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A Background to Shallow Geophysical Methods with Applied Engineering & Environmental Case Studies

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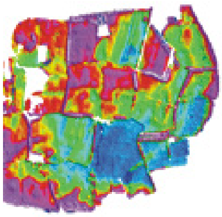
The Use of Shallow Geophysical Surveys Applied to Engineering & Environmental Ground Investigations

Head Office: TerraDat UK Ltd., Cardiff, UK



Main Services & Geophysical Applications

TerraDat has extensive experience in applying state of the art non-invasive ground characterisation techniques to all areas of the geotechnical, civil engineering, mineral, groundwater and environmental industries. Below is a list of some of the more popular applications that are routinely carried out by our team of skilled geoscientists.

Our survey deliverables include clearly annotated interpretative plans in AutoCAD or GIS format overlain with site plans or historical information to make integration of our data a straightforward process for our clients.

1. Contaminated Site Characterisation

- Detection of buried drums and UST's
- UXO location and clearance
- Mine & spoil dump investigation
- Contamination plume mapping
- Landfill design input
- Characterisation of abandoned landfills
- Locating underground fires
- Soil Vapour & Gas Surveys
- Radon Gas Surveys

2. Engineering Geology & Geotechnics

- Bedrock profiling
- Soil and rock engineering properties
- Foundation investigations
- Overburden homogeneity
- Mapping shallow mineworkings
- Investigating Karst structures
- Locating faults & fracture zones
- Animal and wildlife burrows

3. Hydrogeology

- Saline water intrusion mapping
- Ground water exploration
- Groundwater migration pathways
- Hydrothermal resource monitoring

4. Mineral Exploration

- Deposit reconnaissance
- Deposit evaluation
- Overburden mapping
- Mapping of geological structures
- Seismic exploration

5. Other Services

- Mapping of archaeological remains
- Soil moisture mapping
- Sports pitch surveys
- Vibration Monitoring
- HDPE Liner Leak Location
- Forensic searches for buried objects

Key Benefits

of a TerraDat Geophysical Survey

1. Cost Effective

A TerraDat Geophysical Survey can provide detailed information about the subsurface in very little time. Compare the cost of obtaining similar information purely through manual excavation or drilling and the benefit is immediately obvious. Commonly, our surveys are required to provide information between sparse borehole arrays or for optimum targeting of follow-up invasive work.

2. Rapid Ground Coverage

Terradat has invested heavily in state-of the-art equipment enabling us to cover several hectares per day for site characterization or profile along hundreds of metres for detailed cross-sectional investigations.

3. Minimal Exposure to Hazards

The techniques we use require little or no contact with the ground and there are no risks of exposing harmful waste or aggravating ground conditions - which are a frequent limitation of conventional ground exploration methods.

4. Environmentally Friendly

Our survey techniques are non-invasive and involve minimal disturbance to the environment. We commonly carry out surveys in urban regions and areas of natural protection, and incur few restrictions from the relevant authorities.

5. Quality Procedures

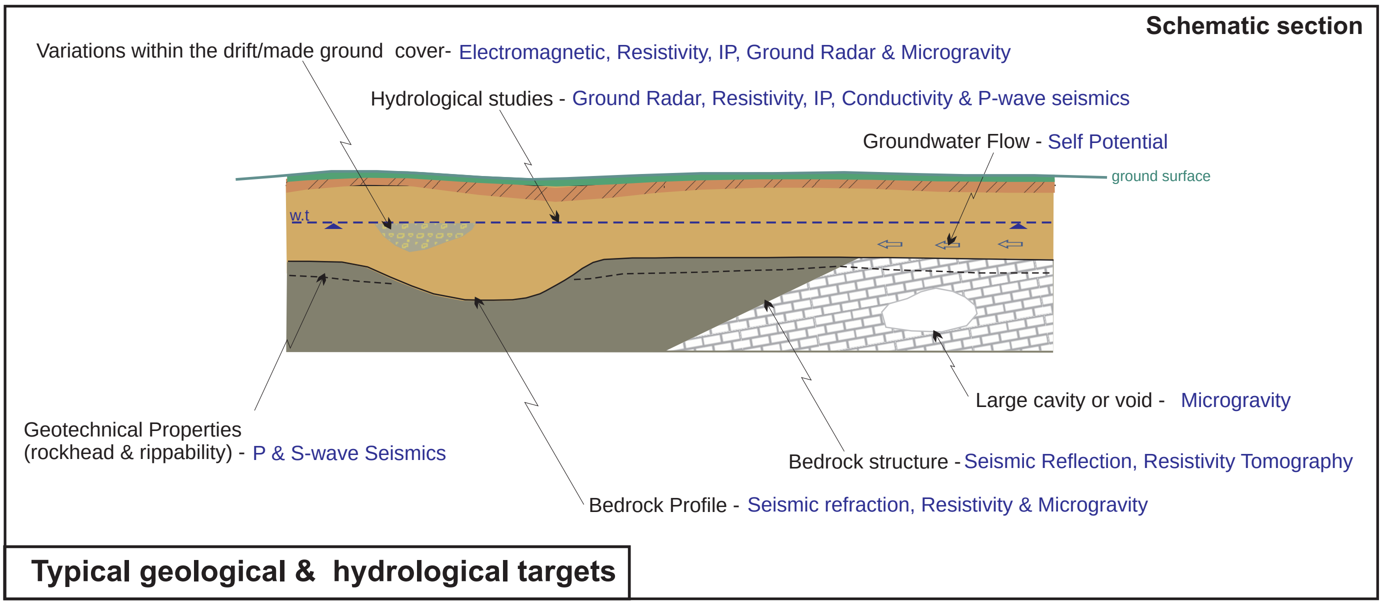
Our scientists are highly qualified with extensive experience in applied geophysics. We place great emphasis on careful survey design and implementation while maintaining a flexible approach to work on site. Our survey results are integrated with existing information or complimentary datasets using GIS techniques for ease of use by the Client. We also draw on our experiences from a wide variety of previous surveys carried out in diverse environments across the World in order to deliver the best service to our Clients.

6. Customer Focused

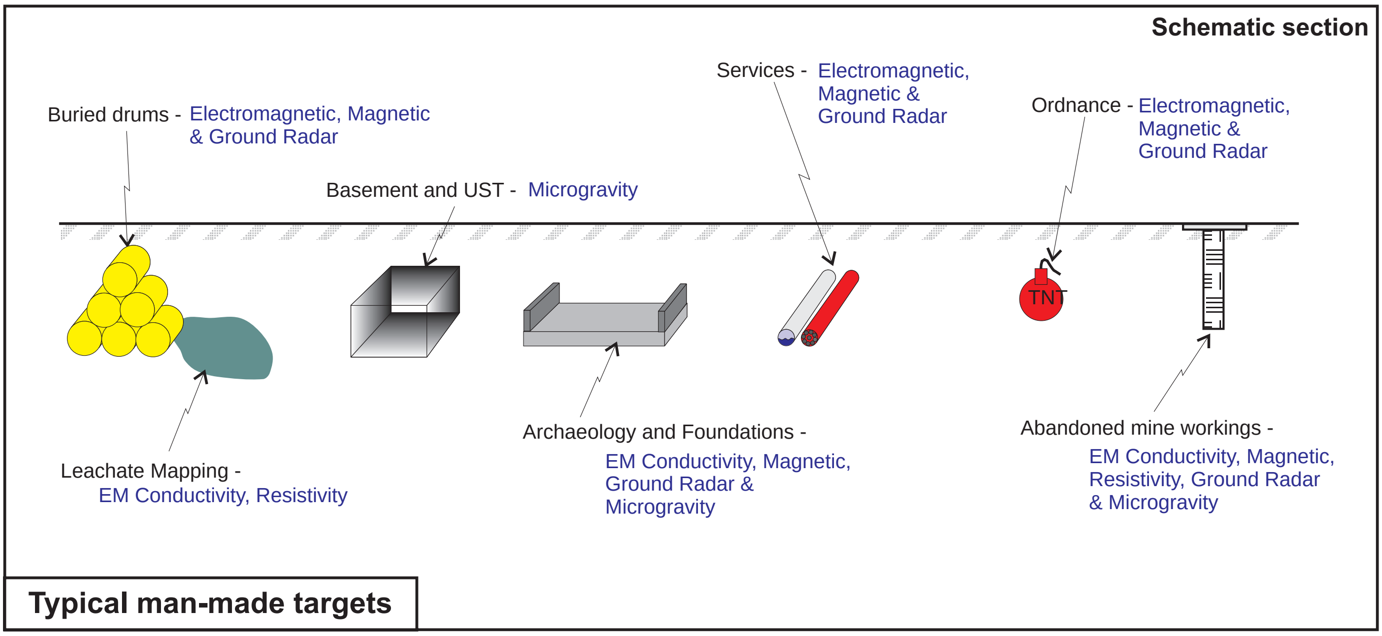
We understand our Client’s needs and ensure that survey results are delivered in a form that can be easily integrated into their work. We offer a flexible approach to pricing and can optimize the survey design to suit a given budget.

Geophysical Surveys are designed to exploit one or more of the physical properties of a target feature that is in contrast with its host environment, e.g., the low density nature of a void is in contrast to the high density nature of surrounding bedrock, etc. Careful examination of the likely physical characteristics of the target (size, depth and properties) is required to enable reliable assessment of whether it is detectable or not. Geophysical surveys are generally carried out at surface using sensitive equipment, so it is also essential to consider the possible influence of the site conditions and the overburden at the design stage, e.g, the presence of thick fill or metal scrap at surface can adversely affect some methods.

Some geophysical methods such as *resistivity tomography*, *seismic refraction* and *ground radar* provide detailed cross-sectional information and are particularly useful for imaging geological structure, groundwater distribution/contamination and determining elastic properties. Other geophysical methods such as *electromagnetics (EM), magnetic gradiometry* and *microgravity* generally involve acquisition of data on a grid format across the survey area and the results are presented in plan view. These methods lend themselves to reconnaissance because of the lateral ground coverage but the results can also be analysed to produce information about any observed anomalies.



Typical geological & hydrological targets



Typical man-made targets

(ABOVE) Schematic representation of typical targets (natural and man-made) and the most appropriate geophysical methods for a survey. The final choice of method (or combination of methods) will also depend on the prevailing ground conditions depth and size of target etc.

resisitivity cable deployment in road verge

Electrical properties are among the most useful geophysical parameters in characterising Earth materials. Variations in electrical resistivity (or conversely, conductivity) typically correlate with variations in lithology, water saturation, fluid conductivity, porosity and permeability.

Resistivity Tomography can be used for the following applications:

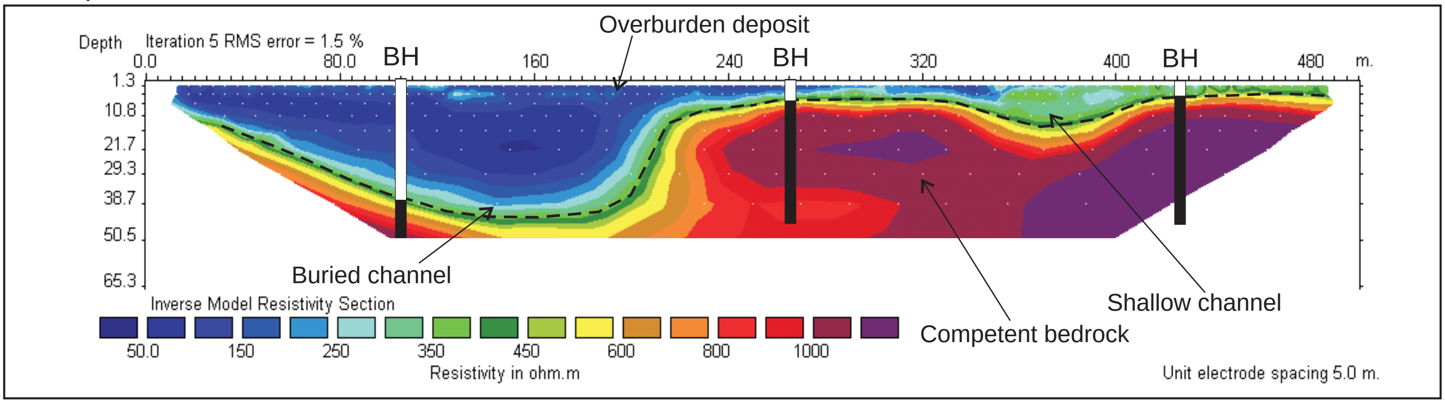
- **Mapping geological features**
- **Detection of buried structures**
- **Karst & solution features**
- **Groundwater exploration**
- **Landfill waste mass studies**

Benefits:

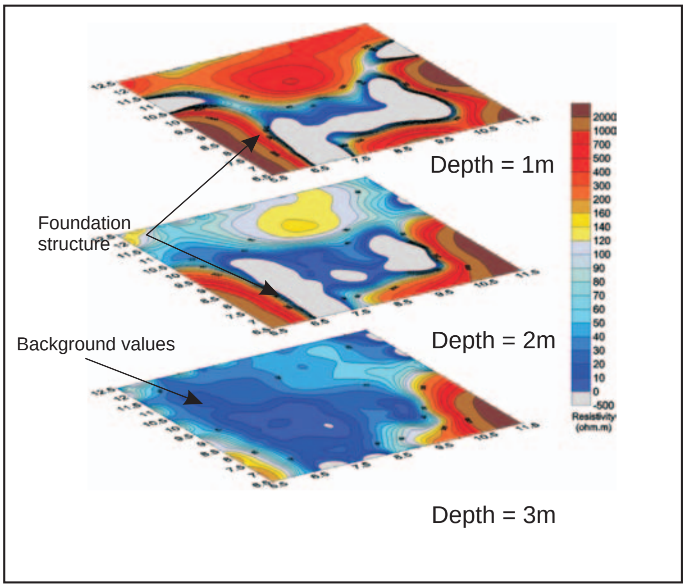
- **Up to 1.5 line km per day**
- **Depths down to 60+ metres**
- **Laterally continuous data**
- **Non-invasive**
- **Exceptional value**

Acquisition of resistivity tomography data involves the deployment of an array of regularly-spaced electrodes which are connected to a central control unit via multi-core cables. Linear arrays are employed for 2D surveys while a square array is used for a 3D survey. Resistivity data are then recorded via complex combinations of current and potential electrode pairs to build up a pseudo cross-section of apparent resistivity beneath the survey line. The depth of investigation depends on the electrode separation and geometry, with greater electrode separations yielding bulk resistivity measurements to greater depths.

The modeled true subsurface resistivity image is then derived from finite-difference forward modeling via specialist software (RES2DINV). The true resistivity models are presented as colour-scaled contour plots of changes in sub-surface resistivity with depth.



(ABOVE) As part of a hydrological study, a series of resistivity tomography profile lines were acquired to map variations within the overburden thickness. The example section above displays an extensive erosional channel feature together with more subtle overburden thickness variations.



(LEFT) A 3D resistivity survey was carried out to map the lateral and vertical extent of buried foundations. The grey zones represent noisy data due to buried services and the high resistivity values (red) reflect the foundation material. The resistivity suggest that the foundations extend to a maximum depth of 2m.

Electromagnetic (Conductivity) Mapping

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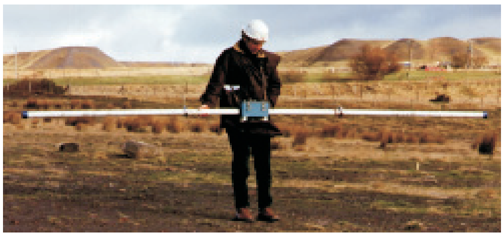
The electromagnetic (EM) technique is based on the response of the ground to the propagation of an electromagnetic field created by the survey instrument. The main components of the EM instrument are a transmitter (for the generation of primary field) and receiver (measurement of the induced secondary field). The EM survey technique has a number of different applications and can be applied to both reconnaissance and detailed ground investigations.

The EM survey method can be used to map the following sub-surface features:

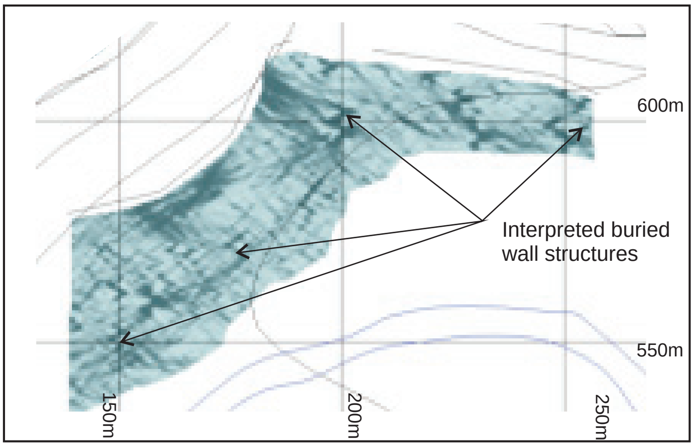
- **Geological & Hydrogeological features : Contaminant Plumes**
- **Foundations and Services : Archeological Structures and Artifacts**

EM-38
(Exploration depth ~1.5m)

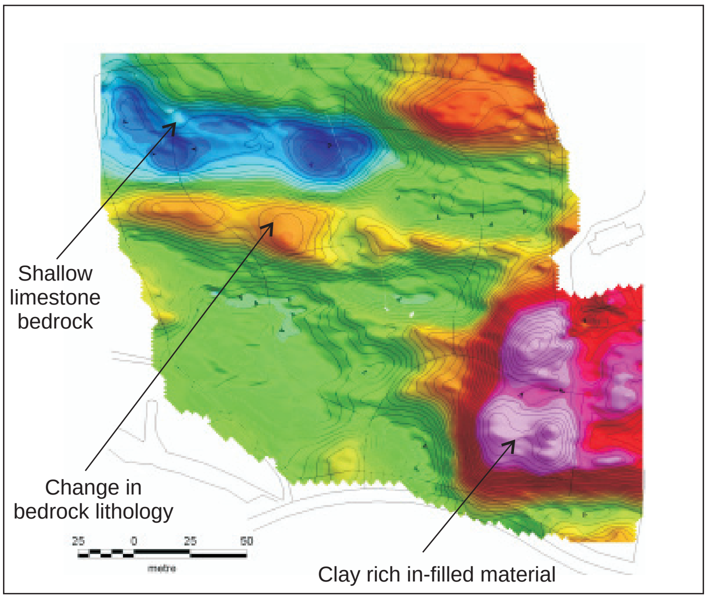


EM-31
(Exploration depth ~3 to 5m)

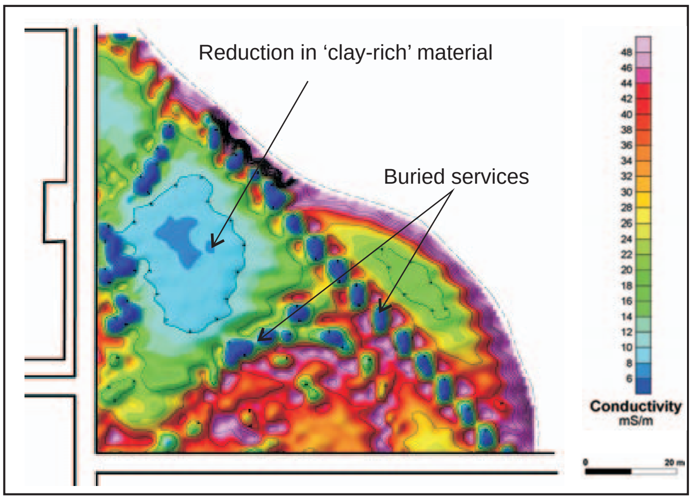
EM-34
(Exploration depth ~7.5 to 60m)



(ABOVE) An EM-38 survey was carried out as part of an archeological investigation of a Bronze Age settlement in Cyprus. The resulting conductivity plan is presented as a mono-colour shaded relief plot. Many subtle lineations are observed which are believed to represent buried wall structures.



(ABOVE) An EM-34 survey was carried out to identify suspected solution features at the bedrock/drift interface. The red and pink coloured contours define 'clay' rich deposits while the blue (low conductivity) contours indicate shallow bedrock. The results from the EM survey formed the basis of an intrusive investigation by allowing the client to optimize a borehole exploration programme.



(LEFT) An EM-31 was used to characterise a former industrial site prior to redevelopment. The buried services are clearly observed on the conductivity plot as narrow zones of extreme high (pinks) and low (dark blue) values. These extreme variations indicate instrument overload due the presence of conductive (metallic) material. In addition, the EM survey has also mapped variation within the fill material.

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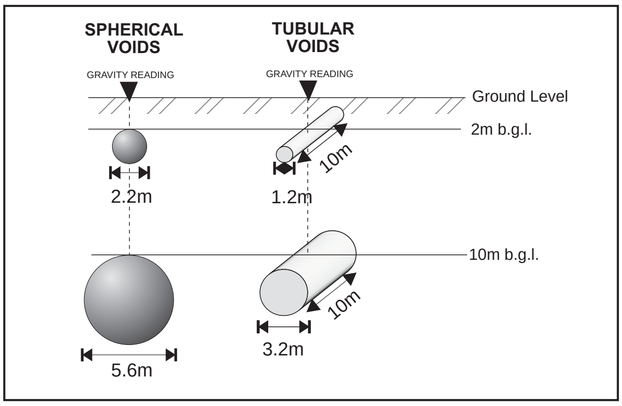
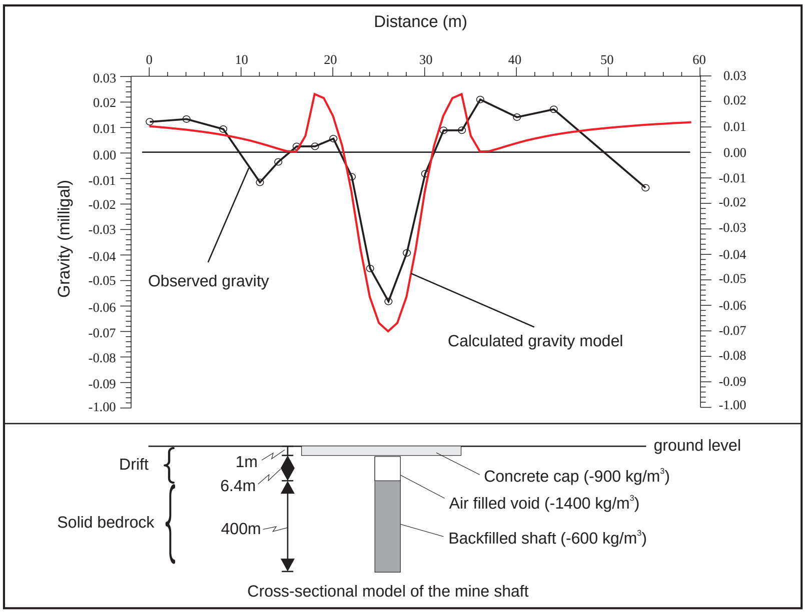
The gravity technique is based on measuring localised variations in the Earth's gravitational field, which are caused by the presence of materials of different densities or voids in the subsurface. The presence of an anomalously high (or low) density body in the subsurface causes a localised high (or low) anomaly in the measured gravitational field. The gravity effects described are extremely small, however, modern instrumentation and exhaustive data processing techniques enable detection of both geological and artificial structures.

TerraDat own and operate a microgal resolution gravity meter (SCINTREX CG3-M), which can be used in the following applications:

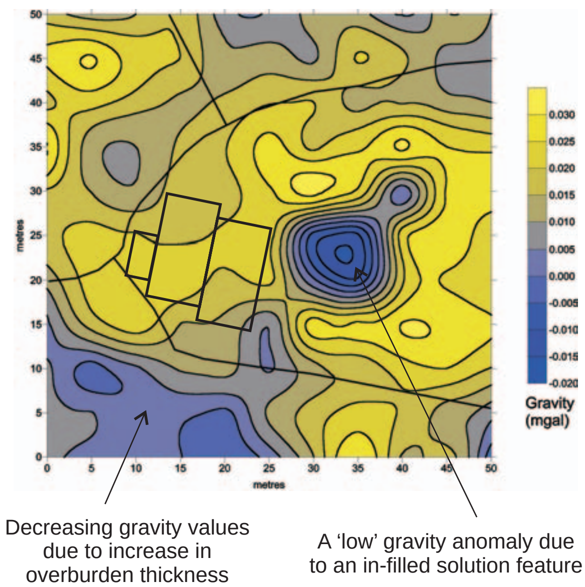
- **Detection of sub-surface voids, e.g., caves, mine workings, basements**
- **Detection of buried structures, e.g., foundations, storage tanks**
- **Mapping bedrock lithology**
- **Mineral exploration**



(LEFT) The size of a gravity anomaly over a buried feature is dependant on a number of factors; the size & shape of the feature, the vertical & lateral separation and the density contrast. The schematic diagram shown left considers the minimum body size required to produce a measurable gravity anomaly (~10 microgal) at ground surface for both a spherical and tubular air-filled void.



(ABOVE) A microgravity survey was carried out to confirm the position of an abandoned mine shaft and to provide information on the degree of backfill. By carrying out a gravity modelling routine, it was shown that the shaft was backfilled to an approximate depth of 6.0m bgl.



(Left) A microgravity survey was carried out to target solution features beneath a site prior to a housing development. The microgravity data was acquired on a 5 x 5m grid and reduced to a Bouguer anomaly plan.

GM-3D Gravity Modeling Software: GM-3D is a gravity modelling software package that allows full 3D inversion of gravity data at both micro and regional scale. GM-3D was developed as an in-house program but due to its successful application it will soon be released commercially.

Seismic Refraction

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Seismic geophone array

"PEG" Elastic wave generator

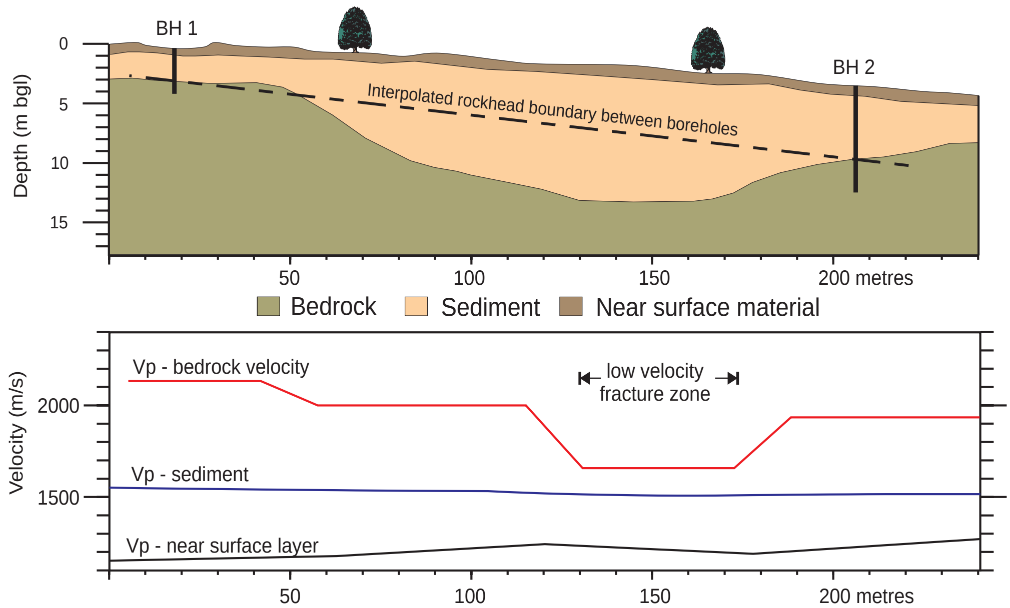
Seismic refraction is a useful method for investigating geological structure and rock properties. The technique involves the observation of a seismic signal that has been refracted between layers of contrasting seismic velocity. Shots are deployed using a hammer/gun/explosive source at the surface and shockwave data recorded via a linear array of geophone sensors. The travel-times of refracted signal are derived from the data and are then processed to determine depth profiles of the targeted geological boundary.

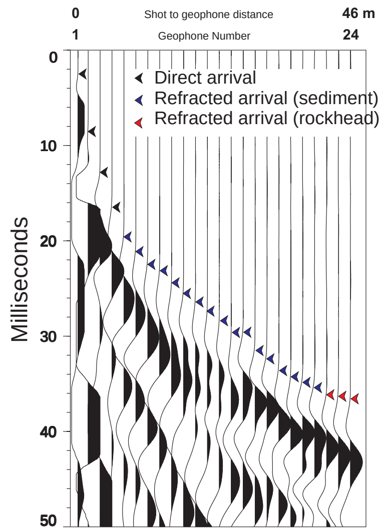
Typical Targets:

- Engineering rockhead
- Weathered rockhead
- Bedrock structure
- Buried channels
- Rock strength & rippability
- Water table

Benefits of seismic profiling:

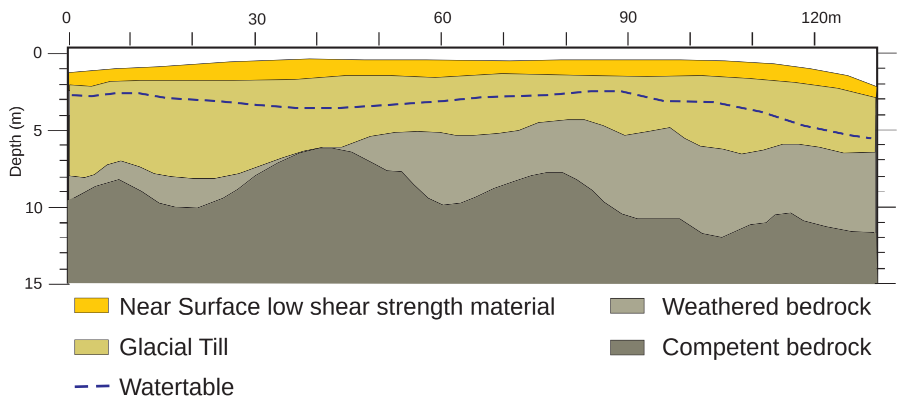
- **Low Cost**
- **High productivity**
- **Continuous profiles**
- **Non-invasive**
- **Environmentally friendly**





Shot record first arrivals

(ABOVE) The cross-section illustrates the advantage of carrying out a seismic refraction survey to map rockhead between exploratory boreholes. The results from the refraction survey identified a 'channel' feature at the bedrock interface, which also correlated to a zone of low seismic velocity. This was interpreted and subsequently proven to be preferential weathering along a bedrock fracture zone.



(LEFT) Combined P and S wave refraction survey. An S-wave survey may be used to profile boundaries where there is insufficient P-wave velocity contrast. An example of this type of boundary would be the top of highly weathered bedrock.

A combined P & S-wave survey also enables the determination of Poisson's Ratio for the sub-surface material.

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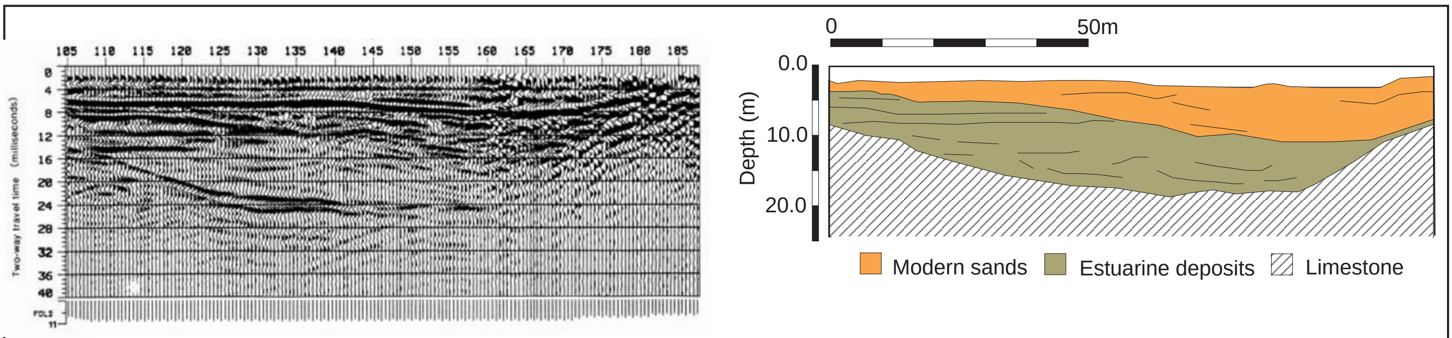
Buffalo Gun source (~100m depth)

Elastic wave generator (~500m depth)

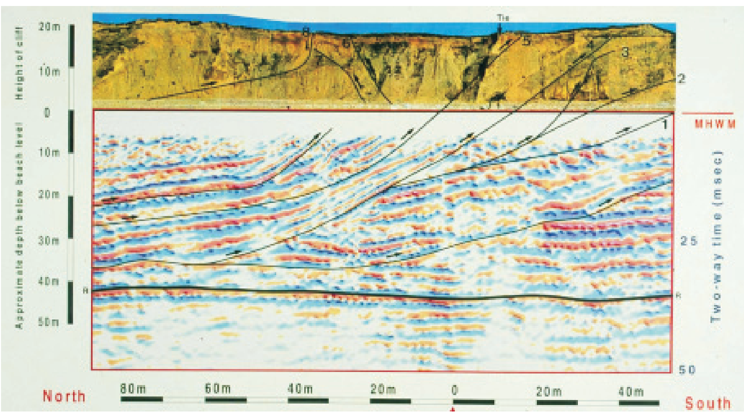
TerraDat has specialist experience in the design and implementation of high-resolution seismic reflection surveys for onshore and transition zone environments. The company routinely carries out seismic survey work for geotechnical and environmental applications as well as larger scale work for oil/mineral exploration.

TerraDat operates a range of state-of-the-art seismic systems that can configured to meet the particular project requirement. These range from a 48-channel seismograph with PC-based processing software to the latest 120 channel telemetry seismic systems and PROMAX software.

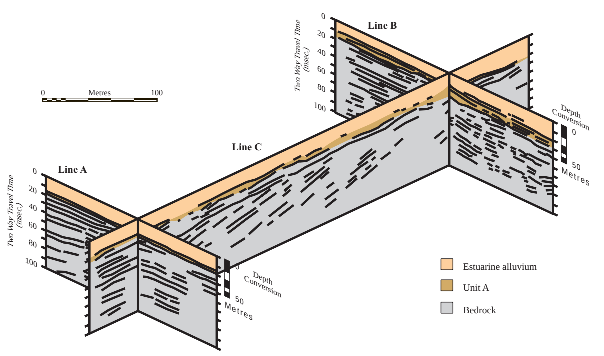
TerraDat is actively involved with ongoing research into the use of shallow seismic reflection in testing environments with an incentive to promote its use for a more diverse range of applications. Several publications have been produced over the years and are available on request. The method requires careful planning where very shallow depths are to be investigated but the results can prove to be invaluable.



(ABOVE) Final stacked section and interpreted depth section from a survey acquired across an abandoned tidal channel.



(ABOVE) High resolution seismic reflection data showing the internal structure of glacio-tectonic deposits in North Wales.



(ABOVE) Three dimensional representation of coal measure structure beneath a South Wales estuary.

Recents developments will see the addition of an IVI miniVib to the TeraDat resource pool and enable high-resolution surveys to be carried out where a vibrator source is optimum due to surface conditions or environmental concerns.

Magnetic & Metal Detection Surveys

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Magnetic survey with a SCINTREX gradiometer

The Magnetic survey technique is based on mapping localised variations in the Earth's magnetic field caused sub-surface magnetic materials which range from naturally occurring magnetic minerals to man-made ferrous objects. This leads to a wide range of applications from small-scale archeology and engineering surveys to detect buried metallic objects, to large-scale surveys carried out to investigate regional geological trends or mineralisation.

Target features:

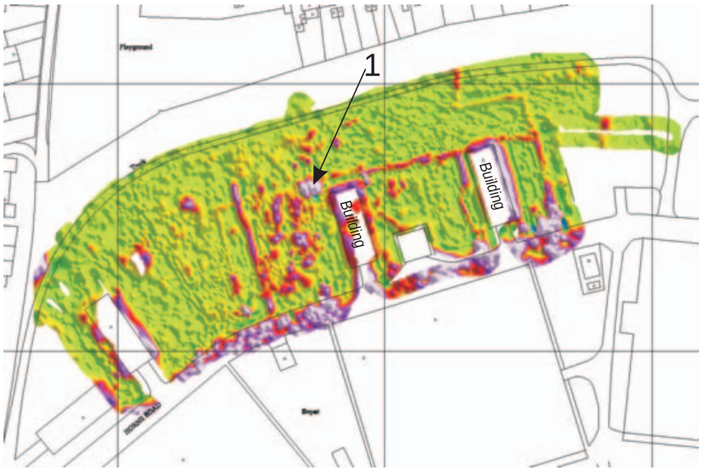
- **Shallow archaeology**
- **Unexploded ordnance**
- **Hazardous metal waste**
- **Services and foundations**
- **Abandoned mine workings**
- **Drums & USTs**

Benefits:

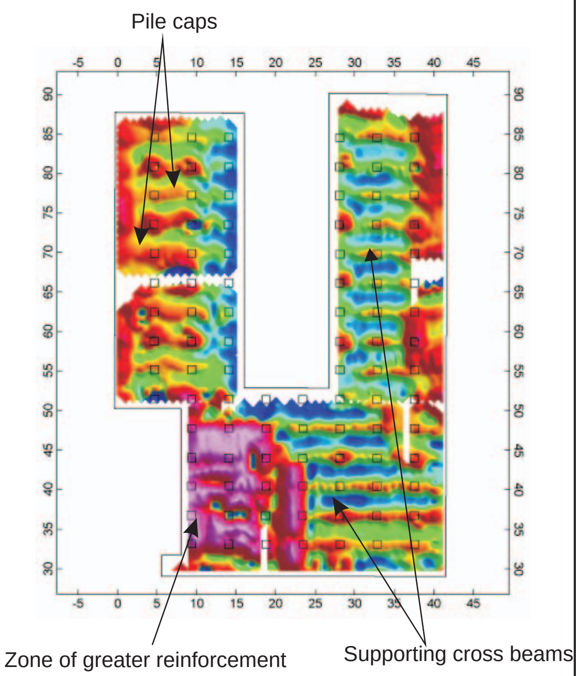
- **Non-invasive**
- **High resolution of targets**
- **Complete ground coverage**
- **Environmentally friendly**
- **Low Cost**

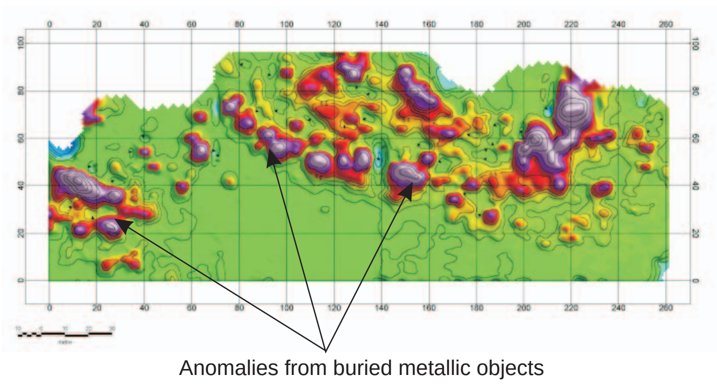
EM-61 High sensitivity metal detector

The EM-61 is based on the time-domain electromagnetic technique which enables the instrument to discriminate between moderately conductive earth materials and very conductive metallic targets.



(ABOVE) Processed magnetic data from a former industrial site showing linear anomalies from ferrous buried services. The isolated magnetic anomaly marked "1" was ground truthed to be an underground fuel tank. (Note the magnetic effect of the buildings).





(ABOVE) The resulting contour plot from an EM-61 survey to locate illegally dumped drums within an old landfill site.

(LEFT) An EM-61 survey was carried out to confirm the locations of pile caps beneath an existing floor slab. The resulting contour plan clearly displays the supporting cross beams which correlate with the suspected pile locations.

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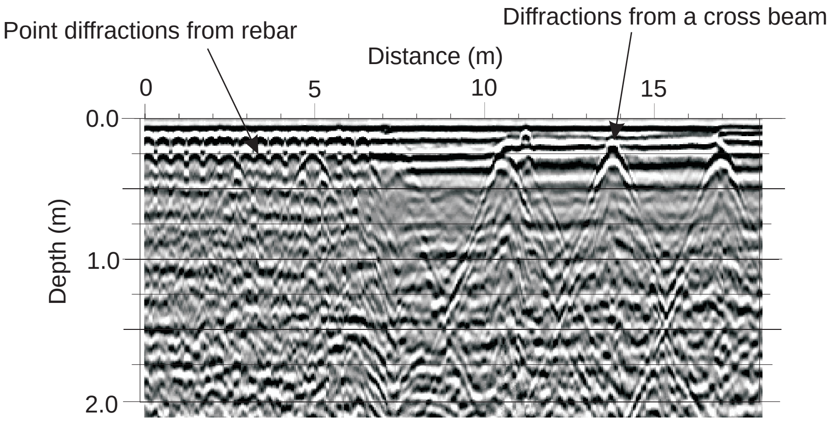
Radar survey to map limestone cavities

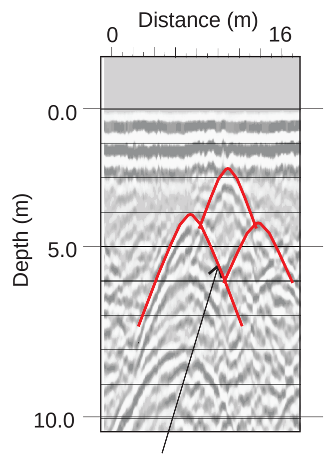
Ground penetrating radar (GPR) utilises pulsed high frequency radio waves to probe the subsurface without disturbing the ground. The GPR data are collected continuously as the instrument is towed over the ground surface and provides a real-time graphic image of the subsurface.

The GPR method can be used to map the following sub-surface features:

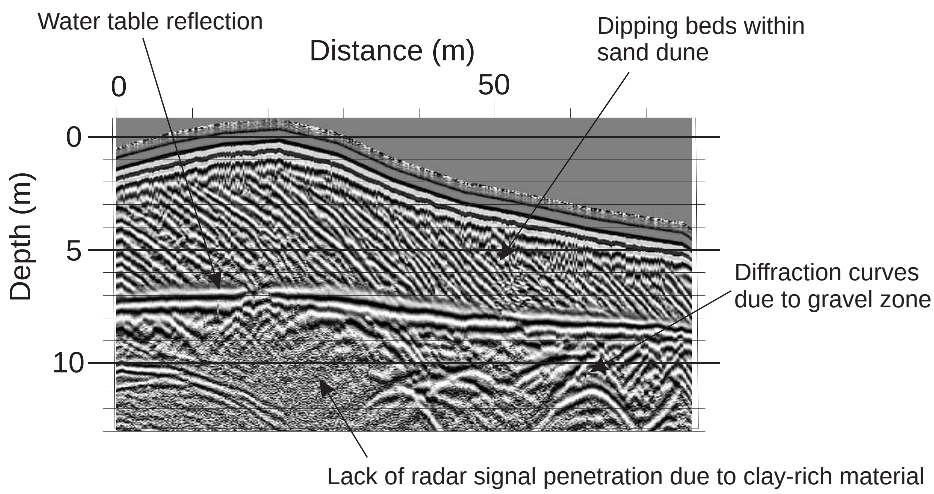
- **Services and foundation structures**
- **Geological boundaries**
- **Cavities, voids & animal burrows**
- **Underground storage tanks**



Example data from the a shielded 500MHz antenna profiling across a concrete floor slab.



Observed diffraction curves over a sub-surface cavity within limestone



Ground Radar profile over a parabolic sand dune (100MHz)

Observed features on a radar section can include:

Reflection event:
A laterally continuous interface with contrasting electrical properties (controlled largely by composition and moisture content of the material). Examples of reflecting surfaces are soil horizons, soil-rock or air-rock interfaces, water tables, and solid metallic and non- metallic objects.

Diffraction Curve:
A diffraction hyperbolic curve usually indicates a 'point' source such as a void, buried service or an edge-feature.

Constraints affecting a GPR survey
The presence of clay-rich soil or saline groundwater can limit the exploration depth by attenuating the radar signal. Both resolution and penetration can also be adversely affected if the subsurface is 'blocky' (fill material, cobbles or rebars), where a large amount of backscattering of the radar signal occurs. Detectability depends upon the dielectric contrast between the target feature and the surrounding material. A relatively even ground surface is also necessary in order to tow the antenna in a continuous line.

Down-hole Shear wave survey through colliery spoil, South Wales

Seismic methods can provide detailed information about rock properties and geological structure between boreholes. Fewer boreholes are needed to achieve a continuous picture of the subsurface thereby reducing overall costs and the risk of missing target features. Borehole seismic methods largely fall into two categories, namely, Crosshole Seismics and Seismic Tomography.

Crosshole Seismics typically involves shooting at regular depth intervals from one borehole to another and simply deriving velocity of the signal travelling between them. Given the measured velocities it is possible to derive elastic modulae for the material between the boreholes as it varies with depth. Carrying out a survey using compressional (P) waves and shear (S) waves enables derivation of Poisson's ratio while the introduction of density information (from measurement or estimation) enables derivation of Bulk Modulus and Shear Modulus values.

TerraDat's New Electro-mechanical (S & P) wave source for Crosshole Surveys

Borehole Seismic Tomography typically involves shooting at discrete depth intervals in one borehole and measuring the velocity of signal travelling to multiple receivers at different depths in another borehole. Using this method, data are acquired along a great number of ray-paths between boreholes enabling derivation of a detailed image of the rock mass through tomographic inversion of the data. The method can be used to resolve features such as voids, large fracture zones and geological structure where contrasting lithologies are encountered.

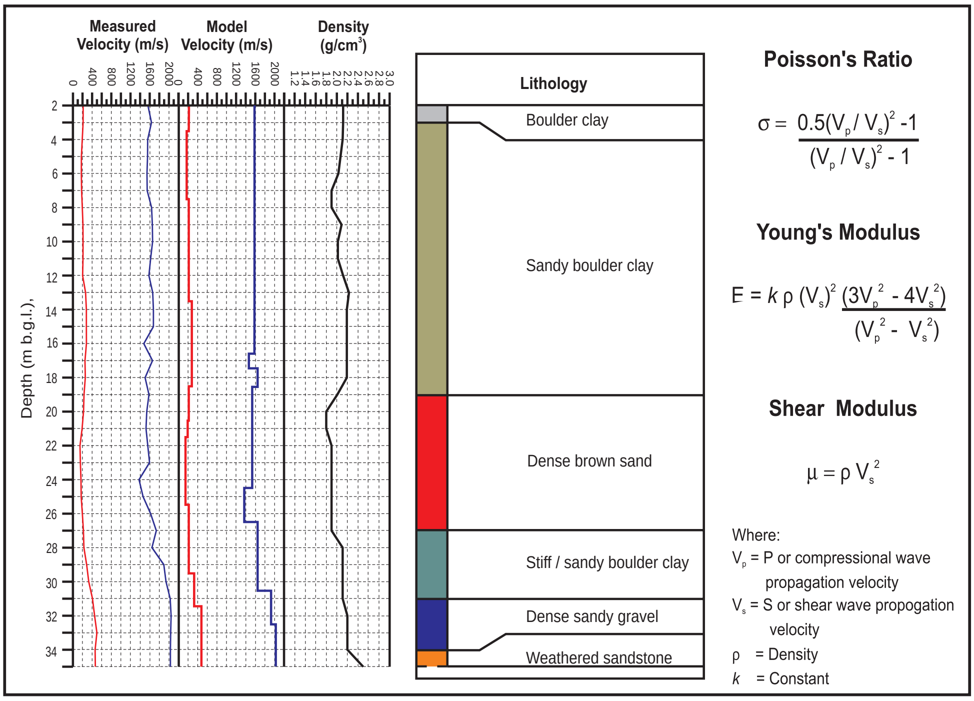
Typical Targets:

- Geological Hazards
- Elastic Modulae
- Fracture Zones
- Caves/Stopes/Adits
- Rock Structure

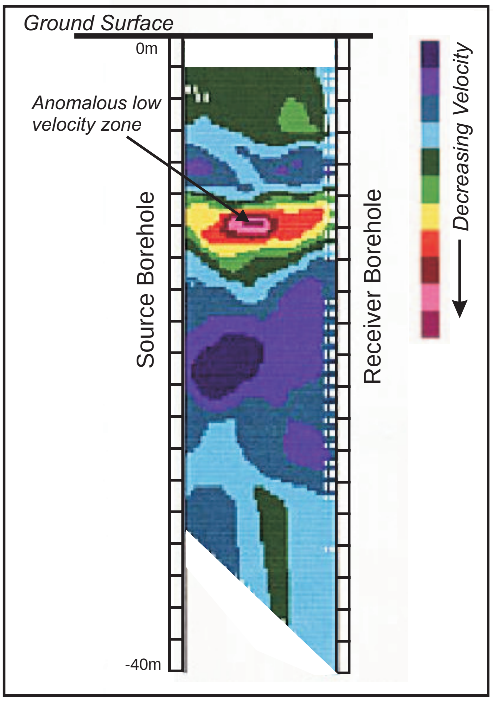
Benefits of Borehole Seismics:

- Cost Efficient
- Images Between Boreholes
- Good Productivity
- Non-invasive
- Environmentally Friendly

(a) Crosshole Survey - Determining Elastic Modulae



(b) Borehole Seismic Tomography



(a) The dynamic elastic modulae of the rock mass between boreholes can be readily derived using Crosshole seismic methods. Density information is required for some modulae and may be estimated from known lithological properties, measured directly in the field/lab or derived from a borehole logging survey. (b) the identification of low velocity zones such as a cavity/solution feature, fracture zone or workings are common requirements of a seismic tomography surveys and are clearly observed on the resulting tomogram.

Geonics EM31 Conductivity instrument with dGPS

Buried foundations and other manmade structures can be an expensive obstacle in land reclamation schemes. TerraDat routinely carries out geophysical reconnaissance surveys to identify buried structures and other subsurface hazards for reclamation or remediation of brownfield sites. This information may then be used by the Client to optimize a trial pitting or borehole program with minimized risks.

A geophysical survey can rapidly characterise several hectares of land in a day without disturbing the surface. Often same day results can be produced to target follow up work during the site investigation.

Recent innovations by TerraDat integrate geophysical data acquisition with global positioning systems (dGPS) giving increased resolution / productivity as well as allowing accurate geo-referencing of anomalies.

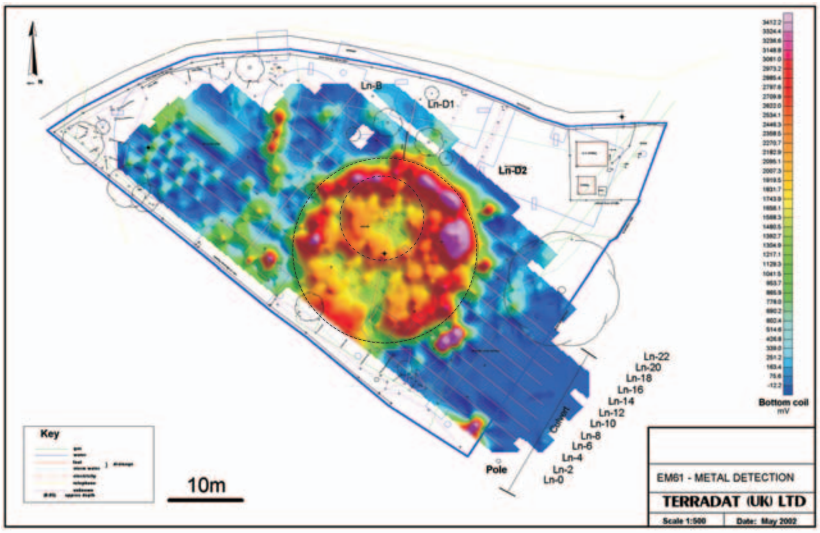
- **Buried UST's / drum location**
- **Characterising made ground thickness**
- **Mapping buried foundations / services**
- **Contamination plume mapping**
- **Unexploded ordnance (UXO)**
- **Finding animal burrows**

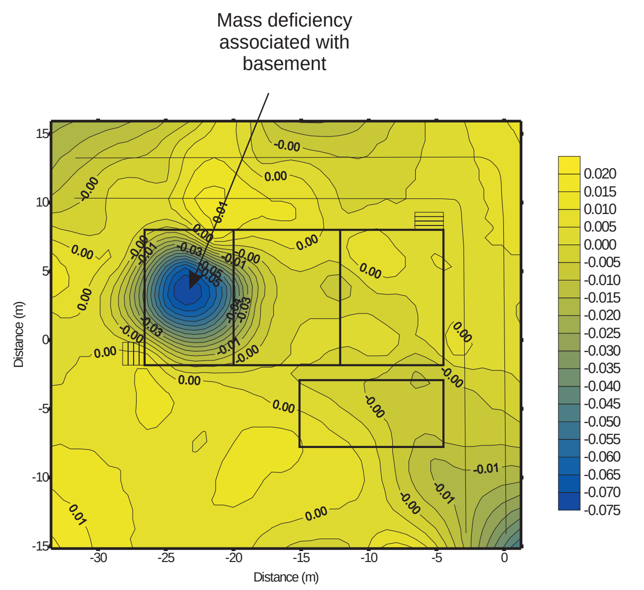
(RIGHT) - Contoured EM61 metal detection data overlain by site plan.

The survey was aimed at locating former gas holder bases and associated tar pits beneath them. The colour contours represent the range of values caused by metal beneath the layer of made ground. Note the smaller foundation from an older tank within the anomaly from the larger tank.

It is often the case with geophysical surveys of brownfield sites that anomalies are mapped from other buried structures that are not the main target of the study. In this case the survey has mapped a line of buried services and foundations from buildings associated with the former gas works.

The survey took one day to complete and a further day to compile the report and produce working plans for the Client.





Contour plan of microgravity data over a suspected basement

(LEFT) The plan shows the contoured results of a microgravity survey from an integrated geophysical survey aimed at mapping and identifying a number of sub-surface features at a former colliery site. The site comprised of both derelict and demolished buildings together with areas that were open and free from obstructions.

An initial combined EM (electromagnetic) and magnetic survey was carried out across the survey area. Selective ground radar profiles were acquired over a number of the identified anomalies to provide cross-sectional information. Most of the anomalies were interpreted as buried services, concrete slabs and variations in the fill material.

One particular problem that was raised from the desk study was the possibility of basements beneath some of the concrete slabs. The rebars within the slab reduced the effectiveness of the EM and radar survey, therefore a detailed microgravity survey was carried out over the concrete slabs in order to identify suspected basements. The blue negative anomaly clearly shows a mass deficiency beneath one of the buildings from a large basement.

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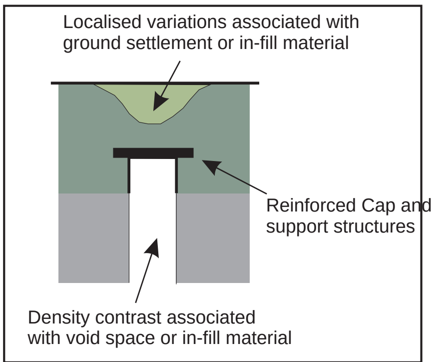
GPR survey to map extent of underground workings

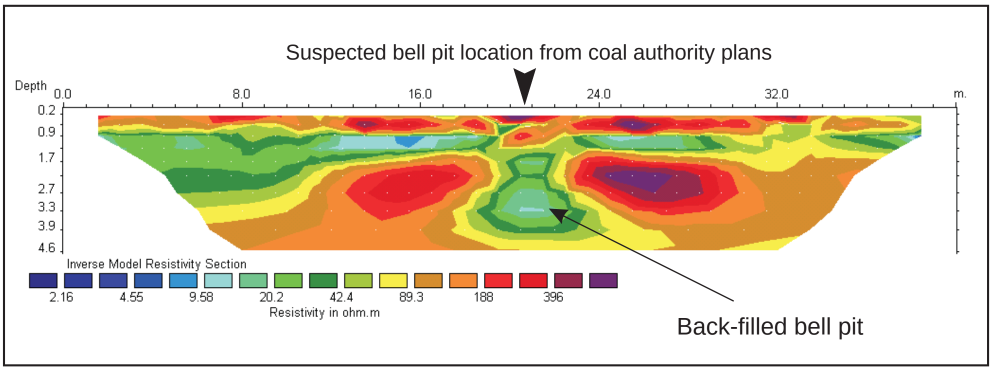
In many regions, mining activity has left a legacy of bell pits, shafts, adits, or subsidence which have a significant influence on present day developments. The majority of mining activity is well documented, but in some cases the accuracy of this information can be questionable.

A geophysics survey coupled with a selective intrusive investigation can provide a rapid and cost- effective means for locating shallow abandoned mine-workings .

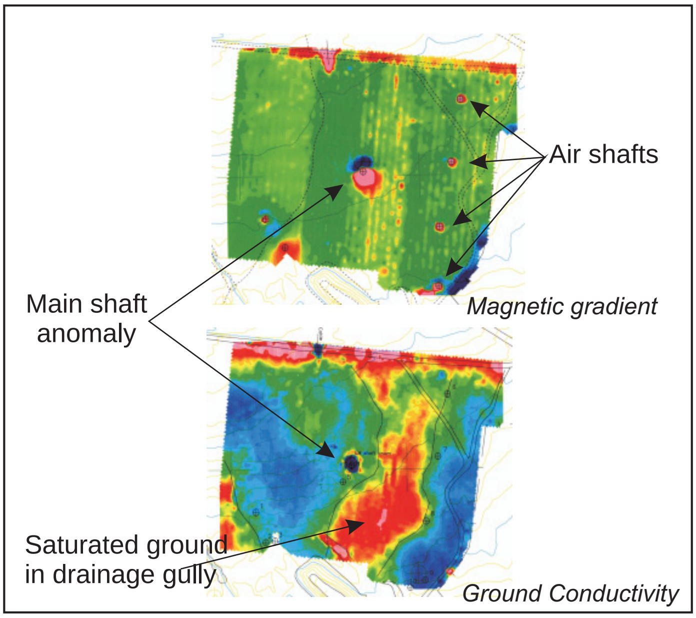
Historical mine-workings can prove to be difficult targets due to the lack of background information on the actual mining activity and the limitations posed by the present day site conditions (e.g., fill thickness, buildings, roads etc). For most sites, TerraDat usually adopt an integrated survey approach comprising a number of different geophysical techniques, which target both direct (e.g. shaft lining/cap, void space) and in-direct attributes (e.g. localised variations in drainage patterns or anomalous backfill material).



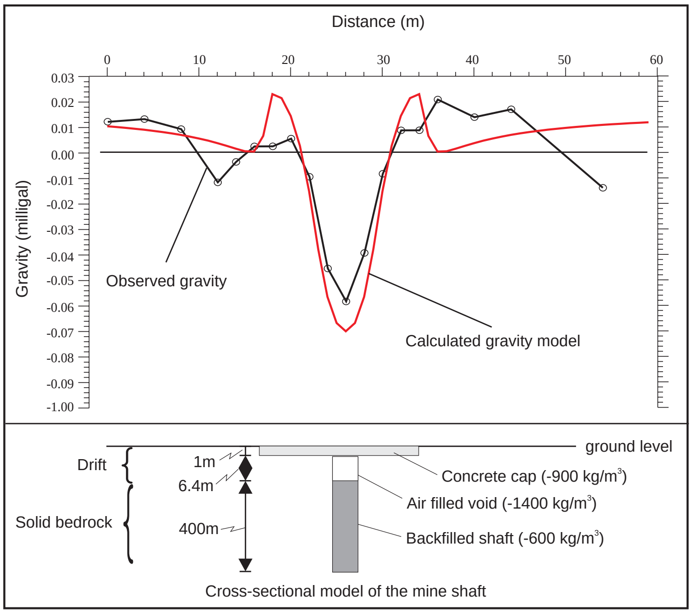
(ABOVE) Selection of geophysical target features associated with abandoned mine workings



(ABOVE) A resistivity survey was carried out to confirm the location of an abandoned bell pit. The results suggest that the bell pit extends to a depth of 4m bgl and has been back-filled with clay-rich material.

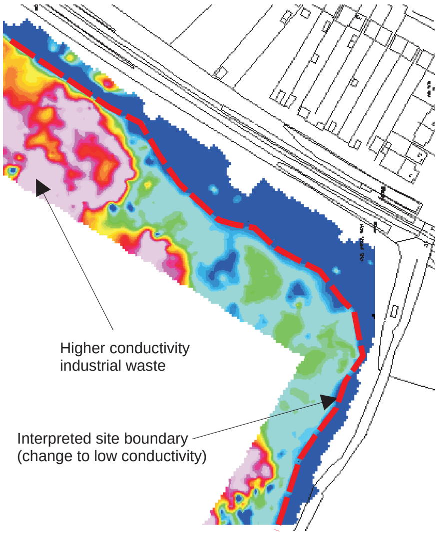


(ABOVE) A combined magnetic and conductivity survey was carried out over an abandoned colliery site in South Wales. A large shaft containing scrap metal is clearly evident in the centre of the site. In addition, four air shafts above an adit have been located using magnetic gradient mapping.



(ABOVE) A microgravity survey was carried out to confirm the position of an abandoned mine shaft and to provide information on the degree of backfill. By carrying out a gravity modelling routine, it was shown that the shaft was backfilled to an approximate depth of 6.0m bgl.

The problem of characterising both active and closed landfills and waste sites is an increasing one in the light of increasing environmental legislation and poor historical records. A TerraDat geophysical survey can be rapidly carried out for a fraction of the cost of obtaining low-resolution information through invasive means, without disturbing the ground.

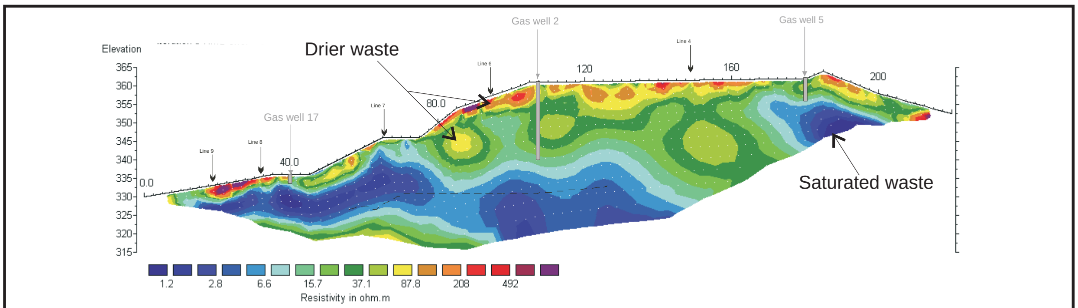


Ground conductivity plan showing variations between waste and surrounding geology

- **Mapping leachate level within landfills**
- **Locating landfill boundaries**
- **Characterising variations in waste composition**
- **Mapping "dry" and "wet" zones for leachate control**
- **Investigating cap integrity**
- **Geological characterisation for new cell design**
- **Leachate plume mapping**
- **Locating voids or poorly compacted zones**
- **Landfill HDPE Liner testing**
- **Locating underground springs**

(Left): The plan shows the how conductivity mapping can be used to rapidly locate the boundaries of a closed landfill where records are missing.

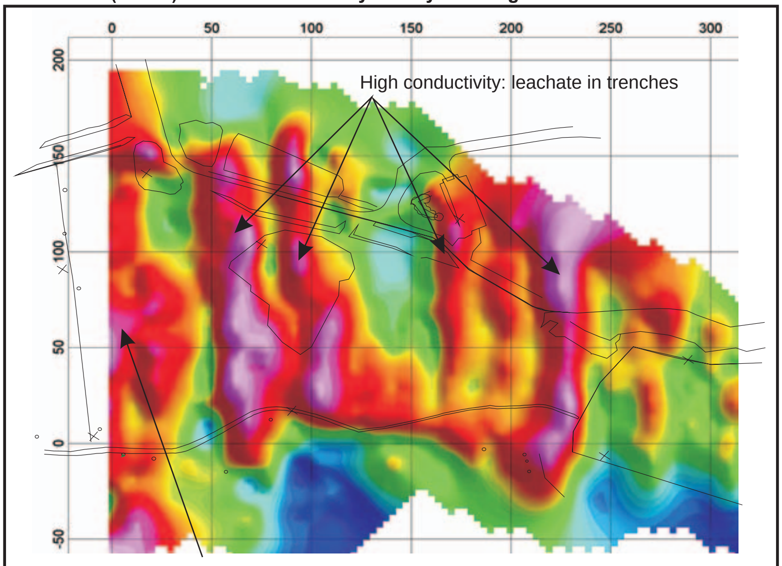
(Below): The section below is from a resistivity tomography survey and shows variations within a landfill cell including wet and dry waste, the landfill base and bedrock characteristics. Up to 1.5km of line can be acquired in one day.



Resistivity Tomography Section to provide cross-sectional information inside a landfill site

Resistivity Tomography

(Below) Ground Conductivity Survey Showing Leachate Plumes



(Left): Characterising the internal composition of a landfill is an important factor when considering the contamination potential and future of either an active or abandoned site. With non-existent or incomplete records, placing random boreholes and probes can be costly and ineffective. Knowledge about lateral changes in the properties of a landfill can identify features such as tip boundaries, different phases of tipping, saturated and dry ground, leachate plumes, and areas of groundwater ingress.

The purple lineations represent conductivity highs in trenches that were excavated into the underlying clay and filled with industrial waste. Subsequent groundwater ingress caused leachate accumulations that concentrated in the trenches.

Further processing of the EM data showed the leachate plumes to be migrating towards the site boundary thus providing optimal locations for pumping wells.

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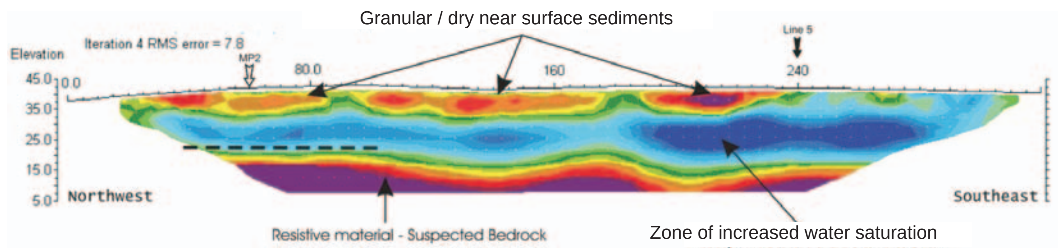
Geophysical surveys can be effectively used on landslips, former industrial tips or unstable slopes to characterise their internal structure and material character with respect to factors that may contribute to failures.

The key targets for geophysics include:

- Bedrock profile
- Variations in the overburden
- Zones of differential moisture content
- Low density or poorly compacted material

Survey techniques include resistivity, seismic refraction, microgravity and ground radar (depending on site conditions etc.) and may be carried out as one survey to gain an understanding of the subsurface, or on a repeat basis to monitor changes over time.

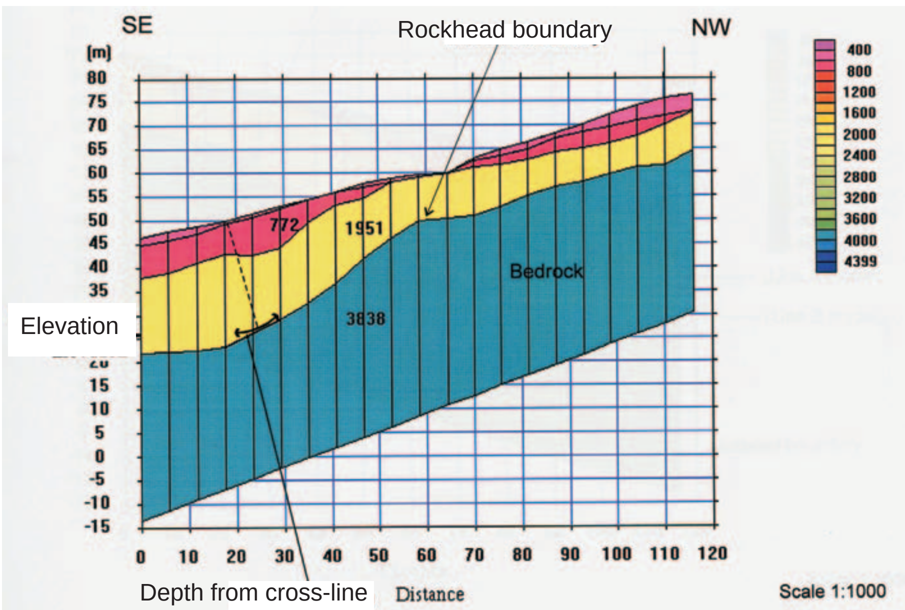


Resistivity Tomography Section to provide cross-sectional information inside a landslip

(**Above**): Result of a resistivity tomography survey aimed at characterising geo-electrical changes within the toe of an active landslip. Depths down to around 50m below ground level can be targeted with this method.

(**Below** right): Seismic refraction survey results from an active landslip in North Wales showing sediments of varying seismic velocity (a function of density/compaction) and the rockhead profile indicated by the highest velocity material(>3500 m/s).

(Below): Typical survey layout involving deployment of electrodes with low environmental impact along a cable array of length 100-400m.



electrode array at Melksham Town Bridge

TerraDat has developed geophysical survey techniques (resistivity tomography & seismic refraction) specifically for river and stream crossing investigations.

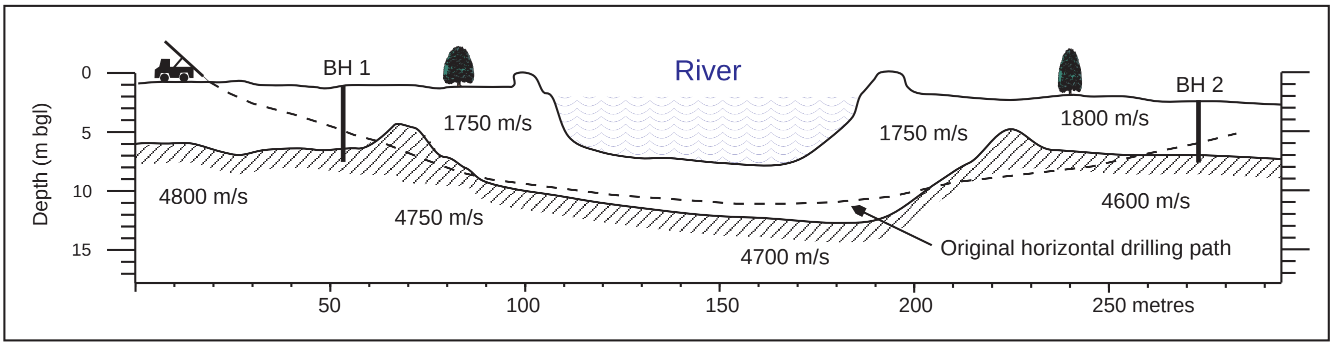
Specific applications where these surveys are routinely applied include:

- Profiling bedrock for geotechnical studies
- Identifying hazards for horizontal drilling
- Examining the foundations of old bridges

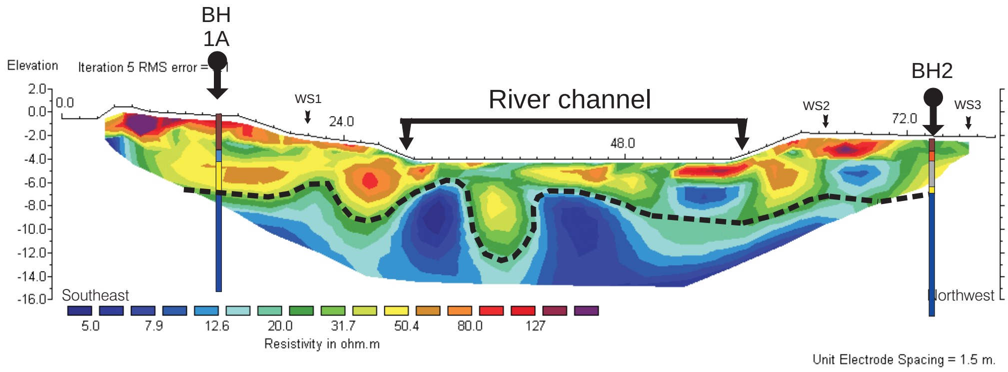
The geophysical contrast between targets such as localised rises in bedrock, lenses of coarse cobbles / gravel or infilled alluvial channels can be mapped very rapidly with no disturbance to the surface.

A river crossing can take between half a day and two days to carry out depending on logistics. The results are presented as scale geological sections and can overcome limitations often encountered in conventional ground investigations such as interpolation between boreholes on the river banks and false impressions of bedrock when large boulders are encountered.

Non-destructive methods
Rapid surveys acquisition
Unaffected by water levels & soft ground



(ABOVE) A seismic refraction survey was carried out to provide rockhead information prior to a horizontal drilling program, By combining the standard land based survey with a static streamer approach, full refraction profile was obtained across a number of river crossings.



Left: resistivity section to profile Clay and gravel beneath river channel

Investigation of Karst Features

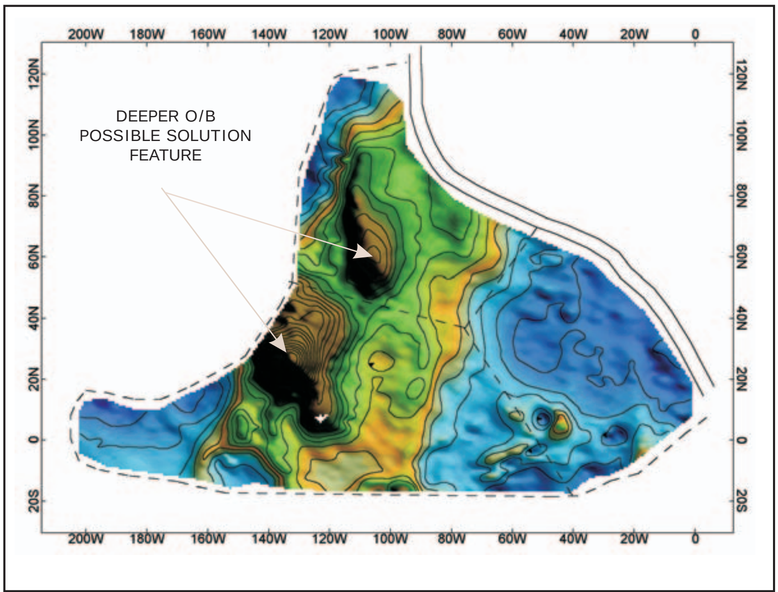
geophysical **innovation**

Geophysical surveys can detect hazardous ground conditions before they become a problem

One of the key considerations for property developments in Limestone or Chalk environments is the presence of sub-surface solution features and voids. The need to fully characterise unstable ground for foundation design is a significant factor for both the valuation, construction and post-development phase.

Solution features can be mapped using geophysical techniques by virtue of lithological contrasts between fill and surrounding geology, mass defficiencies due to voiding, or subtle effects on drainage.

Caverns and fissures within bedrock are often more difficult to target. Size and depth are important considerations when deciding on the most suitable geophysical technique. Micro-gravity is the most suitable method however, it may also be the most costly.

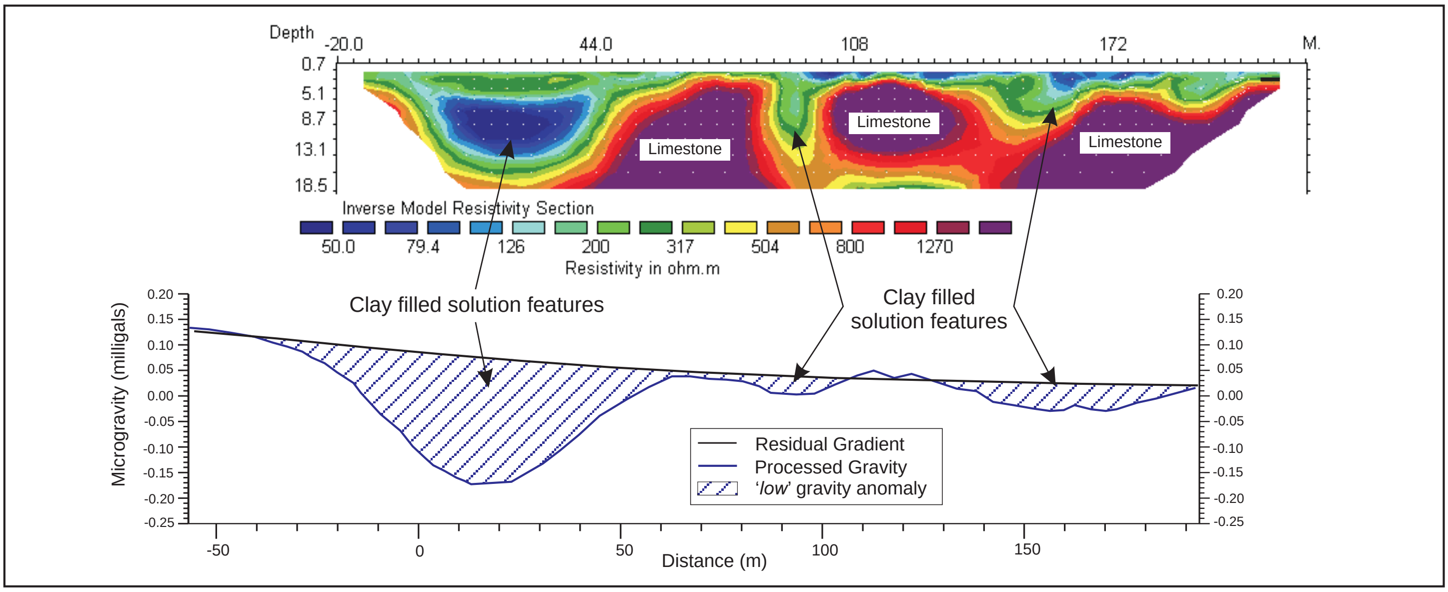


Conductivity Plan

(LEFT) An initial conductivity survey (EM-31) was carried out to map suspected solution features beneath a proposed housing development. The resulting ground conductivity plan shows a band of relatively higher conductivity which was interpreted as either an area of lithological change or increase in overburden thickness.

In order to provide cross-sectional depth information, a number of seismic refraction and resistivity imaging profiles were recorded across the site. The results of the seismic and resistivity indicated that the observed conductive band was due to an increase in overburden thickness and not a lithological change.

Subsequently intrusive investigation suggested that change in overburden thickness was as a result of karst erosional processes.



(ABOVE) A combined resistivity tomography and microgravity survey was carried out along a proposed highway route that traversed an area with known solution features. There was a good correlation between the final resistivity and gravity sections, the clay rich solution feature infill material being both less dense and less resistive than the limestone bedrock.

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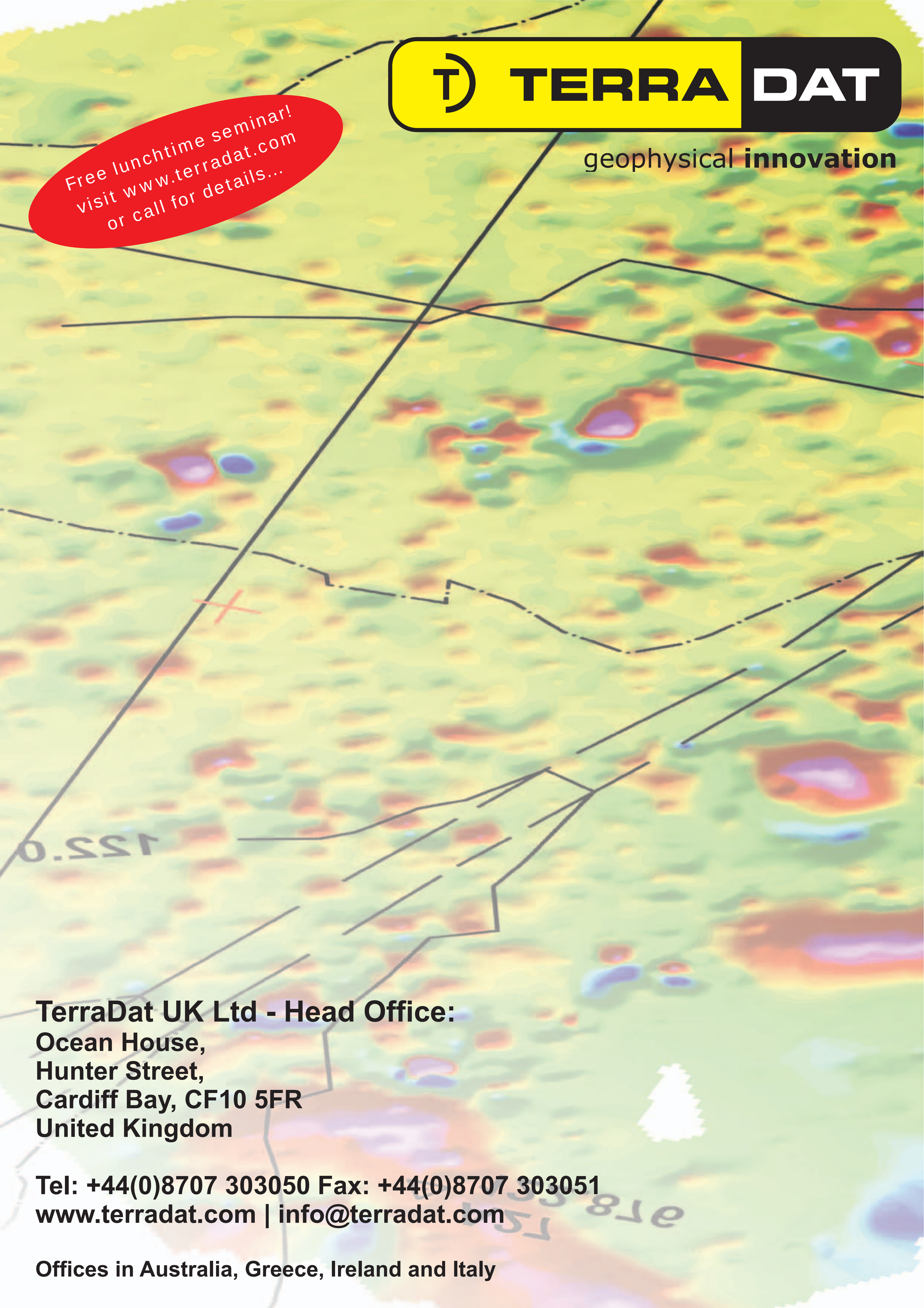
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