Quarterly Journal of Engineering Geology, **25**, 257–267. 0481-2085/92 $03.50 © 1992 The Geological Society

Use of computers in the engineering geology of the urban renewal of London's docklands

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Abstract

A systematic collation of geotechnical information has given engineering geology an important role in the renewal of London's docklands. It has provided a ready source of information to other parties and allowed an improvement in the understanding of the regional engineering geology of the area. A microcomputer database, termed GEODASY, was devised specifically to store the data. This allowed for a projected 10 000 boreholes and holds both stratigraphic as well as field and laboratory test data. The data can be retrieved in a variety of formats. The basic output is a tabulated format which collates and unifies the presentation of the data. Other graphical output produces scaled plans or long sections while preprocessing by the system during enquiry gives X–Y plots allowing a high level of interpretation of the data. The approach could be similarly used wherever there is a strongly defined area of interest.

Introduction

Throughout the 1980s the political aim of Government was to reverse the trend of the preceding decades whereby increasing levels of deprivation had developed in many of the inner city areas of the country. A series of policies was therefore formulated to deal with the problems and revitalize the areas. In 1981 the London Docklands Development Corporation (LDDC) was set up to deal with the major problems present in the former dockland area of east London. A. F. Howland Associates have been retained by LDDC since 1981 to provide an engineering geological and geotechnical advisory role.

Government believed that a successful solution to the problem was only practical with the close involvement of the private sector. Looking back now from the early 1990s and standing in the shadow of the Canary Wharf development, it may be difficult to appreciate that there was once a reluctance to invest in the area. One of the practical reasons for this reluctance was that the ground conditions were widely accepted to be 'poor' and would therefore require extensive substructure costs for even low rise development. The anticipated high cost of foundations when balanced against the returns on investment meant that there was a general unwillingness to invest in the site investigation necessary even to assess sites. In order to overcome this reluctance, the LDDC decided to market the area with sufficient geotechnical information that discussions with potential developers could advance with realistic considerations being given to the ground costs. It therefore needed to establish a suitable approach to the collection of the data and acquire an understanding of the regional setting and the specific problems which could arise from the engineering geology of the area.

Data collection

Shortly after its inception the LDDC began to collect existing site investigation and other ground data for the area. The aim was to provide a pool of information to be made available to interested parties. This came from three sources:

(a) existing ground information in the form of site investigation reports, collected from local authorities and other relevant public bodies;
(b) an overall appraisal of the geotechnics of the area following an extensive literature survey;
(c) a systematic programme of data collection implemented through its own term contracts for site investigation.

The background to the development of the system

The accumulation of data meant that two important aspects had to be considered. Initially, there was the fundamental need of any library system adequately to catalogue and ensure the efficient retrieval of the data. Secondly, the character of the information meant that it would be required for re-use on projects and considerations other than for which it had been first collected.

It was anticipated that about 10 000 boreholes would eventually be collected by the LDDC. A means of storing the data included traditional library systems,

TABLE 1. *A comparison of the main storage systems suited to geotechnical data*

Storage system	Advantages	Disadvantages
Paper archive	• Traditional reports can be stored in original format • General familiarity with the system	• Large storage commitment • Usually centralized • Needs efficient and reliable indexing • Trained staff required to administer the system • Material may be on loan when required • Working copies need to be made for long-term reference • Material may be lost or damaged • Material deteriorates with time
Microfilm/microfiche	• Small storage commitment • Style of original format retained • Rapid perusal of large amounts of data possible by experienced user • May be held at many locations	• Needs efficient and reliable indexing • Trained staff required to administer system • Intermediate hard copies needed to allow comparative perusal of data
Computer	• Small storage commitment • May be held at many locations • Data can be processed by machine	• Data not necessarily in original format

use of microfilm or microfiche and the possibility of some form of computer storage. A consideration of these showed that each had its own advantages and disadvantages, as outlined in Table 1. In view of the importance of the need to readily re-use the data it was decided that the most likely method to meet this aim would be to adopt a computer based system (Howland 1989a,b).

The data derived from borehole records and laboratory test results provides the variation of a number of discrete parameters each recorded against depth as a common reference. They are therefore of a form which is inherently suited to simple tabulation, one of the basic formats capable of storage by computers. The use of a suitable database therefore satisfies each of the fundamental requirements for a system outlined above. It would provide a means of storage and retrieval of the data in its simplest form, and would also lend itself readily to more rigorous enquiries.

The information was intended to form a resource available to all interested parties. It was essential therefore that the system should have certain attributes:

(a) it should provide ready access to the stored information;
(b) it should be capable of revision on a regular basis as more information is collected;
(c) due to the working procedures of the LDDC, it was also required not to involve excessive staff commitments.

In view of the amount of information to be stored, and the on-going commitment to the project by the LDDC, it also seemed necessary that any system developed should not become redundant with time. Indeed it should form a worthy legacy to be handed on by the LDDC to aid and stimulate subsequent generations of development in the Docklands, even after the LDDC itself may have ceased to exist as a body.

During 1983 a prototype system was developed on a minicomputer. The subsequent development of a working system became frustrated due to competing resources on the central machine. During this time a number of advances and, more importantly, a rationalization had occurred within the microcomputer industry. In 1986 the decision was made that the system as proposed was more suited to a stand alone application and that it should be developed on a microcomputer.

The system was therefore required to produce a simple but reliable storage facility for the mass of data that was expected to be collected, and secondly to be able to process and assimilate that data into specific considerations using selection criteria chosen by the enquirer.

Historical perspective of computer storage systems

The use of computers for the storage of borehole and related data is not new (Howland 1989a). It has been

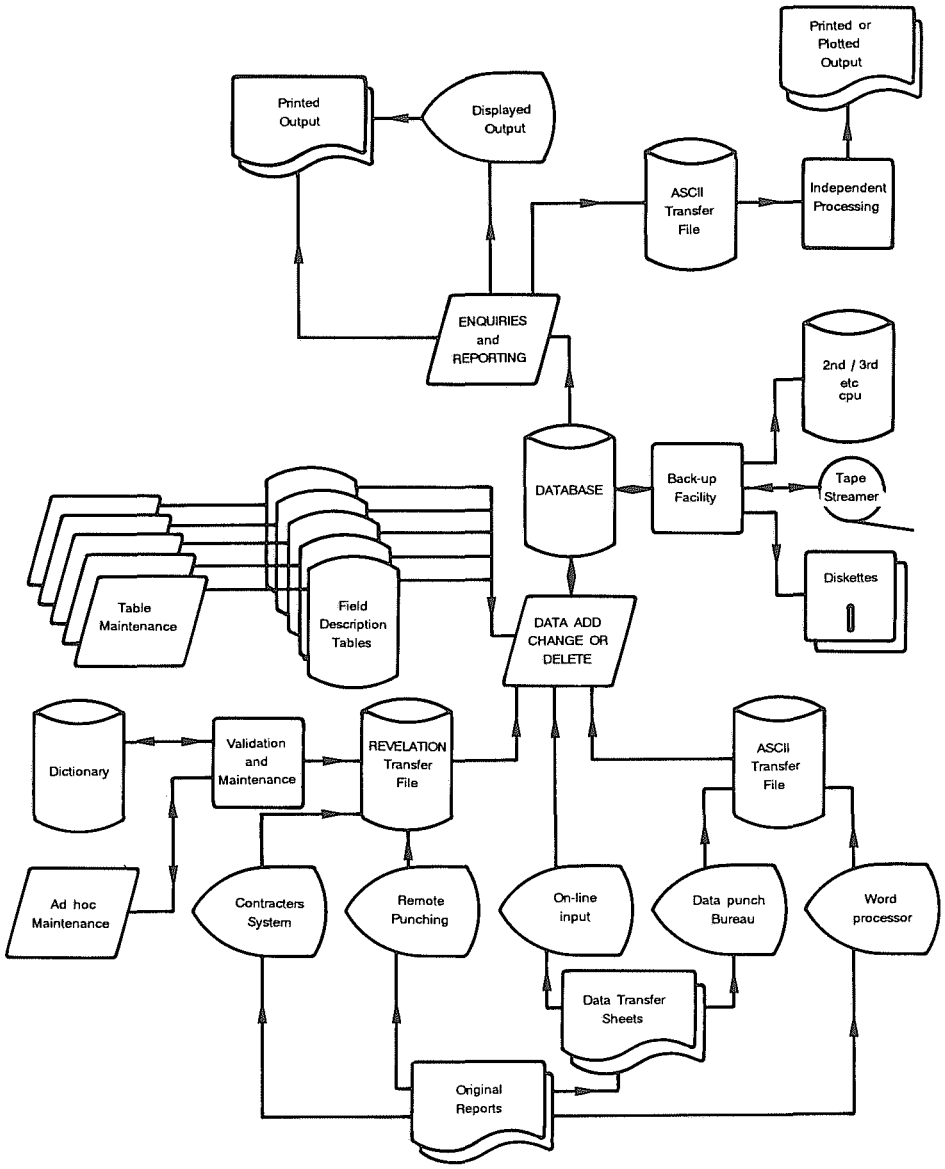


FIG. 1. Flow diagram showing the principal elements of GEODASY and the manner in which they interact.

considered at various times by the British Geological Survey where the practical difficulties of maintaining traditional library systems have been appreciated. The Survey is currently undertaking to build a computerized inventory of borehole data as part of its National Geosciences Information Service (NGIS) and has carried out a pilot study for part of Glasgow to provide a computer database of borehole information. However, in Great Britain there has been a reluctance to establish a unified approach to data collection with the aim of developing a reusable databank. The only assessment of the possibility of a structured national databank for Britain was that undertaken by CIRIA, the Construction Industry Research and Information Association (Tuckwell & Sadgrove 1977). It considered the specific problem of how to store the wealth of site investigation borehole data in the country and how to make them available to other interested parties. Although this dealt specifically with a national requirement the various conclusions have implications on any

DATA TRANSFERENCE TO COMPUTER STORAGE — Bh.No. V68 — SHEET 3 OF 4

GRID REFERENCE 541678 m.E. / 180457 m.N. — DATE BORED 1./.7./.85 / 2./.7./.85 — DEPTH 25 M — ELEVATION 5.19 (mOD) — BORE CLASSIFICATION

REPORT REFERENCE BY SOILS ENGINEERING LTD. — ROYAL VICTORIA DOCK (SOUTH SIDE) — ARCHIVE REFERENCE 1002

BORING TECHNIQUE Shell & Auger — DIAMETER 150mm — PIEZOMETER AT 16.0m — STANDPIPE AT .....
PERMEABILITY TESTS AT 16.0m — VANE TESTS AT ..... — REFER TO REPORT FOR organic content

DESCRIPTION	Legend	Group	Sub-group	Depth (m)	Level (mOD)	Water Observations	S.P.T	Bulk Density Mg/m³	Moisture Content %	C_u kN/m²	ϕ_u Degrees	Liquid Limit %	Plasticity Index %	m_v m²/MN	Grading D10 mm	Grading D60 mm	Grading D85 mm	Permeability m/sec	Additional Tests
				12.00	-6.81										0.85	17	28		
				12.15	-6.96		50												
				13.00	-7.81										0.51	7.8	13.5		
				13.15	-7.96		42												
Medium dense to dense grey brown fine to medium GRAVEL with some medium coarse sand		C	CH	13.70	-8.51														
				13.80	-8.61				18							0.17	0.32		CH
				14.45	-9.26		40												
				14.80	-9.61				16							0.17	0.27		CH
				15.50	-10.31			2.34	12	281	0	29	15	0.033		0.20	0.29		CH
				16.00	-10.81				13							0.21	0.28	8.5 x10⁻⁵	CH
Hard grey green, very sandy silty CLAY, becoming more sandy at depth				16.80	-11.61														
				17.19	-11.96		42												
				17.50	-12.31				18							0.13	0.18		CH

FIG. 2. Data transfer sheet used to allow rapid keyboard entry by a punching bureau of information held on existing reports.

further attempt at the systematic storage of geotechnical data. In particular, CIRIA was concerned that errors would develop during a perceived need to interpret the information to make it more suitable for storage. They also recognized the fact that any users would wish to see the full information.

Clearly, if a system is to supply the user with the full and complete information as contained in the original report it is essential that it is neither précised nor abbreviated either by choice at the input stage or by limitations within the system. The system should merely be able to accept and subsequently output the complete and original information. Consequently, if all the information is to be stored it is only necessary to transcribe the original data. This eliminates any need for judgment at input and therefore the associated scope for errors. The ease and efficiency with which the transcription of the information can be achieved is also controlled by the quality and format of the input programs used. However well contrived the input procedures may be, if the information is to be keyed in at a conventional keyboard, it is not possible to eliminate all transcription errors.

The production of borehole records by microcomputer has significant advantages in time and efficiency (Chaplow 1986; Finn and Eldred 1987; Howland 1986;

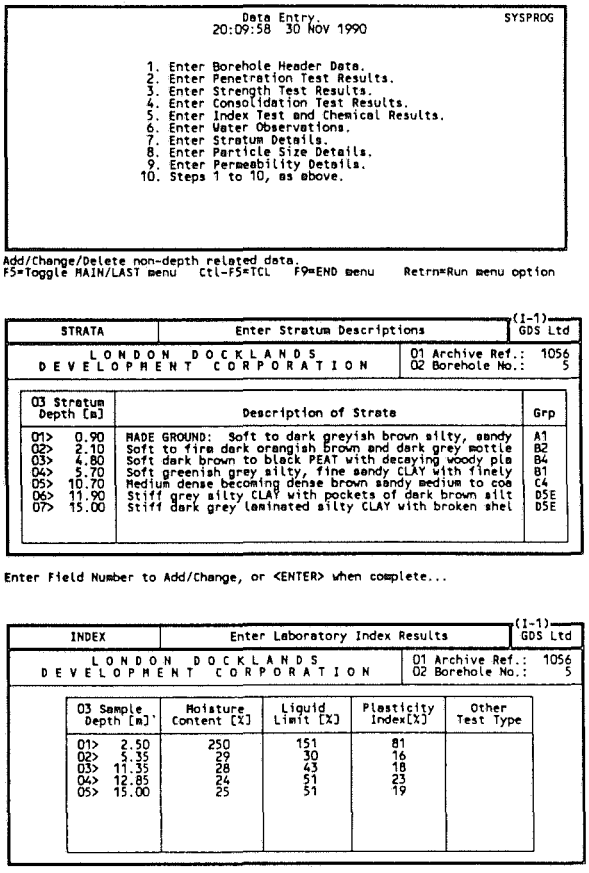


FIG. 3. Entry screens allow the input of data by non-technical keyboard operators. A selection menu calls a series of screens which are designed to suit the data, for example the middle screen prompts for the strata descriptions on the borehole log and the lower screen for plasticity details from the laboratory test results.

Howland & Podolski 1985). The logical extension of this is to consider the two requirements, the production of the borehole record by the computer, and the use of the data in a database as complementary. This can be used to provide particular advantages to the speed with which new information can be passed into the database. More importantly, it maximizes the accuracy between the stored data and the source material as the input of the one and the production of the other are achieved by the single keyboard operation. The problems of re-typing the data would be eliminated so that any errors in the database would only be those related to the original borehole production. Their validity would be as good as the original checking by the author of the records.

The system

Hardware

GEODASY was one of the first applications to be developed remote from the LDDC's mini-computer and one of the first stand-alone technical applications developed for the LDDC.

This approach gave an autonomy which had certain advantages.

(i) The independence isolated the storage commitment for the data from the main computer and therefore any possible interference by competing demands on space from other users.
(ii) It allowed specific hardware peripherals, such as specialized printers and plotters, to be supported locally to the machine, without the need to set up network links.
(iii) Ad hoc enquiries could be addressed more readily by a stand-alone system.

By the mid-1980s the developing microcomputer standard for the industry was that developed by IBM. This had resulted in a degree of uniformity in the microcomputer environment which previously had been missing. Besides imparting a degree of credibility to corporate computer managers this was also expected to result in the increasing availability of peripheral hardware and the production of better and more powerful products from independent manufacturers. At the time that the choice was made, there was a certain amount of faith that the capability would exist in the market when it was needed by the developed system.

An IBM compatible microcomputer was assessed as the most viable base for the proposed system. The use of this standard, with appropriate software, also meant that permanent separation from the existing central minicomputer was avoided. Initial development was carried out on an Olivetti M24SP with a 20 megabyte hard disk running at 10 MHz with 640 kilobytes of memory.

Software

The development of GEODASY (GEOtechnical DAta SYstem) was undertaken by G D Systems Limited, against a system specification drawn up under the auspice of the Data Processing Department of LDDC and based on an independent audit of the requirement of the System within the LDDC. It described both the application software, with which the user interacts, and defined the development software, the commercial computer languages and utilities which provide the tools and building blocks for the application software.

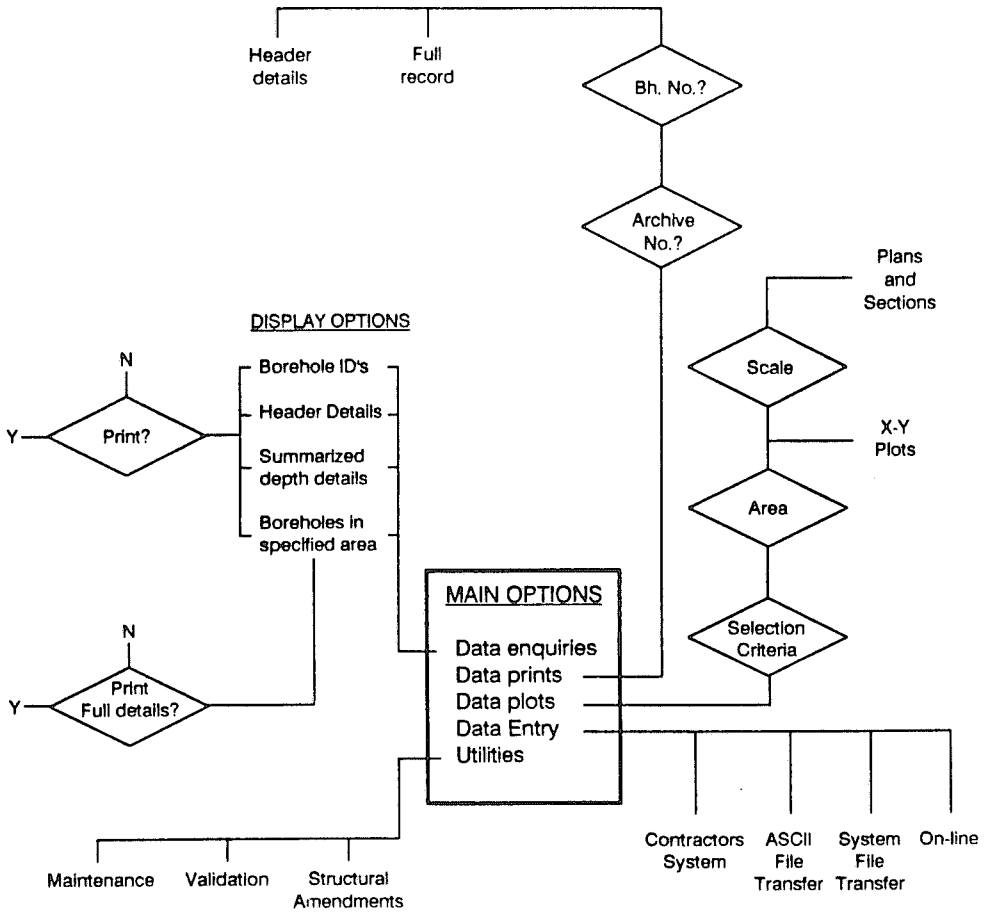


FIG. 4. The principal features of GEODASY at the user interface

The development software chosen was REVELATION, a high-level relational database utility which was assessed as particularly suited to the style of the information to be stored. The advantages and features of relational databases in general have been described by Henderson & Laxton (1986) in connection with the Scottish Land Survey Computer Database developed by the BGS. The principal feature of all these is the manner in which the data is stored. This enables both rapid and very selective retrieval of that data. Although the majority have their own general enquiry language and some quite sophisticated report generators which can be programmed to provide a selection of available searches through the data, access to the data can also be achieved through standard file transfer methods. In this way the data can be manipulated, analysed and output in either printed or graphical format by any enquiry program written in a wide variety of possible languages.

The completed system provides the ability to enter and maintain the data and allows the data to be retrieved to satisfy a number of search options. The various elements of these are shown in a flow diagram (Fig. 1). These elements interact with each other in a way which is largely transparent to the user so that the system can be used with a minimum of training and computer experience.

Data input

The information to be stored in any system is a matter of choice. However, it can be conveniently divided into header information and depth details. The header information contains the entries which are discrete for each borehole record and therefore require only a single entry per record regardless of depth or com-

plexity. The depth details are that information referenced to depth and for which multiple entries will exist to the final depth of the borehole.

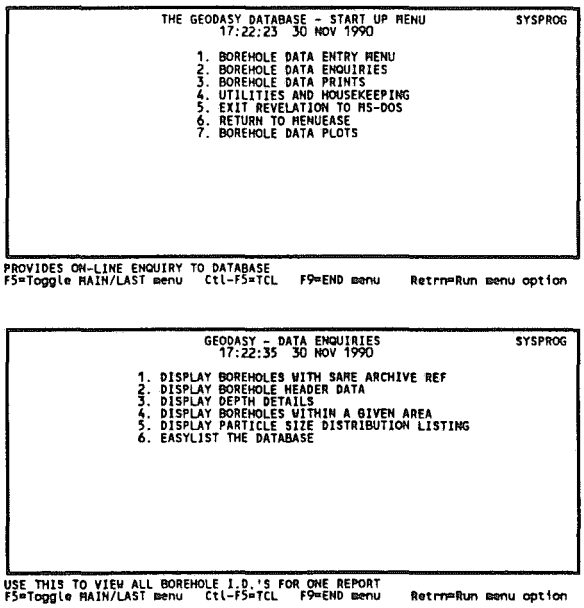
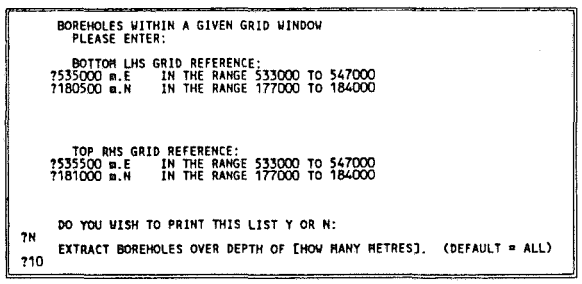


FIG. 5. Menu selection allows for a variety of retrieval facilities. This shows a menu selection of screen based enquiries called from the initial start-up menu.



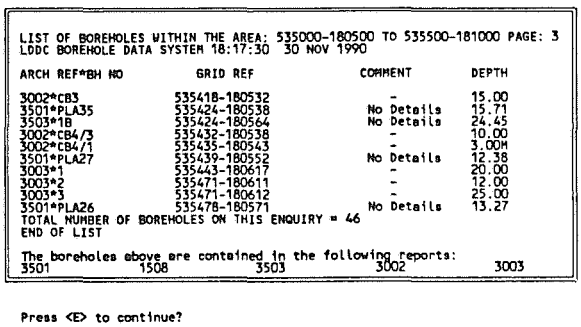


FIG. 6. Selection of option 4 from the lower screen of Fig. 5 displays a list of boreholes with salient details within a defined area of interest.

The usefulness of GEODASY, or any similar system, relies upon the presence of data. The most functional system imaginable is of little use without it. In anticipation of the development of a computer system, the existing site investigation reports held by LDDC had been re-written onto data transfer sheets (Fig. 2). These comprised a simple tabulation of the borehole records and associated laboratory results into a form suitable for easy keyboard entry. The transfer sheets had the advantage that they normalized the presentation of the data and eliminated the vagaries of individual report formats. Although the historical reports which had been collected required transfer sheets to be drawn up as a separate exercise, the initial term contracts for geotechnical site investigations included a requirement to complete the sheets for new work as part of the reporting requirement.

Once the specification for GEODASY was finalized, the services of a commercial punching bureau were used to input the data on the transfer sheets. This allowed a substantial amount of data to be input quickly by operators who did not otherwise understand the information. Accuracy was ensured by double punching, that is the data is keyed twice, each time by different operators, and a comparison made of the two entries. However, this does not eliminate errors on the transfer sheets themselves so that extensive checking of the database has been necessary as a consequence.

In order to improve the accuracy of the data further the later term contracts have included a requirement to supply the data on computer diskette for direct input into the database. An input program, called the Contractors System, was supplied by the LDDC as part of the contract. This provides a number of entry screens which can, if necessary, be modified to suit varying reporting styles (Fig. 3). At this stage the input is subject to a number of validation rules and error traps. The system also provides a simple tabulated output allowing the contractor to carry out a manual check allowing any corrections to be made before the disk is submitted.

Data output

An overriding requirement for GEODASY was a simplicity of use so that it could be searched by even a casual user with a minimum of instruction. It therefore incorporates a number of standard enquiry and print options at the user interface which are summarized on Fig. 4. These are activated by menu driven procedures enabling the system to be used by personnel with no previous computer experience or knowledge (Fig. 5). They do not represent either a limit or the full extent of the type and character of searches that are open to the system but merely those which are most generally

DETAILS OF BOREHOLE NO:B201 ON REPORT NO:3010 (C) THE LDDC BOREHOLE DATABASE SYSTEM 11:17:20 19 MAR 1989

ARCHIVE REFERENCE :3010
BOREHOLE NUMBER :B2
GRID REFERENCE :536800-180566
DATE BORED (from):07/12/87
(to) :11/12/87
DEPTH(M.) : 45
ELEVATION(M.O.D.) :5.04
BORE CLASSN. :
REPORT REFERENCE :LIMEHOUSE
BORING TECHNIQUE :S
BOREHOLE DIA.(mm) : 200 - AT DEPTH OF(M.) :
PIEZOMETER AT : 0 STANDPIPE AT : 0 PERMEABILITY TEST AT : 0 VANE TESTS AT : 0
REFER TO REPORT FOR :CH

Description	SG	Depth	Water Obs.	SPT Values	Bulk Density	Moist. Cont.	Cu kN/m2	PHI(U) degree	Liqu. Limit	Plast. Index	Mv m2/MN	Grading D10	Grading D60	Grading D85
Reinforced concrete surfacing	A3	0.00												
Fairly loose brown clayey gravel, brick rubble etc. (MADE GROUND)	A1	.35												
Soft brown and grey mottled silty clay, gravel, brick fragments, traces of tile, glazed pipe, clinker etc. (MADE GROUND)	A1	.9										.071	.22	.29
		1.15		4					50	29				
		2.2												
		2.35		3			136		29	5			.031	.064
		3.15							62	40				
Soft dark grey black clay, ashes, gravel, brick fragments (MADE GROUND)	A1	3.9			2.01	20	206							
		17.8							27	11		.0074	9	38
		18.15		232										
greenish grey very silty CLAY	D5C	18.6												
		18.7			2.07	10			40	23				
Moderately strong rubbly grey brown calcareous SILTSTONE/LIMESTONE	D5Z	18.9		375										
Very stiff green grey and brown mottled sandy and silty CLAY, traces of SAND seams	D5C	19.5												
		19.6							40	24				
Very stiff green grey, green and brown mottled sandy and silty CLAY occasional silty SAND inclusions	D5C	20										.08	.18	.25
												.099	.21	.29
Hard grey and green grey sandy and silty CLAY with rounded flint GRAVEL	D5B	20.7												
		21	S									.085	.17	.21
		21.15		8								.1	.17	.2
		22												
		22.15										.08	.16	.18
												.089	.2	.27
Hard green grey and brown mottled sandy and silty CL				240									.091	.14
		38											.15	.17
Hard grey sandy CLAY and GRAV	D4A	39.3												
rubbly CHALK emoulded CHALK and flints	D3	39.4												
		39.65		103										
Hard rubbly CHALK and flints	D3	40												
		41.15		121										
		42.35		152										
		43												
- End of Borehole -		45												

FIG. 7. The borehole and laboratory data for each borehole can be printed in a unified format.

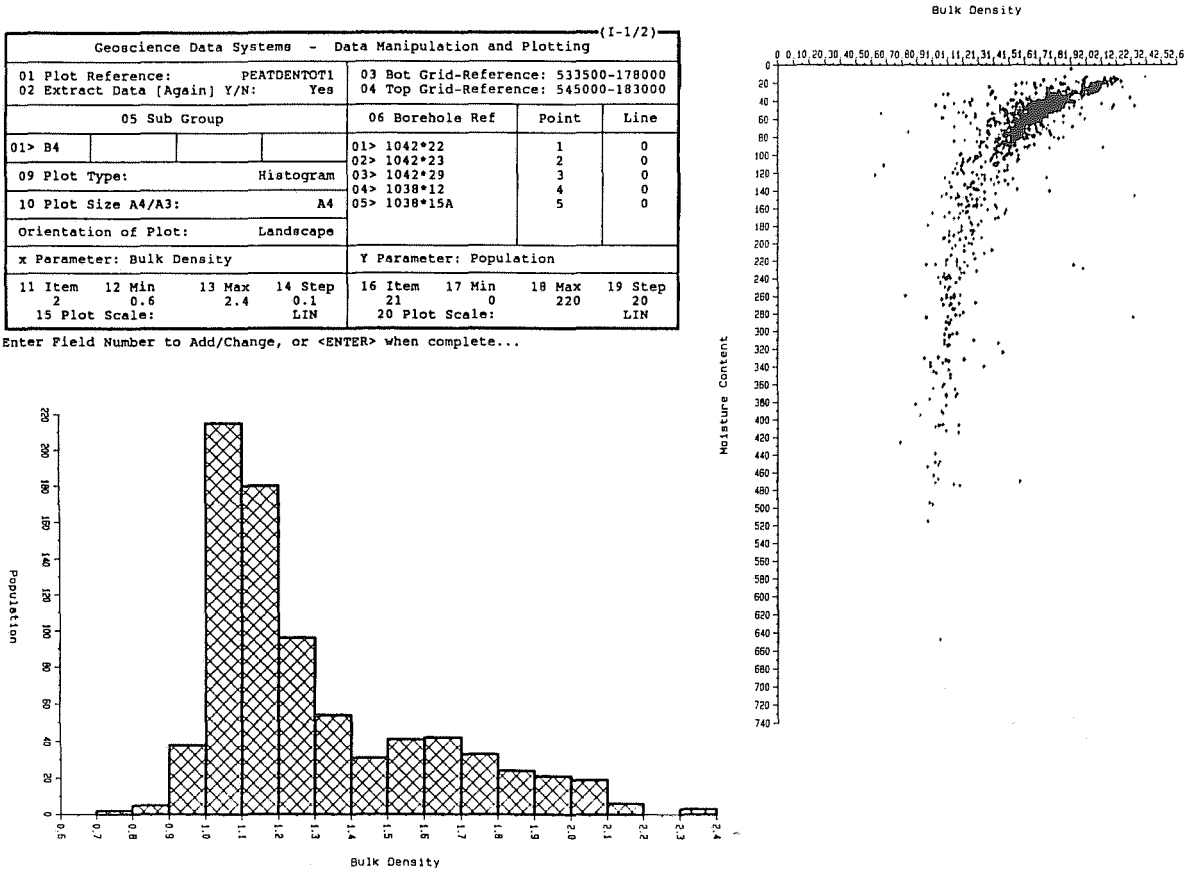


FIG. 8. Graphical output allows a degree of filtering of the data and displays the data as X–Y plots, plans or long sections.

required. For more sophisticated or detailed enquiries it is often more effective to isolate the relevant data into a separate datafile and perform searches using the REVELATION query languages.

Probably the most important attribute of the borehole data is its grid reference which uniquely identifies its geographical position. Most enquirers access the data by area to find any previous investigations that had been carried out in their area of interest. Therefore, the original report, per se, becomes of less concern other than as the vehicle which supplied the data. The original reports are indexed within GEODASY by a sequential archive number. This provides a practical advantage for the storage of a complementary hard copy of the report. If these are similarly filed by the same archive number and not by area, client, contractor or some other attribute, cabinets can be progressively filled.

The content and style of output from any such database is largely idiosyncratic, within the limitations of the software itself. They can be divided into three main groups which are accessed in GEODASY by menu options. These are: general enquiries, where hard copies are not generally required; printout, where hard copies are required; plots, where graphical presentation is required.

Experience at LDDC has shown that the screen based enquiries are satisfied by simple listings to provide, for example, the boreholes within an area of interest (Fig. 6). Although the listed information can also be printed, the specific requests for printed output usually wish for the information in a more complete form. A compilation of all data for each borehole is the most complete of these (Fig. 7).

The plotted output produces X–Y plots, plans and long sections (Fig. 8). This procedure is less readily available to outside parties since the output is based largely on an in-house interpretation of the lithostratigraphic grouping of the borehole record. Therefore the plots are only as reliable as this interpretation. Consequently, it is used mainly within the LDDC. The facility has been used to help develop an improved understanding of the engineering geology of the area (Howland 1989a).

The use of GEODASY

Engineering geology was seen to have a central role within the urban renewal process from the inception of LDDC. A systematic approach to the understanding of the engineering geology of Docklands was believed to be of more benefit to the aims of the LDDC than a series of otherwise unrelated project specific studies.

LDDC saw that an improvement of the infrastructure would act as a general catalyst to the development interest. However, the precise areas of interest were dictated by market decisions, and in particular by the initial financial incentives in the Enterprize Zone on the Isle of Dogs. The LDDC also act as the local planning authority but have maintained a flexible policy on the scale and character of any redevelopment so that each planning proposal can be evaluated for its own potential as a stimulus to the area. It has therefore worked to a less rigid development plan than perhaps had been the norm during the preceding New Town developments.

This led to an uncertainty in the scale of the development or even its distribution and was one reason why a regional approach rather than project led understanding of the engineering geology was adopted. The development of a database was seen as an integral part of this approach.

GEODASY was first installed in 1986 and has been in continual operation since then. It has undergone some amendments to the original specification but these have been largely organic. The most significant being the addition of graphical output.

The system is most commonly used to provide the data within specified areas of interest. Such enquiries can usually be accommodated within the same working day. Once the area is defined by national grid reference, a list of normalized data from the boreholes within the area together with a plan showing their spatial distribution can be sent by return. The graphical output is made available to outside parties with more reluctance since it summarizes information and has therefore undergone a degree of interpretation. It is more usually used as an in-house tool when specific situations arise where a geotechnical opinion is required. This may occur when the LDDC is concerned about the effects of one proposal on existing developments or if a potential Clause 12 claim arises. The immediacy with which information is available makes the role of engineering geology more relevant to the renewal process. The need for quick response is particularly important and GEODASY allows this to be based on facts which might otherwise not be assimilated within the time available.

Conclusions

The use of computer storage has proven to be an efficient method to hold the factual data collected during traditional civil engineering site investigations. Contrary to the conclusions of the CIRIA report which considered a national registry of reports, it has been possible to include the full and complete data. It is also possible to adopt procedures which eliminate many transcription errors. The most efficient of these is to require the contractor to pass information to the client in magnetic format. The necessary level of cooperation from the contractor is easily achieved by including this within the contract. Storage in an appropriate database format allows access to the data and presentation in a variety of formats. An advantage is that the data does not need to be fixed to an original report so that the information can be searched and processed by a variety of other criteria, the most useful of which is grid reference.

A geotechnical database system (GEODASY) has been devised. It consists of a number of related computer programs which interface with each other through a menu driven format. It allows rapid access to the data to supply geotechnical information to interested parties. It has enabled discussions and preliminary decisions to be made where the ground conditions are relevant in advance of the need to collect project specific information.

The collation of geotechnical information in a computer system for the LDDC is the first systematic attempt to involve geotechnics in the central functions of a planning environment. The procedure has proved to be successful and has value in a variety of situations. Any body with a strongly defined area of interest would benefit from the progressively improved knowledge base that is achieved as each report is added to the system.

ACKNOWLEDGMENTS. I would like to express my thanks to the London Docklands Development Corporation for permission to publish details of the work undertaken for them. I would also like to acknowledge the past and present officers of the Corporation, particularly Bill Conchie, David Crompton and Bob Blyth who have encouraged the approach described. I am grateful to Professor John Knill for his initial assocation during my early period with the LDDC.

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Received 11 February 1991; accepted 21 September 1992