Understanding heterogeneity and structure in urban environments: a tool for the assessment of risk and interpretation of geochemical data

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL
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Understanding the spatial and temporal development of anthropogenic and natural soil systems along with associated geological deposits has long been acknowledged as important underpinning information in the planning and geotechnical assessment of new urban developments. However, such information has only rarely been linked with the interpretation and use of urban geochemical surveys during the risk assessment process. In recognition of this the British Geological Survey (BGS) have been developing a portfolio of supporting techniques and methodologies to assist in (a) developing a better understanding of the nature, history and potential future of the urban subsurface and (b) integrating this knowledge into a risk-assessment framework that may be used in a predictive manner with a variety of potential scenarios.

In this poster we present some examples of BGS studies in which we are developing techniques that better enable the incorporation of geochemistry and associated risk assessment models with other contextual data from a range of urban environments. It is proposed that such integrated datasets should form the backbone to a range of scenario development and planning models enabling more accurate prediction of risk and options for its mitigation prior to, during and after extreme events.

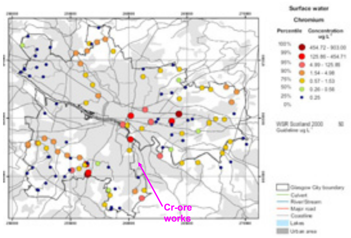
Baseline data

Source: How much? Where? What is it? How long has it been there?

Pathway: What are the most likely pathways, proximity to contamination, geology, hydrogeology, on what time scale is transport likley to occurr and sensitivity to other hazards/extreme events.

Target: What are they? How many are there? Planning consent, proximity to contamination, how sensitive and land use.

Geochemistry



Glasgow Clyde tributaries geochemical survey

During 2003, 118 stream sediment (< 2mm and < 150μm) and 122 stream water samples were collected at a sample density of 1 per km^2 from all tributaries draining into the River Clyde within the Glasgow area.

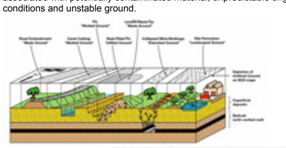
Sediment and water samples were analysed for approximately 60 organic and inorganic substances to provide an overview of the quality of the urban drainage system.

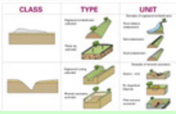
Glasgow was home to the largest Cr-ore processing plant in the world in the 19th century. The works closed in 1967 but during operation, waste from the site was distributed throughout the city.

Survey results demonstrate that nine sites exceed the water quality guidelines for Cr. Some levels are VERY high > 900 μg L^{-1} indicating Cr from chromite waste is mobile and has potential to impact on the water quality of the River Clyde, which has implications for urban regeneration of the Clyde waterfront.

Characterisation of artificial ground

The emphasis of a geological survey has traditionally been on 'bedrock geology' and 'superficial geology', but an improved understanding of the the nature and distribution of artificial ground is becoming increasingly important for engineering and environmental assessments. Information about previously developed ground is especially important, as it is often associated with potentially contaminated material, unpredictable engineering conditions and unstable ground.





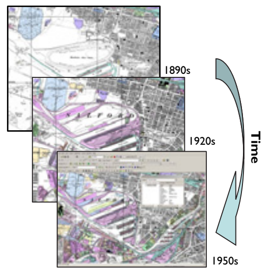
Example of the stratigraphic subdivision of made and worked ground into types and units with different engineering properties and potential contaminant occurences

Definitions of artificial ground

Made Ground: Areas where material is known to have been placed by man on the pre-existing land surface (including engineered fill).
Infilled Ground: Areas where the pre-existing (natural or artificial) land surface has been excavated (Worked Ground) and subsequently partially or wholly backfilled (Made Ground).
Worked Ground: Areas where the pre-existing (natural or artificial) land surface is known to have been excavated by man.
Landscaped Ground: Areas where the pre-existing land surface (natural or artificial) has been extensively remodelled, but where it is impracticable to delineate separate areas of Made Ground, Worked Ground or Disturbed Ground.
Disturbed Ground: Areas of ill-defined surface disruption associated with surface or near-surface development or collapse. The disturbance is typically complex, dominated by zones of subsidence, and includes areas of Worked Ground and Made Ground.

After McMillan, A A and Powell, J H. 1999. BGS Rock Classification Scheme Volume 4. BGS Research Report RR99–04.

Temporal changes in land use

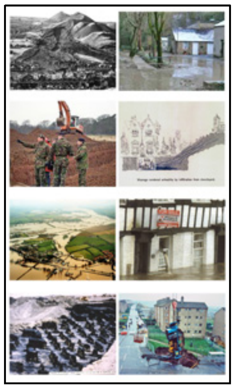


Example of anthropogenic evolution in Trafford Park, Salford, NW England, the world's first industrial estate. Rapid industrial development over time and construction of the Manchester Ship Canal, has left a legacy of highly variable and contaminated ground conditions.

- Anthropogenic activity creates layers of artificial ground associated with activities such as development, burying waste or infilling quarries.
- This results in highly variable physical and chemical properties of the subsurface.

Modelling human impacts on the urban subsurface

- Characterised in 2D and 3D through historical map analysis, borehole interpretation and industrial archaeological modelling.
- Integrated GIS and 3D models.
- Attribution of 3D models and maps to highlight variability of geotechnical, hydrogeological or lithological properties.
- 3D provides the key to understanding the often detrimental human impacts on and beneath the ground to help understand hazards that may affect development and the management of water resources and aquifers.

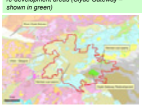


Describing geological and pedological hetrogeneity in 3D and 4D

Attributed 3D geological models for planning and large-scale redevelopment in Glasgow, Scotland, UK

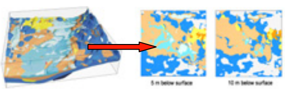
- The city of Glasgow has a legacy of industrial dereliction, shallow undermining, and contamination, is underlain by complex superficial deposits with variable physical properties, and faulted bedrock; and has many environmental issues to address during current re-development.
- BGS has developed 3D geological models (superficial deposits and bedrock) of the city, attributed with geochemical, geotechnical and hydrogeological properties.
- The models are used to generate synthetic sections and boreholes (see below), and for integrated modelling, to assist local authorities (e.g. Glasgow City Council) and others with the planning and re-development of the city.

Traditional 2D map of Glasgow's sedimentary (blue/grey/brown), and volcanic bedrock (pink/orange) with one of the major re-development areas (Clyde Gateway – shown in green)

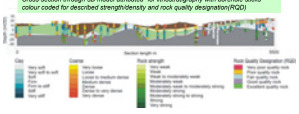


3D model (eastern Glasgow): superficial and artificial deposits with engineering geology classification

Plan views through 3D model of engineering classification to help locate development footprints and select foundation types



Cross-section through 3D model attributed for lithostratigraphy with borehole sticks colour coded for described strength/density and rock quality designation(RQD)

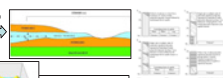


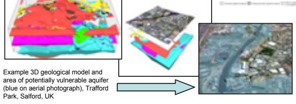
Applied 3D geological modelling

Hydrogeological domains mapping for groundwater management

- 3D geological models built in Manchester and Salford in NW England, UK have been used to derive hydrogeological domains in thick superficial deposits overlying one of the major UK aquifers on behalf ofthe Environment Agency.
- The hydrogeological domainshighlight areas where the underlying bedrock aquifer is potentially vulnerable to polution from contaminants above.
- Understanding and visualisingapplied geoscience data allows national regulators, such as the Environment Agency in the UK to make informed decisions in response to current regulatory requirements.

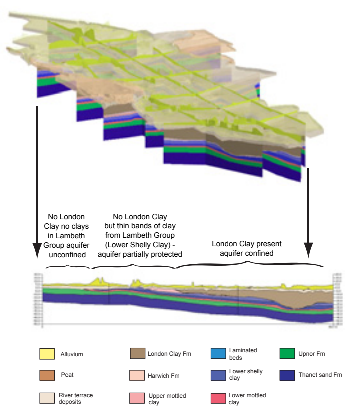
Definition and application of hydrogeological domains to 3D geological model





Example 3D geological model and area of potentially vulnerable aquifer (blue on aerial photograph), Trafford Park, Salford, UK

Urban modelling: Olympic Park Development Zone



The Olympic development will necessitate the opening up of watercourses, the extension of wetland areas along the riverbanks as well as the development of deep foundations, all of which can provide new pathways for contaminants. If unidentified soil and groundwater contamination is present, there is a potential that these contaminants will migrate via these newly formed pathways posing a significant risk to groundwater quality if unmitigated. The 3D model contains information that will aid in the assessment of these risks and provide information to help mitigate the situation before it occurs. This will help planners and developers manage the risks to groundwater and other urban environments.

A detailed 3D geological model has been produced of the Olympic Park Development Zone (Lower Lea Valley). The model can be used to predict potentially difficult ground conditions by assessing the thickness, geometry and distribution of individual geological units. Each unit can be characterised in terms of its lithology, lithostratigraphy and attributed with a variety of properties. The 3D model, covering 10 km^2 is based upon 2000 borehole records.

Integrated risk models

ConSEPT ***Contaminated Site Evaluation and Prioritisation Tool***

Rule-based GIS software for prioritising site investigations - SOURCE RANKING - in the context of Source - Pathway - Receptor paradigm.
Multiple source, multiple pathway, multiple receptor.

- provides an initial screening of potentially contaminated sites within the GIS environment
- prioritises sites for further action
- rules for prioritisation developed by BGS scientific experts
- *not designed to provide a quantitative risk assessment*

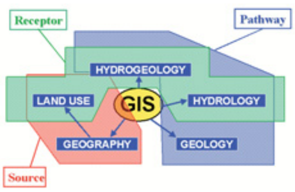
(1) Data collation & attribution

Source
- historical maps
- historical land use classification
- site investigation reports
- geochemical data
- landfills
- IPPC, petrol stations
- EA data

Pathway
- geology
- hydrogeology
- thickness of superficial deposits
- permeability
- preferential pathways
- borehole Index
- EA data

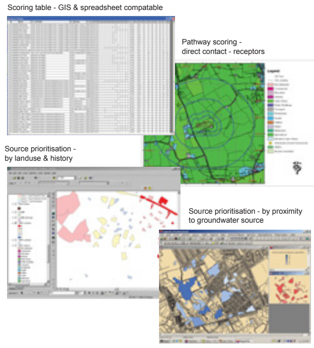
Receptor
- buildings
- ecosystems
- controlled waters
- humans
- residential
- allotments
- sensitive open areas
- education

(2) Pollutant linkage evaluation



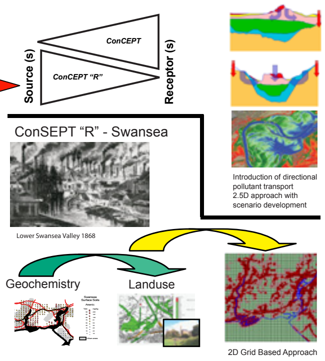
(3) Scoring and reporting

* Scoring written to GIS table prioritisation map
* Site report: site details including all evaluation factor scores pollutant linkage scores & missing data



ConSEPT "R" & ConSEPT 3D

Development of ConSEPT with increased emphasis on identifying receptors at RISK from multiple sources and in three dimensions. Customisable for endusers in planning and risk assessment.



Needs and knowledge gaps:
There is an increasing need for better integration and interpretation of geochemical data with a wide range of other datasets describing the urban environment and its stressors, especially within the context of short and longer term hazards. In the context of the earth sciences and medical geology this requires integration between areas more traditionally focussing on physical hazards, groundwater quality, and chemical and biological hazards. The increasing development and sophistication of 3D and 4D models of urban environments together with GIS based risk assessment tools offers considerable scope for emergency planning either in real time or via scenario planning. However, the design of such systems must take into account the need to be dynamic; linked, updatable in real time and above all user focused.

Acknowledgements: Adrian Minks; Andrew Marchant; Charlotte Herbert.