



**British  
Geological Survey**

NATURAL ENVIRONMENT RESEARCH COUNCIL



Applied geoscience for our  
changing Earth

# **THE CONTRIBUTION OF URBAN GEOLOGY TO THE DEVELOPMENT, REGENERATION AND CONSERVATION OF CITIES**

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Simon Price

# Why urban geology?



# Outline

- **What is urban geology?**
- **How has it developed?**
- **Who are the users?**
- **What geo-information do we use?**
- **How should the geo-information be managed?**
- **The future?**
- **Some concluding thoughts**





# Through the looking-glass

# What is urban geology?

**Canadian Geological Survey, 2008: urban geology provides “...engineers, planners, decision makers, and the general public with the geoscience information required for sound regional planning in densely populated areas.”**



# What is urban geology?

**Karrow & White 1998: urban geology “... spans both regional and applied geology. Some emphasis is usually assumed in the application of geological principles to the solution of construction, and now environmental, problems in or near urban areas.”**

# What is urban geology?

**De Mulder 1996: “an interdisciplinary field in the geo- and socio-economic sciences addressing Earth-related problems in urbanised areas.”**

# What is urban geology?

**Dai Fuchu *et al.* 1994: “...the study of land resources and geologic hazards as they relate to the development, redevelopment and expansion of urban areas.”**

# Urban geology

**The study of the interaction of human and natural processes with the geological environment in urbanised areas and the resulting impacts, and the provision of the necessary geo-information to enable sustainable development, regeneration and conservation**



# How has urban geology developed?

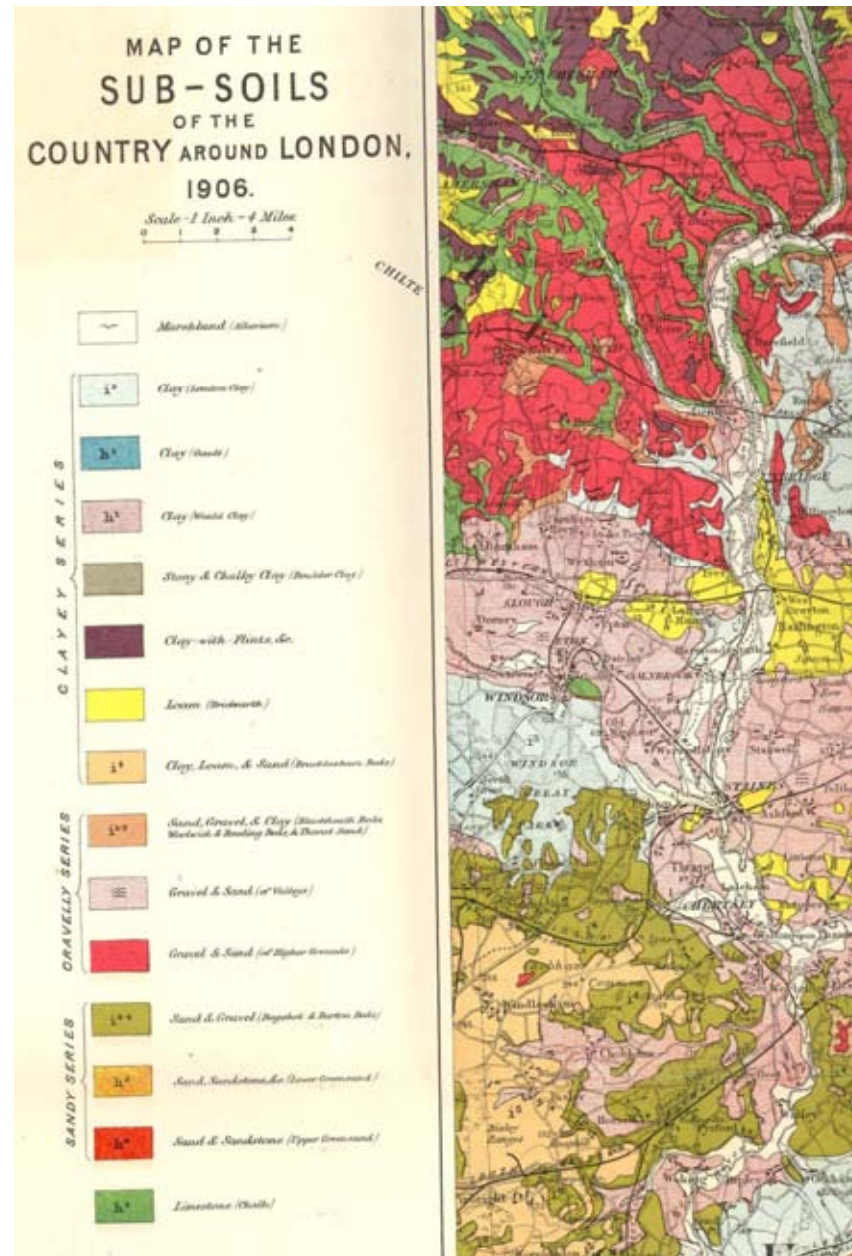


**Mono-thematic**  
**Multi-thematic**  
**Multi-dimensional**

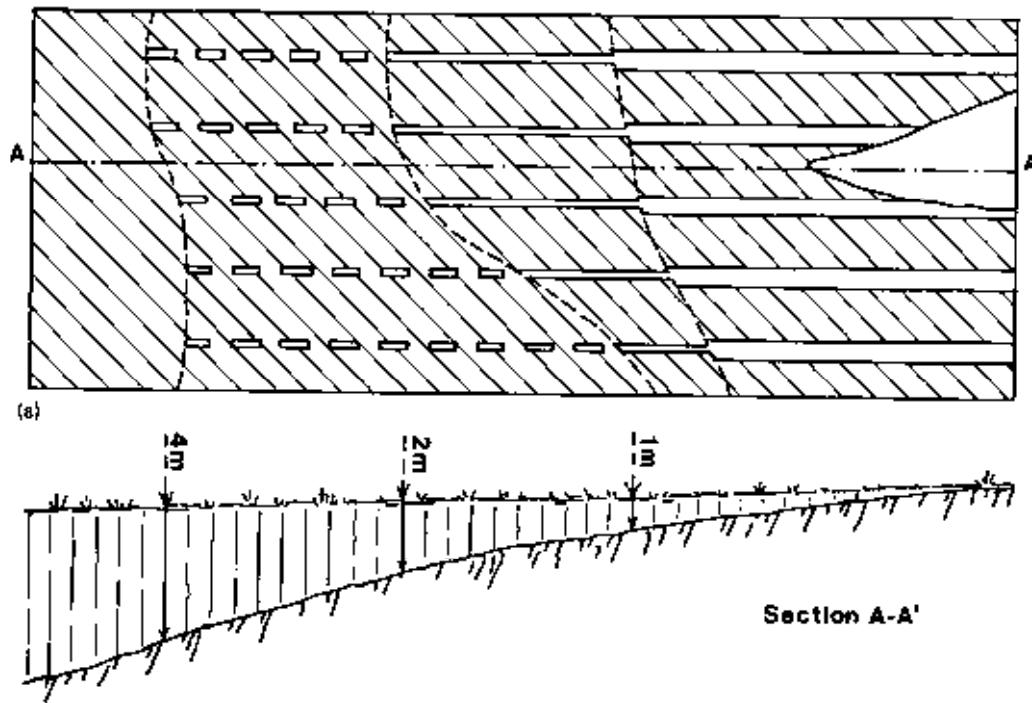


# Mono-thematic urban geology

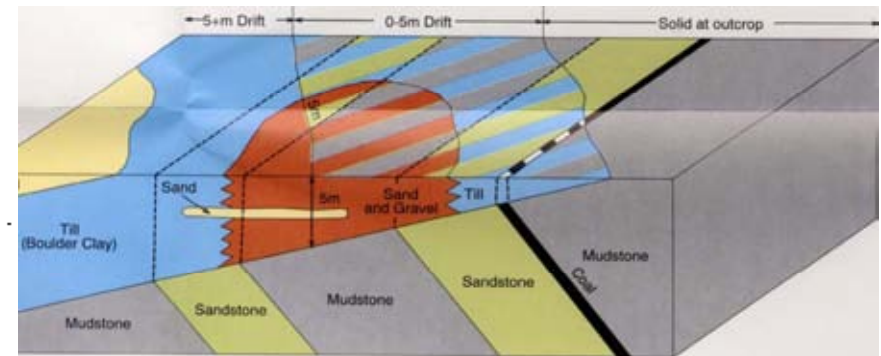
## Woodward's 1906 Map of the "Sub-soils" of Greater London



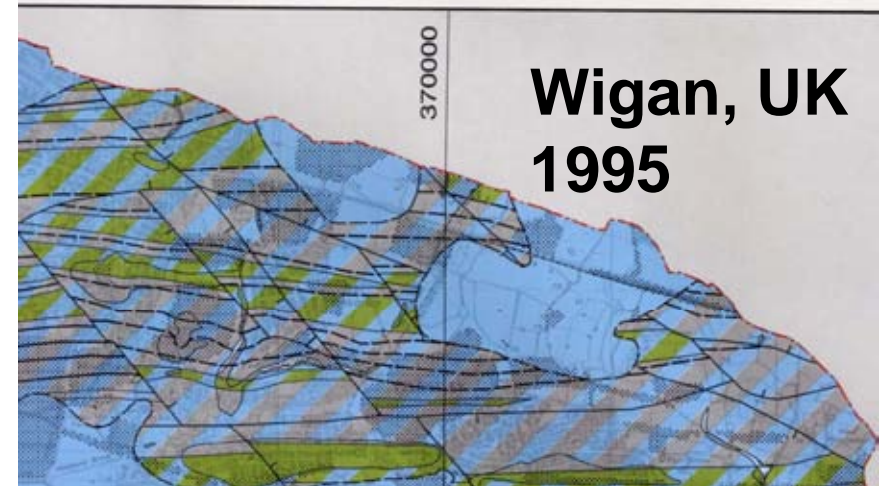
# Mono-thematic urban geology



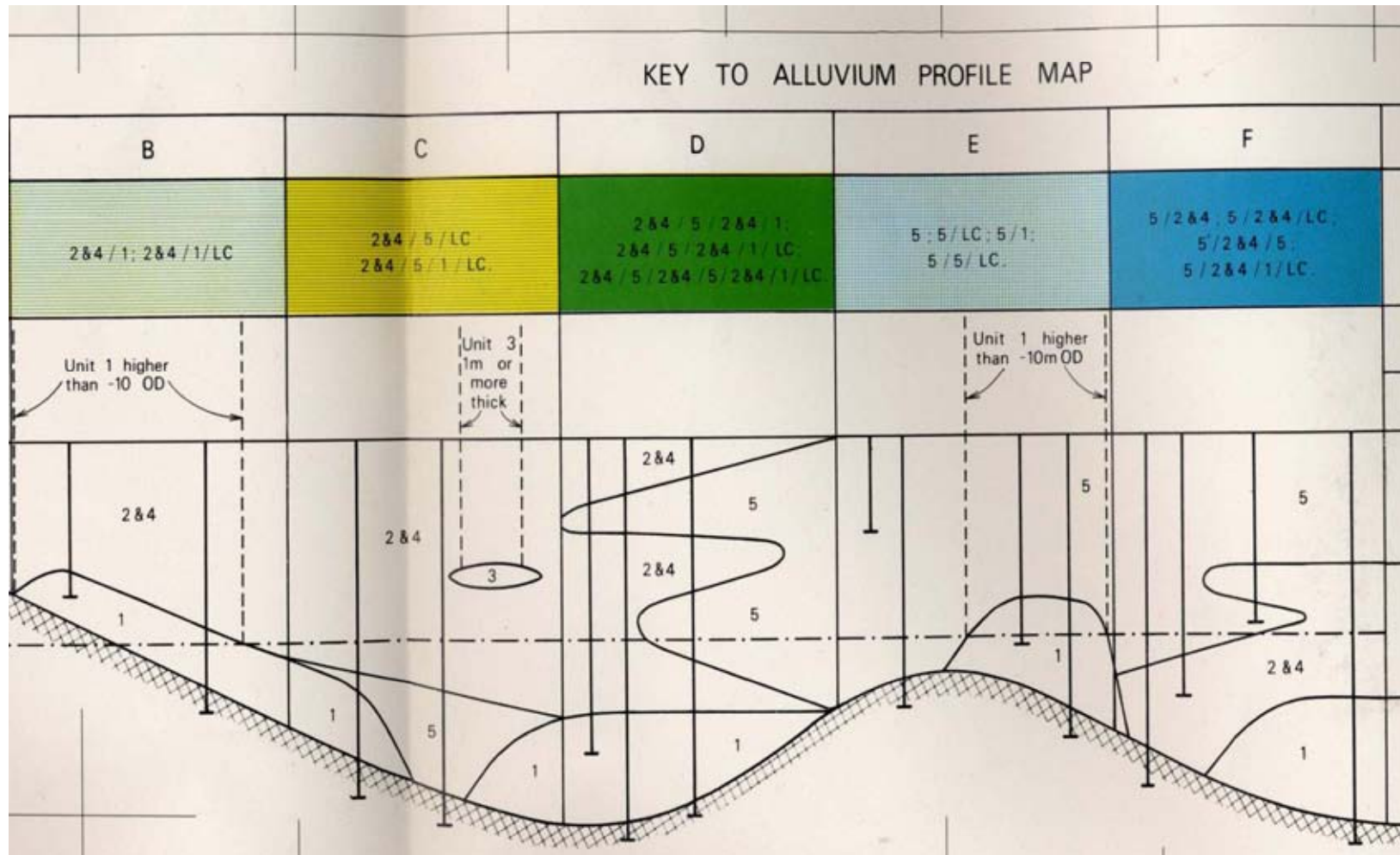
**Zebera's 1947 stripe method to show depth of bedrock below superficial deposits; developed in Czechoslovakia**



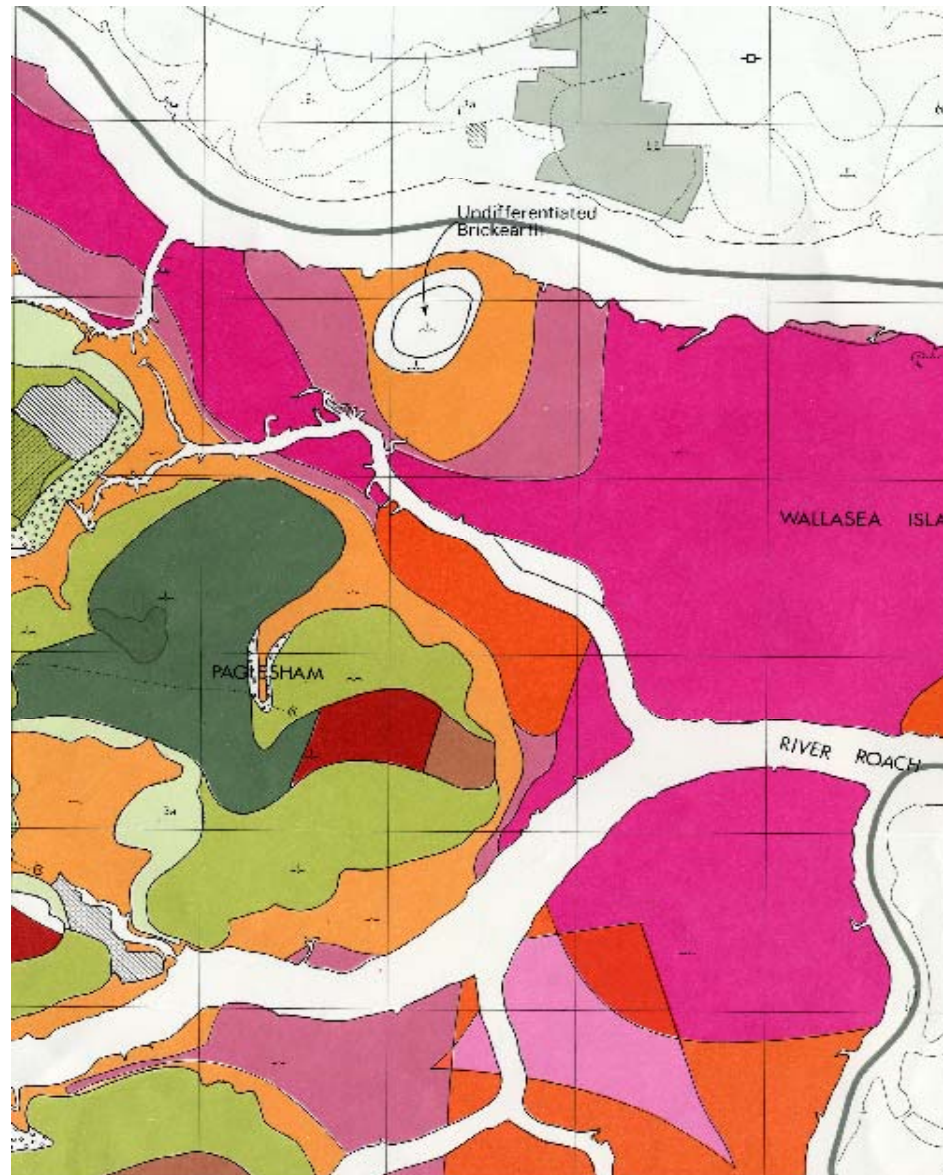
Where bedrock is exposed at the surface or where superficial material is more than 5m thick the engineering unit is shown as a solid colour. Where superficial material is less than 5m in thickness stripes of the superficial engineering unit colour are interspersed with stripes showing the underlying bedrock engineering unit's colour. The superficial engineering units shown at the surface may contain bodies of, or be underlain by, other superficial engineering units whose extent is unmapped.



# Multi-thematic urban geology



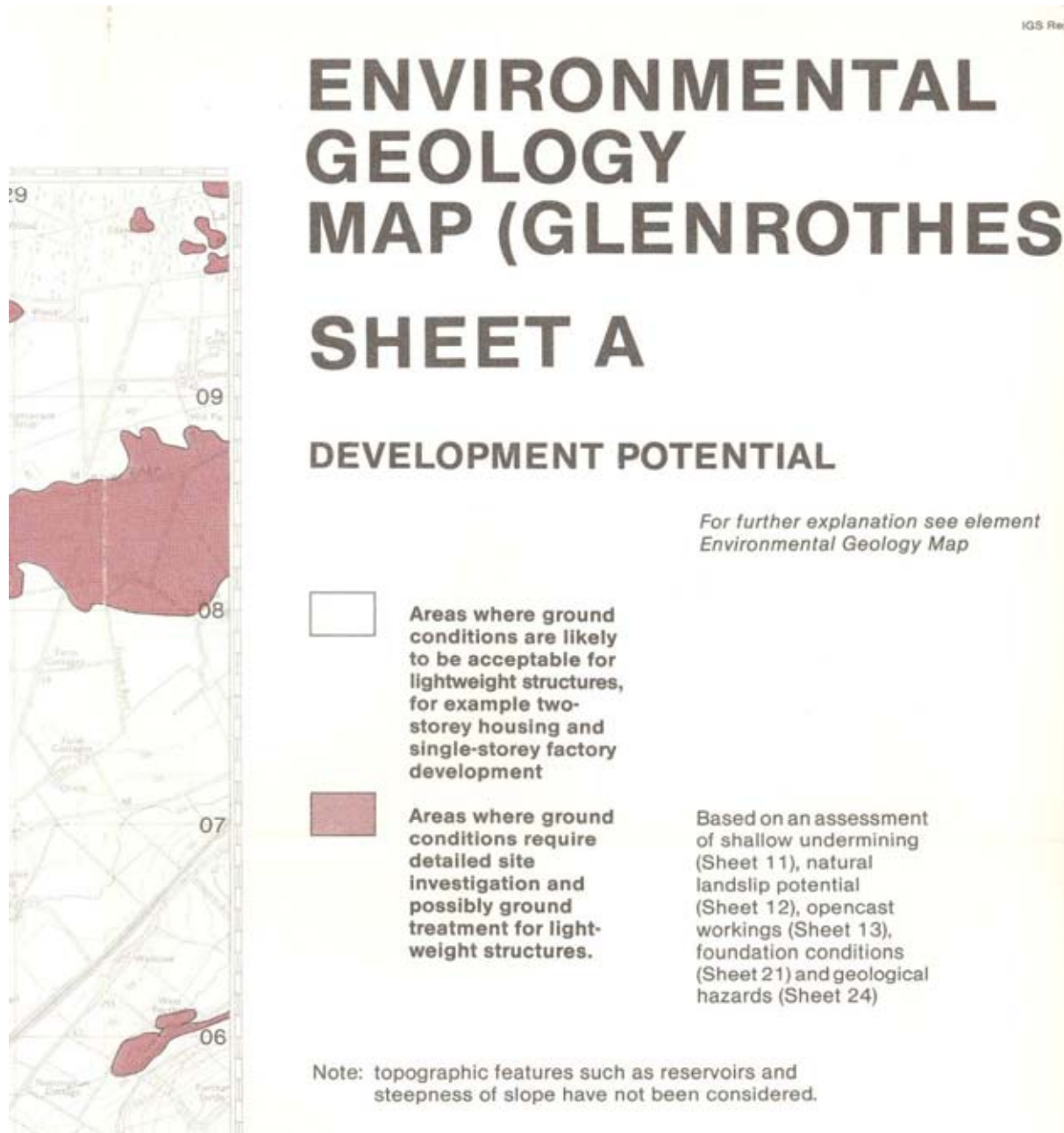
# Multi-thematic urban geology



# Multi-thematic urban geology

GEOLOGICAL GROUP	ZONE	ENGINEERING IMPLICATIONS	SITE INVESTIGATION REQUIREMENTS
Shown on map by 'solid' colours			
Thick Alluvium	1	<p>Soft, plastic surface silty clay (Alluvium Unit 4), requiring wide strip or raft foundations even for housing. Heavier local loads require end-bearing piles to deeper than -10 m OD and embankments require lightweight fill. Excavations require continuous support and pumping. Large excavations may experience bottom heave. Construction traffic should be kept to a minimum to avoid remoulding in situ. Unsuitable for fill, water extraction beneath or near built-up areas, or waste disposal.</p>	<p>Cone penetrometer test (CPT), resistivity or seismic surveys to determine piling depth. Piston core sampling for geotechnical design parameters. Trial well pumping prior to excavation.</p>

# Multi-thematic urban geology

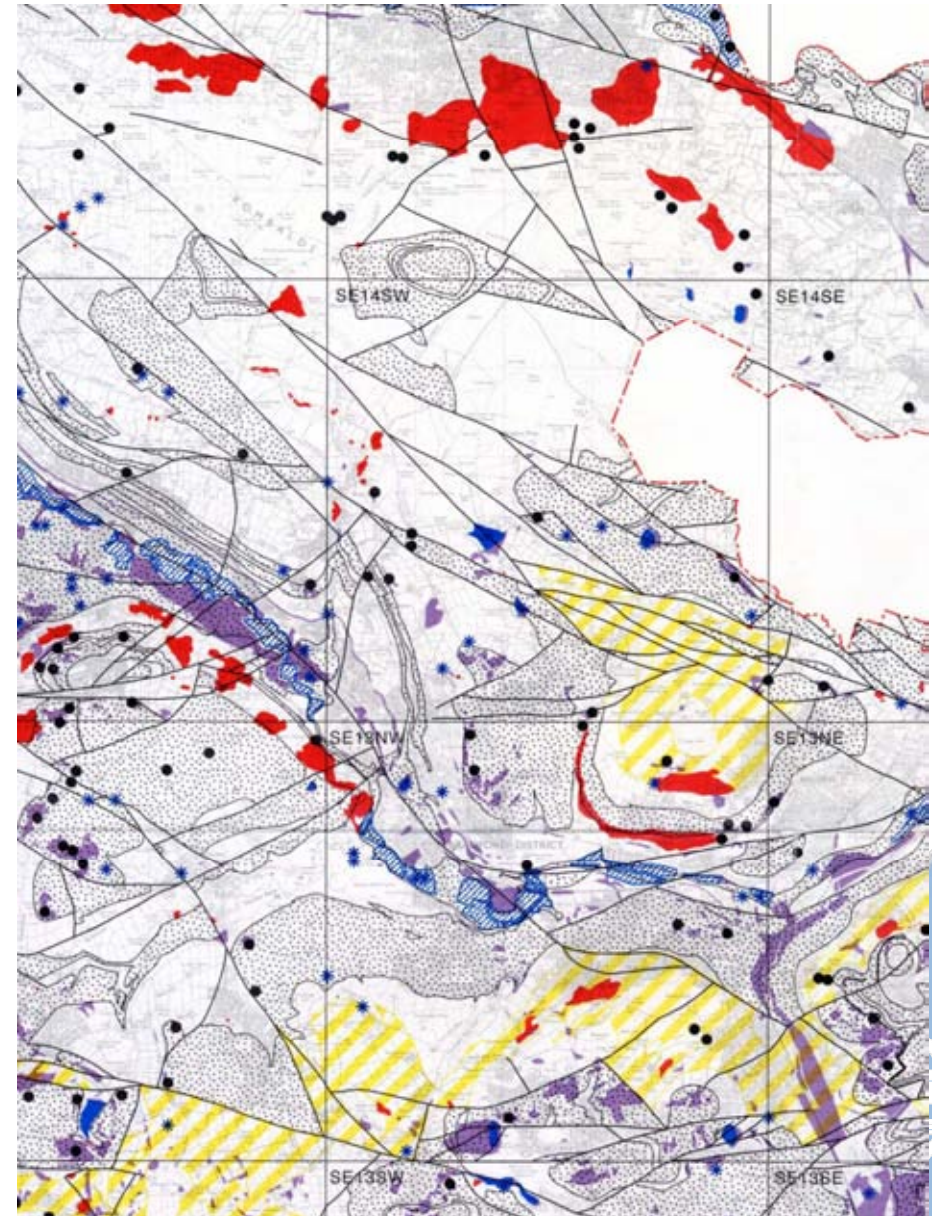
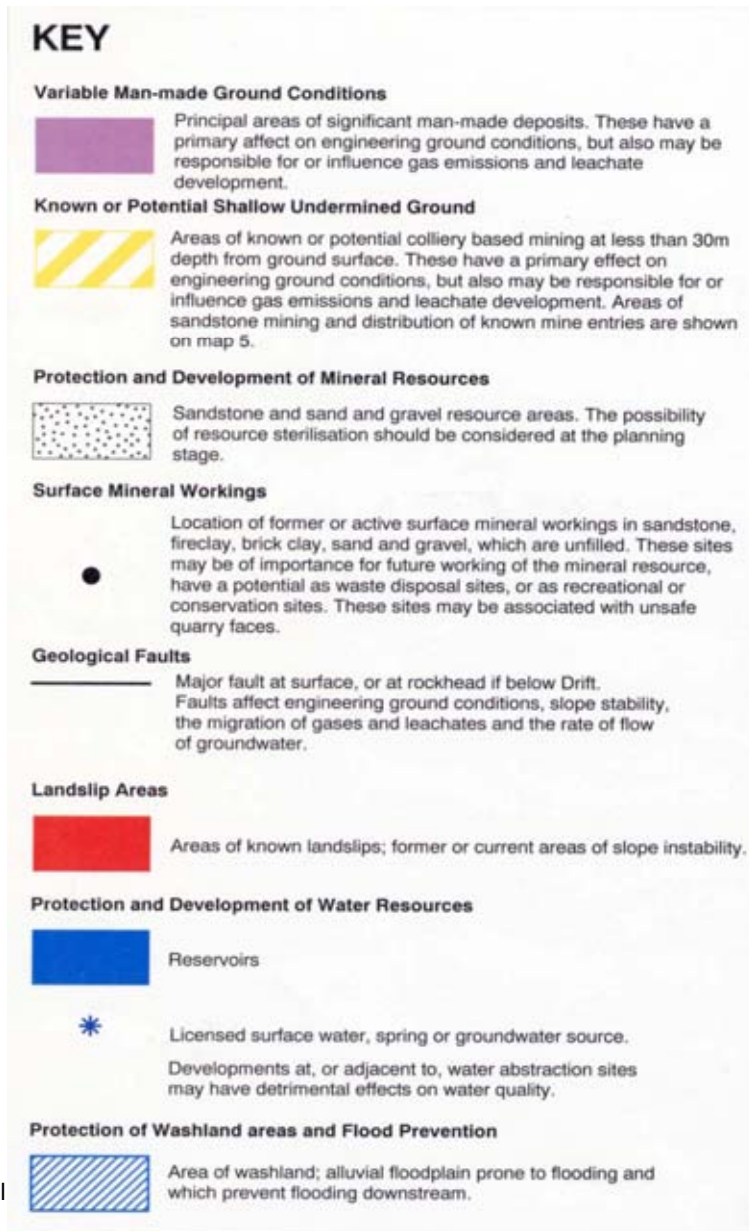


1980-1996  
To: *“investigate the best means of collecting, collating, interpreting and presenting, in sets of maps and reports, geological results of direct applicability in land-use planning.”* (Brook & Marker 1987)



# Multi-thematic urban geology

## Bradford, UK



## **KEY POINT No. 1:**

**Geo-information for urban areas must be kept up-to-date**



## **KEY POINT No. 2:**

**Geo-information for urban areas must be accessible to users**



# Multi-thematic urban geology

*“...until the geological data that fills the files of geological survey departments across Asia and the Pacific can be translated into a dynamic easy-to-use format (GIS or something better), the data are likely to remain in those files, unused for ever.” (John Rau 2003)*



## **KEY POINT No. 3:**

**Data for urban areas must be in a “dynamic and easy-to-use format”**



# Multi-dimensional urban geology

**European Science Foundation Conference  
Spa, Belgium, 2003  
“New paradigms in subsurface prediction”**



# Multi-dimensional urban geology

## Reluctance to use 3D digital, spatial modelling

- **Believed that the benefits did not exceed the cost of using complicated software**
- **Perceived difficulty in quantifying uncertainty, particularly with regard to the quality of expert knowledge used to create the spatial model**
- **Shortage of “*definitive*” data**
- **Requirements of users in urban environments rather different from past users of geological data who were mainly 'resource' orientated**



## **KEY POINT No. 4:**

**Users of geo-information in the urban environment are likely to have a relatively limited knowledge of geology**



# Who are the users?



# The Users

## General public

Geohazard 'victims'

Potential future geohazard 'victims'

Non-'victims'



# The Users

## **Geological professionals**

**Engineering geologists**

**Contaminated land specialists**

**Hydrogeologists**

**Environmental geologists**

**Mineral resource geologists**



# The Users

## Non-geological professionals

Developers

Financiers

Architects

Civil and structural engineers

Surveyors

Builders

Utility and transportation providers

Planners

Archaeologists

Conservationists

Building control officials

Environmental regulators

Health and safety regulators

Insurers

Lawyers

**The media**

**Policy-makers and politicians**



## **KEY POINT No. 5**

**There are many users of urban geological information, all with different needs**



# The media

- **Exists to entertain rather than educate**
- **Education does not make good public relations**
- **The point of public relations is to generate “*warm feelings.*”**

(Nield 2008)

# Policymakers and politicians

- **Understand institutional and decision-making structures**
- **Disseminate as well as present**
- **Tailor outputs to audiences**
- **Use communication experts**
- **Work with social scientists**

(Liverman *et al.* 2008)



## **KEY POINT No. 6:**

**When working with those who have little or no formal training in geology, *clear* communication is important**

## **KEY POINT No. 7:**

**Working out how to adequately communicate geological information and knowledge about the urban environment should involve a *considerable* amount of effort**



# Multi-dimensional urban geology

## Mersey Corridor – Manchester to Liverpool



# Multi-dimensional urban geology

## Mersey Basin – Manchester, Salford, Warrington, Liverpool



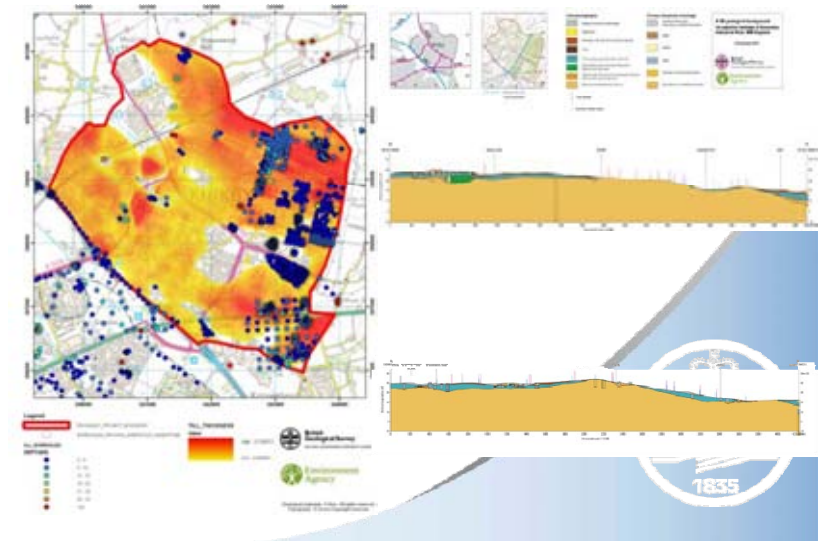
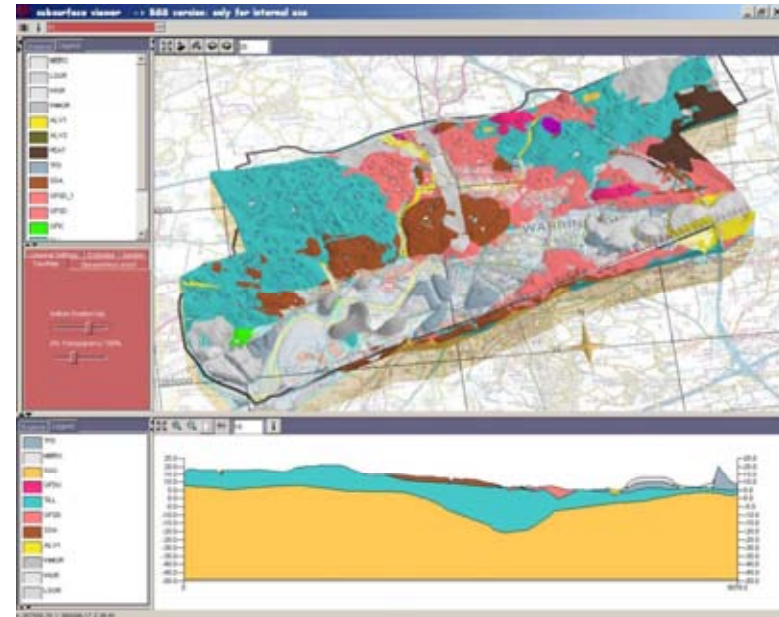
# Why is 3D environmental information needed in the Mersey area?

To develop an attributed 3D environmental framework for one of the UK's major population centres and development zones

To support sustainable urban development and regeneration – societal well-being and economic growth

To quantify anthropogenic processes and impacts – urban landscape evolution

Project area overlies Sherwood Sandstone Aquifer – groundwater recharge and vulnerability research



# Mersey urban regeneration and sustainable development ...



MediaCity:UK Salford  
BBC Media hub



Mersey Gateway  
Bridge Crossing Runcorn



Liverpool – Wirral Waterfront  
“Manhattan of the Mersey”



# Mersey 3D modelling strategy

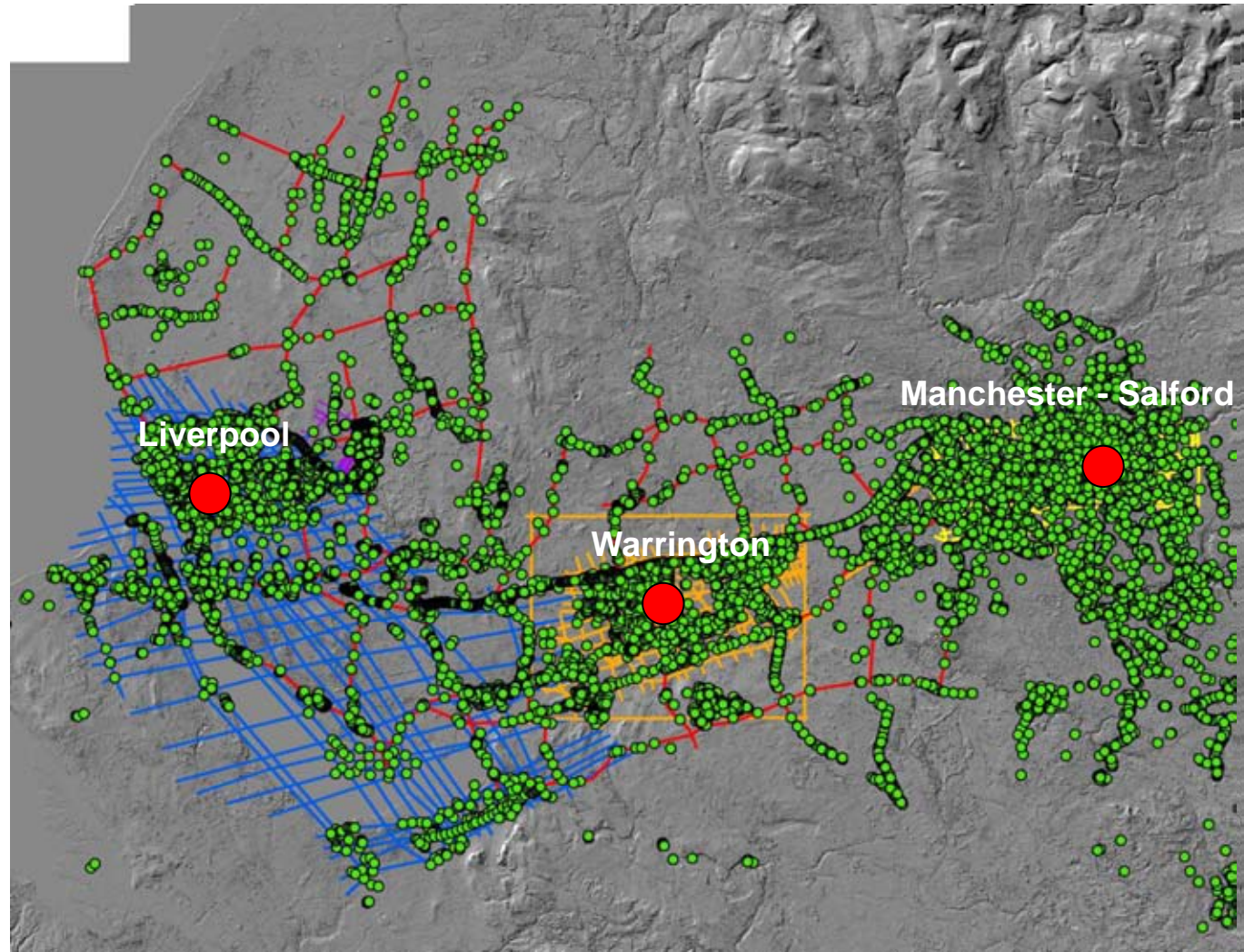
GSI3D low resolution regional model

GSI3D attributed high resolution city scale in Manchester, Warrington and Liverpool (LithoFrame10)

18 800 coded boreholes

Highest resolution along central Mersey development and regeneration zone

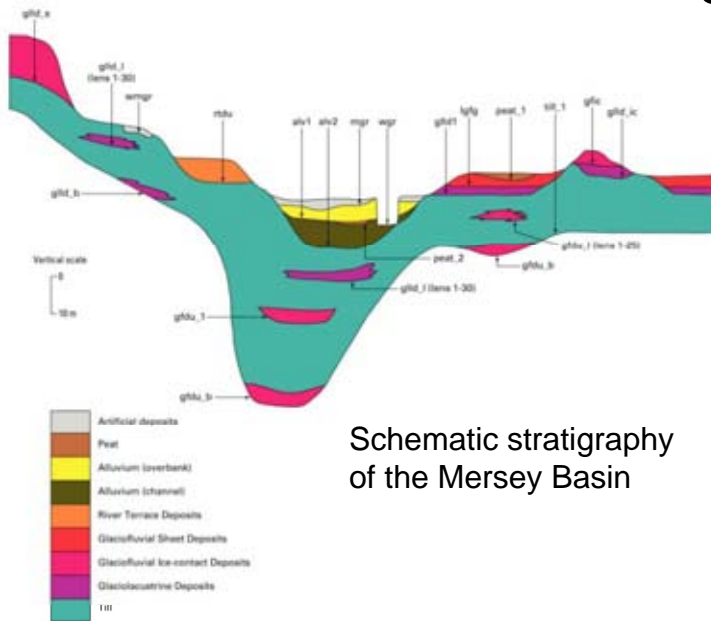
Integration with Permo-Triassic bedrock model



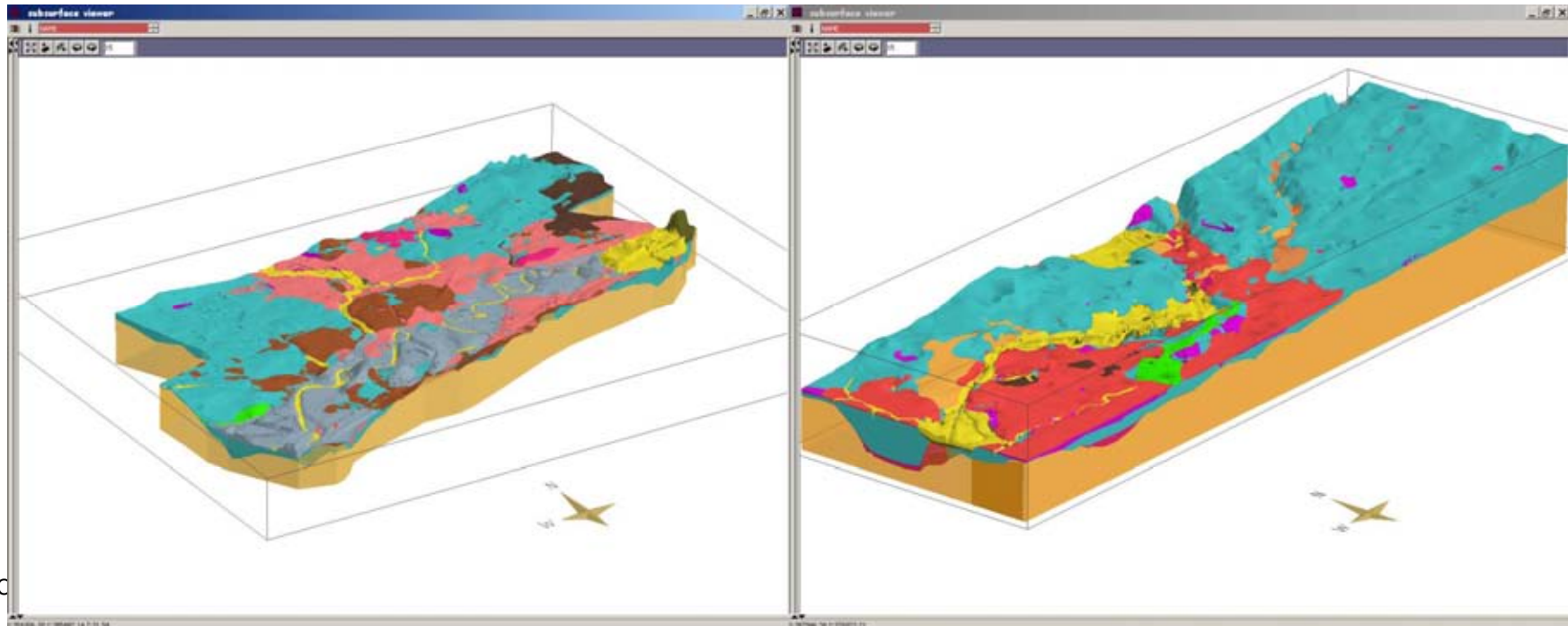
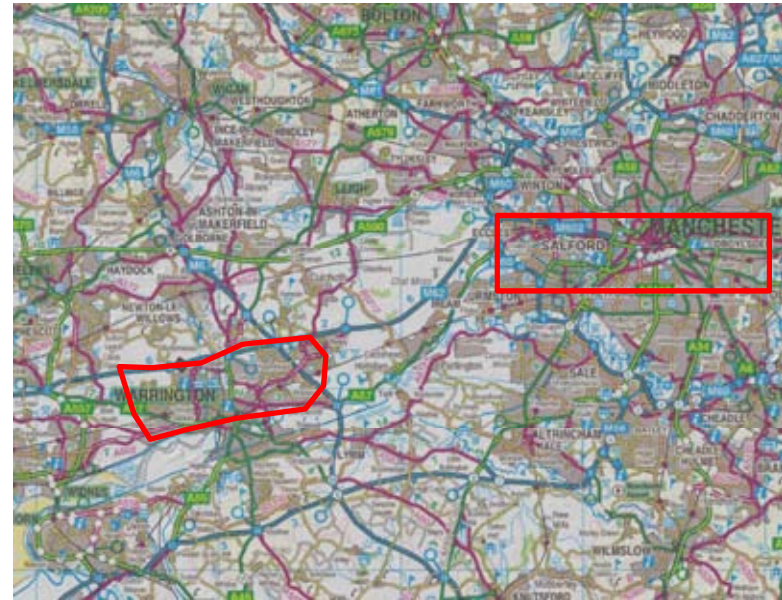
NEXTMap shaded relief courtesy of Intermap Technologies Inc



# 3D glacial evolution



Schematic stratigraphy of the Mersey Basin



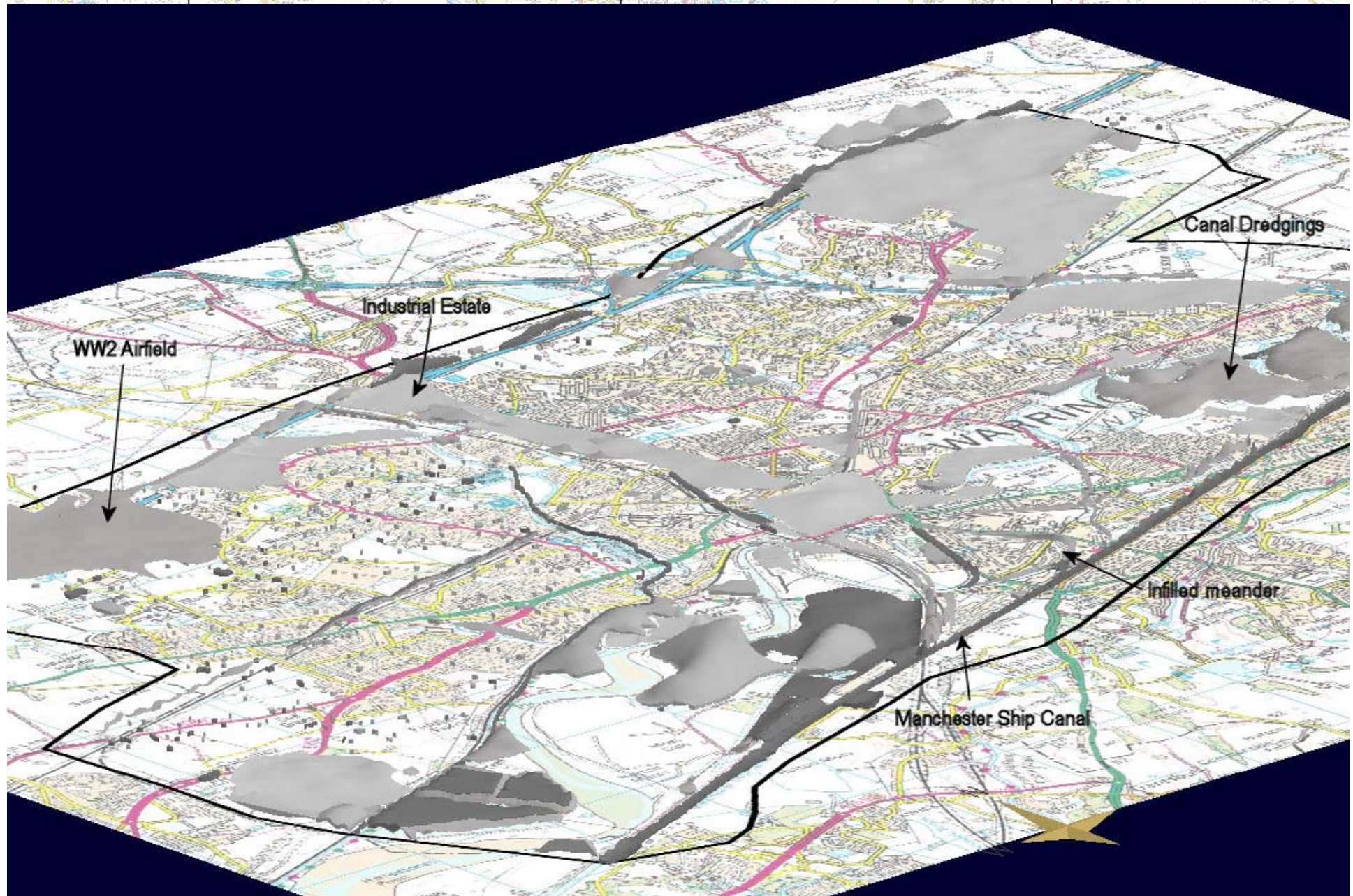
# Warrington – economic growth and early industry



The oldest known painting of Warrington, 1772 (Thomas Donbavand). Glass furnaces, located 300m west of present day Warrington Bank Quay railway station, are circled

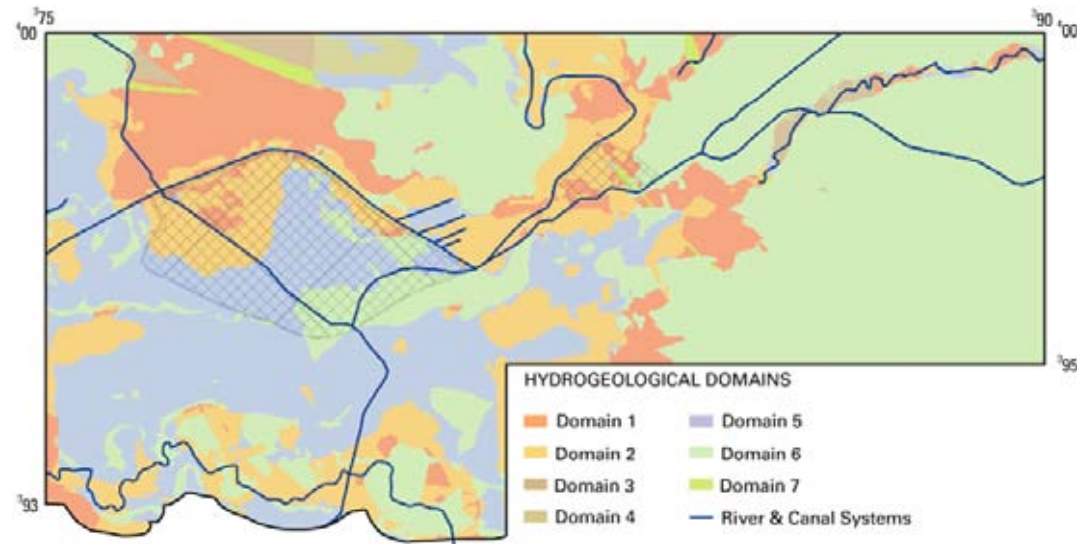
# Artificial deposits in Warrington

High resolution urban 3D model includes artificial features such as pits, quarries, road cuttings and canals

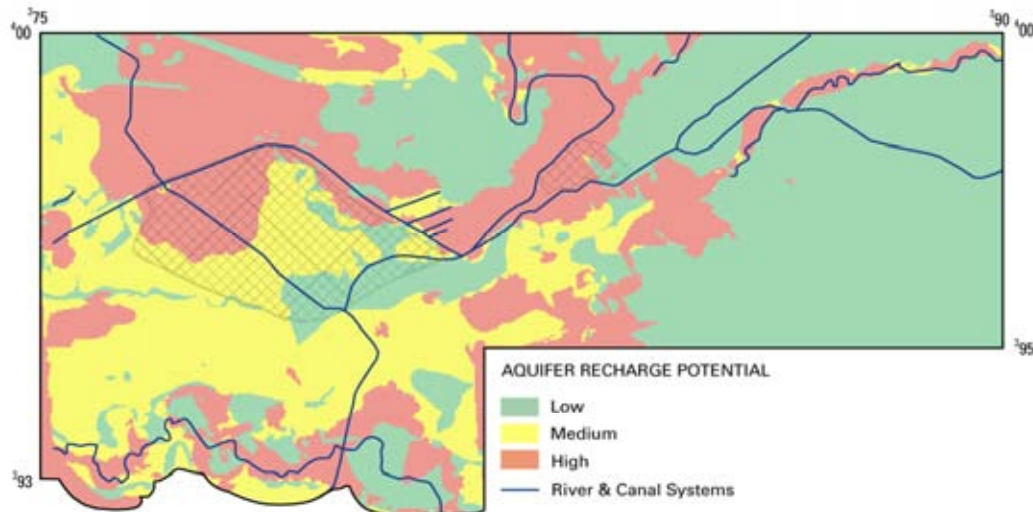


# Hydrogeological domains

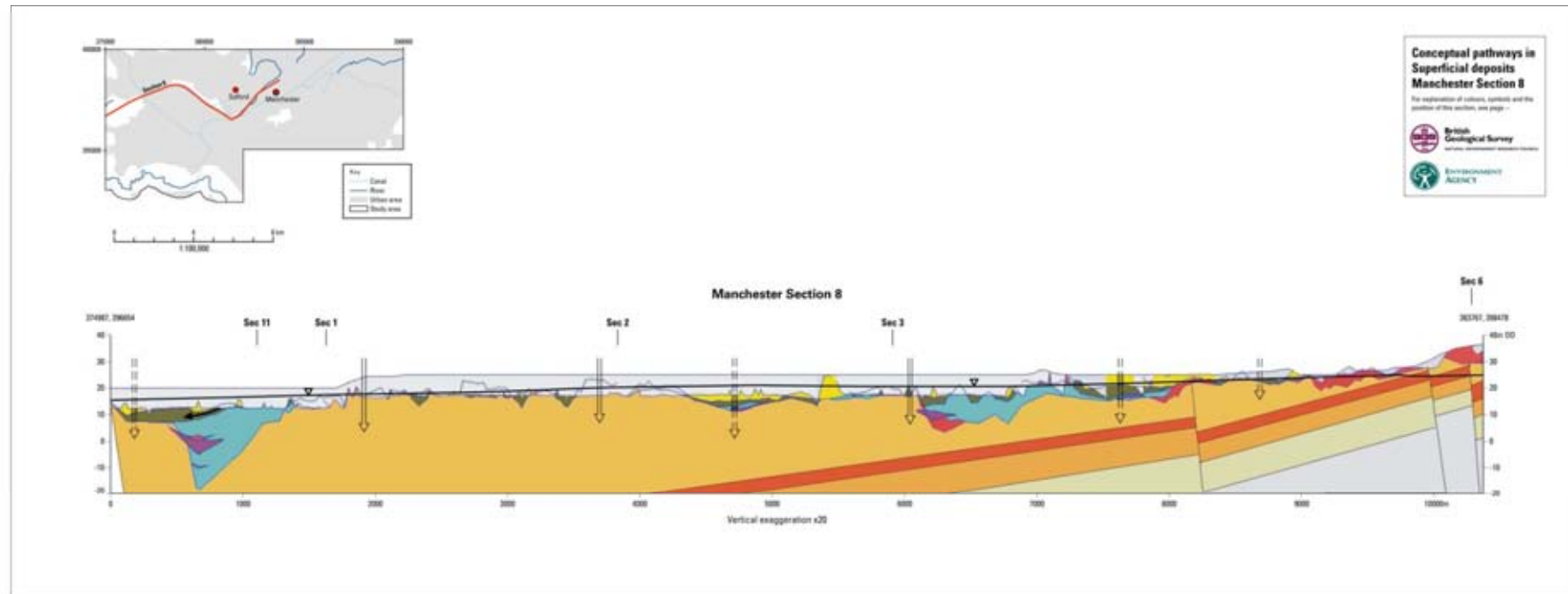
Derived hydrogeological domains



Applied hydrogeological domains – Recharge Potential



# Hydrogeological pathways



Schematic potential hydrogeological pathways shown on synthetic section derived from Manchester 3D model

# Geo-information for urban areas

- **Types of geo-information**
- **Management of geo-information**



# Types of geo-information

- **spatial data, originally in two dimensions printed on paper but more recently in digital form in two and a half, three and four dimensions**
- **databases (now digital) of point information now increasingly combined with the spatial models**



# Types of geo-information

- **site investigation borehole and parameter data**
- **mapping of bedrock, superficial and artificial deposits**
- **mining records**
- **past land-use records**
- **well records and water extraction information**
- **investigations of ground movement**



# New techniques and information Sources

- **LIDAR**
- **PSInSAR**
- **Ground geophysics**
- **High resolution airborne geophysics**
  
- **Spatial data from the web**



# Management of geo-information

- **for many cities, data are plentiful**
- **the problem is finding them**
- **and digitising them**
- **and then managing and enlarging the databases in the long term**



# Long-term data management

- **Should the geo-information available from hundreds or thousands of site investigations, water wells and mineral surveys be collected together?**
- **If so, should the information be collected and then updated at specific intervals or should the databases be continuously updated?**
- **Should the information simply be stored in its original form or digitised?**
- **Who should perform these tasks and how should they be funded?**
- **Is this process likely to be cost effective?**



## **KEY POINT No. 8:**

**It is demonstrable that acquiring geo-information for urban areas and managing and maintaining the databases in the long-term is cost effective, and of societal benefit**



# Long-term geo-information managers

- **Geological Surveys**
- **City authorities**
- **Private data companies**



## **KEY POINT 9:**

**Unless taxpayers, through their governments, are willing to pay the increased costs of digitisation and digital data management, the era of public bodies, such as geological surveys, freely providing access to geological information will pass completely**



# Long-term geo-information managers

- **Geological Surveys**
- **City authorities**
- **Private data companies**



## **KEY POINT 10:**

**For the most part, city authorities do not have the resources or the motivation to build, maintain and develop geological and geotechnical databases for their cities**



# Long-term geo-information managers

- **Geological Surveys**
- **City authorities**
- **Private data companies**



## **KEY POINT 11:**

**There is no guarantee that private data companies will continue to operate and maintain their databases in the long-term or add new information**



# Futures

## New applications:

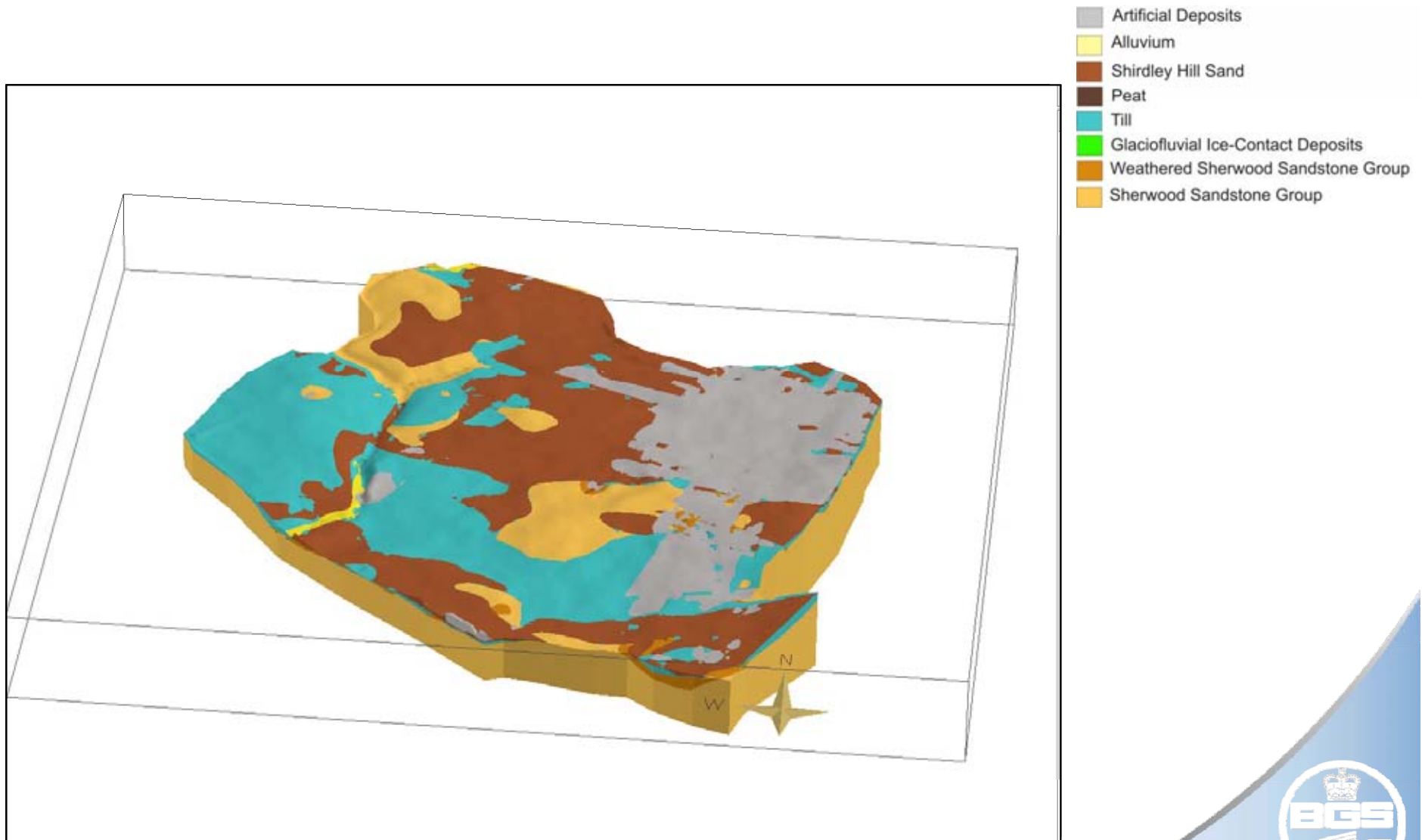
- **Utility maintenance**
- **Sustainable drainage systems**
- **Archaeological assessment**



# Utility maintenance - Knowsley



# Superficial deposits as revealed by 3D modelling

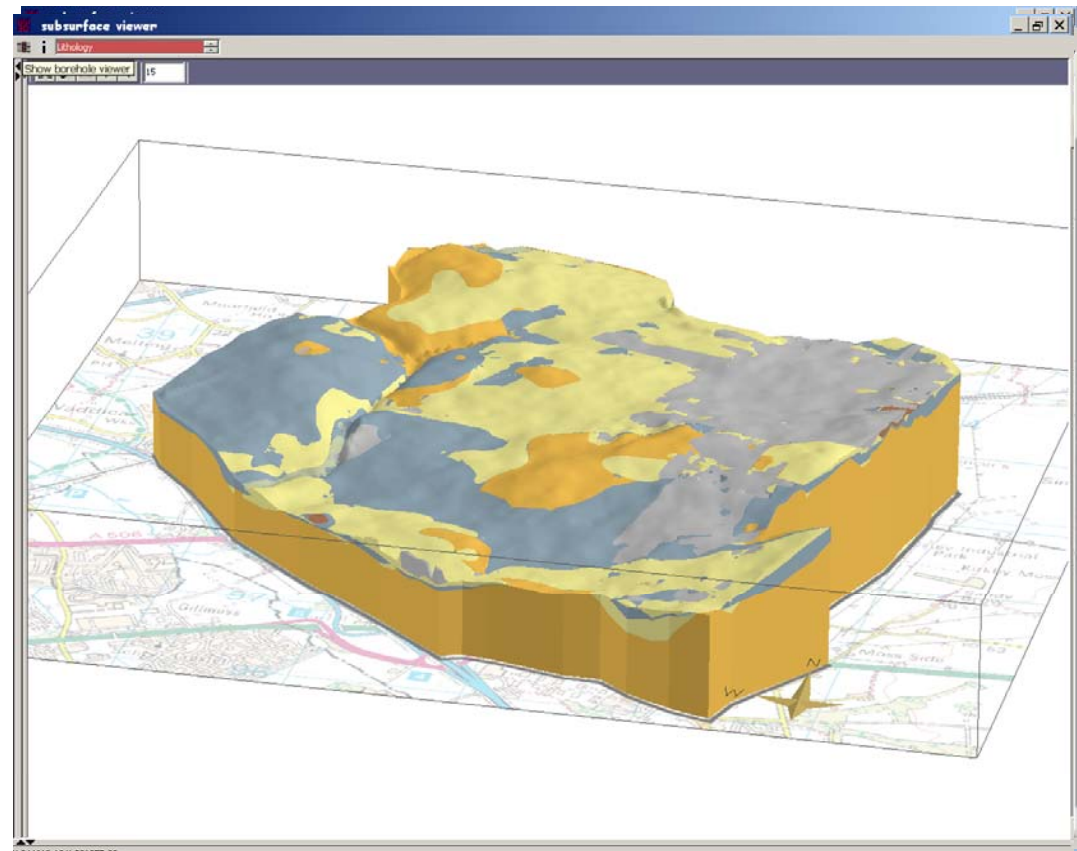


# 3D model classification

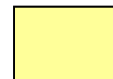
Qualitative assessment of permeability based on lithological composition only

Permeable deposits (sand, gravel and gravelly sand)  
– Glaciofluvial deposits

Low permeability (clay or silt) – Till with lenses of sand



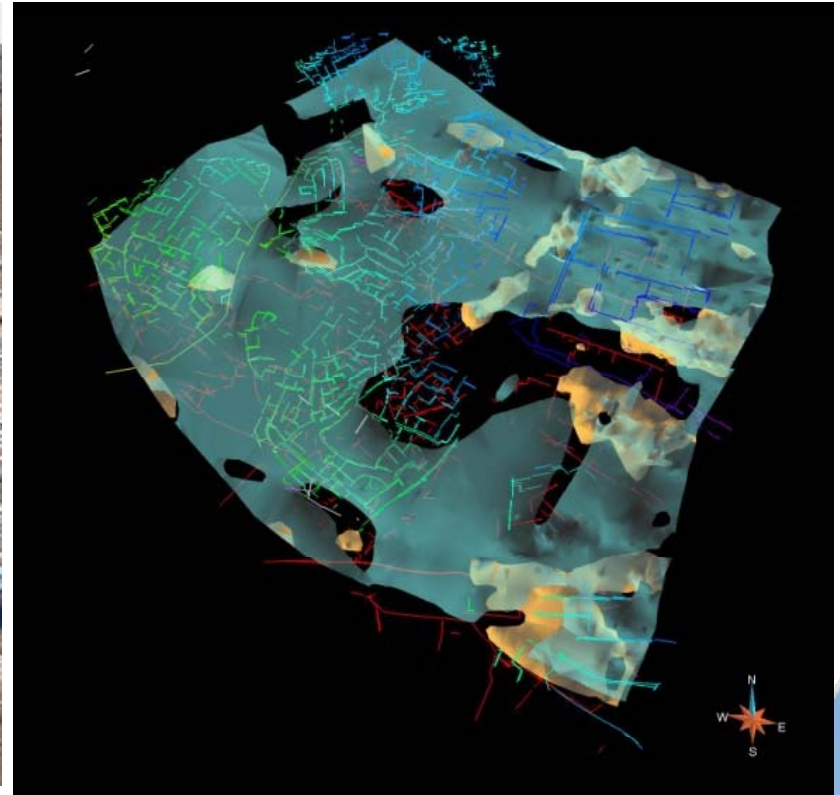
Inferred low relative permeability clay or silt dominated



Inferred high relative permeability sand or gravel dominated



# Combining 3D geological and utilities models

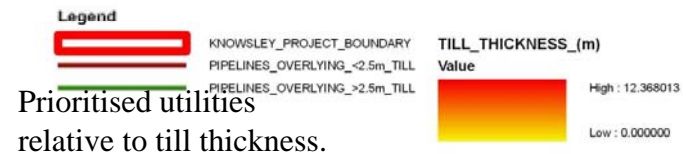
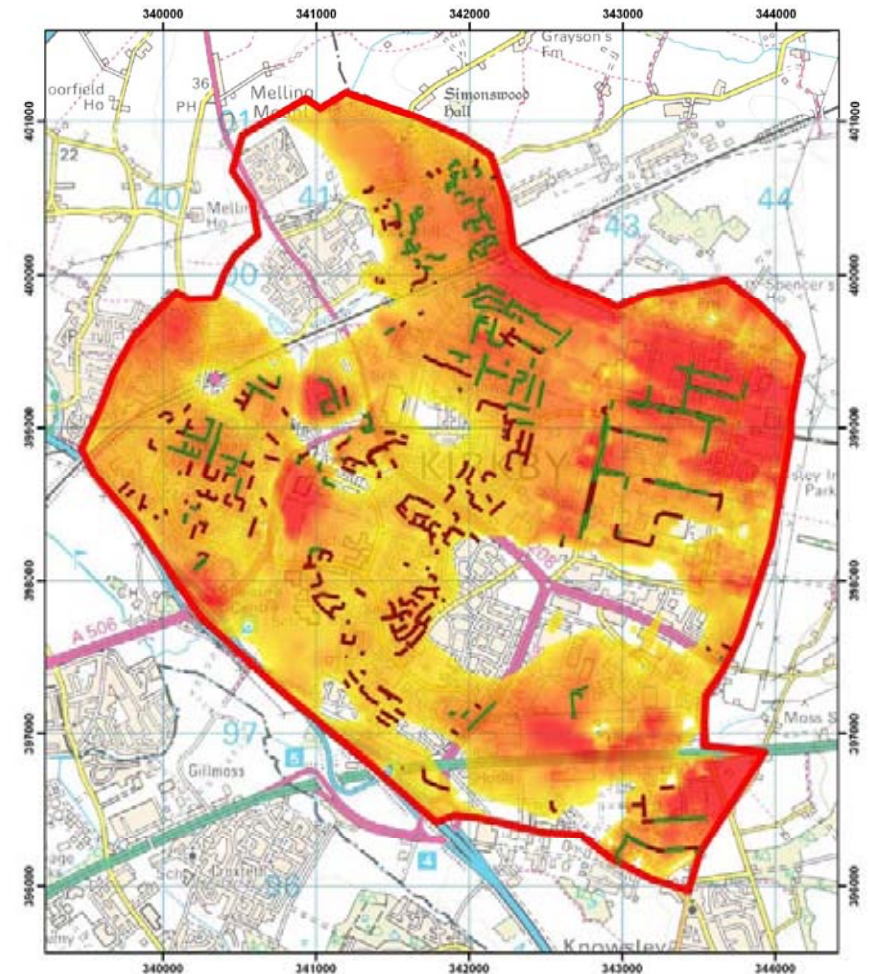


# Relative vulnerability

Utilities below Till or underlain by thin Till represent areas of high relative aquifer vulnerability

Average thickness of Till = 2.5m

Utilities underlain by <2.5m Till represent highest vulnerability parts of Sherwood Sandstone aquifer within Knowsley Industrial Park



# Futures

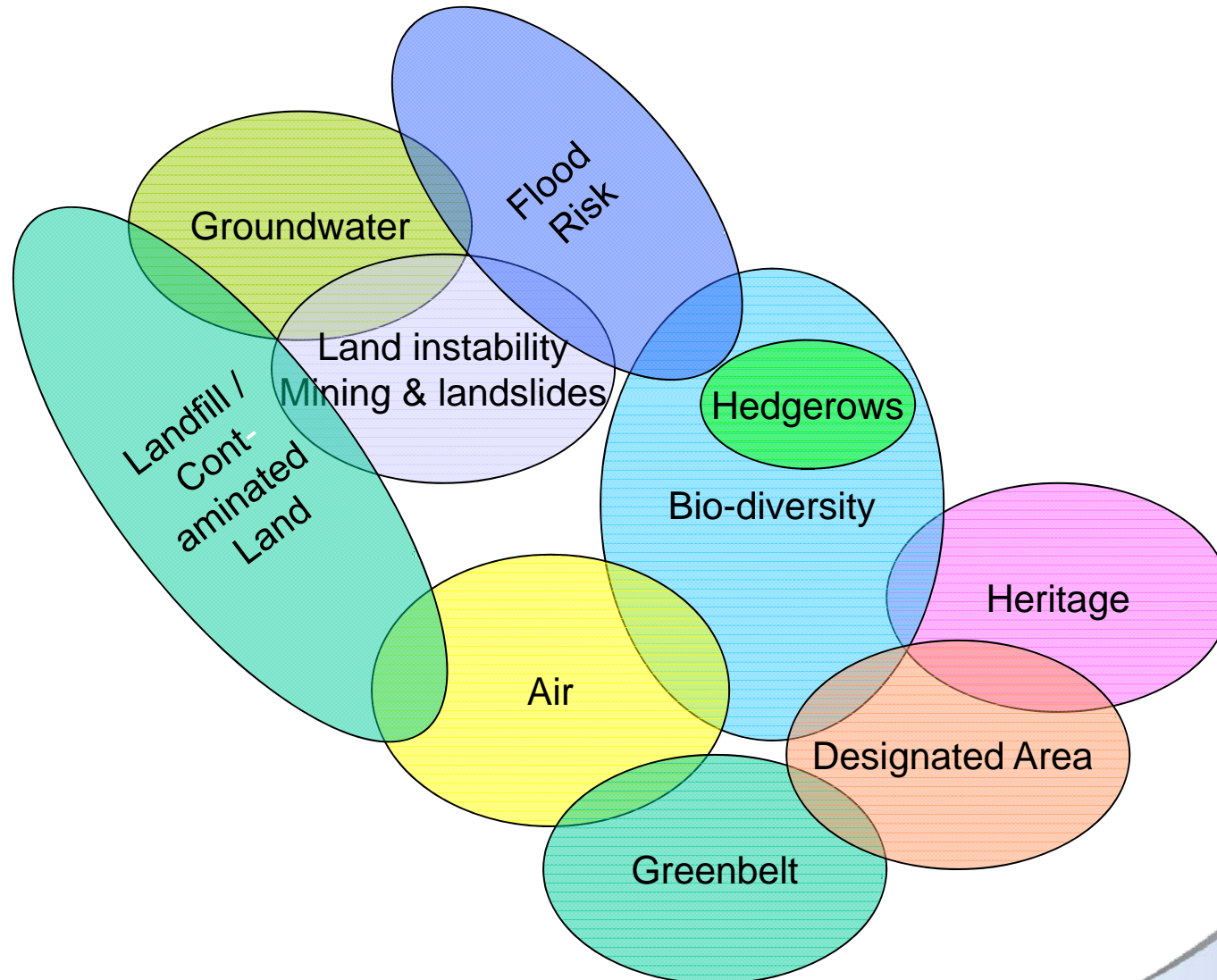
**Environmental multidisciplinaryity – geology's contribution**

**Environmental Information System for Planners  
- EISP**



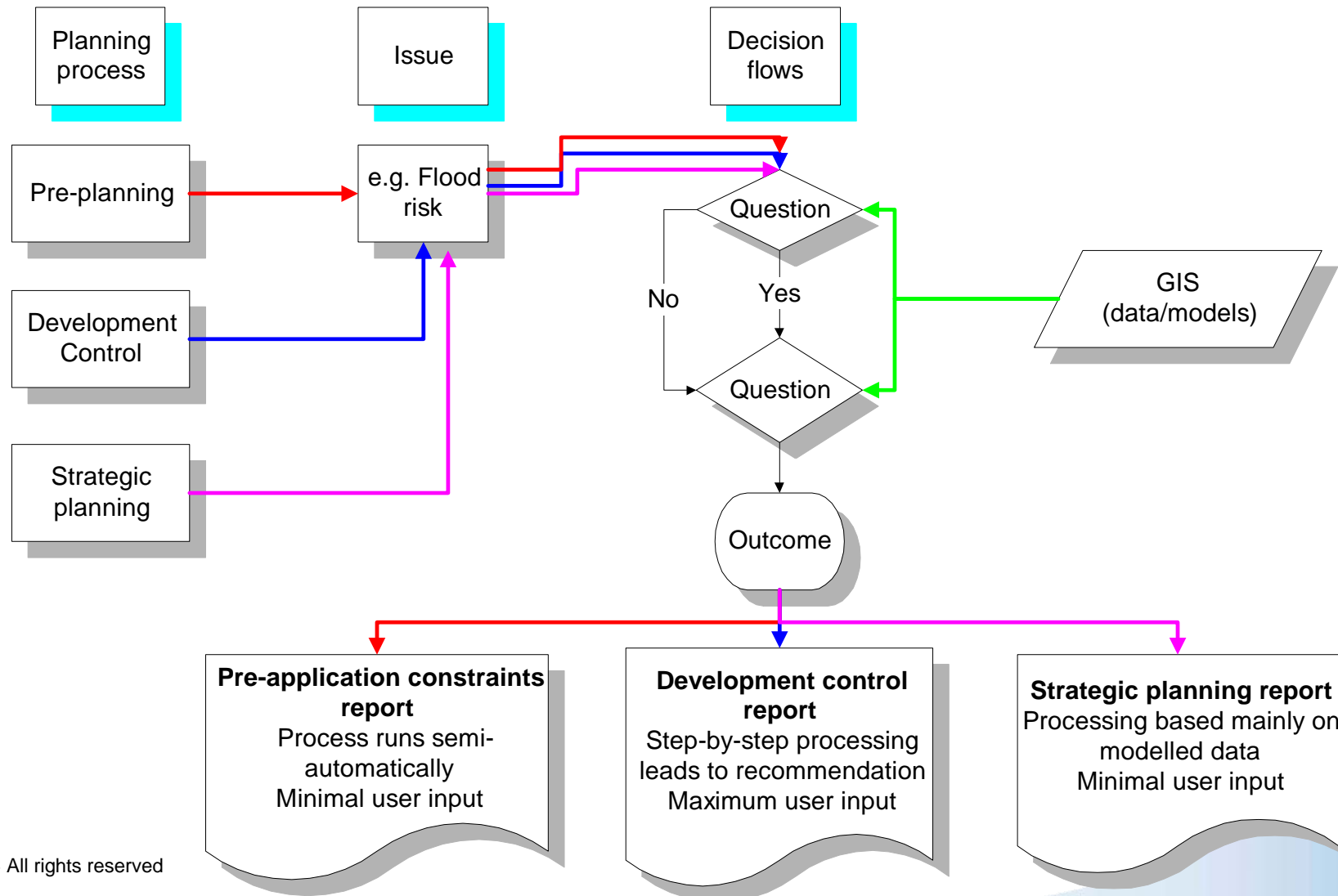
# EISP

## Which environmental issues?



# EISP

## Design overview: the system



# EISP

## The system in operation

**Does the site lie within 50m of a mapped coal seam outcrop?**

*Yes. The site lies within 50m of a mapped coal seam outcrop.*

**Metadata link:** [BGSDGMAP](#)  
**(title)** 50K Digital geological map data  
**(validity)**  
**(completeness)** To Be Completed



**Are there mine entries recorded within 20m of the boundary of the property based on BGS shaft database?**


*No*

Please refer to Metadata link to view limitations of database.

**Metadata link:** [BGSDGMAP](#)  
**(title)** 50K Digital geological map data  
**(validity)**  
**(completeness)** To Be Completed

# EISP

## Application determination



**Defining conditions** [Show Guidance Notes](#)

*Shallow undermining has been identified as a constraint.* Shallow undermining has been identified as a constraint. Please refer to the linked condition.

[Show Conditions](#)

**Defining Conditions - Shallow undermining**

*No. Additional measures against shallow undermining are not necessary.*

Any relevant mining reports and ground stability reports should be passed to a geotechnical engineer for their consideration.

**Is there adequate information to assess mining issues identified in geotechnical brief?**

*Yes - 1. Advise negligible risk of subsidence. Proceed without special precautions.*

**Application Result** Following the guidance, procedures and local authority practices represented here, EISP determines that in the absence of all other factors to be taken into consideration, normal practice would be to:

1. Grant Permission. **Grant Permission.**

# Futures

## Complete multidisciplinary – sustainability - geology's place

- **social and cultural interactions**
- **economic change**
- **political drivers**
- **as well as environmental conditions**



# Futures

## Complete multidisciplinary – sustainability - geology's place

***A vision: “provide the data standards and applications seamlessly to link data models, concepts and numerical simulations concerned with the surface and subsurface.”***

**The models will be capable of being linked to socio-economic models, for example, on population change or commodity prices.**

(Kessler *et al.* 2009)



## **KEY POINT No. 12:**

**In the future, new applications for geo-information will continue to be found**

**However, urban geology will become simply a part of the broad sweep of information and knowledge required to develop our cities sustainably**



# Futures

## Internationalism

### IWGUG (1993-2009)

#### Objectives:

- to improve communication between disciplines working on cities (as well as between urban geologists)
- to raise awareness of the importance of geo-information to urban development
- to initiate and support research and disseminate its findings
- to 'represent' urban geology internationally
- to arrange multidisciplinary training for urban specialists



# Conclusions

- **Geo-information for urban areas must be kept up-to-date**
- **It must be accessible to users**
- **And it must be in a “dynamic and easy-to-use format”**
- **Users of urban geo-information are likely to have a relatively limited knowledge of geology**
- **There are many users of urban geo-information, all with different needs**
- **When working with those who have little or no formal training in geology, *clear* communication is important**
- **Communicating clearly about the urban geo-environment should involve a *considerable* amount of effort**



# Conclusions

- **Acquiring geo-information for urban areas and managing and maintaining the databases in the long-term is cost effective, and of societal benefit**
- **Unless taxpayers are willing to pay the increased costs of digitisation and digital data management, the era of public bodies, such as geological surveys, freely providing access to geological information will pass completely**
- **For the most part, city authorities do not have the resources or the motivation to build, maintain and develop geological and geotechnical databases**
- **There is no guarantee that private data companies will continue to operate and maintain their databases in the long-term or add new information**
- **In the future, new applications for geo-information will continue to be found**
- **And, urban geology will become simply a part of the broad range of information and knowledge required for sustainable development**



# **Actions for urban geologists**

**For geo-information providers (including geological surveys):**

- 1. Gather and digitise urban data**
- 2. Create 3D-4D models of the shallow subsurface and attribute these models with relevant parameter data – linking the databases to the model**
- 3. Give an indication of the uncertainty associated with the models and explain what it means**
- 4. Engage in two-way discussions with the wide range of potential users**
- 5. Provide interpreted outputs of spatial information in exactly the form required by the users and indicate the limitations**
- 6. Carry out cost-benefit studies to demonstrate the value of urban geo-information**
- 7. Integrate physically-based 3D ground models with process and socio-economic models to assess the vulnerability/resilience of the urban subsurface to future environmental change**



# **Actions for urban geologists**

**For researchers:**

- 1. Develop the generic methodologies and techniques to visualise and explain 4D change and uncertainty**
- 2. Provide the understanding of the processes that bring about these changes**
- 3. Research and develop new technologies for monitoring the urban environment such as LIDAR, PSInSAR and geophysical systems**



# **Actions for urban geologists**

## **For consultants:**

- 1. Carry out more thorough desk studies, particularly developing and using three dimensional spatial, digital models**
- 2. Move from current site investigation methodologies, which tend to be necessarily prescriptive based on current guidelines and standards, to ones based on testing the geological model. This will require a new culture for site investigation, with the development of new standards and the modification of old ones.**



# **Actions for urban geologists**

**For all geologists working in the urban environment:**

- 1. Learn how to better communicate with the wide range of users of geo-information. If necessary, this may involve professional communication experts**
- 2. Seek to persuade the policy makers and politicians who, ultimately, control spending on geo-information in our cities, that continuing to do so is cost effective**



# Finally, my thanks to:

**Simon Price**, my co-author, for his innovation and for keeping me up-to-date

**Steve Booth** for his thoughtful review of the presentation and the paper

**Philippa Culshaw** for keeping me going

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