Geospatial Data Integration For Geotechnical Site Characterisation

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Marine Site Characterisation, Fugro

ABSTRACT: Offshore energy developments can cover extremely large spatial extents and have a high potential for encountering variable soil conditions. Datasets acquired to characterise the foundation zone for large sites are similarly large and detailed, particularly as data acquisition techniques evolve and resolution increases. To extract maximum value from the data and improve confidence in geotechnical site characterisation, smart data management is essential.

We use GIS to integrate data from individual disciplines into a map-based database accessible to the entire project team. Integration of multidisciplinary datasets in a geospatial framework is crucial to validate and contextualise each dataset. Spatial analysis of foundation zone data culminates in an integrated engineering ground model. This paper will describe our approach to data integration for offshore site characterisation via the application of bespoke GIS add-ins developed to enhance data access, integration analysis and visualisation.

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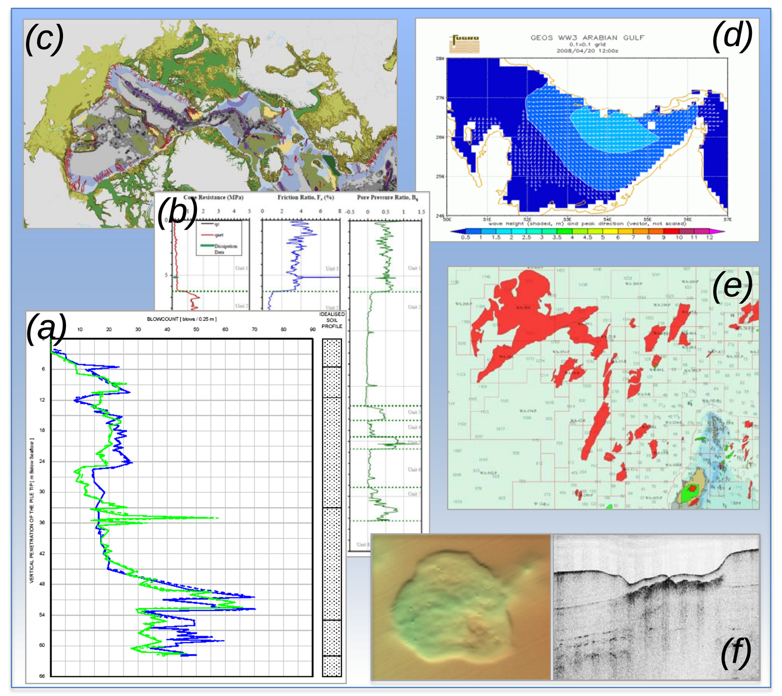
AVAILABLE DATASETS

From initial site selection, data acquisition, design, construction and operation, offshore energy developments generate huge volumes of data emanating from a range of specialist disciplines each uniquely required to support development. These multidisciplinary datasets each have a geospatial component reflecting their geographic location, and interrelation with other locations.



GIS data management offers an efficient way of storing geospatial datasets in a single repository, enabling rapid interrogation, analysis and visualisation while providing data access to all project stakeholders.

The layered structure of a GIS map-interface provides greater site understanding than would be gained by the isolated study of disparate datasets. Map-based visualisation of datasets also portrays the geographic distribution and scarcity of data. Geospatial data integration is therefore crucial for robust site characterisation.

Figure 1: (a) engineering, (b) geotechnical, (c) geological [4], (d) metocean, (e) legislative, and (f) geophysical datasets.

SITE CHARACTERISATION OBJECTIVES AND CHALLENGES

The primary objective of site characterisation is to understand the processes and properties of the seabed and their implications on engineering. Site characterisation typically results in the generation of an engineering ground model.

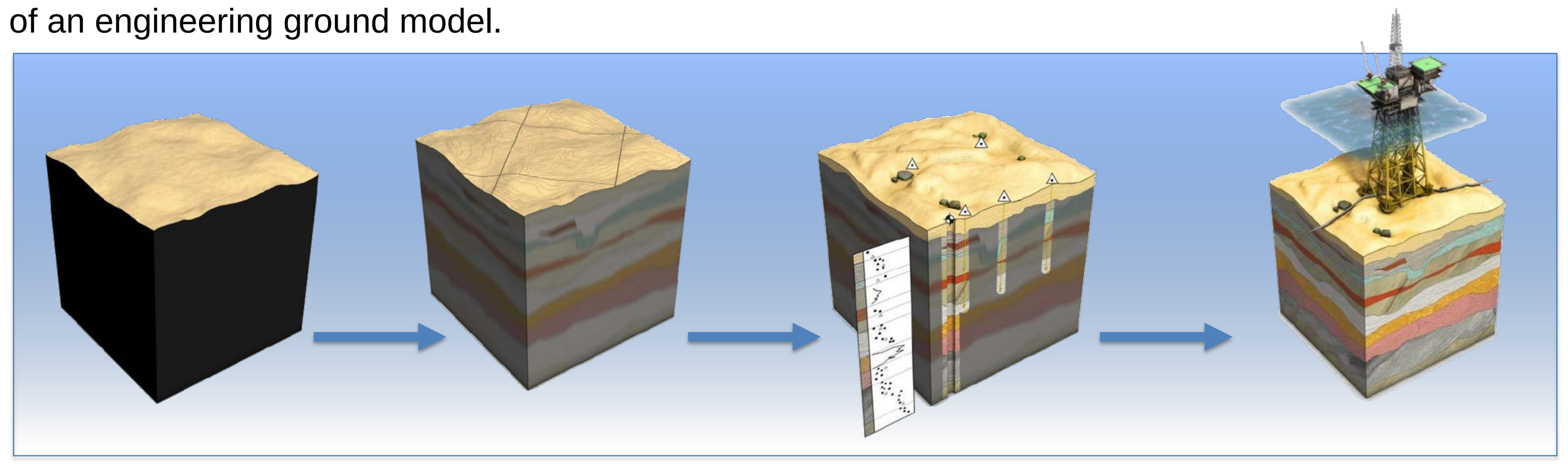


Figure 2: Conceptual evolution of site characterisation from initial site selection to installation and operation. Data integration facilitates characterisation of site conditions as more data are incorporated into the ground model.

Features of offshore developments that can present an engineering or data management challenge with respect to site characterisation include [1]:

- Large spatial extent, particularly pipelines;
- High potential for encountering variable soil conditions;
- Complex equipment layout with numerous foundation locations;
- Potential for requiring multiple foundation concepts;
- Large detailed geotechnical and geophysical datasets;
- Unique engineering considerations.

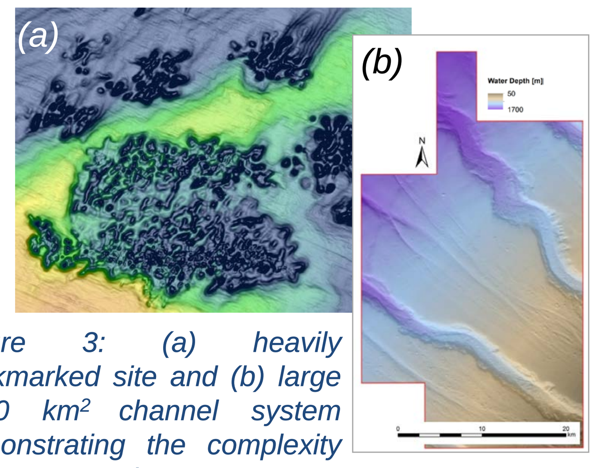


Figure 3: (a) heavily pockmarked site and (b) large ~800 km^2 channel system demonstrating the complexity of deepwater sites.

GEOSPATIAL DATA INTEGRATION

Soil properties have an intrinsic spatial variability that is difficult to capture with any individual site investigation technique. Multidisciplinary datasets are often inconclusive in isolation, but are advantageously complementary when considered in conjunction. The limitations of each investigation technique can be significantly reduced by effective planning and integration as is exemplified in the following two examples.

Example 1: Laterally-continuous geophysical data often enable geotechnical trends to be extrapolated across the extent of the geophysical data. This removes the restriction posed by location-specific geotechnical data acquisition [3].

Fugro's **Composite Plotter** add-in is a bespoke ArcGIS add-in developed to integrate spatially-referenced datasets (Figure 4). A user-defined map selection drives the data that are plotted by the add-in. GIS map layers are configured to read data from a supporting database.

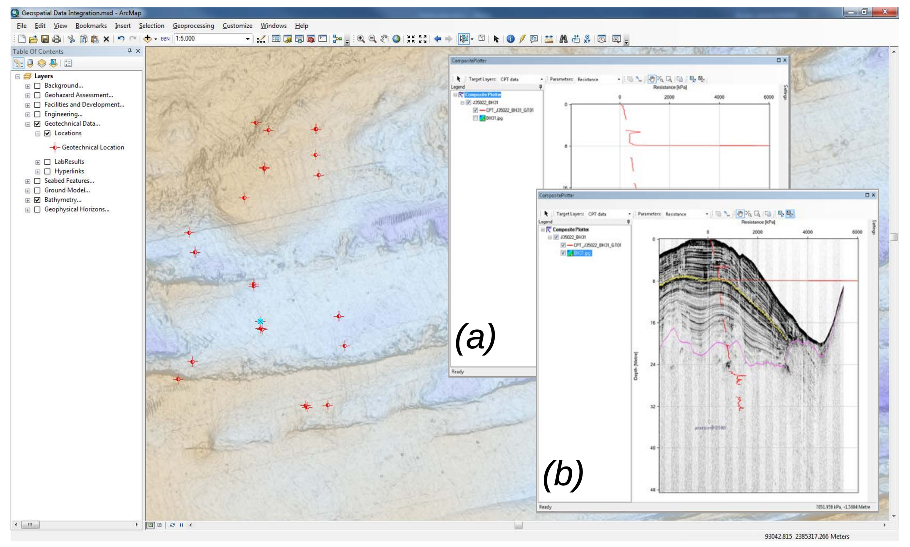
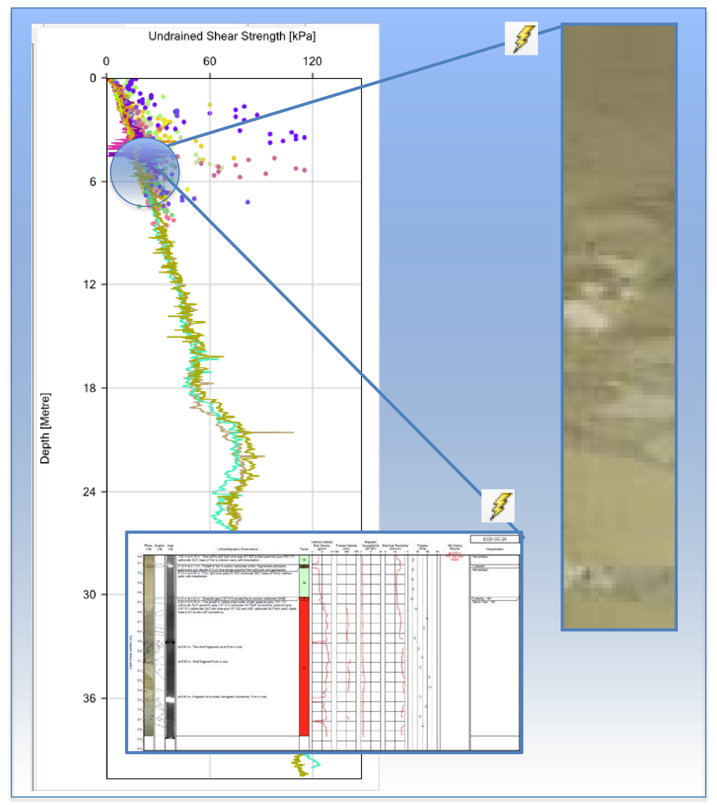


*Figure 4: **Composite Plotter** add-in showing the benefit of complimenting cone penetration test (CPT) data at a discrete location (a) with laterally-continuous sub-bottom-profiler data (b). The resulting interpretation is that the spike in CPT resistance (red) is driven by intersecting a particular geophysical horizon (yellow).*



Example 2: Geotechnical observations can also be explained by consulting geohazard core logs that reveal the depositional history of a site. Sediment age-dating also helps reconstruct a sites geological history.

Figure 5 shows point and line data plotted in the **Composite Plotter** add-in. The data exhibit high shear strength variability between 2 m and 6 m which can be attributed to the differing soil properties of heterogenous constituent clasts observed in the core log. This degree of geological understanding is only achieved through the consultation of all available datasets.

*Figure 5: On-the-fly plotting of user-defined data with the **Composite Plotter** add-in. Supplementary documents e.g. PDF, spreadsheets, imagery are accessed with the hyperlink functionality. GIS data integration enables all of these datasets that relate to the same geographic location to be easily accessed as an integrated dataset.*

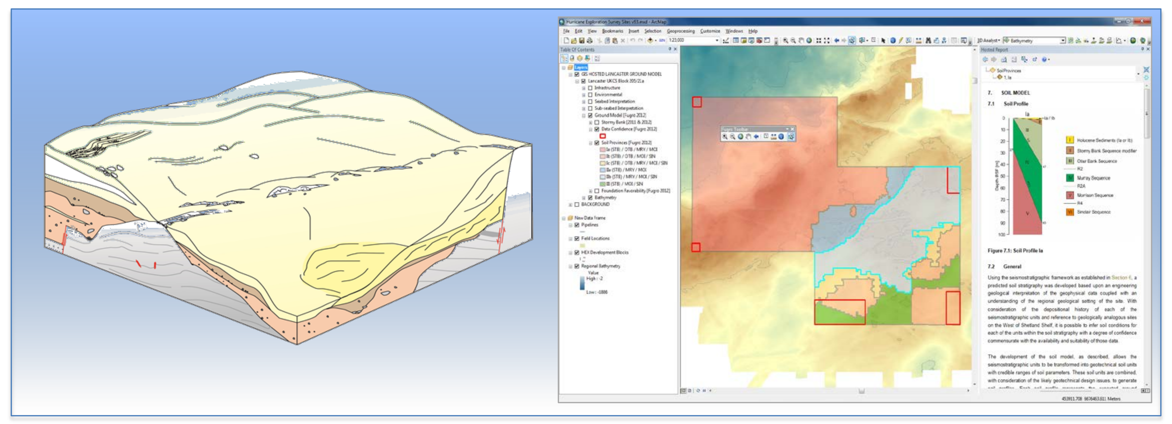
GROUND MODEL

The ground model approach strives to synthesise all available geological, geophysical and geotechnical data to enable a means of appraising and optimising site specific data and the prediction of soil conditions across a site. The ground model manifests itself as a series of GIS layers representing measured and interpreted data which convey the spatial distribution of summarised ground conditions across a site.

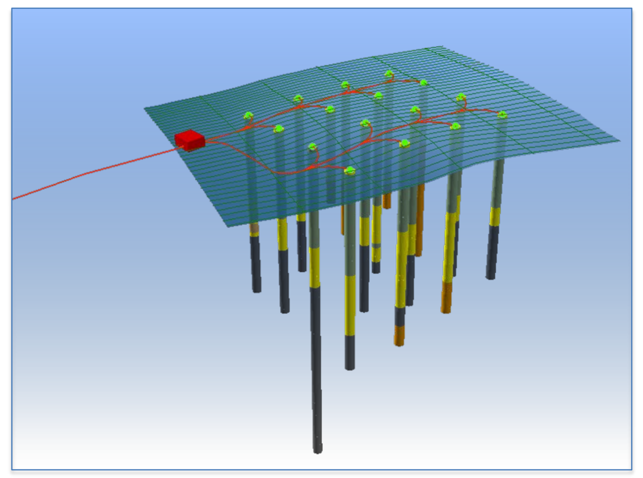
Soil provinces define the lateral extent of similar ground conditions (Figure 6). Each province has a corresponding vertical soil profile that defines the typical formation of soil units and accompanying geotechnical parameters. Geotechnical parameters defined in the ground model typically comprise, at a minimum, undrained shear strength and submerged unit weight. Assimilation of data into these geologically and geotechnically-guided soil provinces ensures that huge quantities of potentially-overwhelming data are coherently sub-divided into informative packages.

Figure 6: Conceptual 3D ground model (left) and ArcMap ground model layers (right).

*Fugro's **Hosted Report** add-in (right) creates an on-the-fly connection between lateral soil provinces and their respective vertical soil profile.*



Mature ground models often evolve to become increasingly tailored to specific engineering applications and have an appropriately defined depth of interest to ensure they are fit-for-purpose. For example pipeline and shallow foundation installation analyses would require different (and are more sensitive to variations in certain) geotechnical parameters than piled foundations.



GIS is particularly well suited to i) present the interconnectedness of spatial and vertical parameters, and ii) query entire datasets to generate tailored subsets for specific exercises. The use of 3D GIS is also instrumental at this stage to appreciate the interrelation of different datasets relative to the depth of planned infrastructure (Figure 7).

Figure 7: 3D depiction of soil type within a grid of borehole locations, referenced relative to the seabed.

BEYOND SITE CHARACTERISATION

Geospatial data integration, site characterisation and the resulting ground model define the most likely ground conditions across a site. Analysts rely on this data model for inputs to engineering-specific geospatial analysis. Predicted ground conditions form the input to quantitative assessments such as:

- Foundation penetration analyses;
- Foundation position optimisation;
- Site-wide and slope-specific slope stability assessments;
- Pipeline and cable route optimisation;
- Site favourability assessments.

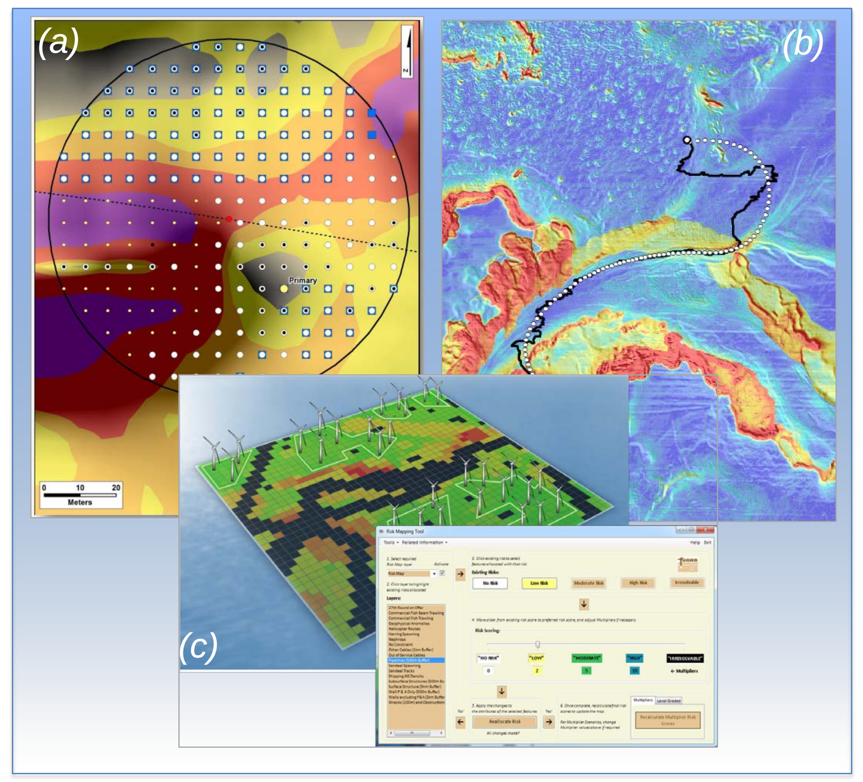


Figure 8: (a) mooring anchor position optimisation [2], (b) GIS-based pipeline route optimisation [6], (c) offshore wind farm site favourability assessment.

CONCLUSIONS

- During the lifecycle of offshore energy developments huge volumes of multidisciplinary geospatial data are generated, which are most-effectively integrated via a project-specific GIS database;
- Systematic integration of multidisciplinary datasets is critical for robust site characterisation;
- GIS accommodates multiple data *types* enabling *all* project data to be rigorously spatially referenced;
- Bespoke GIS add-ins facilitate real integration beyond the standard ArcGIS capabilities;
- Fugro's **Composite Plotter** add-in integrates point, line and image data on-the-fly based on user-defined map selections;
- Fugro's **Hosted Report** add-in links supplementary text and image components to mapped content;
- The benefits of integrating, primarily, geotechnical and geophysical data are such that the approach is now well established throughout the industry (e.g. 5; 7; 9) and forms the basis of an industry guidance document [8];
- Site characterisation allows clients to lower cost of design, construction and operation, to experience higher reliability over project life and to minimise uncertainty and moderate risk.

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