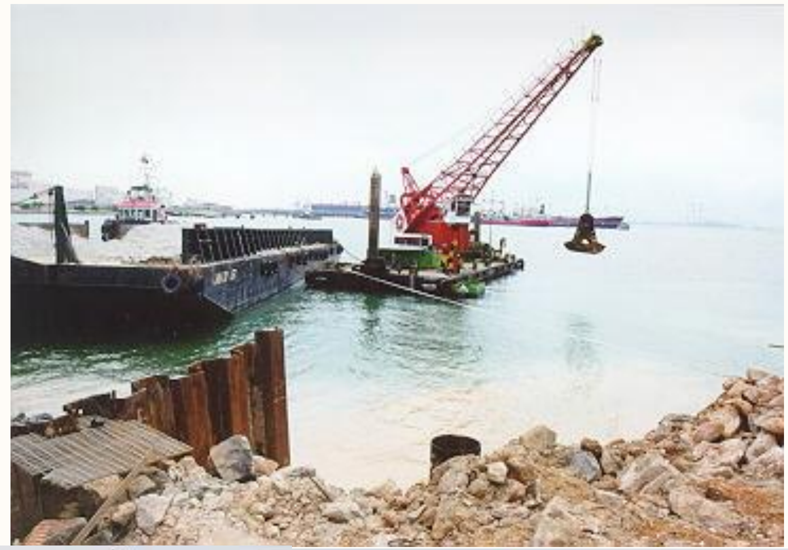
Steel sleepers for pipeline crossing

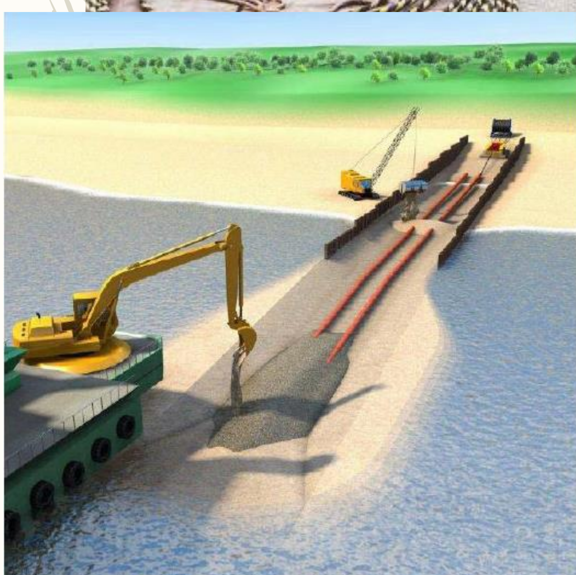


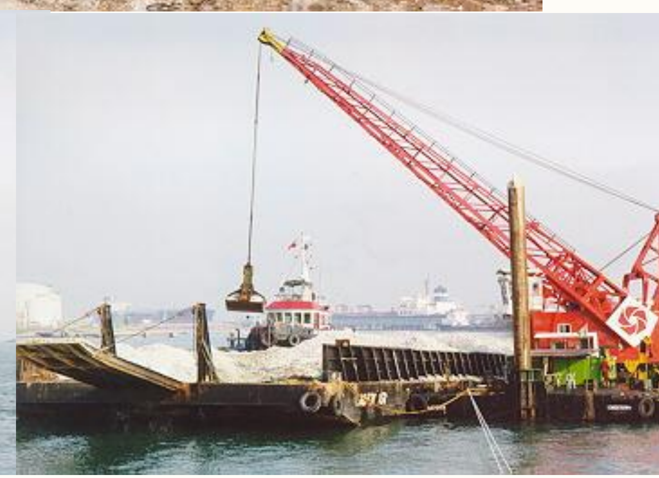


Post-lay Seabed Intervention

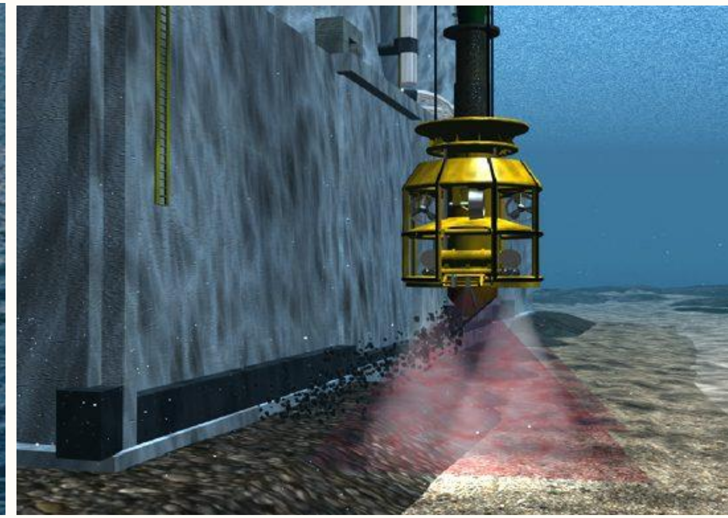
Where Rock Dumping by Specialised Rock-dumping Vessel is not possible (e.g. depth too shallow for vessel draft), Conventional Grab Dredger may be Used

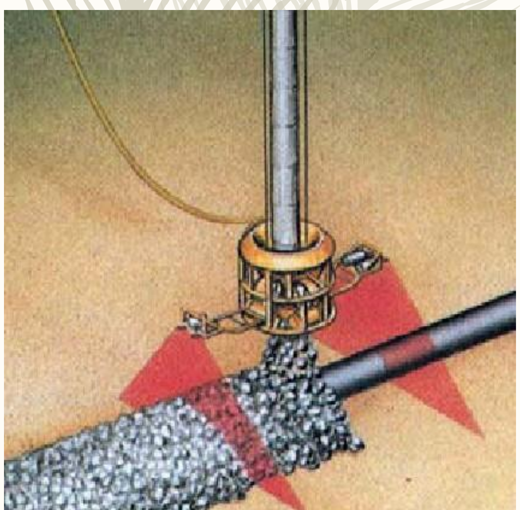


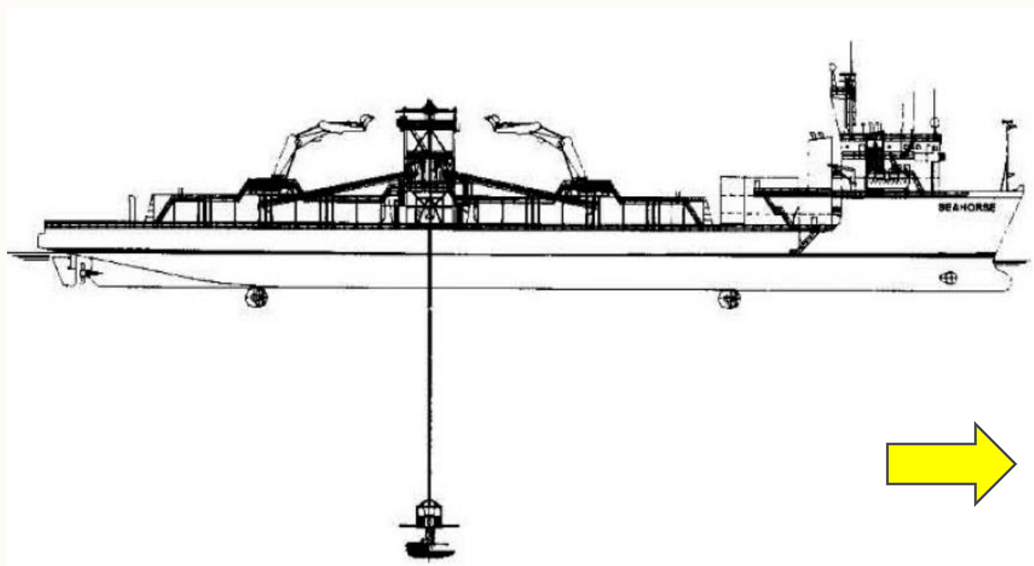




Rock Dumping by Specialised Fall Pipe Vessel (e.g. for pipeline/cable/ structure stabilization, scour protection, seabed preparation, span correction, impact protection, etc.)







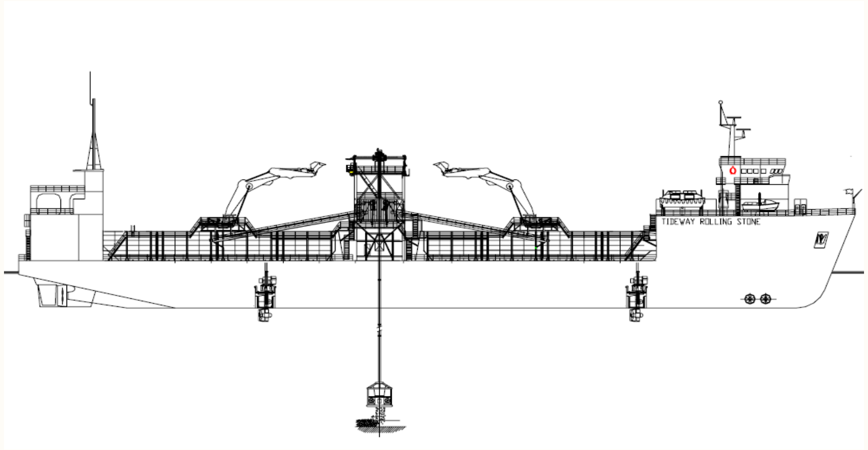
Post -Lay Seabed Intervation

Where post-lay seabed intervention is required to correct unacceptable spans due to the undulating nature of the seabed, possible seabed intervention would include:

- Free span correction using grout bags
- Free span correction by rock dumping
- Jetting to correct spans by removing high spots

Typical Grout Bags for Span Corrections

Span Correction by Rock Dumping

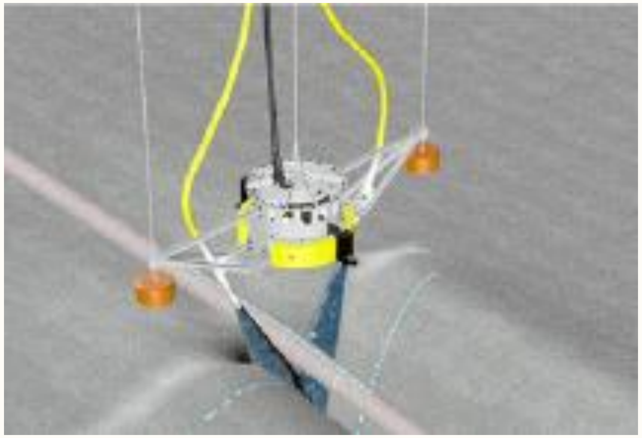


(L) Side Stone Dumping Vessel; (R) Fall Pipe Stone Dumping Vessel

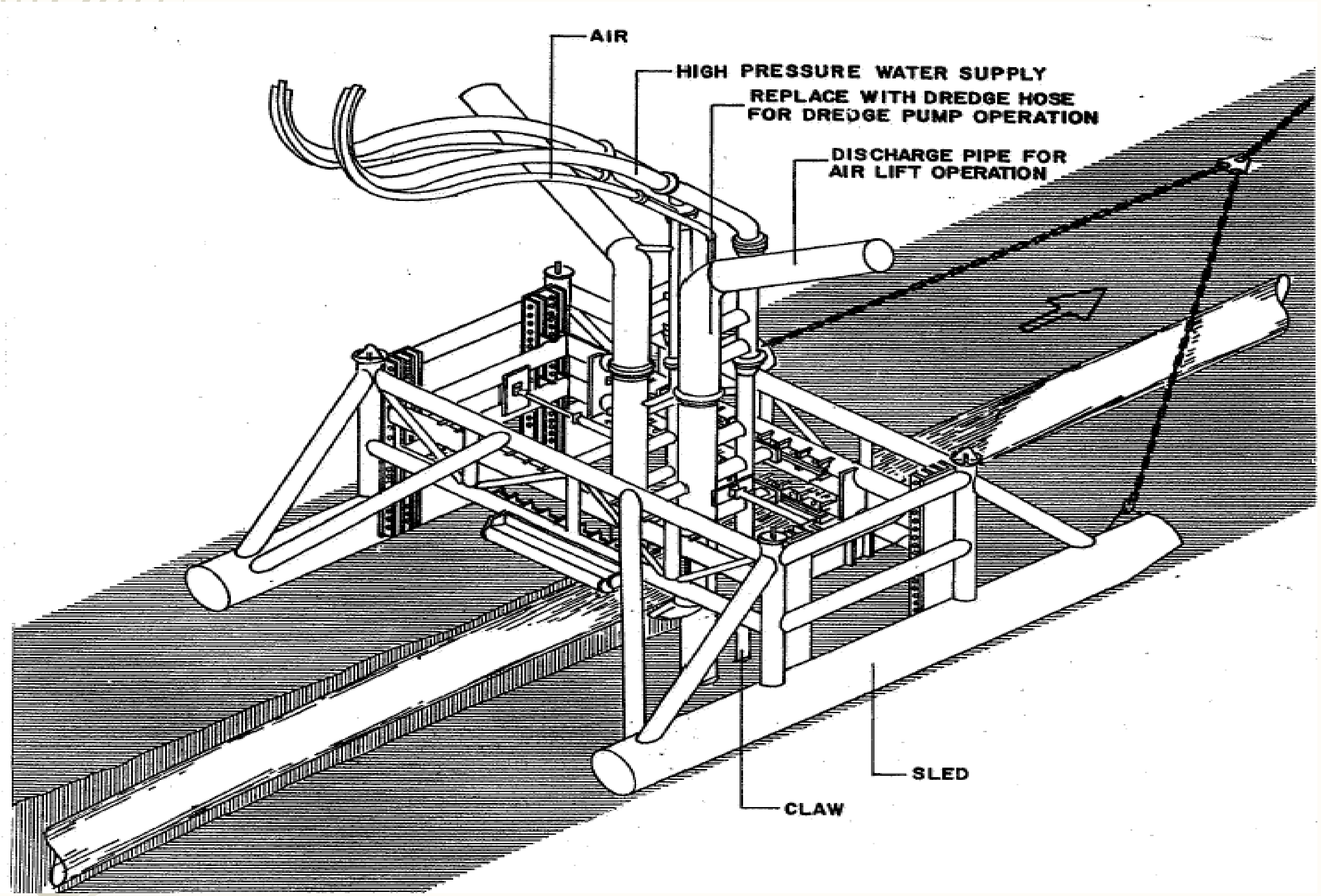
Span Correction by Removing High Spots

Mass Flow Excavators can be used to jet away high spots so that the pipeline settles down and excessive spans are rectified

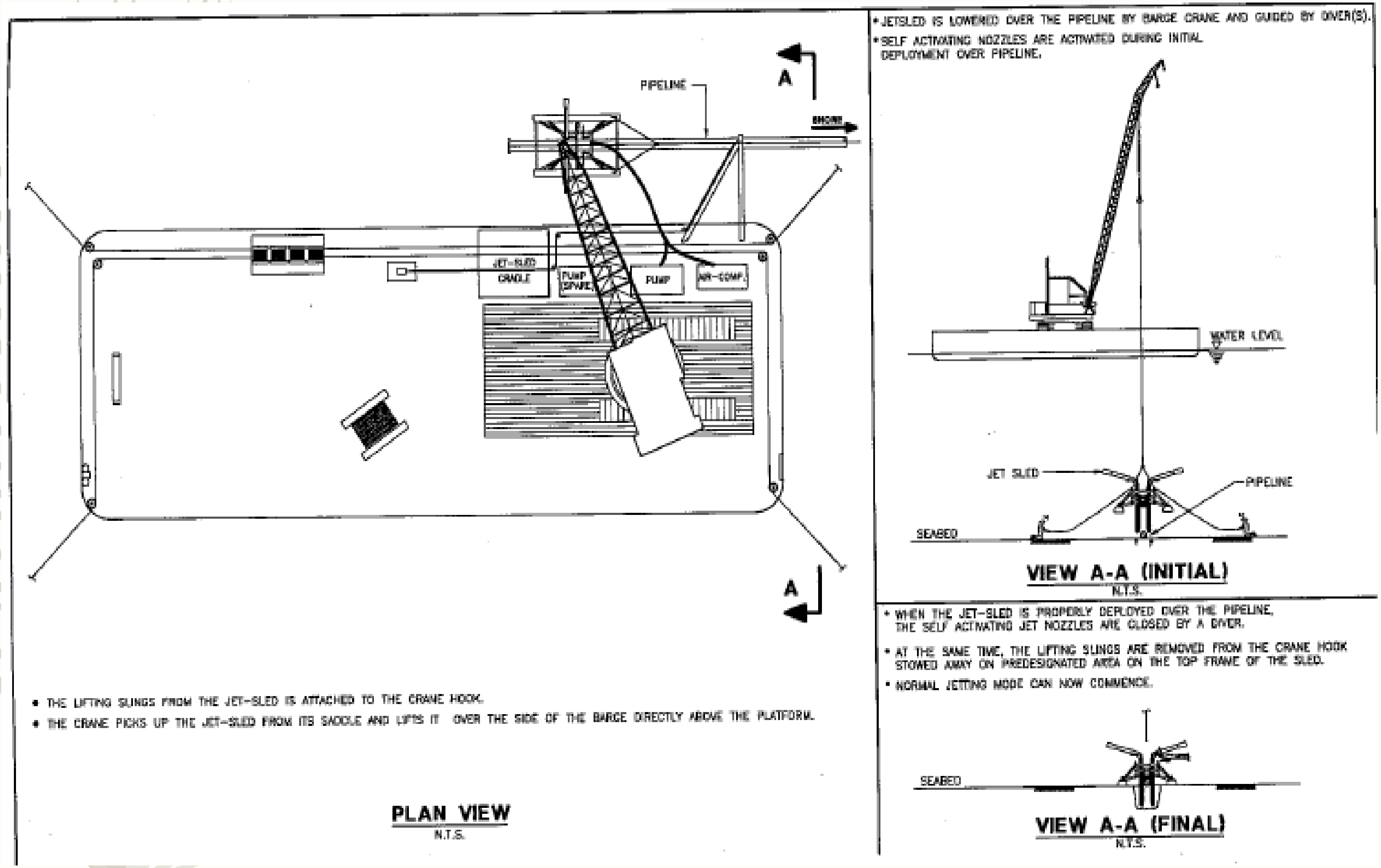
Typical Mass Flow Excavators



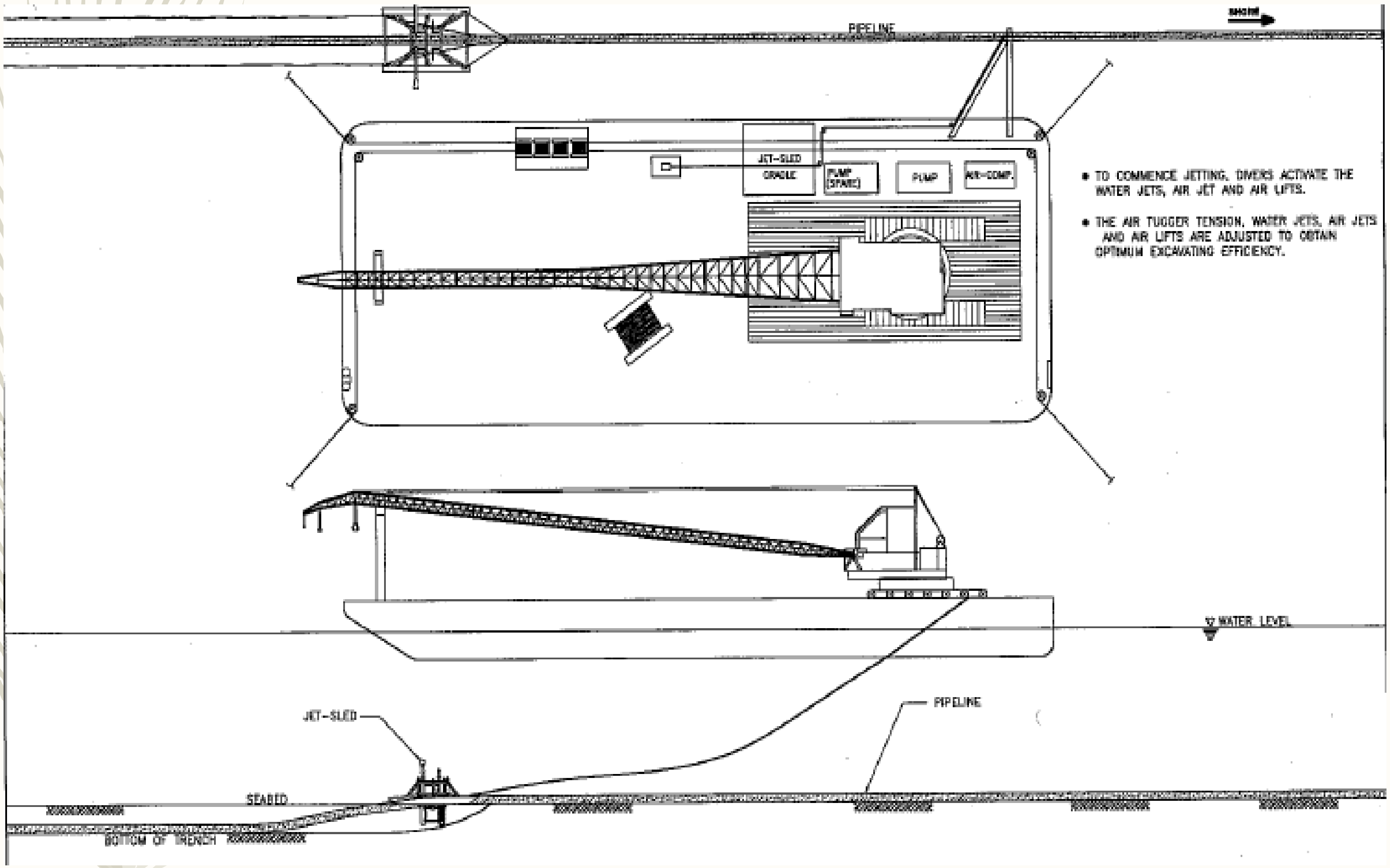
Typical Jetsled Deployed on Pipeline



Schematic Showing Typical Deployment of Jet Sled



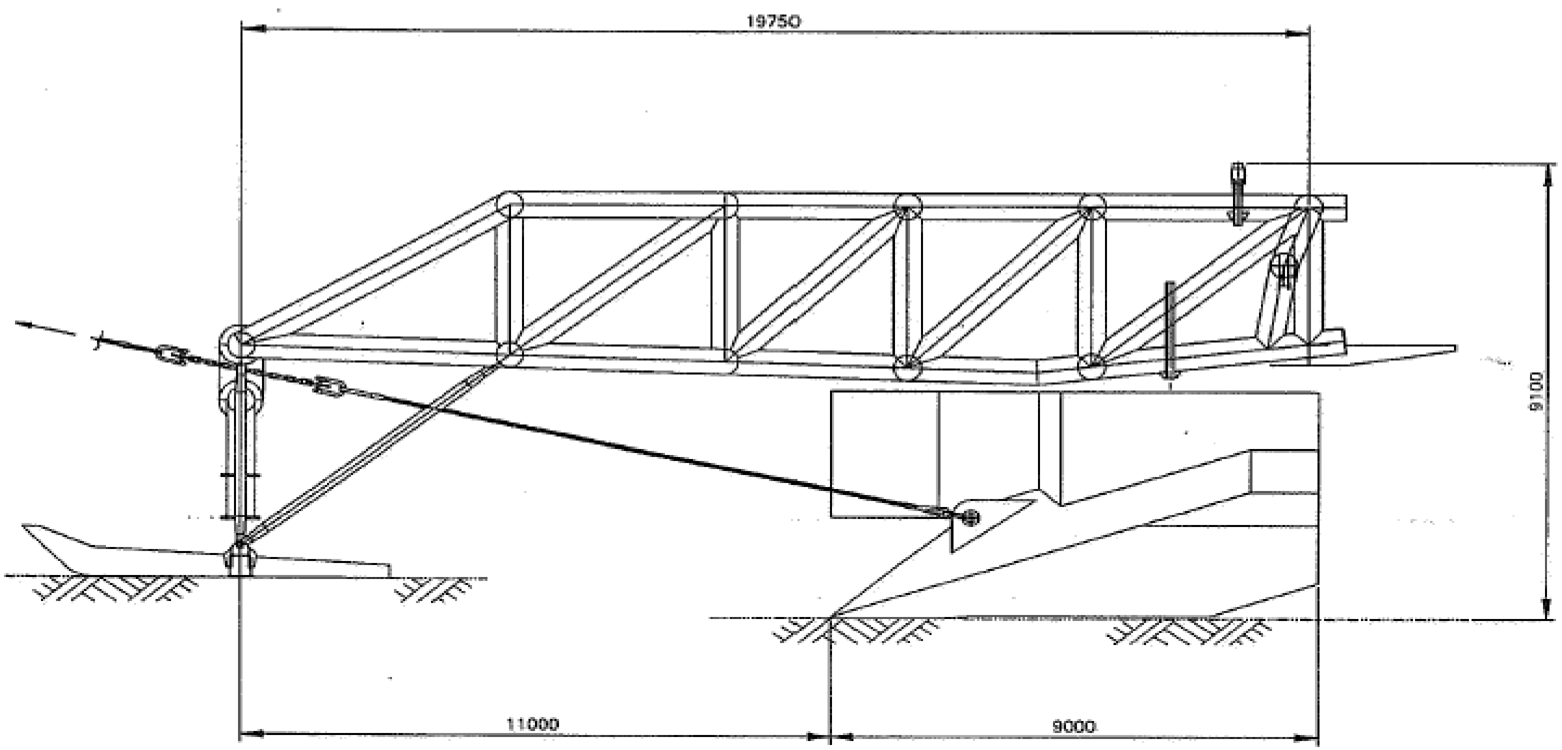
Schematic Showing Normal Jetting Mode During Post-Trenching Operation



Jet-Sled used for post-lay trenching of pipeline

Closer View of Jetting Claw, Showing Nozzles and Eductors

Typical Post-trenching Plough

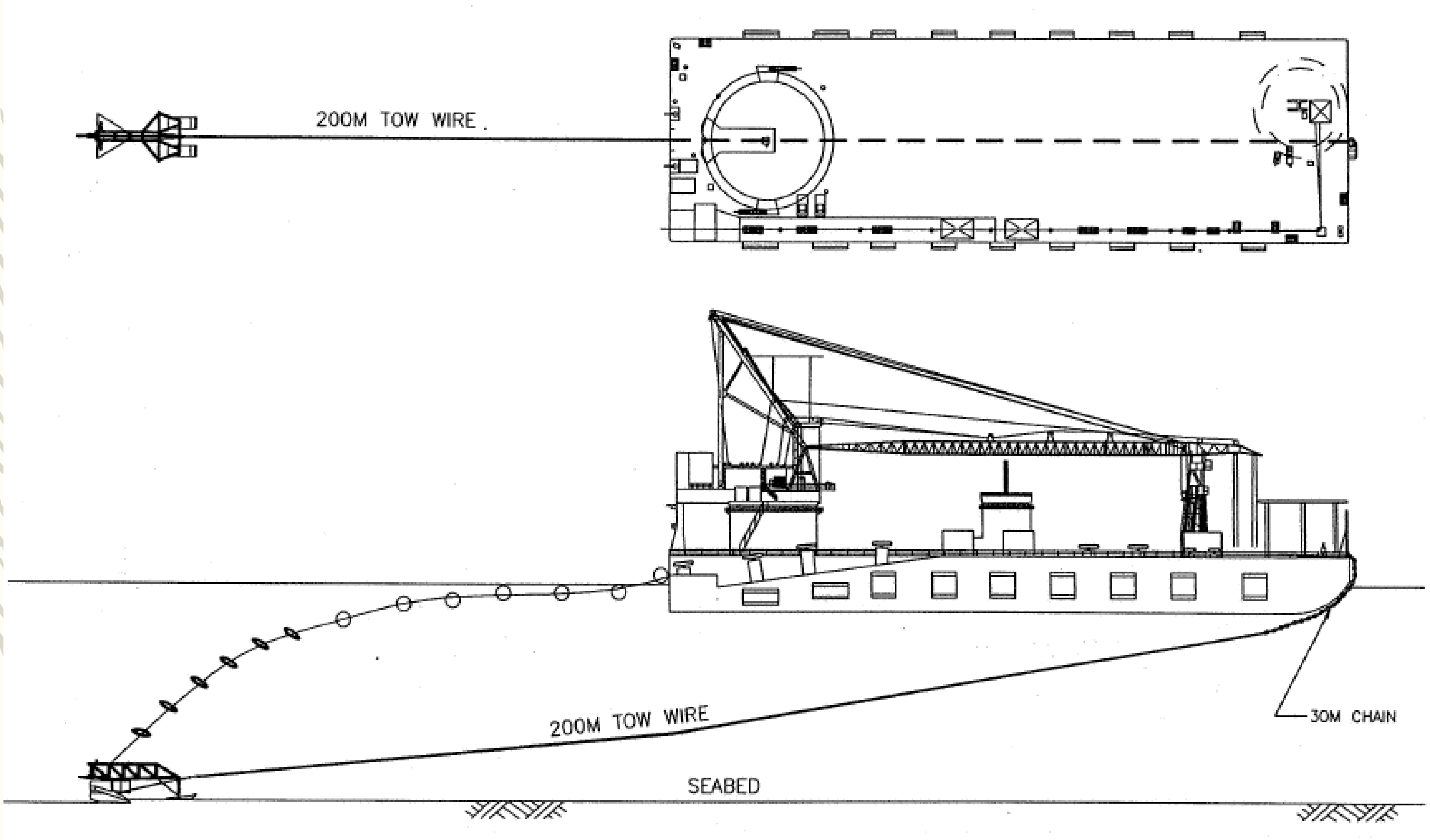


ROCKWATER F.A.S.T. PLOUGH
ELEVATION

View of 2nd Generation Plough in Action during Dry Run

View of Trench made by Plough

Typical Arrangement for Post-trenching using Plough (2nd Generation)

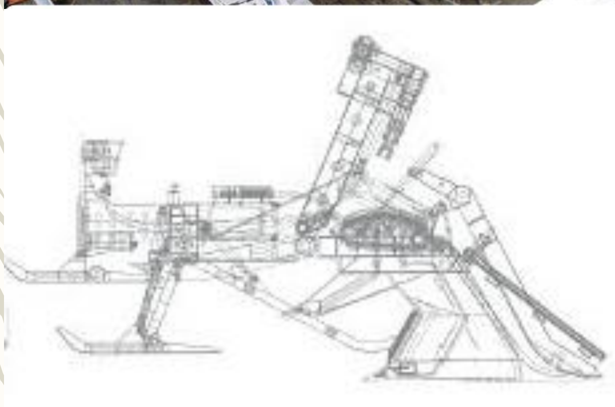


Pipeline burial by Post-trenching Plough

McDermott's 2nd Generation Plough – Successfully used on 2 projects in Malaysia (already scrapped)

- Requires vessel to pull plough
- Max. trench depth = 1.8m
- Suitable for sand and clay

New generation post-lay trenching machines (samples)



CTC Marine's Rockplough2 :

- Cable burial up to 3m depth
- Suitable for various soil types ranging from sand to soft – hard clay and fractured rocks.
- Fitted with echo sounders, sonar, cameras, u/w lamps & enhanced jetting system

CTC Marine's Trencher T1:

- Burial of flexibles (e.g. umbilicals and cable)
- Can operate in jetting or wheel cutting mode
- Can simultaneously lay and trench flexible products
- Up to 1.2m trench depth (cutting mode) and 2m (jetting mode)
- Suitable for sands and soft – very hard clays

New generation trenchers (Cont'd)

CTC Marine's Trencher T3:

- Burial of pipelines, umbilicals and cables
- Can operate in jetting or wheel cutting mode
- Can simultaneously lay and trench flexible products
- Up to 1.2m trench depth
- Suitable for sands and soft – very hard clays

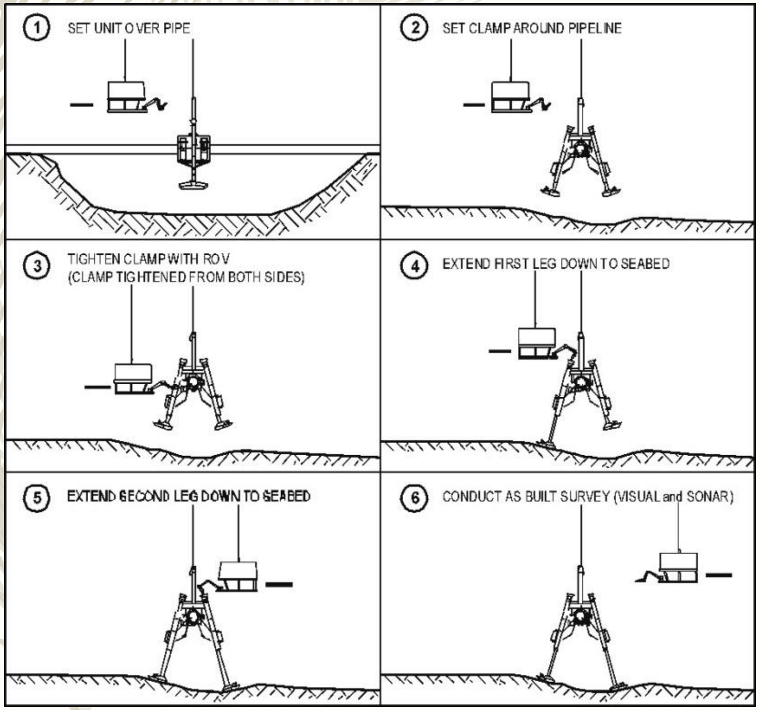
CTC Marine's Trencher T2:

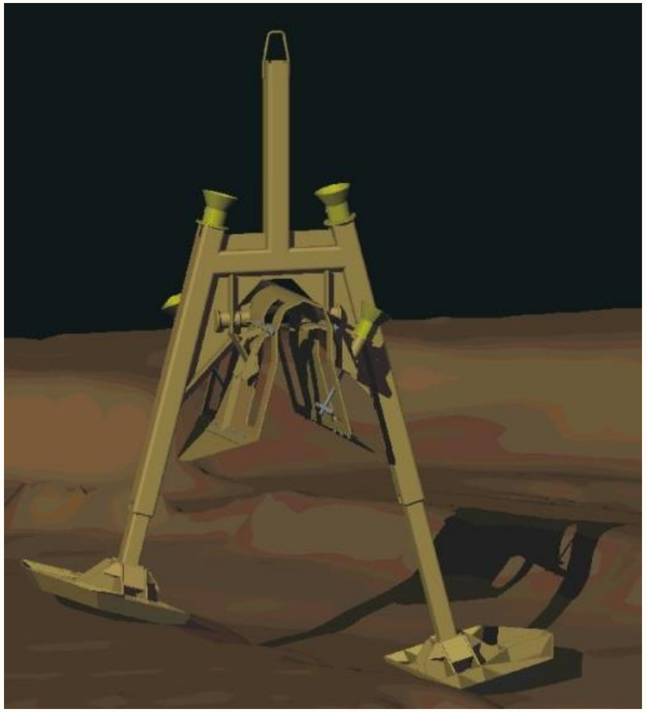
- Burial of pipelines, umbilicals and cables
- Can operate in jetting or chain cutting mode
- Up to 1.6m trench depth
- Suitable for sands and soft – very hard clays

Correcting Spans which are too high or/and too deep

Where conventional methods (e.g. pre-trenching, rock dumping, grout bags, etc) is deemed not viable for span correction, unconventional means may be required.

Below is one example: Using External Clamps





When to choose pre-lay intervention and when to choose post-lay intervention?

Pre-lay intervention vs Post-lay Intervention

- Pre-lay intervention needs to be carried out if resulting spans during pipeline installation will result in pipeline overstress/yield or unacceptable vortex-induced vibration; otherwise, Contractor has option to intervene after pipeline installation

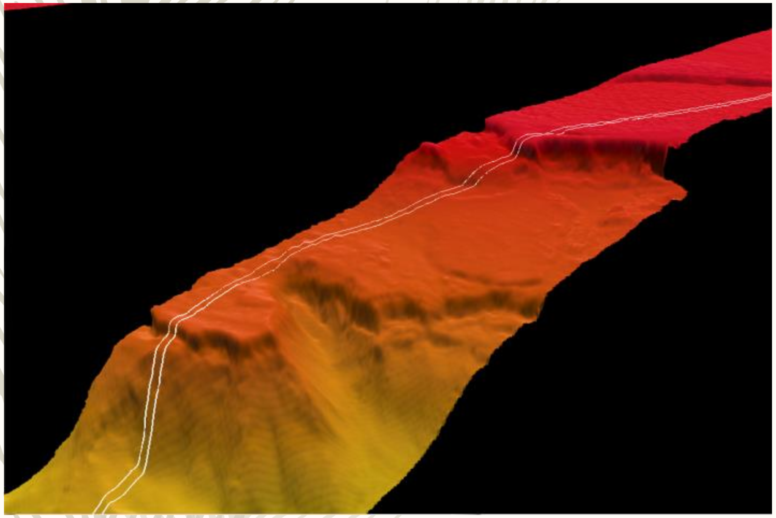
- Due to pipelaying tolerance (typically, +/- 10m), pre-lay intervention requires intervening a relatively large area (hence, costly)

- Advantage of post-lay intervention is that pipeline location is already identified, so Contractor only needs to intervene at specific points

Case Study – Seabed Intervention at Escarpment

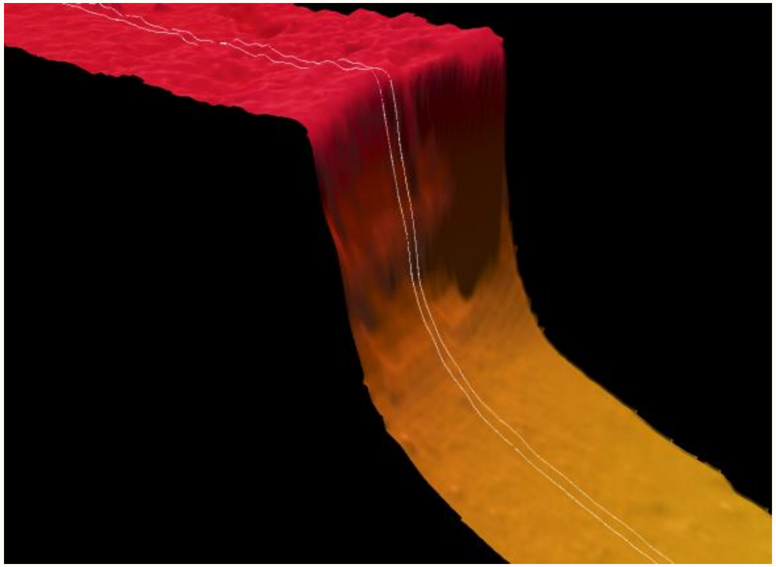
Challenges of laying pipeline through escarpment – Project Example

- On the Gendalo-Gehem pipeline project, the ascent to the shelf break contains channel, growth faults and steep ascent, with highly irregular seabed.



Shelf break & growth faults (Gendalo Pipelines)

Steep ascent to shelf break (Gehem Pipelines)



Summary of Preferred Methodologies from Various Contractors

DESCRIPTION	COMPANY	METHOD
Suggestion for Escarpment & superspan	Global Industries	• Activity at escarpment should be curtailed unless detailed soil investigation has carried out due to concern over slope failure. • If soil data not available, suggest to lay in 2 segments, one from FPU and other from shore, then both abandoned before the escarpment. • Spool (flexible or rigid) to connect both segments subsequently, thereby ensuring minimal intervention at escarpment. • If soil investigation shows that seabed features are stable, then cutting and profiling is the easiest and preferred solution, supplemented by span correction by prefabricated grout bags and mechanical supports.
	SapuraAcergy	• Excavation by Mass Flow Excavator (MHE) at tip of escarpment to remove 'protrusion' this will reduce super span substantially • Dump rocks in between to correct excessive spans, **OR** • Change properties of pipe (increase grade, wall thickness, weight) to reduce span and increase allowable span • Increase allowable strain criteria for superspan • Reduce residual lay tension
	Saipem	• Not studied. Insufficient soil information to provide assessment.

Summary of Preferred Methodologies from Various Contractors (Cont'd)

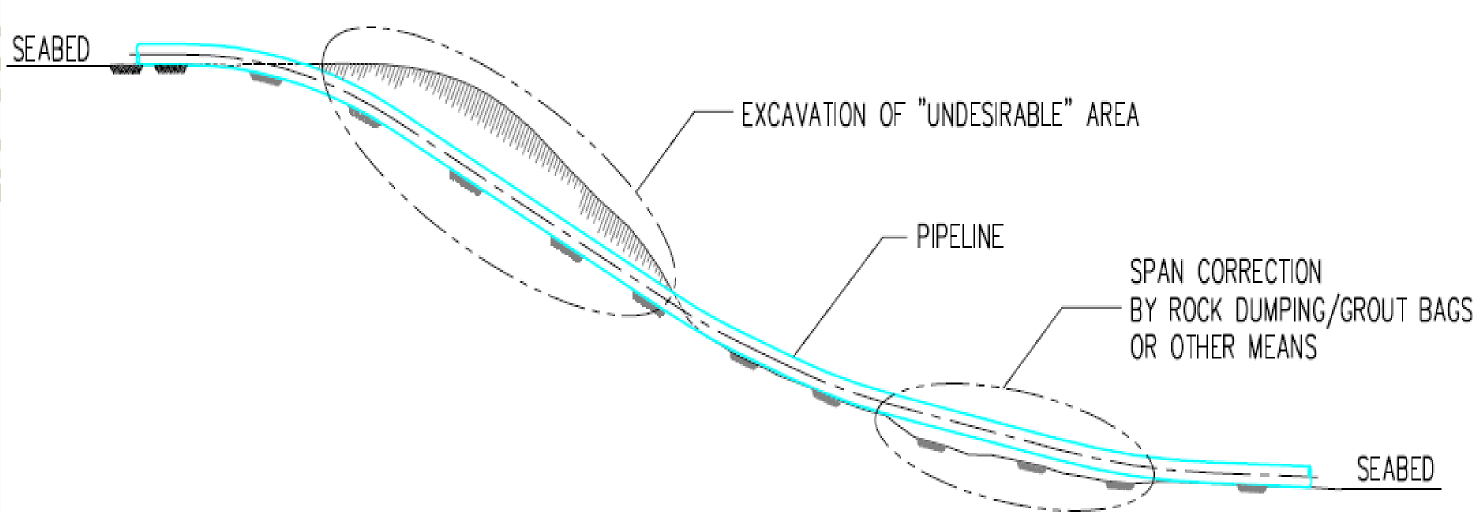
DESCRIPTION	COMPANY	METHOD
	McDermott	One or combination of following: • Dredging • Backfilling • Steel frames
	Nippon Steel	• Pre-dredging or post-trenching (jetting down) • Consider strain-based displacement control design
	COOEC	• Trenching and post-jetting • Installation of grout bridge
	Boskalis	• Trim the top of escarpment using TSHD and install pipe clamps to achieve allowable spans • Rock dumping can replace the pipe clamps if soil is stable
	Tideway	• Trim off top of escarpment using TSHD and dump rocks to eliminate excessive spans
	AGR	• AGR's clay cutter X can cut clay up to 500kPa at rate between 20m^3/hr to 600m^3/hr and is suitable for cutting the escarpment to get a suitable profile which will reduce pipe stresses and spans.
	Jan de Nul	• Trimming of the 'top' and rock dumping to correct remedial span

Eventual Recommended Solution for Escarpment (FEED costing purpose)

Based on assumption that the soil along escarpment is suitable for excavation, the most cost effective and proven method of span rectification (and pipeline stress mitigation) was deemed to comprise:

1) Excavation of ‘undesirable’ areas causing unacceptable pipeline stresses and resultant spans by TSHD or MFE before commencement of pipelaying.

2) Plus, post-lay span correction using either rock dumping (fall pipe vessel for accurate deposition of rocks) or grout bag supports (ROV installed) or other means preferred by EPCI contractor.



General Findings (from Past Studies)

Summary of Preferred Methodologies from Various Contractors

DESCRIPTION	COMPANY	METHOD
Pre-lay Seabed	Global Industries	• Pre-trenching to cut and profile is preferred if soil is stable • Rock dumping is an option • Support frame, concrete slab may be used for expected low height spans
	SapuraAcergy	• CSD will be used within depth limitation to do pre-sweeping • For remainder – not investigated yet; will subcontract to dredging company
	Saipem	Depending on site conditions and could be one or more of : • Mass flow excavation • Clay cutting • Rock bedding • Pre-sweeping by cutting pinnacles • Steel sleeper structures • Concrete mattresses
	McDermott	• Concrete mattresses • Steel frames • Dredging • Backfill
	Nippon Steel	• Pre-sweeping for shallow water • Pre-sweeping up to 155m, rock dumping above 155m

Summary of Preferred Methodologies from Various Contractors (Cont'd)

DESCRIPTION	COMPANY	METHOD
	COOEC	• Primarily by dredging to smoothen seabed profile • Soil replacement to improve foundation properties • Clearing of obstacles along route
	Boskalis	• Typical method is by 'trimming' and backfilling, i.e. cutting off protruding sections and backfilling trenches • Dredging can be by backhoe (up to 30m) or TSHD or dredging bucket • Backfilling using side stone dumping vessel, fall pipe vessel or by buckets
	Tideway	• Suggests trimming and backfilling, i.e. cutting off protruding sections and backfilling trenches • For depth up to 30m, use cutter suction dredger • From 30m to 100m, use TSHD if soil is soft • Rock dumping using fall pipe vessel can be carried out to 1000m
	AGR	• AGR's clay cutter X can cut clay up to 500kPa at rate between $20m^3/hr$ to $600m^3/hr$ and is suitable for pre-trenching works
	Jan de Nul	• For depth up to 32m, cutter suction dredger and backhoe dredger are suitable • TSHD can be used for soft to 3-4 MPa soil from 5m to 160m • Rock dumping using fall pipe vessel can be carried out to 2000m • Fall pipe dredger with grab excavation system can be used to dredge in water depth up to 2000m

Summary of Preferred Methodologies from Various Contractors (Cont'd)

DESCRIPTION	COMPANY	METHOD
Post-lay Seabed	Global Industries	• Span corrections using grout bags • For deepwater, suggested sand/cement bags, pre-fabricated grout bags and mechanical supports • Post-lay jetting • For deepwater, post-lay jetting by ROV for small seabed humps
	SapuraAcergy	• Span corrections using grout bags and mattresses • Pre-sweep using water jetting or mass flow excavator • Rock dumping (if required)
	Saipem	• Span rectification by standard fabric grout support • Rock dumping • Mechanical supports
	McDermott	• ROV operated grout bags • Flexible concrete mattresses • Steel frames with adjustable heights • Rock dumping

Summary of Preferred Methodologies from Various Contractors (Cont'd)

DESCRIPTION	COMPANY	METHOD
	Nippon Steel	• Grout bags, sand bags, mechanical supports, post-trenching, depending on circumstances and soil conditions
	COOEC	• Use mass flow excavator to remove high spots • Rock dumping
	Boskalis Tideway	• Backfilling by side stone dumping vessel (up to 30m), fall pipe vessel or by buckets • For shallow water, side stone dumping is efficient • Fall pipe dumping is good for both shallow and deep water and is used for accurate placement of rock • Rock dumping using fall pipe vessel can be carried out to 1000m
	AGR	• AGR's mass flow excavator, SeaVator, is suitable for removing high spots, which subsequently reduces pipe spans

Support Type Span Correction Methods (mostly post-lay)

Type	Limits	Advantages	Disadvantages	Diverless installation feasible
Grout bags	3 m height	Tolerant to uneven seabed Low risk to pipeline –no heavy lift	Intolerant to scour Unsuitable for steep slopes	Y
Flexible formwork – grout filled		Tolerant to uneven seabed Low risk to pipeline –no heavy lift	Intolerant to scour Unsuitable for steep slopes	Y
Sand bags	2 – 3m height	Do not need specialised equipment or vessel	Require competent seabed soil Unsuitable for steep slopes	N
Concrete flexible mattresses	2m height	Suitable if few spans are anticipated	Becomes very expensive if there are a lot of spans to correct	Y
Steel structures	5m or so	Suitable for steep slopes Positive experience West Seno	Engineered solution required for each span May induce slope failure Sensitive to lateral hydrodynamic loads	y
Spot rock berm		Tolerant to uneven seabed and scour	Requires mobilisation of specialised vessels	Y
Buoy & tether		May maintain pipeline above height of mass flows	Dynamic, requires fatigue analysis Sensitive to submerged weight Unproven	Y
Buoy & drag chain		May maintain pipeline above height of mass flows	Dynamic, requires fatigue analysis Sensitive to submerged weight Unproven	Y

Pre-lay Span Correction methods

Type	Limits	Advantages	Disadvantages	Diverless installation feasible
Grout bags	3 m height	Tolerant to uneven seabed Low risk to pipeline –no heavy lift	Intolerant to scour Unsuitable for steep slopes	y
Sand bags			Require competent seabed soil Unsuitable for steep slopes	N
Spot rock berm		Tolerant to uneven seabed and scour	Requires mobilisation of specialised vessel	Y
Strakes	Suitable when VIV is limiting		Increase drag load	Y
Massflow excavation	Non-cohesive soil	No structures to maintain		Y
Dredging- CSD	20m	Efficient, effective	Requires mobilisation of specialised vessel	Y
Dredging- THSD	20m	Efficient, effective	Requires mobilisation of specialised vessel	Y
Dredging- backhoe	20m	Efficient, effective	Requires mobilisation of specialised vessel	Y

Seabed Modification Type Span Correction Methods

Type	Limits	Advantages	Disadvantages	Suitability		
				Pre-lay	Post-lay	Diver-less
Spot rock berm		Tolerant to uneven seabed and scour	Requires mobilisation of specialised vessels			Y
Trenching- ploughing	Soil strength	No structures to maintain	Not suitable for large span gaps		Y	Y
Trenching- jetting	Soil strength/type	No structures to maintain	Not suitable for large span gaps		Y	Y
Trenching- cutting	Soil strength/type	No structures to maintain	Not suitable for large span gaps		Y	Y
Massflow excavation	Non-cohesive soil	No structures to maintain		Y	Y	Y
Jet AGR type				Y		Y
Massflow excavation	Non-cohesive soil	No structures to maintain		Y	Y	Y
Dredging- CSD	Cemented soil, rock, calcarenite 1-30 MPa			Y		Y
Dredging- THSD	Unconsolidated sediments			Y		
Dredging- backhoe	Unconsolidated sediments			Y		

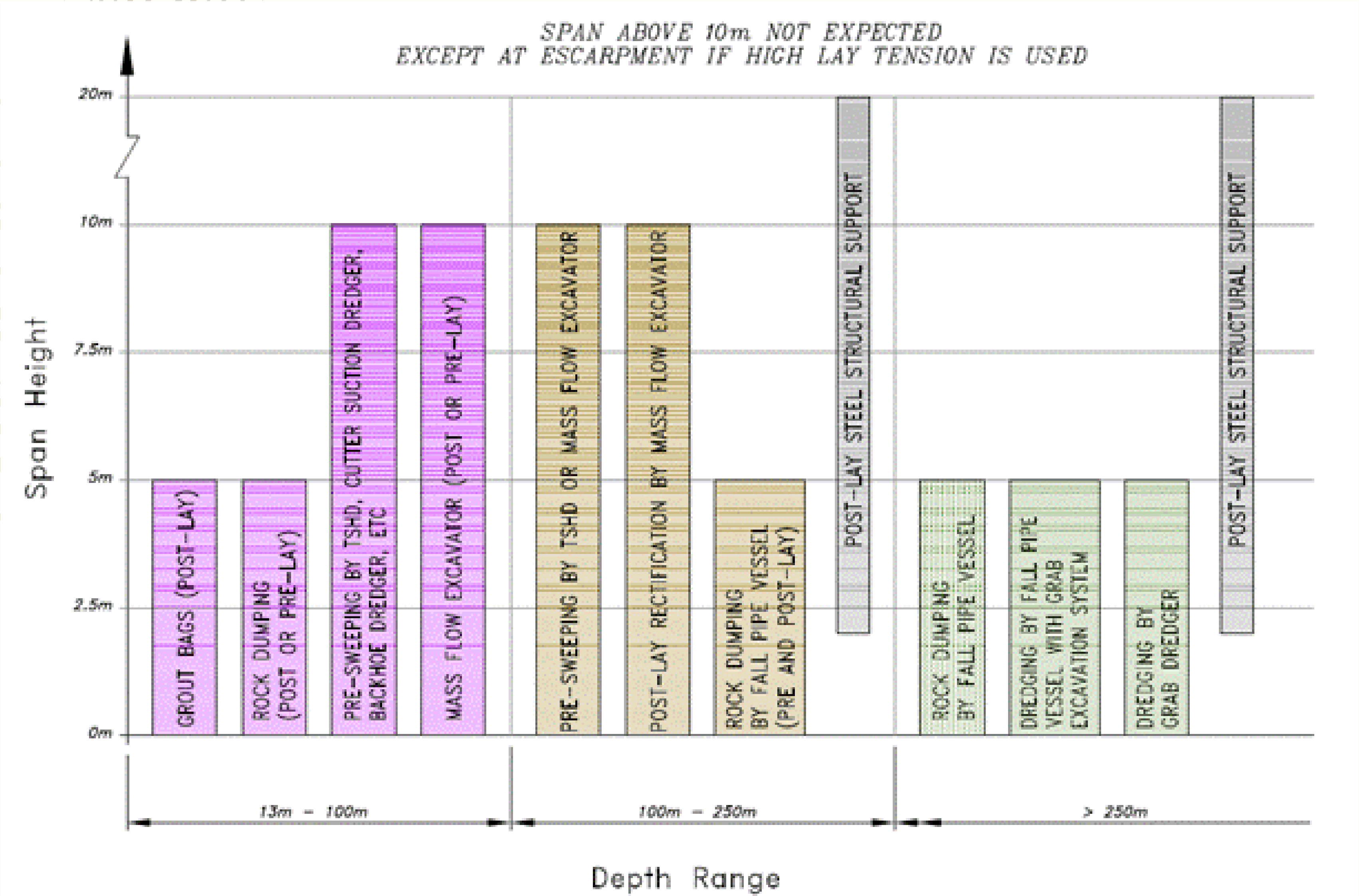
Modification of Pipe Behaviour Span Correction methods

Type	Limits	Advantages	Disadvantages	Diverless installation feasible
Strakes	**Suitable when VIV is limiting**		**Increase drag load**	**Y**
Plastic formation			**Pipeline in plastic mode after span correction – used only as last resort**	

Summary Of Methodolgies For Seabed Intervention (for span correction)

No.	Method	Application	Practical Span Height Limitation	Depth Limitation	Soil Type
1	Backhoe dredger	Pre-lay	20m	32m	Soft to 10MPa
2	Cutter suction dredger	Pre-lay	20m	30m	Soft to 10Mpa
3	Grab dredger	Pre-lay	10m	2000m	Soft to 500 KPa
4	TSHD	Pre-lay	50m	250m	Soft to 3MPa
5	MFE	Pre- and post-lay	50m	850m	Soft to 500 KPa
6	Rock dumping vessel (side stone dumping)	Pre-lay	5m	35m	All
7	Rock dumping vessel (fall pipe)	Pre- and post-lay	5m	2000m	All
8	Fall pipe vessel with grab excavation system	Pre-lay	5m	2000m	Soft to 500 KPa
9	Steel support structures	Post-lay	20m	2000m	All
10	Insertion of flexible spool	Post-lay	N.A.	2000m	All
11	Insertion of rigid spool	Post-lay	N.A.	2000m	All

Potential Methodolgies For Seabed Intervention at varying Water Depths & Span Heights)



Innovative Solution to avoid seabed intervention – Use of Spoilers (subject to seabed condition)

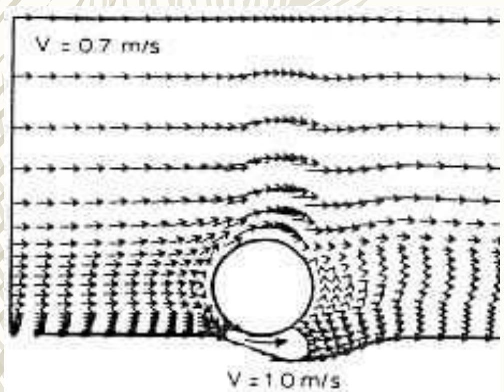
Introduction

- A non-conventional method of pipeline burial is by implementation of spoilers on the pipeline.

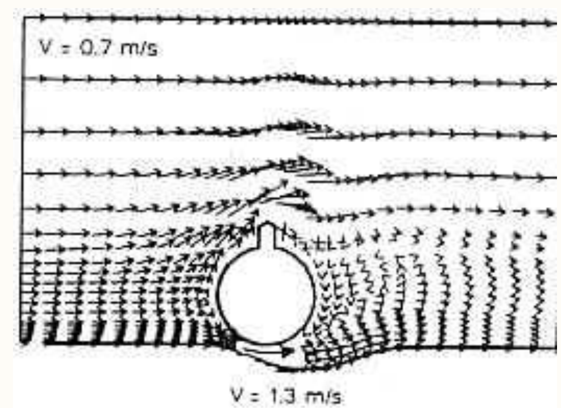
- Where conventional method is not practical or cost effective, e.g. where pipeline is subject to scouring, a self-burial device known as "Spoilers" could be used. This could effective ensure that the pipeline will self bury after becoming exposed due to scouring.

Spoiler Mechanics

The effect of spoiler is based on scouring and fluid mechanical process. The spoiler, which is fitted on the top of pipeline, changes flow pattern around the pipeline compared with a plain pipeline, as shown in Figure 1.



Plain Pipeline



Pipeline with Spoiler

Figure 1 – Flow pattern of plain pipeline and spoiler-fitted pipeline

Spoiler Mechanics (Cont'd)

- The spoiler causes an increased flow velocity underneath the pipeline. This results in tunnel erosion taking place at lower ambient velocities than with a plain pipe and more aggressively not only in the vertical direction but also along the pipeline length.

- The spoiler brings about significant changes in the flow pattern and results in:
  - Smaller upward lift forces when the pipeline is in contact with the seabed;
  - Increased downward (negative) lift forces when the pipeline lifts off from the seabed;
  - Increased hydrodynamic drag and inertia coefficients;
  - Suppressed vortex shedding;
  - Increased stability of the hydrodynamic process - less scatter in drag and lift coefficients.

Schematic of self-burial of a spoiler-fitted pipeline

- The following schematic illustrates the phases and manner in which a spoiler-fitted pipeline achieves self-burial

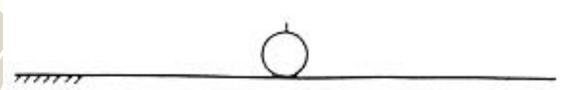
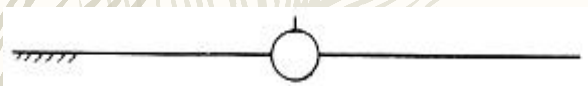
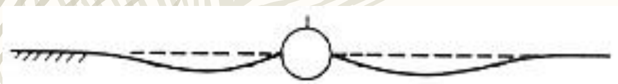
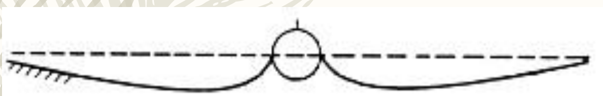
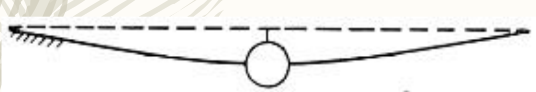
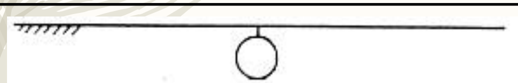
	touch down
	first tunnel erosion, pipe is sagging
	Partial Burial
	start leeside erosion
	pipe on ridge
	second tunnel erosion, pipe is sagging
	second partial burial
	natural backfilling to original seabed

Figure 2: Self-burial illustration

Spoiler Mechanics

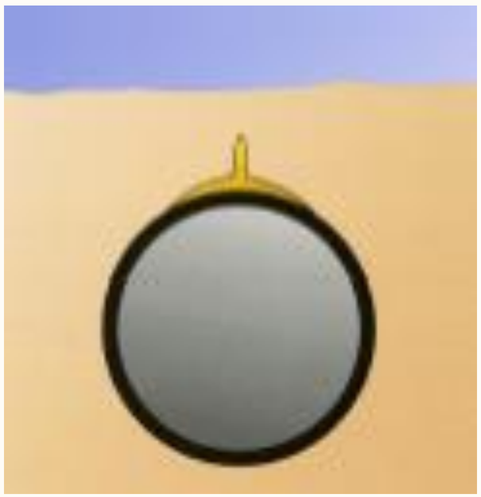
		
First Stage – Touch Down	Second Stage – Tunneling	Final Stage - Burial

Figure 3: Self-burial Stages

Spoiler Mechanics

- Optimal performance of spoiler for pipeline self-burial is best achieved under certain environmental conditions as shown in Table 1 below.
- Based on the results of tests conducted by SPS at Delft Hydraulics Institute in Holland, sufficient tidal current velocity as well as a highly erodible seabed condition should be available to invoke the tunneling erosion effect, which is the mechanism of the self-burial process of pipeline.

Table 1 – Environmental Conditions for Optimal Spoiler Performance

	Complete Burial Expected	**Partial Burial Expected**
Seabed Material (Top Layer)	Sand + Maximum of 10 % Silt	Sand + Maximum of 20 % Silt
Current	Tidal current more than 0.8 m/s	Tidal current more than 0.4 m/s

Spoiler installation at stern of laybarge during pipelaying

Spoilers are strapped on pipeline at stern of laybarge,
just before entrance to stinger

Photo from site (shore approach to landfall)

View of pipeline at shore approach during low tide. Note that minor rotation had occurred during pulling operation, partially due to flooding and receding tides.

Note scour on both sides of pipeline due to spoiler effects.

Evidence of spoiler effect on another project

- On a onshore to offshore pipe pull at Dahej (India) across an inter-tidal zone, the spoiler effect was seen when pipe pull was stopped when the tide receded.
- The buoyancy tanks acted like ‘spoilers’, causing soil of both sides of the pipeline to scour.
- The soil was very fine and highly liquefiable.
- Current was very strong and changes direction four times a day (2 tides a day)

Risks and Challenges of Utilising Spoilers

- The main risk associated with utilizing the spoiler is the effect of additional hydrodynamic forces caused by the presence of the spoilers if self-burial did not occur immediately upon touchdown.

- Ideally, a contingency plan should be in place of the "worst case" scenario, i.e. spoiler fails to initiate self-burial fast enough. A feasible contingency plan is to have a jetting spread on standby. The jetting equipment should be modified such that the spoiler fin will not be damaged during jetting.

Field Verification of Spoiler Performances

- For Hangzhou Bay project, subsea survey was carried out regularly during pipelaying to determine the burial condition of the pipeline.

- Generally, it was found that the pipeline underwent burial almost upon touchdown and the tunneling effect continued until almost all the pipeline was below the natural seabed.

- In areas where there were greater concentrations of fine particles, the burial rate proceeded at a slower rate and portions of the pipeline continued the tunneling at a slower rate until the top of pipeline was below the natural seabed.

- As-built survey of the pipelines showed that prior to hydrotesting, the entire pipeline route achieved at least 50% burial and considerable portions achieved complete burial to over one meter of cover.

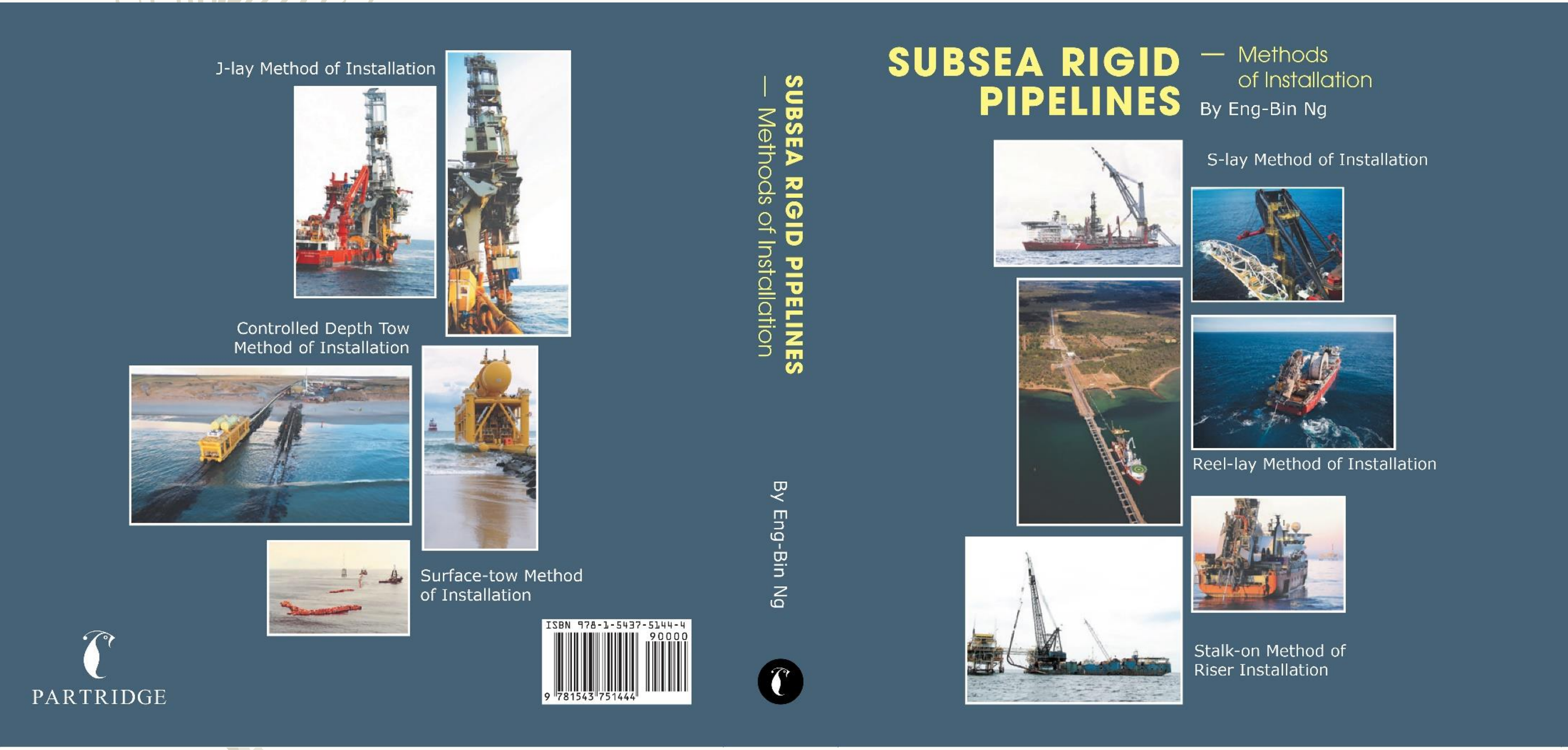
Conclusions (on use of Spoilers)

- The spoiler is particularly suited for areas which experience strong bi-directional currents and have erodable seabed.

- The spoiler is also suitable in areas where dynamic movement of seabed profile is experienced, e.g. Hangzhou Bay, When the pipeline is exposed to the environment due to scouring, the spoiler is expected to re-initiate burial.

- Based on the successful use of spoilers in the Hangzhou Bay Pipeline Crossing project, as well as other applications in the North Sea, it is envisaged that the spoiler would find many more uses for similar projects under similar conditions worldwide.

For more details on seabed intervention, refer to my new book: "Subsea Rigid Pipelines – Methods of Installation"



QUESTIONS ????