Elongation of pipeline spans over buckle initiators

Hongwei An, Weidong Yao, Shuchen Li,
Scott Draper, Fraser Bransby

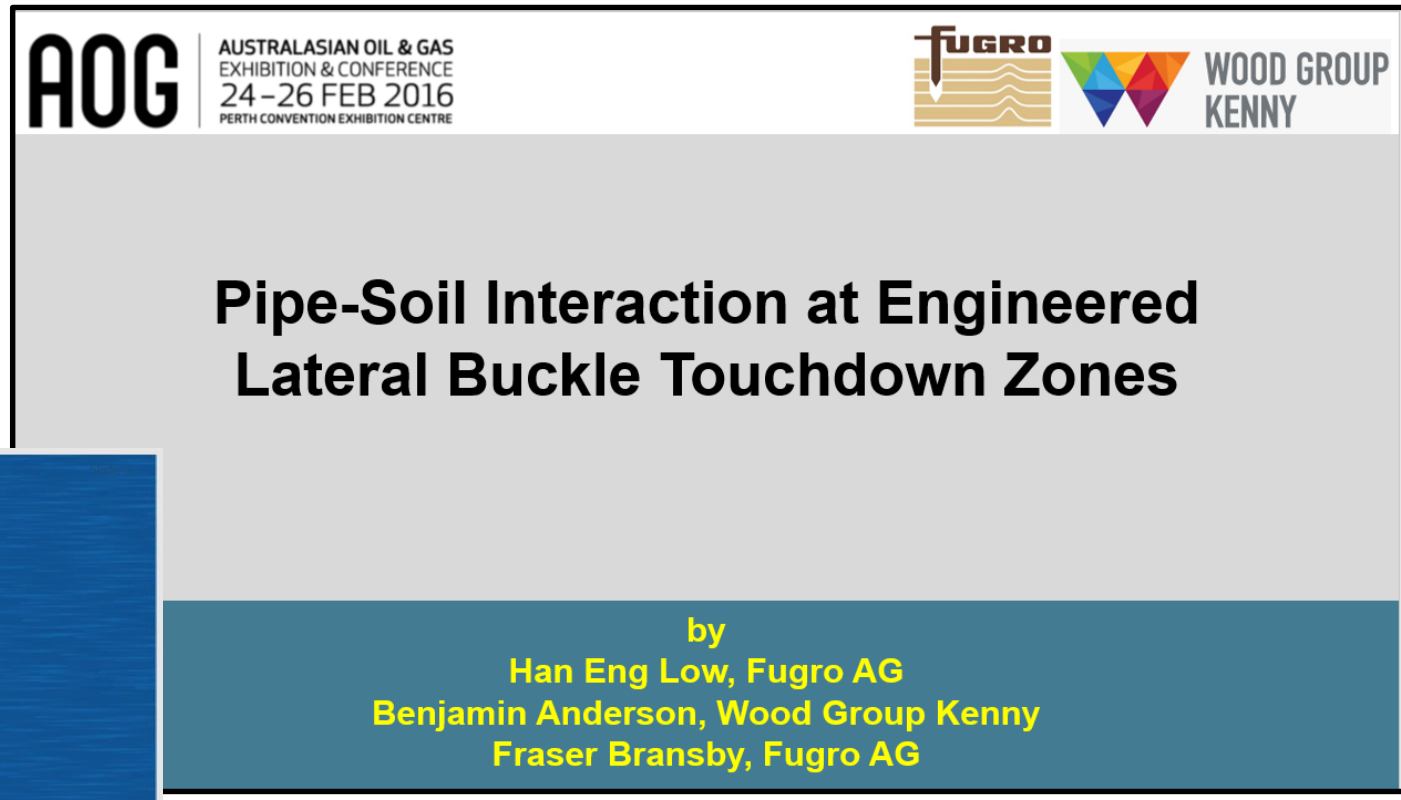
‘Managing Spans’ AOG
15 March 2019

Overview

- 1. Engineered buckle initiators
- 2. Potential effect of sediment mobility on buckle initiators
- 3. Experimental apparatus
- 4. Preliminary results
- 5. Conclusions

Overview II

- Investigated mechanical effects (buckle management) in previous presentations/papers
- Borrowed several slides…



OceanWorks

Part of the Woodside FutureLab Network

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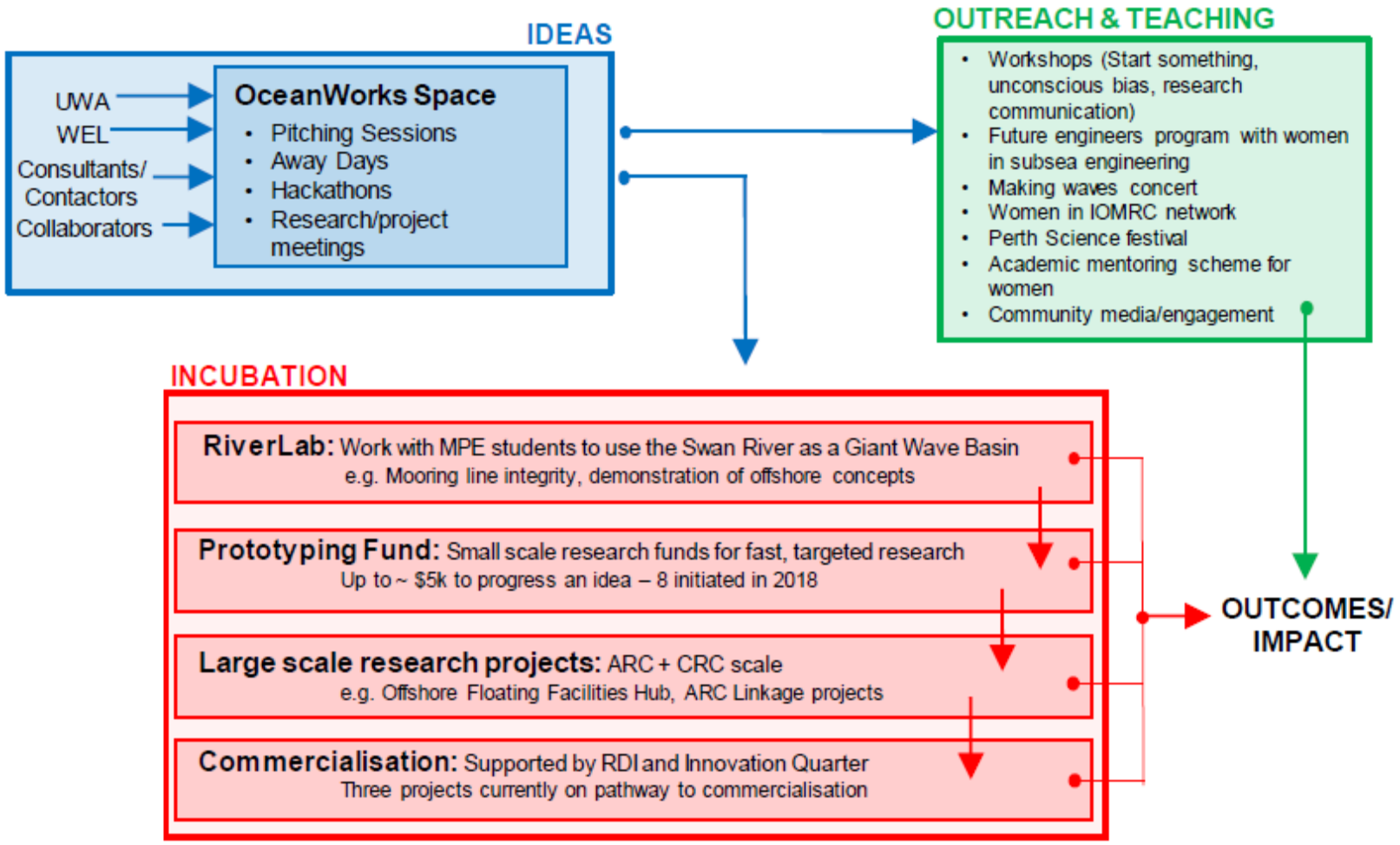
woodside

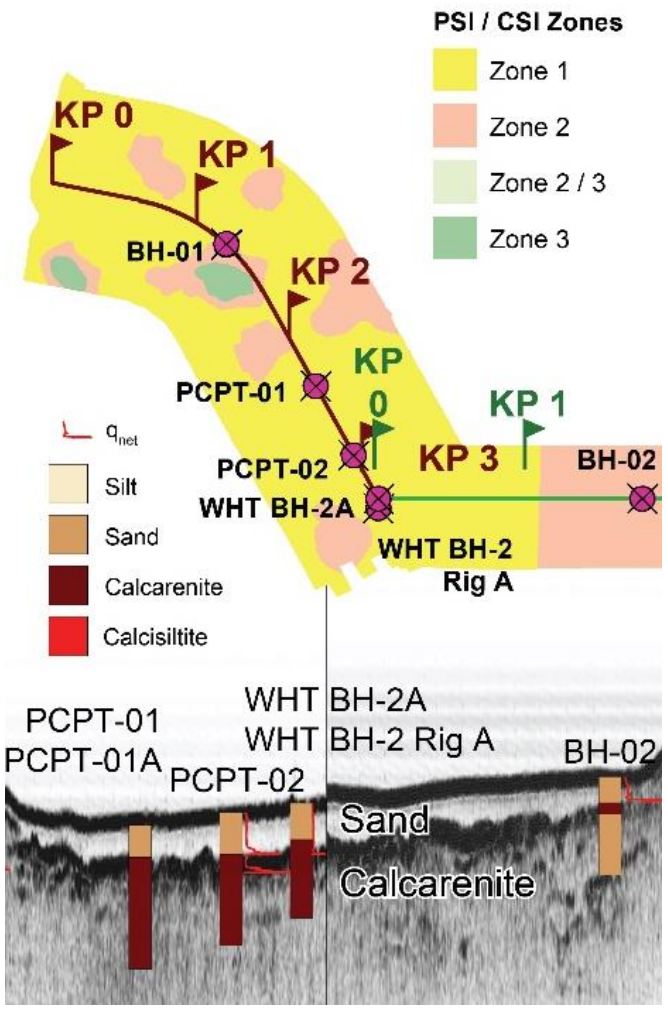
Woodside and UWA run FutureLab OceanWorks, fostering applied research and education in offshore engineering

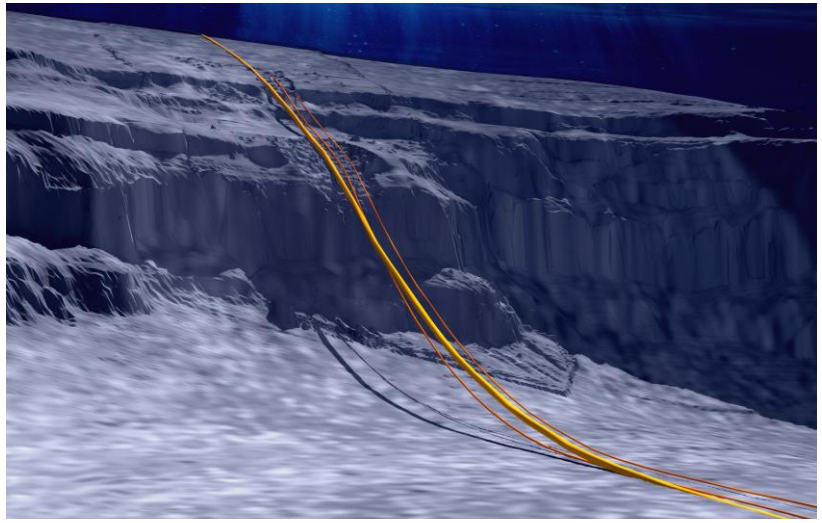


Prototyping fund:
Small-scale research funds for fast, targeted research
(8 projects initiated in 2018, including this one)

Fugro Chair in Geotechnics

The Fugro Chair in Geotechnics supports Professor Fraser Bransby and 2 PhD students at UWA, conducting innovative research relevant to industry needs





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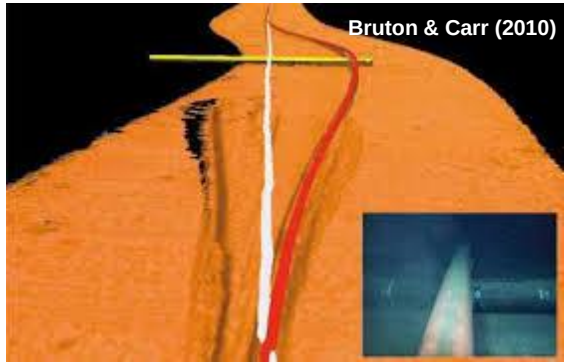
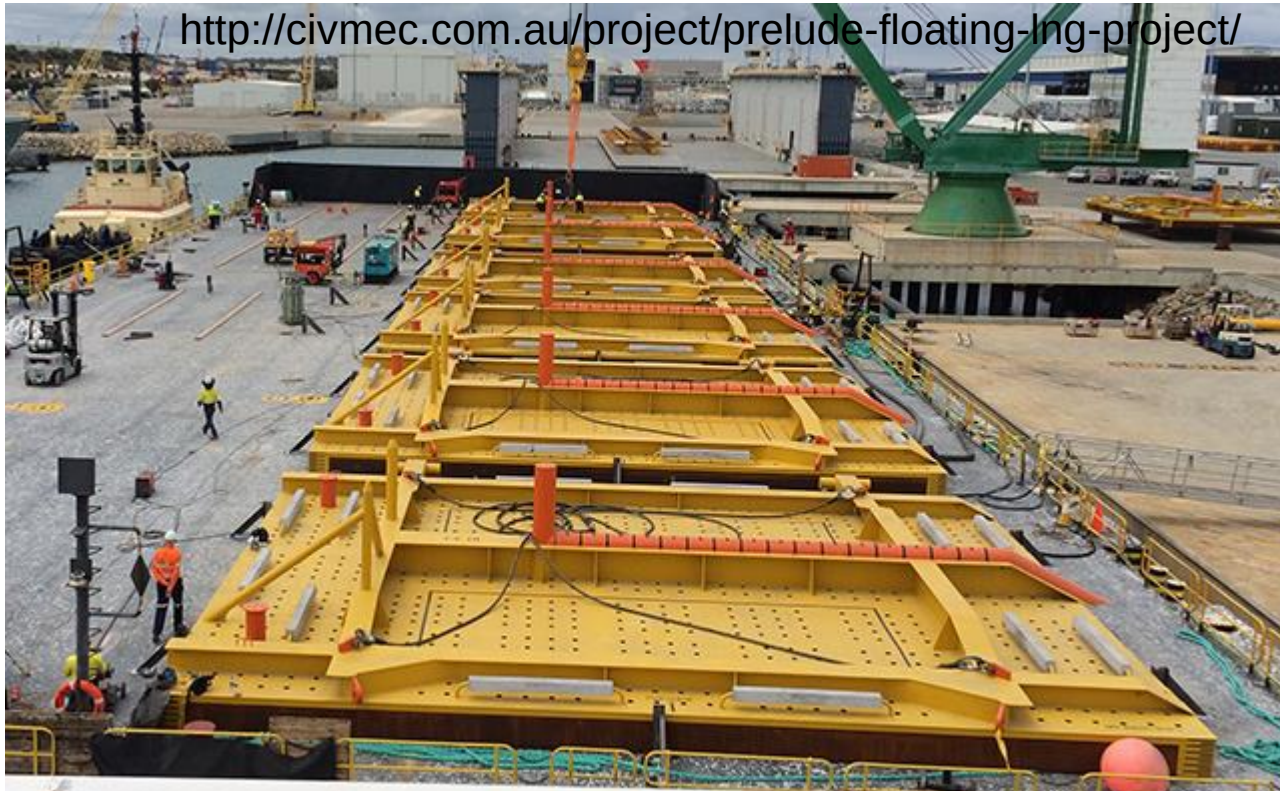
Engineered buckle initiators

- Sleepers
  - Vertical OOS
  - Low friction at buckle apex
  - Medium critical buckling forces
  - Large structure
  - Spans on each side of BI

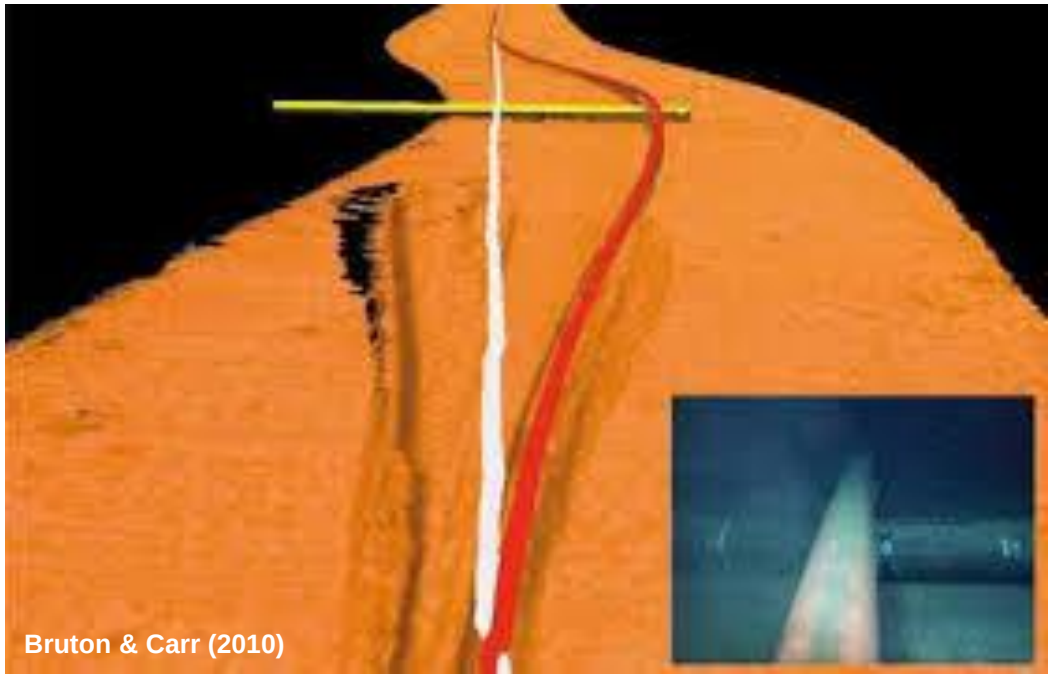
Pluto
Gorgon
Ichthys
Wheatstone
Prelude
Julimar
GWF-2
GED

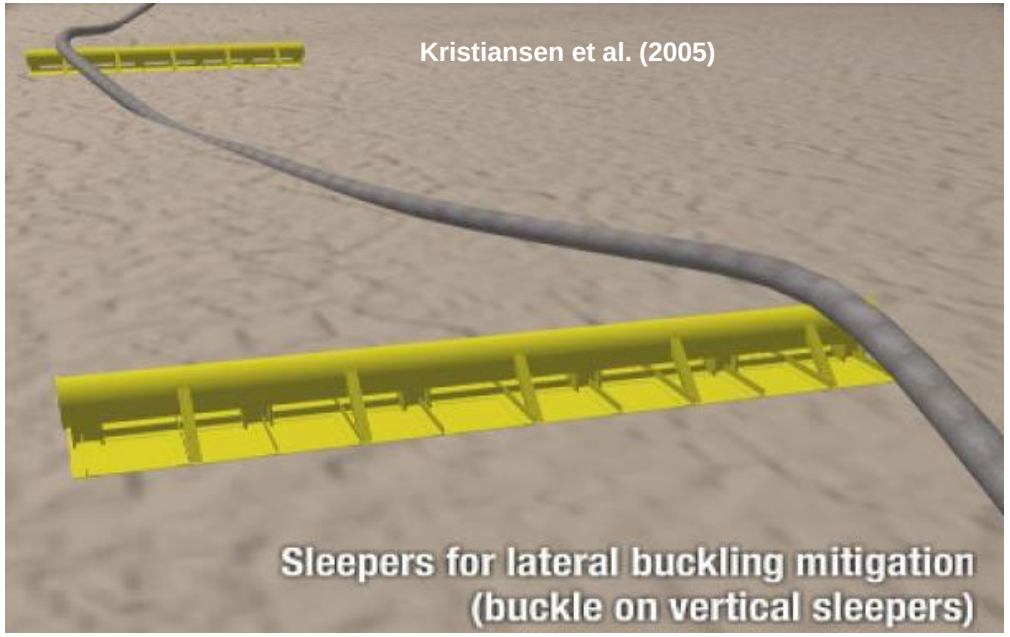
- Zero Radius Bends (ZRB)
  - Vertical + Horizontal OOS
  - Low friction at buckle apex
  - Low critical buckling forces
  - Large structure
  - Spans on each side of BI

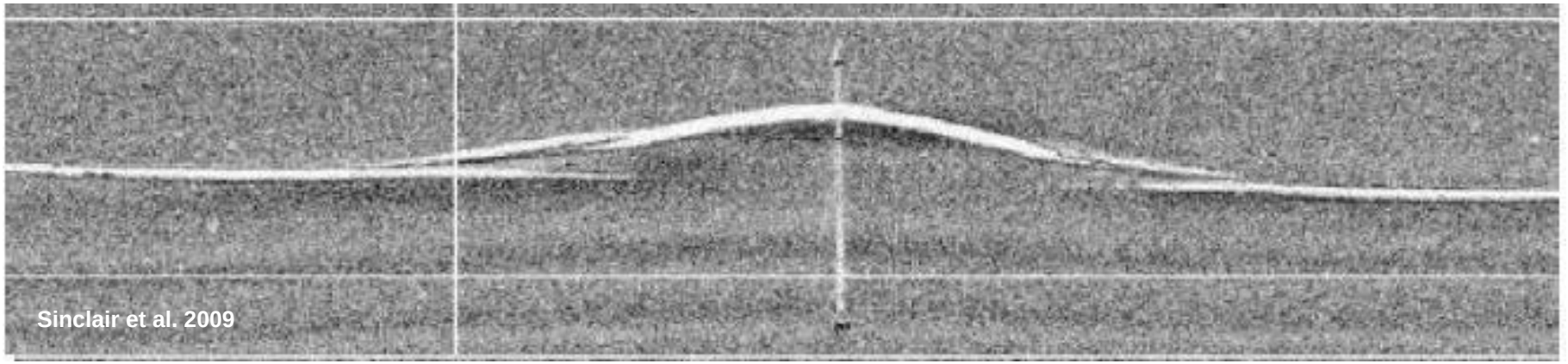




Engineered buckle initiators: Spans and touchdown zones (TDZ)







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Proceedings of the ASME 2018 37th International
Conference on Ocean, Offshore and Arctic Engineering
OMAE2018
June 17-22, 2018, Madrid, Spain

OMAE2018-77981

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ESTIMATING THE RATE OF SCOUR PROPAGATION ALONG A SUBMARINE PIPELINE IN TIME-VARYING CURRENTS AND IN FINE GRAINED SEDIMENT

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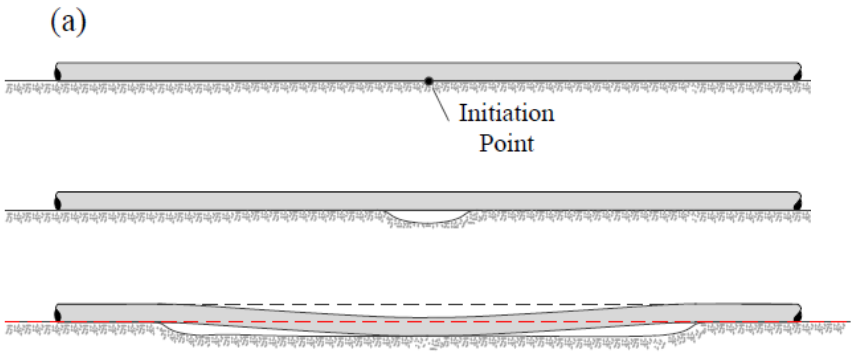
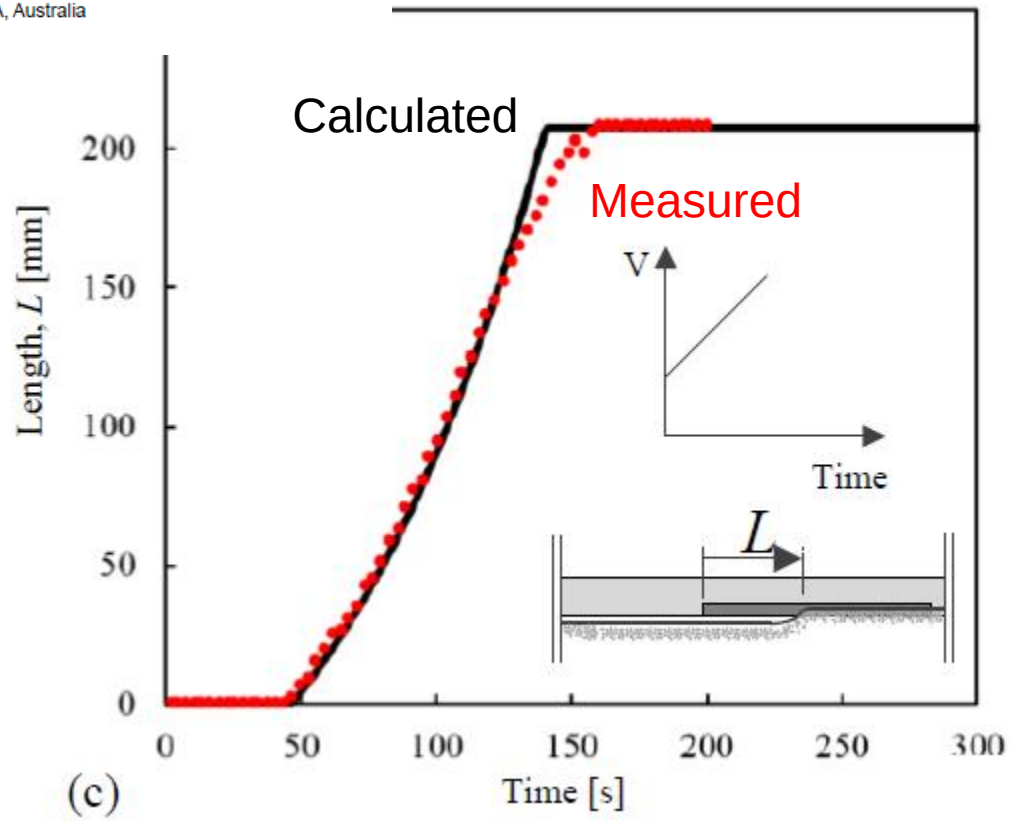


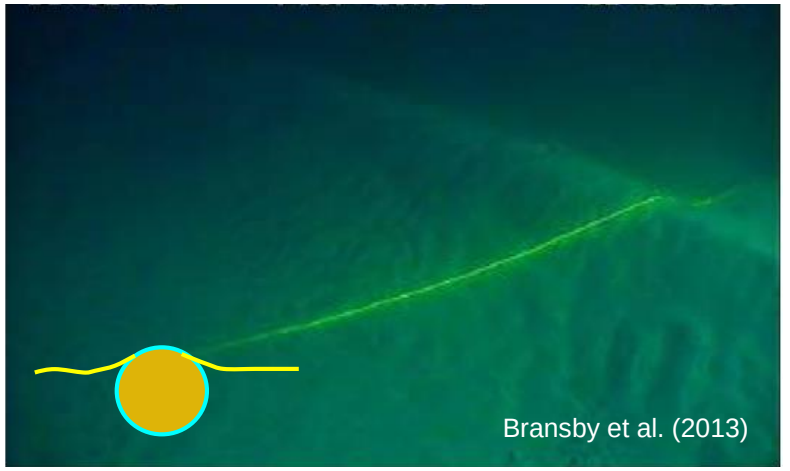


Effects of Sediment Mobility on Pipeline Embedment

As-laid survey

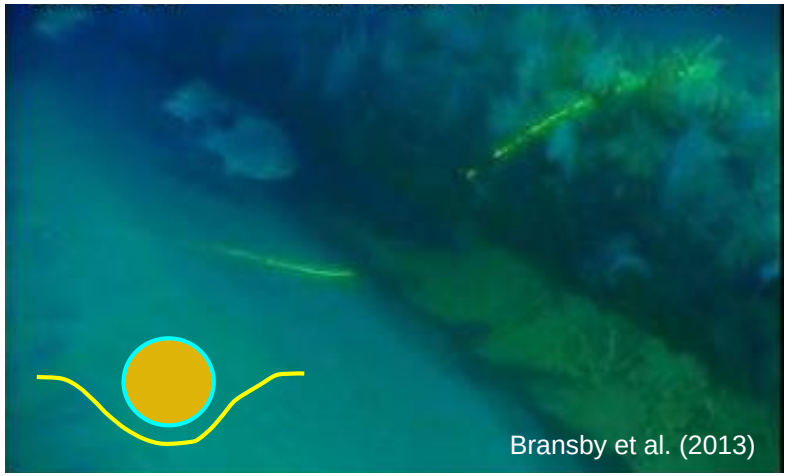
Under ambient metocean conditions

3 years later

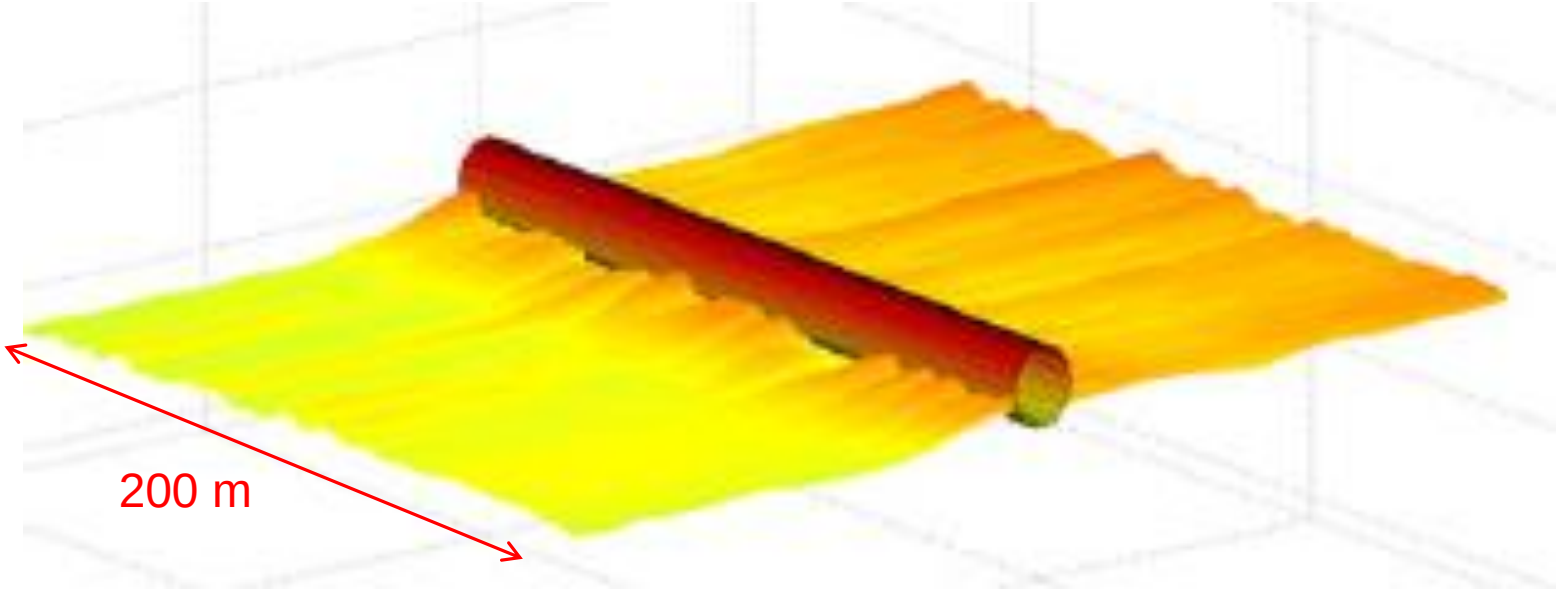


Same pipeline, further along

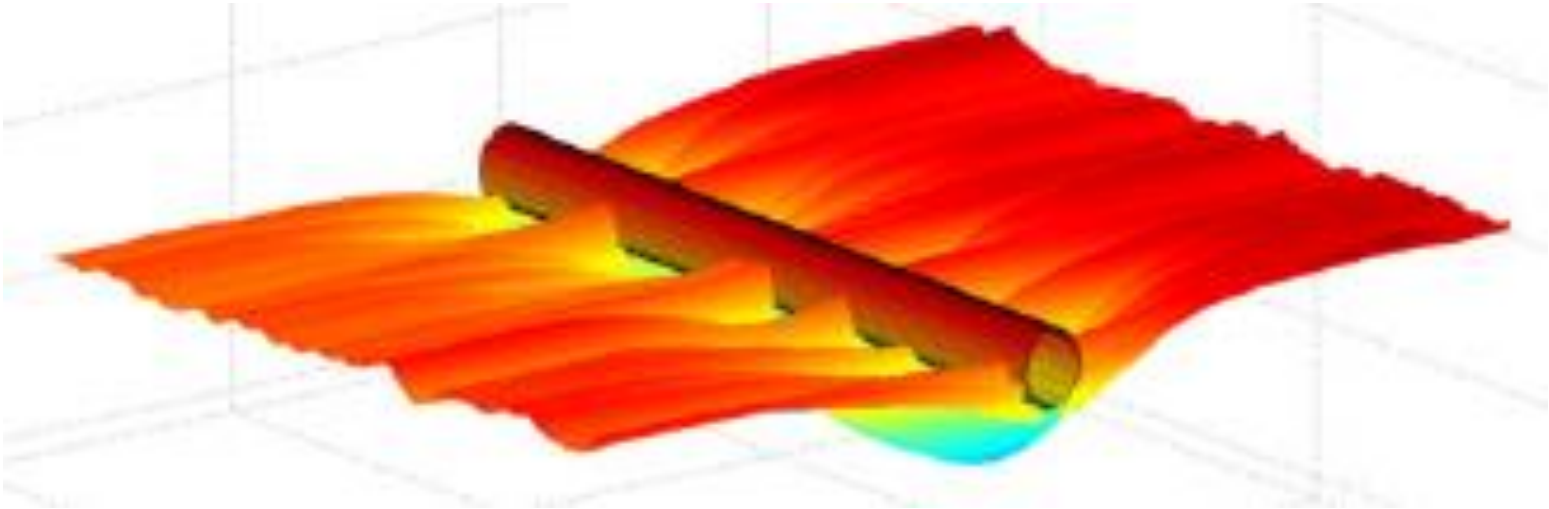
3 years later



Leckie et al. 2015



Pipe A, 2002, 6 months after laying,



Pipe A, 2006, 4 years after laying

Leckie et al. 2016

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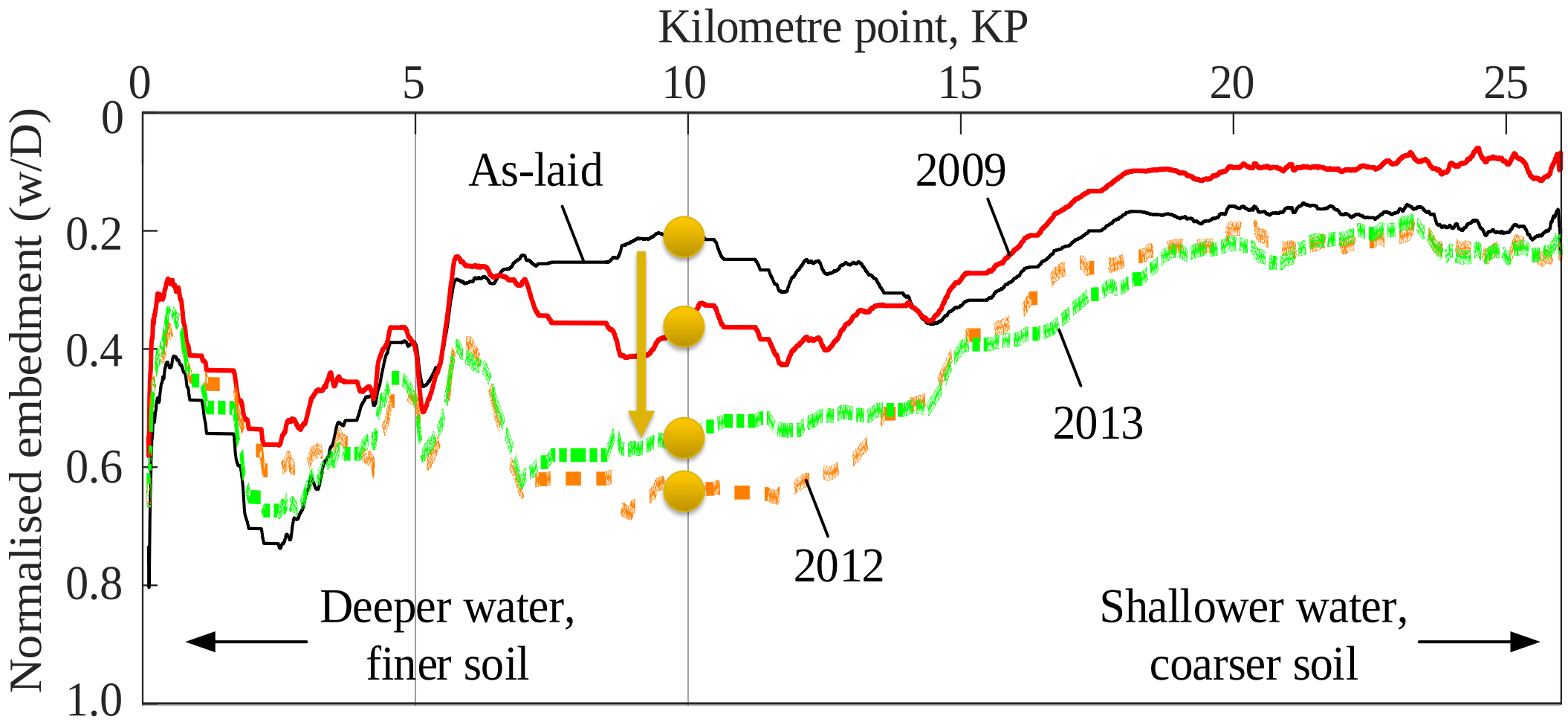
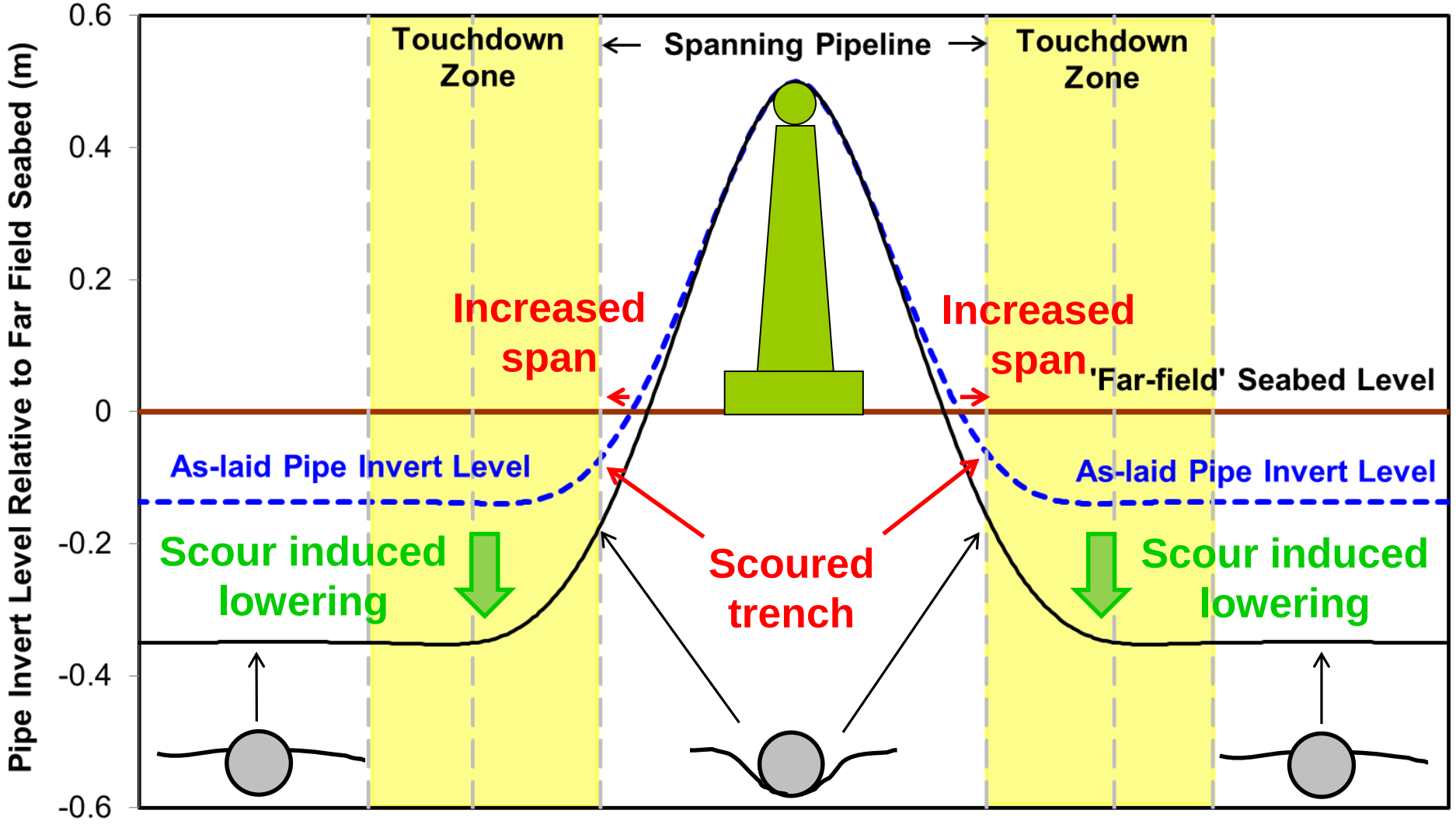
ESTIMATION OF FLUID-PIPE-SOIL INTERACTION



Low et al. (2018)

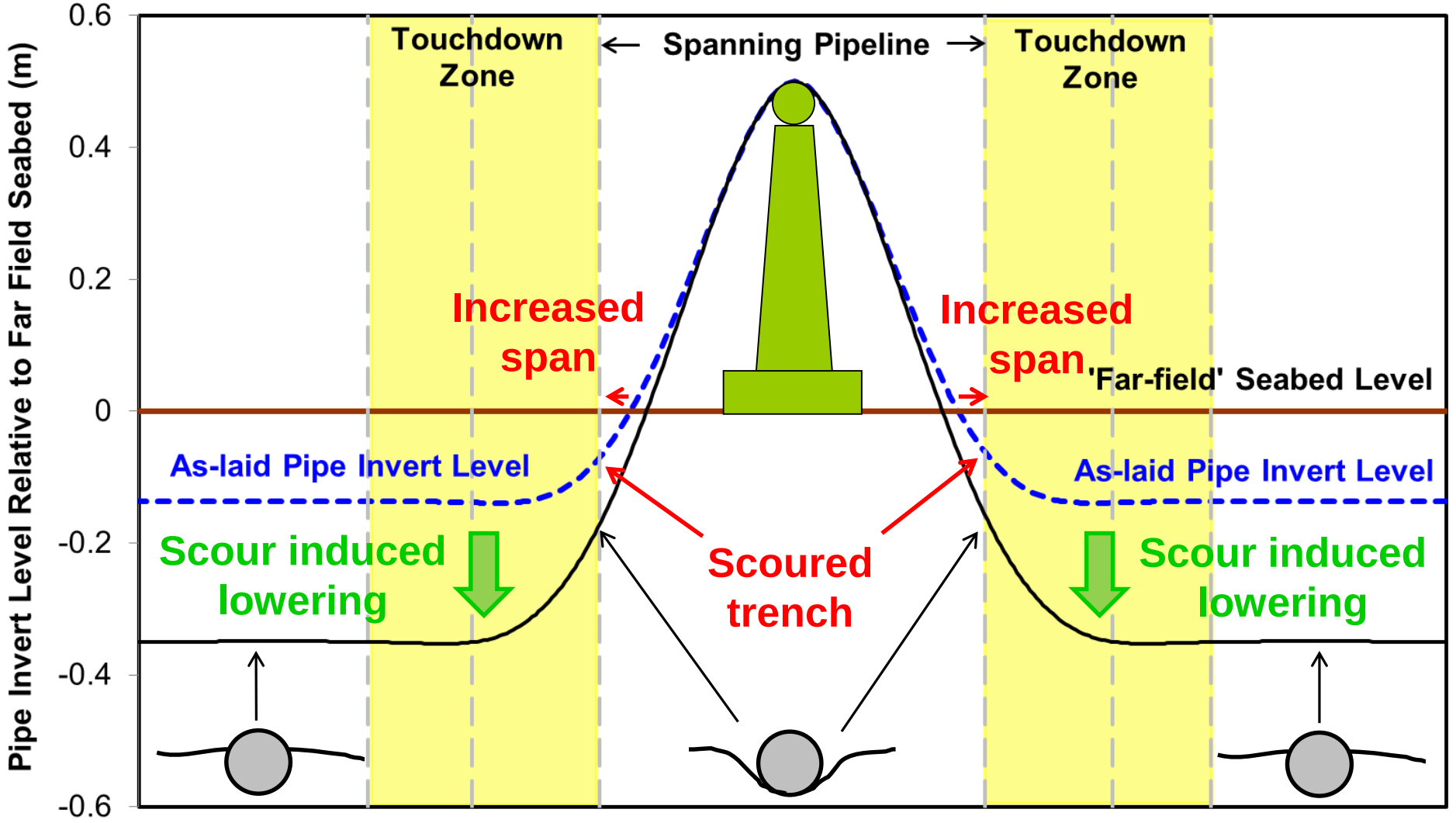
Effects of Sediment Mobility on Pipeline Embedment



- Pipe embedment in TDZ can increase with time
  - ➢ Increase in seabed resistance
- Scoured trench may be formed at touchdown point
  - ➢ Increase in span length
  - ➢ Relax pipeline lateral buckle
  - ➢ Increase in VIV induced fatique

Low et al. (2018)

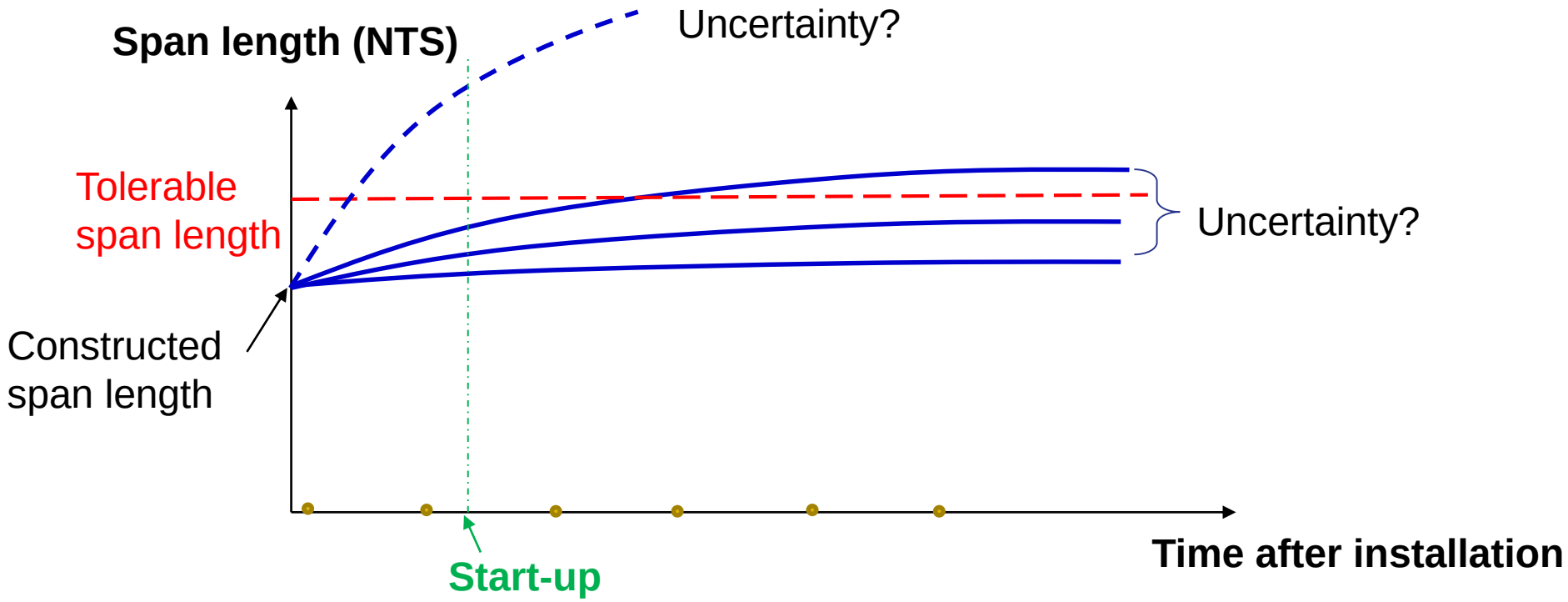
Effects of Sediment Mobility on Pipeline Embedment



- Pipe embedment in TDZ can increase with time
  - Increase in seabed resistance
- Scoured trench may be formed at touchdown point
  - Increase in span length
  - Relax pipeline lateral buckle
  - Increase in VIV induced fatique

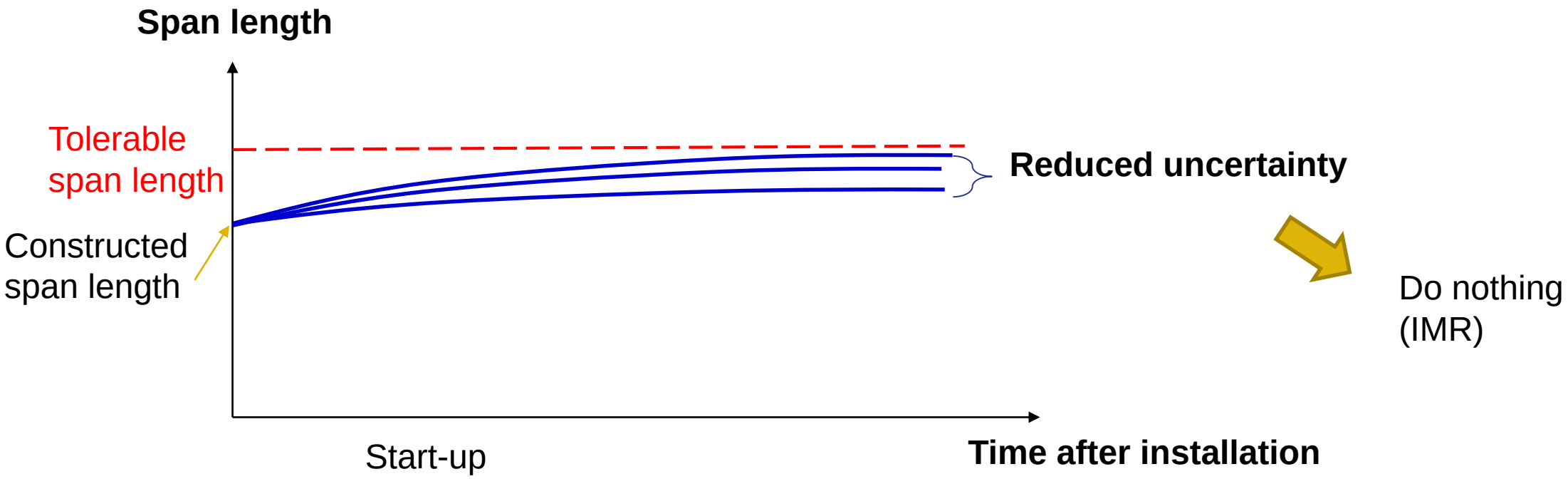
Aim of (pilot) research

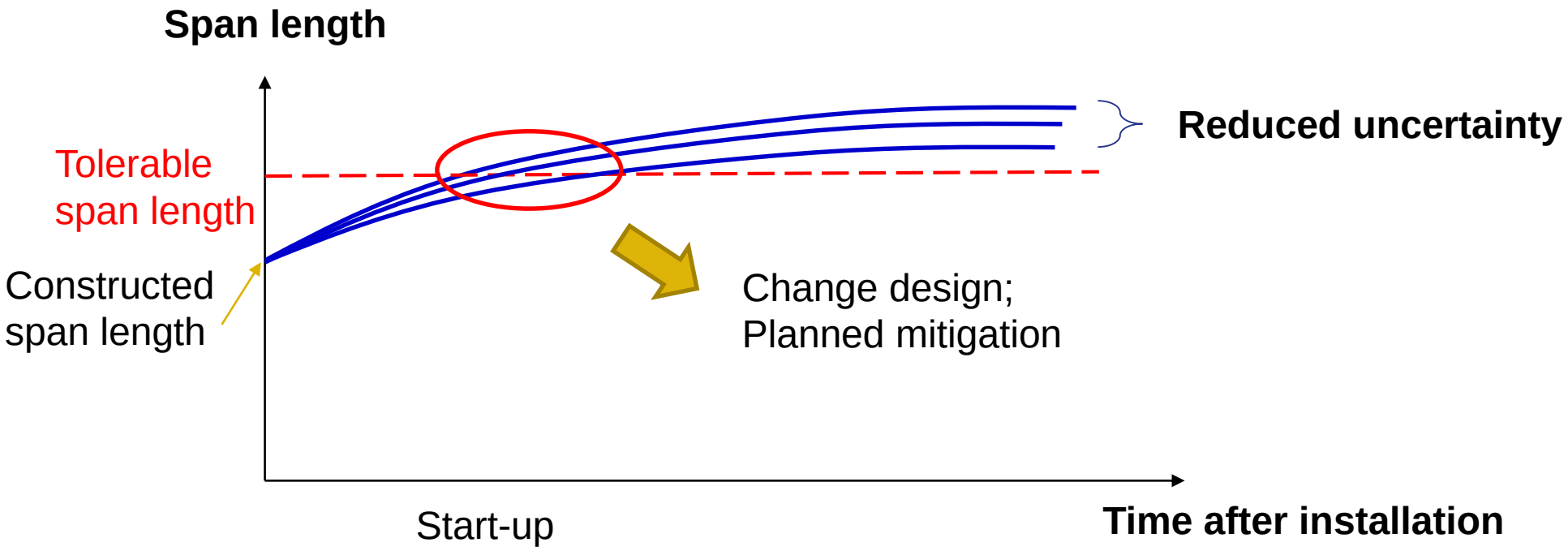
To look at how the span length changes with time after installation



Methodology:

- Experimental testing at small-scale
- Analytical calculations
- (Increasing amount of NWS field evidence exists - not covered here)


Span length
Tolerable
span length
Constructed
span length
Reduced uncertainty
Do nothing
(IMR)
Start-up
Time after installation


Span length
Tolerable
span length
Constructed
span length
Reduced uncertainty
Change design;
Planned mitigation
Start-up
Time after installation

https://www.geoinformatienederland.nl/system/files/documents/607-151014%20Allseas%20presentation%20HSBB%202015.pdf

Buckle initiators

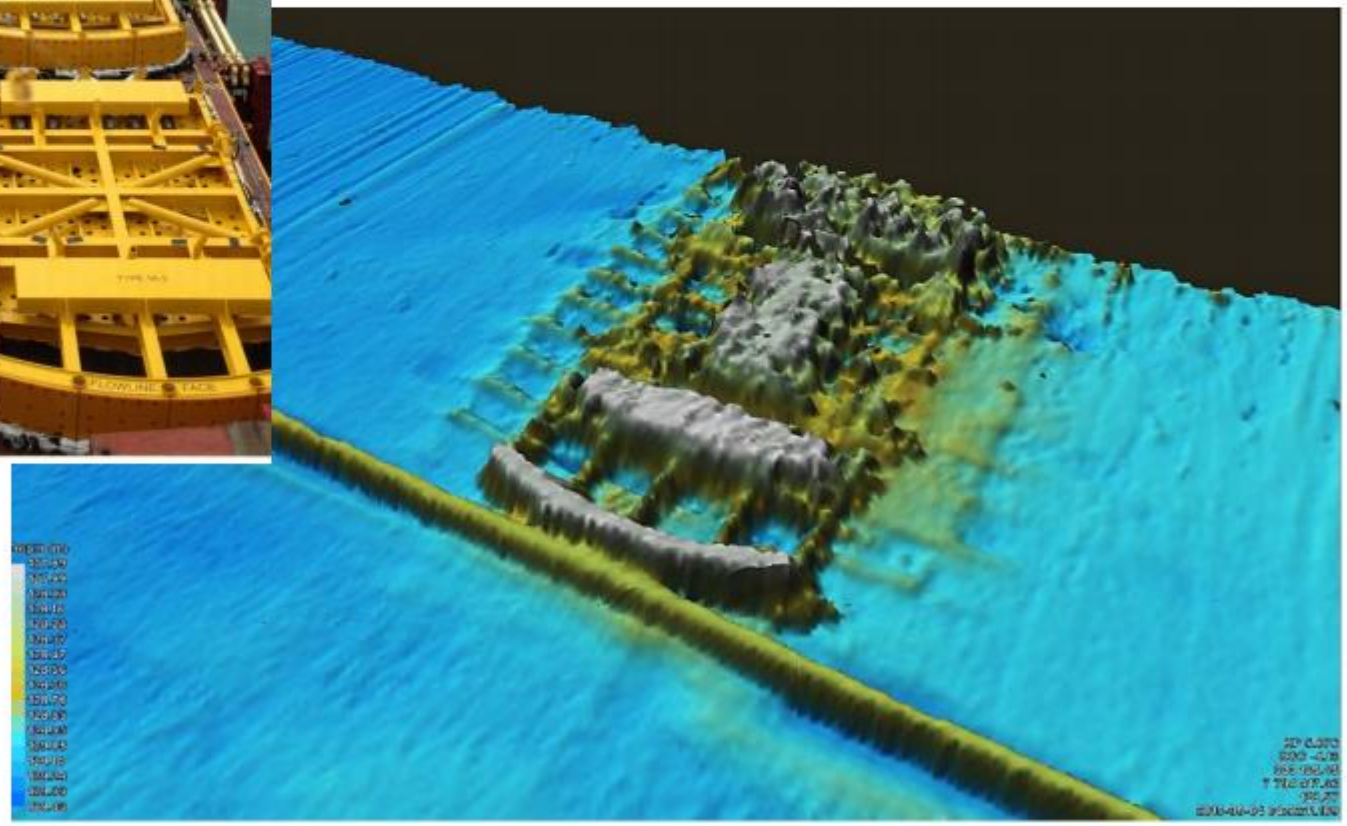


Figure 7: Example of a buckle initiator at KP 5.677

Avoids spans
(and VIV risk)

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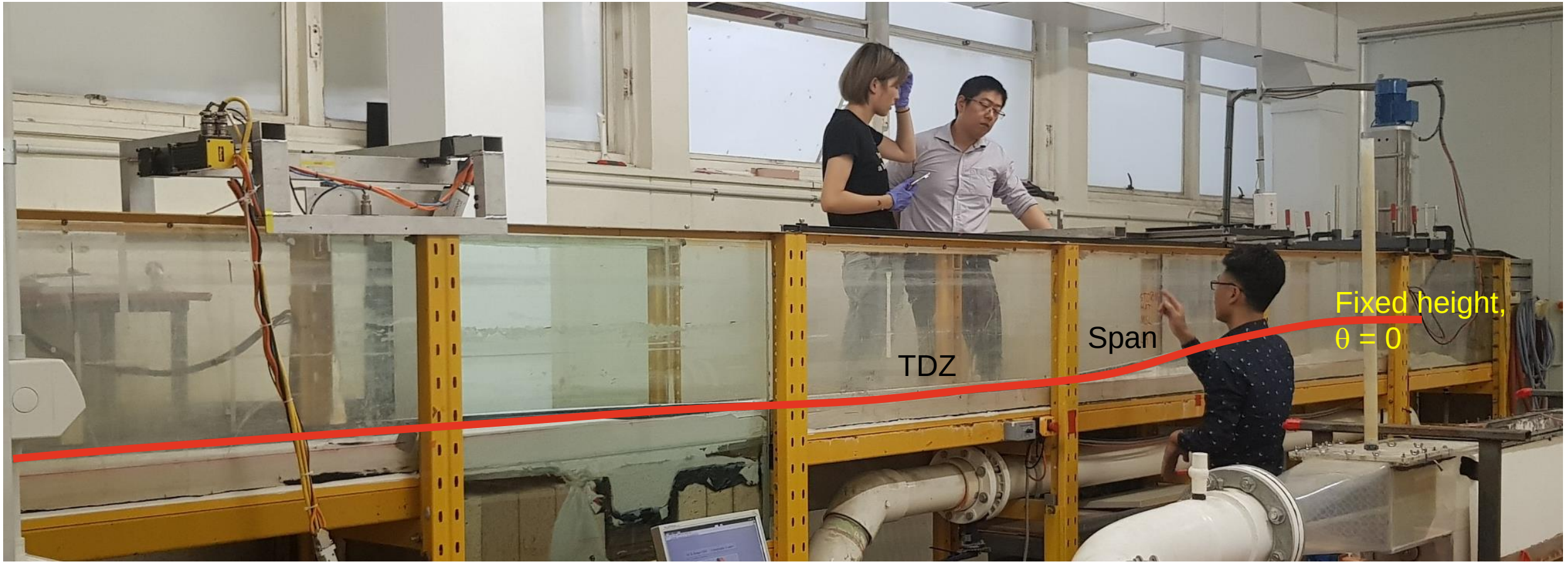
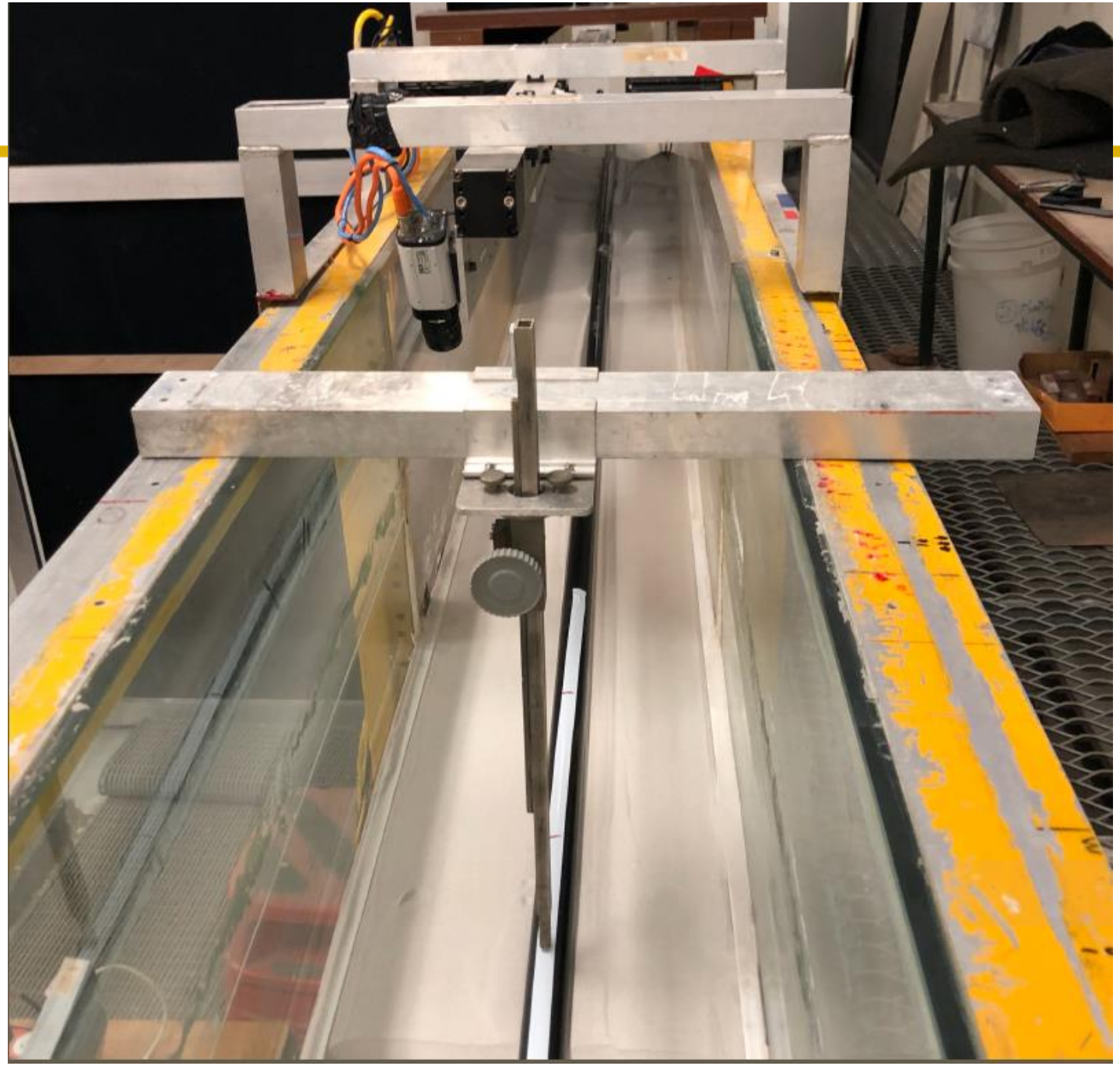
Shuchen Li Weidong Yao Hongwei An

Flume length = 15 m (flow from right to left)
Flume width = 0.4 m
Initial tests will have flow axial to pipeline

Pipeline diameter 40 mm
Pipeline length 12 m (300 D)
Solid Acetal bar (SG = 1.41; E = 2.76 GPa)


TDZ
Span
Fixed height,
θ = 0



Laser scanner across sample

Point measurement

Overview

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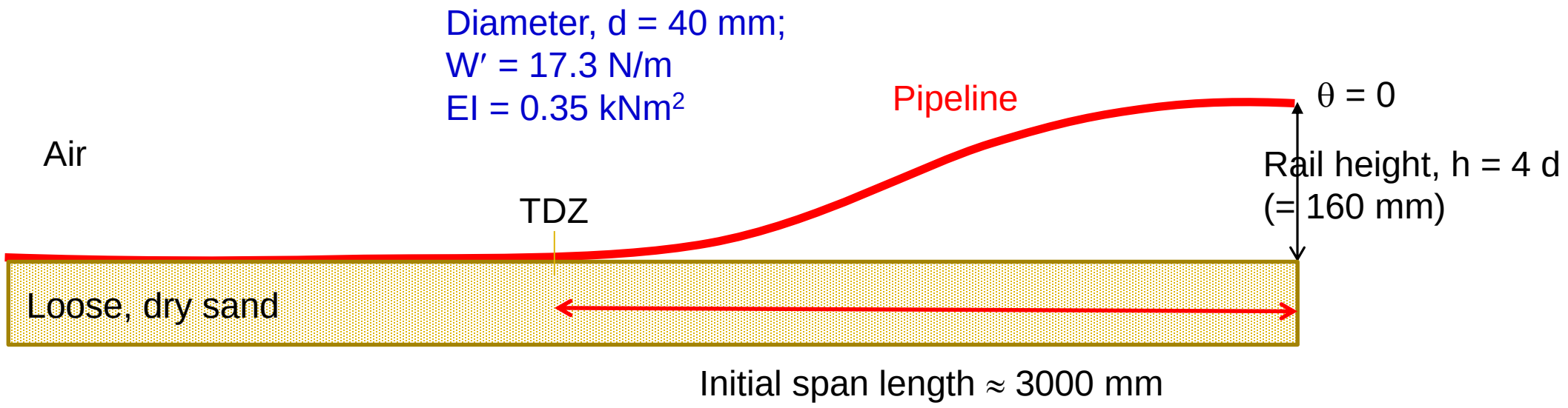
Test 1: Dry sand – manual excavation to 1 D

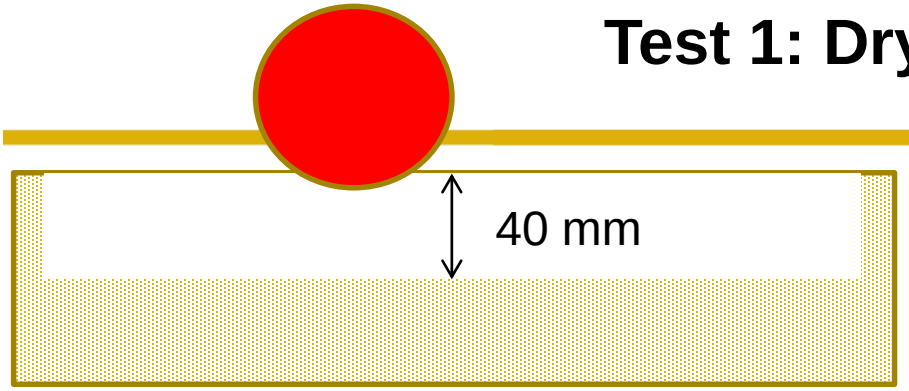
Initial geometry



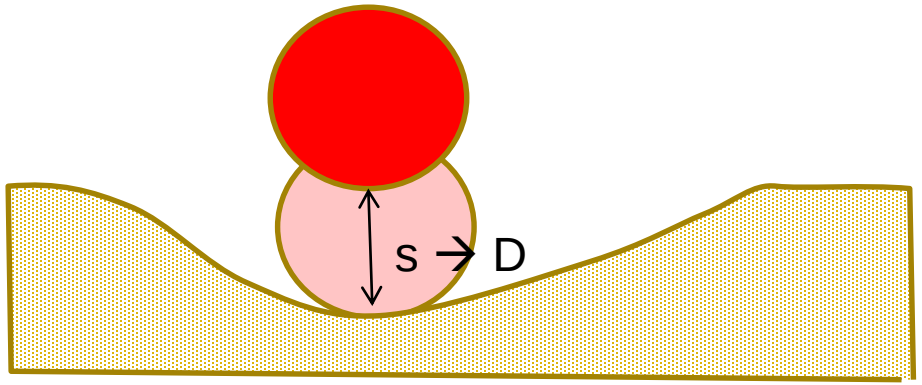
$h=W'L^4/24EI$

Get L = 2.96 m

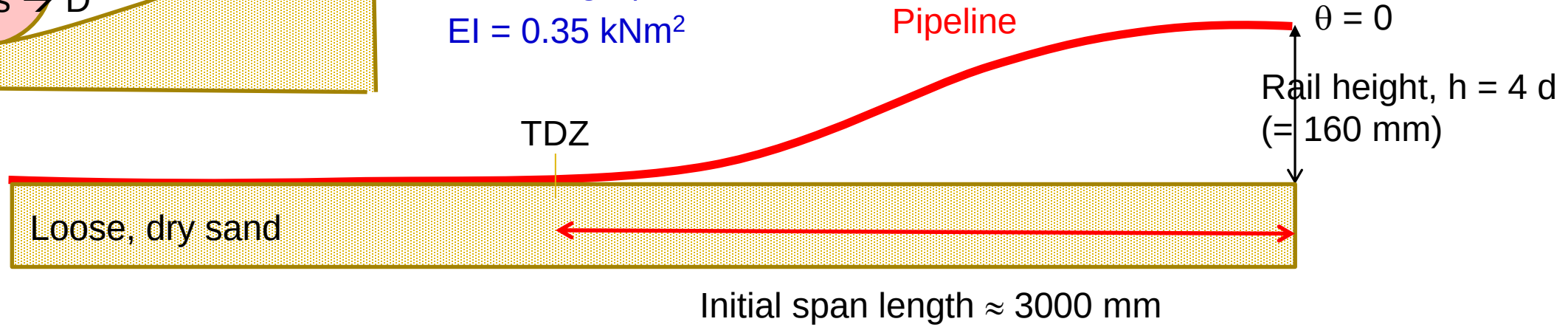
Test 1: Dry sand – manual excavation to 1 D



Initial geometry

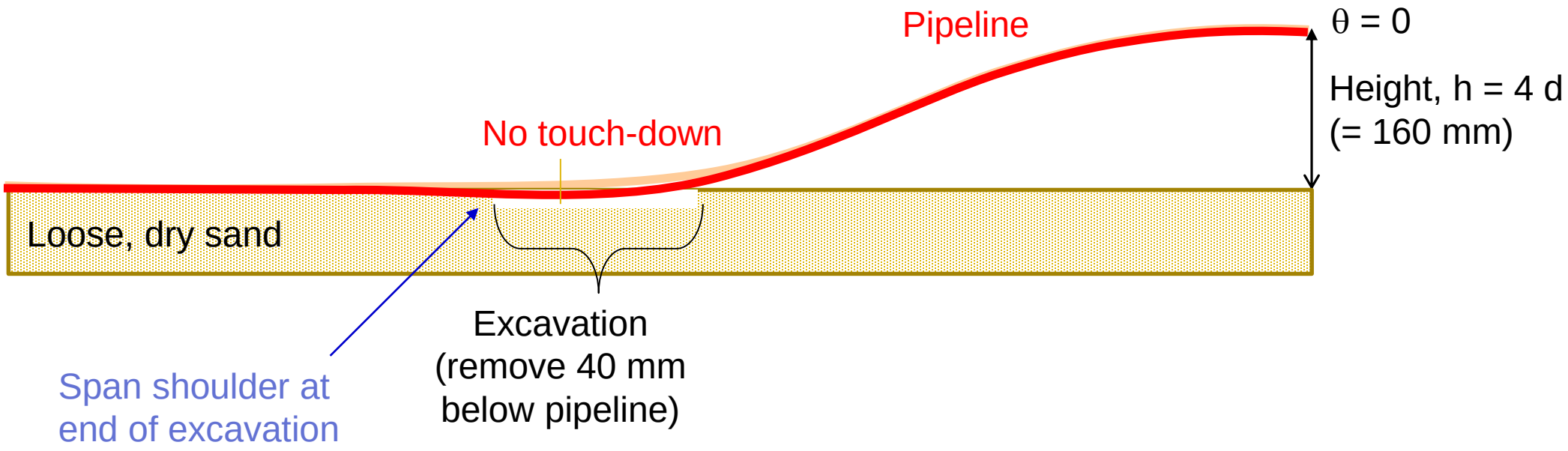


Diameter, d = 40 mm;
W′ = 17.3 N/m
EI = 0.35 kNm^2



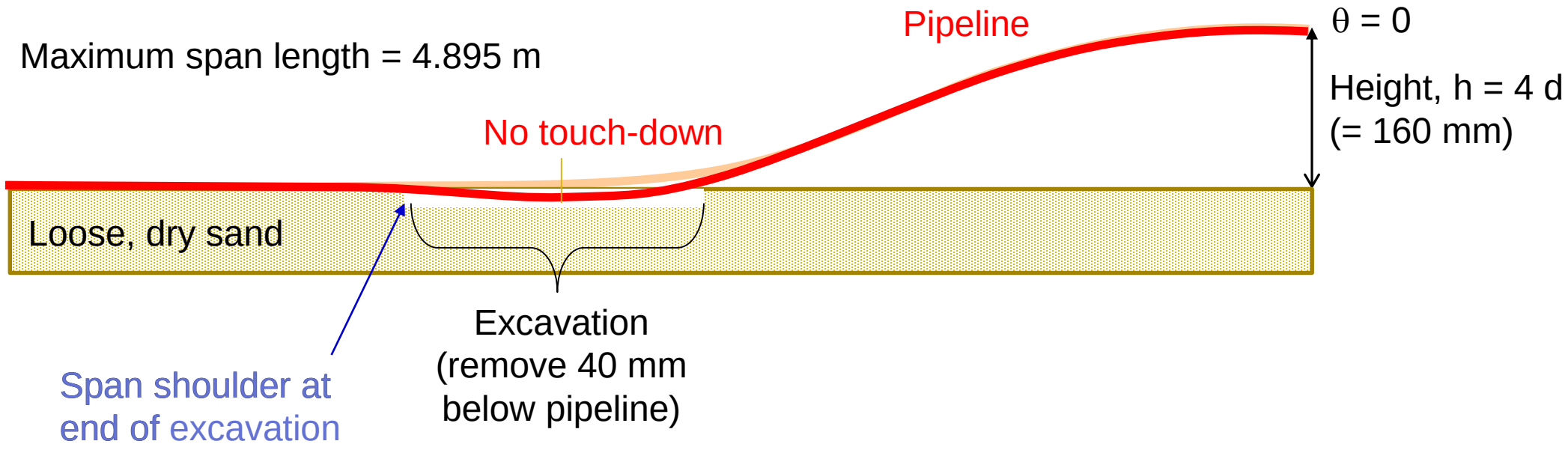
Test 1: Dry sand – manual excavation to 1 D

Interim geometry



Test 1: Dry sand – manual excavation to 1 D

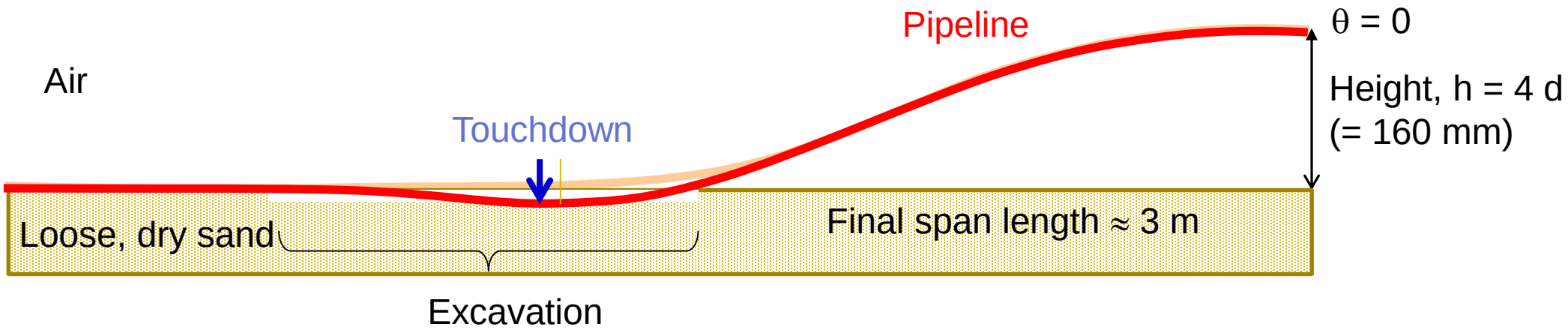
Interim geometry



Test 1: Dry sand – manual excavation to 1 D

Equilibrium main-span geometry

Test stopped



$h=W'L^4/24EI$

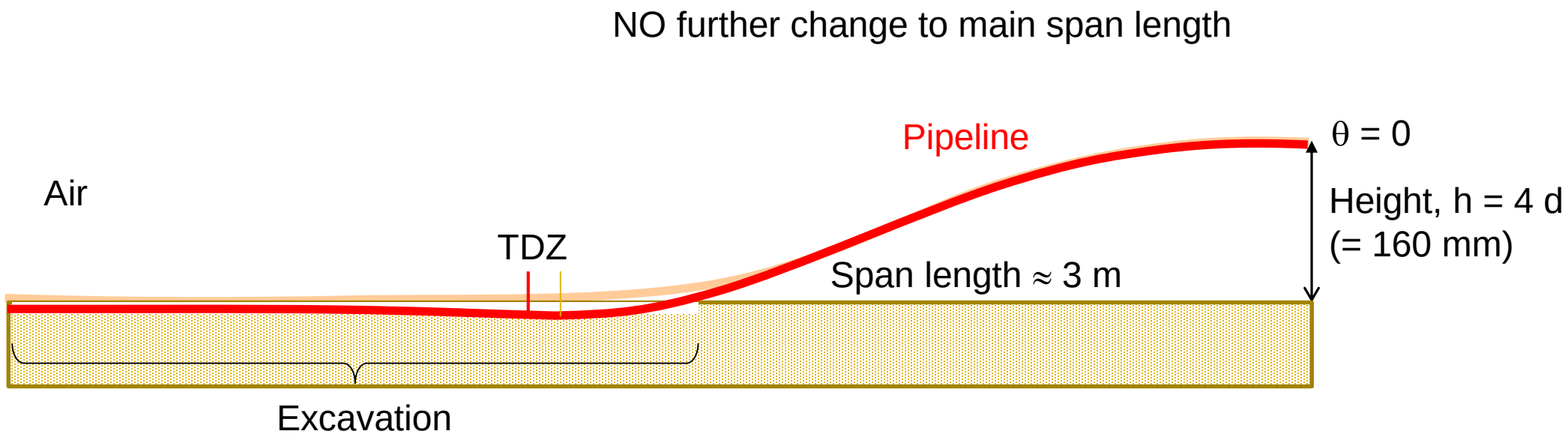
Get L = 2.96 m for s = 0
L = 3.13 m (s = d)
5.7% increase in L

f_n (vertical) ≈ 4.4 Hz; f_n (horizontal) ≈ 3.4 Hz


TDZ
Span
Fixed height,
θ = 0

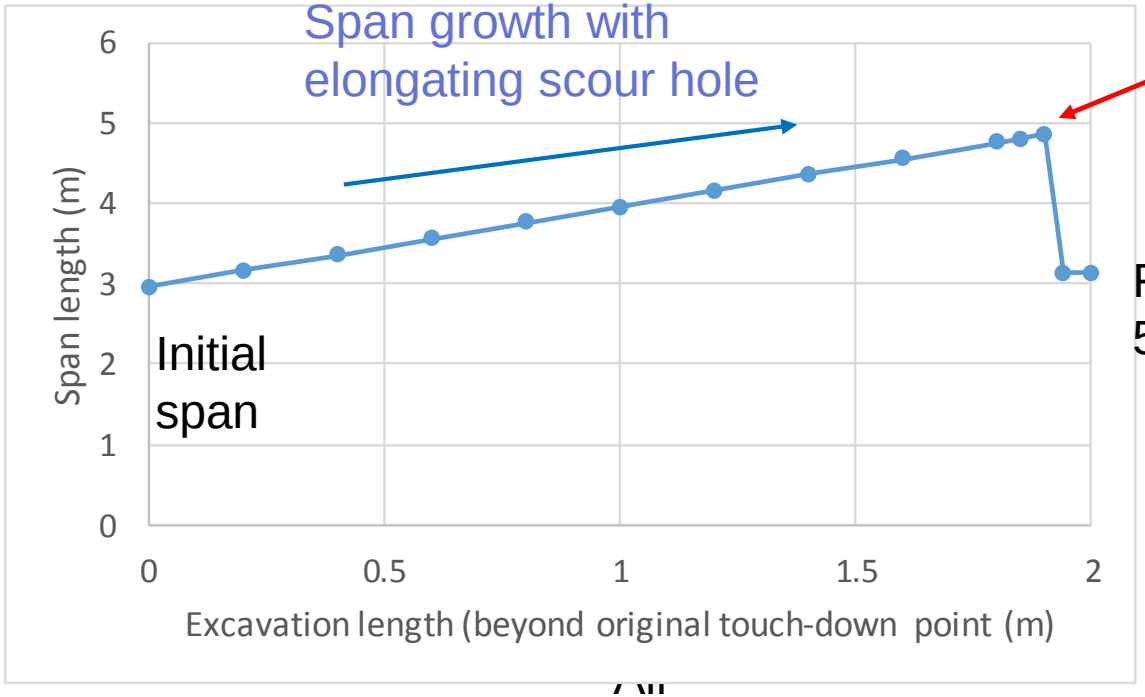
Possible final geometry

Not done in experiment



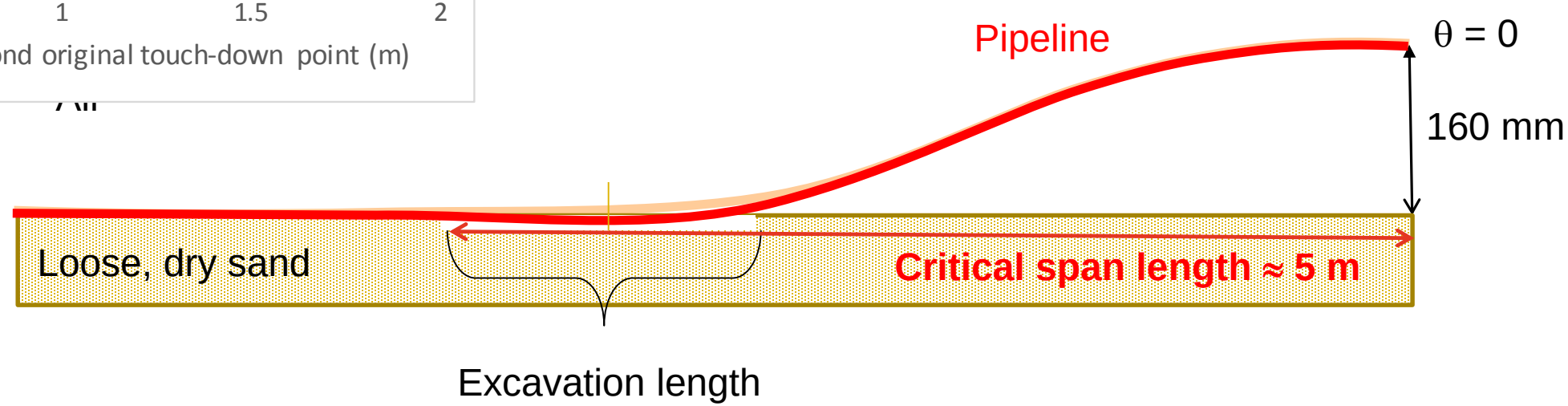
Test 1: Dry sand – manual excavation to 1 D

Summary of results



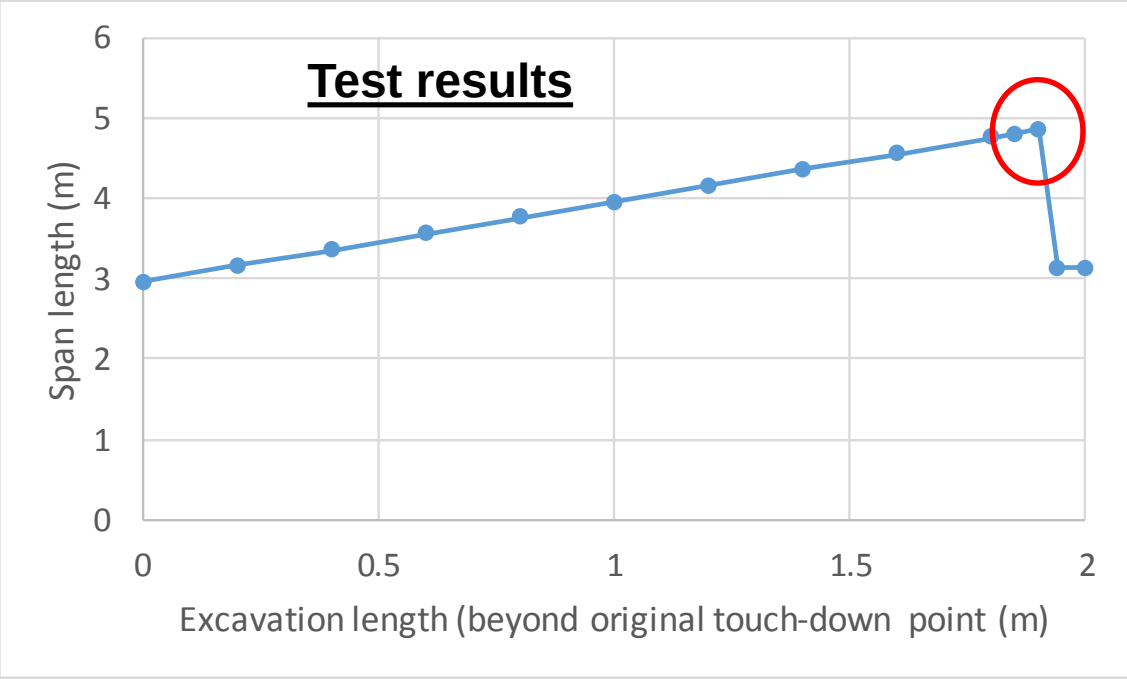
Critical (interim) span length

Final span only
5% longer

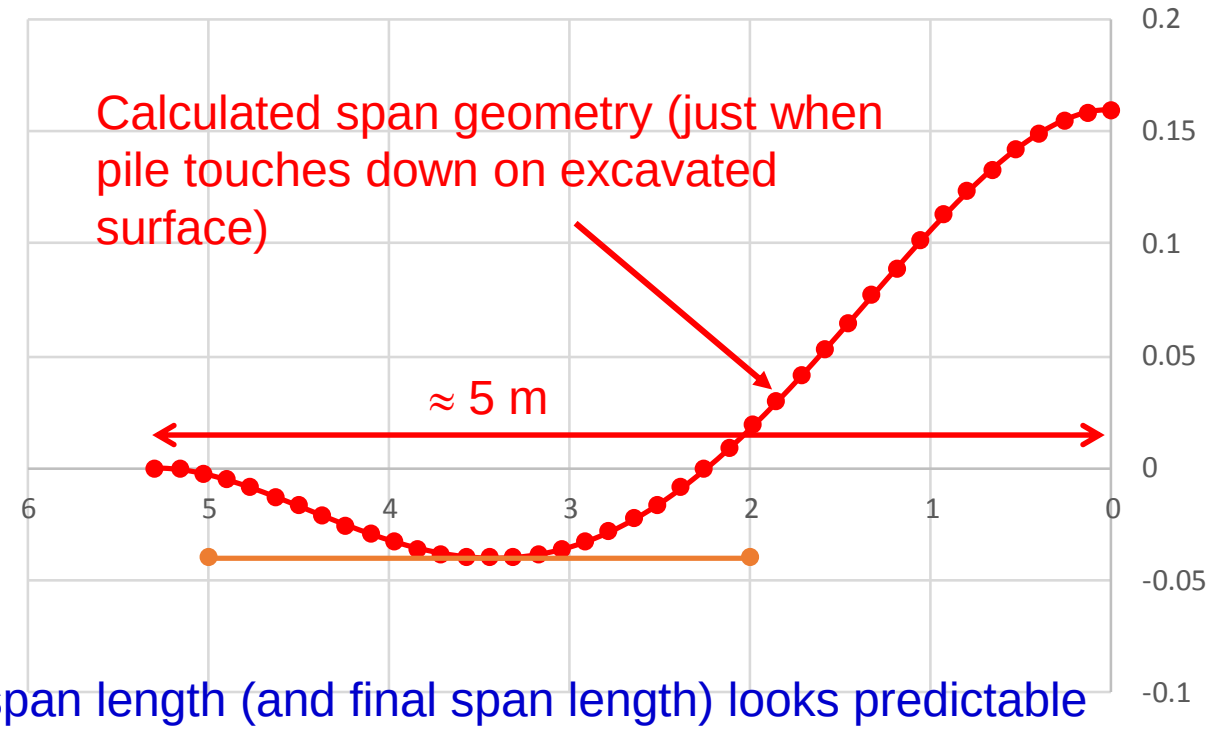


Test 1: Dry sand – manual excavation to 1 D

Summary of results



Simple structural Analysis

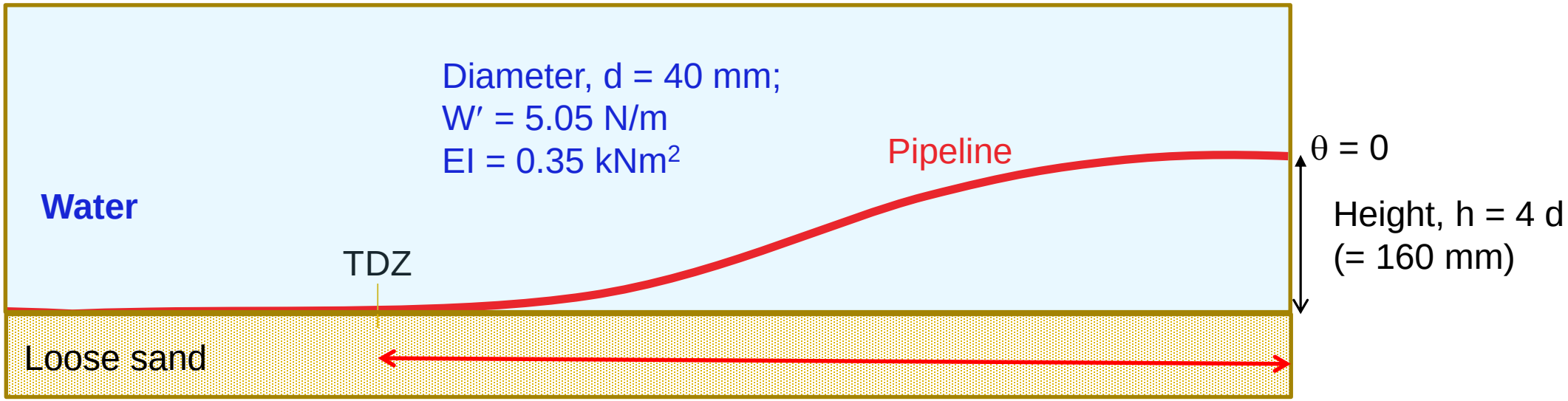


→ Maximum span length (and final span length) looks predictable

Test 2: Submerged – manual excavation to 1 D

Initial geometry

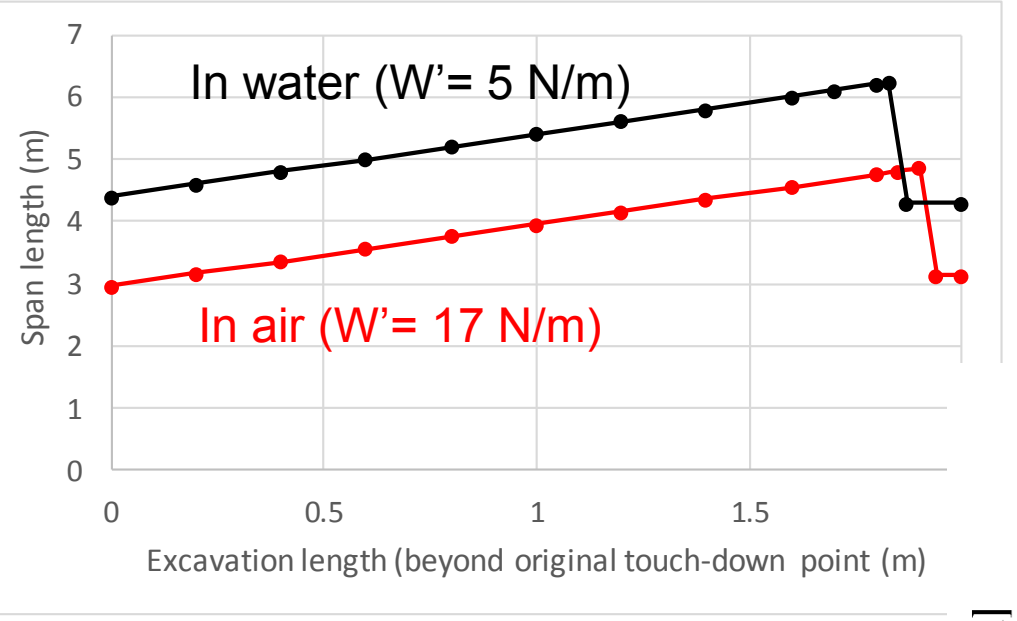
W' reduced because of buoyancy



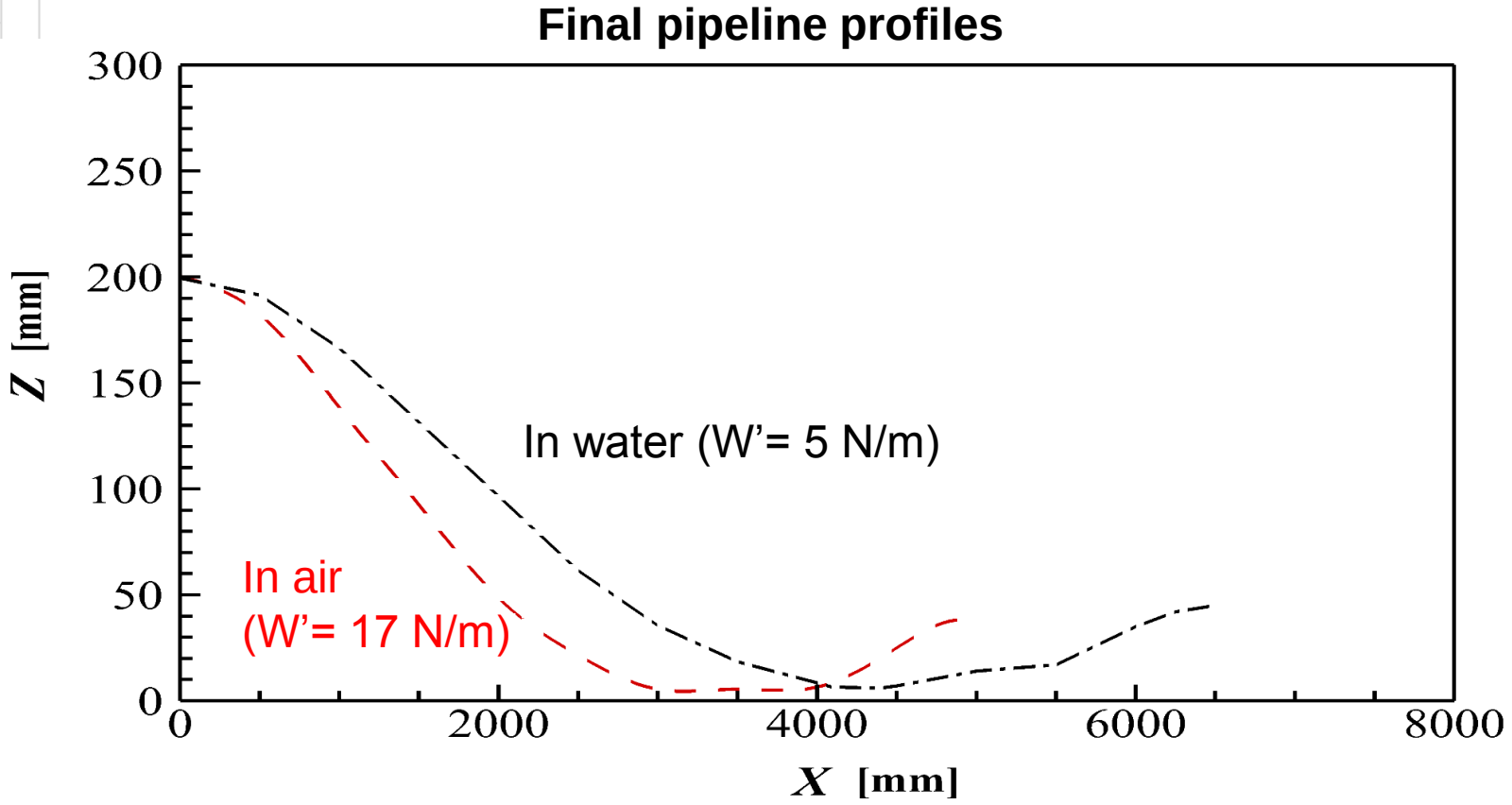
$h=W'L^4/24EI$

Get L = 4.26 m for s = 0
L = 4.46 m (s = d)
4.6% increase in L

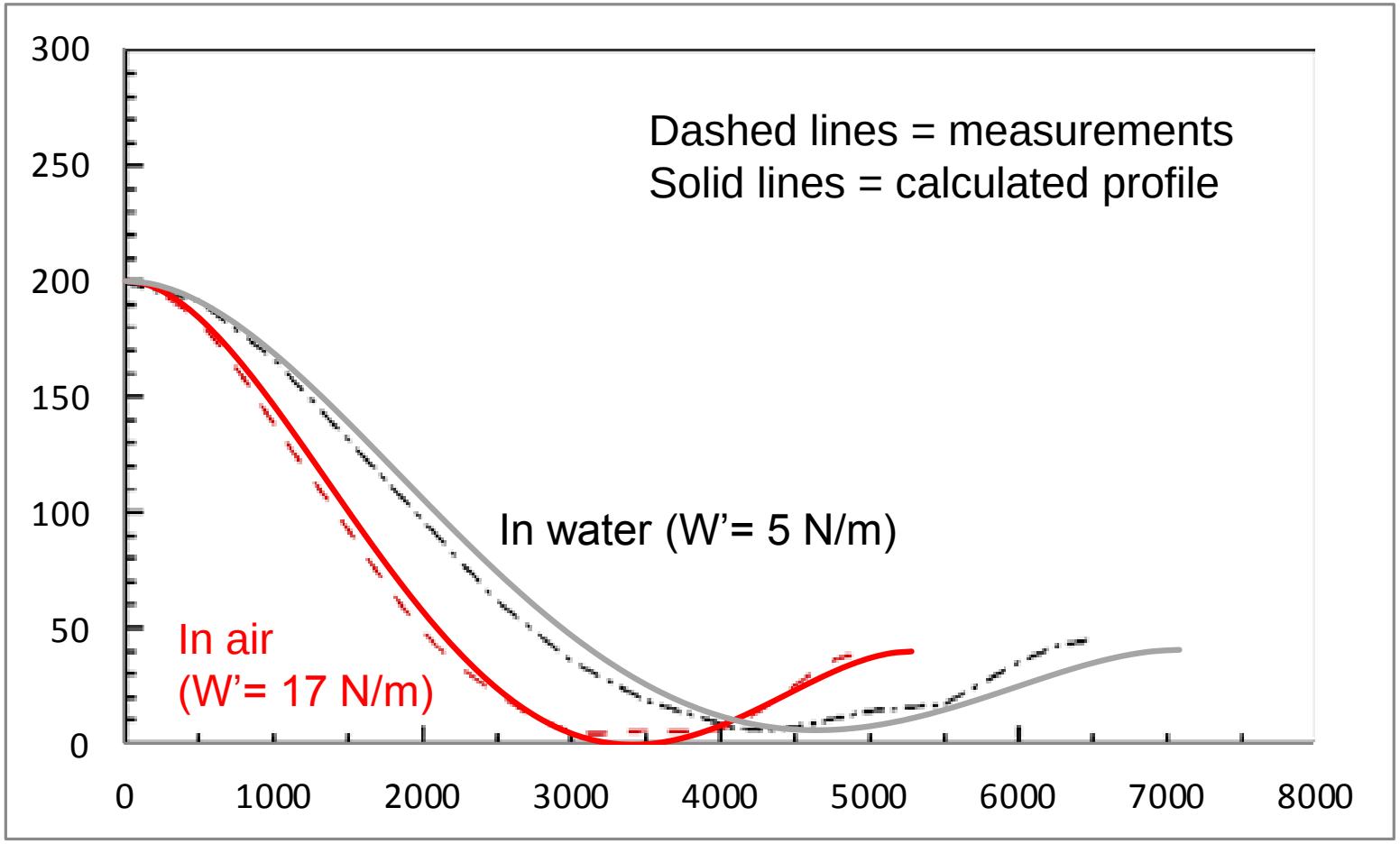
Results (test 1 & 2)



Same process for lighter pipe (but longer spans)



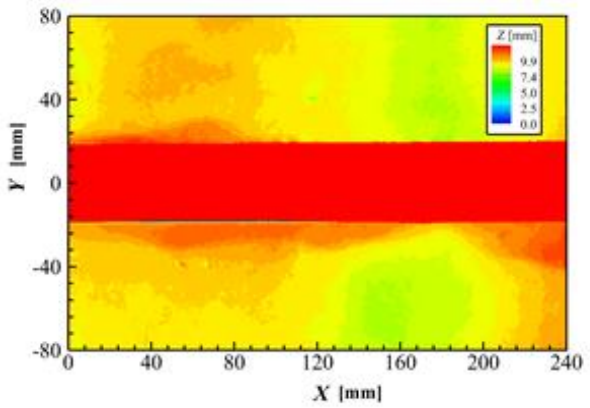
Final post-excavation pipeline profiles

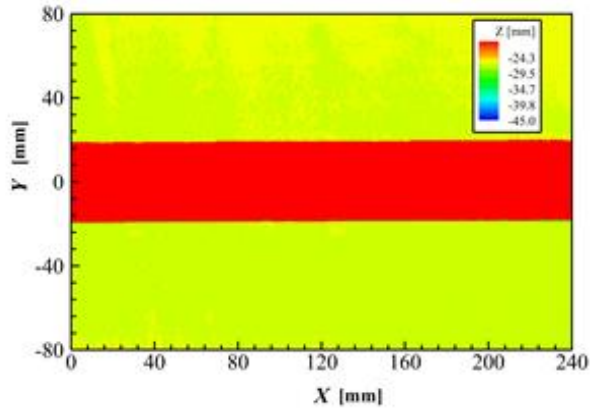


Distance away from buckle initiator rail (mm)

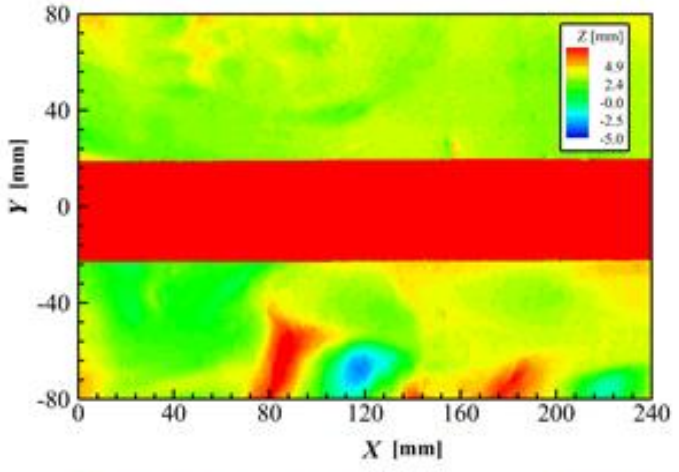
→ **Initial, interim and final span configuration can be approximated simply**

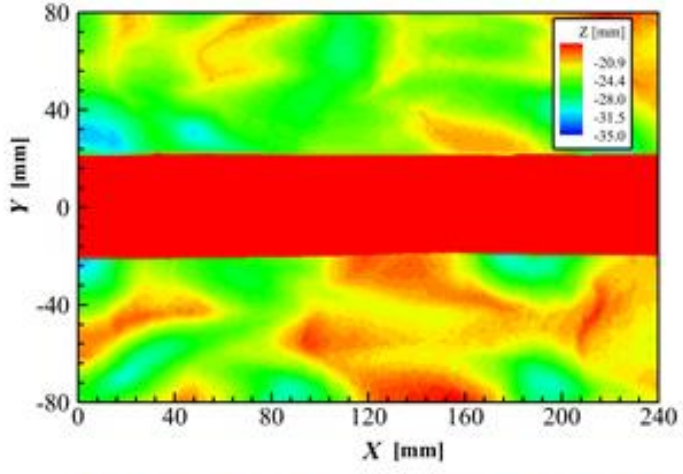
Scour tests ongoing





Test 1





Test 2

- Initial results limited by flow orientation (and ripples).
- Plans for tests in wider flumes to change pipeline orientation.

5. Conclusions

- BI span elongation due to scour is a real design issue which must be addressed (significant mitigation costs incurred on recent projects)
- Field evidence being generated on recently installed projects on the NWS
- Preliminary experiments look encouraging. Suggest that significant span elongations can occur (and their maximum magnitude is likely to be predictable), but that they are likely to be transient.
- Span management / design is likely to involve uncertainty about rate of scour growth at the TDZ compared to fatigue budgets and inspection frequency.
- Span elongation rates may be predictable with knowledge of :
    - Metocean conditions (compared to pipeline heading)
    - Seabed erosion resistance
    - Pipeline, BI and seabed properties
- Initial pilot experimental work suggests that it may be possible to investigate span elongation in flumes, with careful scaling of field conditions.

Fugro Chair in Geotechnics

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