EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

## COST Short Term Scientific Mission (STSM) TU1206-14851

# Improving the delivery and impact of groundwater and wider subsurface data

## STSM Report to COST MC Chair

## *Delivery and impact of subsurface data in the absence of a comprehensive legislative framework – shared issues and difficulties in Odense and Glasgow*

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## Contents

# 1. STSM rationale and purpose

## Rationale

BGS and VCS Odense proposed this STSM based on ongoing work in both cities to improve the delivery and impact of subsurface data within the cities.

Shared difficulties in improving the delivery and impact of subsurface data were highlighted between the cities at the NAG-CITY workshop discussions in Odense (January 2013). In both cities, the lack of standardised data reporting formats, and the selective legislation requirements for reporting subsurface data to national or city authorities, strongly limits the amount and accessibility of subsurface data which is available to inform decision making.

## *Purpose*

The purpose of the STSM was to facilitate knowledge exchange between specialists in *VCS Odense, GEUS, Odense City Municipality* and *BGS* to compare key issues of the subsurface data management within the cities of Glasgow and Odense, in the absence of a comprehensive legislative framework in the UK or Denmark which ensures all borehole data are submitted to national or local public authorities. The STSM also aimed to discuss methods which could be used to improve the delivery and impact of subsurface data within the cities, and which could be transferred as a best practice to other cities within the COST Action with similar legislation.

Improving access to standardised subsurface data, which can be readily available to inform policy and decision making within the public and private sectors, is increasingly required in all COST cities to meet key current urban redevelopment and groundwater management demands. The lessons learnt from the STSM are, therefore, of benefit to all COST-participants, particularly those within countries of similar data legislation.

The main aims and purpose of the STSM between the *BGS, VCS, GEUS and City Odense* were to:

- Facilitate knowledge exchange between specialists in these organisations
- Using Odense and Glasgow as case studies, identify the key issues limiting access to existing subsurface data in urban areas, to support decision making
- Discuss and review possible methods to improve standardisation of data, and data quality and integrity, and discuss ways to achieve a more rapid and dynamic update and exchange of subsurface data between end users and data providers.
- Discuss transferable best practice in data management – for example, the application of the GSPEC specification for data capture and reporting being developed and trialled in Glasgow.

  Of key interest were processes of:

  i. Data collection and retrieval in Odense and Glasgow

ii. Data management systems within GEUS and Odense City Muncipality and VCS for subsurface and groundwater data
iii. Use of technology and web-delivery to access the subsurface data and geo-outputs (e.g. 3D models) held by GEUS

- Examine inter-organisational relationships between GEUS, Odense City Municipality and private sector organisations within the city of Odense, and how this determines, or limits, the impact of existing subsurface data and knowledge within the city for decision making.

***Current relevant work in the STSM institutions:***

- *VCS Odense* is responsible for managing the groundwater-based public water supply in Odense, and VCS works closely with *GEUS* and *Odense City Municipality* to ensure groundwater data, particularly those of long-term data time series, are delivered to the national databases GEUS and can be re-used to inform water management.
- A National groundwater mapping is currently being undertaken by *GEUS*, the Nature Agency and advisors involving a review of both data collation and a quality assurance. Detailed national mapping is possible only due to the effective management of groundwater data by the private water companies such as VCS, and the maintenance of a national hydrogeological database by GEUS.
- The *City Municipality of Odense* is currently working to improve subsurface data availability within the city, as part of a major regeneration project in the centre of Odense – the Thomas B Thrigesgade project. This project will see a major roads in the city be pedestrianised, an extensive redevelopment of the shopping area, and the construction of a two-storey underground car park. The work has highlighted the paucity of subsurface data held within the GEUS national databases and the significant difficulties in re-accessing other available subsurface data held by private companies and third parties.

  *GEUS, Odense City Municipality* and *VCS* are all engaged in the GEUS-led 'Urban Geology' super-project, which aims to develop an agreed city-wide groundwater and subsurface model of Odense. This work requires more subsurface data to be accessible to develop understanding of the subsurface in Odense, and is raising wider questions of how subsurface data management can be improved in Odense, and Denmark, so that data have greater impact and re-use.

The applicant of the STSM [*Helen Bonsor*] in *BGS* is currently developing a pilot study within the city of Glasgow, to improve the accessibility of private sector subsurface data available within the city, to support decision making, urban redevelopment and environmental management. Part of this is particularly looking at how a city wide urban groundwater monitoring network could be developed from existing groundwater monitoring infrastructure and data at individual regeneration and site investigation project. Most of the subsurface data within the city, is generated from private sector

site investigations, remediation and regeneration projects, and very little is reported systemically to Glasgow City Council (GCC) or BGS in the absence of any legislative drivers to do so.

Currently in Glasgow there is:

- no legal requirement to submit shallow (<30 m deep) borehole data and information to the BGS, and as a result no centralised database of the available borehole data collected by the private sector work in the city
- No dedicated urban monitoring network for groundwater in the city. In the absence of this infrastructure data are sourced from disparate regeneration projects and local ground investigations
- There has been no historical driver to monitor the urban groundwater resource – it is not used for public water supply or industry. Future requirements of the Water Framework Directive (WFD), together with key issues of urban groundwater flooding and installation of sustainable urban drainage schemes, are only now, making it a priority.

As a result the majority of subsurface data produced is hard to access and rarely re-used by either the private or public sector to inform future decisions. The work being led by GCC and BGS in Glasgow, is aiming to emplace a systematic reporting of private sector data to GCC and BGS; develop a centralised repository of subsurface data generated within the city; and foster a virtuous cycle of data and knowledge exchange between the public and private sector organisations within the city.

## 2. Work carried out within the STSM

The STSM involved a 5 day visit of the STSM applicant (Helen Bonsor [BGS]), and Carl Watson (BGS) to VCS Odense and GEUS Aarhus from 3 to 7 February 2014. Meeting discussions over the week were centred on methods of subsurface data management and re-use of subsurface data for 3D subsurface modelling and urban redevelopment and environmental management.

The focus of discussions was:

- GEUS National databases – data collation, validation, content
- Access to the GEUS National databases through web data portals
- Subsurface data holdings within the private sector
- Inter-organisational relationships between public and private sector organisations in subsurface data and knowledge exchange.

Meeting were led by a series of different specialists within GEUS, VCS, I-GIS, Odense City and BGS:

- **Susie Mielby, Martin Hansen, Margrethe Kristensen (GEUS)** – GEUS National databases – data collation, validation, content
- **Johan Linderberg (VCS), Susie Mielby (GEUS)** – Collation and management of groundwater data
- **Peter Sandersen (GEUS), Niels-Peter Jensen (I-GIS)** – Development of 3D subsurface models; issues of data availability and access
- **Gert Laursen (Odense City Muncipality)** – Key issues and difficulties in accessing subsurface data to support decision making in Odense.

# 3. Delivery and impact of subsurface data in the absence of a comprehensive legislative framework – shared issues and difficulties in Odense and Glasgow

## 3.1 National GEUS subsurface datasets – data collation, validation and re-access

*Legislative framework*

Danish legislation requires that all boreholes drilled for water supply abstraction, geothermal energy, or official surveys, must be registered with GEUS and the borehole data are stored in the national GEUS data holdings. There is no legal requirement however, for site investigation or geotechnical boreholes to either be registered or reported to GEUS, with the exception of data from contaminated land sites which is captured under the Part 2A legislation. A large subset of subsurface data is therefore not reported to GEUS and is, instead, held within individual private sector databases. Within the UK, there are similar gaps within the legislation framework for reporting subsurface data – boreholes less than 30 m depth are not legally required to be reported to the National BGS database, even though this includes the majority of site investigation boreholes in the UK. Within the UK a proportion of this data is reported voluntarily to the National database by the private sector, or will be made available on request of the BGS for specific research purposes, but within Denmark there are few voluntary depositions outside of major infrastructure projects.

*National databases – GEUS*

GEUS manage three Oracle databases for national subsurface data:

1. Jupiter database – which includes a series of secondary-databases:
    - Borehole database
    - Model data database
    - Reports database
    - Chemistry database
    - Marine borehole database
2. GERDA database – Shallow geophysical investigation data
3. SAMBA database – Oil exploration data and confidential reports

The Jupiter database forms the *primary* database to which borehole data (with the exception of oil exploration boreholes) are registered. Shallow geophysical data are parsed subsequently into the GERDA database from the Jupiter database. Oil exploration boreholes are slightly different and are primarily registered within the SAMBA database. Any relevant, non-confidential data are then copied into the Jupiter database from SAMBA. These manual data transfers between the GEUS databases are preformed daily for all new borehole records. This is preferred by GEUS over an automatic live-link between the databases, to ensure there is strong control over the data content of

each database. The long-term aim is for all three databases (Jupiter, GARDA, SAMBA) to be merged into just one Oracle database, to avoid the present duplication of data between the datasets.

*Data collation and validation*

Any new borehole drilled within Denmark (with the exception of geotechnical boreholes) is required to be registered with the well archive centre before being drilling, and assigned a Danish Geological Survey (DGU [*now GEUS*]) well ID number. Registration is typically the responsibility of the drilling contractor – who must also be certified within Denmark. For site investigation boreholes no data must be legally submitted to GEUS. For water abstraction boreholes, geothermal, or survey boreholes (termed 'A class' boreholes), the following data are legally required to be submitted to GEUS for each borehole:

- Borehole construction information – including screen material and intervals, and gravel pack material
- Borehole lithology
- Drilling information – drill size, bit size, drilling rates
- Drilling samples – every 5 m interval, or at a significant change in geology

These data must be supplied within a standardised digital Access database format, which was designed and implemented by GEUS in 1992. It became a legal requirement to report all new borehole data to GEUS using the format by 1995. The digital Access template does not allow free text, and the pre-set lists within the form match the GEUS geological codes and other GEUS dictionaries. This ensures the data can be input into the GEUS national databases quickly and effectively. Prior to the development of the digital data reporting template, all borehole data were reported to GEUS on non-standardised paper records; input of these data to the GEUS databases was much slower and susceptible to transcription error.

Data received by the well archive centre at GEUS undergo a high-level of validation. Key validation parameters are:

- Accuracy of the borehole grid reference
- Quality and accuracy of the borehole lithology descriptions – cross check of borehole log descriptions with borehole lithology samples.
- Integrity of the data – e.g. does the address and grid reference of the borehole match that previously registered to the DGU ID number.

This level of validation requires a two-person team at the well archive centre. Typically around 100 new boreholes are registered and reported each year. Occasionally incomplete or inaccurate data are submitted, and in these cases GEUS requests re-submission of the relevant data from the data depositors. This is not a common issue, and the validation process is not too onerous or expensive for GEUS to operate.

If borehole data are later revised (e.g. the reference level of the borehole has changed, or the screen interval has changed following borehole repair and rehabilitation, these data are submitted to GEUS using a PDF template form, and the well archive centre manually enters the revised information from the PDF into the Jupiter borehole database.

GEUS don't hold any geotechnical data, due to GEUS, as yet, not having a sufficient database dictionary to accept geotechnical data within the Jupiter database. A new holding database – the B-borehole database – is now being used to collate any new geotechnical borehole data submitted. This database will hopefully be developed in the future to take on a full Oracle geotechnical database structure. In the past, any geotechnical data submitted to GEUS were stored as a scanned PDF within the Reports database of Jupiter.

Data for which there is no legal requirement to submit to GEUS, but which can be voluntarily submitted are termed 'B boreholes' or data:

- Groundwater level measurements
- Geotechnical or ground investigation boreholes
- Reports
- Geophysical data

*Private sector data reporting*

Within private sector companies, B-borehole data are still largely reported and stored in PDF report formats, which are individual to each company. Having a standardised digital reporting format (such as AGS format, or the GEUS Access template) for all borehole data, which was adopted by everyone in Denmark would be of increasing benefit – particularly with the move toward 3D BIMs and subsurface modelling in large scale infrastructure projects, which integrate many different data types and sources.

*Dataflow to the GEUS databases*

GEUS receives borehole from:

- drilling companies (borehole data)
- laboratories (chemistry data)
- 98 Municipalities (borehole, groundwater and drinking water data)
- Consultancies (borehole, geophysics, model data, reports)
- State agencies (groundwater, borehole data, model data, reports)
- Regions (groundwater, borehole data, model data, reports)

There is no set frequency with which data are legally required to be reported to GEUS, so very different amounts of data can be reported at different frequencies from across Denmark and from different organisations. Data can only be submitted to the GEUS databases by 'privileged users', who are Municipalities, national agencies, laboratories, and quarry industry agency. These organisations have 'privileged user' access to the Jupiter database, and can either enter, or update and revise data within the Jupiter database according to their Oracle permission access level. External access to the Jupiter database to these users is facilitated through a SOAP web interface, which enables live-linked editing and data upload to the Jupiter databases.

It is a legal requirement for:

- National agencies to report all new survey, chemistry, environmental and quarry data to GEUS
- Laboratories to report chemistry data to GEUS
- Municipalities to report water works and permit data to GEUS Jupiter database. (It is the responsibility of drilling companies and water supply companies to report all new borehole and groundwater data to the local Municipality for upload).

If data are entered incorrectly, or conflicts or inconsistencies arise between the different parts of the Jupiter database then GEUS is alerted and the data submitter is requested to correct the data entry. The editing permissions within the Jupiter database lie solely with the data submitter (e.g. Odense Municipality) – i.e. GEUS cannot override the data permissions to correct data errors within the Jupiter database, it is only the data submitters who can do this. Therefore if laboratory data must be corrected – the laboratory must correct the chemistry data within the Jupiter database, and separately to this the relevant consultancy must also correct any follow on revisions to the associated borehole data within the Jupiter borehole database. Equally, if a Municipality and Nature Agency both upload groundwater-level data from the same borehole to the Jupiter, but the measurements are to different measurement datum it is the responsibility of both to correct the data entries. Ambiguity can arise from the data submission process are to who is responsible for the data and where the data ownership lies – with the organisation or body who contracted the work and borehole data, or with the data submitter? And if two agencies submitting the same data, who does the data ownership belong to?

There is no formal enforcement by GEUS to ensure all required data are submitted to Jupiter database by the different relevant parties. GEUS see the enforcement of the data reporting legislation to be outside of their remit, although there are some procedures run by GEUS to check a minimum frequency of some data are being submitted (e.g. annual nitrate analysis results). Some individual companies and agencies take it on themselves to check their sub-contractors have submitted the required data to the Jupiter database by manually checking the GEUS Jupiter database portal on-line. For example, VCS check themselves whether the laboratories have submitted new groundwater chemistry data to the database.

These roles of responsibility for data submission, and editing of data within the national GEUS databases is very different to the situation in Hamburg and UK, where BSU Hamburg and BGS control all data input to the national borehole databases. Individual companies, often hold a duplicate database of A-borehole data, which are reported to the GEUS Jupiter database as a cross-check – resulting in many different local versions of the national database.

*Future development*

GEUS are working towards several changes in the future to the data management structure in Denmark.

- It is likely the Jupiter database will in the future be extended to accept: soil and air chemistry from boreholes; soil, water and air chemistry data from surface samples; and, air chemistry data from plants.
- B-borehole data will become fully integrated in the Jupiter databases, and not held within a separate B-database – this will require development of an appropriate geotechnical database within Jupiter by GEUS.
- Development of a database for 3D model data
- Establishment of a national 3D geological model
- Development of web-GIS infrastructure and web map tile services to improve the speed of data access through these services which are main route of data re-access by external users.

**Data responsibilities and permissions:**

- Importantly, it is hoped Municipalities will be able to enter borehole data into the Jupiter database and maintain ownership of the data – rather than ownership of the data remaining held with the drilling contractor.
- Public supply water companies may in the future be allowed to upload groundwater-level measurements directly into Jupiter database, rather than these data being submitted to GEUS through the municipalities.

*Accessing the GEUS National database for external users*

External public users (ranging from private sector companies to the general public) are able to access the GEUS Jupiter databases through web search forms and Google Earth based map interfaces http://www.geus.dk/DK/data-maps/jupiter/Sider/default.aspx – Figure 1. Most of the major consultancies and companies database structures now match the GEUS database structures – which are available for download through web based services. This means companies can download the latest version of the publically available Jupiter database and update their own databases with relative ease. Most of the major consultancies and companies database structures now match the GEUS database structures – which are available for download through web based services, together with the latest version of the publically available Jupiter database.

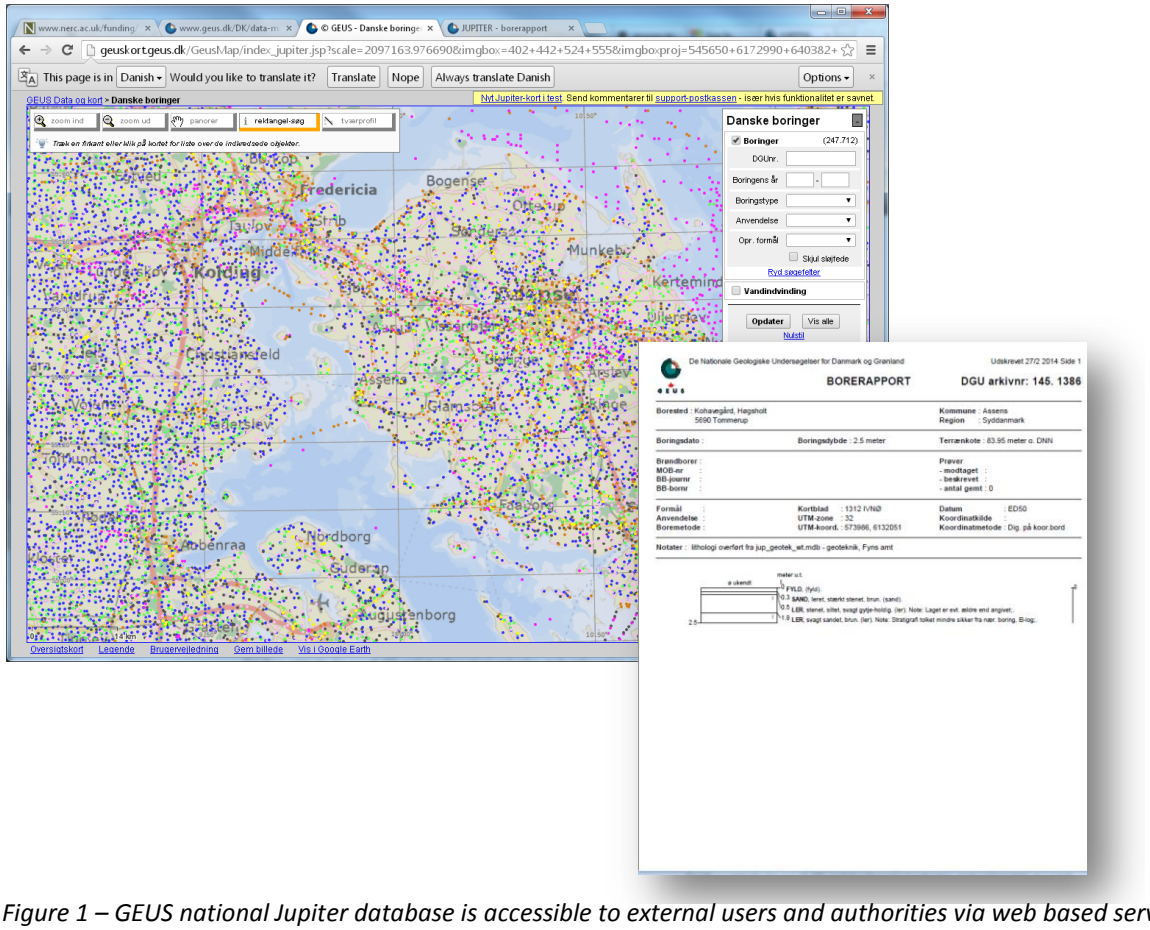



*Figure 1 – GEUS national Jupiter database is accessible to external users and authorities via web based services, such as the map service above. Summary data are instantly available from the map, with the comprehensive data for each borehole downloadable in PDF forms (see inset). (Images: GEUS)*

Authorities (e.g. Municipalities and national agencies) mainly access the datasets through web services – ranging from map services within an ArcGIS or MapScript interface, feature services, or SOAP web services (form-based access). These web map services are quite advanced and display summary borehole information, as well as a live-link to the detailed borehole report – which includes all the borehole construction information for a borehole, time series groundwater level data, chemistry data and any associated PDF reports from a borehole point. There is also a web map portal specifically for groundwater data. This portal is linked to the Jupiter database, and updated daily within any new data uploaded to Jupiter. From the map portal, groundwater data parameters can be displayed and queried - e.g. chloride and arsenic concentrations can be displayed across Denmark from all boreholes. The data are only viewable from web portal; Excel spreadsheets of groundwater-levels and PDF groundwater reports are downloaded from hyperlinks.

3D geological model data can also be viewed within the web map viewer service. There is significant flexibility in how the 3D models can be viewed and interrogated: individual or multiple model layers can be shown, along with values of specified parameters within that layer, and which borehole input

data were used to generate each model layer and parameterization. Fixed cross-section lines can also be viewed.

### 3.2 Subsurface data holdings within the private sector in Odense and Denmark – the 'family silver'

In addition to the A-borehole data which are legally required to be submitted to GEUS, a significant amount of subsurface data is held within private company data holdings within Denmark – so-called 'B-borehole data'. B-borehole data are not legally required to be submitted to national agencies or municipalities (e.g. geotechnical borehole data; ground investigation borehole data) and the data are not held in any national database. As a result, a large amount of shallow (<30 m deep) subsurface data in Denmark is held across many different individual company databases, which are inaccessible and invisible to outside parties, organisations or national agencies.

The extent to which this limits decision making and restricts the work of public agencies and municipalities has been highlighted by: 1) the work by GEUS over the last few years to develop city-scale 3D geological models around Denmark (e.g. Odense and Svenborg); and, 2) the difficulty faced by Odense City Municipality to plan the site investigation of major regeneration work in Odense (e.g. the Thomas B Thrigesgade project) in absence of significant A-borehole data in the city.

*1. Developing city-scale 3D subsurface models*

GEUS is working to develop 3D urban geological models around Denmark, at three different scales: municipality-scale models (15-20 $km^2$); city-scale models (5 $km^2$); and, local scale models (<1 $km^2$). In nearly all areas, the amount of A-borehole data available from the Jupiter database has been found to be insufficient to develop a robust 3D conceptual model of the subsurface geology – Figure 2. B-borehole data held within the GEUS B-borehole database provided substantially more subsurface data which significantly improved understanding of the subsurface. A further 50-70% B-borehole data is estimated to be available within the areas of interest within individual private company databases. It is estimated that the national Jupiter database typically holds less than one third of the total borehole data available in urban areas, and that this is often insufficient to develop accurate and robust 3D subsurface models at city or municipality scale; to do this scale of modelling work requires access to other borehole data from geotechnical and ground investigation boreholes, which are stored in individual company databases.

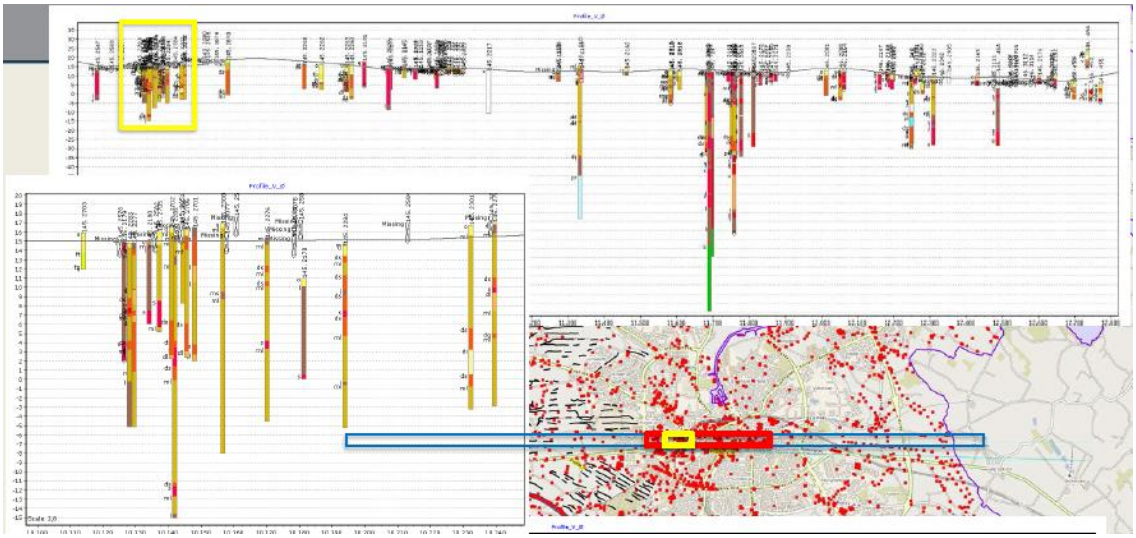
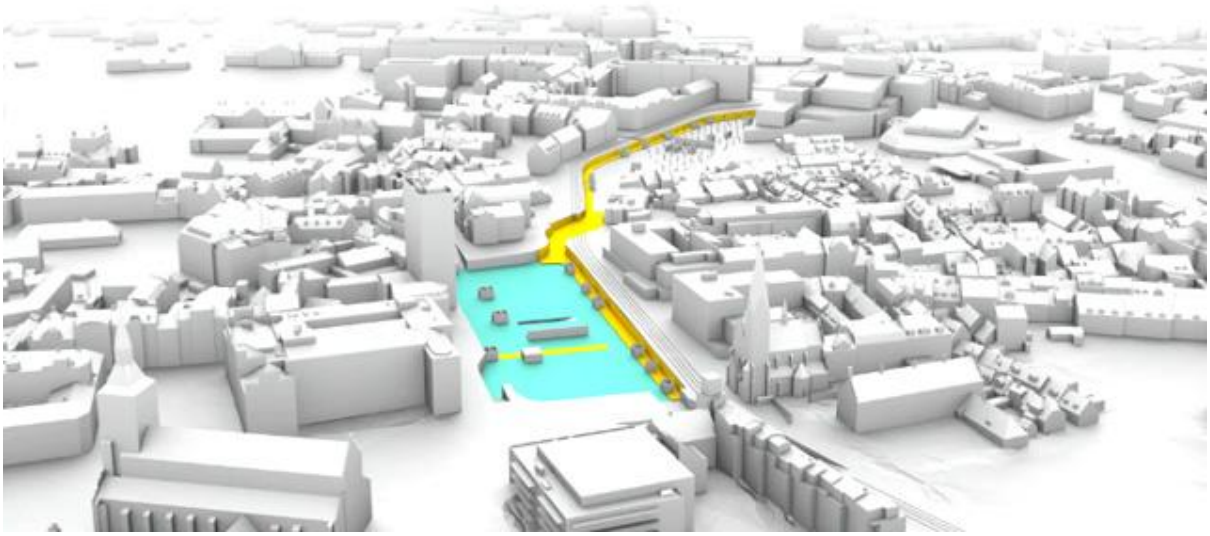


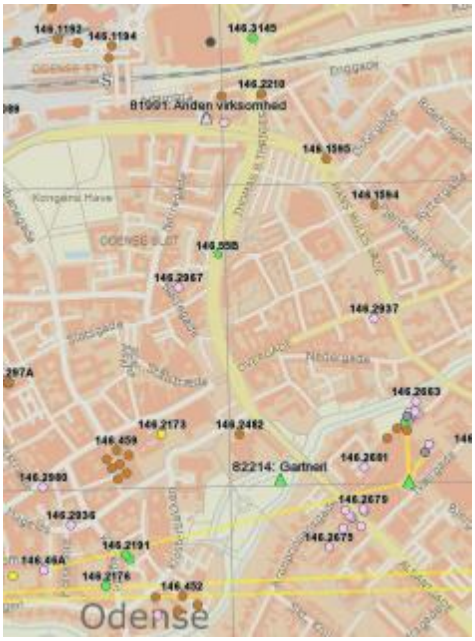
*Figure 2 – A schematic cross-section of Odense city showing the A-borehole data available. Note the large spatial gaps between borehole data points and absence of data at certain depths for large distances. (Images: GEUS).*

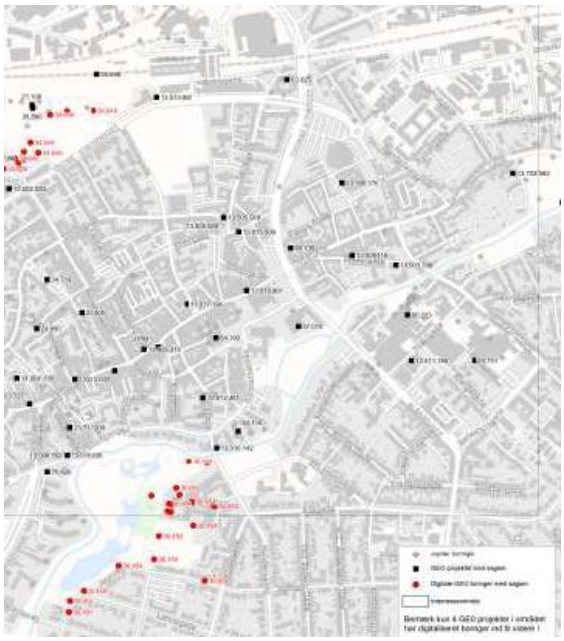
## 2. *Planning site investigations*

The extent to which the inaccessibility of B-borehole data in Denmark limits subsurface knowledge, and decision making by public agencies and municipalities is also shown by the difficulty currently faced by Odense City Municipality to plan the site investigation of major regeneration work in the city. The Thomas B Thrigesgade project is a major regeneration project which plans to pedestrianise one of the major through roads in the city, undertaking extensive redevelopment of the shopping area above ground, and install a two-storey car park underground – Figure 3. Depth to groundwater in the area is very shallow (typically 3 m or less), and detailed understanding of the subsurface is required by the city municipality and the leading consultancy to plan an appropriate level of site investigation. However, there are few A-borehole data within the area of interest. Access to B-borehole data – of which there is sufficiently more (>200 borehole points) (see Figure 3) – is required to be able to adequately plan the site investigation and regeneration project work.

Access to the B-borehole is difficult. In Denmark the consultancy GEO undertake 50 000 site investigation projects each year, generating between 250 000 to 500 000 borehole points. The majority of these boreholes are B-borehole data and are not reported to the GEUS national Jupiter database. In the city of Odense alone GEO have over 5000 B-borehole data points. As result of GEO undertaking such a large proportion of ground investigation work in Denmark, and thereby holding a significant proportion of the shallow subsurface data which exists for Denmark, the company do not make the data available to other companies or third parties, as the data are such a valuable asset – the 'family silver'. Accessing B-borehole data from smaller companies (e.g. drilling contractors and local consultancy firms) is easier, as the companies have much smaller B-borehole data holdings, and the individual data holdings of each company less valuable.





http://www.utopiancityscape.com/ucs/work/tbt.html

*Figure 3 – Top Panel: 3D surface model of the Thomas B Thrigesgade regeneration project, which will involve th epedesitrain of the highway highlighted yellow and the construction of a two-storey underground car park. Lower Panel: (left) borehole data points available within GEUS Jupiter national database in the area of the Thomas B Thrigesgade project; (right) private borehole data points held by GEO consultancy within the Thomas B Thrigesgade project area.*

*'Family silver' – access to 'private' stored geotechnical data*

Extensive negotiations over nine months by Odense City Municipality with GEO consultancy have led, for the first time, to GEO making two offers of data access to Odense Municipality for the Thomas B Thrigesgade project.

1. Under the first option, GEO would sell the raw data for 200 of the 'best' B-borehole data points (i.e. digital georeferenced data records) to Odense Municipality. This would mean Odense municipality would be able to use the data directly as documentation, rather than making new site investigation boreholes.
   *The total cost of this offer is around 40 000 GBP (350 000 DKR) – calculated as one third of the total cost of new site investigation boreholes.*

2. In the second option, GEO would supply data for Odesne municaplity and the acting consultancy to develop a geo-hydrological model. However, the client will only keep ownership of the model developed, and would not have access to the raw data supplied by GEO. The model, therefore, couldn't be used as documentation of subsurface conditions, and new site investigation boreholes would still have to be drilled.
   *The total cost of this offer is 20 000 GBP (175 000 DKR).*

The cost of these offers, together with the time and cost of the negotiations with GEO to gain this access to the B-borehole data is unfeasible to be repeated in every instance B-borehole data is required to supplement the A-borehole data held within the GEUS national Jupiter database. The stranglehold GEO has on access to subsurface data and knowledge exists because they undertake such a large proportion of ground investigations in Denmark.

A very similar situation could have existed in Glasgow if one consultancy was dominant. However, within Glasgow, no-one consultancy undertakes the majority of the site investigation, and therefore individual companies and consultancies are much more willing to provide access to B-borehole data on request by city municipalities, or national agencies. Due to each company having a relatively small subsurface datasets, they are keen to gain access to wider datasets, and to input their B-borehole data to a centralised data holding on a voluntary basis, as there is a clear business benefit to themselves as well as to others to do this.

### 3.3 Key issues limiting delivery and impact of subsurface data in Odense and Glasgow

The main issues limiting the delivery and impact of subsurface data in Odense and Glasgow are very similar – both countries have a similar legislative background, and as a result, incomplete national subsurface databases.

Specifically, the key issues identified in both cities from discussions are:

- Due to the legislative framework in Denmark and UK, not all subsurface data are legally required to be submitted to the national databases managed by GEUS, and BGS. As a result, the national subsurface databases are incomplete, and in some cases contain insufficient subsurface data at city-scales to inform the work of city municipalities and to develop city-scale 3D understanding of the subsurface, and robust subsurface modelling.
- A significant amount of high quality subsurface data exists outside of the national databases, which are not legally required to be submitted to national agencies or local authorities, and held within local databases of individual companies. Access to this data is difficult, as often it is not known that the data exist. Access to the data can also be expensive, or restricted.
- Subsurface data are still predominantly stored and reported by private companies as PDF reports, and not in raw digital format (e.g. AGS format, or Access templates). This leads to several issues which limit the re-use of the data, either by individual companies who own the data, or by national agencies or municipalities who gain access to the data:
    - The PDF format makes it time intensive to extract and re-use the data
    - Borehole construction information are often reported in separate PDF files to groundwater monitoring data or geotechnical data – it is very time consuming to manually link the different data, but this is essential for the groundwater data or geotechnical data to have any spatial or vertical reference.
    - Manual errors are common within free-text PDF forms
- There are several common issues with groundwater monitoring data:
    - The datum of groundwater-level measurements is often not accurately recorded, leading to inaccurate or low confidence groundwater level time series data.
    - 'Shifts' in groundwater-levels due to errors by recording equipment are common, but are not flagged, or identified as being due to instrument error (rather than real shifts) within GEUS database structure – this is only done within accompanying PDF monitoring reports by GEUS. This reduces confidence in raw digital data held in national database.
- Laboratory data:
    - The STANDAT format used by laboratories to report chemistry data to GEUS, and clients, is a standardised electronic format. However, the forms are free text, and the STANDDAT software does not force compliance to the STANDAT reporting standards for laboratory data. As a result, units of reported data can often be incorrect, and incorrect dictionary codes for chemical parameters can be used. The same problems are encountered in the UK with the reporting of laboratory data using the free-text AGS digital format.

***In both countries the key issue is that a significant amount of subsurface data are not legally required to be submitted to national subsurface databases, and as a result a significant proportion (estimated to be over 50%) of nationally available shallow subsurface data are retained within***

***individual local company databases. This data is difficult to access, as it is privately held and owned, and is often not visible or known to exist to external parties – including public and national authorities. In addition, the majority of this data is stored within PDF reports, which makes the data difficult and time consuming (and therefore very expensive) to extract and re-use.***

***The accurate reporting of groundwater-level measurements and laboratory data are also shown to be common issues; free text formats for reporting data measurements mean key units information, or measurement datum are often recorded incomplete, or inaccurately.***

## 4. Opportunities to improve data access and re-use – lessons learnt from Odense and Glasgow

*Key lessons from Odense and Glasgow*

The STSM has shown that very similar issues in data reporting in Odense and Glasgow limit the access and re-use of a very significant proportion of subsurface data available within the cities. A large proportion of subsurface data are inaccessible in both cities, and there are clear examples where this clearly limits subsurface knowledge and restricts decision making by public agencies and municipalities in Odense and Glasgow.

The key issues limiting the delivery and impact of subsurface data within the cities are:

1) the absence of a legislative framework which requires all subsurface data to be reported to national databases;
2) the absence of an enforced digital reporting data standard (e.g. AGS format) for all borehole data; the majority of subsurface data reported in PDF format between data providers and users, outside of the national databases.

The accessibility of subsurface data held within the national databases is, however, very good and there is high re-use of these data, which inform decision making and ground investigations. External access to the national databases via spatial map view platforms, or other web services, make the data highly accessible and also generates a high awareness amongst external users of the potential data available to support decision making. If these national subsurface databases where comprehensive, to include all borehole data available, the impact of the databases and data would be many fold greater.

To access data, which are outside of legal data reporting requirements, relies on strong inter-organisational working relationships between public and private sector organisations. These relationships are instrumental to developing comprehensive and standardised subsurface datasets in urban areas, and to develop a virtuous cycle of data and knowledge exchange.

*Opportunities to improve data accessibility and re-use – transferrable best practice*

Standardisation of, and increasing access to, existing subsurface data is required in nearly all COST cities to meet key current urban redevelopment and increasing groundwater management demands. The lessons learnt from the STSM are, therefore, of benefit to all COST-participants, and not just Glasgow and Odense. There are also shared opportunities for COST participants to improve subsurface data accessibility and re-use.

Within Glasgow significant work has been done between BGS and Glasgow City Council (GCC) to improve data reporting and data accessibility, for both legally required and non-legally required borehole data. This work – term GSPEC "Glasgow SPEcification of data Capture" – is aimed to improve subsurface data and knowledge exchange in three parts:

1) In the absence of a legislative framework which requires all subsurface (borehole) data to be submitted to national databases, Glasgow City Council have now made it a contractual requirement for all borehole data to be reported to the council in a standardised raw digital format (AGS format).

   Similarly within Odense, it has been made a requirement for all borehole data submitted to GEUS to be in a standardised Access template. This has significantly improved the accuracy and integrity of borehole data submitted to GEUS.

2) All borehole data submitted to Glasgow City Council in the AGS format are now transferred to BGS, where it is validated, and will in the future be parsed into the BGS national databases.
3) To improve awareness of the data available, and access to BGS 3D geological models of the city, a knowledge exchange network (ASK – Accessing Subsurface Knowledge) has been set up composed of contractors, consultancies, national agencies and local authorities and regulators involved in either generating or using subsurface data in the city. Organisations who join the network get free access to the BGS 3D geological models of Glasgow, which otherwise are only available under licence. The ASK network should lead to greater awareness and a collective improved subsurface knowledge in the city.

The implementation of a contractual requirement for all borehole data submitted to city municipalities, and the agreement that these data are then passed to national databases, circumvents the need for national legislative change, and has the potential to significantly increase the amount of borehole data accessible within the national databases.

Widespread adoption of a standardised raw digital data format for reporting all subsurface data across the public and private sectors – as currently being trialled in Glasgow, and which has been done in Odense since 1992 – has the potential to significantly increase the ease and efficiency of inputting the data to national databases, and enables a much more efficient process of data and knowledge exchange between data depositors and data users. There can also be much more rapid development and delivery of derived map products and 3D models based on the national databases.

Implementing both these practices is feasible in other COST cities which share similar legislative frameworks to Odense and Glasgow, and in which there is a lack of standardised digital format for reporting borehole data.

Developing strong inter-organisation relationships between public and private sector organisations involved in generating and using subsurface data is key for there to be awareness of the subsurface data and knowledge available within a city and for the subsurface data to be used for greatest effect and impact.

## 5. Future collaboration and outputs

*Continued knowledge exchange:*
Continued discussions and knowledge exchange on subsurface data management and groundwater monitoring practices will almost certainly follow on from the STSM as work in these areas in both institutions progresses.

A reciprocal knowledge exchange visit is likely between GEUS and Odense City Muncipility, with BGS and Glasgow City Council to discuss: different digital data formats which could be adopted for reporting subsurface data; the development of BGS and GEUS national databases to accept a wider variety of subsurface data (e.g. geotechnical data); and, the different 3D modelling software available for developing subsurface models integrating a wide variety of datasets, not just geological and groundwater data. This visit is planned for 27-29 May 2014, alongside the COST TU1206 meeting in Glasgow.

*Engagement of wider group of COST participants:*
It would be a natural extension to this STSM, to engage a wider group of COST participants to the discussions on subsurface data management, and increasing the re-use and impact of the data. This could be achieved through a possible follow-on COST workshop.

*Outputs:*
Hamburg provides a best practice example to the COST Action for subsurface data management in urban areas, and how subsurface data and knowledge can inform policy and environmental management – *see STSM report 14842*. There is potential for a joint output between BSU, GEUS, BGS and the city authorities in Hamburg, Odense, and Glasgow to publish guidelines on how best practice might be applied to other urban areas within the COST Action cities – drawing on the work being done in these cities by these partners.

## 6. Summary

The STSM facilitated an invaluable, focused period of knowledge exchange between BGS, centred on key issues of subsurface data management, and the application of this data for groundwater management. The knowledge exchange initiated between the two institutions in the STSM is envisaged to be continued, and built upon, as work in both institutions in these work areas progresses.

The main issues limiting the delivery and impact of subsurface data in Odense and Glasgow are very similar. The key issues limiting the delivery and impact of subsurface data within the cities are:

1) the absence of a legislative framework which requires all subsurface data to be reported to national databases;
2) the absence of an enforced digital reporting data standard (e.g. AGS format) for all borehole data; the majority of subsurface data reported in PDF format between data providers and users, outside of the national databases.

The implementation of increased data reporting to city authorities through contractual requirements has the potential to significantly increase the amount of subsurface data reported to the public sector, without the need for national legislative change. Adopting of a standardised raw digital data format for reporting all subsurface data significantly increases the ease and efficiency of inputting the data to national databases, and enables a much more efficient process of data and knowledge exchange between data depositors and data users. Implementing both these practices is feasible in other COST cities which share similar legislative frameworks to Odense and Glasgow, and in which there is a lack of standardised digital format for reporting borehole data.

Standardisation of, and increasing access to, existing subsurface data is required in nearly all COST cities to meet key current urban redevelopment and increasing groundwater management demands. The lessons learnt within this STSM are of benefit to all COST-participants, and it is hoped the work of the STSM can be built upon to engage a wider group of COST participants and cities into the discussions.

The COST STSM programme provides an unparalleled opportunity to COST participants and cities, to learn from each other and to gain an insight into the different approaches being developed in cities to address common issues. It is only by developing this level of knowledge exchange that the COST group can really assess examples of best practice and examine the applicability of these to the range of COST cities.

## 7. STSM Host institution approval / sign-off

VCS Odense, February 2014

Johan Linderberg (VCS)