Development of Groundwater Management Tools, Guidelines and Strategies for the Southern Province and the City of Lusaka, Zambia

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1 Introduction

The on-going Project "Groundwater Resources for Southern Province" (GReSP) commenced in May 2005 with the overall objectives to facilitate an effective groundwater resource planning and management and to strengthen the capacities in the Zambian water sector. The project was formulated by the Department of Water Affairs (DWA), under the Ministry of Energy and Water Development (MEWD) for the Republic of Zambia and was implemented under the framework of the German-Zambian "Water Sector Reform Program" supported by the Federal Ministry for Economic Cooperation and Development (BMZ) of the Federal Republic of Germany. The overall supervision of GReSP is the responsibility of MEWD through DWA. The Federal Institute for Geosciences and Natural Resources (BGR) provides technical support.

Phase I of this project, which officially ended in 2009 focussed on the assessment of groundwater resources of Southern Province but also included preparatory works for the groundwater resources study of the Lusaka region. The emphasis of the second phase of GReSP is on offering support in achieving sustainable groundwater development and protection as well as implementing Integrated Water Resources Management (IWRM) activities in the surroundings of the Capital of Zambia. The project areas include tributaries to the Zambezi and to Lake Kariba in Southern Province as well as the Lower Kafue, Mwembeshi and Chongwe sub-catchments. These catchments are part of Lusaka, Central and Southern provinces. The project scope and implementation is considered in line with existing national policies and development plans in the water sector as well as with the Water Resources Management Act (GRZ 2011b).

2 Hydrogeological Overview of the Study Areas

The study covers the largely rural areas of Southern Province and the Lower Kafue, Chongwe and Mwembeshi sub-catchments located within Central and Lusaka Province as well as the urban and peri-urban areas of Lusaka.

2.1 Southern Province

The Southern Province has a share in two of Zambia's major water courses, the Zambezi River including the Kariba reservoir at its southern and eastern boundaries and the Kafue River to its northern margins. But since distances and differences in elevation are large surface water sources cannot economically be distributed to the central areas of the Province. The discharge of most tributary rivers ceases during the prolonged dry periods. During this time, the large majority of the population of the Southern Province depends on water supply from small dams or groundwater. Groundwater constitutes the only reliable and safe water source available throughout the year, especially during periods of drought. Groundwater is stored underground, often available at much closer proximity compared to surface water sources; it is naturally protected against evaporation and immediate pollution and is often of such quality that no treatment is needed prior to its consumption.

About two thirds of the Province is made up of hard rocks including the Neoproterozoic rocks of the Katanga Supergroup and Mesoproterozoic rocks allocated to Basement or the Muva Supergroup. Along the escarpment at the southern and eastern margins of the Province, clastic sedimentary rocks and basalt of the Karoo Supergroup are exposed. The remaining third is predominantly covered by unconsolidated deposits that host potential porous aquifers (Figure 1). Most of the rock formations are characterised as heterogeneous, i.e. their potential to host and produce groundwater is extremely variable.

Based on a comprehensive statistical analysis of assembled hydrogeological data it was concluded that the potential of groundwater in the Province is overall limited (Bäumle et al. 2007). This finding is generally in line with the results of the national inventory of groundwater resources conducted by Chenov (1978). In some areas, namely regions within the Karoo sandstones and basalts, the alluvial deposits of the Kafue Flats and the calc-silicate rocks in the Mazabuka/Magoye area, groundwater conditions are more favourable. The groundwater quality is overall good although concerns must be raised over microbiological contamination near major settlements due to poor sanitary conditions. In general, potential groundwater production from aquifers is regarded insufficient for larger development such as irrigation schemes. Despite these limitations extractable groundwater volumes are sufficient to assure long-term water supply to rural areas and smaller settlements if used sustainably.

2.2 Lusaka

The hydrogeological situation in the Lusaka area has been described by various authors including Lambert (1962), von Hoyer at al. (1978), von Hoyer & Schmidt (1980), Maseka (1994), Nkhuwa (1996), GIBB (1999) and Mpamba (2008). A current comprehensive literature review is included in the report by Bäumle & Kang'omba (2009).

The Lusaka area is covered by strongly folded overthrusted metasedimentary rocks of Katanga (Neoproterozoic) age which have been intruded by granitic and basic bodies. The carbonate rocks cover an area of about 1600 km^2. The main aquifer is hosted by the marbles of the Lusaka Dolomite Formation which is known to form a terrain undergoing recent and active karstification (Figure 2). Subordinate aquifers are developed in the crystalline limestone and dolomite of the Cheta Formation located to the north, west and south of the Lusaka Dolomite aquifer. Local and minor aquifers are hosted by schists, psammites and quartzites of the Cheta and Chunga Formations and alluvial deposits.

The very productive, karstic aquifers are characterised by shallow water tables and a lack of a protective cover, and are therefore considered very vulnerable to pollution. Industrial effluents and improper disposal of sewage and waste constitute major risks for groundwater quality. According to the National Water and Sanitation Council (NWASCO, 2010), the water supply coverage by the Commercial Utility, the Lusaka Water and Sewerage Company (LWSC) is 70%. The sanitation coverage is only 19%.

In 2008/2009, the total water production for the City of Lusaka by the LWSC reached almost 260,000 m^3/d or 95 Mio m^3/a. Currently, the LWSC pumps up to 160,000 m^3/d (pers. comm. with LWSC) from the local groundwater systems whereas the remaining water is sourced from the Kafue river situated about 40 km south of the City. KRI Int. Corp. (2008) estimated the expected water demand by the year 2030 at 640,000 m^3/d corresponding to 234 Mio m^3/a.

A survey covering the major water abstracting industries and commercial farms showed that industries in and around Lusaka mainly use groundwater and abstract approximately 4.5 Mio m^3/a while commercial farms use both surface and groundwater for irrigation (Mayerhofer et al. 2010). In the Chilongolo and Mwembeshi sub-catchments, groundwater is the predominant source (about 80%) for irrigation water. The total groundwater abstraction for irrigation purposes in the Lusaka region totals about 25 Mio m^3/a according to the survey results carried out in 2010.

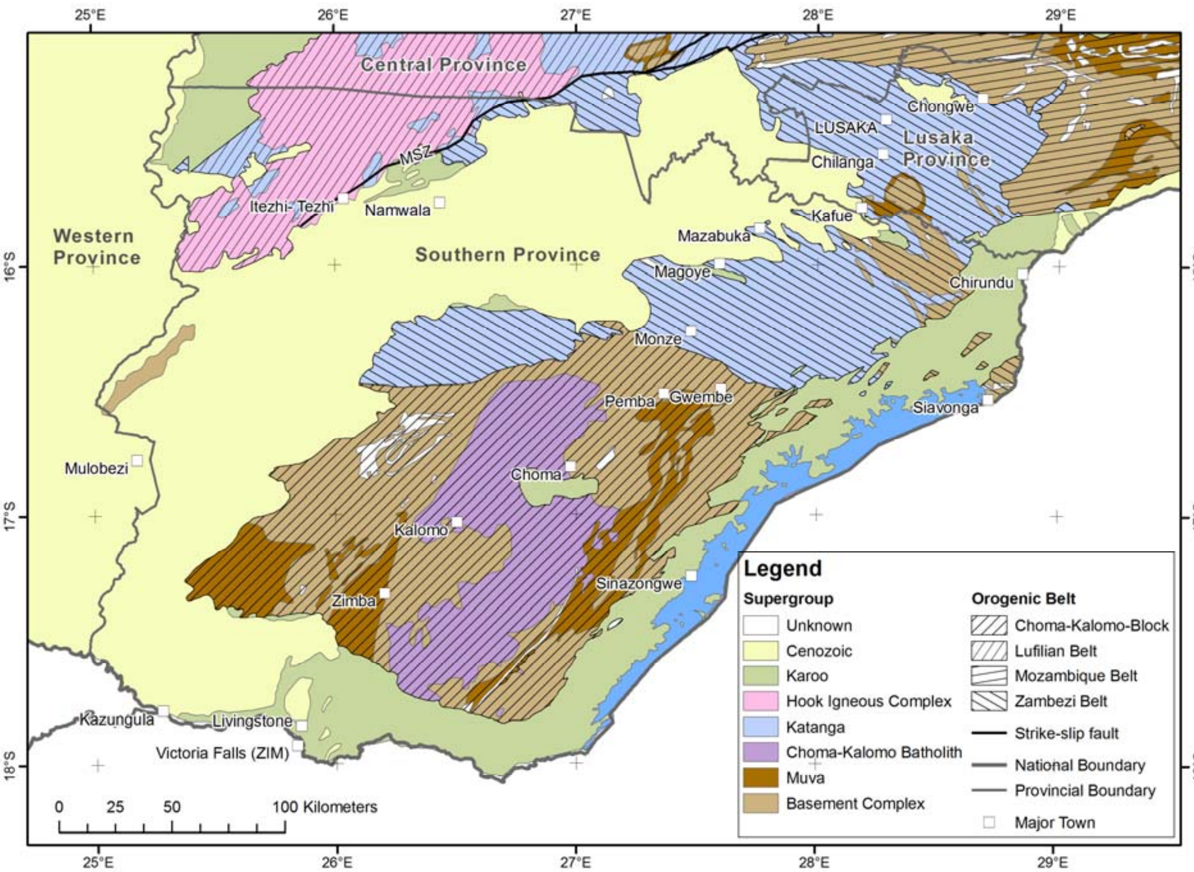


Figure 1 Geological overview of Southern Province and the Lusaka region

Assessments of water quality were recently carried out in two larger campaigns in 2008 and 2010 as well as in a monthly monitoring scheme (Museteka & Bäumle 2009, Nick et al. 2011). The results from the microbiological analyses showed that only one third of sampled boreholes stay below the Total Coliform limit of MPN=20 requested by the Zambian Drinking Water Standard (ZDWS), whereas elevated concentrations of Escherichia coli occur much less frequent. Nitrate levels were found to be very high in many boreholes and often exceeded the ZDWS limit of 44 mg/L. While the large production boreholes of LWSC exhibit nitrate concentrations below the ZDWS, boreholes for the local supply of peri-urban high-density settlement areas showed considerably higher values, with some exceeding 100 mg/L. Under the prevailing pH (median = 7.0, min = 5.8, max = 8.0) in the calcareous geological environment, potentially toxic heavy metals like lead, cadmium or arsenic as well as iron or manganese tend to form hydroxy- and carbonate complexes which are insoluble and can therefore not be found in the water. Thus, concentrations of these cations are far below the WHO limit in all samples analyzed.

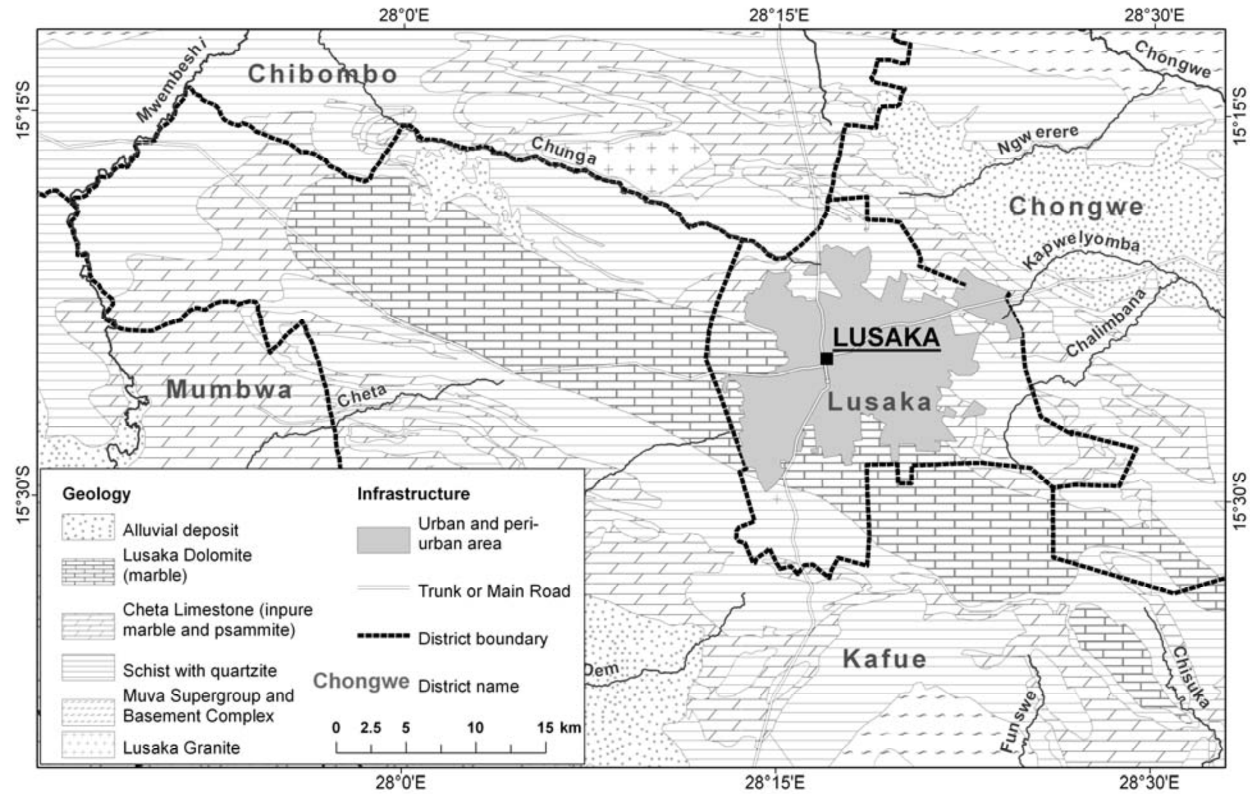


Figure 2 Detailed geology of the Lusaka area

3 Steps in Developing Groundwater Management

Several components are considered essential for a successful implementation of good groundwater management practices in the study areas (Figure 3). The components comprise the development of management tools for planners, groundwater investigations and analysis, capacity building related to groundwater management and activities to raise awareness (advisory) and to advice on the use, relevance and management of groundwater resources.

Comprehensive groundwater investigations are carried out in the Lusaka area incorporating findings from the re-evaluation of groundwater recharge, assessment of surface and groundwater balance, the estimate of groundwater potential of various aquifers, the determining of the groundwater flow system and groundwater - surface water interactions, the assessment of groundwater quality and the susceptibility of the host rock to potential contamination as well as scenario simulations using groundwater modelling.

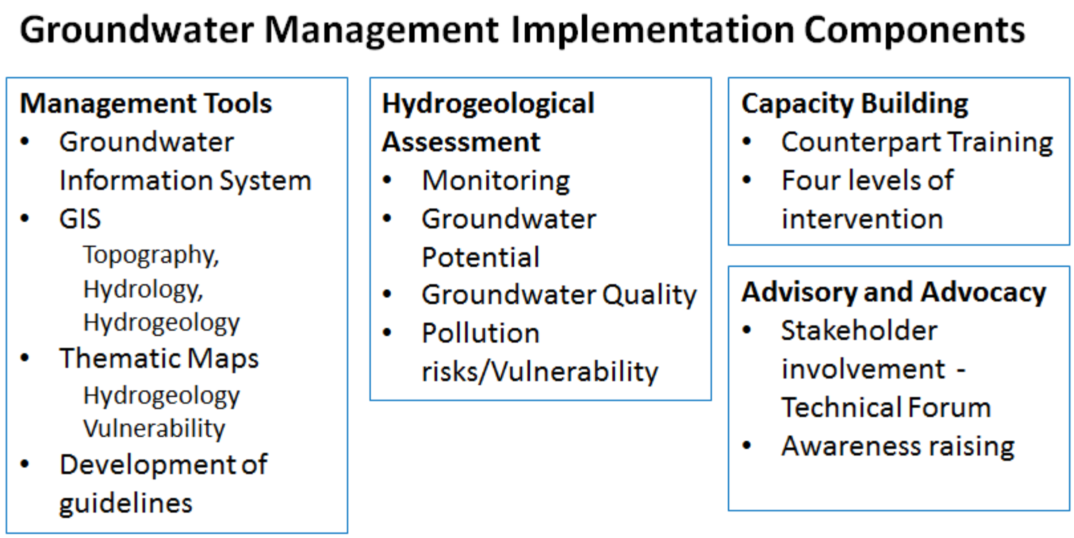


Figure 3 Groundwater management components implemented under GReSP.

The program currently pursues six (6) outputs that were developed during inception of Phase II (GRZ 2011a). These are:

1. Groundwater information system is established and regularly updated.
2. The amount of groundwater that can be sustainably abstracted is quantified.
3. Groundwater quality status and its vulnerability to pollution are established.
4. Institution and Human resource capacity is built in groundwater management.
5. Collaboration efforts and awareness building for groundwater advocacy are promoted and implemented.
6. Sustainable groundwater management plans are adopted and promoted for implementation by relevant planning authorities.

The products of the project are aimed at city planners, relevant governmental institutions and water supply and sanitation utilities. In the Lusaka context these include the DWA and possibly the new Water Resources Management Authority as the responsible governmental department for water resource management, Lusaka City Council (LCC) as the town planning institution in Lusaka District, the LWSC as the commercial utility using groundwater for water supply and being responsible for sanitation services delivery, thus depending on its protection from pollution, and ZEMA as the environmental protection watchdog. The institutions should be enabled to use the thematic maps and recommendations to better plan infrastructural developments (e.g. new industrial areas or landfills), to more efficiently explore new water supply sources or to enhance the scientific basis on which environmental impact assessments are carried out.

3.1 Development of a groundwater information system

The groundwater information system consists of a:

1. Groundwater database

2. Geographic Information System (GIS) related to water resources

All available information of groundwater points such as boreholes, open wells, springs and unsuccessful (dry) holes in the project areas was collected and incorporated in a national groundwater database. The database combines data from the whole of Lusaka Province and Central Province as well as Southern Province with currently over 7,500 water points.

The groundwater database was established using the commercial software package GeODin® with special adaptations made for Zambian requirements. The type of information stored comprises comprehensive and detailed technical information on groundwater hydraulics, borehole design, as well as geology and groundwater quality as summarised in Table 1.

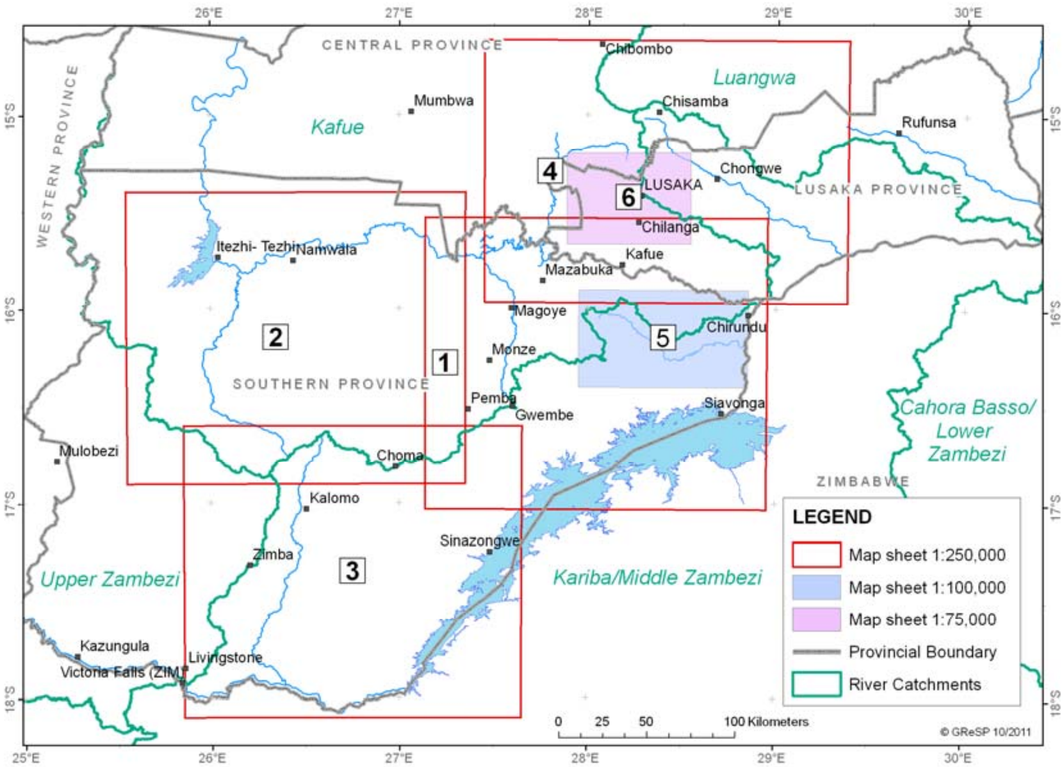
Table 1 Type of information held in the GeODin database

1. General information	
Location	Water Point name and number, geographic coordinates, elevation, location with regard to drainage catchment, location with regard to administrative/political unit
Drilling	Drilling/completion dates, drilling contractor, water point funding
Status	Type and purpose of water point, usage
2. Groundwater hydraulics	
Aquifer	Borehole and aquifer depth and thickness, Aquifer type, static water levels (single values or time-series)
Hydraulic testing	Test pumping data and summary, hydraulic characteristics (yield, permeability)
3. Borehole Profile	
Geology	Lithological and stratigraphic log
Design	Position of casing, screens, etc.
4. Groundwater quality	
Chemistry	Water analyses results, comparisons to drinking water standards, water quality classification

The GIS includes individual digital map layers containing topographic, geological, hydrological and groundwater related information. The scale of the digitised maps varies from large-scale (1:50,000) to national scale (approx. 1:1 million). The GIS layers can be combined for the compilation of various thematic maps or applied to further geo-related applications and analysis.

3.2 Thematic mapping

The hydrogeological map series produced include four sheets at scales 1:250,000, one sheet at scale 1:100,000 (Lusitu Catchment) and one at 1:75,000 (Lusaka and surroundings). Additionally, a groundwater vulnerability map at scale 1:75.000 was developed for Lusaka (Figure 4). The maps of Southern Province were published during phase I of the project (Bäumle et al. 2007) whereas the remaining maps are expected to go in print by the end of 2011.



1	N. Kariba Lake & Kafue Gorge	2	Kafue Flats & Southern Tributaries
3	S. Kariba Lake & Kalomo	4	Mwembeshi & Chongwe Catchments (in prep.)
5	Lusitu River	6	Lusaka and surroundings (in prep.)

Figure 4 Available hydrogeological map sheets. Coverage of vulnerability map of Lusaka is identical to map area 6.

The hydrogeological maps are designed to display groundwater features at catchment and sub-catchment scale. The contents of the maps comprise general topographic features, hydrography including rivers, wetlands and catchment boundaries as well as lithology and geological structures. Groundwater specific features displayed on the maps comprise water points, extent and potential of groundwater systems, groundwater elevation contours and direction of groundwater flow.

The 1:75,000 vulnerability map of Lusaka and surroundings shows different classes (levels) of groundwater vulnerability, i.e. its sensitivity to pollution. It gives assistance in identifying areas which need protection measures. For orientation purpose, infrastructure and groundwater relevant features have been incorporated in the map. It also shows zones with increased risks of groundwater quality deterioration such as industrial and agricultural areas or areas with poor sanitation conditions.

Excerpts of the developed hydrogeological and vulnerability maps are shown in Figure 5 and Figure 6, respectively.

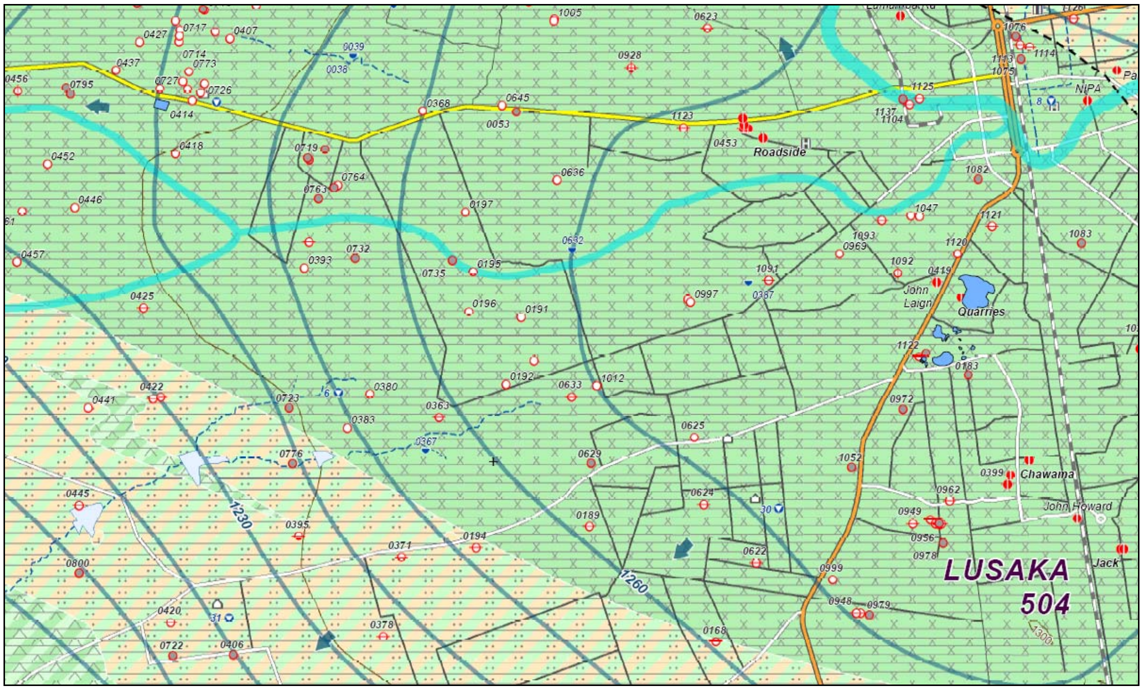


Figure 5 Excerpt of the draft hydrogeological map of Lusaka and surroundings showing catchment boundaries (cyan lines), groundwater contours (blue lines) and regional flow direction (blue arrows)

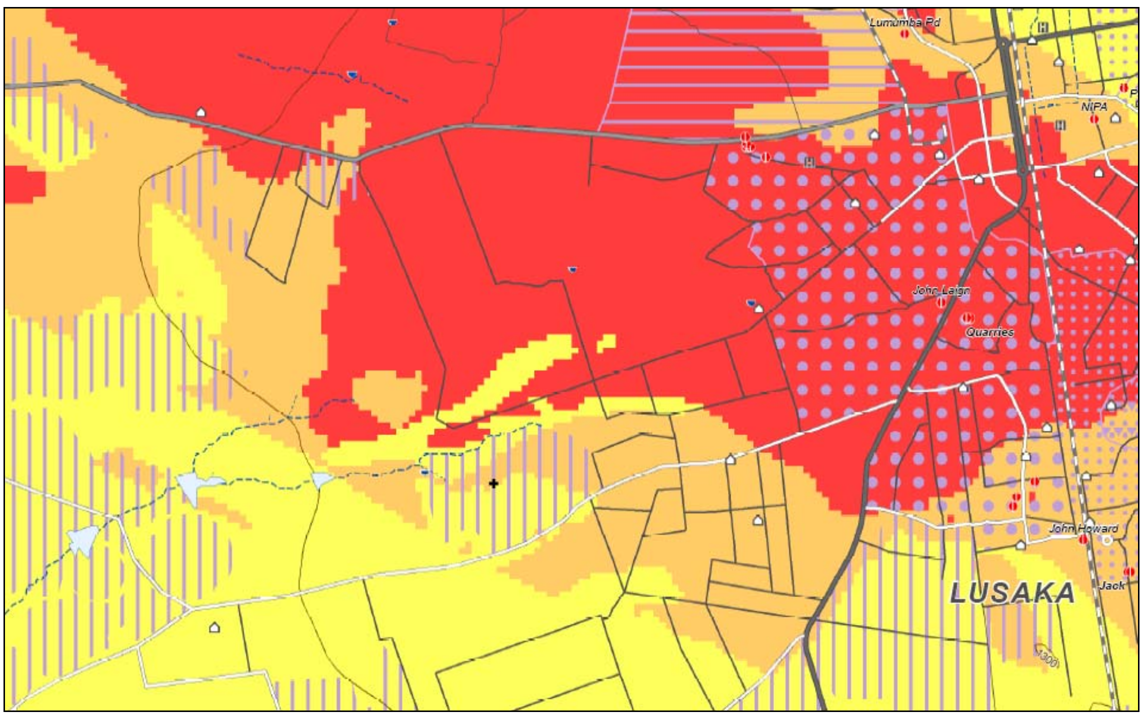


Figure 6 Excerpt of the draft vulnerability map of Lusaka and surroundings showing the various degrees of vulnerability of groundwater (colour scheme), and zones with increased risks of groundwater quality deterioration (grey dots and hatched lines)

3.3 Capacity Building

Capacity building is one of the main activities being implemented in the GReSP project. Capacity building measures carried out by the project focus on enhancing skills in hydrogeological investigations, groundwater information management and hydrochemical methods (Tena & Nick 2010). Measures implemented by the project can be grouped in four different levels as indicated in Table 2.

Table 2 Various levels of capacity building interventions

Level	Type of Training Measure	Implementation
1	On-the-job Training	Continuous since project start
2	Tailor-made, short-term training courses(in-house)	Regularly since project start
3	Support to national training course at national education centre	Pilot Course at UNZA, Aug – Oct 2011
4	Bursaries (MSc Studies in hydrogeology) at international universities	Two bursaries granted starting Oct. 2011

The designed plan is expected to improve the knowledge and skills with regard to groundwater management within the counterpart institution as well as stakeholders, where information for groundwater management is gathered and evaluated.

3.4 Groundwater Advisory and Awareness Raising

It is understood that successful implementation of groundwater management practices can only be achieved in close cooperation with other institutions through avenues such as the established Technical Forum on groundwater and the Water Sector Advisory Group (Water-SAG). The sustainable use and protection of the groundwater resources are continuously advocated for during these and other stakeholder meetings.

LCC is the local authority for the Lusaka district and is supervised and financed by the Ministry of Local Government, Housing, Early Education and Environmental Protection (MLGHEEEP). LWSC is the commercial utility providing water supply and sanitation services to the City of Lusaka. LCC is the sole shareholder of LWSC. These institutions benefit from trainings, meetings and workshops in which the relevance, content and application of the products (e.g. thematic maps) are explained and jointly discussed.

Awareness raising for groundwater as a precious resource is done during World Days (e.g. World Water Day), national celebrations and fairs (Agricultural Show, Trade Fair) to the general public or by theatre performances on special occasions.

4 Conclusions

A multi-fold approach is proposed and has been effected during the course of this project in order to successfully implement good water resources management practices in the study areas. The different components of implementation include:

- Generating groundwater management tools such as the groundwater database and hydrogeological maps under the governmental institutions responsible for water resources management;
- Steadily increase the knowledge base and understanding of the exploited groundwater system by means of comprehensive hydrogeological studies;
- Strengthening the capacities of staff in the fields of hydrogeology, water chemistry and resources planning;
- Establishing a close cooperation with all stakeholders in the sector through avenues such as the established Technical Forum on groundwater and the Water SAG;
- Raising awareness of the importance of protecting groundwater.

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