Geophysics for Critical Infrastructure

Thursday 16th July 2015

BGS Keyworth

Convenors:
Helen Reeves, BGS (EGGS)
Oliver Kuras, BGS (NSGG)

PROGRAMME and ABSTRACTS

This event is kindly supported by:

PROGRAMME

Meeting aims:

- Bring together industry and research professionals from the geophysical, geotechnical and civil engineering sectors to foster a better understanding of mutual needs and expectations
- Highlight geophysical case studies and best practice in critical infrastructure investigations
- Discuss implications for near-surface geophysics of the forthcoming revision to BS5930 (2015)

09.30	Registration, tea & coffee
10:00	Introduction and welcome: Helen Reeves, EGGS, and Oliver Kuras, NSGG
10:10	**Session 1a**: *Reducing uncertainty in ground models with near-surface geophysics*
10:10	**Keynote Address** **George Tuckwell (RSK Ltd): *Role of near-surface geophysics in the new BS5930 Standard***
10:40	Jim Whiteley (TerraDat) et al.: *Filling the gaps: mapping variations in material layer thickness for a proposed pipeline using near-surface geophysics*
11:00	Oliver Chrisp (AECOM) et al.: *Non-intrusive investigations of rail tunnels*
11:20	Refreshments and networking
11:40	**Session 2**: *Novel/unusual applications of near-surface geophysics in critical infrastructure projects*
11:40	Jonathan Chambers (BGS) et al.: *Proactive Infrastructure Monitoring and Evaluation (PRIME): automated time-lapse resistivity imaging for the assessment and management of infrastructure earthworks*
12:00	Anna Stork (University of Bristol) et al.: *Passive seismic monitoring of CO2 storage sites*
12:20	**Poster Session**
12:20	Jonathan Thomas (TerraDat) et al.: *Seismic surveys – Limitation and solutions for bedrock mapping and determining geo-mechanical properties for wind farm development and slope stability studies*
12:30	Matt Stringfellow (RSK Ltd) et al.: *Case Studies: Critical Geophysics for Critical Infrastructure*
12:40	Sebastian Uhlemann (BGS) et al.: *Geoelectrical imaging of moisture dynamics in engineered slopes*
12:50	Oliver Chrisp (AECOM) et al.: *Geophysics for risk management on new infrastructure routes*
13:00	Buffet lunch and networking. **In parallel: Annual General Meeting of the Engineering Group**
14:00	**Session 1b**: *Reducing uncertainty in ground models with near surface geophysics*
14:00	Sarah Tallett-Williams (Imperial College) et al.: *A Review of Development of Shear Wave Ground Profiles for UK Strong Ground Motion Instrument Sites using Geophysical Methods*
14:20	Timothy Grossey (RSK Ltd) et al.: *Pipeline routing – An Integrated Geophysical Survey using multiple techniques successfully incorporated into a Critical Infrastructure Project*
14:40	Bernd Kulessa (Swansea University) et al.: *3D electrical geophysics integrated into ground characterisation and monitoring informs permeable reactive barrier installation and brownfield site re-development*
15:00	Refreshments and networking
15:20	**Session 3**: *Integrating near-surface geophysical approaches with conventional geotechnics*
15:20	Mark Vardy (National Oceanography Centre) et al.: *Ground modelling through inversion of high-resolution marine geophysical data: A new approach to fully integrated offshore site characterisation*
15:40	John Reynolds (RIL) et al.: *Integrated interpretation of geotechnical and seismic data in the development of 3D Ground Models for offshore renewable energy projects*
16:00	Dan Roberts (AECOM) et al.: *Slab track remediation using integrated geophysical geotechnical approach for ground Investigation*
16:20	Discussion and wrap-up: Helen Reeves, EGGS, and Oliver Kuras, NSGG
16:30	Meeting close

ABSTRACTS

Session 1a: *Reducing uncertainty in ground models with near-surface geophysics*

George Tuckwell
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Role of near-surface geophysics in the new BS5930 Standard (Keynote Address)

BS 5930 'Code of practice for site investigations' has been revised, and publication is expected in the next few weeks. Amongst the updates is the section on geophysical ground investigation. This talk will provide an overview of the geophysical aspects of the revised standard, focussing in particular on

- when you would use geophysics;
- how clients should commission it;
- qualifications and experience of geophysical experts;
- protections available for the client; and
- the deliverables the client should expect.

Jim Whiteley
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Filling the gaps: mapping variations in material layer thickness for a proposed pipeline using near-surface geophysics

Intrusive investigations of the subsurface using drilling or trial pitting allow for the acquisition of very detailed information within a highly constrained data. For many ground investigations, interpolating between data collected from such methods is a satisfactory means of deducing subsurface ground conditions. However for projects that extend over large areas, collecting accurate observations through drilling and trial pitting may prove impractical, costly and time-consuming. These problems can be overcome by reducing the number of boreholes and pits, but the payoff is a significant increase in the uncertainty associated with interpolation of results over increased distances.

Pipelines are particularly problematic in that the traverse of the route may span tens of kilometres in length whilst only requiring a relatively narrow corridor of investigation, meaning that adjacent ground conditions at the margins of the proposed route are easily ignored by traditional intrusive investigation practices. Additional unknown hazards, such as potential dissolution within underlying bedrock, can be easily missed through the interpolation of intrusive data, further reducing uncertainty and failing to decrease risk in final conceptual ground models.

In the context of such pipeline investigations, near-surface geophysical techniques can be used to reduce the risk associated with these common issues. An Electrical Resistivity Tomography (ERT) and seismic survey were conducted as part of a major pipeline project in order to ascertain depth to bedrock, determine engineering properties of subsurface materials, and to detect potential solution features along the traverse of the proposed route. The route incorporated areas of difficult terrain, including open fields, areas of urban development and a river.

Oliver Chrisp
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Non-intrusive investigations of rail tunnels

The Electrification of the Great Western Line has led to a number of issues impacting upon structures along the line, particularly in sites with limited clearances, where track lowering or realignment is required to install the overhead lines.

Box tunnel is an example of this, where track lowering is required to achieve clearances. As part of this work we conducted non-intrusive investigations of both the tunnel invert and the tunnel lining.
Invert surveys were requested to identify the thickness of fill materials and identify potential buried structures which could obstruct works.

Lining investigations were to assess the thickness and condition of the soffit and walls and identify potential blind access shafts hidden behind the lining, identifying areas of potential weakness in the structure.
Both investigations utilised GPR of varying frequencies with intrusive investigations used for calibration of the results to improve the confidence in the findings, with data used to add to a 3D model of the structure to aid in the works.

Session 2: *Novel/unusual applications of near-surface geophysics in critical infrastructure projects*

Jonathan Chambers[1], Phil Meldrum, David Gunn, Paul Wilkinson, Oliver Kuras, Sebastian Uhlemann and Russell Swift
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Proactive Infrastructure Monitoring and Evaluation (PRIME): automated time-lapse resistivity imaging for the assessment and management of infrastructure earthworks

We describe the development of a new low cost early warning system for monitoring the physical integrity of vulnerable earth structures (e.g. embankments, cuttings), for application in sectors including utilities and transport - thereby facilitating the shift from more costly reactive remediation of earthwork failures to preventative maintenance. The proposed system combines emerging geophysical ground imaging technology with innovative data telemetry, web portal access and automated image analysis – enabling near-real-time monitoring of the internal physical condition of infrastructure earthworks.

Current research systems have developed proof of concept for key elements of this workflow, but are prohibitively expensive. The new PRIME monitoring platform will substantially reduce instrumentation costs – thereby removing a major barrier to take-up by infrastructure managers. Here we present the initial results of PRIME system tests on railway and canal embankments.

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Passive seismic monitoring of CO_2 storage sites

Carbon capture and storage (CCS) projects capture carbon dioxide (CO_2) at large point-source producers, e.g. power stations, and subsequently sequester CO_2 in suitable geological formations for permanent storage. Passive seismic monitoring of such sites provides a useful diagnostic tool to understand the geomechanical response to CO_2 injection and to verify CO_2 remains at depth. It is vital that a monitoring programme provides warning of potential leaks at CCS sites. Here, we present and compare passive seismic monitoring results from three large-scale projects, Weyburn, In Salah and Aquistore, to highlight similarities and differences between sites and monitoring methods.

CO_2 injection at the Weyburn site is on-going since 2000 with >30 millions tons (Mt) sequestered; nearly 4 Mt of CO_2 were injected at In Salah between 2004 and 2011; and the Aquistore project began injection in April 2015. As expected, we have found that rates of microseismicity (small seismic events, generally with magnitudes < 0) increase with injection rate and the distribution of events correlates with the volume occupied by CO_2. However, rates of seismicity differ considerably between the In Salah and Weyburn sites. At In Salah >9000 events were detected 2009 – 2011 with moment magnitudes, M_w, up to 1.6, whereas at Weyburn only ~100 events were detected 2003 – 2007 with $-3.0<M_w<-1.0$. At both sites a small number of microseismic events occur in the overburden above the injection interval but we propose this is not caused by fluid migration or pore pressure changes in the overburden but by stress transfer. Anisotropy studies, using shear-wave splitting analysis, indicate that fractures sampled by the data have strikes consistent with observed pre-existing fracture sets, suggesting seismic activity occurs on pre-existing fractures.

These current and past CCS projects provide important learning opportunities to improve the design and effectiveness of future passive seismic deployments.

Poster Session

Jonathan Thomas[1] and Rob McDonald
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Seismic surveys – Limitation and solutions for bedrock mapping and determining geo-mechanical properties for wind farm development and slope stability studies.

In addition to mapping the bedrock profile, the role of seismic surveys in ascertaining geo-mechanical properties has steadily increased over the last few years and is now an accepted standard on many sites. As well as providing direct information on the P-wave and S-wave velocities, they are used to derive specific geotechnical parameters such as, Poisson's Ratio and the respective dynamic moduli. When coupled with a conventional drilling and sampling programme, it can significantly enhance the geotechnical understanding of the site and enables a better appreciation of the lateral variability. In addition, seismic surveys can be carried out at locations where drilling is not feasible due to either logistical considerations, environmental sensitivity or is simply too costly.

As with most investigative methods, there are some known limitations with the seismic techniques and these can have a significant impact on the results. Most of these limitations are dependent on the geology of the site such as near-surface organic deposits, water table, overburden thickness, weathering profiles and lithological variations. A series of seismic survey case studies are presented that describe a strategy used to overcome these limitations with particular emphasis on wind farm developments and slope stability studies.

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Case Studies: Critical Geophysics for Critical Infrastructure

Four case studies are used to show where geophysics has been successfully incorporated into larger site investigations for engineering projects. The cases highlight where the conceptual ground model has been enhanced by the application of geophysical techniques.

Applications include the detection of buried utilities, voids and geological mapping in a variety of settings from urban transport projects to rural windfarms.

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Geoelectrical Imaging of Moisture Dynamics in Engineered Slopes

Understanding construction quality and state of embankments used for road and rail infrastructure is critical in the effective management and maintenance of our transport network. Future climatic changes are predicted to lead to up to 20% more precipitation (with a strong increase of winter precipitation), more flash floods, and drier summers. These environmental changes will have inevitable consequences for the serviceability and maintenance of our engineered infrastructure. Yet, current assessment of asset condition is mainly informed by failure events and remediation measures initiated due to emergencies. New intelligent platforms and science to monitor current embankment state and risk are required, that enable proactive remediation measures before failure occurs.

Electrical resistivity tomography (ERT) is a geophysical technique that is sensitive to lithological and mineralogical heterogeneity and changes in ground temperature and soil moisture content. When corrected for temperature changes, repeated resistivity measurements employing permanently installed electrodes will highlight changes in moisture content over time. Therefore, ERT monitoring can be used to image moisture movements in slope, which will inform about accumulation and drainage areas, as well as preferential flow paths. Thus providing a tool to assess the hydrological state of an embankment, which can be used as an indicator for its geotechnical state.

We compare ERT monitoring data acquired on a section of the BIONICS research embankment that was build according to modern Highways England specifications with data from a section representing the building standards of Victorian railway embankments (i.e. poor compaction). These sections show distinct differences in moisture movements and penetration, highlighting an accelerated weathering impact for the poorly compacted section. Thus, the embankment compacted to standard levels will show slower deterioration than historic structures, resulting in a longer life time and lower whole-life-costs.

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Geophysics for risk management on new infrastructure routes

Surveys included Electrical Resistivity Tomography (ERT or Resistivity Imaging) and Microgravity, with techniques chosen to provide material profiles along the route of a new highway and to identify areas of concern for potential solution features within a gypsum band beneath the route. Subsequent intrusive investigations were conducted by the client to target features, proving some of the features. The works allowed appropriate drainage to be designed minimise the risk of undermining in at risk areas.

Session 1b: *Reducing uncertainty in ground models with near surface geophysics*

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A Review of Development of Shear Wave Ground Profiles for UK Strong Ground Motion Instrument Sites using Geophysical Methods

Site conditions in perceived low seismic areas such as the UK are generally unknown, causing significant concern in industry. This is particularly true for the Strong Ground Motion Stations (SGMS) of the UK, Figure 1 (e.g. Lubkowski *et al*, 2004). Little or no information is known about the ground conditions they are situated on, causing uncertainty in the design of critical infrastructure that should rest on rigorous parameters such as nuclear facilities. The ongoing focus of the research is to improve the site classification for seismic hazard in the UK. The aim of this study is to develop and preliminarily test a cost-effective method to produced detailed shear wave velocity (V_S) profiles for sites with little or no previous information such as these SGMS.

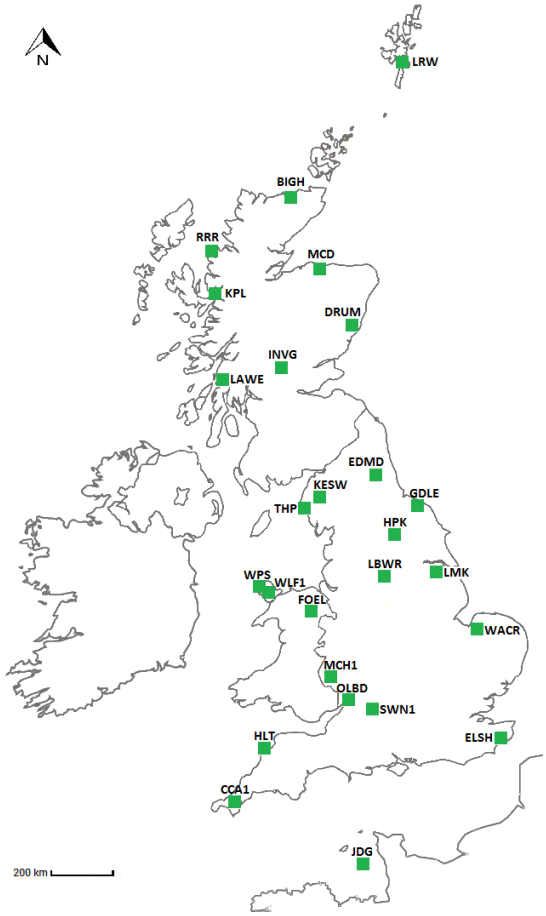

Figure 1. Locations of the strong ground motion stations in the UK

In engineering practice, site conditions are generally accounted for in detailed shear wave velocity profiles of the near-surface (V_{s30}). These values are most accurately determined by site-specific invasive measurement. Yet, this is expensive and, in regions with perceived as low seismic risk, economically unfeasible. In this study, the understanding of the geological setting of the ground profile beneath a SGMS is used to develop a model for a site including a V_{s30}. This is established through a desk study, walk over surveys and previous *in situ* measurements.

Preliminary geophysical testing to improve these ground models and validate the V_{s30} profiles have been undertaken at several of the stations. This has used different economical methods including Nakamura's microtemor method (1989). This technique was carried out at Elham, Folkestone, Figure 2. The site is highly complex and has an extensively weathered profile to some depth. This was predicted by the model. However, the extent of weathering is considerably more than expected and highlights the significance of geophysical site investigation.

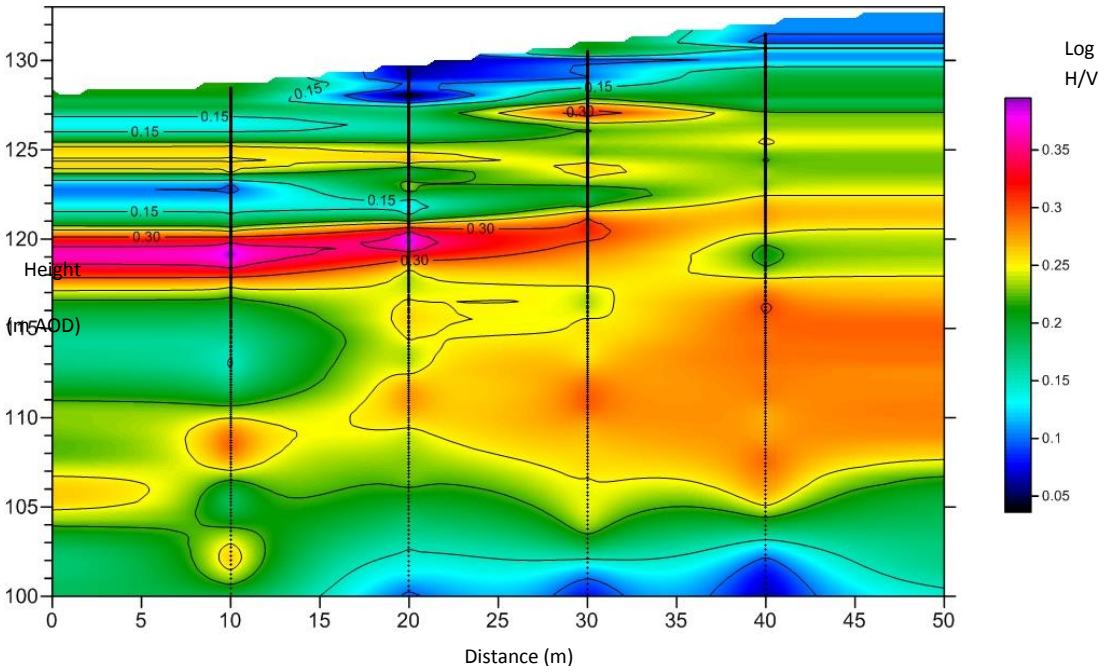

Figure 2. Results of H/V testing using Tromino instrument at station ELSH (Figure 1). The impedance contrast from the chalk suggests it has been highly weathered but not uniformly.

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NAKAMURA, Y. (1989) *Method for dynamic characteristics estimation of subsurface using microtremor on the ground surface. Quarterly Report of RTRI (Railway Technical Research Institute) (Japan),* 30(1), 25-33.

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Investigation of the feasibility of a proposed gas pipeline corridor – An Integrated Geophysical Survey using multiple techniques successfully incorporated into a Critical Infrastructure Project

An 860-MW combined cycle gas turbine (CCGT) power plant is being developed at Carrington, Manchester. The plant will operate at about 57% fuel efficiency compared with 30-35% efficiency of the former power station on the same site. As part of the development, it is proposed to construct a gas pipeline that passes through several land owners to connect the CCGT to the National Grid compound and gas connection 3 km away. The easement available for the pipeline route includes the redundant outfall water culvert and pumphouse, of the former power station, a section of steep embankment on the banks of the Manchester ship canal with an adjacent landfill and a section of a brown field site densely populated with active/ disused services and buildings demolished to foundation level.

ESB International, on behalf of Carrington Power Ltd, commissioned RSK to carry out a geophysical and intrusive investigation in order to determine the location of all the below-ground services, foundations, geological constraints, and other obstructions that would render it infeasible to construct or cause delays during construction of the 600mm diameter steel gas pipe along the proposed corridor.

The case study will demonstrate how an integrated geophysical survey has been successfully incorporated into a critical infrastructure project told from both the clients and geophysicists perspective. The talk will focus on the problems the designer faced on the project and how geophysics was used to overcome the problems and improve the overall ground model for the site.

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3D electrical geophysics integrated into ground characterisation and monitoring informs permeable reactive barrier installation and brownfield site re-development

Novel, low cost, low impact and sustainable remediation methods and monitoring tools are critical if brownfield redevelopment issues are to be addressed economically. We have integrated 3-D electrical resistivity tomography (ERT), 3-D self-potential (SP) tomography and SP monitoring with traditional borehole and trial pit measurements as well as contaminant hydrogeological modelling, to develop an integrated model of complex subsurface pollution and aquifer stratigraphy at a former manufactured gas plant in Portadown, Northern Ireland.

The ground model facilitated successful installation and operation of a biological permeable reactive barrier (PRB) along with a slurry containment wall, and ongoing SP monitoring demonstrates that microbial activity outside the PRB significantly attenuates the complex contaminant plume. The ground model was significantly enhanced through the integration of state-of-the-practice electrical geophysical methods, and allowed risk-based management and re-development of the brownfield site. We propose that our case study can serve as a best-practice guide to future contaminated land assessment and ongoing monitoring, and evaluate future advances of our approach.

Session 3: *Integrating near-surface geophysical approaches with conventional geotechnics*

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Ground modeling through inversion of high-resolution marine geophysical data: A new approach to fully integrated offshore site characterization

Inversion techniques using marine geophysical data have developed enormously over the past 20+ years for remote hydrocarbon reservoir characterisation. While some techniques (e.g., waveform inversion) are prohibitively computationally expensive to permit widespread application across all targets, other less expensive variants (e.g., impedance and amplitude-versus-angle inversion) have become a standard component of most interpretation workflows. Despite these advances for hydrocarbon exploration, there has been little progress toward the application of inversion to shallow (<100 m) high-resolution geophysical data, which are routinely acquired for site characterisation of offshore renewables, pipeline, and oil and gas developments. As a result, ties between geophysical and soil properties are typically only qualitative, relying on visual correlations between acoustic character, bounding stratigraphic surfaces and the need for extensive geotechnical data acquisition. Soil conditions are determined at a point (e.g. borehole), but the confidence in lateral extrapolation (typically 100s to 1000s metres) is reduced drastically away from the calibration point.

Here we present the successful application of post-stack acoustic impedance inversion to marine, near-surface geophysical data, deriving detailed acoustic impedance (Z) structure from Chirp, Boomer and Sparker data. These can be related to P-wave velocity, density, porosity and mean grain size using global empirical relationships, while site-specific parameters (such as G_{max} and cone resistance) can be geostatistically derived using core and CPTU data for calibration. Furthermore, through the application of soil mechanical models (e.g., White's model), these elastic properties can be used to calculate engineering properties like gas saturation, pore pressure, and consolidation. This affords the derivation of a screening-level assessment ground model calibrated against sampling and CPTU sites, but unlike previous coarsely extrapolated models, provides a resolution in-keeping with the marine geophysical data coverage (typically 10s metres). Facies pinch-outs, lateral grading and lateral discontinuities are all accurately incorporated into the model, along with statistically robust confidence limits. The remote derivation of such high-fidelity soil properties has significant applications. It provides a way forward for truly-integrated site geophysical and geotechnical characterization, optimized data acquisition strategies, and obvious advantages for both academic and industry applications.

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Integrated interpretation of geotechnical and seismic data in the development of 3D Ground Models for offshore renewable energy projects

Since 2010 there has been a significant increase in the number and size of offshore renewable energy projects around UK coastal waters, with further interest being expressed in tidal stream and tidal impoundment projects. By their very nature, these are major construction projects where, for the offshore wind farms, for example, project areas cover many hundreds of square kilometres. A key starting point for these projects is the basic mapping of the seabed (bathymetry, seabed features and sediment classification) and investigation of the sub-seabed geology. To begin with, hydrographic and single-channel seismic reflection surveys were commissioned and variably reported on, principally by the contractors who acquired the data. Subsequently, intrusive geotechnical investigations were also undertaken. Hitherto, the interpretation of geophysical and geotechnical datasets has been undertaken largely independently of each other or with relatively superficial cross-correlation between the two types of data resulting in generally low-quality interpretations.

Over the last five years we have developed tailored methods of scrutinising the original seismic datasets with respect to its formatting, navigational controls, and data quality in order to derive significantly improved seismic data that can be used by multiple parties for a variety of purposes, including marine archaeology and seabed sediment mobility studies. We have also pioneered methods whereby geotechnical data obtained from boreholes and Cone Penetrometer Testing can be incorporated into the same 3D interpretation space as the seismic data using RIL's **imagis**™ workflow system to permit integrated and joint interpretation of multiple seismic, hydrographic and geotechnical datasets.

We give examples of how seismo-acoustic facies analysis of newly processed seismic data has been integrated with detailed analysis of geotechnical samples using gINT software to produce a mutually consistent and robust interpretation. Using this approach it has been possible to develop 3D Ground Models where detailed geostatistical analyses have been undertaken to define levels of uncertainty. The resulting primary Ground Model can be used to target second-stage ground investigations that in turn inform a second-stage Ground Model with decreased uncertainty. The Ground Models are suitable for use in the interpretation of soil profiles and foundation designs in which uncertainties can be quantified and understood.

This approach has been successful in minimising the risks associated with complex sub-seabed geology and geohazards. It has proven to be particularly effective when applied to archive seismic survey data that may otherwise have been entirely written off by the wind farm developer. Consequently, the 3D Ground Models derived from the integrated interpretation of geotechnical and geophysical datasets are quantifiably more robust and with lower uncertainty and reduced risk than those derived using conventional approaches. This also results in very significant cost savings to wind farm developers.

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Slab track remediation using multiple geophysical techniques and traditional geotechnics

A slab track presented a unique technical and operational challenge. Based upon geophysical surveys, a series of temporary remediation has been implemented to maintain serviceability. However, a long term solution must be implemented.

The solution must minimise disruption to a major commuting route, whilst replacing the life expired asset with a maintainable and reasonable whole life cost solution. This is complicated by the clay cutting setting and restrictive surrounding civil assets and commercial and residential land use.

Geophysical surveys, including Ground Penetrating Radar (GPR), Multichannel Analysis of Surface Wave (MASW) and Electrical Resistivity Tomography (ERT), were undertaken between November 2010 and March 2015 following observed washout and pumping of clay material and a resulting deterioration of asset integrity. The aims were to: 1) assess construction and condition of the track slab and underlying subgrade; 2) explain causes of defects and condition deterioration; 3) recommend remedial treatment(s) and evaluate their success; and 4) provide correlation between surveys.

The early surveys concluded a loss of support to the track slab by wash out and pumping of the underlying formation and creation of voids. This was exacerbated by the poor stiffness of the clay resulting from a high water content and dynamic loaded interaction with passing trains. Installation of tie bars and concrete stitching were implemented to improve the structural strength of the track slab, along with injection grouting beneath the track slab to fill the voids. Subsequent geophysical surveys confirmed the success of this remedial treatment.

Recent intrusive ground investigations have been undertaken based upon the findings of the geophysical data and have alleviated the concern of deep-seated poor formation and subgrade beneath the track slab. Feasibility options can now be explored to provide a viable long term solution.

Delegate List – Geophysics for Critical Infrastructure

No	First name	Last name	Affiliation
1	Eraclis	Anastassiades	CH2M
2	John	Arthur	Top-Hole Site Studies
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6	Ana	Branco Fernandes	Reynolds International Ltd
7	Michael	Brien	Met Geo Environmental Ltd
8	Antony	Butcher	University of Bristol
9	Michael	Carter	Integra
10	Tom	Casey	Arup
11	Lucy	Catt	Reynolds International Ltd
12	Jonathan	Chambers	BGS
13	Oliver	Chrisp	AECOM
14	Michael	Christie	Piledesigns Ltd
15	Gary	Clarke	University of Birmingham
16	Lindsey	Connelly	CH2M HILL
17	Vicky	Corcoran	Imperial College London / Atkins
18	Martin	Culshaw	Independant Researcher and Consultant
19	Kathryn	Cunningham	ArchaeoPhysica
20	Giulio	Curioni	University of Birmingham
21	Jonathan	Currie	Integra
22	Ben	Davenward	LandScope Engineering
23	Andrew	Dixon	Fugro
24	Douglas	Dodds	National Grid
25	Rory	Doherty	Queen's University Belfast
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30	Martin	Geach	Atkins
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32	Dave	Giles	University of Portsmouth
33	James	Greenfield	Integra
34	Tim	Grossey	RSK
35	Matt	Grove	Geosoft
36	Matthew	Guy	Geomatrix Earth Science Ltd
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45	Ian	Jenkins	MoD
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47	Christina	Kelly	University of Liverpool
48	Aftab	Khan	University of Leicester
49	Brad	Knights	Dunelm Geotechnical and Environmental
50	Bernd	Kulessa	Swansea University
51	Oliver	Kuras	BGS
52	Lucy	Learmonth	Wessex Archaeology
53	Nigel	Lee	Kier Strategic Highways
54	Christopher	Leech	Geomatrix Earth Science Ltd (Exhibitor)
55	Gerwyn	Leigh	RSK Geophysics
56	Tony	Lombard	Apex Geoservices
57	Louise	Lynch	ESB International
58	Jonathan	Marsh	University of Leeds
59	Paul	McEwen	AMEC
60	Phil	Meldrum	BGS
61	Joseph	Milner	RSK
62	Monika	Nawrocka	Apex Geoservices
63	Shane	O'Rourke	Apex Geoservices
64	Sean	Pearce	Atkins
65	Jon	Race	Southern Testing
66	Keith	Reeves	HS2 Ltd
67	Helen	Reeves	BGS
68	John	Reynolds	Reynolds International Ltd
69	Daniel	Roberts	AECOM
70	James	Roberts	Met Geo Environmental Ltd
71	Martin	Roseveare	ArchaeoPhysica
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74	Sohail	Shahzad	Gulf Center for Geophysical and Water Consulting
75	Jon	Stead	Robertson Geologging Ltd
76	Anna	Stork	University of Bristol
77	Matt	Stringfellow	RSK
78	Michael	Summers	Geo-Design Consulting Engineers Ltd
79	Russell	Swift	BGS
80	Sarah	Tallett-Williams	Imperial College London
81	Jonathan	Thomas	TerraDat UK Ltd
82	Andy	Trafford	Apex Geoservices
83	George	Tuckwell	RSK
84	Sebastian	Uhlemann	BGS
85	Ian	Unsworth	Andam Int LLC
86	Mark	Vardy	National Oceanography Centre Southampton
87	Arre	Verweerd	AECOM
88	Philip	Webb	Peter Brett Associates
89	Jim	Whiteley	TerraDat UK Ltd
90	Paul	Wilkinson	BGS

ANNUAL GENERAL MEETING 2015 OF THE ENGINEERING GROUP

THURSDAY 16TH JULY 2015, 1pm, BGS Keyworth

AGENDA

1. **Apologies for Absence**
2. **Minutes of the Annual General Meeting held on 2nd October 2014**
3. **Report from the Treasurer of the Engineering Group.**
4. **Report from the Chair of the Engineering Group**
5. **Appointment of Committee Members**
6. **Any other business**
7. **Close**

Future NSGG meetings:

3rd December 2015, Burlington House, Piccadilly: ***Geophysical Monitoring of the Critical Zone***

11th - 12th February 2016, Burlington House, Piccadilly: ***Integrated Imaging of the Earth*** (British Geophysical Association - New Advances in Geophysics 2016)

May 2016, BGS Keyworth: ***NSGG Student Symposium/Research in Progress***

December 2016, Burlington House, Piccadilly: ***Advances in Archaeological Geophysics***

Future EGGS meetings:

4th November 2015, Burlington House, Piccadilly: ***The 19th Glossop Award***

16th November 2016, Burlington House, Piccadilly: ***Military aspects of Engineering Geology: Past and Present*** (Lecture, Evening Meeting)