Atteris

On-bottom Stability Design of Pipelines and Umbilicals on Seabed Susceptible to Scour: A Multi-Faceted Approach

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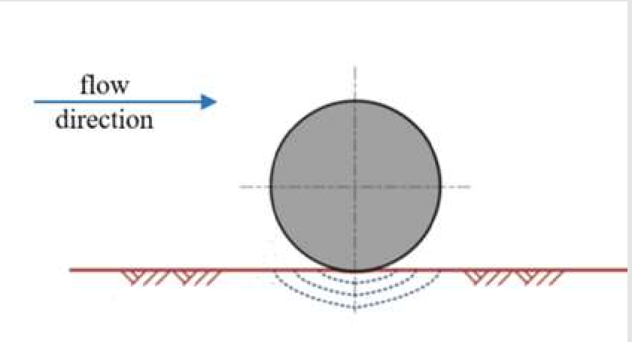
What’s the problem?

Design Stage Stability



Simplistically consider pipeline or umbilical sitting on flat seabed.

Hydrodynamic exposure + Minimal passive resistance

Operating Observations (Erodible seabed)

Self embedment / soil build-up around the pipeline / umbilical.

Hydrodynamic sheltering + Significant passive resistance

In many circumstances the simplistic design approach requires additional weight for stability or secondary stabilisation (e.g. mattressing).

Observed conditions suggest additional weight (i.e. cost) may not be required.

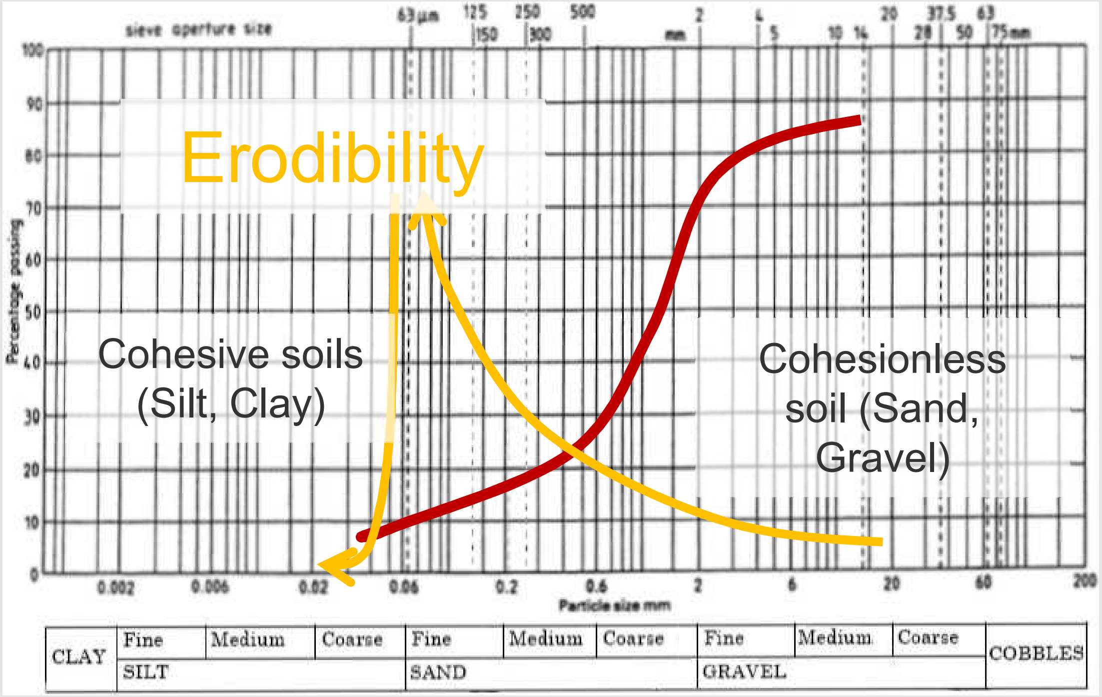
been fully developed”.

Seabed Scour and Erodible Soils

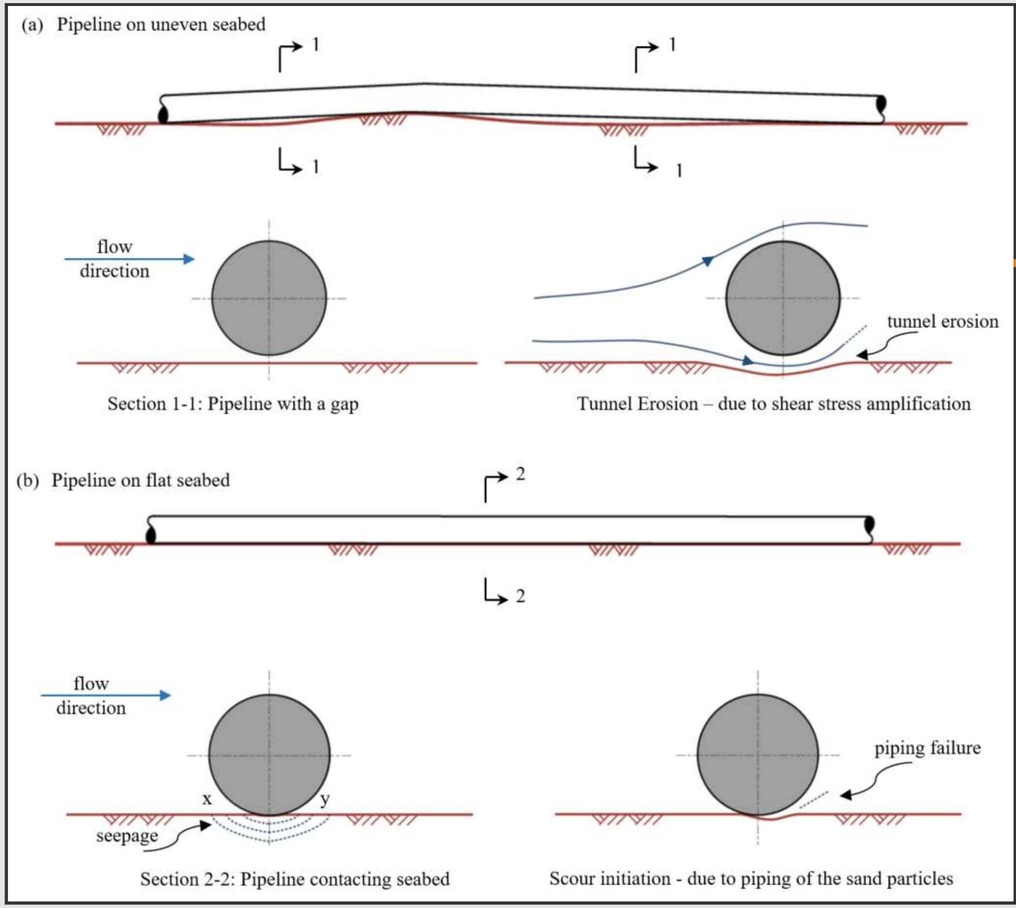
Seabed Scour is the removal by hydrodynamic forces of seabed material in the vicinity of structures.

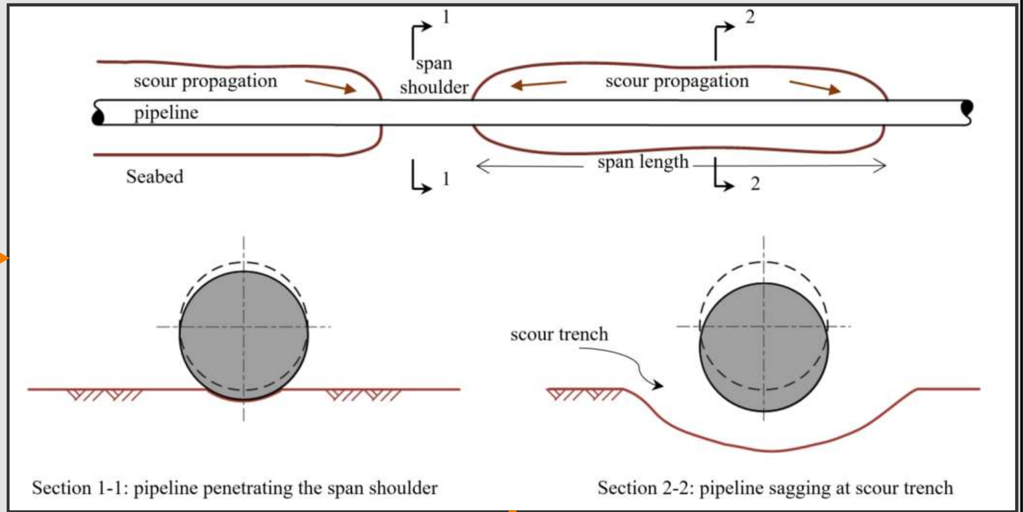
Scour is a specific form of erosion.

Local and global scour around a multiple pile structure (from Whitehouse, 1998).



Mechanism of Scour Induced Lowering of Pipelines





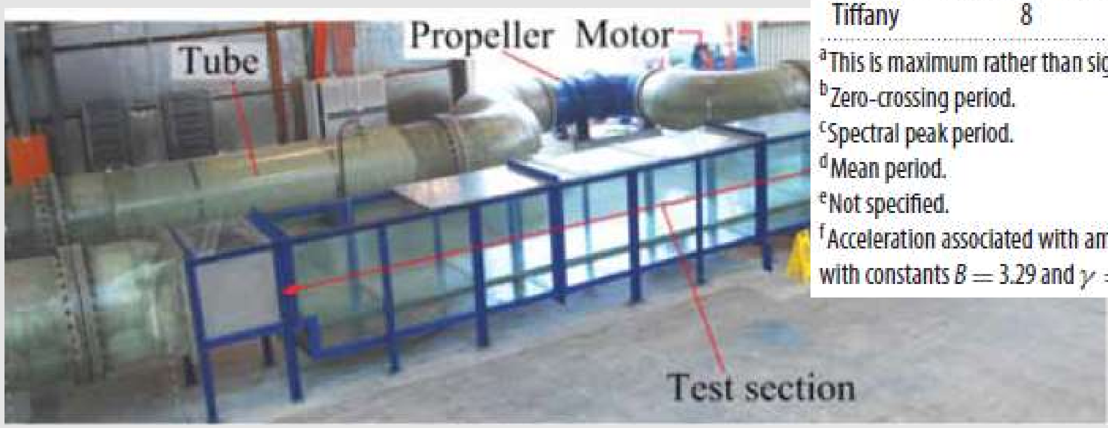
Seabed Scour - Physical Modelling

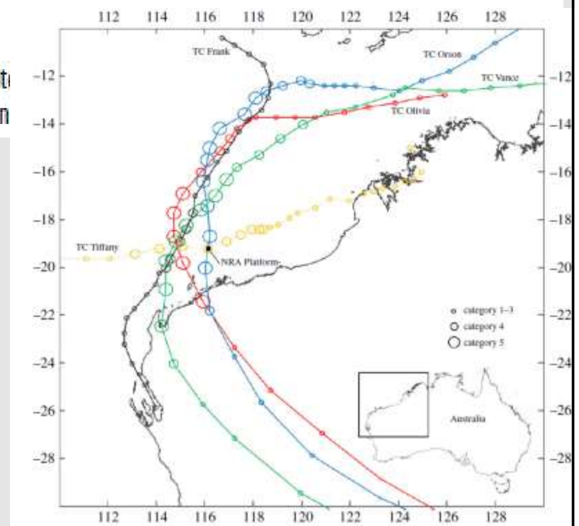
Draper et al. (2015)

“Stability of subsea pipelines during large storms”

	wave height					currents		
tropical cyclone	peak H_s (m)	time to peak (h)	peak rate of increase of H_s (m h^{-1})	period (s)	peak rate increase of amplitude of equivalent wave velocity[f] (m s^{-2})	peak near surface (m s^{-1})	time to peak (h)	maximum acceleration (m s^{-2})
Orson	10–12	24–36	0.85	9.1[b]	3×10^{-6}	approx. 1.2	3–6	7×10^{-5}
Olivia	12–13	12–24	1	12–13[c]	5×10^{-6}	—	—	—
Vance	8–9	24–36	0.3	9–10[d]	1×10^{-6}	—	—	—
Frank	12–14[a]	12–24	0.6[a]	—[e]	—	—	—	—
Tiffany	8	12–24	0.8	8–9[d]	3×10^{-6}	—	—	—

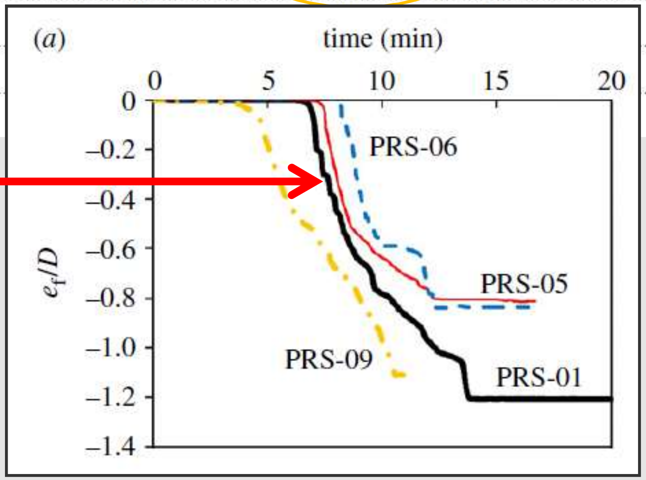
[a] This is maximum rather than significant wave height. Buchan *et al.* [32] suggest peak H_s was 7.3 m.
[b] Zero-crossing period.
[c] Spectral peak period.
[d] Mean period.
[e] Not specified.
[f] Acceleration associated with amplitude of equivalent near-bed velocity, calculat
with constants $B = 3.29$ and $\gamma = 3.3$ [33]. Where relevant, peak period has been

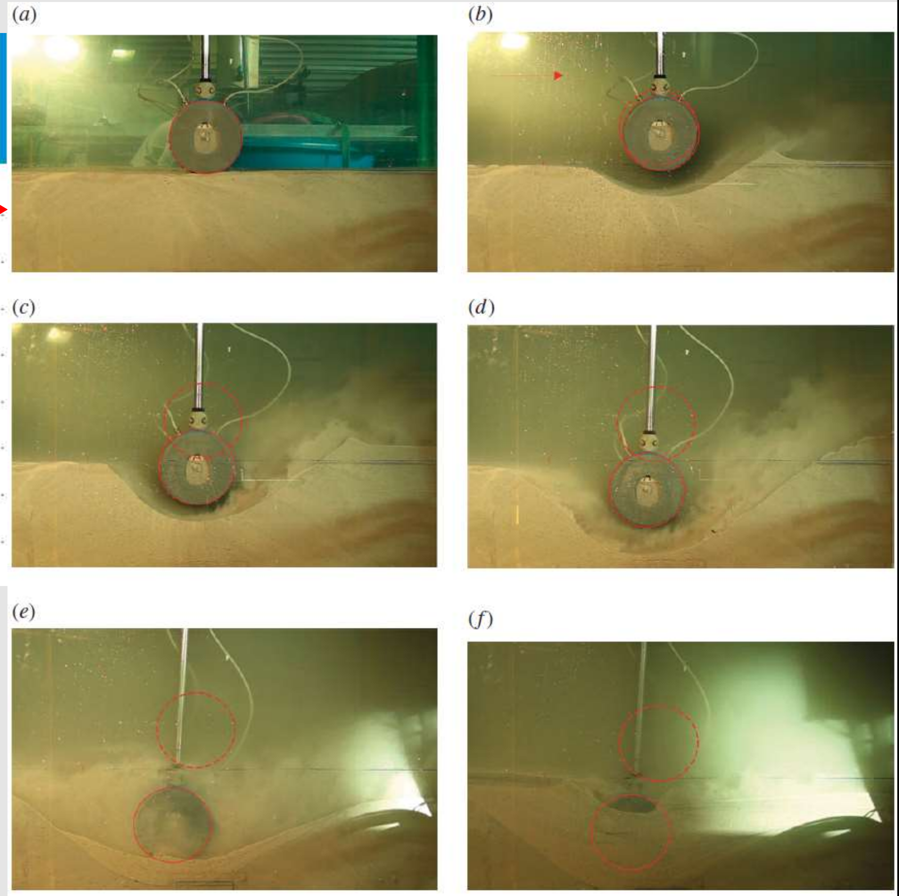




Seabed Scour: Physical Modelling

		flow condition				pipeline properties	
experiment	mechanism	M	period (s)	rate, a_s (m s^{-2})	e_f/D	SG	EI/w' (m^3)
PRS-01	sinking	∞	—	2×10^{-3}	approximately 0	1.5	—
PRS-02	sinking	∞	—	$2 \times 10^{-2.75}$	approximately 0	1.5	—
PRS-03	sinking	∞	—	$2 \times 10^{-2.5}$	approximately 0	1.5	—
PRS-04	sinking	∞	—	2×10^{-2}	approximately 0	1.5	—
PRS-05	sinking	∞	—	2×10^{-3}	approximately 0.1	1.5	—
PRS-06	sinking	∞	—	2×10^{-3}	approximately 0.2	1.5	—
PRS-07	sinking	0.5	12	[illegible]	[illegible]	[illegible]	[illegible]
PRS-08	sinking	0.5	12	[illegible]	[illegible]	[illegible]	[illegible]
PRS-09	sinking	0.5	12	[illegible]	[illegible]	[illegible]	[illegible]





Velocity for onset of scour increases with increased embedment.

Seabed Scour: Physical Modelling

		flow condition				pipeline properties	
experiment	mechanism	M	period (s)	rate, a_s (m s^{-2})	e_f/D	SG	EI/w' (m^3)
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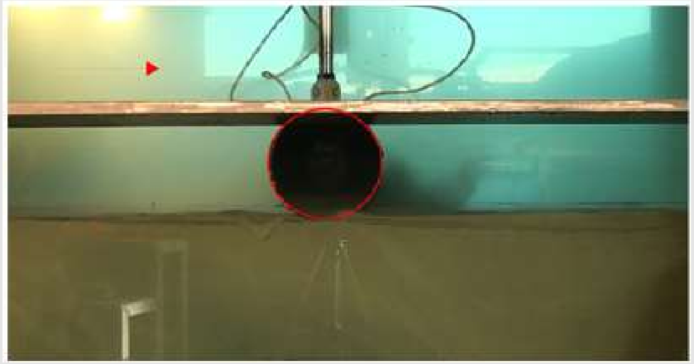
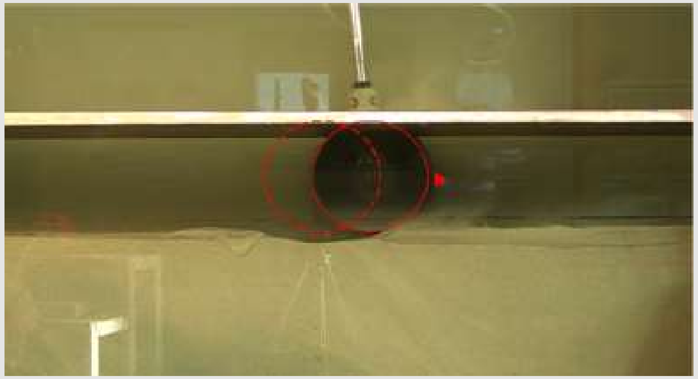
PRS-04	sinking	∞	—	2×10^{-2}	approximately 0	1.5	—
PRS-05	sinking	∞	—	2×10^{-3}	approximately 0.1	1.5	—
PRS-06	sinking	∞	—	2×10^{-3}	approximately 0.2	1.5	—
PRS-07	sinking	0.5	12	2×10^{-3}	approximately 0	1.5	—
PRS-08	sinking	0.5	12	$2 \times 10^{-3.5}$	approximately 0	1.5	—
PRS-09	sinking	0.5	12	2×10^{-4}	approximately 0	1.5	—



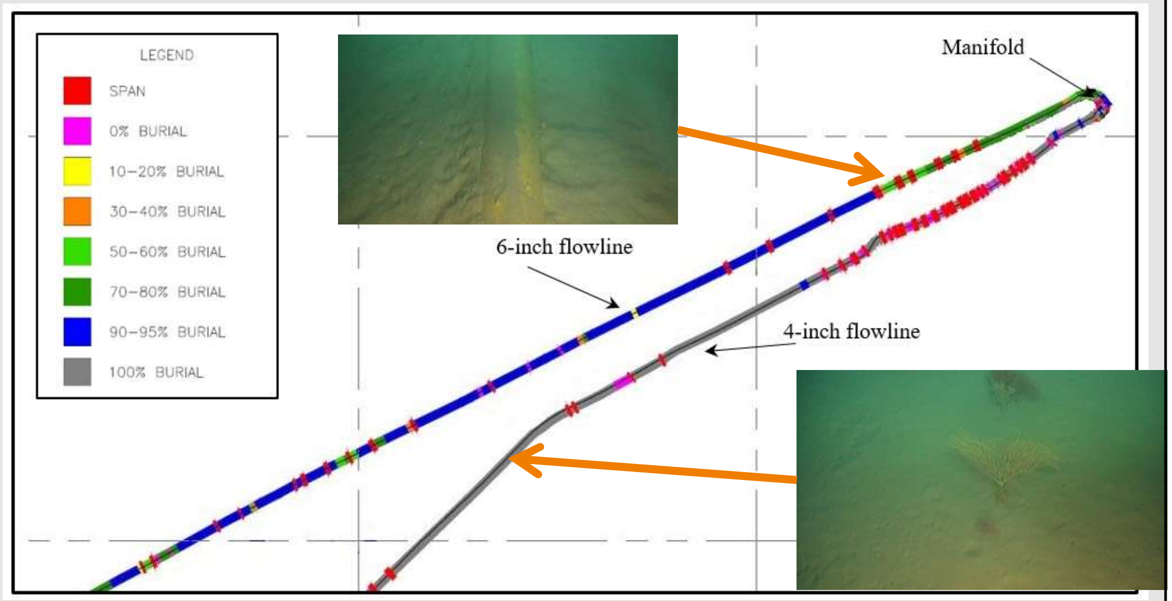


Summary of Scour Characteristics

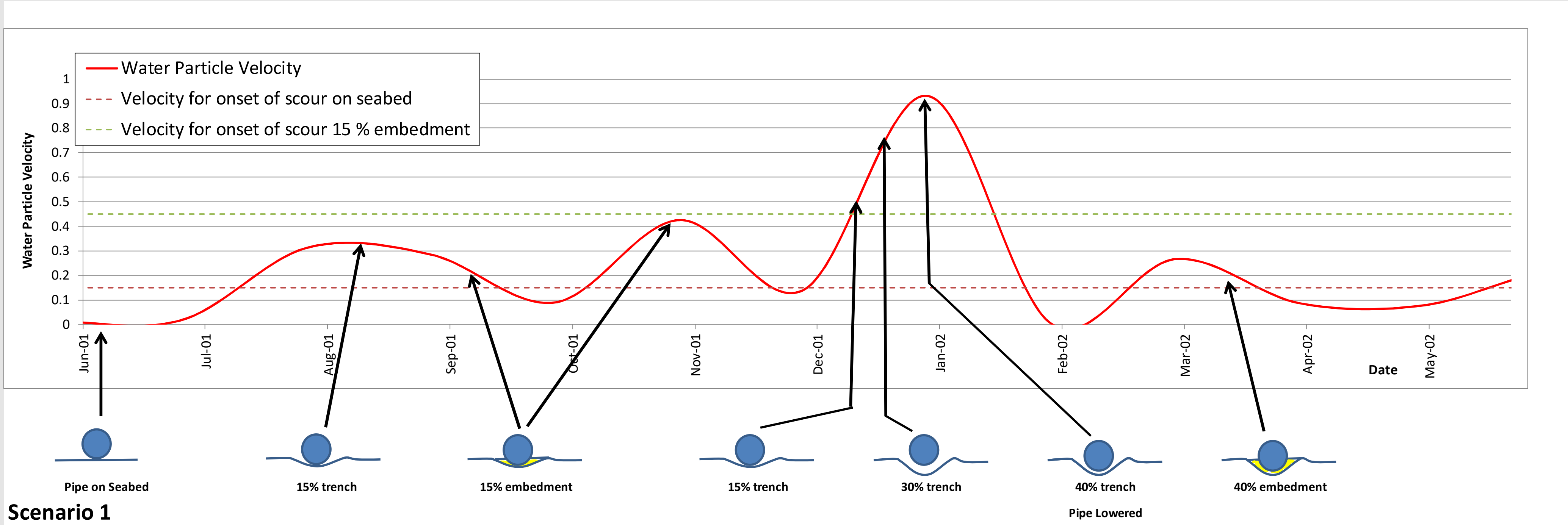
- Susceptibility of soils to scour is dependent on cohesion and grain size.
- Scour is a time dependent process. Ramp up time and duration of hydrodynamic loading are important factors.
- Water particle velocity for onset of scour under a pipeline increases with pipeline embedment.

Example of Observed Scour Effects over an Area

Random nature of scour process due to variable metocean, soil and pipe / soil contact conditions means that it is impractical to provide a deterministic prediction of scour evolution.



Seabed Scour: Effect on Pipelines and Umbilicals



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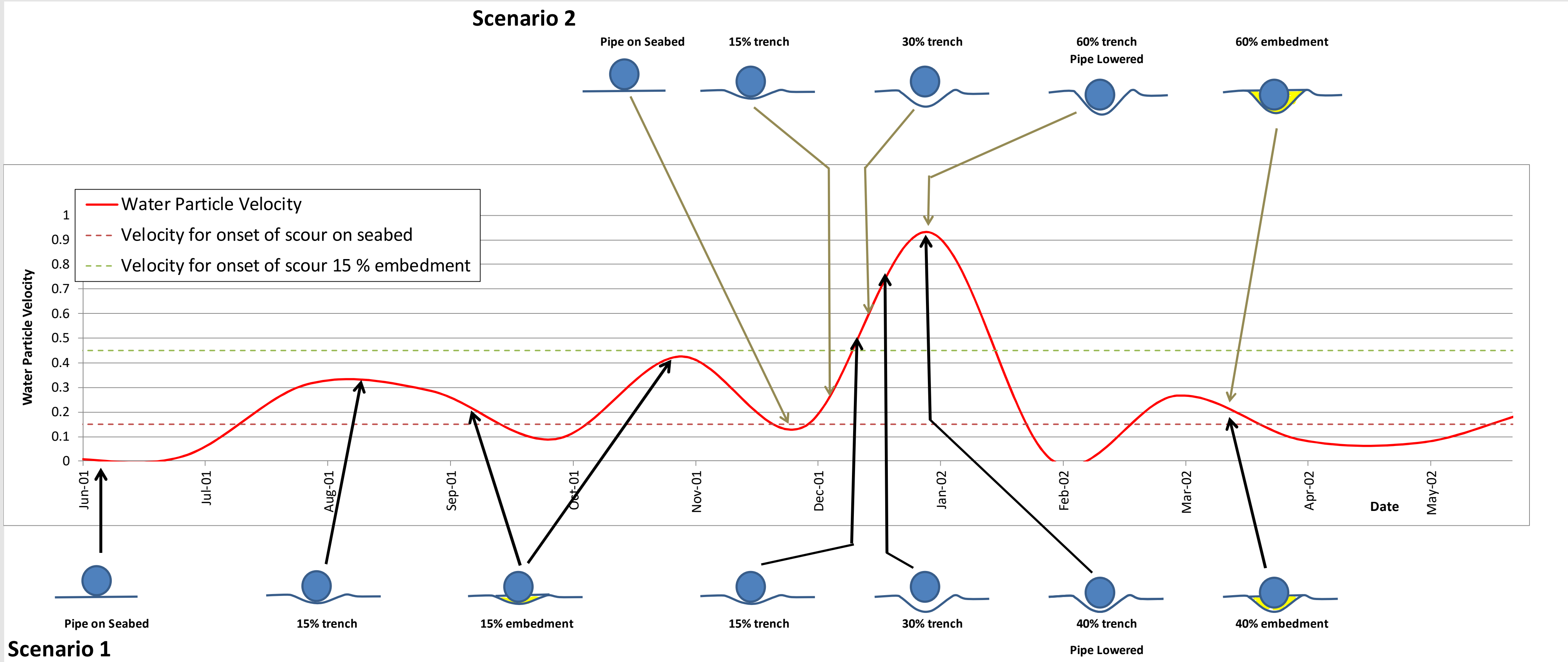

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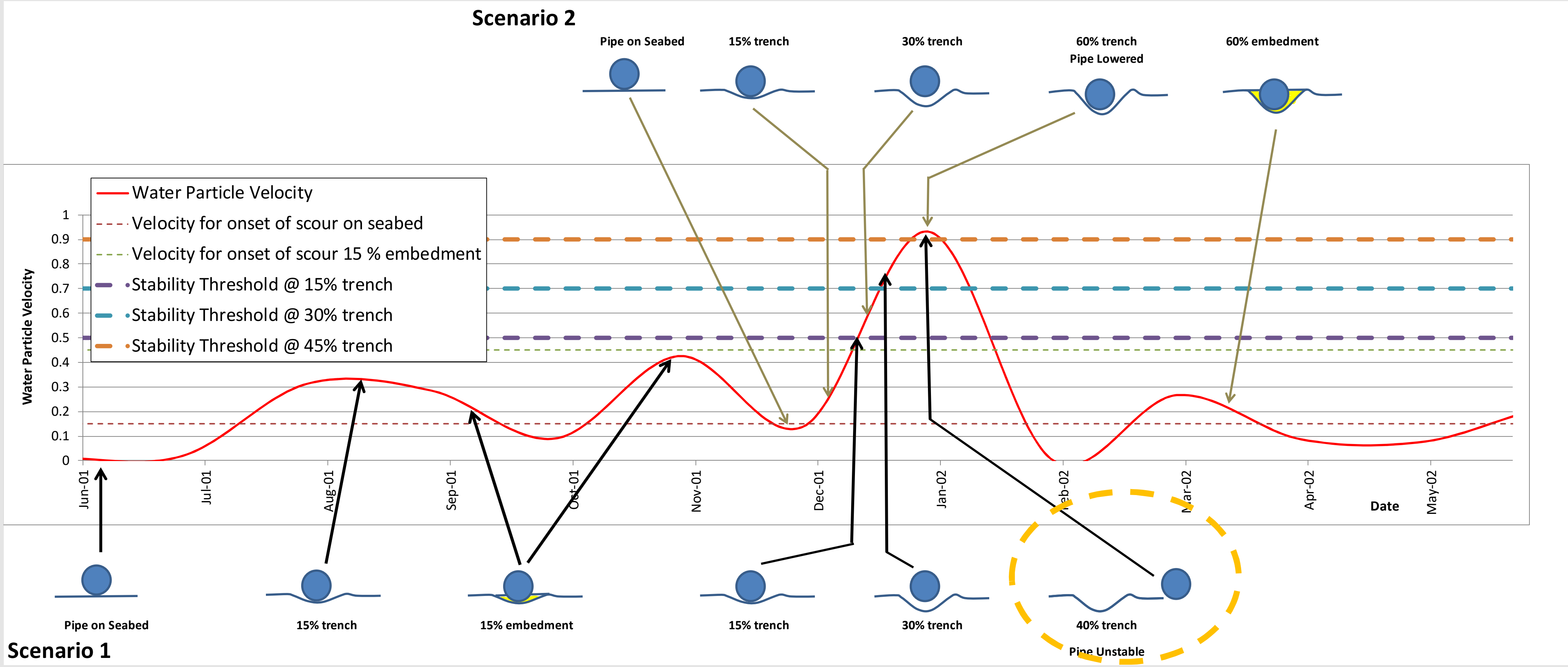

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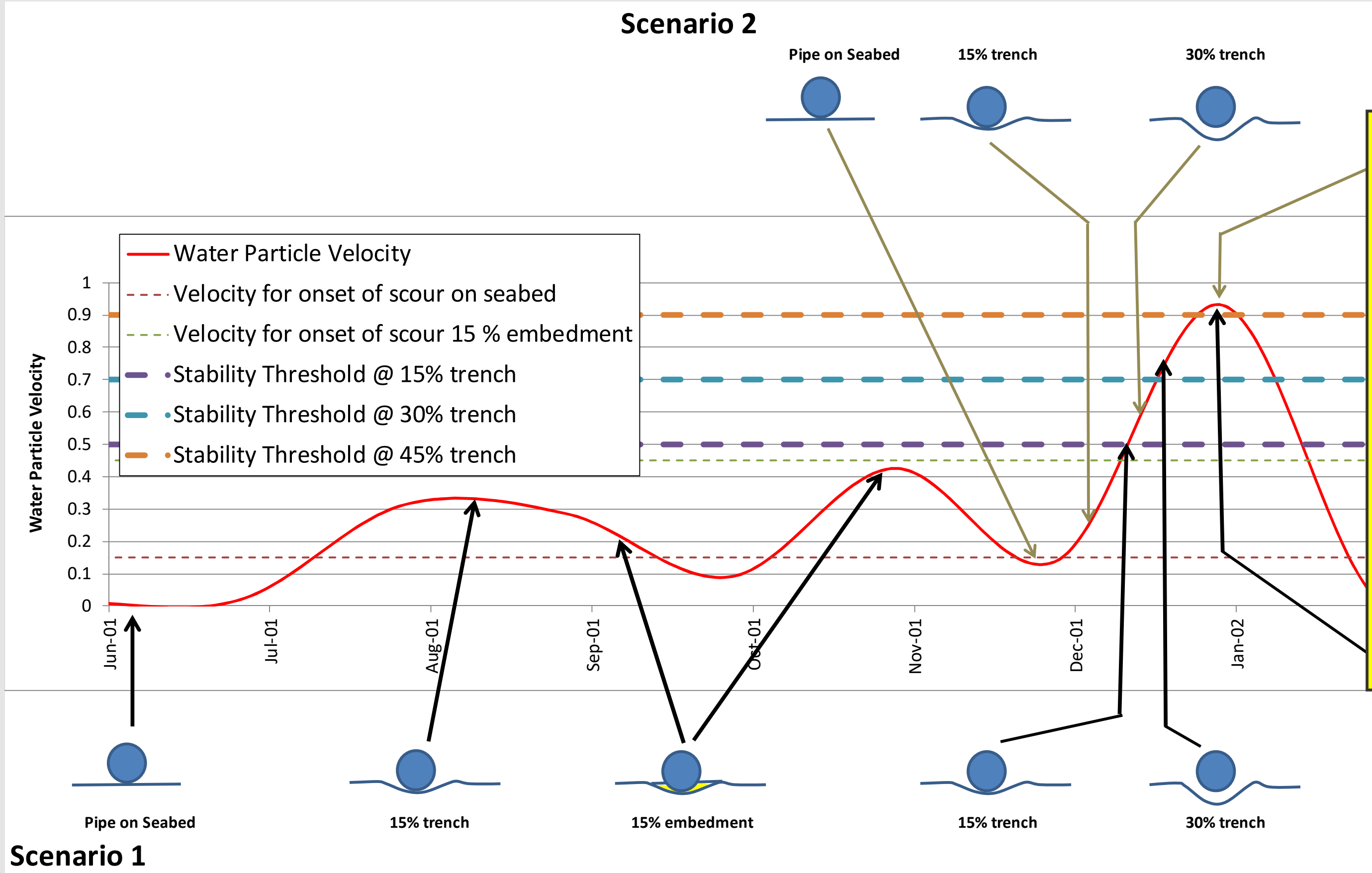
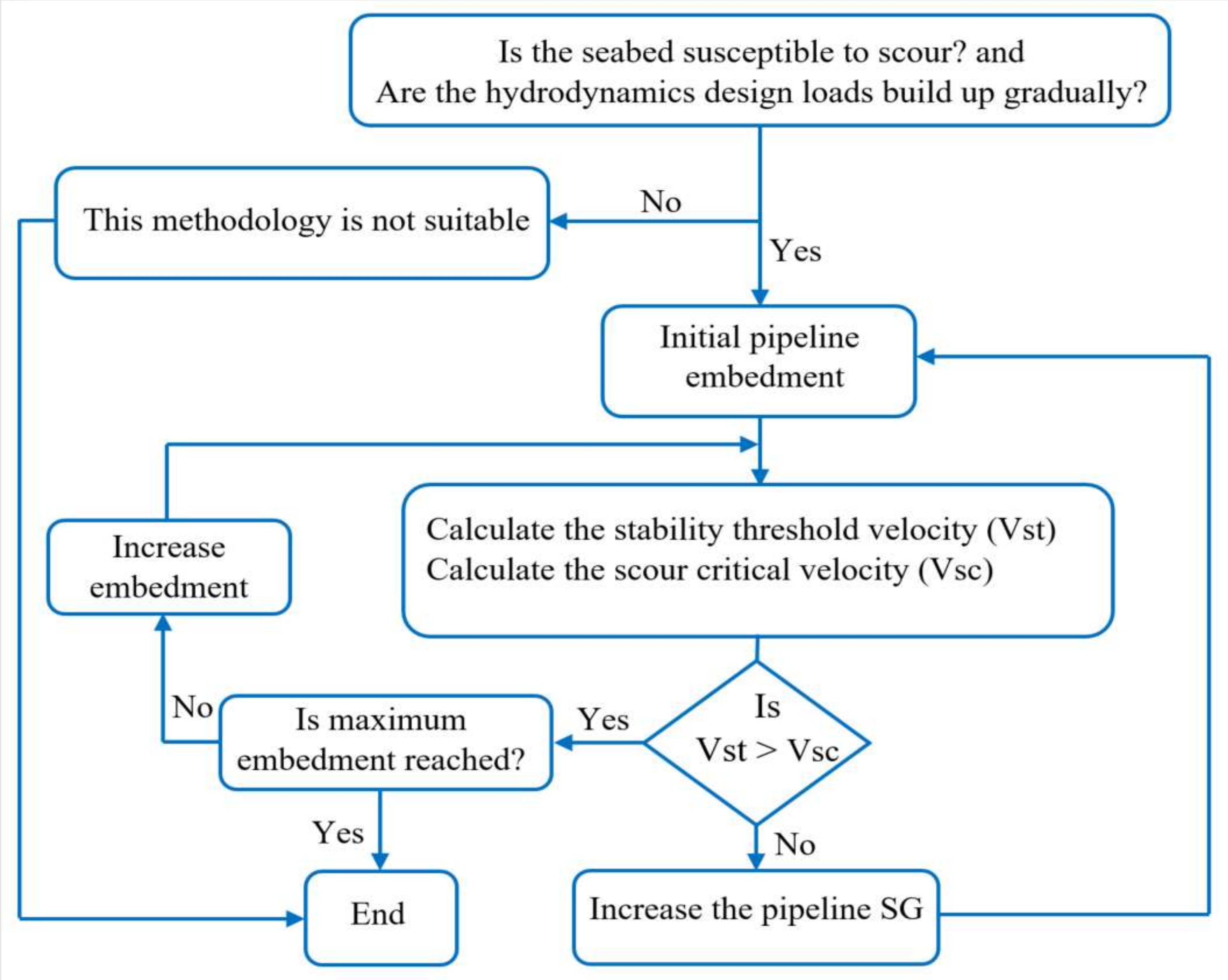


Key requirement for pipeline stability on an erodible seabed is that there is sufficient margin between the scour onset velocity and the stability threshold velocity at all embedment levels.

Outline of Stability Approach



Assessment of Scour Onset Velocity (V_{sc}) - Sumer and Fredsøe

Onset Velocity – Current Only

$$\frac{U_{cr}^{2}}{g\,D\,(1-n)(s-1)} = 0.025\,\exp\left(9\left(\frac{e}{D}\right)^{0.5}\right)$$

U_{cr} = critical current velocity for onset

S = soil specific gravity

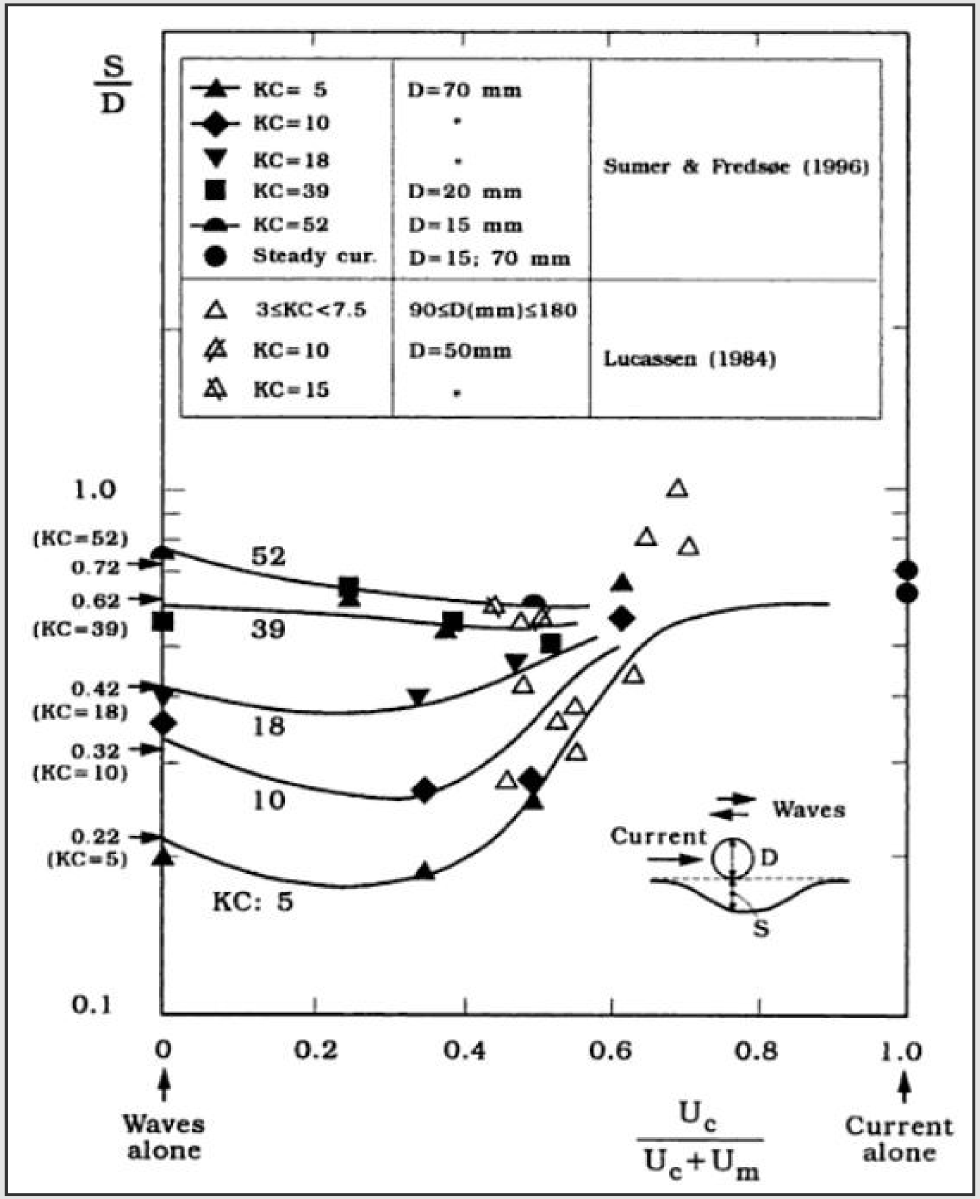
n = the soil porosity

e/D= the pipeline embedment level

Onset Velocity – Wave and Current

$$\frac{U_{cr}^{2}}{g\,D\,(1-n)(s-1)} \geq f\left(\frac{e}{D}, KC\right)$$

Sumer, B.M. and Fredsøe, J., 2002. The Mechanics of Scour in the Marine Environment.

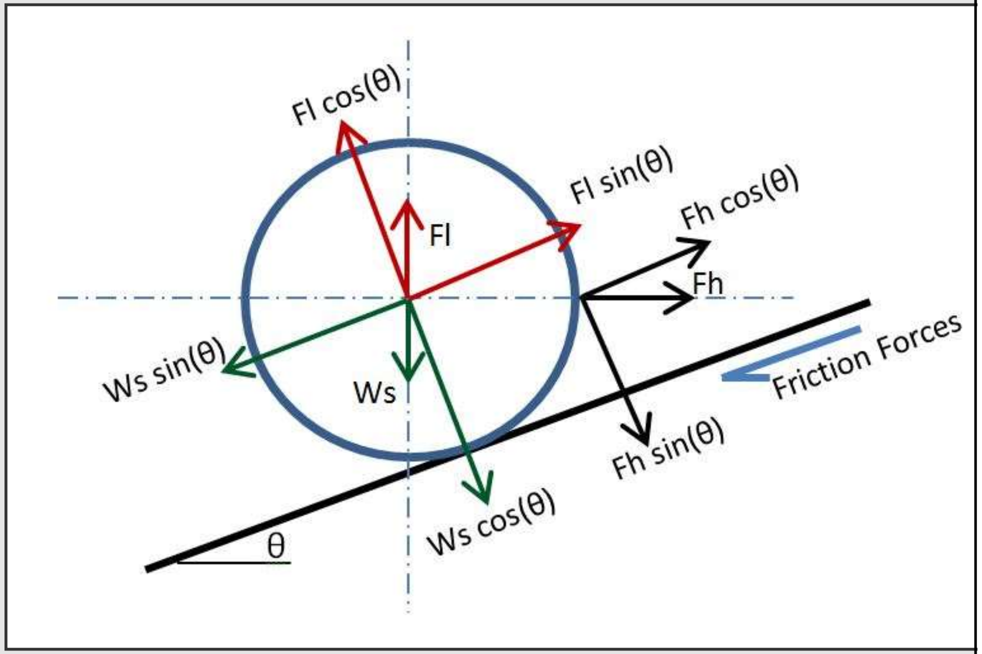


Assessment of Critical Velocity for Stability (V_{st})

Absolute Stability – Force Balance

$$Fh = (Ws - Fl).(\mu + \tan(\theta))$$

The side slope angle (θ) is considered to vary linearly between 0° for no embedment to a maximum of 30° for 50%+ pipeline embedment.

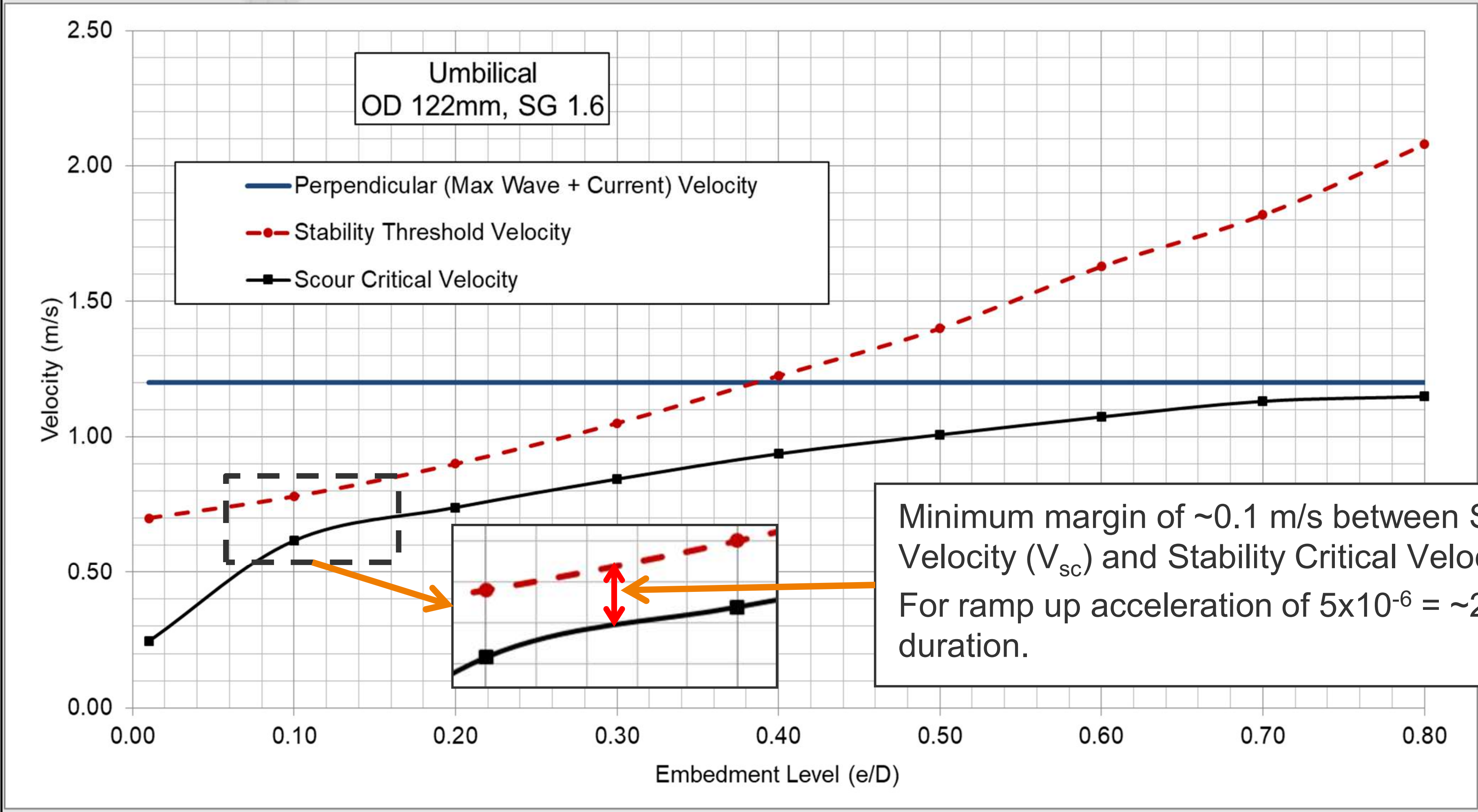


Hydrodynamic sheltering due to open trench considered in accordance with DNVGL RP F109.

Worked Example

Parameter	Umbilical
Outside Diameter, mm	122.0
Specific Gravity, Original Design	2.60
100 year Return Period design conditions	
Max Perpendicular Wave Velocity, m/s	0.45
Wave Period, s	13.45
Steady Current Velocity @1m ASB, m/s	0.72
Current Attack Angle, degree	90
Soil Conditions	
Friction Coefficient,	0.5
Median Particle Size D_{50}, mm	0.2
Submerged Unit Weight, N/m3	8000

Worked Example



Minimum margin of ~0.1 m/s between Scour Critical Velocity (V_{sc}) and Stability Critical Velocity (V_{st}).

For ramp up acceleration of 5×10^{-6} = ~2 hour duration.

- SG based on original design = 2.6
- Acceptable SG = 1.6

Conclusions

- New approach accounts for effects of scour on stability.
- Side-steps the challenge of deterministically predicting scour behaviour.
- Has been sense checked against observed umbilicals and flowlines.

Applicability

- Small diameter pipelines, flowlines and umbilicals.
- Erodible seabeds.
- Not applicable where hydrodynamic load onset may be relatively quick, e.g. solitons.

Acknowledgements

1. Draper, S., An, H., Cheng, L., White, D.J., Griffiths, T., 2015. Stability of Subsea Pipelines during Large Storms. Royal Society Publishing, A 373, 20140106.

2. Sumer, B.M. and Fredsøe, J., 2002. The Mechanics of Scour in the Marine Environment. World Scientific. Singapore.

Thank You & Questions