**3DSBP Analysis of Trenching Techniques and their Influence on Cable Burial Performance**

## Introduction

Successful trenching is critical to ensuring the long-term integrity and operational lifespan of subsea cables. Adequate burial protects cables from external hazards such as fishing activity, anchoring, and hydrodynamic forces, while also contributing to thermal stability and mechanical protection (Brunning & Machin, 2014). However, achieving consistent burial depth remains in some cases a significant challenge due to spatial variability in seabed conditions and the differing capabilities of trenching technologies. Sub-Bottom Imager (SBI) synthetic aperture sonar (SAS) data provides high-resolution imaging of the shallow subsurface, enabling detailed assessment of cable burial performance and cable–soil interactions across a range of shallow soil environments. This study evaluates the effectiveness of multiple trenching methodologies through analysis of SBI SAS data, with the aim of identifying trends in performance, understanding the influence of shallow soil variability, and assessing the likelihood of undesirable installation outcomes.

The analysis focuses on four principal trenching techniques commonly employed in subsea cable installation: jetting systems, mass flow excavators (MFE), mechanical trenchers (specifically chain cutters), and ploughing. These techniques represent a spectrum of excavation approaches, ranging from sediment fluidisation to mechanical cutting and passive displacement. Jetting and MFE systems rely on fluidisation processes, using seawater jets to mobilise and redistribute sediments, whereas mechanical trenchers physically cut into the seabed using rotating chains fitted with cutting picks (Njock et al., 2010). Ploughing involves towing a seabed tool that displaces sediment laterally to create a trench into which the cable is laid (Bransby et al., 2018). Each method exhibits distinct performance characteristics depending on sediment type, strength/density, and seabed morphology, making the selection of an appropriate trenching technique highly dependent on local shallow soil conditions (Figure 1).

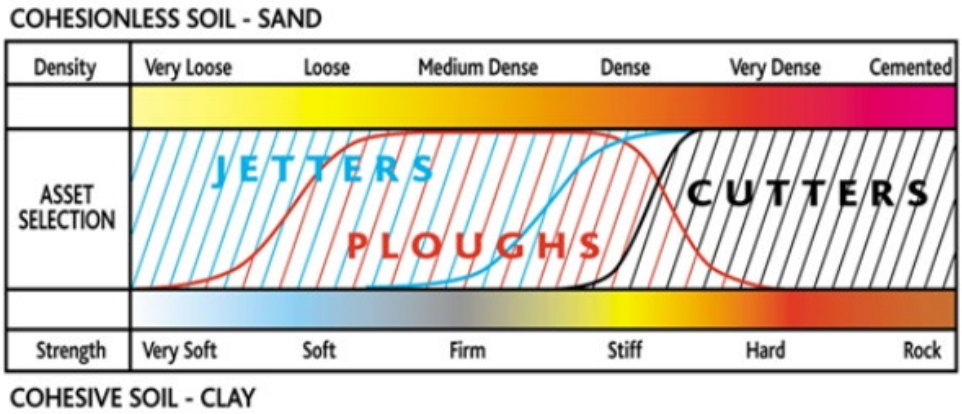


*Figure 1 The expected trencher applicability for various shallow soil conditions for planning which trenching technique should be used (Brunning & Machin, 2014)*

## Analysis Parameters and Results

To ensure consistency and reduce the influence of external variables, the analysis was restricted to export cable bundles surveyed using a single SBI platform. Parameters that cannot be directly observed within SBI data, such as weather conditions during installation or cable lay tension, were excluded. The study assumes that trenching techniques were initially selected based on the prevailing shallow soil conditions along each cable route. Deviations from expected performance are therefore interpreted as responses to unanticipated or spatially variable shallow soil conditions. The analysis focuses on quantifiable metrics derived from SBI data, including the percentage achievement of target depth of cover (DoC), lateral and vertical deviations from the planned cable route, and variations in acoustic response indicative of sediment redistribution and seabed disruption.

The results demonstrate clear differences in trenching performance across both technique and shallow soil setting. Mechanical (chain) trenching consistently exhibits the most robust performance, particularly in high-strength sediments such as hard clays and very dense, coarse sediments such as glacial till (with high gravel content). SBI data shows that this method is capable of achieving relatively uniform burial depths with consistent backfill, even in areas of geological transitions (Figure 2A). Minor deviations from target burial depth are observed in zones containing localised heterogeneities such as cobbles and boulders, which can reduce penetration efficiency (Mellett et al., 2015). However, these variations are generally limited in magnitude and do not significantly compromise overall trenching performance. The ability of mechanical trenchers to directly cut through high-strength/very dense sediments makes them less sensitive to changes in sediment properties, resulting in a high probability of achieving desired installation depths.

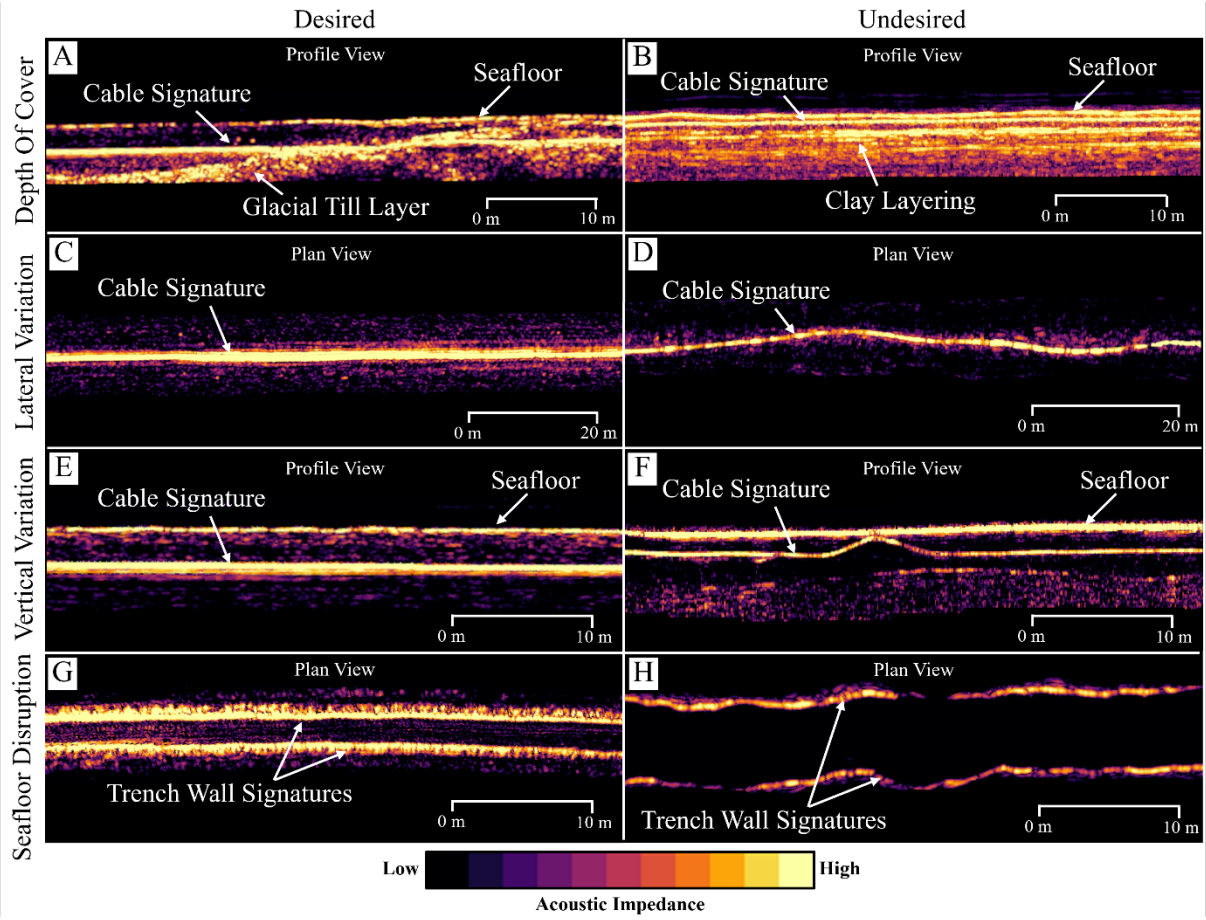


*Figure 2 - SBI SAS data examples illustrating desired and undesired trenching outcomes across key performance variables. (A) Consistent depth of cover (DoC) achieved by mechanical trenching across varying shallow soil conditions. (B) Failure to achieve target DoC for a MFE in high strength clay-rich sediments. (C) Minimal horizontal deviation of a cable installed using jet trenching. (D) Increased horizontal variability associated with jet trenching in very low strength sediments, likely due to vehicle instability. (E) Consistent vertical cable profile achieved by mechanical trenching. (F) Vertical variability in cable position during jet trenching, potentially related to variations in applied jetting pressure in the absence of clear geological controls. (G) Minimum seafloor disruption by jet trenching with a uniform trench produced (H) High degree of seafloor disruption from MFE, creating an irregular, broad trench where potentially the full extent of the seafloor disruption goes outside of the SBI data coverage as undisturbed seafloor outside the trench were not captured*

In contrast, MFE is shown to be the most sensitive to shallow soil variability. While MFE systems perform effectively in homogeneous, non-cohesive sediment such as sand, their performance degrades significantly in the presence of cohesive high-strength sediments (Figure 2B). SBI observations indicate

frequent failure to achieve target burial depth in such conditions, with some cable sections remaining partially exposed. In areas where cohesive sediment strength increases, MFE systems are unable to penetrate sufficiently, resulting in reduced burial and increased variability in cable depth. Furthermore, repeated passes of MFE equipment in heterogeneous shallow soil environments do not necessarily improve burial depth but instead lead to increased trench width and more chaotic sediment redistribution (Figure 2H). This behaviour reflects the non-contact nature of MFE systems, which rely on fluidisation rather than direct excavation. Therefore, they are limited by the resistance of underlying materials. As a result, with MFE typically demonstrating desirable results in non-cohesive sediments, MFE does exhibit the highest occurrence of undesirable outcomes with being the most susceptible to high-strength, cohesive sediments.

Jet trenching occupies an intermediate position in terms of performance and sensitivity to shallow soil conditions. It is most effective in low strength, fine-grained cohesive sediments such as clays and silts, where fluidisation can be achieved efficiently (Figure 2C). In these environments, jet trenching is capable of producing adequate burial depths with relatively consistent results. However, because jet trenchers typically operate as tracked vehicles in contact with the seabed, their performance can be compromised in very low strength cohesive sediments. SBI data reveals instances where the trenching unit becomes unstable and sinks into the seabed, leading to irregular trench geometry and inconsistent cable burial (Figure 2D). Additionally, in stratified sediments where loose non-cohesive or low strength cohesive sediment layers overlie coarser, dense non-cohesive sediments such as low strength clay overlaying very dense gravelly sand, jetting may expose the underlying layers without achieving sufficient penetration. This can cause the cable to follow the interface between sediment types rather than reaching the desired depth. This highlights the importance of understanding shallow soil conditions when selecting jetting as a trenching method.

Ploughing techniques demonstrate a distinct set of characteristics, particularly in relation to lateral cable positioning. The highest degree of lateral variability was observed in cases where pre-installation ploughing was used as the sole trenching method. Under this approach, the cable is laid directly into the pre-formed open trench, the width of which limits positional control and results in increased lateral deviation from the intended route. While ploughing can be effective across a range of sediment types and is advantageous in terms of operational efficiency, its performance is influenced by both sediment properties and the absence of any following post-lay trenching using other techniques. Despite these limitations, ploughing remains a viable method in cobble/boulder rich sediments, particularly where cost and operational constraints are significant factors.

Vertical cable variability is observed across all trenching methods and is primarily attributed to shallow soil influences and, to a lesser extent, installation parameters. SBI data indicates that vertical deviations often correspond to changes in sediment properties, particularly in heterogenous shallow soils environments. Conversely, in very low strength cohesive or loose non-cohesive sediments, excessive fluidisation can lead to over-penetration and downward displacement of the cable. These findings emphasise the complex interaction between the trenching technique and shallow soils, and the difficulty of achieving consistent burial in heterogeneous shallow soil environments.

**Discussion**

A comparative evaluation of the four trenching methods was conducted using a scoring matrix (Table 1) based on the probability of encountering undesirable outcomes under changing shallow soil conditions. The assessment assigns qualitative scores reflecting the susceptibility of each method to performance variability, with lower scores indicating higher sensitivity to shallow soil changes.

*Table 1 Scoring matrix used to evaluate trenching method performance under changing shallow soil conditions, based on observations from post-installation SBI surveys. Scores reflect the probability of undesirable outcomes, with lower scores indicating greater susceptibility to shallow soil variability and higher scores indicating more consistent performance across differing sediment conditions.*

| Method | Not Achieving DoC | Lateral Variation | Vertical Variation | Seafloor Disruption | Score |
|---|---|---|---|---|---|
| Mechanical | Low (2) | Moderate (1) | Low (2) | Low (2) | 7 |
| Jetting | Moderate (1) | Moderate (1) | High (0) | Low (2) | 4 |
| Ploughing | Moderate (1) | High (0) | Moderate (1) | Moderate (1) | 3 |
| MFE | High (0) | Low (2) | High (0) | High (0) | 2 |

Mechanical trenching ranks highest, demonstrating the greatest resilience to variations in sediment strength/density and composition. Jet trenching achieves moderate scores, reflecting its effectiveness in suitable shallow soil conditions, however reduced reliability in complex or highly variable shallow soil environments. Ploughing exhibits moderate to high variability, particularly in terms of lateral control, while MFE ranks lowest due to its pronounced sensitivity to sediment strength/density and limited penetration capability in heterogeneous shallow soil settings.

It is important to acknowledge that this analysis is constrained by the limitations of SBI data, which provides detailed 3D acoustic imaging of the shallow subsurface, however the data does not capture all factors influencing trenching performance. Variables such as environmental conditions during installation, equipment configuration, and operational parameters cannot be directly assessed using post-installation 3DSBP geophysical survey data. However, by analysing numerous SBI datasets spanning multiple projects and shallow soil settings, the study is able to identify consistent trends and reduce the influence of isolated or site-specific factors. This approach provides a robust basis for comparative evaluation, despite the inherent limitations of the data.

## Conclusion

The findings of this study highlight the critical role of shallow soil variability in determining trenching performance, showing that even when methods are selected based on the prevailing route conditions, localised sediment differences can lead to significant deviations from expected outcomes. Integrating pre-cable lay 3DSBP geophysical survey data with other geophysical and geotechnical data provides a promising approach to identifying spatial variations in shallow soil conditions and optimising trenching method selection along cable routes. Overall, trenching performance is strongly influenced by both methodology and shallow soil conditions: mechanical trenching offers the most consistent results across varied environments, MFE is most susceptible to performance degradation in heterogeneous or high-strength cohesive sediments, and jet trenching and ploughing present intermediate advantages and limitations. The use of SBI data further enhances the understanding of cable–shallow soil interactions, emphasising the importance of integrated data approaches to improve method selection, reduce undesirable outcomes, and mitigate installation risk in complex shallow soil environments.

## References

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