A digital geotechnical data system for the City of Glasgow

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Abstract: The development and regeneration of the city of Glasgow relies on a full understanding of ground conditions, both natural and those resulting from man's activities through two centuries of development, mining and industrial contamination. Glasgow City Council (GCC) employs a team of earth scientists and geotechnical engineers to provide advice on ground conditions. These officers rely for background information on an archive of borehole data and reports accumulated over many years, together with maps and reports published by the British Geological Survey (BGS). Initial efforts to move from hard copy to digital data storage and retrieval were accelerated by funding from the GCC's Access Glasgow programme in response to the UK government's e-Government initiative. Simultaneously, links with BGS were strengthened through co-funded projects, both to acquire new data and to manage existing data digitally. The outcome is a GIS-centred system, which presents centrally held spatial and tabular datasets to officers in 3 separate Council departments. Datasets include geological and thematic maps, both licensed from BGS and developed by GCC, and a key feature is a seamless link from the GIS to a digital archive of scanned reports and borehole logs held in a proprietary electronic document management system. Continuing partnership with BGS is being directed to the development of a 3D digital model of Glasgow's ground conditions to supplement the existing 1D borehole records and 2D maps. The paper describes the development of the digital data system, commenting on the significant issues that had to be addressed along the way, and provides illustrations of its use in the Council's activities.

Résumé: Le développement et la régénération de la ville de Glasgow comptent sur une compréhension pleine de conditions de sol, naturelles et ces résulter des activités de l'homme par deux siècles de développement, extraire et la contamination industrielle. Le Conseil Municipal «Glasgow City Council» (GCC) emploie une équipe de géologues et d'ingénieurs geotechnique pour fournir le conseil sur les conditions de sol. Ces officiers comptent pour l'information de fond sur une archive de données de sondage et de rapports a accumulé par-dessus beaucoup d'années, ensemble avec les cartes et les rapports publié par le «British Geological Survey» (BGS). Les efforts initiaux pour se déplacer du tirage à l'emmagasinage de données numérique et de la récupération ont été accélérés en subventionnant de l'émission du programme «Access Glasgow» de GCC en réponse à l'initiative d'«e-Government» du gouvernement de Royaume-Uni. Simultanément, les liens avec BGS ont été fortifiés par les projets de co-subventionné, les deux acquérir de nouvelles données et gérer des données existantes numériquement. L'issue est un système d'information géographique (GIS), qui présente les ensembles de données spatiaux et en tableau, de façon centralisée tenu, aux officiers dans 3 départements Municipaux séparés. Les ensembles de données inclut des cartes géologiques et thématiques, les deux autorisé de BGS et développé par GCC, et une caractéristique importante est un lien continu du GIS à une archive numérique de rapports et les journaux de bord de sondage balayés, tenus dans un système de direction de document électronique. Le partenariat continuel avec BGS est dirigé au développement d'un modèle numérique en «3D» de conditions de sol de Glasgow pour compléter l'existant rapports de sondage en «1D» et les cartes en «2D». Le papier décrit le développement du système de données numérique, commentant sur les problèmes significatifs qui doivent être adressé en cours de route, et fournit des illustrations de son usage dans les activités du Conseil.

Keywords: geographic information systems, environmental urban geotechnics, urban geosciences, case studies.

INTRODUCTION

Glasgow City Council (GCC) is a unitary authority administering an area of 176km^2 with a population of around 600,000, within a larger metropolitan area occupying the valley of the River Clyde in the west of Scotland.

The settlement of Glasgow originated at the lowest reliable crossing of the River Clyde, and by the Middle Ages it had become a small cathedral and university city. Maritime trade, particularly with America, led to the rapid economic growth of the city in the early eighteenth century. Exploitation of local coal and ironstone deposits and improvements in transport by ship, canal and then railway, accelerated the development of the "Second City of the Empire" as a world centre of the engineering, textile and chemical industries. Twentieth century economic decline has seen the loss of both industry and population, but the present-day focus is on regeneration, bringing population and employment back into the city by redeveloping brownfield sites.

The city's underlying geology (Hall, Browne and Forsyth, 1998) comprises a succession of Carboniferous strata from the Middle Mississippian Strathclyde Group to the Middle Pennsylvanian Coal Measures Group, cut by late Carboniferous to Permian basic sills and dykes. These are overlain by Quaternary glacial and post-glacial deposits comprising Devensian glacial till and periglacial sands followed by marine clays and silts ("raised beach deposits"), overlain by Flandrian alluvial sands and lacustrine clays and peat. Finally, there are significant bodies of man-made deposits associated with historical urban development. The thickness of the superficial deposits ranges from zero to

over 50m, the greatest thicknesses being associated with the River Clyde and the former channel of its tributary, the River Kelvin.

Altitude ranges from 200m above sea level in the south of the Council's area and 100m in the north, to less than 10m at the River Clyde. Drumlins are a prominent feature of the glacial till deposits, but towards the Clyde they become "drowned" by the low-relief marine clay and silt deposits. The alluvial flood plain of the river itself is cut into the marine deposits and widens from a few hundred metres in the east to 2.5km in the west. The River Kelvin flowing into the Clyde from the north is incised in a steep-sided gorge.

ENGINEERING GEOLOGICAL AND GEOTECHNICAL ISSUES IN GLASGOW

The engineering geological issues which must be addressed in Glasgow arise from a combination of the natural geology and 200 years of mineral resource exploitation and urban and industrial development. Key issues are outlined in Table 1 and include potentially life-threatening geohazards such as unstable shallow abandoned mineworkings (including mine entries) and serious contamination. To accord with usage in GCC, the term "geotechnical" is used in the remainder of this paper to include "engineering geological".

Table 1. Key geotechnical issues in the Glasgow area

Issue	Examples
FOUNDATION CONDITIONS	
Variability in distribution, thickness and properties of fill and made ground	Loose ash; Reworked clay; Dense iron or steel slag
Natural superficial deposits of widely varying properties	Compressible peat; Soft/loose saturated clays/silts; Overconsolidated glacial till
Variability in thickness of natural deposits	Rock at surface; >30m of soft marine clays and silts
Rapid lateral variability in distribution and thickness of natural deposits	Peat – till; Marine clay/silt – buried till drumlin; Sand – rock
Vertical variability in properties of natural deposits	Firm desiccated crust on soft marine clays/silts
Shrinkable deposits	Marine silts
GROUND STABILITY	
Shallow abandoned mineworkings	Coal; Ironstone; Limestone, fireclay, sandstone
Abandoned mine entries	Shafts; Adits
Infilled quarries	Sandstone, limestone, fireclay, alum shale, dolerite; Brick clay, sand and gravel
CONTAMINATION	
Contaminative former land use	Gasworks; Chemical works; Metal processing works
Contaminated fill or made ground	Coal ash; Soda waste; Chromium ore processing residue; Domestic refuse
GROUNDWATER	
Isolated bodies of confined groundwater in otherwise impermeable deposits	Sand lenses in glacial till
Contaminated groundwater	Leaching; Direct discharge; Minewaters
Minewaters under artesian pressure	Locally only
Potential for infiltration (SUDS*)	Permeability; Volume of potential aquifer

* Sustainable Urban Drainage Systems

Mining ceased in the Glasgow area in the 1980s. Owing to the density of development win the GCC's boundaries, there is almost no scope for present-day exploitation of mineral resources, so resource management is not at present a significant issue. The only likely future exception is the groundwater resource, not for supply, owing to the plentiful surface supply to Glasgow, but as a source of low-grade geothermal energy: a recent successful installation potentially shows the way.

GEOTECHNICAL FUNCTIONS IN GCC

There has long been recognition of at least some of these geotechnical issues in GCC and its predecessor, Glasgow Corporation. Mining reports dating from the 1920s are held in the current geotechnical databank (GDB). The construction of extensive peripheral housing estates in the 1940s and 1950s led to the formation of a Foundation Engineering group within the Department of Architecture to design, procure, supervise and report on site investigations and to make recommendations for foundation design to the department's structural engineers. The group's role was maintained through the inner-city redevelopment schemes in the 1960s and 1970s and beyond. A separate Ground Engineering unit was established in the Department of Building Control to ensure that Glasgow's particular engineering geological issues were adequately addressed by both public and private sector in relation to Building Regulations.

Scottish Local Government reorganisation in 1996 brought further geotechnical functionality into GCC from the former Strathclyde Regional Council (SRC). The SRC Department of Architecture's Geotechnical section was absorbed by the GCC former Department of Architecture Geotechnical group in a new department, eventually named Development and Regeneration Services (DRS). SRC Roads Service's Geotechnical Design Team remained as an

independent unit within GCC's new Land Services (LS) department. The restructuring moved the Ground Engineering unit of GCC Building Control into a new Environmental Protection Services (EPS).

Each of the geotechnical groups maintained its own databank of hard-copy technical files relating to its own particular fields of activity, although there were frequent exchanges of information for specific projects. The technical files occupied significant volumes of storage and, as working databanks, had to be readily accessible, not stored as archives. There was also an issue of backup, should fire or flood damage the files.

Both the DRS and EPS groups used hard-copy "index maps", showing the boundaries of sites for which information was held, as the primary search tool for accessing information in their databanks. The LS files related mainly to linear (road) sites, and indexing by road name/number was adequate for their purposes.

In 2002, the EPS Ground Engineering unit was merged into the Development and Regeneration Services Geotechnical group. EPS had been given additional responsibility for the statutory contaminated land regime enacted in 2000; the geotechnical aspects were thus transferred to DRS, while the regulatory role remained with EPS Public Health Unit.

The current organisation of geotechnical functionality in GCC is shown in Table 2. There is a close working relationship between DRS and EPS because of the shared responsibility for contaminated land. LS operates largely independently, although information has always been shared among the functional groups, even during the existence of the separate former Strathclyde Regional Council.

Table 2. Geotechnical functionality in GCC

Department and Group	Areas of Operation
Development and Regeneration Services Geotechnical Group 5 Geotechnical Engineers 4 Engineering Geologists	Geotechnical consultancy to DRS: Planning and regeneration strategy Development projects Vacant and Derelict Land Land transactions/valuation Private sector grant-aided mining consolidation Geotechnical consultancy to other GCC services Construction Landfill/waste disposal Contaminated Land (Environmental Protection Act Part IIA) – technical aspects Building Control (Building Regulations) – site preparation and foundations
(Environmental Protection Services Public Health Unit Environmental Health Officers)	Contaminated Land (Environmental Protection Act Part IIA) – regulatory aspects Development Control – contamination aspects
Land Services Geotechnical Design Team 3 Geotechnical Engineers	Trunk roads (as agent of Scottish Executive) Local roads Parks

DIGITAL GEOTECHNICAL DATA DEVELOPMENT IN GCC

The potentialities of digital geotechnical data and of Geographical Information Systems (GIS) in particular were recognised at an early stage by both the then geotechnical groups within the Council. In the early 1990s, consideration of GIS in GCC was based on experience with the corporate Coordinate automatic mapping system, and CAD applications individually procured by Council departments. Strenuous efforts were made to initiate development of geotechnical GIS, unfortunately without success due to service priorities and resource constraints.

Nevertheless, in 1995, funding was obtained for a one-off GIS project in response to a requirement to undertake a risk assessment in relation to abandoned mine entries. Utilising a solitary GIS licence supplied with the then departmental standard Bentley Intergraph CAD system, the British Geological Survey (BGS) was contracted to set up a GIS application using a combination of GCC-supplied and BGS-supplied data. The system fulfilled its purpose, but consideration of further development was overtaken by subsequent events.

The 1996 local government reorganisation brought the former SRC Cartographic/GIS/Information Management function into GCC's Development and Regeneration Services. Thereafter, ESRI ArcGIS products were adopted as the corporate GIS platform. This established GIS environment made local departmental development easier, although a corporate approach to GIS development was initially missing. Each of the then geotechnical groups adopted a different local strategy to GIS development:

- DRS Geotechnical lacked resources for in-house digitising and sought to licence datasets from outside suppliers
- EPS Ground Engineering assigned resources to digitising data from in-house records
- LS did not accord a high priority to Geotechnical GIS development

DRS Geotechnical particularly looked towards the British Geological Survey (BGS) as a key supplier of both geological data and expertise in data management. GCC collaboration with BGS dates back to the compilation of a set of hard-copy applied geology thematic maps (the "Environmental Geology Maps") for the Glasgow area in the

1980s (Browne, Forsyth and McMillan, 1986) and has become closer since the 1995 mine entries GIS project described above.

3D modelling has been undertaken where practicable. DRS licenses HoleBase and KeyHole borehole management and modelling applications from Key Systems. All site investigation contracts issued by DRS specify digital borehole data in Association of Geotechnical and Geoenvironmental Specialists (AGS) format as a deliverable. Resource limitations unfortunately restrict the amount of modelling undertaken, but a useful database of digital borehole data is being built up. The former EPS Ground Engineering unit has used the less specialised Golden Software Surfer application to good effect in mining consolidation works.

In a separate but ultimately related development, Ground Engineering participated in a trial within EPS of an electronic document management system (DMS) supplied by I-Document Systems (Idox). Procedures were set up for scanning new documents and plans were laid for scanning the historic databank of files.

Based on their experience to up to that point, the newly combined DRS Geotechnical group articulated a vision for a digital geotechnical data system in the following terms:

- All data and applications required to provide an effective and efficient service should be available at each Geotechnical officer's desktop PC
- Applications should be integrated to permit free exchange of data
- Data should be held once, be managed effectively and be secure
- Partnership should be sought with the BGS as a key supplier of data and expertise

GIS was envisaged as the "window" into the digital geotechnical data system, but with 3D modelling an ultimate goal. The resource commitment required to produce a fully digital system was not underestimated and an incremental approach to digitisation was adopted, with each stage requiring increasing resources:

- Indexes: where hard-copy data can be found
- Scanned images: electronic equivalents of hard-copy documents
- "True" digital data: extracted from scanned images; capable of being manipulated, combined, analysed and modelled.

Reflecting the generally recognised difference between factual and interpretative information, a distinction was also drawn between forms of digital output, again recognising an increasing resource required in production:

- Factual: matters of record
- Interpreted: "processed" factual data.

THE ACCESS GLASGOW GEOTECHNICAL DATABASE PROJECT

In response to the UK government's 2001 "Modernising Government" initiative and the subsequent "e-Government" strategy, GCC set up an umbrella project named "Access Glasgow" to implement the government's vision of moving towards the wider availability of digital public services. Individual projects are approved and funded by the Access Glasgow board, and one of the first such projects was the Geotechnical Database project, approved in 2002.

Initially proposed by the DRS Geotechnical group, the Access Glasgow Geotechnical Database project focussed on developing the existing DRS Geotechnical GIS with links to the other geotechnical specialist groups in EPS and LS. The merger of EPS Ground Engineering into DRS Geotechnical provided an additional opportunity to combine firstly their respective databanks of technical files and secondly the best elements of both systems into a single GIS application. The expanded Access Glasgow Geotechnical Database Project offered to provide a significant step towards the information management vision articulated by the combined Geotechnical group.

The specific objectives of the project were to:

- Develop a new GIS application for the geotechnical function in the Council
- Distribute the application to officers in the 3 participating departments DRS, EPS and LS
- Integrate the hard-copy technical databanks of the participating geotechnical groups
- Scan the databanks into the Idox DMS
- Link the GIS and the DMS
- License selected datasets from external suppliers
- Provide user training and continuing support

Subsidiary objectives were to:

- Assess the suitability of ESRI 3D Analyst for 3D modelling
- Assess the suitability of Crystal Reports for automatic reporting
- Consider wider access to the system through links to other Access Glasgow projects

Project management of the Access Glasgow Geotechnical Database project was undertaken by the DRS Information Management group, following the Office of Government Commerce PRINCE2 project management methodology. The project team comprised a user group, representing all three interested services (DRS, EPS and LS) and a development group of IT professionals, linked by the Project Manager and the Senior User (DRS Geotechnical). The key project milestones and actual timescales were:

- Bid approved by Access Glasgow Board March 2003
- Project Initiation Document June 2003
- Specification of Requirements November 2003
- Implementation Proposal November 2003
- Data Management Plan December 2004
- End of Project Report (partial) January 2005

As will be described below, a separate sub-project was established in relation to document scanning which has yet to be completed.

THE DIGITAL GEOTECHNICAL DATA SYSTEM – PROJECT OUTCOME AND ISSUES ADDRESSED

The core of the system is, as envisaged, the Geotechnical GIS application based on ESRI ArcGIS8, accessible to selected officers in each of the participating departments DRS, EPS and LS (Figure 1). Not all of the elements of the system have been taken up by each department at present, dependent on local considerations.

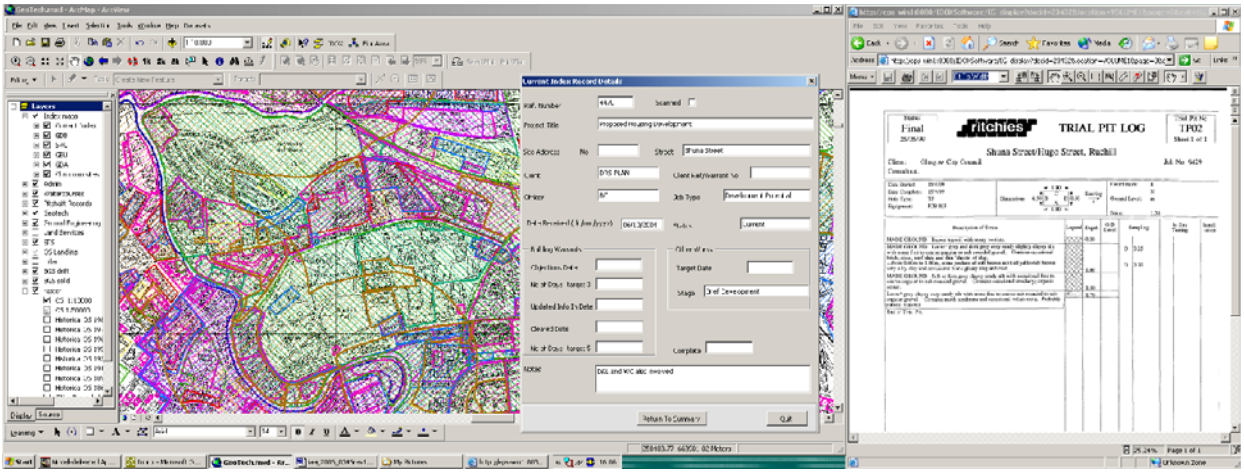

Figure 1. The digital geotechnical data system: GIS window (left), job management module (centre) and Idox DMS window (right)

The GIS application provides access to a range of spatial and tabular datasets, both licensed from external suppliers and digitised in-house. The main datasets are listed in Table 3.

Table 3. Datasets accessible through the Geotechnical GIS

Thematic Layers: In-house	
Index Maps	Boundaries of sites for which geotechnical data is held from the following sources: Current unified databank Pre-2002 Geotechnical group Pre-2002 Ground Engineering unit Pre-1996 SRC EPS Development Control referrals
Borehole Locations	Selective coverage at present
Mine Entries	4 datasets from different sources comprising 2 types of data: Digitised from historical records (maps, plans etc.) Digitised from actual site records (actual locations)
Old Quarries	Digitised from historical OS maps Used in combination with BGS dataset
Contaminative Landuse	Digitised from historical OS maps
Mining Consolidation Works	Digitised from site records
Index to Mine Abandonment Plans	Boundaries of areas for which mine abandonment plans have been obtained from the Coal Authority (and predecessors)
Index to Historical Aerial Photos	Centre points of historical aerial photos obtained from RCAHMS*
Various corporate datasets	Watercourses/flooding records Vacant and Derelict Land Survey City Plan Administrative boundaries etc.
Thematic Layers: External Suppliers	
Ordnance Survey Mapping 1:1250, 1:10000 and 1:50000	Corporate licence
Landmark Historical OS Mapping 1:2500	8 epochs from 1860 to 1980
Current Air Photography	1999/2002
BGS Geological Mapping 1:10000	Bedrock (incl. Faults) Superficial deposits - Quaternary Artificial deposits
BGS Thematic Mapping 1:10000	Geomorphology Drift thickness Shallow Mining Mine entries Quarries
BGS Geochemical Data	G-BASE River Clyde and Tributaries Sediment Surveys (joint BGS/GCC projects)
Infoterra Lidar Digital Terrain Model	Contoured at 0.5m intervals
Links to Other Applications	
Corporate Address Gazetteer	Zoom-to-address function
Idox Document Management System	Point and click on-screen access to scanned documents
Crystal Reports	Reporting application
Arc3DAnalyst / ArcScene	3D modelling/ viewing

*Royal Commission on the Ancient and Historical Monuments of Scotland

One of the key custom elements of the application is a job management module (Figure1), at present fully used only by the DRS Geotechnical group. All new work is recorded and tracked through the GIS application as follows:

- Site boundary digitised as a polygon in the Current Index layer
- System automatically assigns sequential job number
- Job details entered
- Job details updated until completion

Details of all work undertaken by the group are available to managers and status reports can be generated. In particular, quarterly performance indicator figures for building warrant jobs are generated to meet statutory obligations.

All the layers in the GIS Index Maps category (Table 3) have been linked to the Idox DMS, allowing point-and-click viewing of scanned documents for any selected site boundary polygon (Figure 1). The logical development of this would be to link individual scanned borehole records to a GIS point layer representing borehole locations, but this could not be accommodated within the scope of the project. This objective, and the longer-term aim of digitising the information from the scanned borehole logs to produce “live” data for analysis and modelling, proved unlikely to be achievable by the Council from its own resources.

Building on the relationship developed over the years with BGS, the strategy adopted was to set up a sub-project to achieve the objective of scanning the historical geotechnical databanks by contracting with BGS to undertake the scanning and indexing of the documents on a co-funded information-sharing basis. This would have the advantages both of using BGS's expertise in scanning, indexing and quality control, derived from their own identical in-house scanning programme, and of putting in place the basis for future projects to digitise borehole locations and to digitise information from the scanned logs for 3D analysis and modelling.

In order to give BGS licence to use the scanned records in this way, legal advice on copyright issues was sought. The advice given was to obtain licence from the owners of copyright in the documents in the geotechnical databanks firstly for the digital conversion of the records and secondly to give BGS licence to use them for the purposes envisaged. Again, BGS had undergone a parallel exercise when initiating their own scanning programme. The identification of copyright ownership is fraught with difficulty: although copyright is vested in the originator (the contractors who prepare borehole logs and factual reports; the consultants who prepare interpretative reports), the right can be passed on to other parties through contract conditions. The approach agreed with the legal advisors was to issue a public notice indicating our intentions and seeking consent to proceed in trade magazines and newspapers and to directly contact as many geotechnical contractors and consultants as could be identified from documents in the databanks. Responses from around 150 organisations were received, overwhelmingly granting consent for the process. The few dissentions were mainly for reasons of confidentiality of data, and ways of managing these concerns are being explored.

The copyright "clearance" exercise took longer than expected and the scanning sub-project is still some way from completion. However, all new records generated since the completion of the GIS application have been scanned as part of a routine file closure procedure; some users are showing the way forward by scanning documents as they come in and working as much as possible with electronic documents.

Assessment of Crystal Reports indicated that significant effort would have to be applied to develop an automatic reporting application to meet the Geotechnical group's requirements. As for the digitising of scanned borehole information, the resource implications has dictated consideration of external assistance; this element is one of the strands identified for future development.

Similarly, Arc3DAnalyst was assessed as inappropriate for the needs of the Geotechnical group. The existing 3D modelling applications (KeyHole and Surfer) are therefore still being used. For the time being, the ArcScene 3D viewing application has promise as the medium through which these applications can be integrated with the core GIS application. However, the main thrust of 3D development is being directed elsewhere as described later in this paper.

Issues of information management arose during development and have been addressed. One example is the treatment of mine entries (Table 3). A number of datasets was available to the Geotechnical group, and consideration was given to developing a single combined dataset. However, two distinct types of data are present:

- Historical documentary records of mine entry locations
- Actual records of mine entries located during site works (and normally including records of treatment to mitigate the risk posed)

Historical records from different sources frequently record rather different locations for the same mine entry, up to tens of metres from the true location revealed by site works. The possibility of editing the historical datasets to remove erroneous locations for shafts that had been reliably located on site was considered, but there could be residual uncertainty about whether the records removed could relate to a second mine entry in that locality. It was concluded that the integrity of the historical datasets should be retained, and that all the mine entry datasets should be considered together by the specialist officers before reporting the most likely situation to their clients.

USE OF THE SYSTEM – EXAMPLES

The system is used in a number of different ways. The primary use is as the access point for data for undertaking desk studies. The BGS maps and the Index Maps linked to the scanned documents and borehole logs are invariably the first layers to be consulted, but almost any of the types of data accessible through the system could be relevant. While the output reports contain significant interpretation by the specialist officers for their clients, illustrative map generation is rendered straightforward by the GIS. This is particularly relevant in reporting strategic or large area studies, where the use of maps allows large amounts of information to be readily assimilated by the client.

Spatial analysis has been used to prepare constraints maps for large-area studies, for example illustrating where a particular constraint (e.g. mining instability, potential contamination or difficult foundation conditions) is either "likely", "possible" or "not expected". However, relatively few city-wide strategic analyses of constraints, hazards or risks have been commissioned by Council. Particular examples include:

- Mine entries risk analysis
- Shallow mineworkings risk analysis
- Contaminated land prioritisation

The latter was a bespoke application commissioned by EPS from BGS but using many datasets in common with the Geotechnical GIS.

Telephone enquiries from both internal clients and the public (or their agents) can sometimes be answered instantaneously by using the GIS. The Council is routinely asked by legal advisors acting for house purchasers to confirm whether or not mineworkings beneath a property have been stabilised; an immediate verbal response is appreciated in the timescale of property transactions, pending dispatch of written confirmation.

FUTURE DEVELOPMENTS

It is intended to continue development of the existing digital geotechnical data system in three main ways:

- complete the scanning of the technical file databank
- explore automatic reporting for routine desk studies
- digitise additional GIS themes from in-house data

Work proceeds as resources and/or funding becomes available. However, the most significant developments are anticipated to be in the direction of 3D modelling, in collaboration with BGS. The development of 3D modelling in BGS has been documented by Culshaw (2005). 3D modelling is now an integral part of BGS's work programme, with detailed work being targeted in the highest priority areas, which include the Clyde Basin and Glasgow in particular.

BGS have developed a pilot model of a 25km^2 sector of Glasgow which is currently licensed to GCC for evaluation purposes. A collaborative project is under consideration to build on this work, the key elements for GCC being:

- sharing of data between GCC and BGS
- establishment of a digital database capable of visualisation in 3D, 2D (maps and sections) and 1D ("synthetic boreholes")
- extension to the whole of the GCC area
- addition of engineering and hydrogeological data
- ability to "clip" out data from the "global" model for a particular site; add new data; revise the site model for the specific purposes of the project; and implement any changes to the "global" model occasioned by the new data

CONCLUSION

The system has made a significant contribution to the efficiency of the geotechnical officers in DRS and LS and is in daily use by those officers. The equivalents of all the former paper maps used on a day-to-day basis (geological maps, file index maps) are available digitally on the officers' desktops. Scanned recent documents are also available on the desktop via the point-and-click link to the Idox document management system

While the project is considered a success by the users, compromises had to be made both in timescale and deliverables. The in-house project team found that other demands on their time caused timescales to slip, as no additional resources were available. When the amount of effort required to develop the reporting and modelling applications became apparent, it was agreed that further work on these aspects should not be undertaken. As has been outlined, a different approach to 3D modelling has been adopted; automatic reporting remains an area to be explored further. The particular circumstances causing the scanning of the historic geotechnical databanks to be delayed have also been outlined. On the positive side, the project management methodology was considered successful, and good practice recommendations were made to the Access Glasgow board for incorporation in other projects.

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