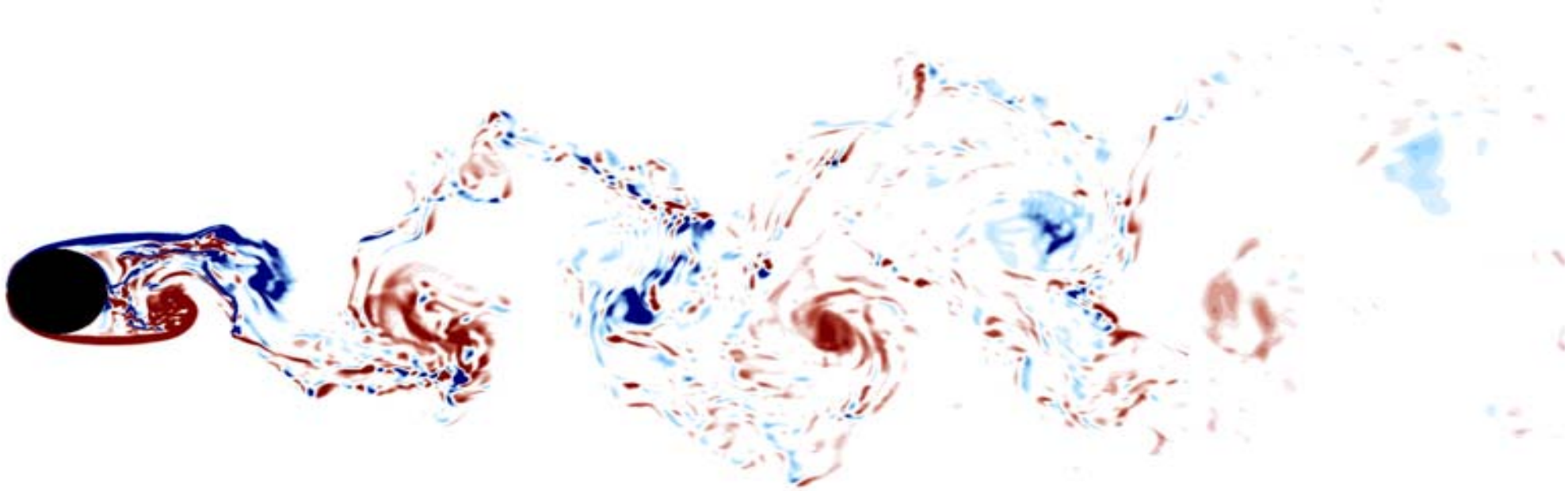
DNV·GL



Free-Spanning Pipelines in the Digital Age

Nicholas Nielsen & Olivier Royet

1

Context
What are free spans?

2

Current approach
How do we estimate fatigue life?

3

New science
What's a better way of estimating fatigue life?

4

New service
A great service both for DNV GL and friends.

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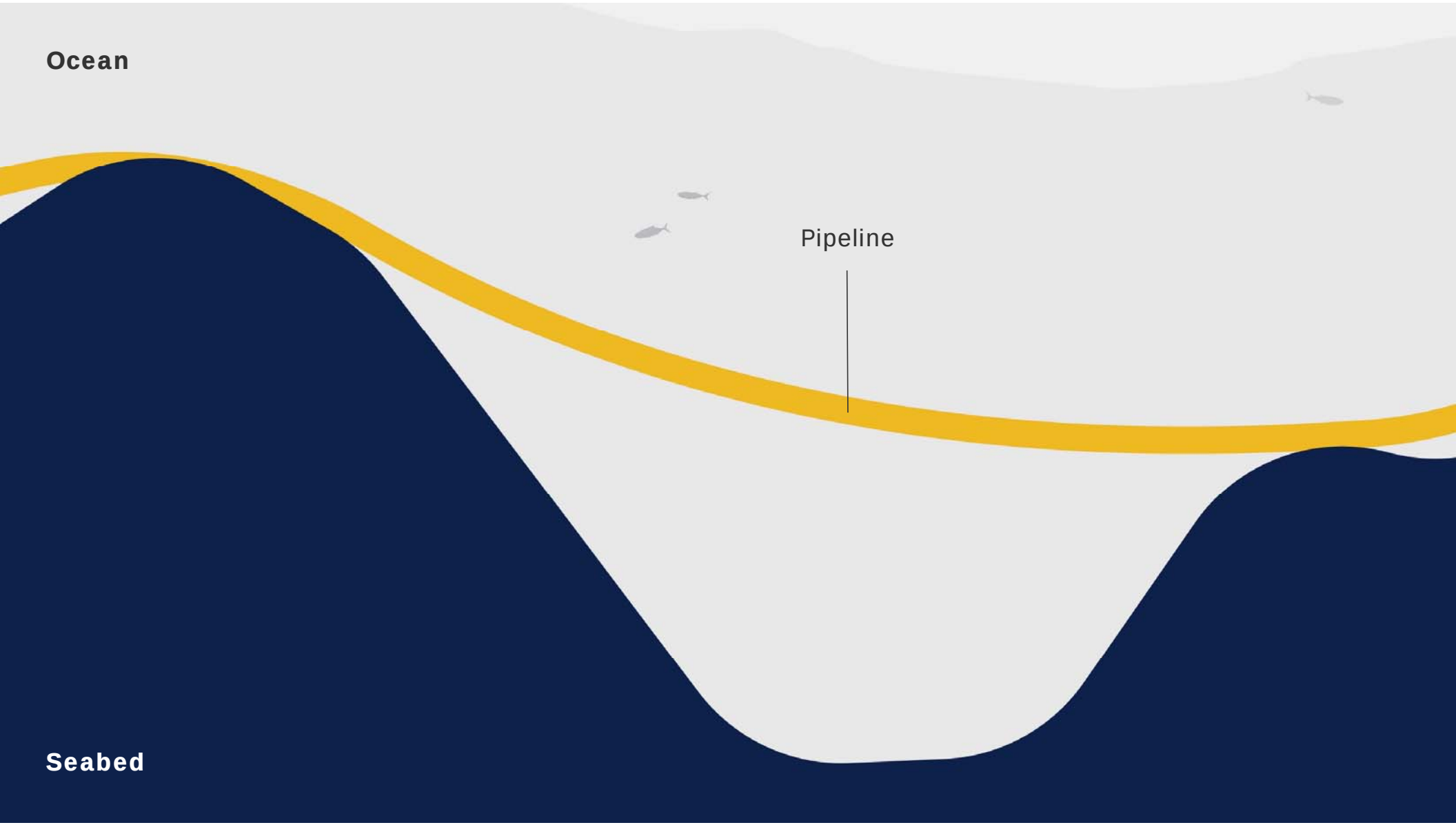
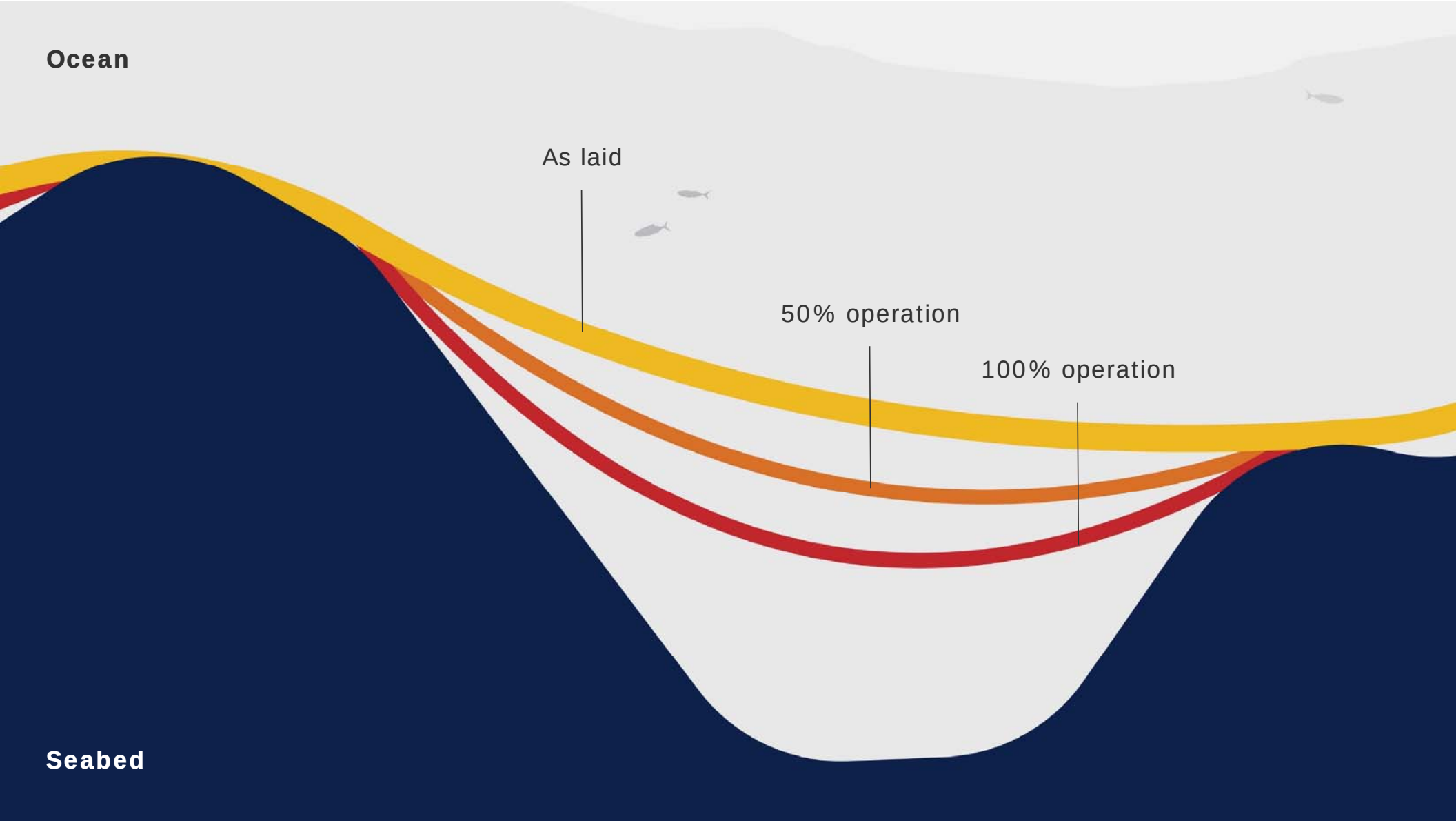
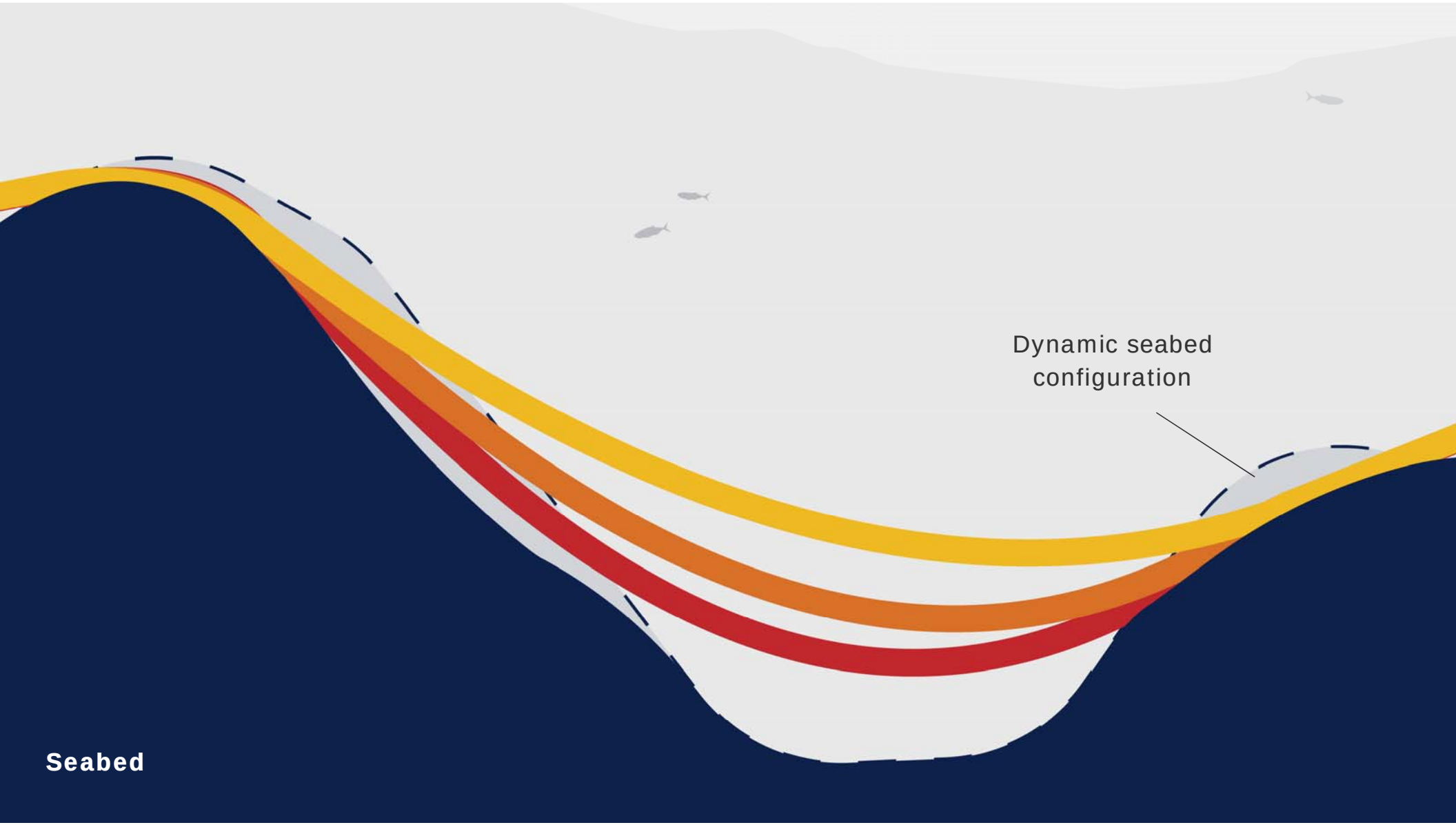
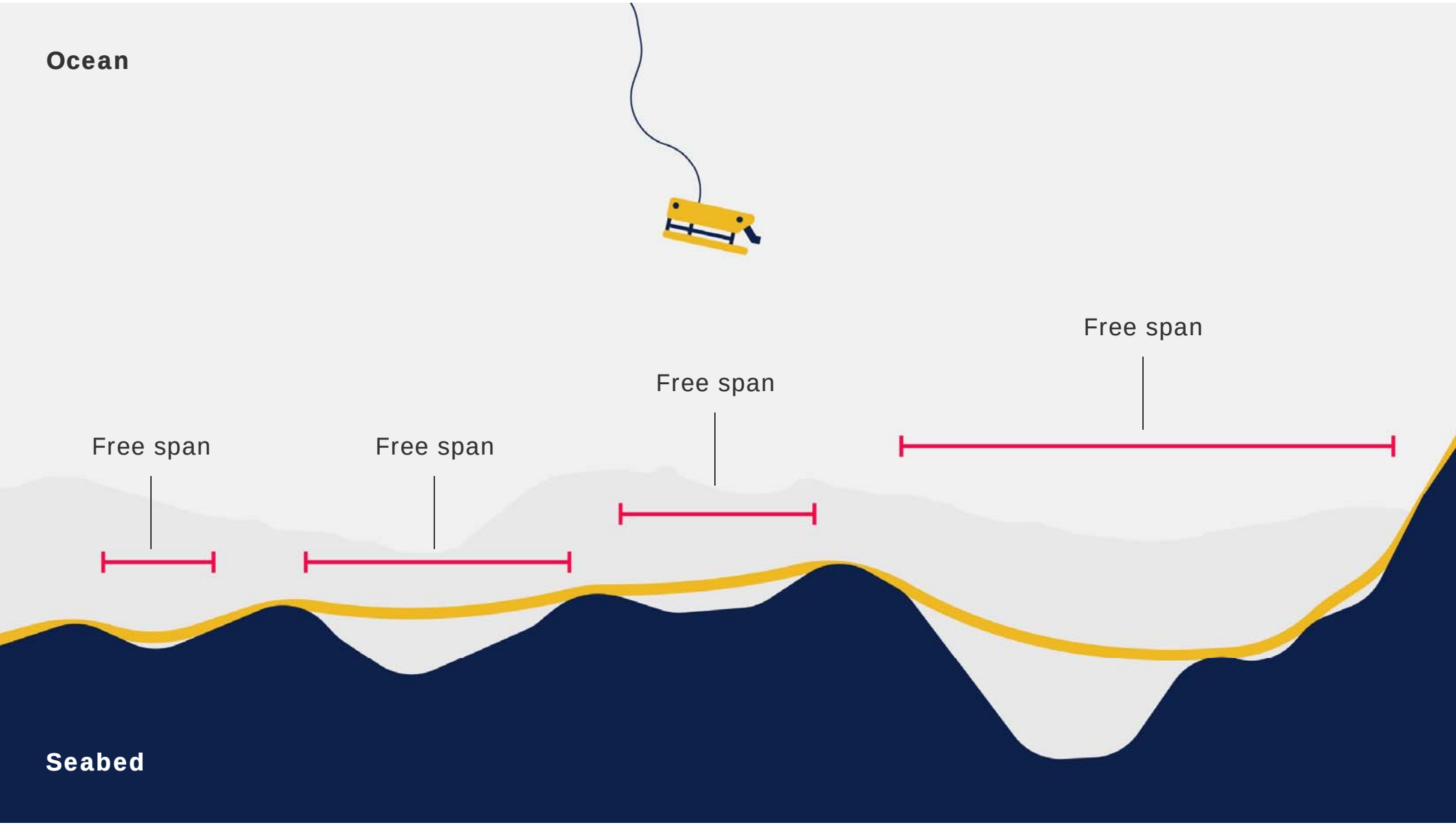

Ocean
Pipeline
Seabed


Ocean
As laid
50% operation
100% operation
Seabed


Dynamic seabed
configuration
Seabed


Ocean
Free span
Free span
Free span
Free span
Seabed

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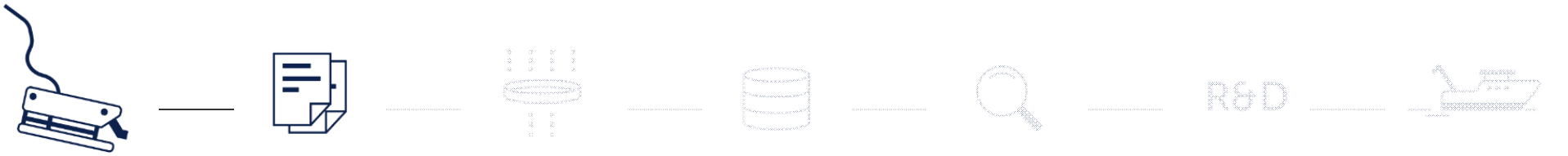
Current Approach - Operations

Survey

Typically every one or two years.

Current Approach - Operations

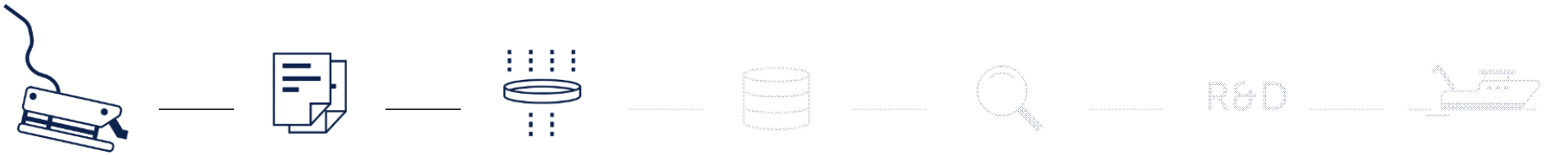


Survey | **Survey** assessment | Level 1 screening | Level 2 assessment | Level 3 assessment | Potential research and development | Intervention (if needed)

Survey assessment

Comparing span listings and survey profile, sometimes with FEA.

Current Approach - Operations



Survey

Survey assessment

Level 1 screening

Level 2 assessment

Level 3 assessment

Potential research and development

Intervention (if needed)

Level 1 screening

Automatic screening against span listings, identifying potential span threats.

Current Approach - Operations

Survey

Survey assessment

Level 1 screening

Level 2 assessment

Level 3 assessment

Potential research and development

Intervention (if needed)

Level 2 assessment

Database of fatigue calculations, reducing number of threats and identifying multi-span configurations.

Current Approach - Operations

Survey

Survey assessment

Level 1 screening

Level 2 assessment

Level 3 assessment

Potential research and development

Intervention (if needed)

Level 3 assessment

Detailed analysis of high risk pipelines and multi-span configurations.

Current approach - Operations

Survey

Survey assessment

Level 1 screening

Level 2 assessment

Level 3 assessment

Potential research and development

Intervention (if needed)

Intervention

Costly result when level 3 and sometimes R&D analysis are insufficient to build enough confidence.

Current Approach - Operations

Survey

Survey assessment

Level 1 screening

Level 2 assessment

Level 3 assessment

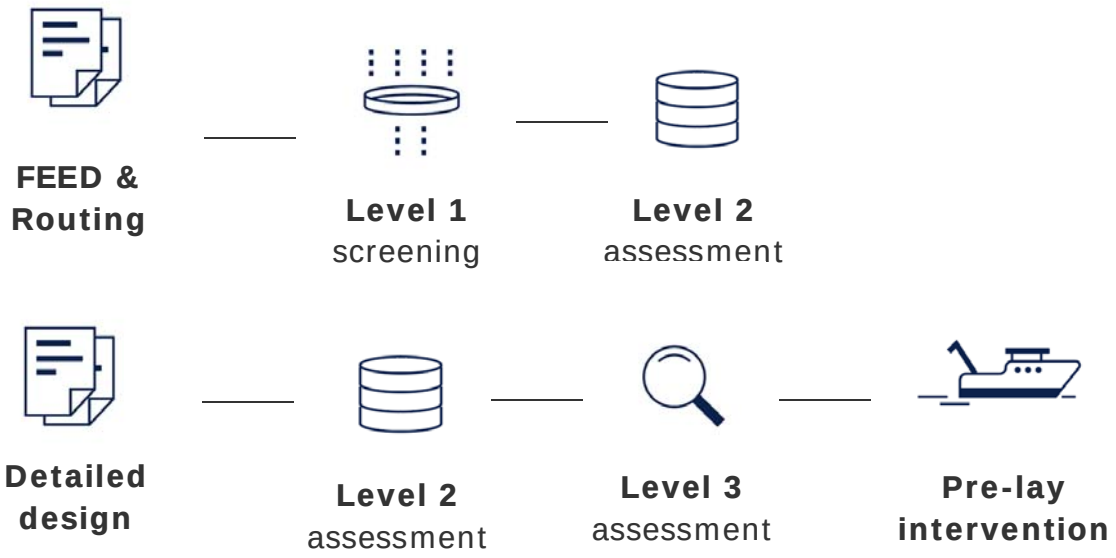
Potential research and development

Intervention (if needed)

In total

A good approach, but calculating span by span is a slow and manual process and especially tedious to account for interacting multi-spans. The result often ends with overly conservative remaining fatigue life and consequently unnecessary interventions.

Current Approach – Routing and Detailed Design



A robust approach, but

- Slow and manual
- Conservative risk assessments
- Repetitive
- Developed when computational power was limited

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New research available

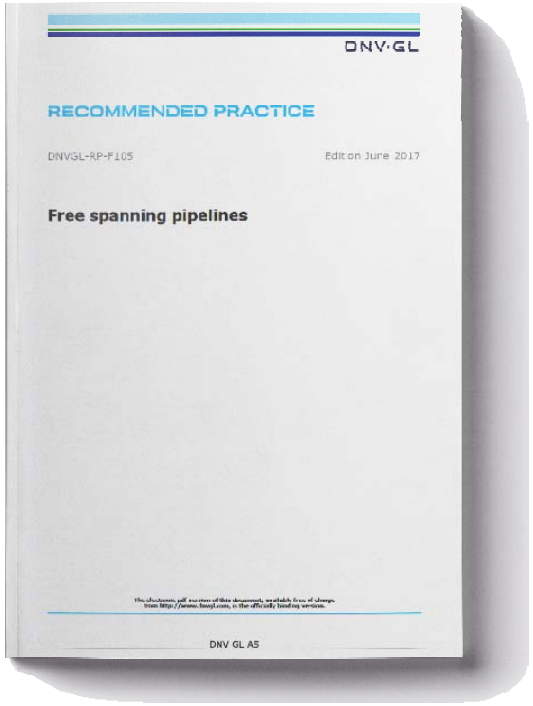
- **Research**

  Flat seabed modal response approximations and an improved FEA solver for dynamic response for a given static configuration.

- **Advanced geotechnical assessment**

  Amplitude dependent stiffness and damping

- **New revision of DNVGL-RP-F105**
  - A new force model for direct wave action, which allows for multi-mode and multi-span analyses
  - Highly accurate modal response quantity calculation procedures for short spans
  - A new response model for cross-flow VIV in waves with low Keulegan-Carpenter numbers



Recent advances with R&D – Next revision of DNVGL-RP-F105

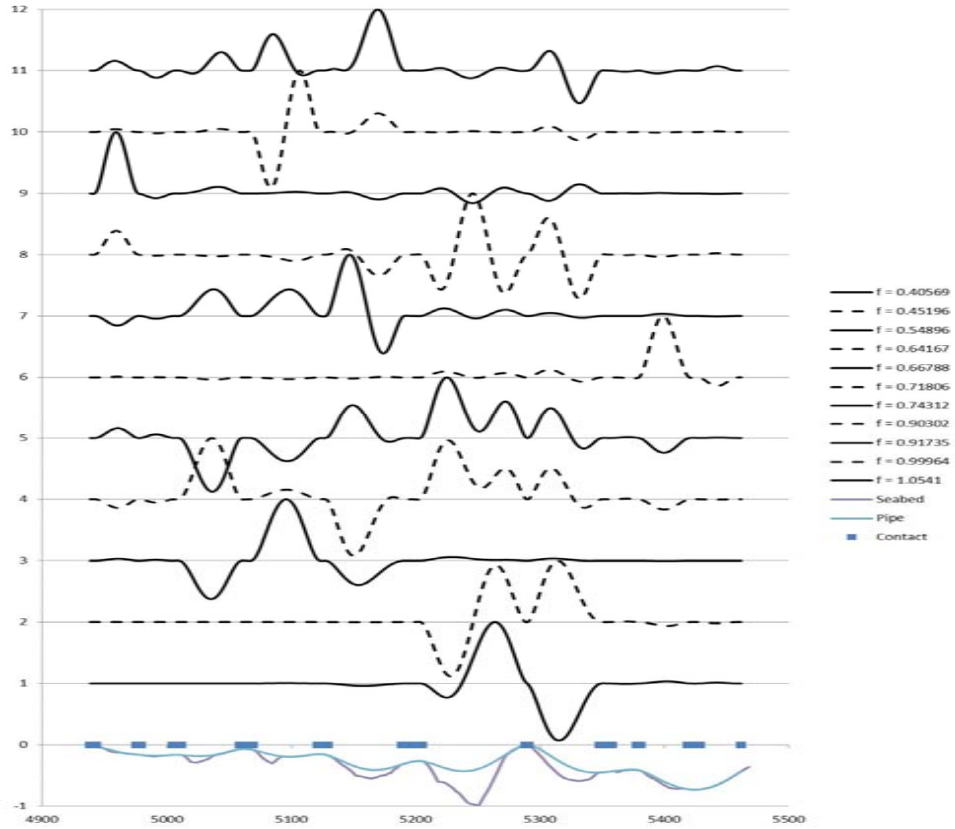
- Non-linear soil damping and stiffness
  - Increased damping for IL VIV, with particular advances in multi-span configurations
- FIST JIP, running now and expected to complete Q2 2019
  - Solves the small gap, IL VIV in irregular waves and scour trench shielding problems
- Three PhD works from University of Oslo and NTNU, 2014, 2016 and 2018
- Boundary layer corrections in combined wave and current conditions (from PILS JIP)

Reduced conservatism in fatigue
and extreme environmental load predictions

Cloud computing & storage

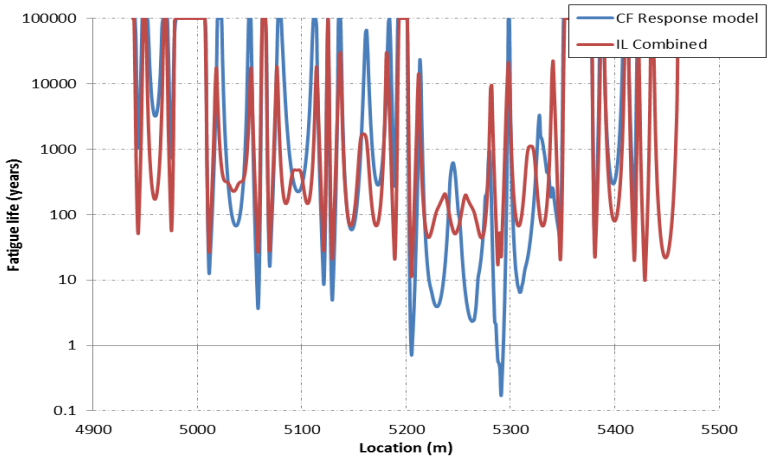
With added computational power

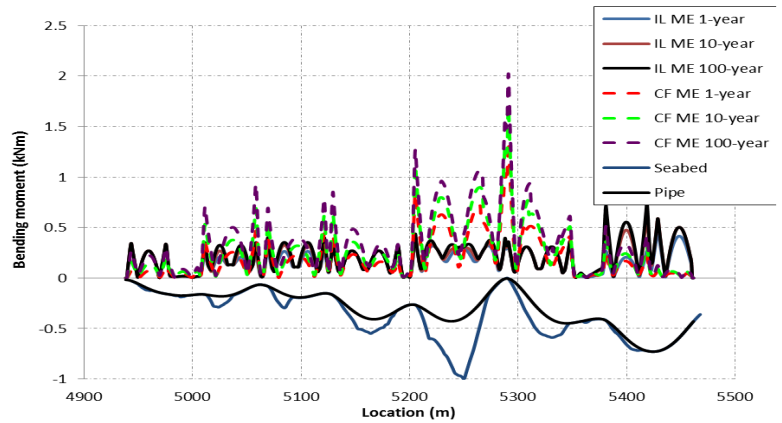
- Parametric bottom roughness analyses
  - Determine best fit to survey configuration
  - Reduce uncertainty on key input parameters
  - Automated identification of survey inaccuracy
- Parametric dynamic analyses
  - Eigen-value calculations counting around 5-6 times the number of spans
  - Automated identification of interacting spans
  - Solves the “long model problem”
- Parametric full level 3 fatigue analyses for the entire pipeline accounting for
  - Continuous variation in operational conditions
  - “Level 4” Assessment: 1000’s of full Level 3 assessments account for all survey cycles and changing conditions over pipeline’s lifetime



With systematic unlimited storage

- All input stored for all survey cycles and all other reported sources of fatigue
- Damage is stored as function of KP
- Once database is established, new surveys can be included and results updated with little effort
- Systematic comparisons between surveys and Bottom Roughness Analysis
  - Excellent confidence on stationary beds
  - Tracking movement and scour developments on mobile beds
- Updates to inputs, including past conditions, or new models/methodologies can be run with immediate effect and retroactively





New Approach - FatFree Global - Operations

Survey

Survey & Parametric BRA

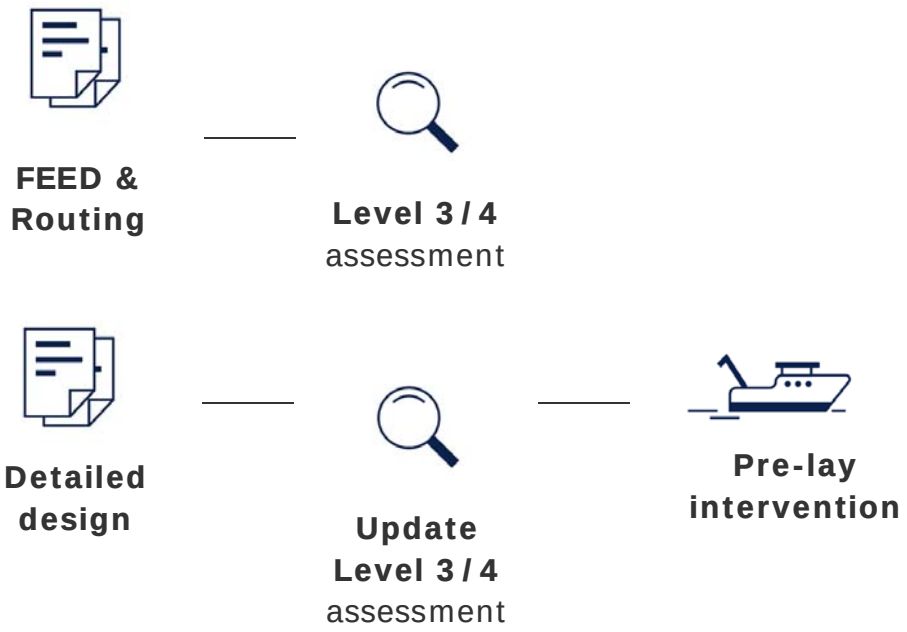
Level 4 (whole pipeline length & history) in combination with R&D

Intervention (if needed)

Better approach

- Automated BRA, so we're working with accurate data.
- Optimised approach and "Level 4" assessment, to reduce unnecessary conservatism.
- Full Level 4 assessment, at lower cost than current Level 3 assessment.

New Approach – FatFree Global - Routing and Detailed Design



Top benefits

- Significantly reduced time and cost for engineering
- One automated run for the entire pipeline (Level 3/4)
- More accurate, reducing unnecessarily conservative risk assessments
- Automatically accounts for interacting multi-spans
- Significantly increased accuracy of pre-lay intervention cost estimates in Routing design
- Decreased impact from design changes

Problem (meta-) breakdown

Bottom roughness →
- Static configuration
- Effective axial force
- Contact assessment
- Operating phases

Dynamic FEA →
- Short (as possible) model beneficial
- Modal interaction assessment

Identification of span areas →
- Sorting span areas and single spans

Data processing
- Onset assessment
- Packaging (span areas)
- Modal stresses

↓

All other input →

FatFREE calculation engine

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Case Studies

Case I – Bypass pipeline

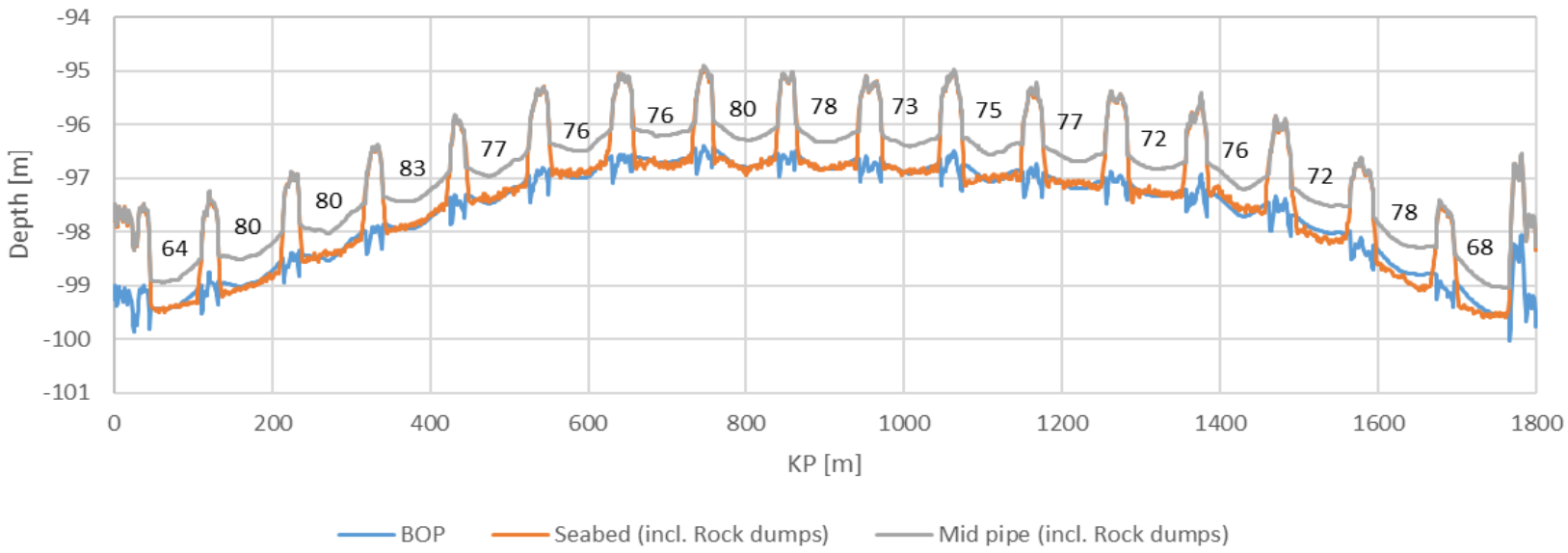
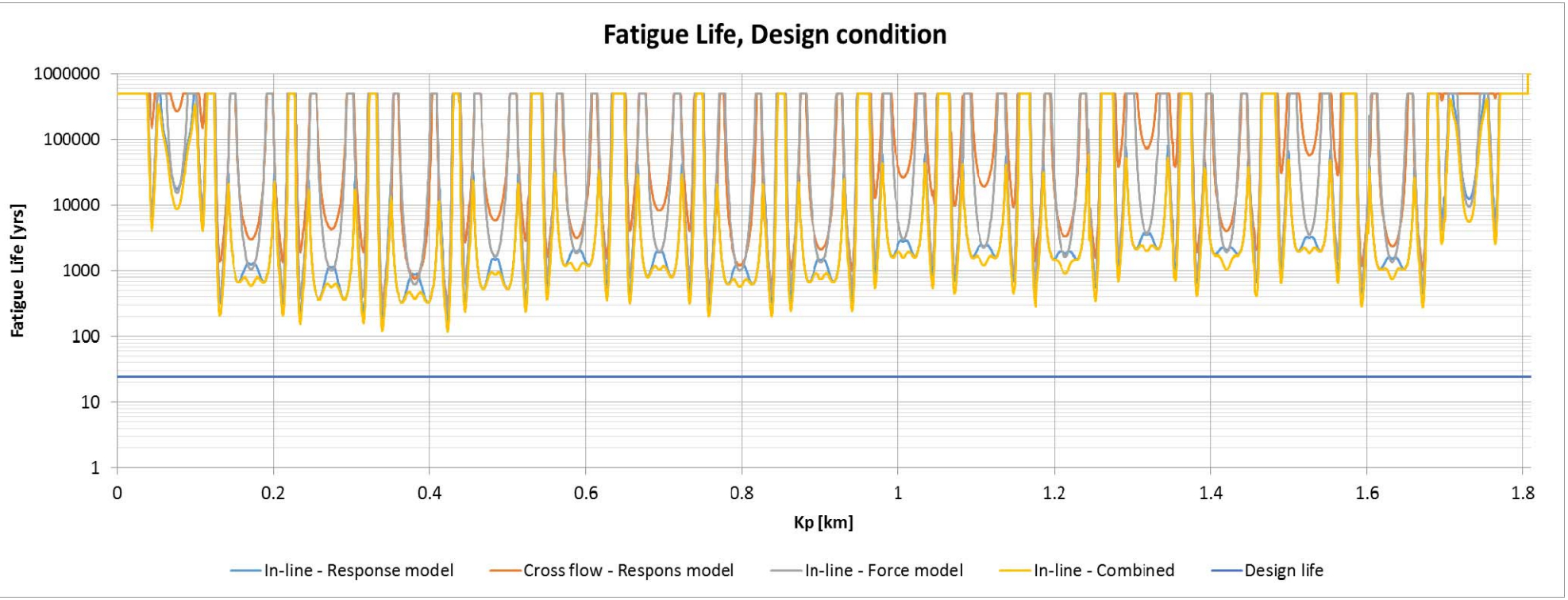


Figure shows static configuration of pipeline bypass with free spans between rock berms.

Previous work indicated fatigue life of 4 years, and plans were to cover the ~2km of pipe with a rock-berm.

Case I - Accumulated remaining fatigue life prediction



Actual Fatigue Life > 100 years.

Discussions

Causes of change in conclusion (from 4 to 100 years of fatigue life)

Improved understanding of survey and input

Improved account of historical fatigue exposure

Improvements to methodology

Case I

1.77 km pipe-in-pipe bundle with an outer diameter of 40''.
17 consecutive, interactive free spans of length 65m-83m driven by scouring.

- Calculations using Global Free Span Service shows that present configuration is acceptable and there is no need for intervention.
- Planned rock installation campaign avoided

0.8-1.2 mAUD cost reduction

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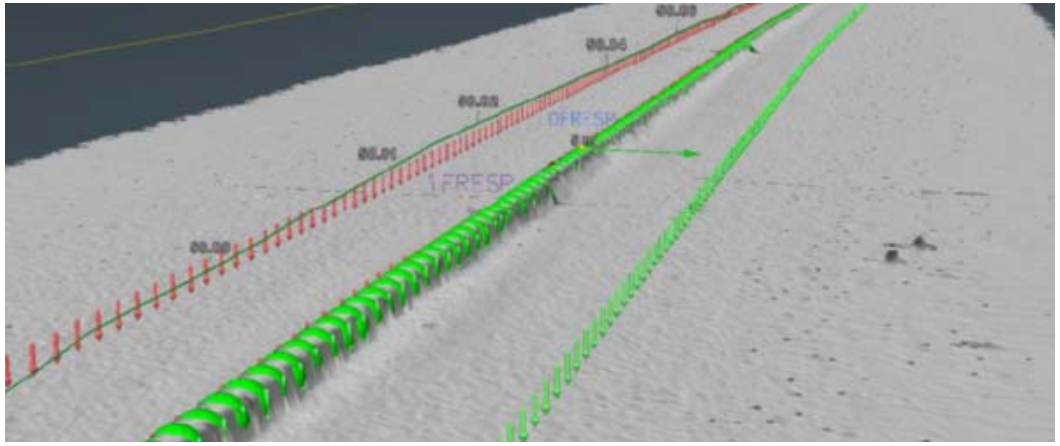
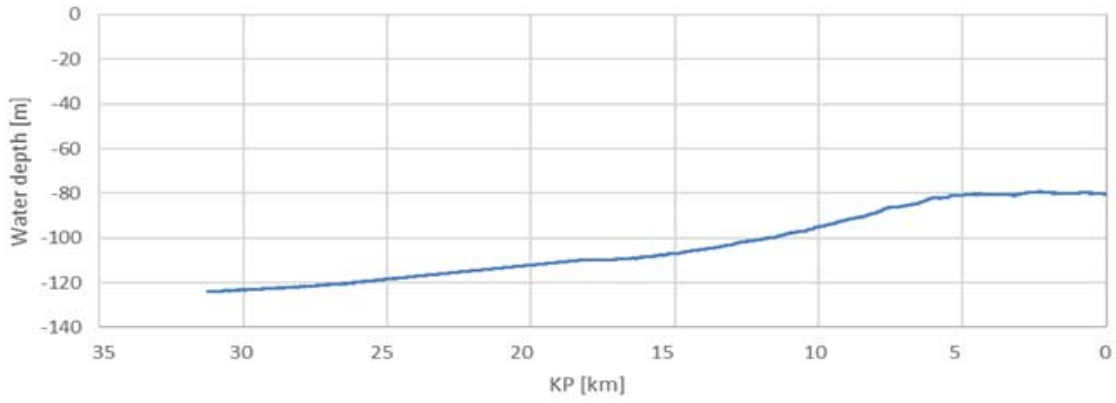
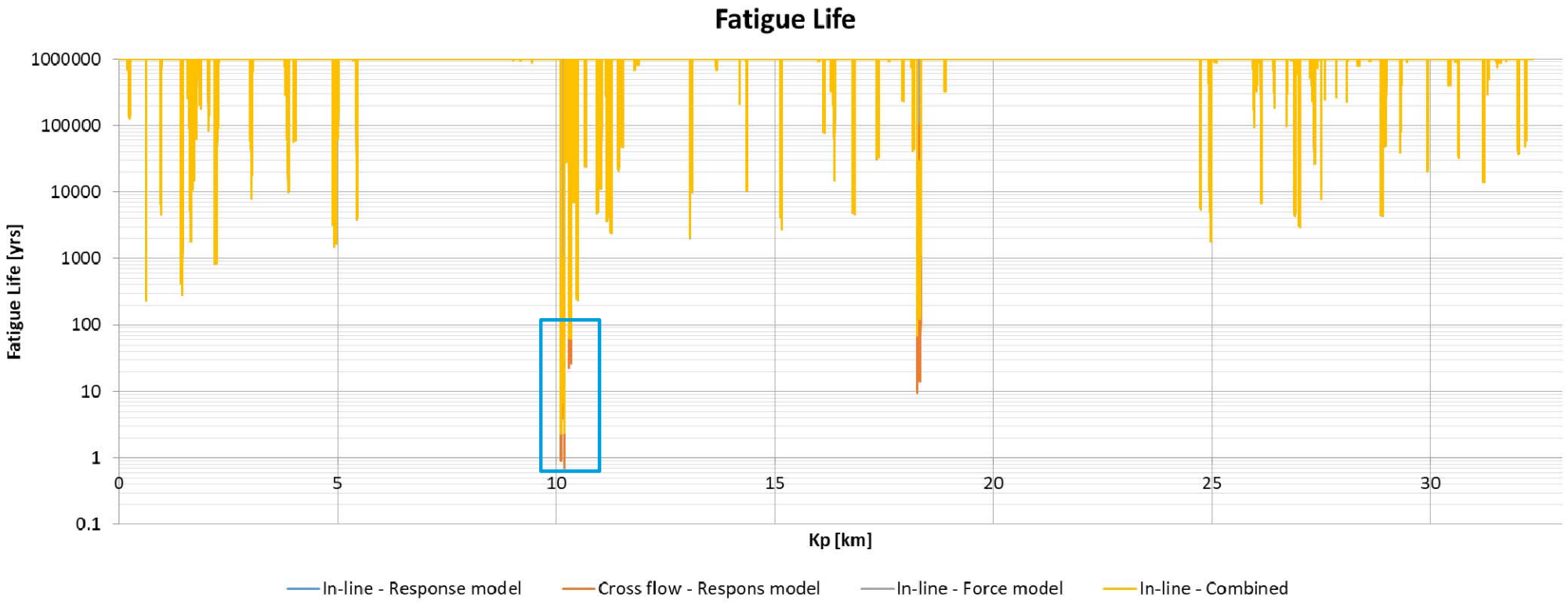
Case II

- Length: approx. 33km
- Size: 12'' (273.1mm x 12.7mm)
- Seabed: Sand
- Water depth: 80m - 125m
- Operated since 1993 with 22 surveys conducted
- Sandy mobile seabed with considerable scouring

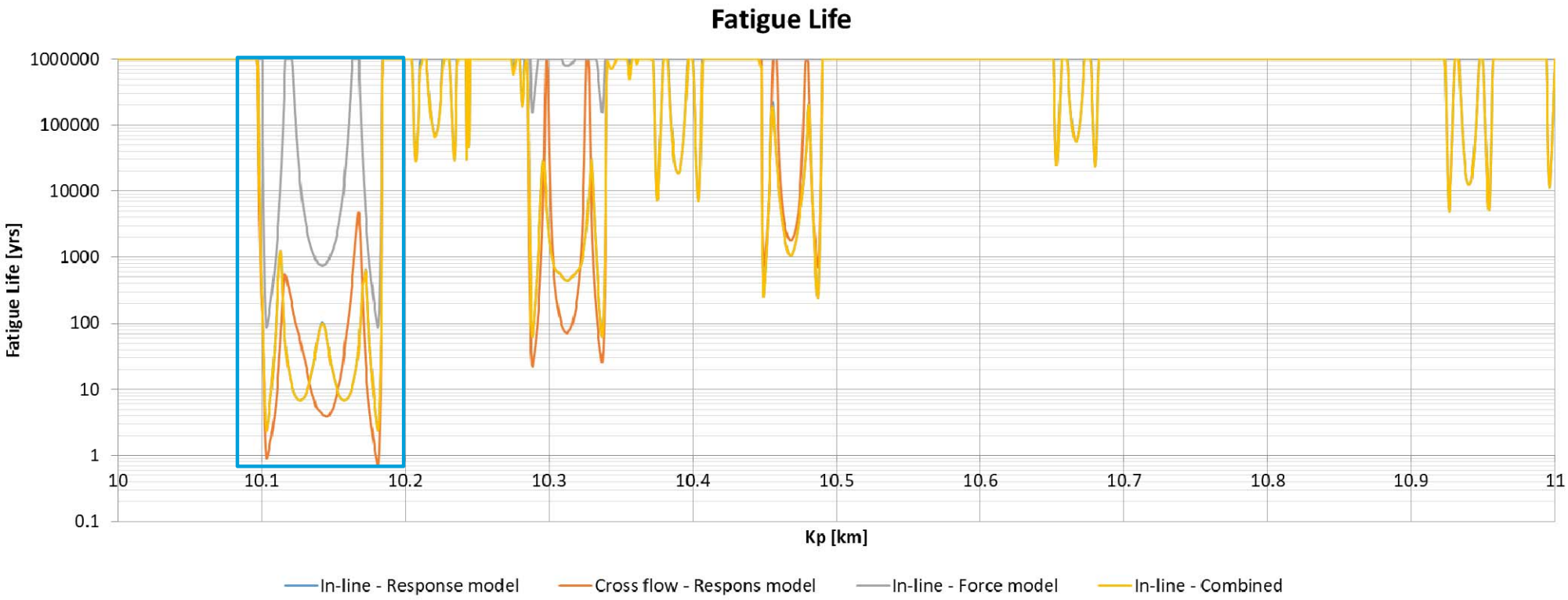




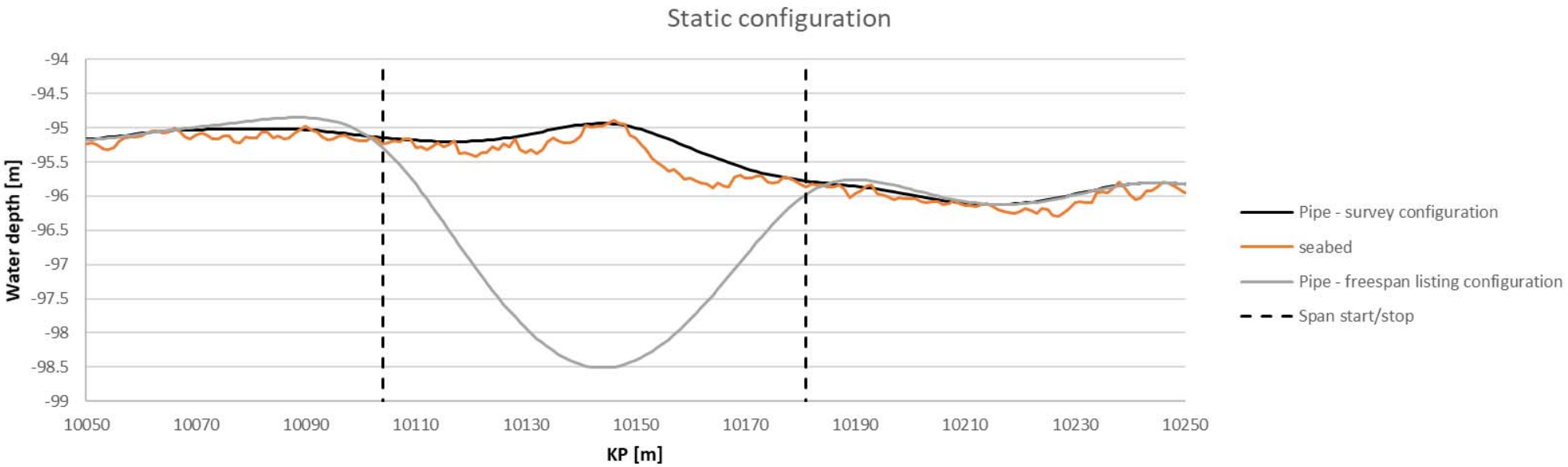
Case II - FLS results



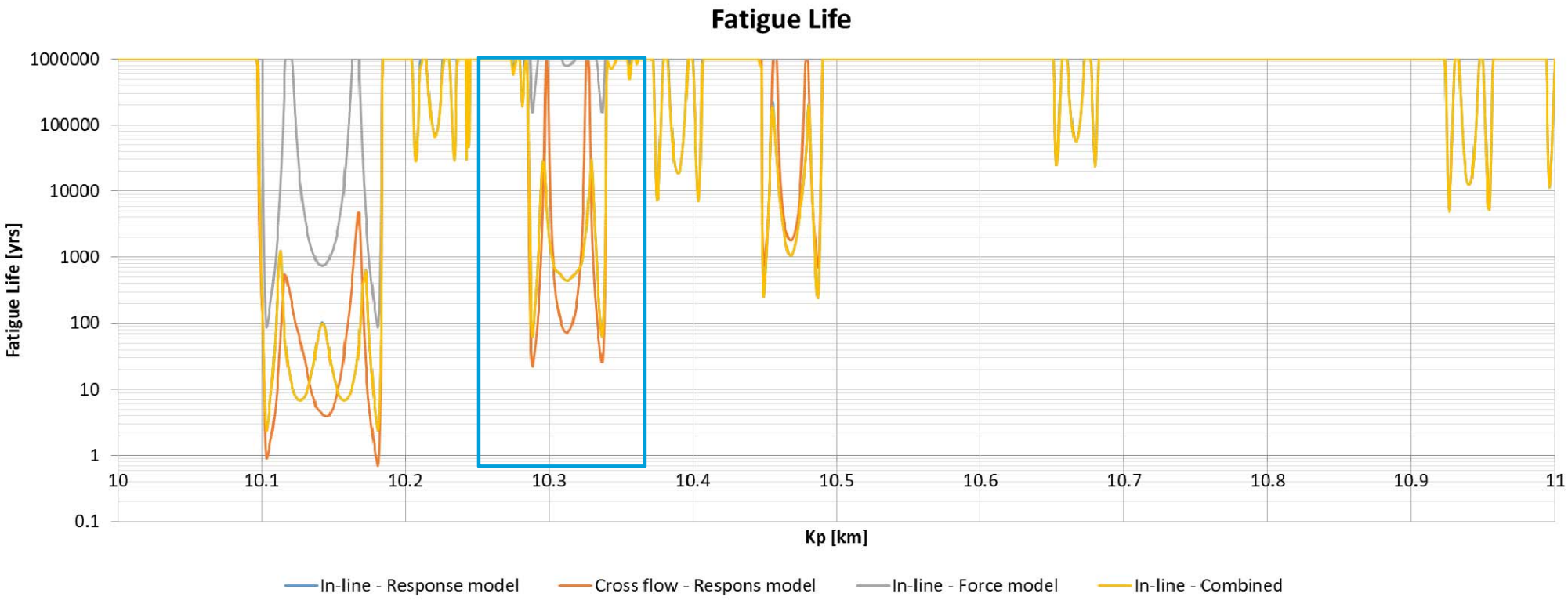
Case II - FLS results (KP 10.0 – KP 11.0)



Case II - Static configuration



FLS results (KP 10.0 – KP 11.0)



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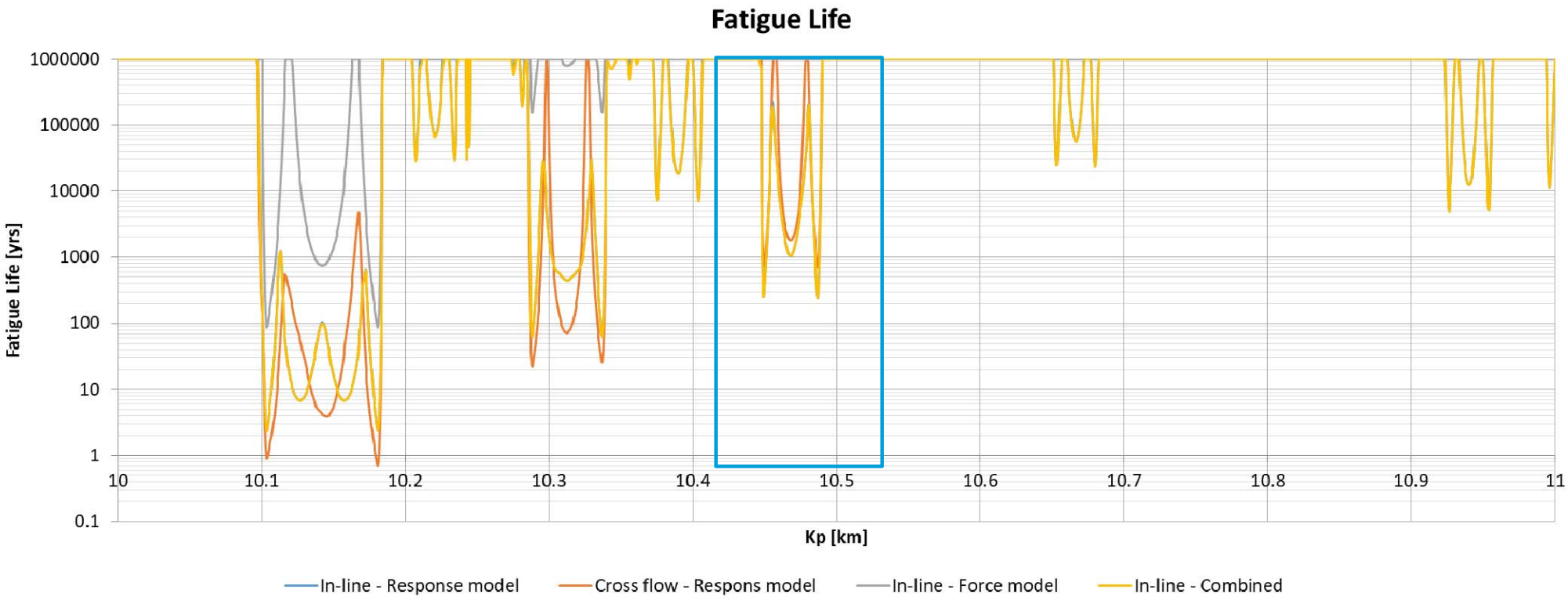
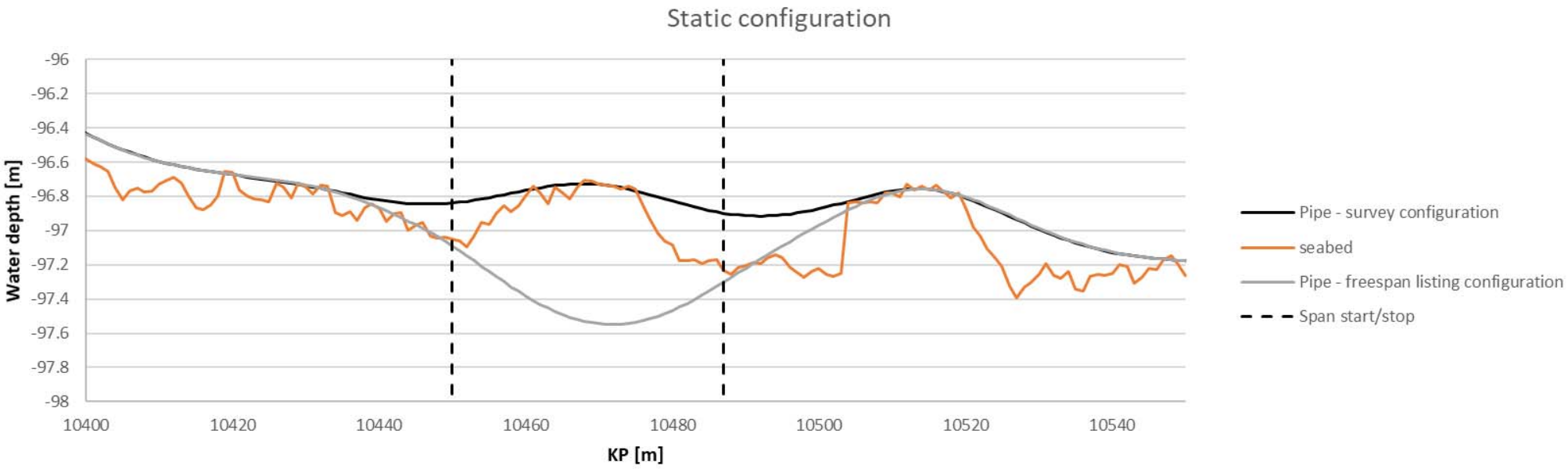


Static configuration



Work in progress.
Awaiting cost impact.

Case II

33 km long 12'' gas export gas pipeline.

Difficulties with mobile seabed.

- Interventions early 2000 and new interventions 2016
- All of them could have been avoided
- Reduced criticality
- High potential saving in reduced survey frequency

XXX mAUD potential cost reduction?

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Case III

54 km long 32'' gas export pipeline installed in 2001.

- Severe scouring issues triggering a lot of activity:
  - 11 surveys in the years 2002-2016
  - Intervention on 71 spans in 2006
  - Intervention on 192 spans in 2011
- Estimating the remaining fatigue life using Global Free Span showed that the free span intervention campaigns could have been avoided.

2.5-3.3 mAUD in potential cost reduction

Key takeaways

Automated BRA optimises inputs and identifies inaccurate survey data.

The latest R&D & “Level 4” approach improves accuracy and reduces conservatism of results.

Full Level 3/4 assessment of entire pipeline, for the same effort & cost as a Level 3 for a selected span area previously.

Real case studies show significant savings in reduced engineering effort and interventions.

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