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GROUNDWATER DATA MANAGEMENT BY THE MALAWIAN MINISTRY OF IRRIGATION AND WATER DEVELOPMENT - A CASE STUDY

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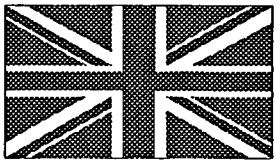

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Preparing to carry out a pumptest, irrigation well drilled in alluvium close to Lake Malawi

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PREFACE

Groundwater data management is an essential task in any organisation responsible for groundwater development or groundwater exploitation. Accurate and accessible data on the groundwater resource is a necessary prerequisite of any planning or management task. All too often, however, groundwater data management fails to attract the resources required for effective operation and receives a low priority in institutional planning. It is perhaps understandable that with scarce resources managers give precedence to investment in capital and water resource infrastructure; drilling new boreholes often comes before recording details of the success or failure of existing boreholes.

Accurate records of the location, geological and hydrogeological conditions, exploitation and water quality of boreholes allow hydrogeologists to accurately predict the likely success or failure of new drilling. They allow managers to assess and plan water supply and maintenance programmes and they provide the basic information for the compilation of hydrogeological and water resource maps.

It is now common practice in institutions to use computers to manage groundwater data. Increasingly, sophisticated systems for groundwater data management are run on relatively cheap personal computers. The British Overseas Development Administration has supported a project entitled "Data Management Systems for Groundwater in Developing Countries". The project aims to examine the range of software available for groundwater data management, to examine data management practice in a selection of institutions in developing countries and to establish guidelines for managers and technicians that will allow effective use to be made of available technologies.

The project recognises that institutional factors contribute much more to the success or failure of an institution's groundwater data management than either software or hardware. Some very successful data management exercises use simple technology, and the best technology can not compensate for lack of investment in staff to collect, enter and manage data. Nevertheless groundwater data management's importance is increasing. A move to decentralised institutions, and a relative increase in groundwater development by privatised institutions and non governmental organisations means that many national data management institutions have to adapt to ensure that data is still collected, and at the same time meet new demands for the effective dissemination of information to implementing agencies. It is hoped that this project will contribute to that process.

This report examines groundwater data management within the Ministry of Irrigation and water Development, Malawi. It is based on an examination of existing information systems and user needs. On the basis of its assessment revisions to current data management practice will be recommended, the subject of a separate report.

EXECUTIVE SUMMARY

This report examines groundwater data management within the Ministry of Irrigation and water Development, Malawi.. It is one of two case studies of groundwater data management practice undertaken as part of an Overseas Development Administration project entitled "Data Management Systems for Groundwater in Developing Countries". The project aims to examine the range of software available for groundwater data management and to examine data management practice in a selection of institutions in developing countries. It will establish guidelines for managers and technicians that will allow effective use to be made of available technologies.

The Ministry of Irrigation and Water Development (MIWD) in Malawi was selected as an example of an institution with centralised management of data, established data management procedures and some degree of computerisation of archives. Within the hydrogeological department there is a relatively formalised flow of data, built around the process of siting, drilling and maintaining boreholes. The most important documents and their data flow are summarised. The principal repository for copies of all these documents is the Water Data Office, housing archives on paper.

A computerised hydrogeological database, GWATER, was introduced into the Water Department in the late 1980s.. The system was designed to hold the data that is currently entered on paper records. It is based on the relational DBase III database. The GWATER system has, unfortunately, not lived up to the expectations of its designers. User satisfaction with the system is low. No new data has been entered into the system since 1991. The Water Department has not been able to adapt the program to changing requirements, nor resolve several minor programming flaws.

The problems with GWATER can be ascribed to several factors:

- A cumbersome user interface
- Complex mapping and graphing routines
- Obsolete hardware.
- Use of inappropriate administrative subdivisions

Three major user categories, and their data requirements, have been identified within the department. Four categories of external user are identified. This allows the main requirements for effective groundwater data management to be identified.

From the analysis of dataflow within the hydrogeology section it has been ascertained that there is scope for a re-appraisal of the role of the Water Data Office. A revised dataflow in which the Water Data Office is given a central role as a registry and information processing centre has been developed. The GWATER system, as software, is failing to meet the needs of users. The phased introduction of an updated and revised version of GWATER is recommended.

The case study has emphasised the important role of the institution in groundwater data management. An institution provided with effective software, building on a comprehensive paper based archive, was unable to fully capitalise on the investment made in hardware and software as the database remained remote from the user.

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ACKNOWLEDGEMENTS

This case study has been largely based on interviews with staff of the Ministry of Water and Irrigation Development, who during a visit to Malawi gave their fullest co-operation. The MIWD provided open access to their existing data management systems and staff were frank in their assessments of its strengths and weaknesses.

The author would also like to acknowledge the assistance provided by the ODA project R6233, 'Groundwater management in drought prone areas of Africa', whose staff provided data, assistance and considerable support in liaison with the MIWD.

1. INTRODUCTION

As part of an ODA funded study, Data Management Systems for Groundwater in Developing Countries, Project reference R5973, two institutions in the developing world were selected for detailed study of their groundwater data needs, and existing groundwater data management practices.

The first case study carried out was of the department responsible for groundwater development within the Ministry of Irrigation and Water Development (MIWD) in Malawi. The ministry was selected as an example of an institution with centralised management of data, established data management procedures and some degree of computerisation of archives.

This report documents the case study. It identifies the role and responsibilities of the department responsible for managing groundwater data. It establishes what data are collected, how data moves through the organisation and how they are ultimately archived in an existing computer database.

The report examines the extent to which existing systems satisfy user demands for access to data and are capable of sustainable operation and development to meet future data needs.

Looking to the future leads to a more detailed examination of the data needs of users within the department, and the interrelationships between the users and third parties.

Finally consideration is given to the future of data management within the department, and how both institutional developments and the introduction of new software for data handling might contribute to development of effective groundwater data management, providing the users with the data required to fulfil their functions.

This report represents a snap shot of data management within a dynamic and evolving institution as it stood during 1995 and 1996. Many of the issues discussed were being actively addressed and data management practices will have been refined and further developed since the work on which this report is based was carried out.

2. GROUNDWATER in MALAWI

Groundwater plays an important role in the Water Sector in Malawi, despite relatively abundant surface water resources. Table 1 summarises key hydrological indicators.

Table 1 - Water Resources in Malawi

	Rate	Total
Rainfall	400 - 2000 mm/year	98,000 Mm^3/a
Potential Evaporation	1100-1700 mm/year	-
Runoff	200 mm/year	18,000 Mm^3/a
Groundwater recharge	5-100 mm/year	24,000 Mm^3/a
Groundwater abstraction	1-3 mm/year	188 Mm^3/a

Nationally surface water is the dominant source of supply for major urban centres, and for large scale irrigation projects, but 23% of the population, 2.5 million people, depend on borehole sources. In rural areas 31% of the population depend on boreholes, with a further 9% estimated to rely on shallow wells. In some districts groundwater plays an even greater role, providing water to up to 45% of the population. In 1990 it was estimated that there were 10,000 drilled boreholes in Malawi. With approximately 500 new wells drilled each year, the current figure must be around 13,000.

Groundwater in Malawi occurs predominantly in weathered Precambrian Basement and Quaternary alluvial aquifers. Figure 1 shows the geology of Malawi.

For much of the country the weathered basement provides the only source of groundwater. The water in this formation is generally found at shallow depths. Boreholes are sited where it is estimated that weathering will be developed to the greatest degree. Even in the most productive parts of the aquifer borehole yields rarely exceed 1 l/s.

Alluvial aquifers are found on the shores of lake Malawi, in the Shire Valley and the Lake Chilwa basin. They consist of interbedded sands and clays, and boreholes within these formations are much more productive, although limitations in borehole construction and development have resulted in yields above 2 l/s being rare.

The aquifer characteristics determine that most boreholes for rural supply in Malawi will be small diameter wells drilled rapidly by air flush percussion rigs and equipped with handpumps. Within the weathered basement aquifers some hydrogeological input is usually necessary before drilling to optimise siting and subsequent yield. Boreholes are preferred over hand dug wells by donors and the MIWD as they are perceived as being more resistant to drought and less prone to pollution.

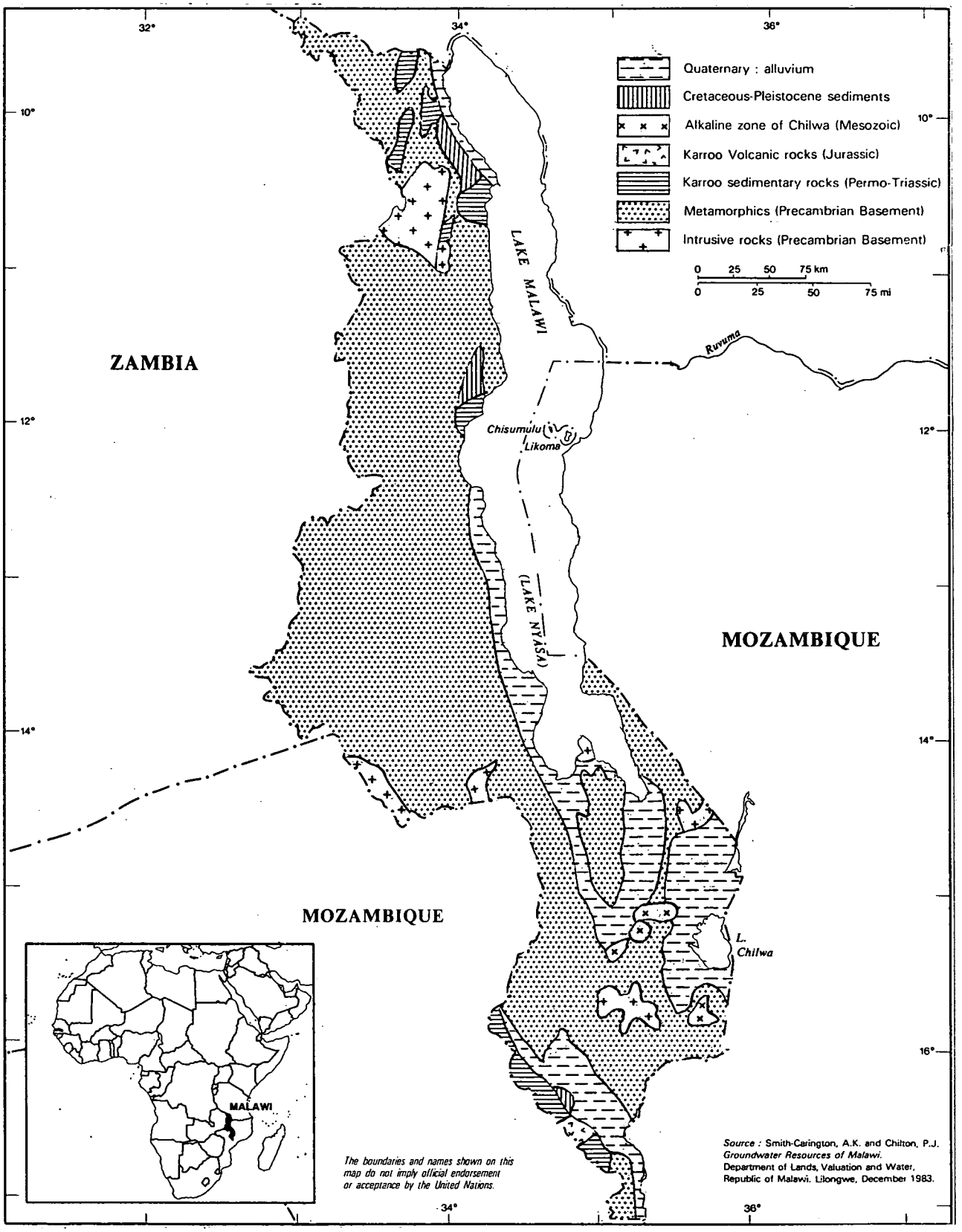

Figure 1 - Geology of Malawi. From Smith-Carrington and Chilton (1983)

3. INSTITUTIONAL RESPONSIBILITIES

The Ministry of Irrigation and Water Development is a ministry within the Malawian government formed in the mid 1990s. The ministry has responsibility for the development and management of water supplies at national level. It has its headquarters in Lilongwe, and staff are deployed in a structure based first on a division into a Northern, Central and Southern region, and then on 24 district offices.

Amongst other institutional components it includes the Water Department, formerly an independent entity, which has particular responsibility for rural water supply programmes, and maintains a capability for investigation, siting, construction and maintenance of water supplies. The Water Department acts on behalf of central government, as facilitator and contractor for multilateral and bilateral aid programmes and as contractors to individuals or institutions requiring water supplies.

3.1 Organisation

There are several sections within the Water Department, but this case study concentrates only on the hydrogeological section. This consists of a Chief Hydrogeologist, who reports to the Chief Water Resources Officer. An important section responsibility is the presentation of hydrogeological advice to the national Water Resources Board, whose representatives meet periodically to review groundwater licence applications.

The Chief Hydrogeologist supervises senior hydrogeologists responsible for borehole siting, based in the three regional offices. He also controls the section's drilling activities, which are managed by a Drilling Superintendent, and borehole maintenance under a Senior Maintenance Technician. The drilling and borehole maintenance activities are based in the regions, with maintenance further devolved to district offices.

Several hydrogeological technicians support the field and office activities of the hydrogeologists. An administrative staff is responsible for managing contracts and accounts, mostly related to drilling for individuals, communities or development programmes.

3.2 Data flow

Within the hydrogeological department there is a relatively formalised flow of data, built around the process of siting, drilling and maintaining boreholes. This data flow has been analysed and is summarised in Figure 2.

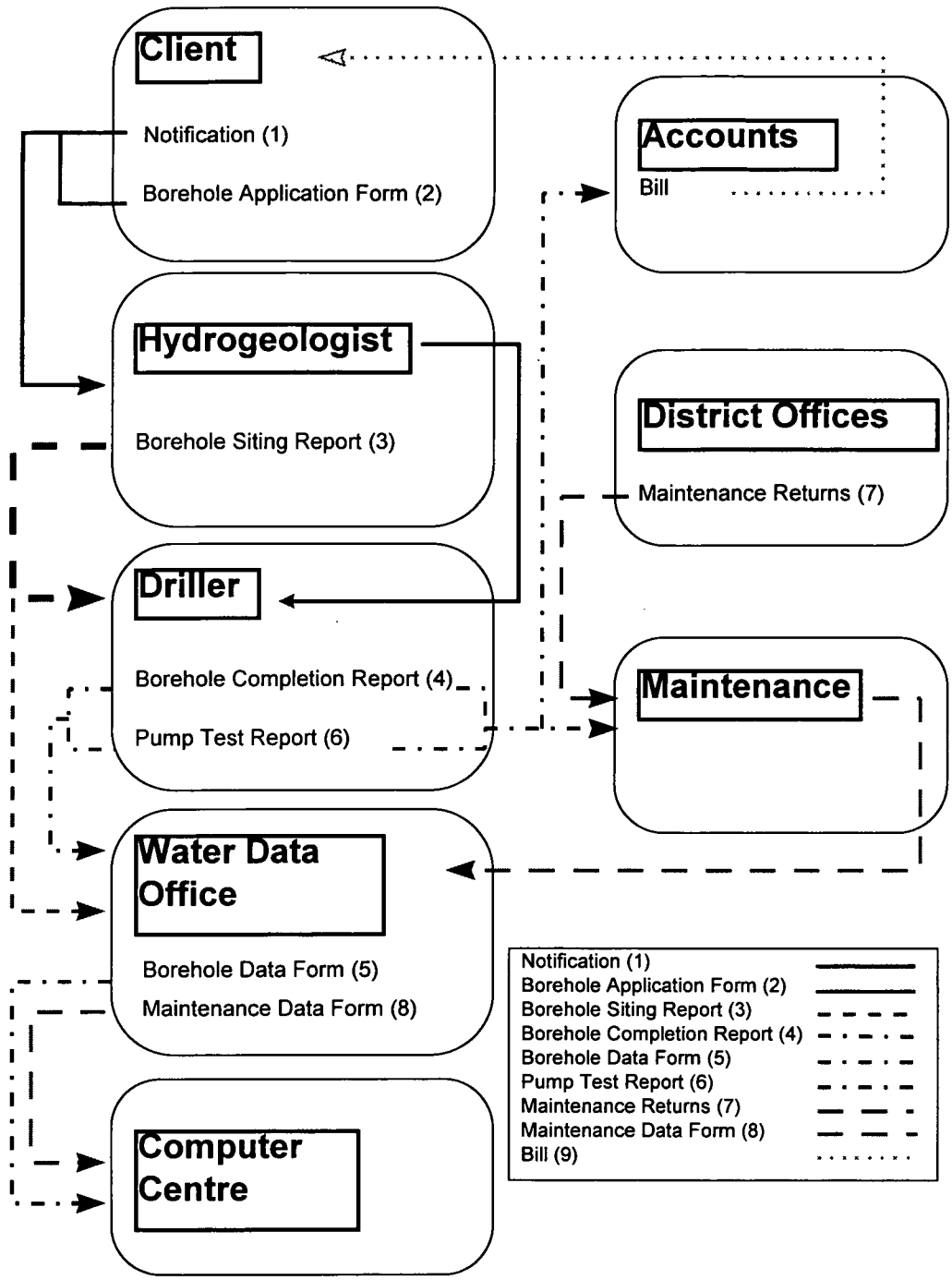

Figure 2 - Existing flow of groundwater data within the Water Department

Nine major documents are handled routinely as part of the process of siting, drilling and maintaining boreholes and wells. These are:

1. Notification prior to application for a grant of water right. This is a legal requirement. It consists of a short form that is completed by the applicant and remitted to the Water Department. After well drilling a formal application is passed to the Water Resources Board, accompanied by a recommendation from a hydrogeologist. For many rural boreholes for village supply the granting of a licence is a formality, but for significant abstractions detailed analysis is carried out, and the applicant may be required to carry out pumptests, or the licence may be granted with limitations.

2. Borehole and shallow well application form. This document normally accompanies the application for a grant of water right. It details the work to be carried out by the hydrogeological section, and the arrangements for payment.

3. Borehole siting report. Following a request to site a borehole a hydrogeologist will carry out a survey. This normally consists of a desk study and a geophysical survey. These are summarised in report form. On completion the siting report will be passed to the drilling superintendent as a basis for instructions to the drilling crews. Borehole siting reports are given a number, derived from the initials of the siting hydrogeologist, followed by a number. This number forms the basis of the well numbering system used throughout the Water Department. One inconsistency noted is that where no site is selected some hydrogeologists still issue a number, and others do not. Equally some sites with issued numbers will never be drilled. Siting reports are filed under the name of the responsible hydrogeologist.

4. Borehole completion report. After a borehole has been drilled a completion report will be filed. This report details both borehole construction, drilling progress and geology. If the borehole has been drilled by Water Department rigs a standard pro-forma is used, and this forms the basis for the preparation of an invoice for work carried out. If drilling is carried out by a contractor they are legally obliged to lodge a report with the Water Department. Copies of the borehole completion report are sent to the maintenance department, and the report is filed in the Water Data Office, under the borehole number.

5. Borehole Data Form (CARDEX). On receipt of a borehole completion report the Water Data Office enter details of the document into a ledger, and before filing the report they transfer details of borehole construction and completion to a 5" x 8" card. The borehole is assigned a second identifying number based on a division of the country into 18 drainage basins. The cards are then filed by drainage basin. The use of drainage basins appears to cause some difficulty for subsequent retrieval of data, as drainage basin boundaries are not coincident with districts, which are the normal administrative unit.

6. Pump Test Report. For those boreholes which are to be equipped with motorised pumps a pump test will be carried out. This will be filed in the Water Data Office with the Borehole Completion Report. The results of the test will be transferred to the Borehole Data Form.

7. Maintenance Unit Returns. As borehole maintenance is carried out at district level weekly or fortnightly returns are made, summarising the interventions made for each borehole. The returns are compiled at regional level into a set of reports summarising borehole maintenance status. The detailed returns are passed to the Water Data Office for filing.

8. Maintenance Data Form (CARDEX). The details of maintenance interventions are transposed to a record card that summarises borehole construction and logs all visits made. Where water levels have been measured during maintenance these may be also entered on the Borehole Data Form.

9. Bill. The details of borehole construction are passed to the accounts department who render a bill to the client.

Examples of some of these forms are included in Annex 1.

The principal repository for copies of all these documents is the Water Data Office. This consists of an office housing archives on paper. While the data is organised by category, some areas appear to lack systematic indexing, and there do not appear to be systems to ensure that data is not lost or misplaced.

The Water Data Office is used by the staff of the Water Department whenever data is required for a desk study. Access to data is not helped by the lack of indexing, and the organisation of original siting reports and originals of borehole completion reports by hydrogeologist's initials rather than by a geographic designator makes it hard to assemble all the data for a given geographic area. It is theoretically possible to tie together relevant data for an area, for instance by cross referencing borehole completion reports and siting reports for a given location. In practice this would be time consuming. If siting work had been carried out without corresponding drilling a comprehensive collation of material would depend on knowledge that a given hydrogeologist had worked in the area.

The overall impression of the data office is that it is used principally as a store room for data, and that it is not designed for the provision of comprehensive data on a routine basis.

The department's computerised archives, discussed in detail below, are housed in separate offices. The Water Data Office itself operates without any computerisation, even at the level of indices.

3.3 Computer archives

Between 1988 and 1990 a computerised hydrogeological database was introduced into the Water Department, with finance and consultancy provided by the United Nations Development Programme. The system was designed to hold the data that is currently entered on the Borehole Data Form CARDEX. It was originally envisaged that data from the Borehole Maintenance Data Form CARDEX would also be entered, but there is no evidence that this was ever implemented.

The system used is known as GWATER. It is a hybrid system based entirely on commercially available software packages.

DBase III is used to store data on boreholes. Separate tables are used for data on borehole construction, geology, pumptests, hydrographs, chemistry and maintenance. The data structure used is outlined in Figure 3.

The user interface is based on forms and menus designed within the DBase environment. An example of the main menu screen and the screen for selection of standard reports is shown in Figure 4. Menus and prompts generally require numerical responses.

Graphical and analytical capability are provided by a combination of PC packages; Lotus 123, 'Grapher' and 'Surfer'. Lotus 123 is used to handle statistical analyses of data. 'Grapher' is used in conjunction with interpolation routines written in BASIC to present hydrographs. 'Surfer' is used to grid spatial data sets and to draw up contour maps. The interrelationship between components is outlined in Figure 5.

Further details and examples of data output from GWATER are included in Appendix 2.

The system currently holds details of approximately 7000 boreholes. All data pertaining to boreholes drilled before 1986 are entered, and the majority of data on boreholes drilled between 1986 and 1991 are thought to be entered, although this has not been verified.

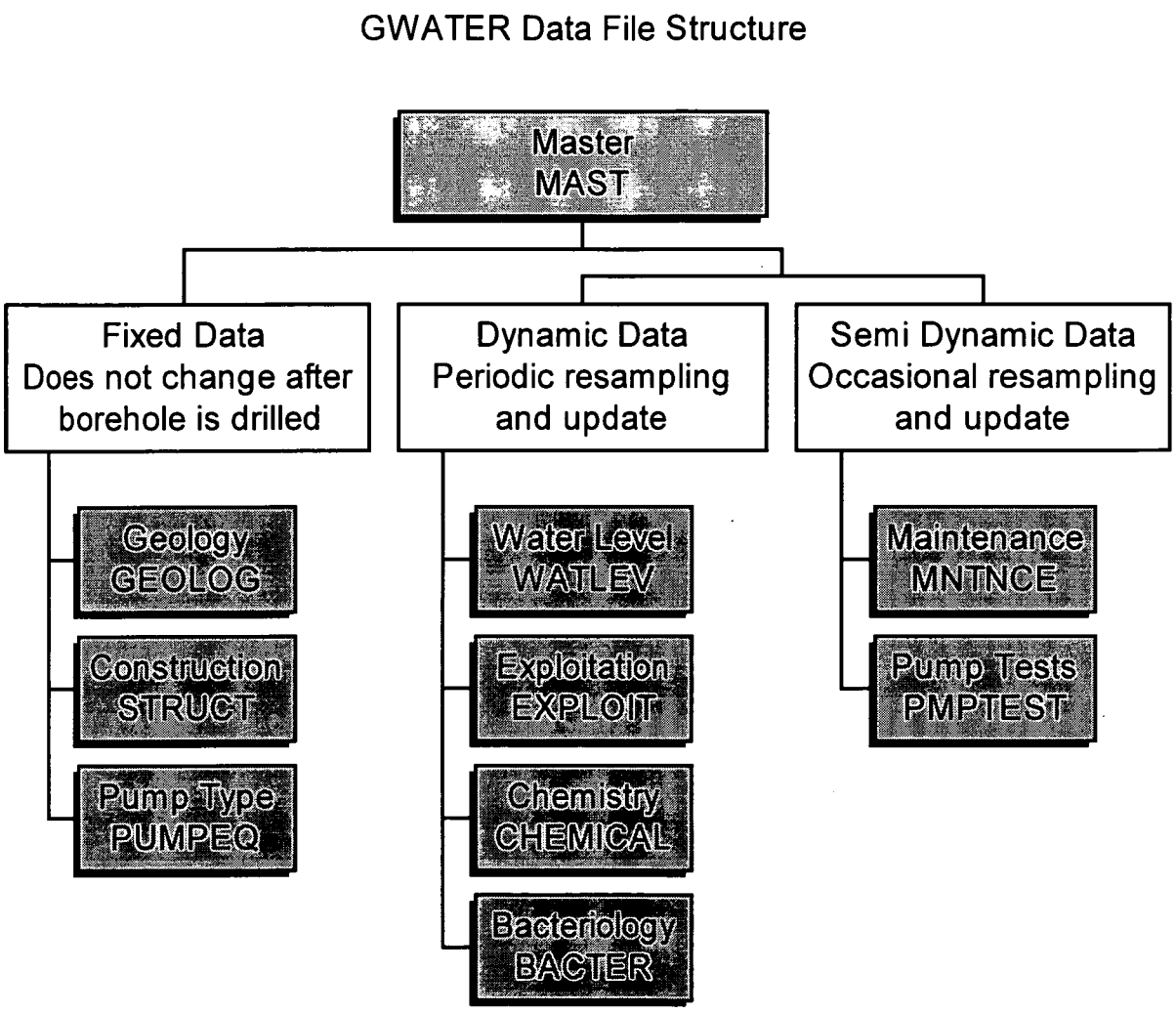

Figure 3. **Data structure of the GWATER System**

```
        MALAWI GROUNDWATER COMPUTER CENTRE
        ----------------------------------
              DATA RETRIEVAL MENU

           0. Exit to Main Groundwater Menu

           1. Combine Basins (BASIN "99")

           2. Standart Reports

           3. Water-Level & Water Quality Hydrographs

           4. Contour and Surface Maps

           5. Statistics with Lotus


                        Make Your Choice 0-5   0

MAINMENU‖                          ‖                    ‖                    ‖   Num
```

```
                  MALAWI GROUNDWATER COMPUTER CENTRE
                        STANDART REPORTS MENU
                        **********************
              0. Exit to Main Groundwater Menu
              1. Basic Borehole Data
              2. Available Geological Data
              3. Well Structure Logs
              4. Well Pump Equipment Data
              5. Well Pump Test Data
              6. Water Level Records for a Given Well
              7. Water Chemistry-Major Constituents
              8. Water Chemistry-Other Constituents
              9. Bacteriological Data
             10. Maintenance Records for a Given Well
             11. Maintenance Summaries
             12. Spare Parts & Costs of a Given Pump
             13. Exploitation Estimates

Note: Choices 9, 10, 11 and 13 are not available yet (Sep 8, 1989)

                        Make Your Choice 0-13    0
MAINMENU‖                          ‖                    ‖                    ‖   Num
```

Figure 4: **GWATER: Examples of GWATER data screens** *(printed directly from GWATER)*

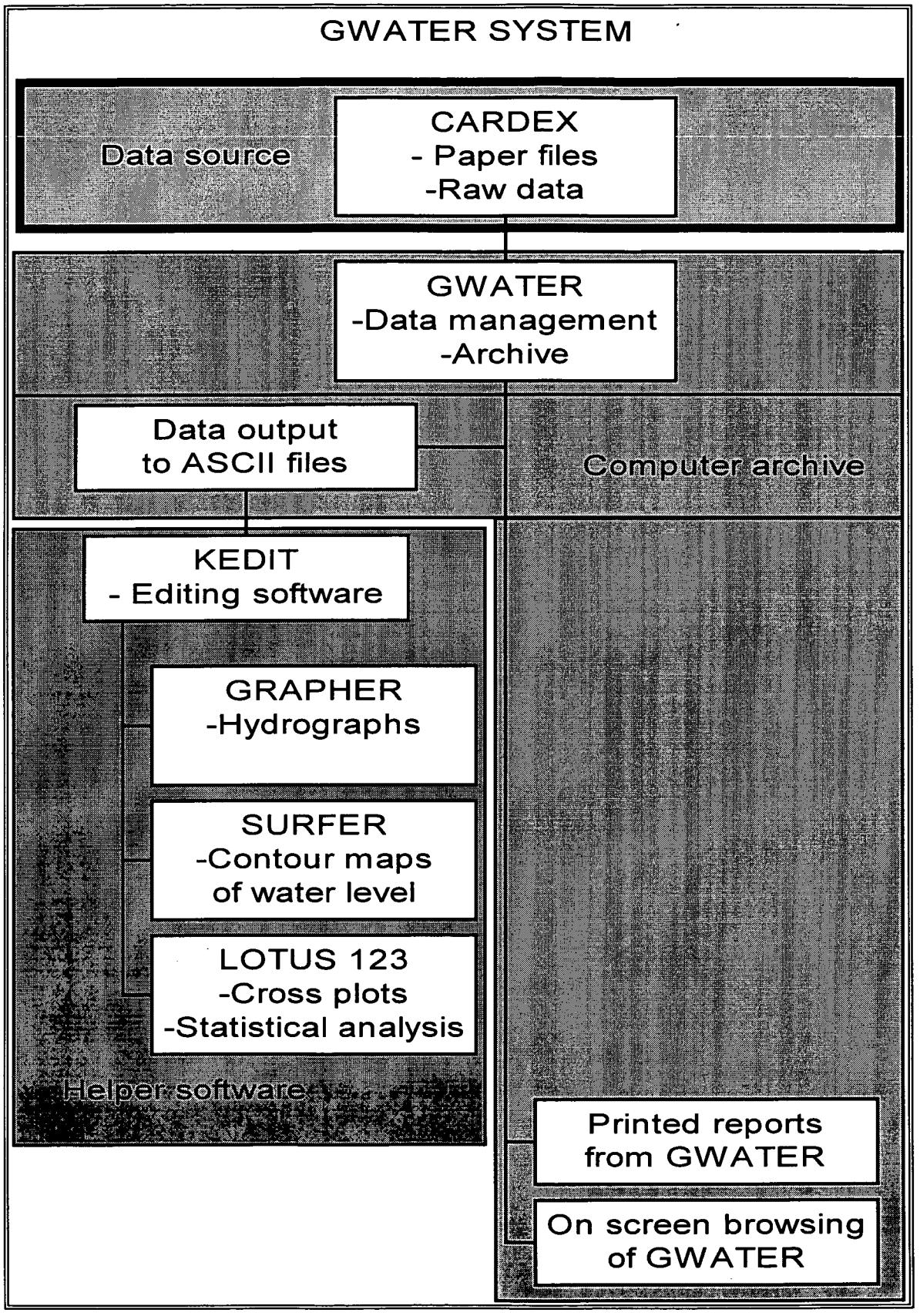

Figure 5: **GWATER: Relationship between data, database and external programmes**

3.4 GIS and Other Data Systems

There is currently no GIS in regular use within the Water Department, although there are plans to introduce a system, possibly Arc-Info or ArcView in the future. It is hoped that this system will allow the integration of groundwater data with meteorological and hydrological data.

Hydrological data is currently stored in the 'Hydata' system designed by the Institute of Hydrology in the UK. This is a PC based system using its own proprietary database software. It is designed expressly for the management of river flow time series data.

Other data systems in use within the Water Department include the Water and Sanitation Assessment and Monitoring System (WASAMS). This is a PC based database and reporting system, introduced during 1995 by UNICEF, and is designed to provide comprehensive statistical information on the level of coverage of water supply and sanitation programmes at village, district, regional and national levels. It is primarily a tool to allow effective targeting of investment programmes.

4. ANALYSIS OF EXISTING SYSTEMS

As part of the current review discussions were held with users and operators of the GWATER system. The resulting subjective impressions of the system's limitations are recorded below.

It is worth emphasising that the software appears to have been designed carefully. Within the technological limitations imposed by the computer hardware and software available in the late 1980s, there is no reason why the system could not have been successful.

4.1 User satisfaction

The GWATER system has, unfortunately, not lived up to the expectations of its designers. User satisfaction with the system is low. No new data has been entered into the system since 1991.

Some new data has been entered onto simplified database files within the GWATER system directory, but no attempt has been made to relate the data in the GWATER system to the new data

Several factors of the GWATER design and its implementation have led to a lack of effectiveness.

The user interface, while acceptable when the software was designed, now appears dated and cumbersome. Data entry and data editing is through separate menus.

Data entry procedures are straightforward, but querying and printing requires the user to follow complex sequences of prompts, and fairly arbitrary use of codes.

Mapping and graphing routines using external packages such as 'Grapher' and 'Surfer' require the user to understand the required data formats, and to edit data files manually prior to plotting.

The software is run on an IBM PS2/50Z computer, a system based on the now obsolete Intel 80386 SX processor, response times are extremely slow.

To help alleviate the limited speed of the system the data was separated into directories based on hydrological drainage basins. This leads to a requirement for the user to repeatedly specify the basin of interest. When data is required by district the procedures for retrieval are complex.

No simple system for the design of new reports has been provided. The reports that are provided are not closely focused on user requirements.

4.2 Sustainability of GWATER

The majority of the GWATER system was written in DBase. A comprehensive user manual was provided. The manual documents the data structures used. Maintenance of the system should have been within the capability of the Water Department. In practice the sustainability of the system has been severely limited by three factors.

> The first factor was the apparent lack of documented source code. This limitation has been compounded by the complexity of the system of programs and menus, which has discouraged modifications.
>
> The rigid system of reports and the complexity of obtaining results from the database in a useful form meant that hydrogeologists did not become familiar with the day to day operation of GWATER, but left data entry and retrieval to specialised staff.
>
> The third factor has been the organisation of the database by hydrological basins. This means that the addition of new data tables would rely on harnessing those elements of the program that deal with the selection of a given basin.

The combination of these factors has left the database essentially in the state it was in when the consultants left. The Water Department has not been able to adapt the program to changing requirements, nor resolve several minor programming flaws. Unavoidable changes in personnel associated with the project further limited the department's ability to maintain the program. In particular the tragic death of Francis Msonthi, Senior Hydrogeologist, who was responsible for establishing the Malawi Groundwater Computer Centre, just as the GWATER system was commissioned, robbed the project of valuable impetus.

4.3 Institutional resources

In common with many institutions the groundwater section of the MIWD faces significant pressure on its operational budgets. Resources for capital investment in new computer hardware and software are extremely limited. The section did, however, have adequate staff resources. Two groundwater technicians are employed in the Water Data Office to manage the CARDEX system. A computer technician and two data entry clerks were available for data entry. While none of these staff are fully committed to groundwater data management there should not be a problem instituting routine data entry for new boreholes, given updated software and hardware.

5. USER REQUIREMENTS

A user requirement was defined for the groundwater section by examining the capabilities of the existing systems, both paper and digital, and by interviewing MIWD staff.

5.1 Identified users

Three major user categories have been identified within the department, based on existing sub-divisions within the hydrogeology section. They are detailed in Table 2.

Table 2 Outline of users and their principal data requirements.

User	Main data requirement	Notes
Hydrogeology Hydrogeologists in headquarters office and in regions.	Siting reports sorted by area, *by geologist, by date.* Borehole completion reports sorted by area. Water level data from observation boreholes and monitoring boreholes. Water chemistry	Minimum data required on siting reports would be the location and a summary of the work carried out, but more detailed recording of co-ordinates and results of geophysical surveys would be useful.
Drilling Drilling superintendent.	Siting reports sorted by area. Borehole completion reports sorted by area, *by drilling rig, by date.* *Borehole costing for accounts.*	The ability to cross-reference borehole names, localities and borehole ID would be useful.
Maintenance Maintenance technicians in headquarters and in regional offices.	Borehole completion reports sorted by area. Maintenance records sorted by area, *by date, by maintenance unit.* Water level data from monitoring boreholes.	Summary reports giving a monthly overview of the number of operating and non-operating pumps by district.

Note entries in *italic type* indicate data required for internal administration rather than for technical purposes.

A significant proportion of this data would be available from the GWATER system if it was fully operational, and if flexible report formats geared to user requirements were available. One area that is not addressed at all by GWATER is the provision of data on borehole siting.

5.2 Linkages to other groups

An effective groundwater data management system should address not only user requirements within the groundwater section, but also the needs of other users. The recent report on groundwater management in drought prone areas of Malawi (Calow et al, 1996) highlights the data required for effective planning of drought relief programmes and early warning of problems. The needs identified include:

- Geological data on aquifer thickness, T & S, and yields
- Well and borehole coverage, type of equipment
- Water level data and seasonal variation in level
- Location of dry wells
- Water quality

Table 3 below lists some users and the broad categories of data required.

Table 3 Outline of external users and their principal data requirements.

User	Main data requirement	Notes
MIWD Water Resource Planners	Aquifer properties data and summaries of yield sorted by area/aquifer Water level data from observation boreholes and monitoring boreholes. Water chemistry	The data needs to be integrated with several other spatial data sets, including rainfall/runoff data, land use, population density etc., implying the use of a GIS.
Water Resources Board	Summaries of groundwater usage in given areas.	To give the board information on potential resource conflicts.
NGOs	Borehole completion reports sorted by area. Borehole siting reports sorted by area.	The level of detail required by NGOs will vary from detailed data needed for borehole siting to summary information for planning purposes.
Private sector	Borehole completion reports sorted by area. Borehole siting reports sorted by area.	Data mainly required to allow optimal borehole siting.

6. FUTURE DEVELOPMENTS

It is clear that the GWATER system has not proved itself as an effective tool for managing groundwater data within the hydrogeological section. Indeed, its performance has been so disappointing that its abandonment would not materially affect operations of the section. Nevertheless there are compelling arguments, based on economic and scientific efficiency, for maintaining an efficient archive of borehole and water well information. The investment in the CARDEX system and in GWATER has been considerable, and may form the basis for an enhanced system, given suitable software and, perhaps most importantly a clear role for data management within the institutional structure of the section.

6.1 Institutional issues

From analysis of the flow of data within the hydrogeology section it has been ascertained that there is scope for a re-appraisal of the role of the Water Data Office. Its present role, principally as a data repository limits its ability to collect and provide comprehensive data and leads to a tendency to undervalue its services within the section.

The data flow presented earlier in Figure 2 encourages the users to pass information directly to the 'downstream' user, often keeping copies of reports for their personal use. This may lead to difficulty in identifying the most up to date or accurate copy of a report. A further effect of this system is that to derive overviews of the activities of all sub-sections requires the Chief Hydrogeologist to approach each sub-section individually.

Figure 6 presents a possible revised dataflow in which the Water Data Office is given a central role as a registry and information processing centre.

The current practice of registering data on the paper archive system (CARDEX), and subsequent entry to a database would be reversed. The principal data repository would become the computer database. The CARDEX system and allied paper records would be maintained purely for data security.

For the data office to be effective in this new role several conditions would need to apply.

> The data office would need to be staffed and supervised at a level commensurate with their enhanced responsibilities.
>
> The data office would have to guarantee rapid processing of documents to avoid impeding progress of the siting and drilling programmes.
>
> The data office would need to be provided with suitable computer software to manage the registration of information, and suitable hardware on which to run the software.

Training of staff would be a key element in ensuring that the conditions are met, coupled with selection of a computer system and software that was sustainable from within the department's own resources.

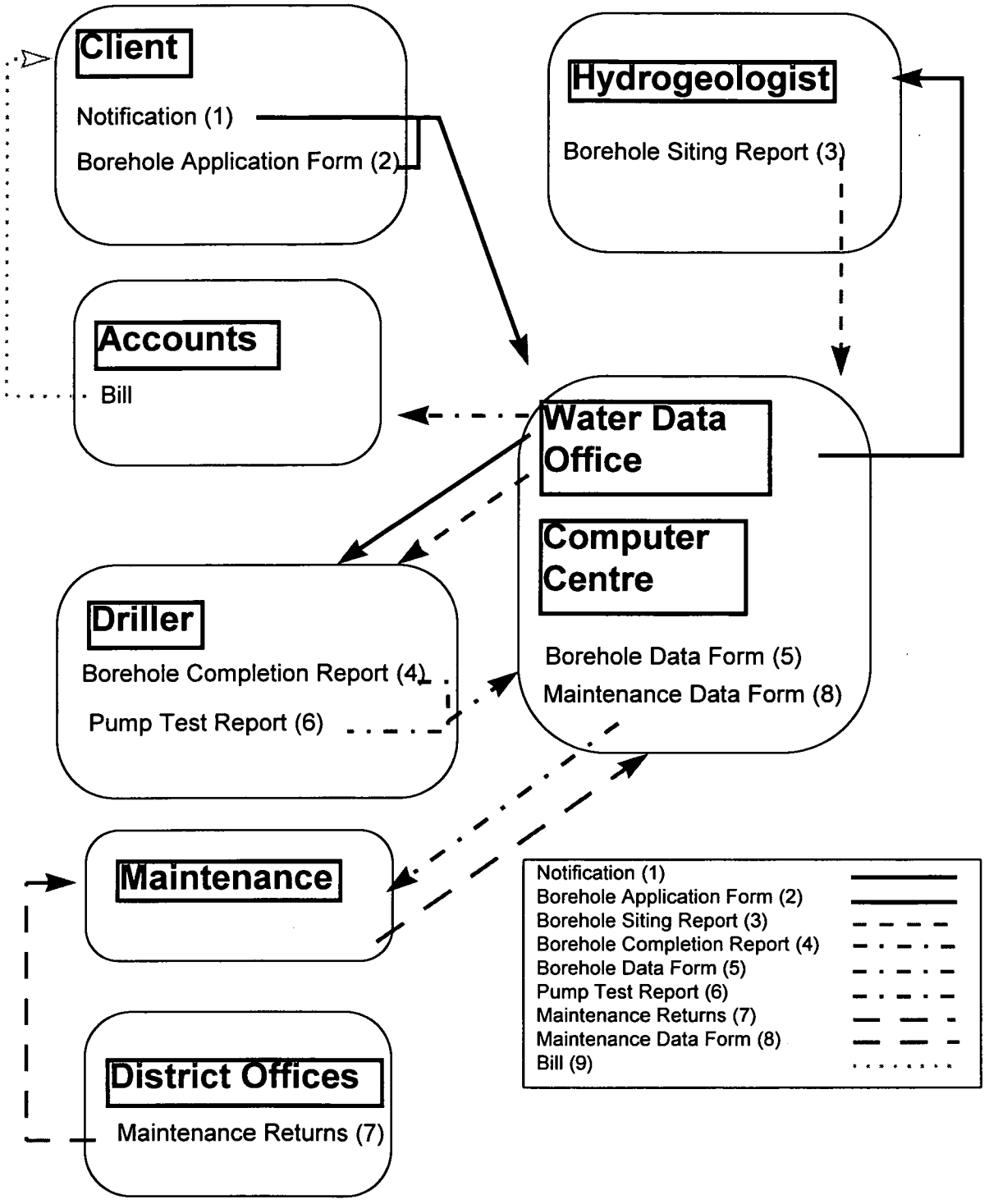

Figure 6 - Proposed revision to the flow of groundwater data within the Water Department

6.2 Data management software

The GWATER system, as software, is failing to meet the needs of the hydrogeology section of the MIWD. This failure is at two levels. At the first level the software fails to provide the section with the information it was originally designed to provide. At the second level the software lacks the ability to respond to changing needs for data and enhanced requirements for accurate reporting.

Addressing these deficiencies will require the introduction of a new computer system. To maximise the benefit from the existing data that has been fed into GWATER a new system should be introduced in a series of steps.

A possible sequence would be:

1. Duplication of the functionality originally envisaged for the GWATER system within a modern Windows based database programming environment.

2. Transfer of the GWATER data from DBase files to a new database structure, at the same time eliminating the division of the data into basins.

3. Introduction of a flexible reporting environment, allowing reports to be customised to user requirements.

4. Incorporation into the system of a database of borehole siting reports.

5. Replacement of the analytical and graphical routines provided by 'Surfer' and 'Grapher' with Windows based packages.

6. Introduction of a vector based GIS system to provide a spatially based interface to all groundwater data, and to allow its integration with other water resources data.

This evolutionary, rather than revolutionary approach should minimise the time taken to introduce a new system, and also limit the amount of training required for operators. Nonetheless if the factors that led to GWATER's lack of sustainability within the Water Department are to be avoided for a successor system careful attention will need to be paid to staff training, to documentation and to a significant period of testing and revision of the system to meet the Department's needs.

7. CONCLUSIONS

The GWATER database system adopted for groundwater data management in Malawi has failed to live up to all the expectations of its designers and users. The original software, implemented as a DBase III relational database, functions as expected, but failed to take full account of the need for an easy to use system that can be easily operated by non specialist staff. After an initial period of intensive digitisation during 1988 and 1989, when a substantial proportion of an existing paper archive was transferred to PC, the system has to all intents and purposes fallen into disuse.

It would be possible to ascribe the lack of success of the system to the software, but analysis of the flow of data within the water department suggested that institutional factors have contributed. Data which is generated by the department's hydrogeologists, by the drillers and by maintenance teams is archived in the department's Water Data Office. The unit acts as a repository, and is not routinely consulted. Important documents are copied and passed direct from user to user, for instance from hydrogeologist to driller. The Water Data Office and the office responsible for operation of GWATER are not co-located, and communication between the units is limited.

Improvements in groundwater data management within the department will require progress on two fronts. The first, critical, area will be a revision of the operation of the Water Data Office and the computer archive. By merging the two functions, and revising the flow of data to give the Water Data Office a central function as a broker of information, it should be re-vitalised. It will ensure that accurate data is held and disseminated as required to users. The second area requiring attention is the GWATER database. It requires a re-design to capitalise on developments in database software over the last eight years, and to address the principal failings in the user interface.

The Malawi case study has emphasised the important role of the institution in groundwater data management. An institution provided with effective software, building on a comprehensive paper based archive, was unable to fully capitalise on the investment made in hardware and software as the database remained remote from the user.

REFERENCES

Calow R C and others. Groundwater management in drought prone areas of Africa. Malawi inception report. BGS Technical Report WC/96/28. 1996.

Mercado, A. Project MLW/88/021- Summary Report and User's Guide. Department of Lands Valuation and Water, Republic of Malawi, Lilongwe, Internal report. 1990

Smith-Carrington, AK and Chilton, PJ. Groundwater Resources of Malawi. Department of Lands Valuation and Water, Republic of Malawi, Lilongwe. 1983.

ANNEX

Examples of data management proforma

Borehole And Shallow Well Application Form

Notification Prior To An Application For Grant Of A Water Right (Ground Water)

Borehole Data Form BDF1

Maintenance Record

MINISTRY OF WORKS

WATER DEPARTMENT, GROUNDWATER SECTION

BOREHOLE AND SHALLOW WELL APPLICATION FORM

Complete one copy of this form for each borehole or shallow well required and send to the Officer-in-charge, Groundwater Section, Private Bag 390, Lilongwe 3. Please indicate the item applied for by circuling borehole or shallow well.

1. ORIGINATOR OF REQUEST:

   NAME : .....

   ADDRESS : .....

  L

   .....

2. GOVERNMENT DEPARTMENT PROGRAMME, COMPANY OR PERSON FOR WHOM THE REQUEST IS BEING MADE:

   NAME : .....

   ADDRESS : .....

   .....

   .....

3. LOCATING OF REQUESTED BOREHOLE OR SHALLOW WELL

   SITE NAME: .....

   VILLAGE HEADMAN: .....

   TRADITIONAL AUTHORITY: .....

   DISTRICT: .....

   GRID REFERENCE FROM: 1:50,000 MAP).....

4. INDICATED THE TYPE OF SURVEY REQUESTED BY CIRCLING THE APPROPRIATE LETTER(A OR B)

   B. An extensive detailed survey

5. INDICATE THE TYPE OF PUMP REQUIRED BY CIRCLING THE APPROPRIATE LETTER (A OR B)

   A. A HAND Pump is to be installed by Department of Water

   B. A motor pump is to be installed by the lient.

6. SPECIFY THAT THE BOREHOLE OR SHALLOW WELL WATER WILL BE USED FOR:

7. FINANCING OF BOREHOLE SHALLOW WELL
   Complete the appropriate section (A or B) below

WATER RESOURCES ACT

(CAP. 72:03)

NOTIFICATION PRIOR TO AN APPLICATION FOR A GRANT OF WATER RIGHT (GROUND WATER)

This form is to be submitted to the Chairman of the Water Resources Board, Private Bag 390, Capital City, Lilongwe 3.

(1) Full name of applicant .....

.....

Postal address .....

.....

Occupation .....

(2) Location of land on which borehole is to be sunk: 1:50,000 Sheet No. .....

N.G.R. .....

Traditional Authority ..... District .....

.....

(3) Briefly describe purpose for which water will be used .....

.....

.....

.....

.....

.....

.....

.....

.....

Date .....

.....

Signature of Applicant or his duly Authorized Agent

NOTE: This form is intended to notify the Board of the applicant's intention to drill or sink a borehole. Full details as to the purpose for which water is required will be shown in paragraph (7) of Form WRB. 2. Having known the yield of his well or borehole, the applicant will be in a position to decide whether water will be abstracted by hand or pump; and if by pump, the applicant may then fill paragraph (6) of the said Form WRB. 2 with the necessary details.

WATER 104134/2M/2.92

BOREHOLE DATA FORM BDF1

DESCRIPTORS

Locality

Grid Ref.

Map Sheet

Depth b.d. (m)

RWL (construction)(m)

Datum altitude AOD(m)

RWL AOD(avg min)(m)

RWL AOD(avg max)(m)

District

Client

Detailed Geology

G.S Ref No

Borehole No.

CONSTRUCTION

Driller / Contractor

Drilling Method

Start | Drilling Finish

Drilling		diam (mm)	from(m)	to (m)
	1			
	2.			
	3.			

Water Struck (m)			
	1.	rising to	
	2.	rising to	
	3.	rising to	

Casing		diam (mm)	from (m)	to (m)
Plain	1.			
	2.			
Slotted	1.			
	2.			

Casing Material : Plain | Slotted

Slot Size (mm) | Open Area %

Pump: Type | Suction (m b.d)

Filter: quantity (m^3) | d50(mm)

Q	RWL bd	SC	EC		

PERFORMANCE

Driller's Pump Test

☐ hour yield (l/min)

☐ hour drawdown (m)

☐ hour Spec. Cap(l/min/m)

Detailed pump test

Transmissivity (m^2/d)

Storativity x 10^{-}

See file no.

SITING

Geologist

Date

CST Spacing interval (m)

(10 Ωm) Point resistivity

DP: ϱ_1(10 Ωm) m

ϱ_2 m

ϱ_3

Recommended : drill to (m)

PLUMBED DEPTH and WATER LEVEL 1

Date	Depth (m)	W.L. (m)

PLUMBED DEPTH and WATER LEVEL 2.

Date	Depth (m)	W. L. (m)

CHEMISTRY

Date				Date	EC (μ S.)
Ion	mg/l	mg/l	mg/l		
Ca					
Mg					
Na					
K					
Fe					
HCO_3					
SO_4					
Cl					
NO_3					
F					
TDS					
EC					
pH					
T°C					

NOTES

BORED—WELL NO.

GRAVEL PACKED YES/NO LOCATION DISTRICT

T.A.

Depth Ft.	Tested Yield G.P.H.	Static Rest Level	Type Pump Head	Casings, size type and depth from surface	Size Rising Main	Size Rods	Date Constructed	Deposits from surface in feet		
								Surface Deposits and type	Weathered Rock and type	Fresh Rock and type
								From To	From To	From To

MAINTENANCE

Date	Repairs, depth and rest level	Materials	Date	Repairs, depth and rest level	Materials

BORED WELL NO.

MAINTENANCE (*Continued*)

Date	Repairs, depth and rest level	Materials	Date	Repairs, depth and rest level	Materials