# *D:* LESOTHO

## *D.1 INTRODUCTION*

Lesotho is a small (30,648 km$^2$) country completely surrounded by South Africa. The country was visited by Flenner Linn representing Groundwater Consultants during the week of 15-19 April 2002.

## *D.2 BACKGROUND*

### D.2.1 Physiography and Climate

Lesotho can be divided into four major geomorphic regions; namely the mountains or the highlands, the mountain foothills, the lowlands along the Mohokare River Valley and the Senqu River Valley. The country's runoff drains into three major drainage basins; Senqu River basin (20,847km$^2$), Mohokare River Basin (6,890 km$^2$) and Makhaleng River Basin (2,911 km$^2$). The Climate of Lesotho is semi-arid to temperate. The annual precipitation varies from approximately 500 mm along the Senqu Valley to over 1150 mm along the northwestern escarpment of the highlands with 85% of the rainfall occurring between October and April.. The mean annual precipitation is approximately 780 mm.

### D.2.2 Water Resources

The bulk of the water resources of Lesotho are contained in the relatively abundant surface water resources. Groundwater is primarily present in fractured and fractured/porous aquifers of limited extent and relatively low sustainable yields. The total availability of surface water resources is 170 m$^3$/s (DWA), with much of the highland resources in the process of being developed through the Lesotho Highlands Development Authority. These dams are developed primarily as a water transfer scheme for South Africa and represent an important income to the Government of Lesotho. Groundwater, however, continues to play an important role as a supply source to rural villages as well as a component of supply for a majority of the major towns of Lesotho.

### D.2.3 Overall Institutional Framework Of Water Sector

The Department of Rural Water Supply (DRWS), the Water and Sewerage Authority (WASA) and the Department of Water Affairs (DWA) are the key role players in groundwater development in Lesotho, with a very minor level of activity related to some other government and non-governmental organisations.

DRWS is responsible for village water supply, including source development (primarily springs and boreholes), design and construction of infrastructure and operations and maintenance. WASA is a parastatal organisation responsible for water supply to the major towns (including Maseru), and is also responsible for source development, design and construction and operations and maintenance.

The mandate of the Groundwater Division (GWD) is to regulate and assist the other agencies in groundwater assessment, development, and protection. Its field activities generally focus on exploration programmes to locate areas of good groundwater potential, as well as assessment of aquifer contamination (i.e. near Maseru landfill). Good groundwater sources established by GWD are made available to DRWS and WASA for their uses (such as Maputsoe Wellfield). Only rarely, and on specific requests from the government agencies, does DWA undertake groundwater source development directly for supply.

The other governmental and non-governmental agencies play a very limited role in groundwater development. Most of these agencies, such as Micro Projects Management Unit (MMU), LHDA, Irish Aid etc. are involved in some degree of rural development projects, with an increasing level of coordination with DRWS in the water supply component.

### D.2.4 Role of Groundwater in Water Sector

With a population of greater than 2 million, it is estimated that Lesotho will require a total of 5.18 $m^3/s$ of water allowing for all industrial, irrigation and domestic demand (WRMPS, 1996). Groundwater from both springs and boreholes is the predominant source of supply to the rural areas. Groundwater also plays an important role in water supply to many urban centres, either through high capacity boreholes or through boreholes and wellpoints in alluvium. Particularly during the dry seasons and recurrent drought periods, groundwater provides an effective means of water supply. At present only two of the 16 urban centres are supplied entirely through surface water schemes (Maseru and Mafeteng).

## *D.3 GEOLOGICAL AND HYDROGEOLOGICAL FRAMEWORK*

### D.3.1 Geology and Hydrogeology

The geology of Lesotho is characterised by horizontally layered basalts of the highlands (comprising approximately two thirds of the country) and underlying sedimentary formations of the Karoo Sequence. Structure is limited with only very gentle folding and limited faulting. Groundwater occurrence in Lesotho is characterised by a complex heterogeneous aquifer system. Groundwater occurs within fractures and to a lesser degree primary porosity in sedimentary formations and in weathered mantle and fractures in the basalt. The complexity of the groundwater occurrence is reflected in borehole yields that vary from nearly dry boreholes up to 8.0 l/s (blow-out yield) within a few metres. There are four broad categories of aquifers in Lesotho: Sedimentary, Basalt, Dyke-related and Alluvial Aquifers. Average borehole yields and hydrogeological characteristics of these aquifers was assessed on the basis of statistical analysis from selected boreholes of a groundwater database consisting of over 8,000 borehole records (TAMS, 1996).

### D.3.2 Natural Groundwater Quality

Groundwater quality is, in general, good. In terms of major ion chemistry, groundwater can roughly be divided into two major types, a $Ca\text{-}Mg\text{-}HCO_3$ type and a $Na\text{-}HCO_3$ type (Arduino et al, 1994). Both of these are fresh and typical of actively recharging areas. TDS for borehole water averages 260 mg/l and for springs 112 mg/l. The significantly lower TDS average for spring water in comparison to borehole water is due to its lower residence time in the subsurface. Although the vast majority of groundwater in the country is acceptable by international drinking water standards, some local areas have been found to have a high level of fluoride (up to 15 mg/l). The extent and threat to groundwater contamination is, however, an important issue, especially considering the shallow and fractured nature of aquifers.

## *D.4 DATA ACQUISITION*

### D.4.1 Institutional Framework for Data Collection

The institutions and personnel contacted as part of this project are summarised in Table 1.

**Table 1. Institutions and Personnel Contacted in Lesotho**

| COMPONENT | INSTITUTION | PERSONNEL |
|---|---|---|
| General GW Information<br>Monitoring Data (GW)<br>Hydrogeological Mapping | Dept. of Water Affairs Groundwater Division | Mr. J. Lesupi<br>Mr. M. Mojakisane<br>Mr. S. Lerotholi<br>Ms. P. Raliile<br>Mr. T. Matlanyane<br>Mr. T. Mohobane |
| General GW Information | Dept. of Water Affairs Water Resources Division | Mr. P. Nthathakane |
| Monitoring Data (SW) | Dept. of Water Affairs Hydrology Division | Mr. T. Telejane<br>Mr. L. Khaba |
| General GW Information<br>Monitoring Data (GW) | Department of Rural Water Supply | Mr. Khabo<br>Mr. Cheli<br>Mr. Ntepe |
| General GW Information<br>Monitoring Data (GW) | Water and Sewerage Authority | Mr. Paul Lerotholi<br>Ms. M. Makhaba |
| Monitoring Data (rainfall) | Lesotho Meteorological Services | Mr. S. Tsukulu |
| Mapping: topographic, infrastructure, boundaries | Land Surveys and Physical Planning | Mr. Tlaba<br>Mr. Rolf |
| Monitoring Data (SW) | National Environmental Secretariat | Mr. Molapo<br>Ms. B. Puling |
| General GW Information | LHDA | Mr. Tsehlo<br>Mr. Thokoe |
| | Irish Aid | Mr. Leokaoke<br>Ms. C. Hannon |
| | Office of Permanent Secretary | Mr. Tau |

GW: groundwater
SW: surface water

The institution ultimately responsible for hydrogeologic data collection is the Department of Water Affairs (DWA), Groundwater Division. In addition to data they collect through projects or as part of their monitoring activities, all other organisations involved in groundwater development are required to pass hydrogeologic data to DWA. However, in practice, this is rarely the case and is related primarily to the limited enforcement provisions in the existing water law as well as lack of awareness in other organisations.

Data collected by DWA is primarily derived from on-going monitoring activities as well as specific projects implemented within DWA. The other major institution collecting large quantities of hydrogeological data is the Department of Rural Water Supply (DRWS). Generally, DRWS is the most active entity in groundwater development and is responsible for operation and maintenance of the largest number of boreholes in the country. Additionally, DRWS monitors a large number of springs primarily in the highlands areas as part of yield assessment. The parastatal Water and Sewerage Authority (WASA), which is responsible for town water supply, is the second largest user of groundwater in the country. Of the 16 major towns in the country only two are solely supplied through surface water (Maseru and Mafeteng). Groundwater for town water supplies comes from boreholes, well points in river alluvium and springs. Hydrogeologic data collected by WASA include lithologic, construction and yield data for boreholes and wellpoints (usually contained in reports) and abstraction, water level and quality monitoring data. Monitoring data are maintained at the regional offices and only collected by the Maseru headquarters in the case of problems. Community development projects instituted by the Lesotho Highlands Development Agency (LHDA) as part of compensation to communities affected by the construction of dams also often include water supply development. Due to the location of these communities in the highlands, water supply is based on spring catchments. Consultants contracted to design these water supply systems carry out some limited spring flow measurements, with data provided in reports. Finally, some limited groundwater development and hydrogeologic data collection occurs as part of community development projects carried out by NGOs, church organisations and small scale bi-lateral aid projects.

## *D.5 GROUNDWATER INFORMATION SYSTEMS*

### D.5.1 Hardware and software

#### *D.5.1.1 Department of Water Affairs*

Since the Italian Groundwater Project, several hydrogeological databases have been implemented for short periods. Since 2000, the Groundwater Division has decided upon a single, comprehensive database (Hydrocom) that replaces the bulk of existing databases, aside from monitoring data. A summary of the information systems for DWA is presented in Table 2 with details provided in Section 5.2.1.

**Table 2. Summary of DWA Information Systems**

| Database / Source | In use | No. of records | Format | Useable[1] | comments |
|---|---|---|---|---|---|
| Hydrocom | yes | 206 | DBase IV | yes | Can export to a variety of formats; coordinate accuracy is poor at present |
| Monitoring | yes | 122 (S), 89 (B) | Excel 97 | yes | Coordinate accuracy poor at present |
| IGP | no | 1047 | ? | no | Code written in Italian |
| TAMS | no | 8070 | Dbase IV | yes | Many records have only minimal information |
| IGP reports, data | no | unclear | paper | no | Range of data available in IGP reports, papers, etc.; unreferenced library |

[1] Easily useable for the regional hydrogeologic map
S: spring
B: boreholes

#### *D.5.1.2 Department of Rural Water Supply*

DRWS created a national borehole database in the early 1990s, but this is no longer active. Data from that database are available in the TAMs database maintained at DWA (see Section 5.1.1). The data from that database includes borehole depths, original rest water levels, lithologic logs, construction information and estimated yield. Location information is based on location on topographic map sheets. A new Excel spreadsheet is being used to maintain data on DRWS boreholes, both those in use and those no longer equipped. Details of the new database are presented in Table 3.

**Table 3. Summary of DRWS Information System**

| Database / Source | In use | No. of records | Format | Useable[1] | comments |
|---|---|---|---|---|---|
| Groundwater | yes | 2,774 | Excel 97 | yes | Contains only basic information, data is geo-referenced |

[1] Easily useable for the regional hydrogeologic map

### D.5.1.3 Water and Sewerage Authority

WASA primarily monitors daily abstraction volumes from boreholes and wellpoints, and discharges from developed springs (Mapoteng). There is more limited monitoring of water levels in wellfields (Morija, Roma, Butha Buthe). These data are kept in paper format in regional offices. Groundwater chemistry analyses for boreholes and wellfields are conducted monthly. A summary of their groundwater information is provided in Table 4.

**Table 4. Summary of WASA Information Systems**

| Database / Source | In use | No. of records | Format | Useable[1] | comments |
|---|---|---|---|---|---|
| Wellfield | yes | Unknown (data in regional offices) | paper | no | Data includes daily abstraction rates, ad hoc water level data |
| Chemistry | yes | Unknown | Excel 97 | yes | Data from 2000 |
| Chemistry | no | Unknown | paper | no | Pre-2000 data in files |
| GW source development and testing | no | unknown | paper | no | Extensive data from specific groundwater development projects carried out for WASA in reports. |

[1] Easily useable for the regional hydrogeologic map

### D.5.1.4 National Environmental Secretariat

The NES has recently set up a meta-data database covering all databases associated with water (groundwater, surface water), air and sewerage. This database may be useful at the initiation of the hydrogeologic map project to get a recent update on the status and availability of relevant data.

**Table 5. Summary of NES Information System**

| Database / Source | In use | No. of records | Format | Useable[1] | comments |
|---|---|---|---|---|---|
| Environment Metadata | yes | N/A | MS Access | yes | Created in 2001 |

[1] Easily useable for the regional hydrogeologic map

## D.5.2 Data saved

### D.5.2.1 DWA

The Water Law (1978) directs that all drilling must be preceded by application to DWA and issuance of a groundwater development permit. As part of this procedure, all data generated through the groundwater activities must be passed to DWA. However, this rarely occurs and DWA rarely receives data from other government departments or the private sector. However, during a national assessment of the water sector, carried out by TAMS consultants in 1996, a large percentage of existing borehole data was compiled and a simple database created. DWA is still using that database for the old data, but has implemented a new hydrogeologic database which includes recent drilling records. However, continuing collection of data from sources outside of DWA is still largely problematic.

Similar to borehole records, data from test pumping are required to be submitted to DWA. However, test pumping data available in DWA are largely only from DWA projects. Recent data (since 2000) are also maintained in the new hydrogeologic database. Older data are largely in hardcopy form and located in various reports and annual summaries.

In terms of water quality, extensive natural groundwater samples were analysed from all aquifers throughout the country as part of a multi-year groundwater assessment (Italian Groundwater Project) carried out for DWA and completed in 1994. The data were plotted on trilinear diagrams and characteristic groundwater types identified. At present annual samples from the national monitoring network (boreholes and springs) are analysed.

*Existing Databases*

Before the implementation of the Hydrocom database, several databases were variously used in the past. These databases are:

- The Italian Groundwater Project (IGP) database. This database was developed specifically for the data generated through the project. The database code was written in Italian, as was the associated literature. As a result, the database was not used after the project and DWA was not able to export the data to another format.
- TAMS database. This database was created by combining existing DWA borehole records with the national borehole database of the DRWS. A random quality check was carried out on the data prior to compilation. The database is in Dbase IV format and linked to various geologic and other maps created in Arcview. There are 8,070 records in the database.

With the implementation of the Hydrocom database, the data from these databases have yet to be imported. As such, when older data are required, the TAMS database is still occasionally used. Test pumping data are not present in any of the old databases.

*Hydrocom Database*

The Hydrocom Database forms the main hydrogeological database for DWA and is considered to be an effective and user-friendly database. The database was implemented in 2000 and all data generated since then have been entered. All borehole and testing data are entered in the database. It can produce borehole logs and geologic cross sections. The database is maintained on a single PC and is not available via network. As there are relatively small quantities of data generated in DWA, there is no data entry backlog. Data can be exported in various formats.

Visual presentation of data from the database, i.e. borehole logs, stratigraphic sections, is accomplished through a WISH software link. No digital maps are at present used with the data.

*Monitoring Database*

Monitoring data collected from springs and boreholes are maintained in an Excel spreadsheet. Data collected since 1994 are entered in the database, which has a data entry backlog generally of less than 3 months. Data for each borehole or spring are entered on a separate sheet, with one file containing all the data. The temperature, EC, pH, Redox potential, and TDS are measured for all pumping boreholes and springs in addition to water levels (for boreholes) and yield (springs). For non-pumping monitoring boreholes, only water levels are measured.

*Hardware and Software*

Personal computers are used in DWA, which are not networked. In addition to Hydrocom, Excel is the main software used for data graphing and analysis. As mentioned previously, the Hydrocom software is user-friendly and is considered to address the needs of the Groundwater Division.

### *D.5.2.2 Department of Rural Water Supply*

*Groundwater Database*

A new borehole database is in the process of being created using Excel in the Water Resources Office. At present it only includes boreholes equipped with handpumps, but high capacity boreholes equipped with powered pumps will be entered before the end of 2002. It includes both operational as well as non-operational boreholes. This database could be valuable to the regional hydrogeological map due to the large number of boreholes entered. Information on rest water levels, specific capacity and average borehole depth can be derived from the database. Data included in the database are summarised in Table 6.

**Table 6. Summary of Data Fields: DRWS Database**

| Field | Units |
|---|---|
| Village Reference No. | |
| Name | |
| Borehole No. | |
| Coordinates | UTM eastings and northings |
| Date Drilled | Year/Month |
| Depth | meters |
| Static Water Level | meters |
| Dynamic Water Level | meters (at 600 liters/hour) |
| Handpump type | |
| Installation Depth | meters |
| Single or double cylinder | |
| **Periodically monitored data (latest data recorded)** | |
| Date | Year/Month |
| Depth | meters |
| Static Water Level | meters |
| Dynamic Water level | meters (at 600 liters/hour) |

Summary sheets have been also set up that provide average statistics, by District, for the various fields. A total of 2774 borehole records are presently in the database. The distribution of data by district is indicated in Table 7.

**Table 7. Distribution of DRWS Borehole Data by District**

| District | Number of Boreholes |
|---|---|
| Butha Buthe | 130 |
| Leribe | 332 |
| Berea | 864 |
| Maseru | 514 |
| Mafeteng | 585 |
| Mohale's Hoek | 306 |
| Quthing | 31 |
| Thaba Tseka | 12 |
| Mokhotlong | 0 |

The distribution of boreholes in the district largely reflects the predominance of borehole supplies in the lowland districts and the reliance on spring sources in the highland districts.

*Hardware and Software*

DRWS uses basic personal computers which are networked. Software used consists of the basic Microsoft office suite.

#### *D.5.2.3 Water and Sewerage Authority*

The only digital data source at WASA is their water chemistry database (Excel) which is maintained by the senior chemist at the WASA laboratory. Regular water quality testing is only carried out by WASA. Both DWA and DRWS do less regular water analyses and have some data. WASA maintains its own laboratory and samples are analysed from wellfields and wellpoint systems on a monthly basis. Spring sources (i.e. Mapoteng) are not regularly tested. Analysis consists of basic chemistry, microbiology (coliforms), and alkalinity. Metals (iron, manganese and aluminium) are also regularly tested. The data are maintained in an Excel spreadsheet at the laboratory with data from 2000 (when computers were introduced) entered. Data prior to 2000 are kept as paper files in the laboratory offices.

Good quality data are available for specific areas (i.e. wellfields and wellpoint systems) from projects implemented by private consultants for WASA. These data include borehole logs, water strike information, test pumping data and interpretations, water quality analyses and sustainable yield assessments. The data are available in reports (paper format only) for these projects at the WASA offices.

*Hardware and Software*

WASA uses basic personal computers which are networked. Software used consists of the basic Microsoft office suite.

### D.5.3 Quality of Data

#### *D.5.3.1 DWA*

Data quality is relatively variable. In general, older data are more likely to contain errors. The best data is that entered since 2000 in the new database of DWA, since these data were primarily collected by hydrogeologists or trained technicians. One of the major problems in the older data is missing data. In the existing TAMS borehole database, only 4 to 5% of boreholes have yield data and only 1 to 3% have transmissivity or storativity data recorded.

There is no specific QA/QC procedure during data collection or data entry, although ad hoc visual examination of data sheets and data records is undertaken.

#### *D.5.3.2 DRWS*

The new groundwater (borehole) database being developed in DRWS has good quality data. When data are collected, data sheets are filed in both the regional offices as well as the headquarters in Maseru. During data entry into the groundwater database, the two records are compared to identify/ resolve any discrepancies.

#### *D.5.3.3 WASA*

The water chemistry data in the quality database are of good quality. The laboratory follows applicable internationally standardised QA/QC procedures. There is no specific checking of data during entry or of data in the database for errors.

## *D.6 GROUNDWATER MONITORING*

DWA is the government organisation responsible for groundwater monitoring and groundwater resource protection. DWA maintains the only true national monitoring network, although other institutions carry out more limited levels of monitoring. Although these data are legally required to be submitted to DWA, in practice data remain with the organisations that are collecting it.

The National Environmental Secretariat is also becoming involved in monitoring of water quality in the country. At present, the NES relies on data collected from other organisations, but has recently purchased data loggers and will begin some limited monitoring of surface water quality. There are no plans as yet to undertake any groundwater monitoring.

### D.6.1 Monitoring Network and Frequency

#### *D.6.1.1 Department of Water Affairs*

The national monitoring network consists of 122 springs and 89 boreholes located across the country. The objective of monitoring is primarily resource management and protection. Due to the physiographic conditions of the country, the borehole data are logically biased toward the lowland areas. Chemical parameters are measured with field meters and transducers have been used on a limited basis, but to date they have not been considered to be reliable. Samples are collected once a year for laboratory chemical analysis. Data are kept in an Excel spreadsheet in DWA. Table 8 provides a summary of monitoring at DWA.

**Table 8. Summary of DWA Monitoring**

| Type and number of monitored points | Measured Parameters | Frequency | Comments |
|---|---|---|---|
| Boreholes (89) | Water levels, EC, pH, Redox, TDS | Bi-monthly | Some data extends back to 1980's; digital data is available since 1994 |
| Springs (122) | Yield, temp, EC, pH, Redox, TDS | Bi-monthly | Some data extends back to 1980's; digital data is available since 1994 |

Good water level data are available since the mid-1990's but prior to that, considerable data gaps are present.

#### *D.6.1.2 Department of Rural Water Supply*

There is regular programme of spring discharge monitoring at DRWS but no regular programme of borehole monitoring. The objective of monitoring is strictly to assess spring yield for their potential use as water supply sources. Spring flows of monitored springs are measured at least twice a year for those that are being considered for a village water supply source. However, after a spring is developed as a supply source, it is generally not monitored any more. Data are kept in district offices. Borehole water levels, quality and yield are generally only measured once at the completion of the borehole. Data are collected by trained staff from DRWS. Sporadic borehole water levels are available from the last 10 years, while spring flow measurement data extends more than 20 years, although this does not reflect a consistent set of springs. Table 9 provides a summary of monitoring at DRWS.

**Table 9. Summary of DRWS Monitoring**

| Type and number of monitored points | Measured Parameters | Frequency | Comments |
|---|---|---|---|
| Springs (number varies year to year) | yield | Twice yearly | The number of monitored springs varies year to year as some are developed while new ones are included in monitoring. |
| Boreholes (highly variable) | Rest or pumping water level, depth | Very sporadic | No systematic programme of monitoring |

#### *D.6.1.3 Water and Sewerage Authority*

WASA monitors abstraction, water quality and water levels in boreholes it operates. Generally, flow rates from individual boreholes are measured by in-line flow meters, but in some cases total flow from a whole wellfield is monitored. The objective of monitoring is wellfield management, with the primary interest being in maintaining supply quantities and quality. Abstraction is recorded daily in a standard logbook with data kept in regional offices. Water levels are only measured in an ad hoc manner, based on locations where problems have been identified. In some cases, such as Thaba Tseka, borehole water levels were monitored for several years after their commissioning, but once water levels were seen to be generally stabilised, monitoring was discontinued. On-going water level monitoring is being undertaken at Butha Buthe, Morija and Roma Wellfields. Table 10 provides a summary of monitoring at WASA.

**Table 10. Summary of WASA Monitoring**

| Type and number of monitored points | Measured Parameters | Frequency | Comments |
|---|---|---|---|
| Boreholes (number not certain) | Abstraction | Daily | Data recorded in logbooks kept in regional offices |
| | Chemistry | Monthly | Data in database |
| | Water levels | sporadic | More regular monitoring of wellfields; data kept in field offices |

### D.6.2 Quality of Monitoring Data and qa/qc

In general, the quality of the monitoring data in Lesotho is moderate, with major drawbacks being gaps in the record and limited extent of the network. Since the mid-90s there are no significant data gaps. The on-going expansion of the national monitoring network by DWA is improving this situation.

There are no standardised QA/QC plans in relation to monitoring data collection or data storage in any of the monitoring bodies.

## *D.7 HYDROGEOLOGICAL MAPPING*

### D.7.1 Existing Hydrogeological Map

There is one existing hydrogeologic map for Lesotho, completed in 1994. The map is at a scale of 1:300,000 and was created as part of the IGP. The map shows the location of all boreholes as well as major springs and considerable information on surface flow. Associated text describing key aspects of the hydrogeology are presented surrounding the map.

Graphs showing average river discharges and baseflow per month are indicated for selected stations. Trilinear diagrams with project chemistry data and interpretations are provided. Selected boreholes have small tables connected which include number, EC and temperature. Exploitable yield is indicated by symbol size. A typical example of a local groundwater flow system is protrayed in an inset map along with a typical lithostratigraphic cross section. A regional cross section showing the relationship of the major formations is also provided.

### D.7.2 Derivative maps

Derivative maps are presented on the main map showing rainfall (mean, effective precipitation, rainfall coefficient), the planned Lesotho Highlands Water Scheme and a groundwater contour map for the Maputsoe area.

### D.7.3 Water Resources Management: Policy and Strategies

In 1996 a water sector review project was completed (TAMS, 1996) which included a detailed review of groundwater. As part of this project, aquifer maps were developed. In contrast to the National Hydrogeologic Map (Section 7.1) the aquifers were defined based on the major stratigraphic units and their extent was determined based not only on the outcrop area, but also where they would be present at a given depth range in the subsurface, beneath other units.

### D.7.4 Classification and Legend of Maps

The hydrogeological map contains a detailed legend and descriptive text and graphs which include:

1. Exploitable yield.
2. Aquifer lithologies.
3. Groundwater hydrochemical characteristics.
4. Flow rates of major springs and spring lines.
5. Location of thermal springs
6. Surface water features and baseflow information

The groundwater development pattern is shown as filled polygons in light colours with symbols (points and lines) and hatch patterns signifying different aspects. The details are tabulated in Table 11.

**Table 11: Hydrogeological Map Legend Summary**

| LEGEND | DETAILS OF LEGEND |
|---|---|
| **Aquifers**<br>Aquifer extent defined by geology. | a) porous generally unconsolidated formations<br>b) jointed rock<br>c) fissured and jointed rock<br>d) fissured, bedded and intergranular rock<br>lithology indicated by hatch pattern within hydrogeologic units; description gives general potential and hydraulic characteristics of each unit |
| **Springs** | Size of symbol indicates discharge: 0.1<0.5 l/s, 0.5-4 l/s; thermal spring denoted by color |
| **Linear Springs** | Base flow measured from linear spring lines; symbol size indicates discharge: 5<50 l/s, 50<200 l/s, 200<1000 l/s, 1000<2000 l/s; EC shown connected to symbol |
| **Surface Water** | • Rivers |

| LEGEND | DETAILS OF LEGEND |
| --- | --- |
| | • Main water divide<br>• Secondary water divide<br>• Fresh water lake<br>• Existing dam (capacity indicated)<br>• Water transfer and delivery tunnels<br>Hydrometric stations indicated with station code, mean annual discharge, minimum discharge and catchment area in attached box |
| **Meteorological Stations** | Type indicated by symbol: rainfall, climate, agrometeorological, synoptic |
| **Borehole Yield**<br>"Exploitable yield" (not specifically defined on map) | Yield range indicated by size of symbol: dry, 0.1<0.3 l/s, 0.3<1 l/s, 1-4+ l/s |
| **Borehole Details**<br>Indicated for selected boreholes | Small table provides code, EC and temperature. |
| **Well Point Pumping Station** | Symbol indicates abstraction range: 50-1,000 $m^3$/d, 15,000-25,000 $m^3$/d |
| **Captured Spring** | Mean annual discharge of 0.5-4 l/s |
| **Other Symbols** | • geologic contact; grey line<br>• Fault; thick black solid, downthrow indicated<br>• Volcanic neck, diatreme: symbol<br>• Line of cross section |
| **Topographic symbols** | Topographic symbols include:<br>• International and district boundaries;<br>• Topographic contours (500 m interval)<br>• Main towns, villages<br>• Main roads, track, minor track |

Details of the aquifer definitions as used for the maps created as part of the Water Resources Management Project (TAMS, 1996) are presented in Table 12.

**Table 12: Aquifer Maps**

| LEGEND | DETAILS OF LEGEND |
| --- | --- |
| **Aquifers** | Based on existing stratigraphic divisions:<br>• Stormberg (basalt)<br>• Clarens (sandstone)<br>• Elliot (sandstone and mudstone)<br>• Molteno (primarily sandstone, minor mudstone)<br>• Burgersdorp (primarily mudstone, minor sandstone)<br>• Dike associated aquifers |
| **Aquifer Extents** | Aquifer extents were defined and mapped based on where they would be at least 20 meters thick (where outcropping) or where their base would be less than 120 meters below ground (in the subsurface). Dike aquifers strictly based on mapped dikes. |

### D.7.5 Existing Geological Maps

Geological maps of the country are produced by the Department of Mines and Geology. All the maps are available in printed form. The maps date from 1982 and have never been updated. A summary of the geologic mapping is presented in Table 13.

**Table 13: Summary of Available Geologic Maps**

| Map | Scale | Number of maps |
| --- | --- | --- |
| National Geologic Map | 1:250,00 | 2 |
| Geological maps | 1:100,000 | 4 |
| Geologic maps | 1:50,000 | 12 |

The national geologic map was digitised as a shape file in Arcview as part of the TAMs (1996) project and is available with DWA.

### D.7.6 Existing Topographic Mapping

The Department of Lands, Surveys and Physical Planning (LSPP) maintains and sells national and local topographic and other maps. The national map is at 1:250,000 with a map series at 1:50,000. They were last updated in 1994. The only digital versions of maps available are line maps of the major towns at 1:2,500.

## *D.8 DATA AVAILABLE FOR A SADC HYDROGEOLOGICAL MAP*

Based on the existing data sets and mapping, Table 14 summarises the data available for specific legend items that may be desirable to portray on a regional hydrogeologic map.

**Table 14: Hydrogeological Map Legend Summary**

| LEGEND | SOURCE DATA | PROCESSED DATA | NOT AVAILABLE |
|---|---|---|---|
| **Aquifers**<br>Aquifer type and extent based on geology | National geology in digital form (Arcview 3.2) with DWA (TAMS) | | |
| **Springs** | Spring locations, discharges, EC in DWA monitoring database (Excel) | | |
| **Linear Springs** | | Data only on hydrogeological map | |
| **Surface Water** | Raw flow data available (hydata format) with DWA<br>Divides in digital (Arcview 3.2) format with DWA (TAMS)<br>Digital reservoir extents and infrastructure Highlands project with DWA, LHDA | | |
| **Meteorological Stations** | Locations and rainfall data available in Glycom database with LMS | | |
| **Borehole Yield** | Data for 206 boreholes with DWA Dbase IV format; some sporadic yield data in TAMS database (Dbase IV) | | Data used in map only in reports |
| **Borehole Details** | EC and SWL data for 122 boreholes in DWA monitoring database (Excel); SWL for up to 2774 boreholes in DRWS database (Excel); Additional EC | | |
| **Well Point Pumping Station** | Abstraction rates and locations in WASA reports (paper) | | |
| **Captured Spring** | Yield rates in DRWS files in regional offices (paper) | | |
| **Other Symbols** | Major infrastructure, towns, boundaries available with DWA (TAMS) in Arcview 3.2 format. | | |
| **Topography** | Topographic maps only in paper format at present. | | |

**Table 15: Aquifer Extent Mapping**

| LEGEND | SOURCE DATA | PROCESSED DATA | NOT AVAILABLE |
|---|---|---|---|
| **Aquifers**<br>Aquifer maps (each as individual shape file | (Arcview 3.2) with DWA (TAMS) | | |

## *D.9 COMMITMENTS AND CONCERNS*

### D.9.1 Commitments on Contribution to the Regional Mapping Project

#### *D.9.1.1 Department of the Water Affairs*

Manpower in the Division of Hydrogeology is very limited, but some assistance in accessing and compiling data could be provided.

#### *D.9.1.2 Department of Lands Surveys and Physical Planning*

The LSPP would like to be kept aware of the regional map activities and could assist with manpower and computer facilities. Definite commitments would only be possible when a time frame and terms of reference are defined.

### D.9.2 Concerns

Water sector personnel commonly expressed the opinion that although the main map may be of a large scale, small scale insets or separate maps would be required so that a country of Lesotho's size is effectively portrayed.

Additionally, members of DWA expressed the interest that the development of the regional hydrogeologic map could also form a platform for improving data sharing between country. In particular, there was concern that larger countries may not feel compelled to share data with smaller neighbours. In some cases, mutual trust is not developed between water sector personnel between adjacent countries and hinders control of shared resources.

There was also the concern that as transboundary aquifer commissions are developed independently or as part of river commissions, they should not be piecemeal. An example was given of the proliferation of different commissions responsible for various aspects of the Orange River system.