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Ministry of Energy and Water Development

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BGR

Development of a Groundwater Information & Management Program for the Lusaka Groundwater Systems

REPORT NO. 4

Survey on Commercial Farming and Major Industries

- Land Use, Groundwater Abstraction & Potential Pollution Sources -

Christoph Mayerhofer, Beauty Shamboko-Mbale & Rockie Mweene

Lusaka, October 2010

Development of a Groundwater Information & Management Program for the Lusaka Groundwater Systems

Survey on Commercial Farming and Major Industries - Land Use, Groundwater Abstraction & Potential Pollution Sources -

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

ACRONYMS AND ABBREVIATIONS

BGR	Bundesanstalt für Geowissenschaften und Rohstoffe (Federal Institute for Geosciences and Natural Resources)
DWA	Department of Water Affairs
EC	Electrical conductivity
ECZ	Environmental Council of Zambia
EPA	Environmental Protection Agency (United States)
FAO	Food and Agriculture Organization of the United Nations
FNDP	Fifth National Development Plan
GIS	Geographic Information System
JICA	Japan International Co-operation Agency
LWSC	Lusaka Water and Sewerage Company
m bgs	Meters below ground surface
MACO	Ministry of Agriculture and Cooperatives
MPN	Most Probable Number
TSB	Technical Service Branch
ZNF	Zambian National Farmers Union

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1 Introduction

1.1 Project Background

The project “Groundwater Resources for Southern Province” (GReSP) is carried out as a technical co-operation in the water sector between the Governments of the Republic of Zambia and the Federal Republic of Germany. Aimed at supporting practices of Integrated Water Resources Management the project is being implemented by the Department of Water Affairs (DWA), Ministry of Energy and Water Development, Zambia with assistance from the Federal Institute for Geosciences and Natural Resources (BGR), Germany. During the first phase, from 2005 to 2009, along with hydrogeological field investigations, a comprehensive groundwater information system for the Southern Province was developed at the Department of Water Affairs. This information system includes a groundwater database, established using the software package GeODin®, and a Geographic Information System (GIS), using ESRI® ArcGIS, for hydrogeological mapping. The project was aimed at strengthening the capacities of the Zambian water sector through the regulation of groundwater development, use and management in the Province. Phase 2, with emphasis on the Lusaka groundwater systems, started on January 1st 2010 and is covering a three-year period ending in December 2012. The size of the project area in phase 2 is about 2800 km². The goal of this current phase is the development of a groundwater management strategy for the highly vulnerable groundwater resources of the wider Lusaka area as well as the extension of the existing groundwater information system (Figure 1). It is the vision of Zambia, mentioned in the Fifth National Development Plan (FNDP), to see that by 2030 people have access to adequate safe drinking water and sanitation, and that water is utilized in an efficient and sustainable manner. In order to ensure sustainable development and the supply of Zambia’s water resources, the increasing demand of groundwater in agriculture, commercial and domestic use needs to be regulated. Therefore, to secure the management and use of water resources in a sustainable way, an effective groundwater information system and a countrywide assessment of the available quantities and qualities of groundwater are required.

1.2 Objectives

For a comprehensive assessment of the current status of groundwater use the DWA relies on information of the major groundwater users including commercial farming and industries in the Lusaka area. The main objectives of the whole project are a better understanding of the groundwater situation in Lusaka, to optimize the use of groundwater in the region and to facilitate a safe and sustainable abstraction of this resource. This survey aims at making a significant contribution towards the groundwater balance and recharge assessment to provide a base for future groundwater modeling. In order to determine the actual groundwater recharge of a specific area, detailed information on climate, soil and land use, especially from large scale cultivated areas, is mandatory. The information on commercial agriculture will be an input for the groundwater balance and recharge assessment. Furthermore, this report reviews the abstraction of groundwater from the major water users in the project area. An input for the water quality assessment will provide information on potential pollution sources at commercial farming and major industries (Figure 1).

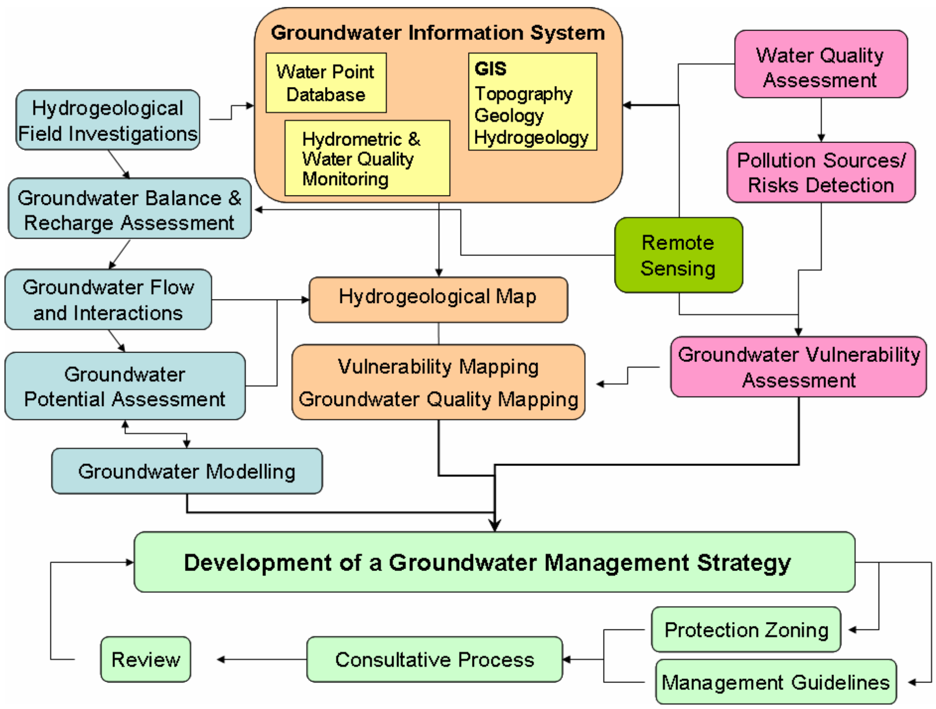

Figure 1 Simplified flowchart showing the investigation program of the project (Bäumle & Kang'omba 2009)

This survey addresses two main topics, namely:

- Information on land use, irrigation and potential pollution risks from large scale commercial farmers in the Lusaka area
- Water usage as well as the handling of hazardous substances and effluents by major industries in Lusaka

1.3 Investigation Program & Methods

For a more detailed and differentiated determination of the groundwater balance a questionnaire-based survey was conducted. Prior to the actual survey, The National Farmers Union and The Environmental Council of Zambia (ECZ) were approached to obtain information on the location and the contact details of potential interview partners for this study. The provided information contributed to a more effective completion of this survey. The field work was carried out during April and May 2010 when a total of 43 commercial agricultural farmers and 53 industrial enterprises were interviewed.

The assessment on farming targeted large scale commercial farmers who mainly grow cash crops. The survey helped to obtain the following data:

- The size of cultivated lands in the project area
- The size of irrigated areas
- Type of crop, crop rotation and growth period
- Surface coverage in dry season
- Irrigation practices
- Water demand for irrigation purposes
- Type of water source
- Application of fertilizer and pesticides
- Sanitation system
- Distribution of the farming areas within the project area

The questionnaire used for interviewing commercial farmers is shown in Appendix 1.

The assessment of industries targeted different types of major industries to determine the main water users as well as their handling of effluents and substances potentially hazardous to water. This part of the survey aimed at defining the following information:

- Type of industry
- Production rate
- Amount of water used in production
- Water sources

- Treatment process of effluents
- Sanitation system
- Handling of potentially hazardous substances necessary for production
- Handling of spillage and by-products during production

Appendix 2 shows the questionnaire used for industries.

Further, the water level (in meter below ground surface, bgs) was measured with a dip-meter at all boreholes with suitable access. This information, along with the GPS coordinates of each borehole, was used to extend the existing water point database GeODin®. For a better orientation in the field, a satellite image (Landsat, dated Feb. 22, 2002) was used in order to locate the farms within the project area.

2 Commercial Agriculture

2.1 Agricultural Lands in the Project Area

During the investigation program 43 commercial farmers, listed in Appendix 3, were interviewed. The survey revealed that these 43 farms cover a total agricultural area of 12,830 ha, whereas the total irrigated area is 6,150 ha. These numbers do not include small-scale irrigation farming. Thus, almost half of the area available for cultivation is under irrigation. Looking at the total project area of ca. 2,800 km^2, 4.6% is used for cultivation and 2.2% is under irrigation.

Figure 2 shows the agricultural lands around Lusaka investigated by remote sensing (Hahne 2010). Some of the cultivated areas are located north of “mile ten”, south of Chilanga, in the eastern part of Chalimbana catchment or in the Kafue Flats catchment. Those areas are outside of the project area and do not form part of the Lusaka aquifer systems. The total area of agricultural lands situated inside the project area determined by remote sensing is 24,160 ha. This would mean that the 12,830 ha of all commercial farmers surveyed represent 53% of the agricultural area found by remote sensing.

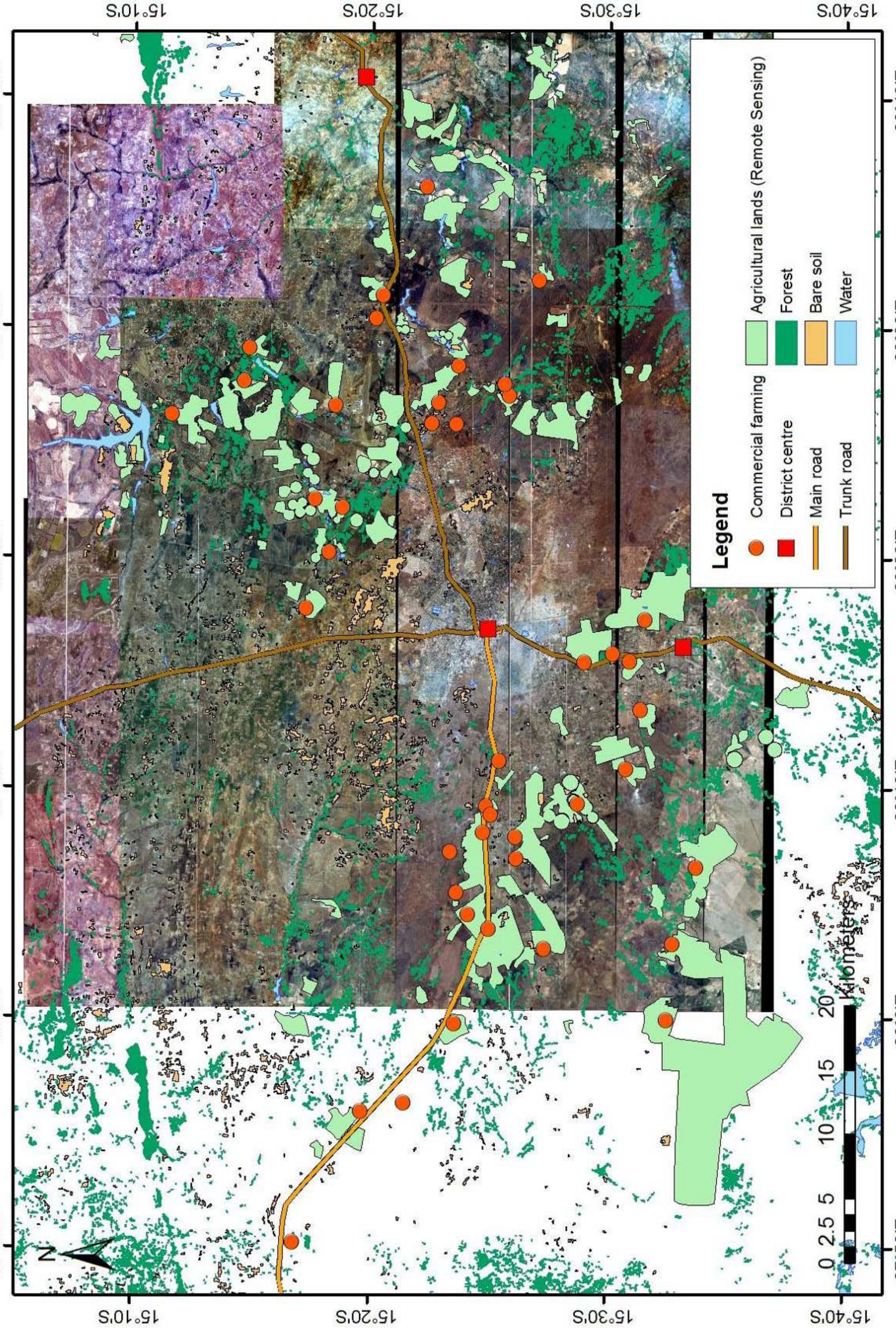

Figure 2 Agricultural lands identified by remote sensing and location of commercial farms surveyed

2.1.1 Cultivation Practices

Table 1 shows the main type of crops grown by commercial farmers in the project area. Furthermore, it also highlights the area covered by each crop as well as the allocation in the rainy and dry season. It clearly points out that maize, soybeans and wheat are by far the most common crops. These three types are covering 81% of the total area under cultivation, whereas all the other crop types together are covering 19% of the total area (Figure 3).

Table 1 Type of crop, area coverage (% and ha) and allocation in the rainy and dry season

Type of Crop		%	Total Area (ha)	Area in Rainy Season (ha)	Area in Dry Season (ha)
Maize	81%	29.7	3793	3741	52
Soybeans		28.5	3648	3278	370
Wheat		23.1	2947	0	2947
Barley	19%	2.3	300	0	300
Sorghum		2.0	250	250	0
Potatoes		1.9	237	103	134
Baby Corn		1.8	230	200	230
Mixed Beans		1.5	189	189	87
Citrus Fruits		1.3	161	161	161
Sunflower		1.2	150	150	0
Pepper		0.9	120	80	120
Cabbage		0.9	117	112	95
Onion		0.9	116	84	116
Groundnuts		0.8	104	104	0
Sugarsnap		0.7	90	0	90
Tobacco		0.6	75	75	0
Peas		0.4	55	0	55
Green Beans		0.4	50	50	50
Sunn Hemp		0.4	46	46	0
Feed Maize		0.3	40	40	0
Tomatoes		0.3	34	24	34
Seed Cotton		0.2	31	1	30

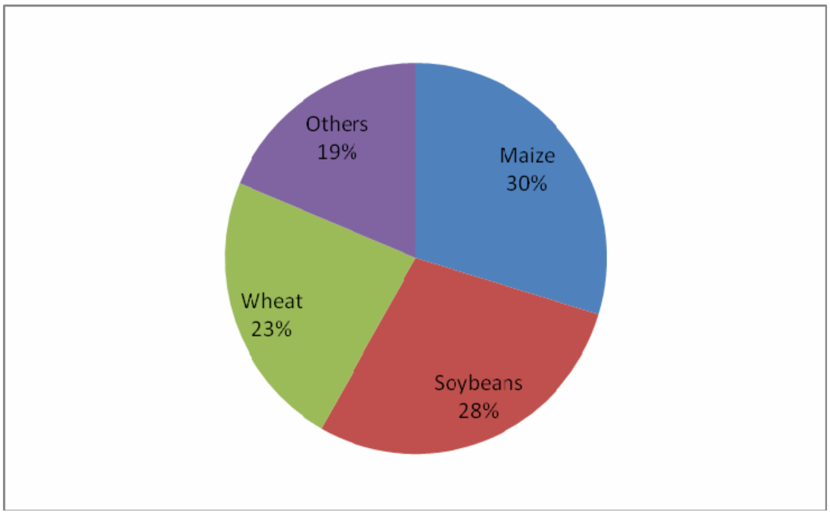

Figure 3 Percentage of crop of the total size under cultivation

Maize and soybeans are the dominant crops in the rainy season, grown by 77% and 65% of all farmers, respectively, whereas, in the dry season irrigated wheat, planted by 70%, is the most common crop. The typical growth period in the rainy season is, depending on the crop, from October/November/December to April/May and during the dry season from April/May to September/October/November. Fallow land is the most common type of surface cover when the fields are not cultivated during the dry season (4,700 ha). On a much smaller area of 300 ha, crop residuals are left on the fields during the dry season. In between the seasons the majority of farmers leave their fields fallow or with crop residuals. Only very few plant a green manure crop for soil improvement, in specific, the legume Sunn Hemp (*Crotalaria juncea)* with its potential to produce large amounts of biomass in only 60 – 90 days. This nitrogen fixing species requires moderate warm conditions and grows well on relatively dry soil with low fertility (United States Department of Agriculture 1999).

90% of all farmers interviewed follow a specific crop rotation. The most frequently applied order of crop is maize and/or soybeans in the rainy season followed by wheat in the dry season. A rotation of onions, cabbage and tomatoes is often used by farmers growing vegetables. Potatoes, if grown, are usually planted every four years on the same field.

2.1.2 Irrigation Methods and Water Sources

The survey has shown that all farmers use irrigation systems during the dry season and almost two thirds of them (63%) apply irrigation during the rainy season. This is either to supplement water during times of drought or to irrigate green houses. 74% of the farmers use groundwater exclusively whilst 14% use only surface water. 12% of the farmers use both types of water sources. However, the amount of water taken from the ground of these 12% is negligible. Therefore, it can be concluded that around one quarter of the farmers use surface water as their main source for irrigation. Farmers who use surface water irrigate 39% (2,373 ha) of the total irrigated area (6,150 ha) and mainly abstract their water from the Chalimbana or Ngwerere River, while farmers using groundwater cultivate 61% (3,777 ha) of the total area under irrigation and pump their water on average from 10 boreholes at each farm.

The most frequently used irrigation systems are centre-pivot (Figure 4) and overhead sprinkler (Figure 5). Centre-pivot is applied by 77% of all farmers and overhead-sprinkler by 44%. These systems are typically used to irrigate wheat which is the most common crop under irrigation during the dry season. Drip irrigation (Figure 6), applied by 28% of all farmers, is generally used for vegetables or green houses; however, this is on a much smaller scale.

Figure 4 Centre-pivot irrigation system

Figure 5 Overhead-sprinkler irrigation system

Figure 6 Drip irrigation system

2.1.3 Location of Farms in the Project Area

Figure 7 shows the main catchment areas of surface water in Zambia, these being: Barotse, Kafue, Zambezi, Luangwa, Luapula, Chembeshi and Tanganyika. 17 farms are located in the Zambezi catchment and 26 farms in the Kafue catchment. The more detailed map in Figure 8 outlines the distribution of farms within the various sub-catchments in the Lusaka area. (Upper) Chongwe is a sub-catchment of the Zambezi located in the project area. The Chalimbana and Ngwerere stream-catchments are part of the (Upper) Chongwe sub-catchment. The Kafue catchment includes three sub-catchments with commercial farming in the investigation area, namely: Chilongolo, Mwembeshi and Kafue Flats sub-catchments. The Chunga stream catchment is part of the Mwembeshi sub-catchment. 26 commercial farms are located in the Kafue catchments: seven in the Mwembeshi catchment (excluding Chunga), six in the Chunga stream-catchment and 11 in the Chilongolo catchment. The Chongwe catchment hosts 18 commercial farms of which seven are located in the Ngwerere stream-catchment ten in the Chalimbana stream-catchment and one in the (Upper) Chongwe catchment. One farm is located in the Kafue Flats catchment (Table 2).

Figure 7 Main catchments of Zambia and location of the investigation area

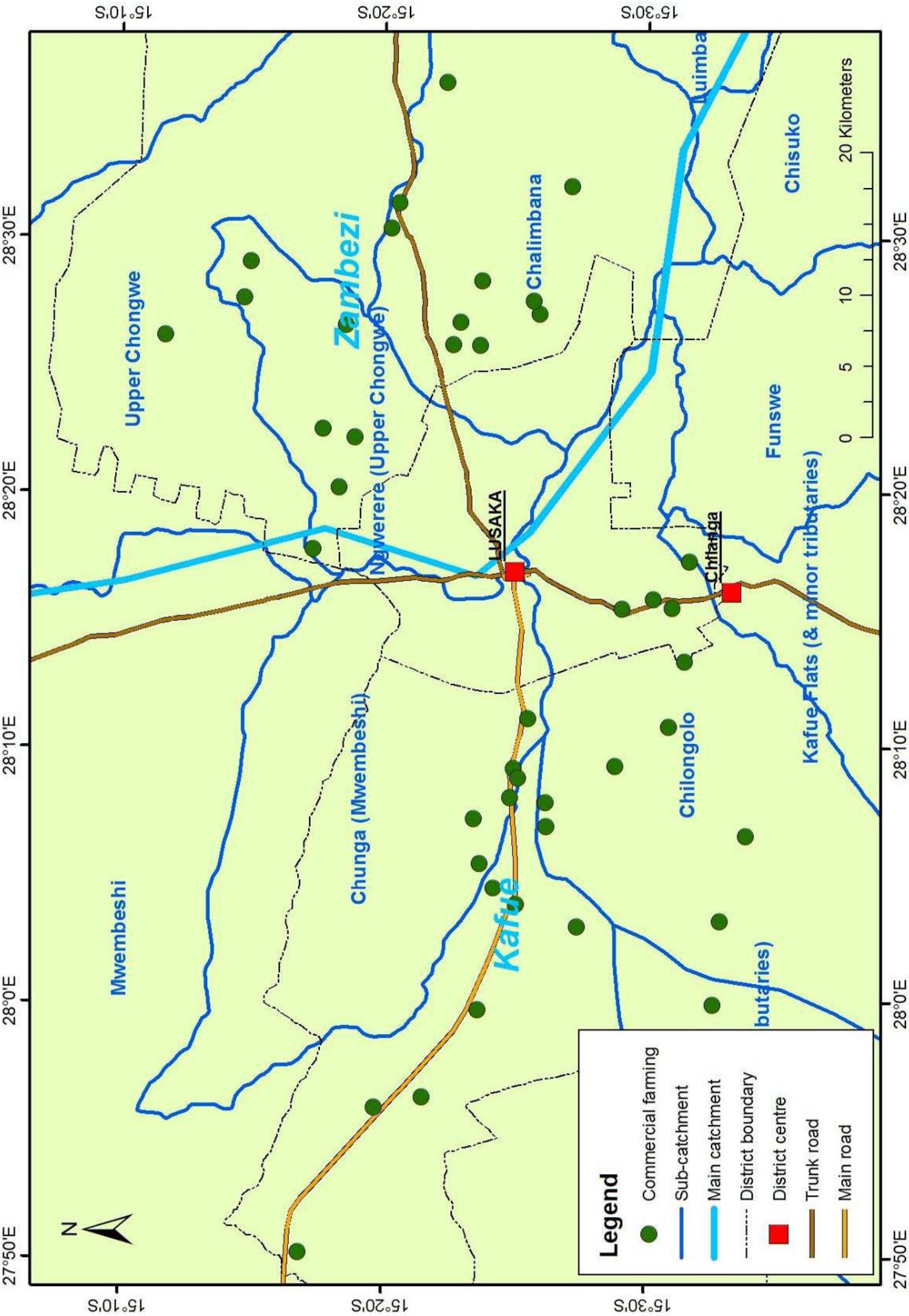

Figure 8 Map showing catchments around Lusaka and distribution of commercial farms included in the survey

Table 2 Distribution of farmers within the different catchment areas

Catchment Area	Sub-Catchment	Stream-Catchment	No. of Commercial Farms
Kafue	Chilongolo	-	11
Zambezi	(Upper) Chongwe	Chalimbana	10
Zambezi	(Upper) Chongwe	Ngwerere	7
Kafue	Mwembeshi	-	7
Kafue	Mwembeshi	Chunga	6
Kafue	Kafue Flats	-	1
Zambezi	(Upper) Chongwe	-	1

2.2 Water Abstraction by Commercial Farmers

Most farmers were able to supply quite accurate data on their water abstraction for irrigation. For those with no information available, an appropriate approximation was applied in order to determine their water demand. According to interviewed farmers a good average figure to calculate the total water demand is 600 mm of water per growth period for any crop. In addition, crop water requirements, applied by the Food and Agriculture Organisation of the United Nations (FAO), for the main crops maize, soybeans and wheat reads as follows: maize (500 – 800 mm), soybeans (450 – 700 mm) and wheat (450 – 650 mm). The exact value depends on the climate and soil conditions.

One mm/ha equals 10 m^3/ha of water. For example: A farmer grows irrigated wheat on a total area of 100 ha. The water demand for irrigation for this crop would roughly be: 600(mm) x 100(ha) x 10(m^3) = 600,000 m^3. This estimation was used for farms, where only information on the area under irrigation could be provided.

The amount of water abstracted from the aquifers for irrigation is 24,870,000 m^3/year (Table 3) with an average amount ranging between 82,900 m^3/day and 103,600 m^3/day, depending on the weather during the peak irrigation season (March/April to November).

Table 3 Abstraction rates for groundwater (Totals based on data from farms surveyed)

Abstracted groundwater in m^3/year	Average m^3/day	Average during the dry season m^3/day
24,870,000	68,100	82,900 - 103,600

With a volume of about 14,982,000 m^3/year (Table 4) water abstracted from surface waters is 40% less than the amount of water taken from the ground with an average ranging from 49,900 – 62,400 m^3/day during the dry season.

Table 4 Abstraction rates for surface water (Totals based on data from farms surveyed)

Abstracted surface water in m^3/year	Average m^3/day	Average during the dry season m^3/day
14,982,000	41,000	49,900 – 62,400

2.2.1 Per Hectare Abstraction of Groundwater

The total area cultivated by farms using groundwater amounts to 9,300 ha of which 3,777 ha are under irrigation. It may be assumed that the area from which groundwater is abstracted equals the total cultivated land. As mentioned above, the amount of water taken from the ground is 24,870,000 m^3/year. Divided by the total area under cultivation, the average abstraction per hectare from commercial farms is calculated as:

(24,870,000 m^3/year) / (9,300 ha) = 2,674 m^3/year/ha;

The total abstracted water is then applied on 3,777 ha under irrigation in one year. This is mainly during the dry months of the year from around March to November. This means, that an average of 6,585 m^3/ha/year ((24,870,000 m^3/year) / (3,777 ha)) is used for irrigation on a yearly basis. Given in mm water, irrigated land receives 658 mm of water for irrigation during one year. This calculation shows the irrigation rate (in mm/year) of water if all farmers using groundwater would apply the same amount of water for irrigation. This calculation confirms the earlier mentioned description to estimate the water demand (600 mm) from farms with no information on their abstraction rates available.

2.2.2 Per Hectare Abstraction of Surface Water

Farmers using surface water for irrigation cultivate 3,530 ha. Their total water demand per year is 14,982,000 m^3/year (Table 4). The average abstraction per hectare is calculated as follows: (14,982,000 m^3/year) / (3,530 ha) = 4,244 m^3/ha/year; Considering the 2,373 ha under irrigation, 6,313 m^3 are applied for each hectare in one year for irrigation. Again, this is mainly during the dry months from March to

November. Expressed in mm/year, the amount of surface water applied for irrigation is 631 mm/year. As in chapter 2.2.1 this is the amount assuming that all farmers apply the same quantity of water.

2.2.3 Catchment Abstraction

Table 5 and Figure 9 show the abstraction rates of groundwater and surface water for irrigation within the various surface catchments in the project area. The highest abstraction rate occurs in the Ngwerere catchment with 12,068,000 m^3/year, though, over 10,000,000 m^3/year are taken from surface waters and only 2,000,000 m^3/year from groundwater. In the Chilongolo catchment over 10,000,000 m^3/year, in the Mwembeshi catchment over 6,000,000 m^3/year and in the Chunga catchment almost 4,000,000 m^3/year are taken from groundwater exclusively. In the Upper Chongwe, Ngwerere and Chalimbana catchment, where surface water is the main source for irrigation, farmers extract the surface water mainly from the Ngwerere and Chalimbana River or their tributaries. All farmers using surface water need to apply for a permit (water rights) at the Water Board in order to use surface water. The total valid water rights for abstracting water from streams of all farmers using surface water for irrigation are 21,483,170 m^3/year according to the Water Board. The actual abstraction by farmers holding water rights is 11,983,500 m^3/year. Therefore, it appears that farmers using surface water abstract a much smaller volume of water than they have permission for.

Table 5 Water abstraction within the different surface catchments

Catchment Area	Sub-Catchment	Stream-Catchment	Total Abstraction (m^3/year)	Groundwater (m^3/year)	Surface Water (m^3/year)
Kafue	Chilongolo	-	10,307,000	10,307,000	-
Kafue	Mwembeshi	-	6,141,000	6,141,000	-
Kafue	Mwembeshi	Chunga	3,987,000	3,987,000	-
Kafue	Kafue Flats	-	978,000	978,000	-
Zambezi	(Upper) Chongwe	-	2,160,000	-	2,160,000
Zambezi	(Upper) Chongwe	Ngwerere	12,068,000	1,929,000	10,139,000
Zambezi	(Upper) Chongwe	Chalimbana	4,211,000	1,528,000	2,683,000

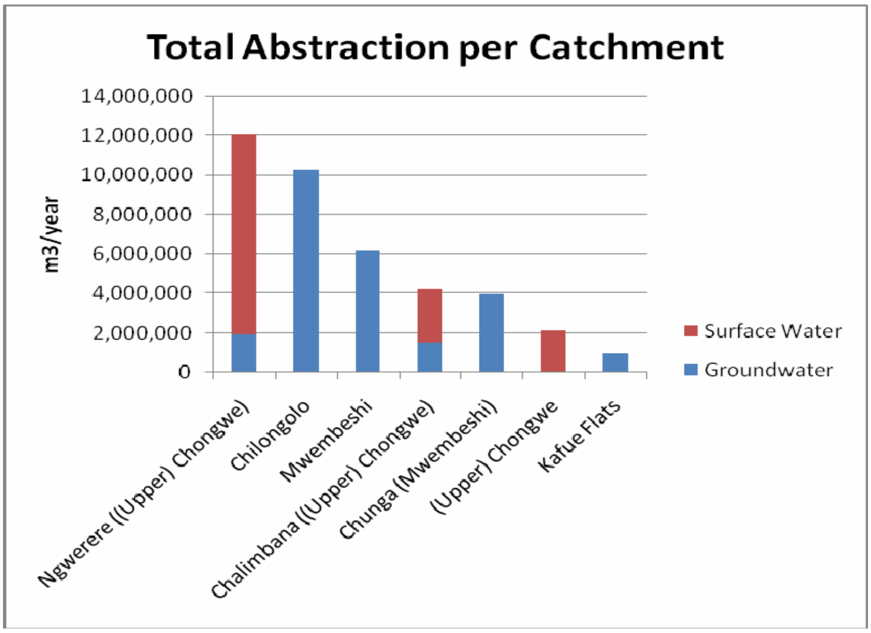

Figure 9 Groundwater and surface water abstraction within catchments

The highest irrigation rate was found for the Upper Chongwe catchment with 900 mm and the lowest with 558 mm in the Chunga catchment (Table 6). Table 6 shows the applied mm water for irrigation on the total irrigated area within a surface catchment. Again, these values are averages assuming that all farmers use the same amount of water.

Table 6 Total irrigated area and irrigation rate (mm/year) per catchment

Catchment Area	Sub-Catchment	Stream-Catchment	Total Irrigated Area (ha)	Irrigation rate (mm/yr)
Kafue	Chilongolo	-	1,455	708
Kafue	Mwembeshi	-	1,068	575
Kafue	Mwembeshi	Chunga	714	558
Kafue	Kafue Flats	-	163	600
Zambezi	(Upper) Chongwe	-	240	900
Zambezi	(Upper) Chongwe	Ngwerere	1,842	655
Zambezi	(Upper) Chongwe	Chalimbana	668	630

2.3 Seasonal Abstraction

The seasonal abstraction is shown by two well-documented examples for 2009. York Farm and Kashima Farm kindly provided accurate monitoring data on their abstraction rates for irrigation (Figure 10)[1]. York Farm is located about six km south of the city centre along Kafue Road and Kashima Farm is situated about 15 km west of Lusaka along Mumbwa Road. Values are ranging between 968 m^3/week in December and 71,651 m^3/week in August at York Farm. Kashima Farm also has its minimum extraction in December with 562 m^3/week and its maximum water usage, being 117,176 m^3/week, in August. The highest demand for irrigation in 2009 occurred between week 16 and week 46 (mid-April to mid-November) at both farms (Fig. 10).

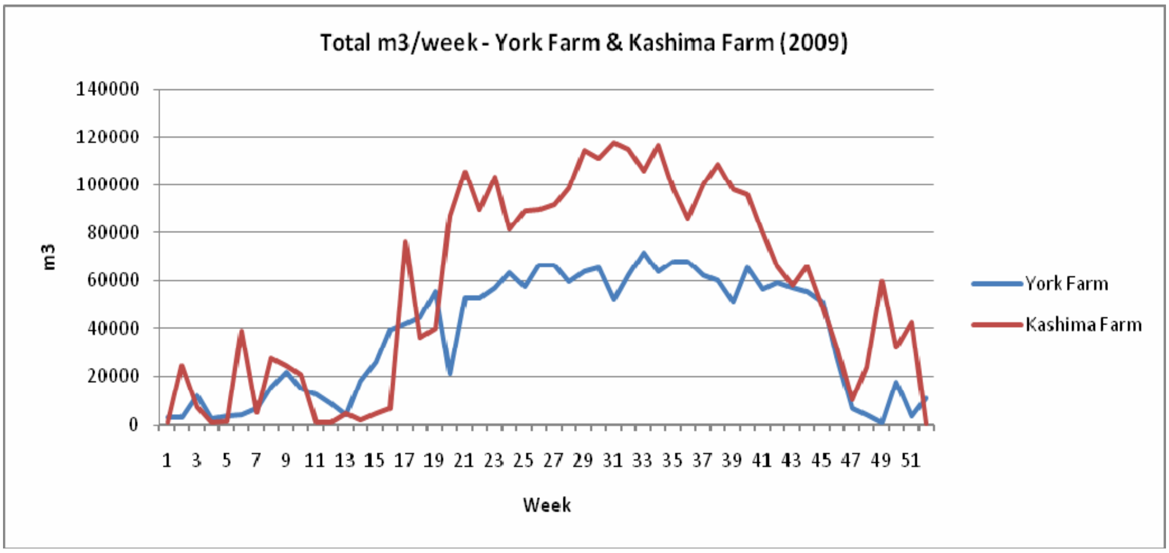

Figure 10 Weekly groundwater abstractions from York Farm & Kashima Farm 2009

During this period York Farm was using an average of 57,823 m^3/week (average for the whole year: 47,958 m^3/week) to irrigate 200 ha. Kashima Farm was extracting an average of 89,916 m^3/week (average for the whole year: 58,685 m^3/week) for 600 ha under irrigation during these 30 weeks. In fact, York Farm applied 90% of its total water demand during the earlier mentioned period from mid-April to mid-November, and Kashima Farm used 89% of its total abstraction for irrigation during this dry period. The similar abstraction pattern observed at the two farms indicates that similar

[1] All data kindly provided by Mrs. Lister Nyemba (Assistant Farm Manager, York Farm) and Mr. Brian Crawford (Farm Manager, Kashima Farm).

irrigation practices are implemented by most commercial farmers. Therefore, it can be concluded that in general 90% of the total water demand for irrigation is applied from April – November and only 10% during the rainy season.

Figure 11 compares the weekly rainfall and total demand for irrigation at York Farm during the hydrological year 2008/09. The time series were recorded by York Farm Management. According to this data total rainfall in 2008/09 was 898 mm. With 971 mm, the amount of water used for irrigation exceeded the yearly rainfall by 73 mm.

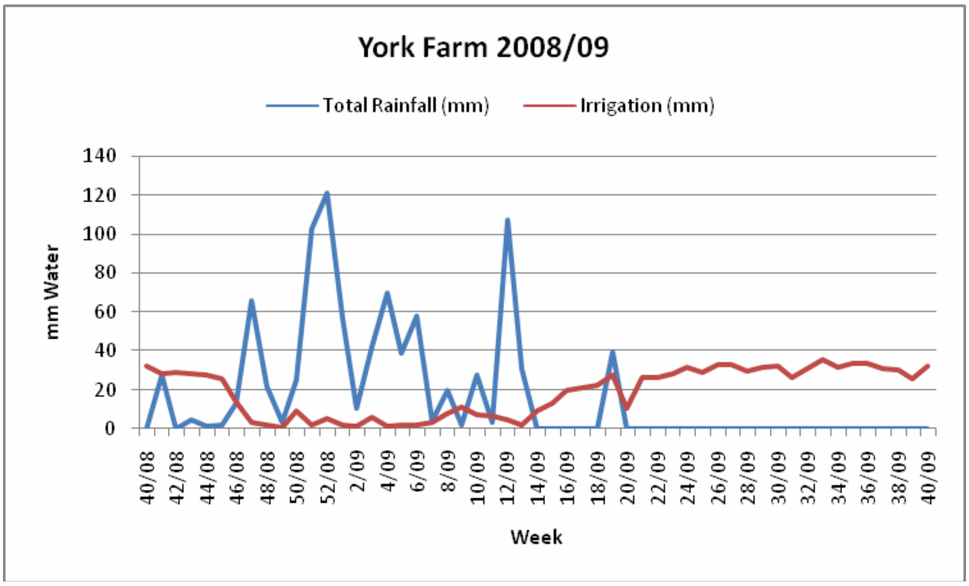

Figure 11 Total rainfalls (mm) and irrigation (mm) at York Farm 2008/09

2.4 Potential Pollution Sources of Groundwater

2.4.1 Fertilizer

The survey showed that the application of industrial fertilisers is widespread. 98% of the farmers frequently apply fertilizers on their fields. Only one organic farm was encountered. Most farmers follow recommended application guidelines for fertilizers (Zambian Fertilizers – Application Guide, Industrial Area, Lusaka). The usual practice is to apply a basal dressing at planting followed by one or more top dressings at different maturation stages. The amount and type of fertilizer per application as well as the exact date of application depends on the crop grown and also on the soil type. The most frequently used fertilizers according to this survey were D Compound (N 10%, P 20%, K 10%), applied by 86% of all farmers, Urea 71% (N 46%, P 0%, K 0%), Ammonium-Sulphate and Ammonium-Nitrate (both 29%) as well as Calcium-Nitrate (17%) and Potassium-Sulphate (14%).

2.4.2 Pesticides

Besides the organic farmer, all farmers apply pesticides on their fields. 21% of the farmers interviewed apply pesticides from the very beginning of planting in order to prevent their crop from any pest infestation. The rest of the farmers only apply pesticides after identifying some pest by scouting. The following pesticides were found to be frequently used by commercial farmers in the project area:

- *Dursban* (Chloropyrifos, organophosphate, insecticide);
- *Cypermethrin* (Pyrethroid, insecticide)
- *Endosulfan* (organochlorine, insecticide)
- *Azoxystrobin* (fungicide)
- *Tebuconazole* (systemic fungicide)
- *Chlorothalonil* (non-systemic fungicide)
- *Karate* (Lambda-cyhalothrin, Pyrethroid, insecticide)

2.4.3 Storage of Diesel

Storage of diesel also contains a risk potential for groundwater at the farms. 86% of all farmers covered by the survey store diesel. In total 350,000 l of fuel are stored either in underground tanks, which applies to 40% of the farmers storing diesel, surface tanks (30%) or drums (30%).

2.4.4 Used Oil

Servicing the vehicles, which is done on-site at most of the farms, can also affect the groundwater in particular through inadequate handling of used oil. As a matter of fact, some farmers dispose their used oil and also empty pesticide containers on an informal dump site at the farm. However, the most prevalent way of handling used oil is to reuse it in construction, where it is often used in fencing to paint poles in order to keep termites off, or to give it off to individuals and garages.

2.4.5 Sanitation System

Another contamination source is the insufficient sanitation system, especially in the more rural areas where most of the farms are located. Pit latrines are found at 67% of the farms and septic tanks at 77%. Usually a new pit latrine will be build when the old one fills up. 30% of all septic tanks are emptied by a vacuum tanker once a year. All other septic tanks run for years as so-called “soakaways” (septic tanks with soil infiltration) and do not need to be emptied. The sanitation system at most farms is, on average, within a distance of 200 m to the nearest borehole.

3 Industries

3.1 Types of Industries and Location

During this survey 53 different industrial enterprises were interviewed (listed in Appendix 4). A total of around 7,000 people are employed by all industries as a result of this study. The following industrial categories were part of the investigations program:

- Cement Producer
- Brewery
- Abattoir
- Drink Manufacturer
- Oil Manufacturer
- Food, Dairy or Tobacco
- Tannery & Leather Manufacturer
- Grain Miller
- Detergent Manufacturer
- Plastic Products
- Seedlings Producer
- Chemical and Cleaning Products
- Candle Manufacturer
- Paint Manufacturer
- Fertilizer & Pesticide Manufacturers
- Wholesaler
- Foam Manufacturer

70% of all industries are located in the industrial area, Chunga catchment, north-west of the city centre of Lusaka. 17% are situated in the Ngwerere catchment, north of the city centre, and 8% in the Chilongolo catchment, south of Lusaka. In the Kafue Flats, Upper Chongwe, Mwembeshi and Chalimbana catchments only one industry was contacted, respectively. Figure 12 and Table 7 illustrate the distribution of industries within the different catchment areas of Lusaka.

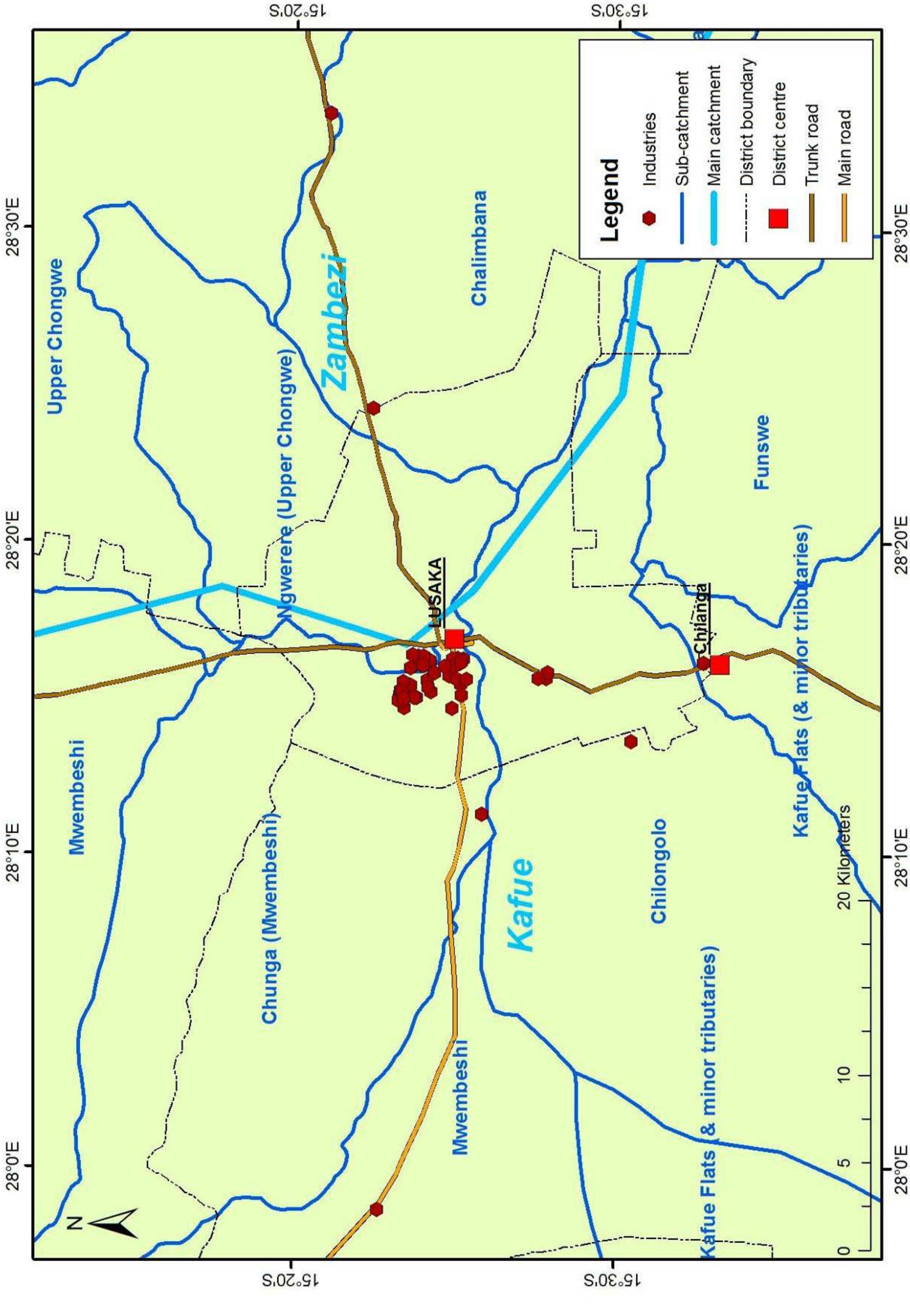

Figure 12 Map showing catchments around Lusaka and distribution industrial enterprises included in the survey

Table 7 Location of industries within the different surface catchments

Catchment Area	Sub-Catchment	Stream-Catchment	No. of Industries
Kafue	Mwembeshi	Chunga	36
Zambezi	(Upper) Chongwe	Ngwerere	9
Kafue	Chilongolo	-	4
Kafue	Kafue Flats	-	1
Zambezi	(Upper) Chongwe	-	1
Zambezi	(Upper) Chongwe	Chalimbana	1
Zambezi	Mwembeshi	-	1

3.2 Water Sources & Abstraction Rates

Concerning the type of water source, 32% of all industries are connected to the LWSC network and 68% use groundwater from private boreholes. However, industries using LWSC water use only 5% (220,000 m^3/year) of the total water demand of all industries included in this study, whereas, the water taken directly from the aquifer on site is 95% (4,305,000 m^3/year) of the total amount. Table 8 shows the main industrial water users, representing 23% of all interviewed industries. The survey has shown that these 23% extract 98% (4,419,000 m^3/year) of the total amount of water used by all industries, this being 4,525,000 m^3/year. A minor amount of 106,000 m^3/year (2% of the total demand) is used by the remaining 77% of industries.

Table 8 Major industrial water users

Major Water Users	Type of Industry	m^3/year
Lafarge	Cement Producer	2,912,700
Zambian Breweries	Brewery	720,000
Zamanita Limited	Oil Manufacture	240,000
Tombwe Processing	Tobacco	165,360
National Breweries	Brewery	116,400
California Breweries	Brewery	62,400
Kembe Meat Products	Abattoir	51,782
Midlands Breweries	Brewery	46,800
Manzi Valley	Mineral water	33,000
Zamleather	Tannery & Leather Manufacture	24,960
Verino Poultry	Abattoir	23,360
King Quality Meat Producers	Abattoir	21,840

The cement producer Lafarge, located on Kafue Road 11 km south of the city centre, alone uses 64% of the total water consumption by industries investigated during this survey. The second highest water user with 16 % of the total amount is Zambian Breweries and 5% is abstracted by the third biggest consumer, Zamanita Limited. These "top 3" water users abstract 85% of the total water volume used by industries and utilize groundwater exclusively.

Unlike farms, no seasonal variation in the abstraction of groundwater by industries was identified.

3.3 Risk Potentials to Groundwater

3.3.1 Hazardous Substances in Production

GIBB (1999), cited in Kampeshi (2003), sub-divided the industries in Lusaka into main types including their correlative potential pollution risks. This information was used in order to distinguish different categories of potential pollution risks of industries in Lusaka. The following types of industries and their respective risk potentials, indicated by the bold letter in brackets and explained in Table 9, were mentioned in the report:

- Petroleum wholesaler **(a)**
- Plastic products **(a)**
- Tannery & leather manufacturers **(b)**
- Fertilizer, pesticides supplier/manufacturers **(c)**
- Cotton ginnery **(d)**
- Food processing, dairy or tobacco **(d)**
- Detergent manufacturers **(d)**
- Timber products **(e)**
- Paint manufacturers **(a);(e)**
- Chemical & cleaning agents **(d)**
- Refrigerant dealers & plastic manufacturers **(f)**
- Oil manufacturers **(e);(a);(f)**

Table 9 Potential pollution risks of industries

(a)	*Petroleum products;*
(b)	*Chromium, phenols, sulphides, heavy metals;*
(c)	*Phosphates, nitrates, and other organic compounds;*
(d)	*Acids and bases;*
(e)	*Solvents, paint;*
(f)	*Halogenated hydrocarbon compounds;*

15% of all interviewed industries indicated that they store and use any of the above mentioned substances, these being:

Table 10 Storage facilities and handling of spillage during production

Industry	**Storage Facilities**	**Handling of Spillage during Production**
Zamleather **(b)**	*Chemical store, tank for sulphuric acid with catchment system for any spillage*	*Drainage system, then treatment plant*
Zambian Fertilizer **(c)**	*Shed for chicken manure, containers for other compounds*	*Collected and reused*
Decotex **(f)**	*Store room for liquids and powder*	-
Trade King **(d);(e)**	*Warehouse*	*Collected and reused*
Dulux Paint **(e)**	*Storage facilities with catchment system and report in any case of spillage or leaking*	*No spillages occur according to management*
Victory Import & Export **(d);(e)**	*Canister and drums*	-
Amiran **(c)**	*Storage facilities with cement floors*	-
Lafarge **(a);(e);(f)**	*Petroleum products are stored in tanks within a bundwall (retaining wall) system and chemicals in a chemical store*	*Collected and recycled back into the system*

Table 10 shows all industries which store and use any of the substances mentioned in Table 9. The applied practices do not suggest any impact to groundwater quality from the storage or production. Further substances found to be used by industries were enzymes, used by “opaque” (sorghum-) beer breweries, and bleaching clay, used by Unified Chemicals and Zamanita. Caustic soda (Sodium-hydroxid) is used by opaque breweries and Zamanita.

3.3.2 Sewer System

50% of the visited industries are connected to the LWSC sewer network. LWSC runs six treatment plants / ponds for waste water: Manchinchi, Chunga, Matero, Ngwerere, Kaunda Square and Chelston. The other half of industries has septic tanks for collecting their discharge. Most of the septic tanks are emptied by vacuum tankers into one of the LSWC plants and some of them work as soakaways. One industry also has a pit latrine on their property.

3.3.3 Effluents & Wastage

38% of all industries have facilities to either fully treat their effluents, to pre-treat for LSWC or to separate liquids and solids. The identified treatment processes reads as follows:

Table 11 Effluent and wastage treatment by industries

Industry	***Treatment Process***
Zamleather	*Effluent treatment plant*
Tiger Animal Feed	*Drainage system, solid collector*
Unified Chemicals	*Filtration plant*
Noor Industries	*Waste recycled back into the system*
Best Beef Company	*Septic tank and soil infiltration (soakaway)*
Trade King	*Sulphuric acid for treatment, pH reduction before discharge to LWSC*
Crest Chicken	*Pre-treatment plant before effluents are discharged to LWSC*

Industry	***Treatment Process***
Dulux Paint	*Effluent treatment plant, Precipitation with ferro-sulphide followed by sedimentation to separate liquids and solids*
Chat 2 Breweries	*Drainage system, solid collector*
Dreamland Icecream	*Treat wastewater with chlorine, then LWSC*
Mukwa Breweries	*Lime and chemicals to pre-treat, then LWSC*
Midlands Breweries	*Septic tank with compartments, solids settle, water goes in soakaways into the ground, disposal of solid parts*
Hi Protein Foods	*Water treatment, ion exchange*
Kembe Meat Products	*2 ponds from where the waste water is taken to farms and spread on the fields, solids as manure for the fields*
Grand Butchers Abattoir	*Blood is collected in tanks and picked up by some agriculture company, disposal of solids*
Citizen Breweries	*System to separate liquids and solids, liquid to LWSC*
National Breweries	*Sedimentation system to separate solids and liquids, caustic soda to neutralize the water before it goes to LWSC*
Golden Breweries	*Effluents are stored in a tank, monthly tested and if required some treatment done by UNZA to meet the standards by ECZ*
Majoru Meat	*Settling pond (containing microorganisms, lactic acid bacteria), then soakaway into the ground*
Verino Poultry	*Treatment plant, soakaway planned; now septic tank for discharge to LWSC, vacuum tanker gets it every 2-3 months*

Table 11 displays the treatment of effluents and wastage by different types of industries. Many opaque-breweries have systems to separate solids and liquids with the solids being disposed and liquids discharged to LWSC. Abattoirs and meat processing companies often have septic tanks (soakaways) for their effluents. Some abattoirs also supply their slaughterhouse waste to agriculture companies or directly to fields as organic compound nutrients. Industries discharging to LWSC usually pre-treat their effluents with chemicals, like chlorine, in order to meet the standards according to ECZ.

4 Results & Discussion

4.1 Commercial Agriculture

4.1.1 Land Use

In the National Water Resources Master Plan (YEC 1995), the national total irrigated area was estimated at 53,020 ha. The area irrigated by the commercial sector totalled 30,750 ha (58%). In the Lusaka Province the irrigated area in the dry season was estimated at 5,674 ha, based on a survey conducted in 1993. The investigated area of 6,150 ha under irrigation during this survey clearly demonstrates the increase of irrigated land, especially since these 6,150 ha are only within the project area and the 5,674 ha refer to irrigated land in the whole Lusaka Province.

A total agricultural area of 24,160 ha within the project area was obtained by remote sensing analysis. The total area used for cultivation during this survey was 12,830 ha (see Chapter 2.1). The significant difference in size could be a result of the inclusion of small- and medium-scale farmers by remote sensing, whereas, this survey targeted only large scale commercial farmers. Furthermore, satellite images from 2007 were used for remote sensing and may not present the current status of commercial farm land.

4.1.2 Irrigation

The quantities of water for irrigation by farmers using groundwater (658 mm) and by those using surface water (631 mm), according to Chapters 2.2.1 and 2.2.2, are based on the assumption that all farmers use the same amount for irrigation. However, the actual amount for irrigation differs quite considerably on individual farms.

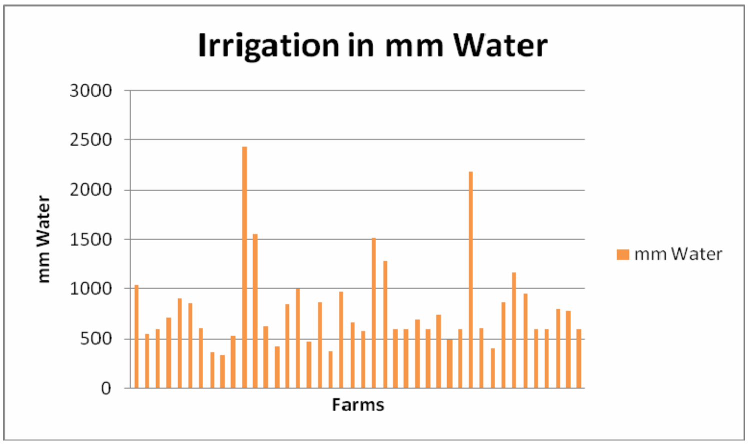

Figure 13 Total irrigation in mm water per year of all interviewed farms

Values of annual irrigation rates range from 333 mm to 2433 mm (Figure 13). However, there are only a few who significantly deviate from the general trend. In addition, the farm with the maximum demand of 2433 mm grows roses which require 4.5 – 7.0 mm per day (total of 2,433 mm in one year) and are grown all year round. The second highest amount with 2,187 mm is applied by a farm growing, amongst others, citrus fruits. With 900 – 1,200 mm citrus fruits have a higher water demand compared to grain crops (500 – 800 mm). On the farm with the third highest amount applied (1,555 mm) exclusively pepper is grown with the required water demand being up to 1,250 mm. 1,512 mm and 1,282 mm are applied by farms growing bananas (required water demand of 1,200 – 2,200 mm) among others (all values for the required water demand were taken from FAO). The exact amount for irrigation varies notably between the individual farms; however, there is a general trend for the most frequently applied irrigation practice. In fact, around 80% of all interviewed farmers use between 300 and 900 mm water per year (Figure 14). The median of all individual irrigation practices is 646 mm per year. Detailed monitoring data on the seasonal abstraction for irrigation could be gathered only from two farms during this study. However, due to their similarity it can be safely assumed that commercial farmers with large irrigation schemes use 90% of their total water demand per year during April and November and 10% during the rainy season from December to March (see Chapter 2.3). In the future, if the size of irrigated fields at a farm or in a specific area is known, a good approximation on the total water demand can be obtained by using a rate of 650 mm (median of all farmers during this study being 646 mm) of water per year for water balance calculations.

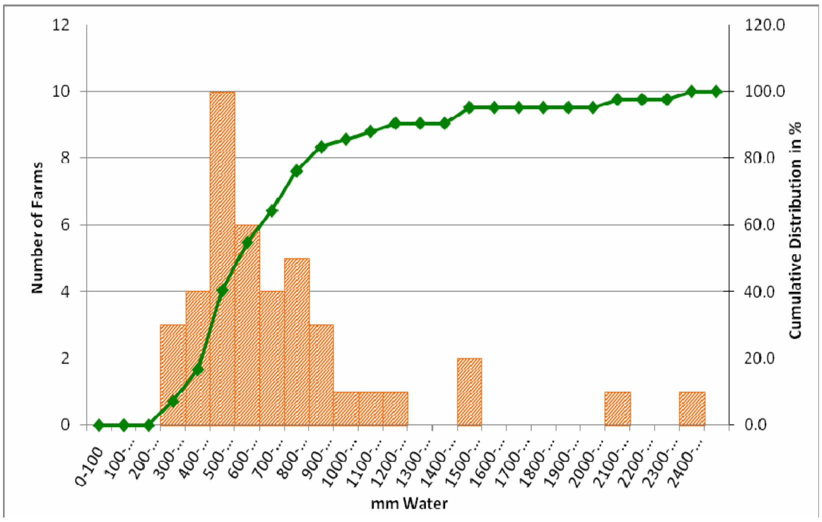

Figure 14 Cumulative distribution of applied mm water for irrigation

4.1.3 Surface Water – Ngwerere River

The defined total runoff potential per year at Ngwerere River for a period of over 40 years varies between 2,900,000 m^3/year and 36,000,000 m^3/year. Between 2000 and 2005 the total runoff at Ngwerere River was 18,672,000 m^3/year on average. The minimum runoff during this period occurred in 2003 with 15,736,000 m^3/year and the maximum in 2000 with 22,583,000 m^3/year (data were taken from HYDATA database at the DWA which contains readings from station number 5016, Ngwerere River). During this survey the total capacity of water being abstracted from farms situated in the Ngwerere catchment was 10,139,000 m^3/year. Water is either taken directly from the Ngwerere River or its tributaries. This means that on average, according to the data from 2000 – 2005, 54% of the total runoff per year at Ngwerere River is applied for irrigation purposes. The readings from the station, however, are not reflecting the actual total runoff. Due to its position the station is not covering the whole catchment area and therefore refers only to a third of the Ngwerere catchment.

4.1.4 Groundwater

As mentioned in 2.2 the abstracted groundwater by commercial farmers is 24,870,000 m^3/year with the average amount being 82,900 – 103,600 m^3/day during the dry season. This amount equals about 75% of the daily abstraction rate of the public service provider which, according to LWSC, totals approximately 125,000 m^3/day (Bäumle & Kang'omba 2009).

4.1.5 Potential Pollution Sources

Fertilizer and Pesticides

The application of fertilizer and pesticides may be a risk to groundwater quality through leaching by percolating water. Excess use of fertilizers may cause increased nutrient concentrations like nitrate in groundwater.

Maize for instance requires a basal application of 200 kg/ha D or X Compound (D Compound: N 10%, P 20%, K 10%; X Compound: N 20%, P 10%, K 5%) at planting and an additional two top dressings at three and five weeks of 100 kg/ha Urea (N 46%, P 0%, K 0%). Vegetables, however, require a much higher basal dressing of 300 – 800 kg/ha and up to four top dressings of 50 – 160 kg/ha (Zambian Fertilizers – Application Guide, Industrial Area, Lusaka). All farmers apply fertilizer according to these standards. The applied amount of fertilizers by commercial farmers was not found to exceed the recommended standards.

However, some of the used pesticides in fact are considered to be highly toxic to the environment and health. Endosulfan, used by 14% of all farmers, is considered for addition to the list of chemicals banned globally under the treaty of the Stockholm Convention. The report also points out its potential to bioaccumulation as well as high toxicity and ecotoxicity (IISD 2008). The chemical is also linked to male reproductive harm, autism and birth defects; it is already banned in over 60 countries including the European Union and several African and Asian countries. In June 2010, the Environmental Protection Agency (EPA) announced an imminent phase-out in the US (PAN North America, homepage).

Diesel

Diesel presents a potential pollution source, especially through spillages when filling up the tank or tractors but also by leaking tanks. Most farmers have their tanks underground and hence, it may be difficult to detect any leaking. One farmer actually had to close the underground tank due to decreasing fuel levels caused by a leakage. By the time of realizing any seepage of diesel quite a considerable amount must have entered the ground already. Small leakages are probably hard to find at all and the tank can release diesel to the environment for years without it being recognized.

Used Oil

The informal disposal of used oil and reuse for fence poles also bear a risk to groundwater. Since the used oil is applied near or dumped into the ground, either in a small dump site or as a termite protection on poles, it is highly susceptible to mobilisation by percolating water. Used oil can therefore reach groundwater very easily and quickly.

Sanitation System

As in the whole Lusaka area pit latrines and soakaways, which were found at all farms, create another contamination source to groundwater through seepage into the ground. The distance from the sanitation system to the nearest borehole varied between 30 m and 2000 m. This represents a risk for contaminated groundwater being abstracted. However, the low density of commercial farmers and the location in the more rural areas of Lusaka minimize its potential for contamination.

4.2 Industries

4.2.1 Water Abstraction

With about 4,525,000 m^3/year, the total amount abstracted by industries during this survey is substantially lower than the amount of water used for irrigation by commercial farmers (39,852,000 m^3/year – groundwater and surface water). According to the Zambian Standard for Water Supply System, the industrial water demand is ranging between 30 m^3/ha/day and 90 m^3/ha/day depending on the type of industrial area. The JICA Study Team estimated the industrial water use in Lusaka at 80 m^3/ha/day. This figure is based on a questionnaire survey for factories in Zambia (KRI et al. 2008c). According to Kampeshi (2003) the Lusaka heavy industrial area covers around 600 ha. Assuming that all industries during this study were actually located in the industrial area, though some are not, the abstraction would then be 24 m^3/ha/day. Lafarge as the main water user of industries is located outside of the industrial area. Leaving Lafarge out of the calculation, the per hectare abstraction in the industrial area would then be only 8.6 m^3/ha/day. This amount is much less than the estimated abstraction of 80 m^3/ha/day; however, JICA also included other criteria for estimating the total water demand in the industrial area, whereas, this survey only presents the amount of water used in production excluding any domestic use.

4.2.2 Potential Groundwater Contamination

A widespread contamination, including microbiological pollution and elevated levels of electrical conductivity (EC), nitrates, sodium, chloride and sulphates, in the industrial area was detected by a groundwater contamination assessment by ECZ in the early 2000's (Kampeshi 2003 and other studies). The different treatment processes of effluents, mentioned in Table 11, contain substantial potential risks to the quality of groundwater. Especially the frequently applied septic tanks and soakaways present a source of serious microbiological contamination through seepage. Simultaneously to this survey, a water quality campaign was conducted by DWA and BGR during April/May 2010 (Nick & Musetaka 2010). The industrial area was among the visited places for water sampling. The water was taken directly from the borehole without any exposure to air. Some parameters like EC and pH were taken in the field by using appropriate probes. The Most Probable Number (MPN) for Total Coliforms (TC) and E. coli were determined in the laboratory at DWA. Museteka and Bäumle (2009) stated that natural (unpolluted) groundwater from the karst aquifers should have an EC of less than 800 µS/cm. Hence, higher levels in EC indicate an anthropogenic impact. Indeed, EC values of 1,232 and 2,910 µS/cm were found in the groundwater at some industries (Table 12). The outlet of the treatment plant at Zamleather actually showed an EC of 31,000 µS/cm. Seepage from the treatment plant into the subsurface could be an explanation of the high EC value of 2,910 µS/cm found in the groundwater from the Zamleather borehole.

Table 12 Unpublished results from the GReSP water quality sampling campaign, April/May 2010

Industries	**EC** (µS/cm)	**pH**	**TC** (MPN[1)]/100 ml)	**E. coli** (MPN[1)]/100 ml)
Tombwe 1	670	7.1	>1	>1
Tombwe 2	690	7.3	629.4	11
Decotex	849	6.9	12	>1
Zambian Breweries	688	7.1	42	1
Aquarite	1,232	6.7	1011.2	3
Zamleather	2,910	7.0	2	1
Outlet of Zamleather Treatment Plant	31,000	8.0	-	-

1) MPN: most probable number

Microbiological contamination also suggests the influence of human activities on the quality of groundwater. The presence of coliforms indicates that pathogens are in the water system. E. coli found in the water samples of some industries show faecal contamination of groundwater (Table 12). During the water quality campaign 2010, 87% of all tested boreholes throughout Lusaka were positive on TC and 34% were positive for E. coli. Interesting results were found at Tombwe Processing where two boreholes have been tested within a distance of roughly 150 m. Borehole 1 showed no microbiological contamination at all, whereas, borehole 2 was affected by one of the highest contaminations by TC and E. coli found during the whole water quality campaign in 2010 (Table 12). Since the dolomite and limestone aquifers of the Lusaka formation are characterized by an abundance of karst features, it can be assumed that a complex system of connected and separated caves and holes exists. This fact, on the one hand, may lead to completely different conditions at boreholes being only a short distance apart, and on the other hand, to a high vulnerability as contamination may spread quickly and over long distances through underground cavity networks.

From previous studies (Kampeshi 2003, Museteka & Bäumle 2008) as well as from the results obtained from the April/May 2010 sampling campaign (Nick & Museteka 2010), an impact on groundwater quality by activities in the industrial area is observed. This could be attributed especially to insufficient treatment and handling of effluents. Hence, most industries, in particular manufacturers of beverages have to apply huge expenses to treat the groundwater in order to achieve the required standards. At the times of compiling this report, the full analytical results of the 2010 water quality survey carried out by DWA/BGR were not available as the samples were sent to Germany.

5 Summary

This survey provides input for the groundwater balance and recharge calculation as well as the water quality assessment. These are some of the main prerequisites for the development of a groundwater management strategy for Lusaka. The outcomes of this survey include:

- Information on land use, irrigation and potential pollution risks to groundwater from large scale commercial farmers in the Lusaka area
- Water usage as well as the handling of hazardous substances and effluents by major industries in Lusaka

Commercial Farming

Covering 81% of the total area under cultivation (12,830 ha) maize, soybeans and wheat are the most common crop grown by commercial farms in the project area. The survey has also revealed that all interviewed farmers use irrigation systems. Around half of the total area available for cultivation (6,150 ha) is under irrigation. The total investigated area under cultivation (12,830 ha) during this survey covers 53% of the agricultural land obtained by remote sensing (24,160 ha). The most frequently applied irrigation methods are centre-pivot and overhead-sprinkler. Farmers irrigating with groundwater abstract 24,870,000 m^3/year to irrigate 3,777 ha (61% of the total area under irrigation) while farmers using surface water irrigate 2,373 ha (39% of the total irrigated area) with 14,982,000 m^3/year. Abstracted groundwater for irrigation can reach over 100,000 m^3/day during the dry season. In comparison, according to LWSC the daily abstraction rate of the public service provider is approximately 125,000 m^3/day. Surface water taken from the Ngwerere River for irrigation can reach over 50% of the river's total runoff per year. The peak period for irrigation occurs between April and November during which 90% of the total amount of water for irrigation is applied. The amount of water used for irrigation considerably differs among individual farms. The general trend for the most common irrigation practice, applied by around 80% of all farmers, is ranging between 300 and 900 mm. 646 mm represents the median of all individual irrigation practices. Therefore, if the size of an irrigated area is known, a reasonable approximation on the total water demand per year of a farm or in a specific area can be achieved by using 650 mm for the calculation in future.

98% of all interviewed farmers regularly apply fertilizers and pesticides. Fertilizers may represent a source for nitrate contamination of groundwater, whereas, some pesticides used by farmers are considered to be highly toxic and ecotoxic and are already banned in many countries. The storage of diesel is another risk potential, in particular by leaking tanks and spillages during decanting and filling the tank. Informal disposal of used oil and reuse for protecting fencing poles also contain a risk to the quality of groundwater.

Industries

The industries surveyed use a total of 4,525,000 m^3/year. Commercial farmers use nine times more water for irrigation than all industries for production. 68% of all industries use groundwater whilst 32% are connected to LWSC. Most of the water is abstracted from boreholes (95% of the total amount) and only a minor part of 5% is supplied by LWSC. The survey clearly reflects that there are major water users within the industries who use a considerable percentage of the total volume. In addition, the 12 biggest water users (23%) utilize 98% of the total amount and the “top 3” water users take up 85% of the total amount of water used by industries. The water consumption (expressed in m^3/ha/day) equals 24 m^3/ha/day (without Lafarge: 8.6 m^3/ha/day) which is much less than the estimated abstraction of 80 m^3/ha/day by the JICA Study Team (KRI et al. 2008c).

Considering the storage facilities of substances containing potential pollution risks as well as at the handling of spillages during production no direct impact to groundwater quality could be concluded from the applied practices. However, some of the applied treatment processes present a risk to the quality of groundwater. Especially critical are septic tanks and soakaways. First results of the simultaneously conducted water quality campaign through DWA/BGR in 2010 suggest an impact on groundwater quality from activities in the industrial area. Increased values of EC as well as detected total coliforms and E. coli indicate anthropogenic impact. For instance, the EC at the outlet of the treatment plant at Zamleather was 31,000 µS/cm whilst the borehole at Zamleather showed an EC of 2,910 µS/cm. This indicates a contamination of groundwater through seepage from the treatment plant.

6 Recommendations

Due to limited time some commercial farmers and industries could not be covered by this survey. Further investigations would contribute towards an extension of the data of this report as well as to confirm certain findings. It is estimated that another 2,000 ha of commercial farm land exists in the project area which were not covered in this survey. For instance, Evergreen Farm and Okapi Farm, both located on Mumbwa Road, were identified during the investigations but no data could be collected. DK Enterprises, manufacturers of “Thirsty” drink, and Parmalat, also located along Mumbwa Road could also be of interest.

There are some large agricultural lands inside the project area identified by remote sensing which could not be assigned to any of the commercial farms surveyed (Figure 2). It is improbable that the remaining 11,330 ha (24,160 ha from remote sensing minus 12,830 ha from this survey) of agricultural area, is actually also commercial farm land. The satellite images are dated from 2007 and therefore may not represent the current situation. It would be useful to physically investigate these agricultural areas, found by remote sensing, inside the project area to define the current land use. This would provide additional validated data on commercial farm land for the water balance assessment.

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APPENDIX 1 Questionnaire for Commercial Farming

Survey on farming in the Lusaka area as part of the "Groundwater Information System & Management Program for Lusaka"
- Department of Water Affairs -

Farm: ……………………………………………………………………………………………………….………

Interviewed Person & Position: ……………………………………………………………………………..…

Location: …………………………...…..………………………..…...………...…………………………….

GPS Coordinates: ………………………………………………...………………………………….………

Date: ………………...….   [Catchment Area: ……………………………………………..…….]

Survey No.: ……………...

1.) What is your total farm, plot size?

…. ……………………………………………………………………………………………..

1.1) What is the size of the area only used for cultivation?

………………………………………………………………………………………………

1.2) For how long has this farm been existing? ………………………………………….

2.) What type of farm do you run? *(Two answers possible)*

□ Crop agriculture

□ Livestock agriculture ***(Livestock only ⇨ Question 6.1)***

Animal					
Amount					

3.) What type of crop do you grow?

Type of crop	Size	Rainy season	Dry season	From….. - …...
Maize				
Sorghum				
Millet				
Potatoes				
Mixed Beans				
Soybeans				
Groundnuts				
Cassava				
Cutting flowers				
Sunflower				

Cabbage, Lettuce				
Sweet corn				
Seed cotton				
Rice				
Wheat				
Sugarcane				
Tomatoes				
Onion				
Fresh asparagus				
Strawberry				
Green beans				
Carrot				
Pepper				
Citrus fruits				
Banana				
Peaches				
Barley				
Butternut				
Pumpkin				
Peas				

4.) Do you follow any crop cycle?

□ NO ⇨ *Question 5.)*
□ YES
└▻ **Rotating every**………. **years with the following order of crops:**

Type of crop	From….. - …..

5.) If you do not use your fields during dry season, what kind of surface coverage do you have?

□ Fallow land
└▻ Size: ………………………………………………………………………
└▻ Period: ……………………………………………………………………

□ Crop residual
└▻ Size: ………………………………………………………………………
└▻ Period: ……………………………………………………………………

□ Others ……………………
└▻ Size: ………………………………………………………………………
└▻ Period: ……………………………………………………………………

6.) Do you use any irrigation system?

- □ YES, during dry season
- □ YES, during dry and rainy season
- □ YES, but only on a specific area – about ………………ha
- □ NO⇨ *Question 7.)*

If YES,

6.1) What type of water source do you use? *(Livestock only⇨ Question 6.4)*

- □ Groundwater (borehole, well, etc.)
  - └→ **Number of boreholes**: ………………………………………………..
- □ Surface water
  - └→ □ stream..………………………………...………………………...
  - □ dam
- □ Others……………………………………………………………………………...

6.2) How do you irrigate?

- □ Drip irrigation
- □ Sprinkler irrigation
  - └→ □ Pivot
  - □ ………………………………………………………………...
- □ Furrow irrigation
- □ Green houses
- □ Flooding
- □ Others……………………….……………………………………………………..

6.3) What is the amount of water used for irrigation purposes?

Type of crop	Field size	Amount of water

- □ ………………………………………………………………………………………..
- □ Less than 1,000 m^3/day
- □ More than 1,000 m^3/day but less than 5,000 m^3/day
- □ More than 5,000 m^3/day but less than 10,000 m^3/day
- □ More than 10,000 m^3/day

□ Pump is running for …….. h/day, fills up a tank with the volume ………. m^3, this takes about ……… h and the water lasts for ……... days;

□ Pump specification………………………………………………………………………...

6.4) What is the water demand for Livestock? *(Livestock only⇨ Question 9.)*

……………………………………………………………………………………………

7.) Do you apply any fertilizer?

□ NO⇨ *Question 8.)*
□ YES
└▻ **7.1) Type of fertilizer?**

□ Mineral
└▻ □ Nitrate
□ Phosphate
□ Potassium

□ Organic
└▻ □ Animal manure
□ Compost

└▻ **7.2) Frequency of application?**

□ Once per growing period
□ Split application
└▻ □ 2 times per period
□ 3 times per period
□……………………

└▻ **7.3) Kg of fertilizer per application?**...............................kg/ha

└▻ **7.4) The exact name of the fertilizer used?**..

Compound D	MOP	Amm. Nitrate		
Urea	Calc. Nitrate	Potas. Sulphate		
Amm. Sulphate	Potassium	Amm. Phosphate		

8. Do you use any pesticides?

□ NO⇨ *Question 9.)*
□ YES
└▻ **8.1) Frequency of application?**

□ Once per growing period
□ Once per month
□ More than once per month

└▻ **8.2) Date of application?** ……………………………………………………..

└▻ **8.3) Average amount per application in kg/ha?** ……………...…………...

└→ **8.4) The exact name(s) of the product(s) used:** ………….............................

Dursban	Alsystem	Azoxy-strobin	Chlorothalonil	
Cypermethrin	Pyrethroide	Tebuconazole		
Endosulfan	Diphenhydramine	Trimangol		

9.) Do you store any fuel?

- □ NO ⇨ *Question 10.)*
- □ YES

└→ **9.1) Type of fuel?** ……………………………………………………………….

9.2) How do you store the fuel?

- □ In a tank
  - └→ □ underground tank
  - □ surface tank

  └→ **Volume:** ………………………………………………………….

- □ In canister

└→ **9.3) Amount of fuel stored?**

- □ Up to 100 liters
- □ More than 100 liters but less than 1,000 liters
- □ More than 1,000 liters

10.) How do you dispose used oil?

……………………………………………………………………………………………....

………………………………………………………………………………………………

11.) What kind of sanitation system do you have?

- □ LWSC – sewer network
- □ Pit latrine
- □ Septic tank
- □ ………………………………………………………………………………………..

If pit latrine or septic tank:

11.1) How often do you have to empty it? ………………………………………..……..

11.2) How do you empty it? ………………………………………………………...…….

(Additional: How close is the sanitation system to boreholes?)

…………………………………………………………………………………………...

Thank you very much for your cooperation.
Please place any additional information and comments here:

APPENDIX 2 Questionnaire for Industries

Survey on information about industries in the Lusaka area as part of the "Groundwater Information System & Management Program for Lusaka"
- Department of Water Affairs -

Industry: …………………...……………..…………………………………………………………….………

Interviewed Person & Position: …………………….………………………………………………….…

Location: …………………………...…...………………………..…...……….....…………………………….

GPS Coordinates: ……………………………………………………...………………………………………

Date: ………………...….   [Catchment Area: ……………………………………………………..….]

Survey No.: ……………...

1.) What type of industry do you run? *(a-g, Question 8.) Page 3)* □ Grain miller □ Transporters & Garages **(a)** □ Petroleum wholesaler **(a)** □ Plastic products **(a)** □ Tannery & leather manufacture **(b)** □ Brewery □ Fertilizer, pesticides & herbicides supplier/manufacture **(c)** □ Cotton ginnery **(d)** □ Food processing, dairy or tobacco **(d)** □ Detergent manufacture **(d)** □ Timber products **(e)** □ Paint manufacture □ Chemical & cleaning agents **(d)** *Continues next page!!!* □ Drink manufacture □ Drug manufacture/supplier □ Refrigerant dealers & Plastic manufacturer **(f)** □ Oil manufacture **(d);(a);(f)** □ Steel fabricator □ Ceramic, chalk or blasting □ Others……………………………………………………………………………...
2.) How many people work here? ………………………………………………………………………………………

3.) What is your monthly production rate?

□ Amount of items………………………………………………………………………...

□ Quantity (tons etc.)……………….………………………………………………….

4.) What is the amount of water used in production?

□ Exact number…………………………………………………………………………
□ Up to 500 m³/day
□ More than 500 m³/day but less than 1,000 m³/day
□ More than 1,000 m³/day but less than 2,000 m³/day
□ More than 2,000 m³/day but less than 3,000 m³/day
□ More than 3,000 m³/day but less than 5,000 m³/day
□ More than 5,000 m³/day but less than 10,000 m³/day
□ More than 10,000 m³/day

5.) Where do you get your water from?

□ LWSC – Lusaka Water and Sewerage Company
□ Private well / borehole……………………………………………………………….
□ Surface water
  → □ stream
    □ dam
□ …………………………………………………………..………………….......

6.) Do you have any treatment process for the discharge from production?

□ NO
□ YES
  → **What type of treatment do you have?** ………………..……….……………..

  ……………………………………………………………………………...…..

If YES
  → **6.1) How do you use the products of the treatment process?**

  → □ **Disposal**……………..……………………………………….…………..

  → □ **Storage**……………………………………………………………...

  → □ **Reuse**…………………………………………………………………..

  → □ **Others**…………………………………………………………………

7.) What kind of sanitation system do you have?

□ LWSC – sewer network
□ Pit latrine
□ Septic tank

☐ ………………………………………………………………………………………………..
8.) How do you store substances necessary for production? ☐ (a) – Petroleum products, ☐ (b) – Chromium, phenols, sulphides, heavy metals, ☐ (c) – Phosphates, nitrates, and other organic compounds, ☐ (d) – Acids and bases, ☐ (e) – Solvents, paint, ☐ (f) – Halogenated hydrocarbon compounds, ………………………………………………………………………………………………… …………………………………………………………………………………………………
9.) How do you handle spillage and remainings during production? ……………………………………...……………………………………………………………… ………………………………………………………………………………………………... ***Thank you very much for your cooperation.***
Please place any additional information and comments here:

APPENDIX 3 List of all farmers

Farm	Cultivated Area (ha)	Irrigated Area (ha)	Catchment	District
Zamseed	800	100	Ngwerere	Chongwe
Galaunia_Farms	660	660	Ngwerere	Chongwe
Rose_Bloom	125	87	Ngwerere	Chongwe
Ellensdale_Farm	650	650	Ngwerere	Chongwe
Kayanje_Farm	240	240	(Upper) Chongwe	Chongwe
Water_Force_Farm	148	148	Chalimbana	Chongwe
Airport_Farm	600	180	Ngwerere	Chongwe
Scimitar_Farm	20	10	Chalimbana	Chongwe
MRI_Seed	240	240	Chalimbana	Chongwe
Seven_Kings_Farm	300	75	Chalimbana	Chongwe
Annabel_Flowers	4.5	4.5	Chalimbana	Chongwe
Zambian_Extracts_Oil	150	40	Chalimbana	Chongwe
Liempe_Farm_UNZA	230	30	Chalimbana	Chongwe
Palabana_Training_Institute	80	60	Chalimbana	Chongwe
Pebblebrook_Farm	140	40	Chalimbana	Chongwe
Silverrivers_Farm	162	20	Chalimbana	Chongwe
Enviro_Flor	125	75	Ngwerere	Chongwe
Kasisi_Agricultural_Centre	160	90	Ngwerere	Chongwe
Balmoral_Farm	400	140	Chilongolo	Kafue
York_Farm	200	200	Chilongolo	Lusaka
Lilayi_Farm	700	300	Chilongolo	Lusaka
Eureka_Farm	350	120	Chilongolo	Lusaka
Musekese_Farm	125	60	Chilongolo	Lusaka
Chitempha_Farm	18	15.6	Chunga	Kafue
KP_Farm	100	100	Chunga	Kafue
China_Zambia_Friendship_Farm	300	150	Chilongolo	Kafue
Sunlight_Farm	65	50	Chunga	Kafue
Marydale_Farm	500	130	Mwembeshi	Kafue
Seed_Co_Research_Farm	260	160	Mwembeshi	Kafue
Kashima_Farm	800	600	Mwembeshi	Kafue
Hartley_Farm	400	130	Mwembeshi	Kafue
Rosedale_Farm	8	8	Chunga	Kafue
Sunrise_Farm	400	240	Chunga	Kafue
Mayflower_Farm	300	300	Chunga	Kafue
Mwembeshi_Prison_Farm	300	40	Mwembeshi	Kafue
JM_Farm	40	8	Mwembeshi	Kafue
Mwembeshi_Farm	1500	0	Mwembeshi	Kafue
Munganga_Farm	14	6.5	Chilongolo	Kafue
Ambrosia_Farm	400	178	Chilongolo	Kafue
Azeeb_Farm	100	90	Chilongolo	Kafue
Bunde_Farm	300	160	Chilongolo	Kafue
Noorani_Farm	250	50	Chilongolo	Kafue
Christian_Vision_Farm	163	163	Kafue Flats	Kafue

APPENDIX 4 List of all industries

Industry	Type of Industry	Catchment	District
Zamleather	Tannery & Leather	Chunga	Lusaka
Tombwe_Processing	Tobacco	Chunga	Lusaka
DuncanCo_Distillery	Drink	Chunga	Lusaka
Zambian_Fertilizers	Fertilizer	Chunga	Lusaka
Devmin_Investments	Wholesaler	Chunga	Lusaka
Seba_Foods	Food	Ngwerere	Lusaka
Tiger_Animal_Feed	Food	Chunga	Lusaka
Unified_Chemicals	Food, Foam manufacture	Chunga	Lusaka
Nisco_Industries_Golden_Foods	Food	Chunga	Lusaka
Ujala_Ltd	Food	Ngwerere	Lusaka
Decotex	Paint	Ngwerere	Lusaka
Noor_Industry	Plastic	Ngwerere	Lusaka
Lamis_Industries	Plastic, Milling, Food	Chilongolo	Lusaka
Zambian_Breweries	Brewery	Chunga	Lusaka
Aquarite_Limited	Drink	Chunga	Lusaka
Best_Beef_Company	Abattoir	Chunga	Lusaka
National_Milling	Milling	Ngwerere	Lusaka
Trade_King_Ltd	Food, Detergent	Chunga	Lusaka
Crest_Chicken	Abattoir	Chunga	Lusaka
Dulux_Paint_Zambia_Ltd	Paint	Chunga	Lusaka
California_Breweries	Brewery	Ngwerere	Lusaka
Victory_ImportExport	Detergent, Chemical & Cleaning	Ngwerere	Lusaka
Zayaan_Investments	Food	Chunga	Lusaka
Goldstar_MillingAPGLtd	Milling	Chunga	Lusaka
Chat_Flour_Milling_Ltd	Milling	Chunga	Lusaka
Chat_2_Breweries	Brewery	Chunga	Lusaka
Dreamland_Icecream	Food	Chunga	Lusaka
Luanshya_Breweries	Brewery	Chunga	Lusaka
Mukwa_Breweries	Brewery	Chunga	Lusaka
Midlands_Breweries_LusakaBeer	Brewery	Ngwerere	Lusaka
Hi_Protein_Foods	Food	Chunga	Lusaka
Foam_King_Manufacturers	Foam manufacture	Chunga	Lusaka
Kembe_Meat_Products	Abattoir	Chunga	Lusaka
Amiran_Ltd	Seedlings	Chunga	Lusaka
Chat_1_Breweries	Brewery	Chunga	Lusaka
King_Quality_Meat_Producers	Abattoir	Chunga	Lusaka
Zamanita_Limited	Oil manufacture	Chunga	Lusaka
Ghirardi_Milling	Milling	Chunga	Lusaka
Grand_Butchers_Abattoir	Abattoir	Chunga	Lusaka
Aquasavana	Drink	Chunga	Kafue
Quality_Commodities	Food	Chilongolo	Lusaka
Batul_Investments_Ltd	Food	Chilongolo	Lusaka
Tangy_Drinks	Drink	Chunga	Lusaka

Industry	Type of Industry	Catchment	District
Citizen_Breweries	Brewery	Chunga	Lusaka
National_Breweries	Brewery	Ngwerere	Lusaka
Sparlight_Candles_Ltd	Candle manufacture	Chunga	Lusaka
Golden_Breweries	Brewery	Chunga	Lusaka
Musa_Biscuits	Food	Chunga	Lusaka
Manzi_Valley	Drink	Chalimbana	Chongwe
Majoru	Abattoir	Chilongolo	Kafue
Lafarge	Cement	Kafue Flats	Kafue
Eureka_Chicken	Abattoir	Mwembeshi	Kafue
Verino_Poultry	Abattoir	(Upper) Chongwe	Chongwe