SUSTAINING URBAN GROUNDWATER-FED WATER SUPPLIES AND SANITATION SYSTEMS IN AFRICA

The Royal Society-DFID Capacity Building Initiative for Africa Network Grant Award (AN130031)

Case study: Lukaya Town Council (Kalungu District)

Situational Analysis report

By

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1. Introduction

1.1 Background

A situational analysis was carried out within the framework of the Network Grant Award for the proposal on *Sustaining urban groundwater-fed water supplies and sanitation systems in Africa*, with the main aim of developing the scientific evidence required to inform policies and practices that sustain the quantity and quality of urban, low-cost water supply and sanitation systems. The key scientific specific objectives include to:

1. map and characterize urban aquifers, well catchments, sanitation facilities, and groundwater supply coverage and use for the respective cities;
2. analyze aquifer dynamics, surface-groundwater interaction, and vulnerability of the aquifers to point and non-point source pollution;
3. quantitatively assess the impact of different low-cost, sanitation strategies on urban groundwater; and
4. build capacity to assess, manage, and sustain urban groundwater systems.

The study is based on three scales of investigation where Lukaya town, Uganda is the smallest setting, Kisumu is a city and Dakar, Senegal is the mega-city (Fig. 1). Lessons e.g. the avoidance of major problems such as nitrate contamination shall be drawn from large cities (e.g. Kisumu and Dakar) to inform small towns (e.g. Lukaya).

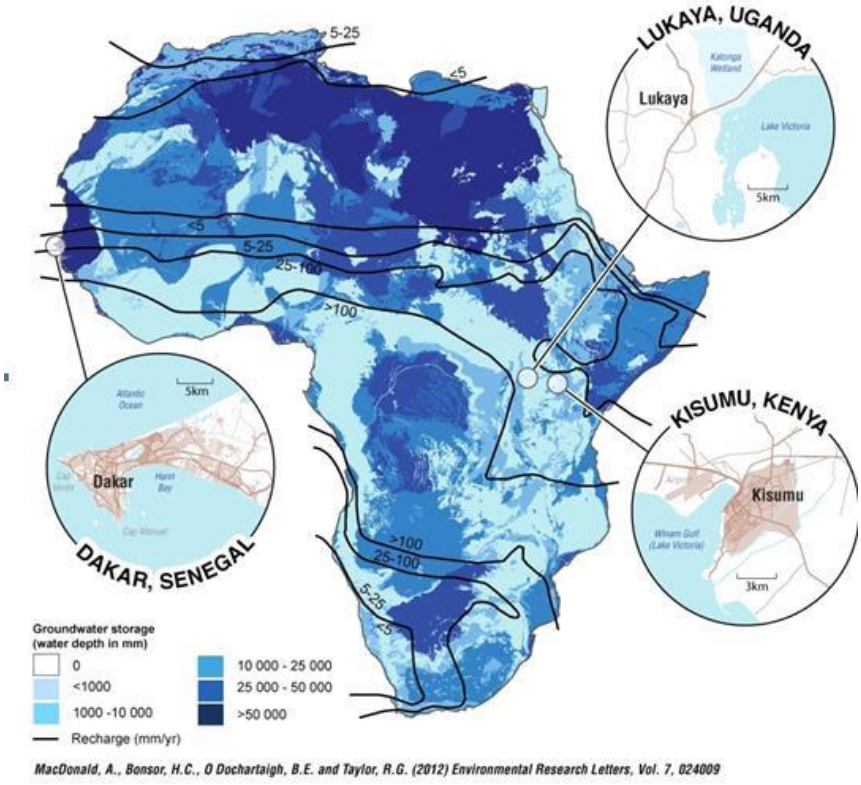

Figure 1: Map of Africa showing the study locations of Lukaya, Kisumu and Dakar.

1.2 Activities carried out

The key activities carried out during the situation analysis visit included:

- briefing the local council and water supply authorities on the objectives and scope of the research project;
- understanding issues and challenges of water supply and sanitation at Lukaya;
- assessing the groundwater pumping station with boreholes used to pump water for town water supply ;
- visiting and appraising specific local institutions including schools and community

organizations on water and sanitation issues;
- engaging with some stakeholders and local inhabitants along the way on water and sanitation issues in the town council.

1.3 Places visited

The places visited in Lukaya were:

- Lukaya Town Council – where all the water and sanitation information management and governance is coordinated.
- Bright Services - the main water supply company for Lukaya town.
- Lukaya Town groundwater supply station.
- Local groundwater sources (e.g. springs and shallow wells).

1.4 List of Officers met

During the visit, the following officers were met:

- Mr. David Mugaga, Head of Water Dept, Lukaya Town Council
- Mr. Musa Dhabuliwo, Health Inspector
- Mr. Moses Ndagije, Manager, Bright Services
- Mr. Richard Sebandeke, The Town Clerk
- Mr. Gerald Majera Ssenyondo, The Local Council 3 Chairperson (Mayor of Town Council)

2. Legal, Policy and Institutional Framework

Water and sanitation activities in Uganda take place within a set legal, policy and institutional framework (MWE, 2007). The legal framework outlines the rights and responsibilities of different stakeholders and gives a legal basis for water resources management and regulation which include; The Constitution of the Republic of Uganda (1995); The Water Act (1995); The Local Governments Act (1997); National Environment Act (1995); The Public Health Act (2000); The Water Resources Regulations (1998) and Waste Water Discharge Regulation (1998); The Land Act (1998); The Public Finance and Accountability Act (2003); and The Public Procurement and Disposal of Public Assets Act (2003).

The policies provide the principles of action to be followed in the implementation and they provide the rules of practice and give direction to the activities in the sector which include; The Poverty Eradication Action Plan (PEAP, 2005); The National Water Policy (1999); The National Health Policy (1999); The Environmental Health Policy (2005); and The National Gender Policy (1999).

The institutional framework details the roles and responsibilities of key sector players which adopted the Sector Wide Approach to Planning (SWAP, 2002). The four key sub-sectors of the water and sanitation sector include; Water Resources Management (WRM); Rural Water Supply and Sanitation (RWSS); Urban Water Supply and Sanitation (UWSS); and Water for Production (WFP).

3. Study Location

Kalungu district includes Lukaya and Kalungu Town Councils and 4 sub-counties (Lwabenge, Kyamulibwa, Kalungu and Bukulula) (Fig. 2). Lukaya town council stretches into Lake Victoria with the town of Lukaya lying across the Kampala-Masaka highway. The town of Lukaya is situated about 105 km southwest of Kampala city.

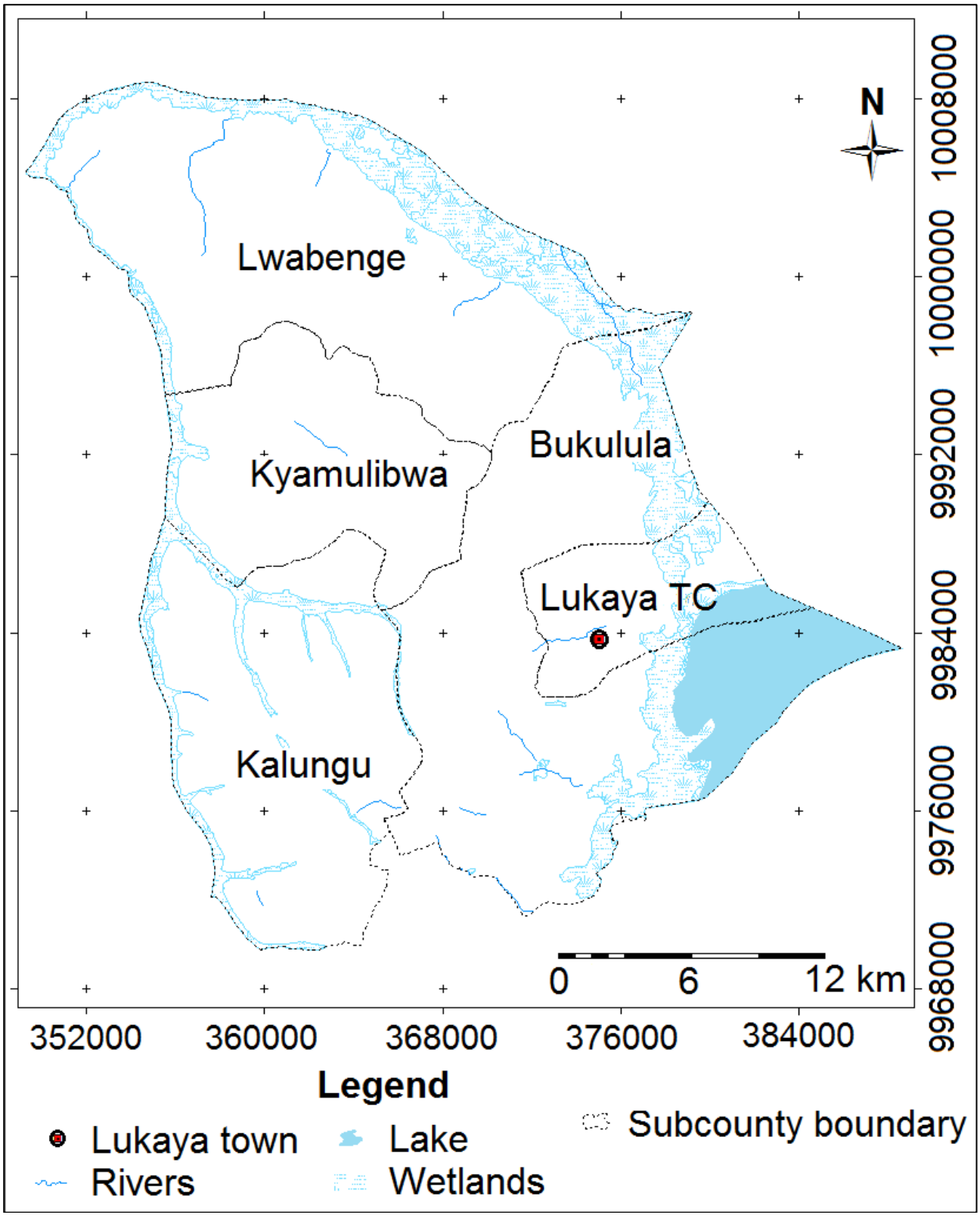

Figure 2. The sub-counties of Kalungu District including Lukaya Town Council.

4. Demography

Kalungu district had a total population of 184,134 people from the 2014 national population census (PHC) with Lukaya Town council (TC) having 24,250 people representing about 13% of the district's population (MFPED, 2015).

Table 1: Total number of households and population distributed by gender in Lukaya TC (KDSER, 2012).

	No. of Households	Total Population		
		Male	Female	Total
PHC, 2002	3,826	12,204	13,195	25,399
PHC, 2014	6,284	11,586	12,664	24,250

5. Economic activities

According to KDSER (2012), the main economic activity in Kalungu district is agriculture (~38%) followed by the service sector, trade and least is manufacturing. Lukaya TC has mostly services (~13%), trade (~9%) and agriculture (~9%). The district is largely dependent on agriculture (69%) which includes crop farming, livestock keeping, poultry keeping, fish farming and bee keeping. Most of the farming for livelihoods involves crop farming (~95%), livestock rearing (~43%) and poultry keeping (~33%). Main crops that are grown are coffee, beans, cassava, sweet potatoes, bananas, maize, finger millet, sorghum, Irish potatoes and rice. Livestock kept include cattle, pigs, goats, sheep, rabbits and donkeys. In Lukaya TC, beans are the most grown crop (~49%) and cattle are the most kept livestock (~66%).

6. Climate

There are six weather stations in the neighbourhood of Lukaya TC (Fig. 3). Regional rainfall from these six stations is depicted in Figure 4. The region is humid with rainfall that is variable but follows a bimodal pattern with first rains occurring during the period March to May and second rains from September to November, (Fig. 4). Long term mean annual rainfall from these stations ranges from 709 to 890 mm. Monthly rainfall peaks are 168 mm (April) and 108 mm (October). Lukaya is within a region where potential evapotranspiration has been estimated to range from 1,350 to 1,750 mm per year (NWRA, 2013). Monthly minimum temperatures range from 10 to16 ^{o}C and maximum temperatures from 16 to 25 ^{o}C.

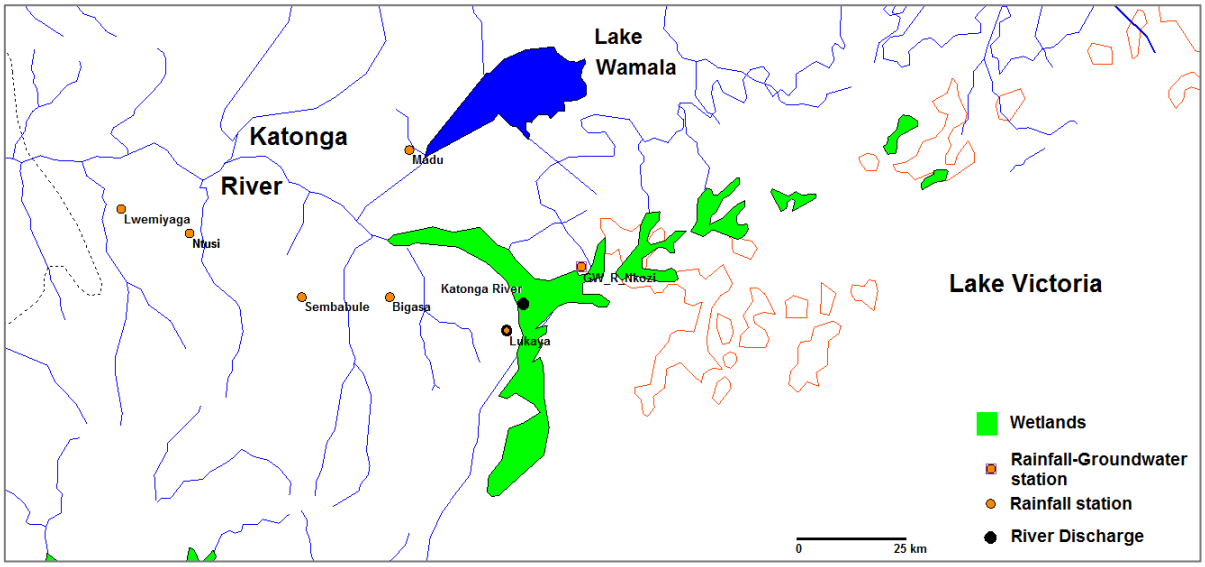

Figure 3. Map of rainfall, groundwater and river discharge stations around Lukaya region.

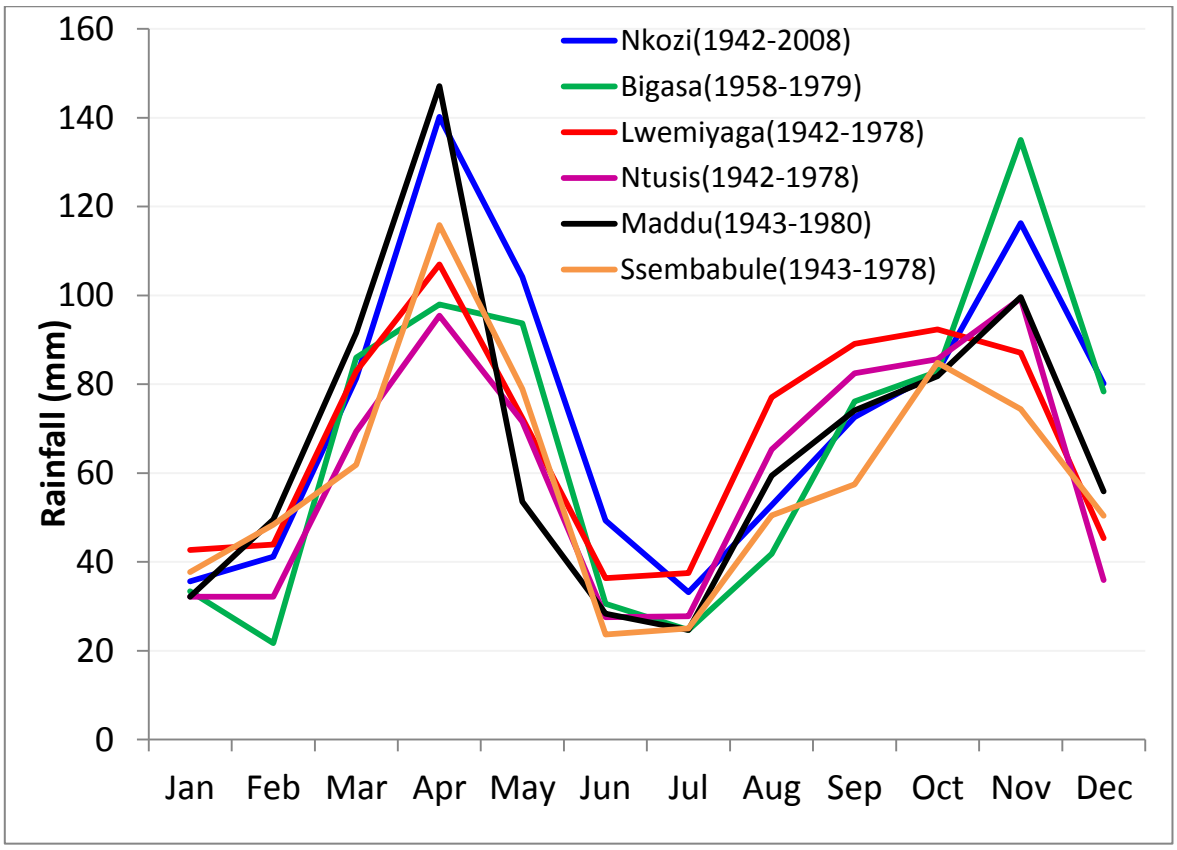

Figure 4. Long-term average monthly rainfall from six stations in the neighbourhood of Lukaya TC.

7. Physiography and drainage

Rift-related, tectonic processes since about early Miocene are considered to have shaped the present landscape of Lukaya and thus influence surface hydrology through the development of low relief landscape features. This landscape includes depositional or infill landscapes which occur along valleys on the plateau and on the margins of Lake Victoria. In areas east of the axis of the western uplift, a reduction in relief led to the ponding of surface water in the wide drainage channels linked with the former west-flowing headwaters (e.g. Katonga) of the Congo basin. Along much of the Lake Victoria's perimeter, particularly in the north and south, the shoreline is highly irregular and appears partially drowned (Kendall, 1969). Where the Katonga River flows into Lake Victoria, its former course is marked by a deep channel passing between the Sese Islands (Temple, 1970). Remnants of the lowland surface (Miocene-Recent) that are envisaged to have resulted from these latest episodes of rift-related volcano-tectonic processes, occupy areas of less resistant rocks, like granites, gneisses and mica schists of the Katonga valley (Doornkamp and Temple, 1966). North and south of the lake the watershed is less than 25 m above lake level (Kendall, 1969). Depths of less than 50 m (typically 4-7 m) are typical of the western and northwestern parts of the lake. The lakeshore fringing swamps showed a distinct succession of zones associated with the water depths, which include, water-lily zone, fern and sledge zone, papyrus zone, palm swamp, and a fringing forest (Carter, 1956).

Lukaya TC lies within the Lake Victoria catchment within a low relief region that is dominated by slow discharge of streams into wetlands that drainage the lake (Fig. 5). Mean elevation over most of the town council is slightly higher than the average lake level of 1,134 masl. Higher relief reaching 1,238 masl is on the western part of the town council.

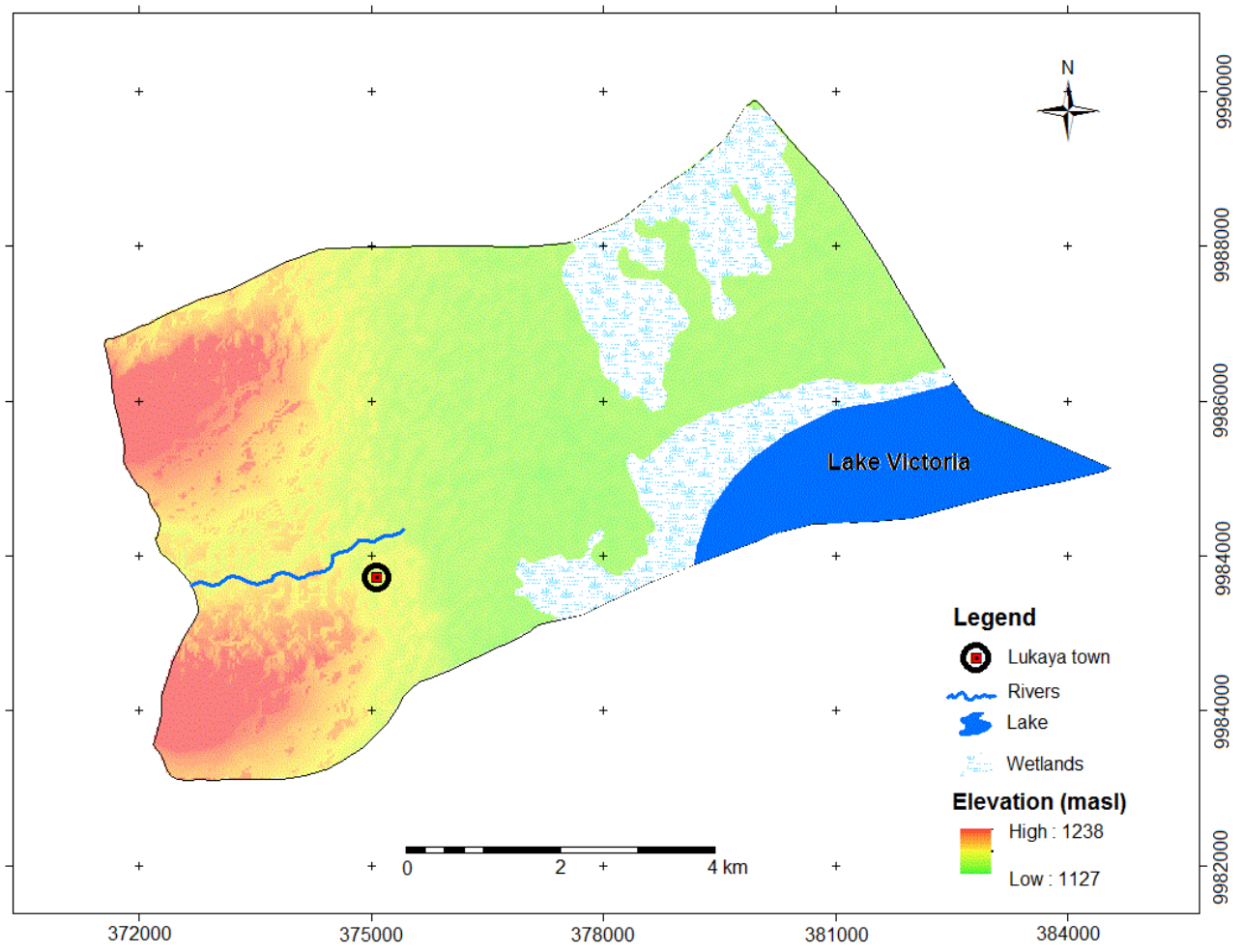

Figure 5. Map of elevation contours and drainage of Lukaya TC.

The main Katonga River discharges through the northwestern wetlands of the town council into the lake. Daily discharge from 1999-2010 of station 81259 managed by the Directorate of Water Resources and Management (currently not operational due to damage from road works) ranged from 0.008 to 17.6 m^3s^{-1} with a mean and standard error value of 2.5±0.04 m^3s^{-1} (Fig. 6). Apart from the period of 2003-2008, there are large and distinct seasonal discharge responses to the bimodal rainfall pattern which is characteristic of the region.

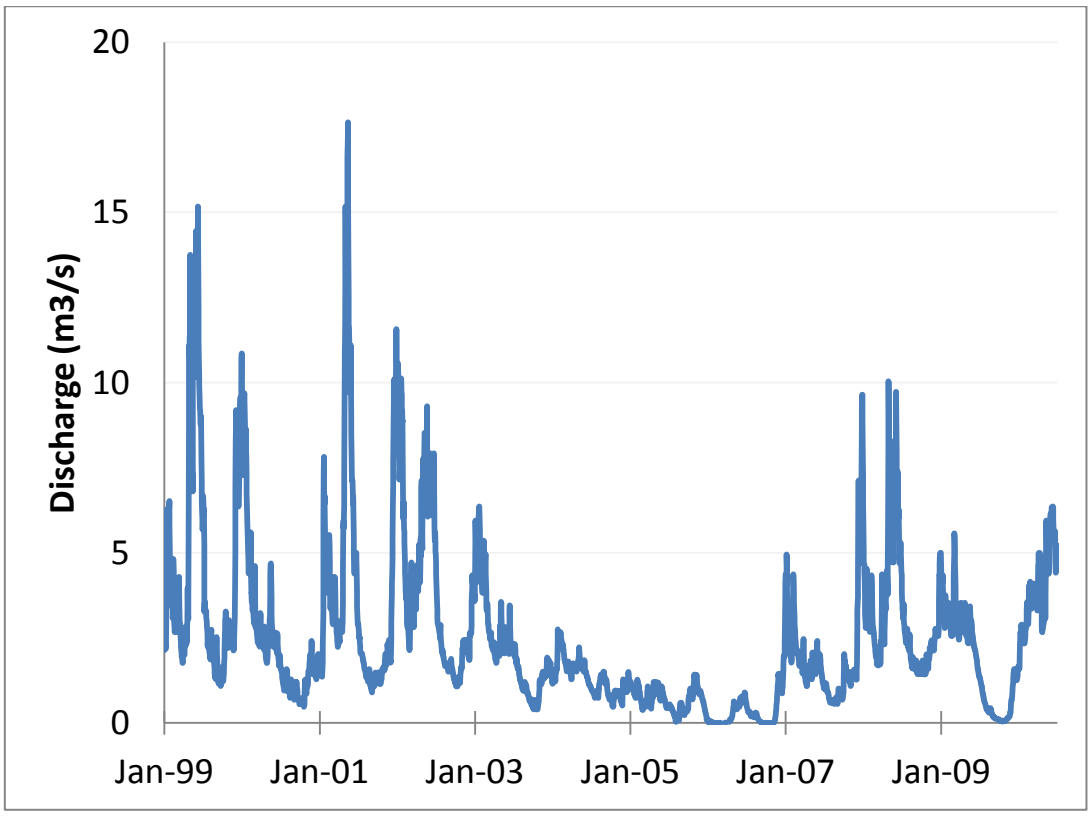

Figure 6. Daily discharge of River Katonga measured from 1999 to 2010 (data from station 81259, Directorate of Water Resources and Management).

8. Soils

Soils in the Lukaya region are generally ferrallitic characterized by areas of red clay loams, loams, yellow-red loams all underlain by soft laterite. Grey coarse sands are found in the wetlands that border Lake Victoria.

9. Geology

Regionally the Lukaya region which lies northwest of Lake Victoria has quite varied geology (Fig. 7). The regional geology include sediments and rocks of the Buganda Group that comprise slate, phyllites, mica schist, metasandstone. Muyaga Group comprises mudstone, shale, phyllite quartzite, conglomerate, with algal fossils. Mityana Group comprises conglomerate, sandstone, siltstone, gritstone. Others are Namuwasa Group, Bwezigoro Group, Mubende batholith and Singo batholith (Westerhof et al., 2014). Regional structural lineaments trend in a NW-SE direction.

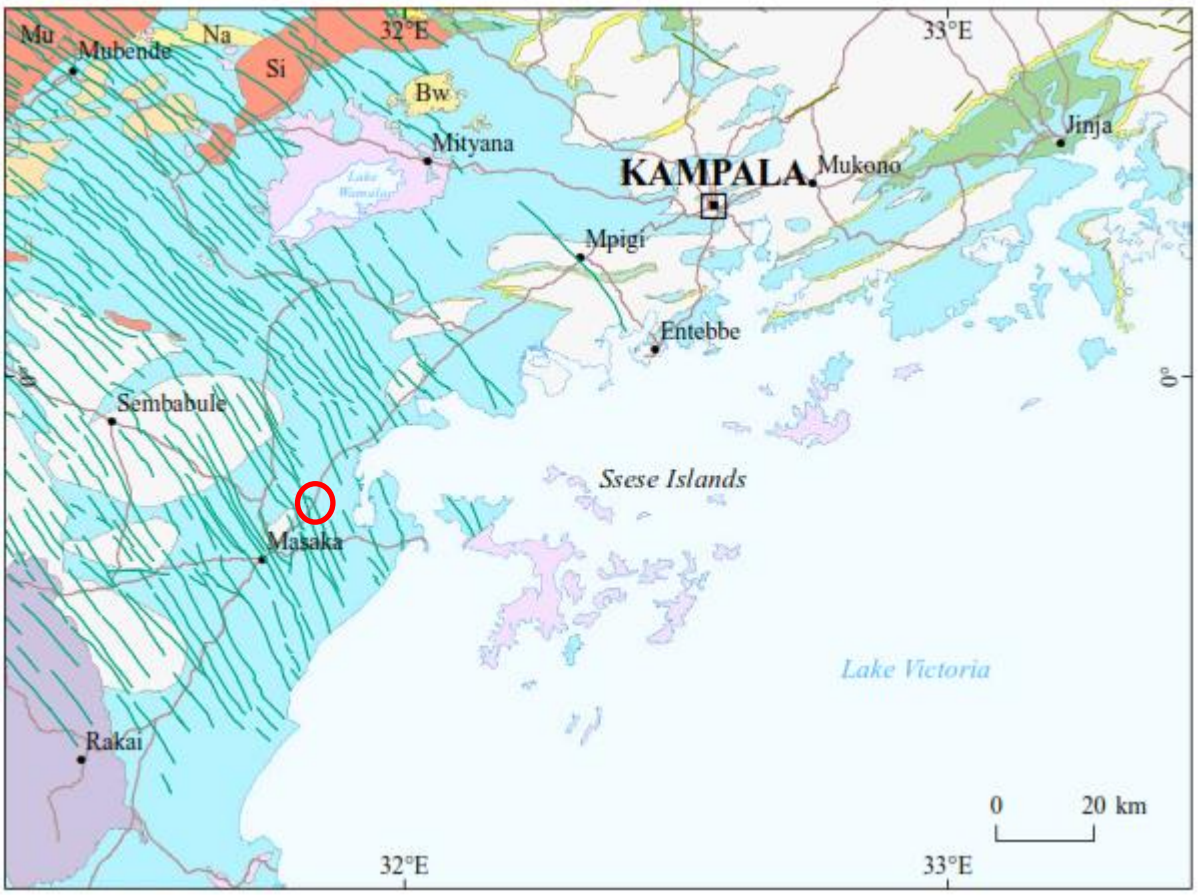

Figure7. The location of Lukaya (red) including regional geology includes sediments and rocks of the Buganda Group (slate, phyllites, mica schist, metasandstone: yellow/green/blue). Key: Muyaga Group (mudstone, shale, phyllite quartzite, conglomerate, with algal fossils: dark lilac), Mityana Group (conglomerate, sandstone, siltstone, gritstone: lightlilac), Na=Namuwasa Group, Bw = Bwezigoro group, Mu = Mubende batholiths, Si = Singo batholith (modified from Westerhof et al., 2014).

Within Lukaya TC, the low relief area is largely occupied by Recent sediments (Fig. 8). The western part is characterized by basement rocks which include gneisses and granitic rocks.

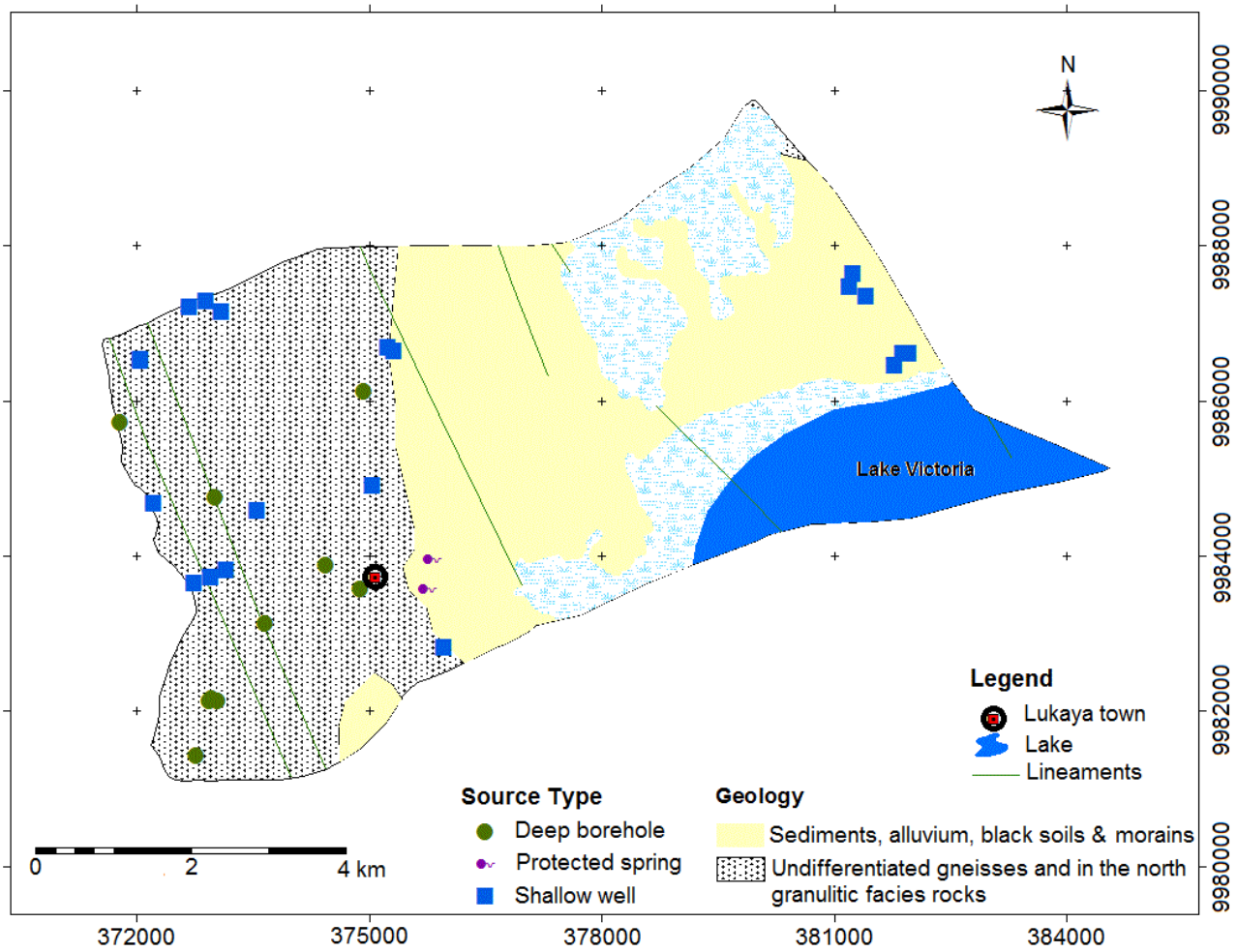

Figure 8. Geology and main water sources in Lukaya TC.

10. Hydrogeology

The low relief region is characterized by deeply weathered crystalline rocks. Thus, the hydrogeological environment is largely crystalline rock aquifers comprising fractured bedrock and overlying regolith. Overlying the crystalline rock aquifers is alluvial and lake sediments which form a shallow aquifer (former palaeo drainage channel) which is commonly thin and variable in geometry.

In Lukaya, the litho-stratigraphy of the region from borehole lithological logs include a top soil which is brown (murrum) to grey/black (loamy) with clays; followed by yellow, reddish brown to grey clays; underlain by weathered zone composed of granites, sandstones, quartzites, gneisses, shales and schists; above the bedrock is fractured bedrock. Aquifers are predominantly within the weathered zone through the interface with fractured zone as well as the fractured zone. Across the district up to 5 lithological layers are identified with maximum depths of 48, 76, 120, 136 and 153 mbgl, respectively. Summary statistics of aquifer geometrical characteristics from borehole lithological logs of Kalungu district show water strike depths of 9 to 115 mbgl (Table 2). Static water levels are as shallow as 0.45 and reach 64 mbgl. Estimated discharge of the wells reaches 4.7 m^3h^{-1} which indicates low to medium groundwater potential.

Table 2. Summary statistics of aquifer geometrical characteristics from borehole lithological logs of Kalungu district.

District	Min	Max	Mean	Standard error
Total drilled depth (mbgl)	37.4	168	94	3

Depth to bed rock (mbgl)	17	107	55	2
Depth to water strike 1 (mbgl)	9	115	62	3
Depth to water strike 2 (mbgl)	30	150	79	4
Depth to water strike 3 (mbgl)	50	104	73	10
Static water level (mbgl)	0.45	64	29	2
Total estimated discharge (m^3h^{-1})	0.16	4.7	1.5	0.2

The shallow static water level (up to 0.5 mbgl) is characteristic of the low relief areas that include Lukaya town council (Table 3). Depth to bedrock is also fairly shallow up to 33 mbgl. Borehole yields are generally low (0.5-1.5 m^3h^{-1}).

Table 3. Summary statistics of aquifer geometrical characteristics from borehole lithological logs of Lukaya TC.

District	Min	Max	Mean	Standard error
Total drilled depth (mbgl)	90.8	117.8	102.0	4.3
Depth to bed rock (mbgl)	33.0	90.6	57.9	9.3
Static water level (mbgl)	0.5	9.0	4.5	1.6
Constant discharge yield (m^3h^{-1})	0.5	1.5	0.9	0.2

The closest national groundwater monitoring borehole to Lukaya town is at Nkozi where groundwater levels have been logged (using an automatic chart recorder) proximate to rainfall measurements (rain gauge) since 1999 (Fig. 3). Groundwater levels are shallow and seasonal responses to rainfall recharge vary between 1.5 and 4 mbgl. Rapid vadose zone velocities induce short lag time groundwater level responses to rainfall inputs which also suggest low groundwater storage from the spiky groundwater level changes.

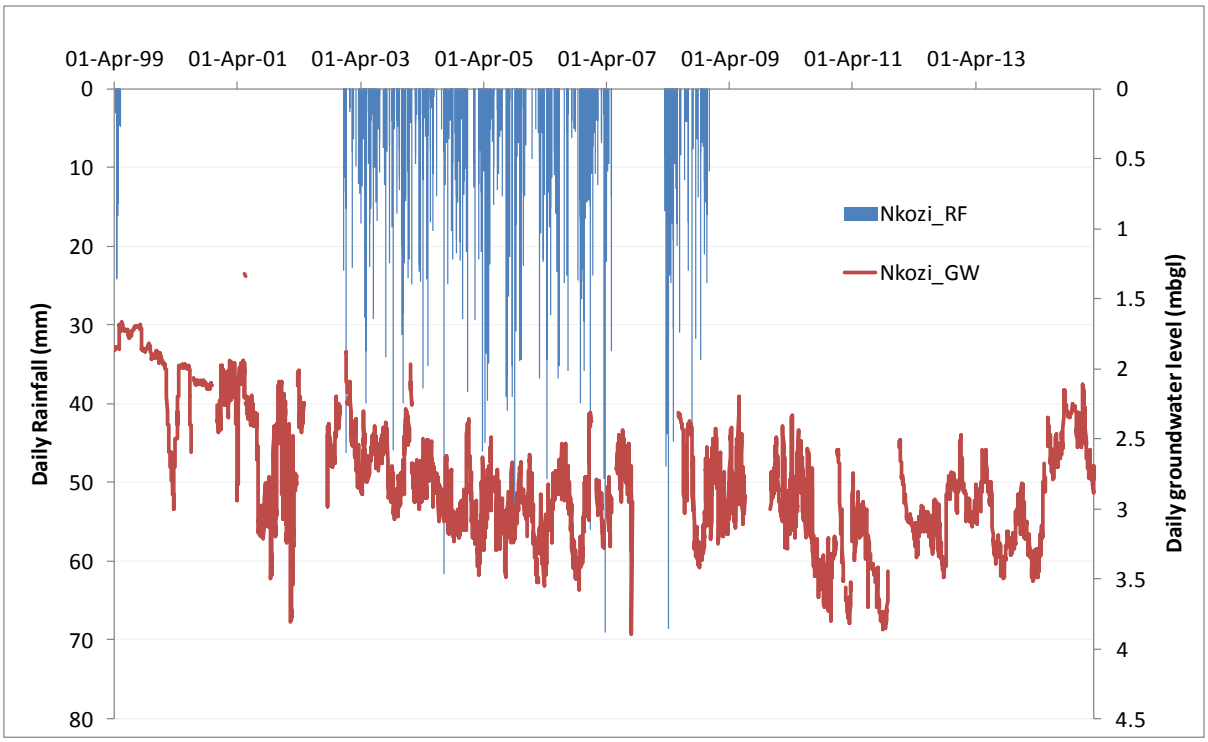

Figure 9. Daily groundwater level and rainfall measurements at Nkozi from 1999 to 2015.

11. Water and sanitation coverage and management

In Kalungu district the safe water coverage is at 67%, functionality at71% and sanitation 89.2% (MFPED, 2015).The rural safe water access is 93%; functionality of safe water sources is 58%; equity in distribution of rural water points is 23%; rural latrine coverage is >77%; management percentage of water service committee functionality is 62% with a high percentage of key positions (80%) occupied by women (MWE, 2014). There are 281 water sources under community management with 173 sources having established water service committees; 108 sources have functional water service committees; 138 sources have water service committees with at least one woman in a key position; 62% of the water service committees are functional; 80% water service committees have women in key positions; there are water boards each with 5 members but none has women in key positions.

In Lukaya TC, the water department is managed by a water board whose membership includes an officer in charge of water affairs. The health officer is not part of the water board. The main source of water supply (>60%) is groundwater abstracted and treated with chlorine from a neighbouring sub-county. Water is supplied and managed by Bright Services which charges user fees. Other sources are shallow boreholes that are in high demand because people do not have to pay for water access. A storage tank (200 m^3) supplies an area of 32 km^2 with central outlets and several individual connections. The storage tank and a small radius of piping grid are inadequate to meet current water demand. Records of water points (quantity and quality) and well completion records are held at the town council. Siting of water sources in the area, involves stakeholders, however, the drilling contractors invariably determine locations of final well points without regard for sanitation facilities. Due to a shallow groundwater table in the area, latrines are shallow and they are emptied manually into surrounding wetlands, posing a critical waste management issue in the central part of the town. Specific issues regarding water supply include; boreholes with turbidity problems during the wet season; poor maintenance of water infrastructure; dormant water and sanitation committees although the DWRM (Technical Service Unit) for the Lake Victoria catchment (based in Mbarara) provides some support.

12. Water resources

Groundwater is the dominant source of water in Lukaya TC with the lower-income people exploiting shallow groundwater sources (e.g. spring sources and shallow wells are ostensibly free though maintenance costs are sometime charged). The high variability in well yields and inconsistent performance lead to uncertainty in supply (weak aquifer despite growing population) which poses a challenge of whether these resources can meet rising demands.

12.1 Water sources

The main sources of water of Lukaya TC for various livelihoods are presented in Table 4 (KDSER, 2012). Water for drinking (32.5%) and other household uses (35.5%) is mainly from public taps. Livestock is largely watered equally (28.2%) from protected springs and river/lake/pond/stream sources whereas irrigation uses mainly rainwater harvested. Use of unprotected springs for both drinking water and other household uses also feature prominently (>9%).

Table 4. Percentage distribution of the main sources of water for various livelihoods in Lukaya TC (after KDSER, 2012).

	Total Households	Private piped water	Public taps	Bore hole	Protected springs	Un Protected springs	River, lake, pond stream	Vendor/ tanker truck	Gravity Flow scheme	Rain water	Others
Drinking Water	6,333	6.4	32.5	19	10.5	9.3	1.8	12.3	0.8	0.2	7.3
Other Household uses	6,333	1.3	35.5	25.8	3.2	9.2	3.3	11.3	0.2	-	10.3
Livestock	6,333	2.6	5.1	-	28.2	2	28.2	-	-	2.6	18

Irrigation	6,333	-	-	-	-	6	-	-	-	87.5	6.3

12.2 Water access

Across Kalungu district, 23% of the households cover less than 0.5 km to access water for various uses (KDSER, 2012). More than 43% of households cover 0.5-1.5 km, 21% cover 1.5-3 km, and >13% cover >3 km distance to access water. On average 56% of households wait for >30 minutes to access water for any use, whereas 18% have to wait <30 minutes and 25% do not have to wait in order to access water for any use. Information on monthly payments for water collected showed that 52% do not pay for water; <50% pay below UGX 10,000 per month; two out of three households reported that their water source was reliable.

12.3 Groundwater quality

Data on the quality of groundwater water sources is limited to a few boreholes scattered across the district. Figure 10 shows the locations of boreholes with major and selected secondary chemistry data. The total iron content is a major concern to users because of its effect on the aesthetic properties of water. Groundwater is mainly of the Ca-Mg and HCO_3-SO_4 types (Fig. 11) which reflect recently recharged waters that have not been in storage long enough to be chemically modified by processes in the aquifers. All the water samples have TDS less than 1000 mg/l which indicate fresh water types readily useful for drinking and household purposes, although a few boreholes have electrical conductivity in excess of 1,000 µS/cm. The pH falls within a range of 6 to 9.

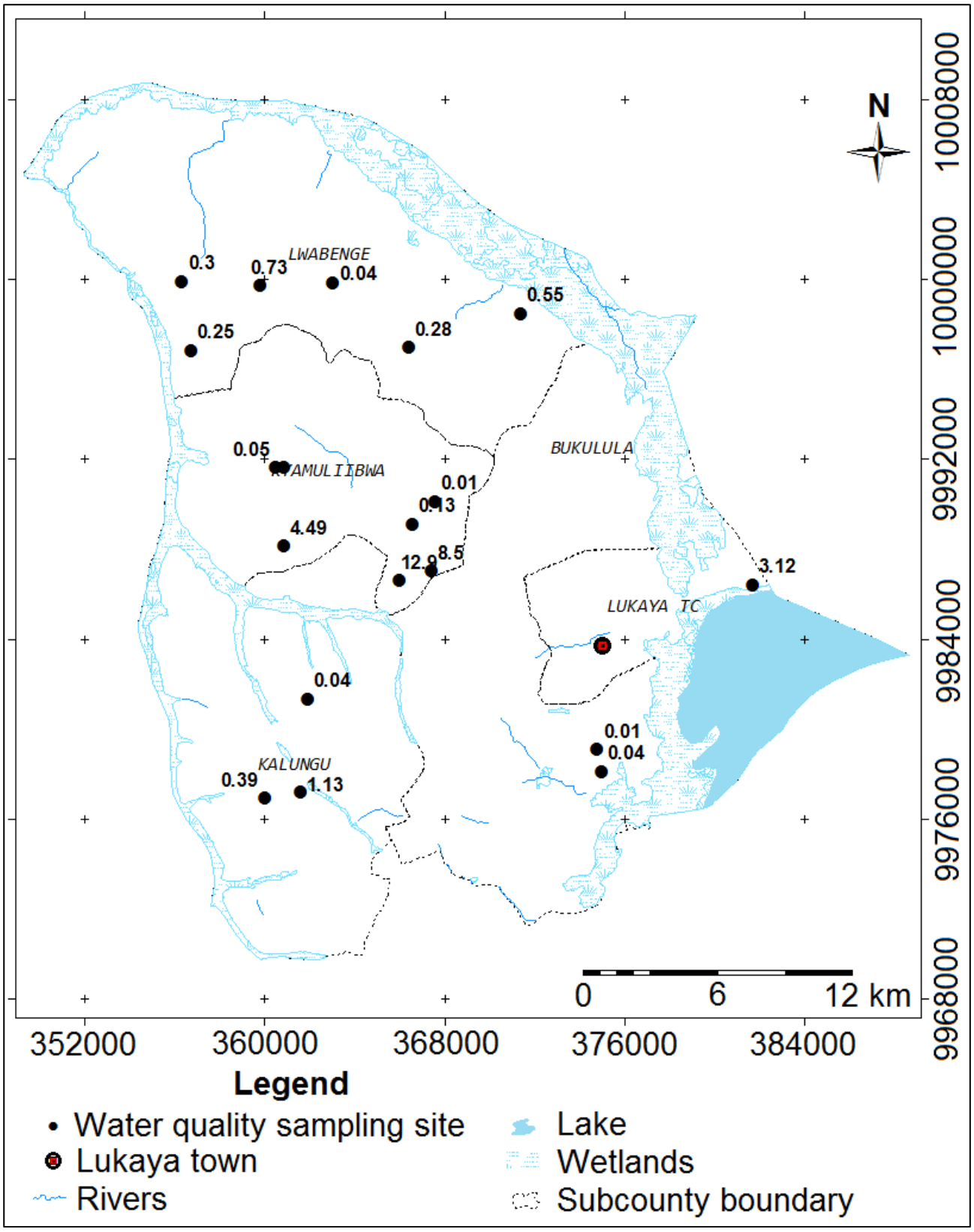

Figure 10. Groundwater water chemical quality sources in boreholes across Kalungu district. The figures indicate total iron contents in mg/l.

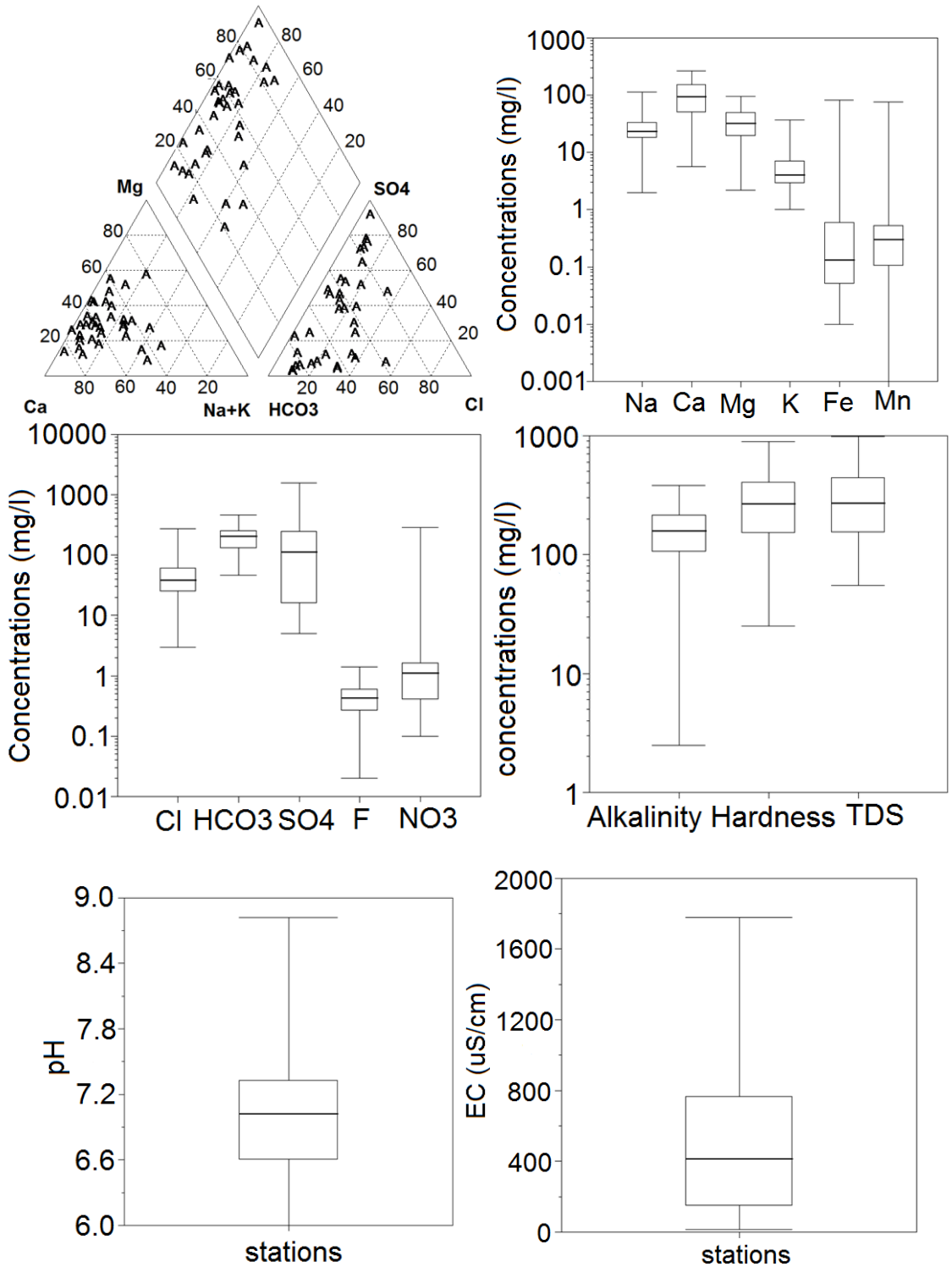

Figure 11. Piper and box plots of the major, physico-chemical and selected secondary chemistry of groundwater across Kalungu district.

13. Sanitation and health

Due to the low relief and shallow groundwater tables in Lukaya TC, the majority of sanitation facilities are elevated pit latrines. Proper methods of emptying these pit latrines are not used with waste being discharged into steams during rainy seasons. Thus, by-laws have been proposed for proper waste management which include an appeal for an emptying vehicle to reduce on associated health risks. There are also issues of limited functional public toilets which need to be increased.

Malaria is among the communicable diseases that account for over 50% of the total disease burden in Kalungu district (KDSER, 2012). A study on malaria and diarrhea during a 30-day study showed that malaria is more prevalent in persons aged 0-4 years (31%) than diarrhea (9%) for the same age group. In Lukaya TC, malaria prevalence rate for 0-4 years was 32% and 26% for ≥5 years(Table 5). Diarrhea however, had a prevalence rate of 10% among the 0-4 years and 4% among the ≥5 years of age. It was also noted that >45% of children aged ≤4 years had completed full immunization schedule whereas 20% had partial completion and 3% had none.

Table 5. Distribution of the population that suffered from diarrhoea by subcounty (after KDSER, 2012).

Disease	0-4 Years		5 years & Above	
	Population	%	Population	%
Malaria	3,387	32.4	22,012	26.1
Diarrhea	3,387	10.13	22,012	4.31

14. Conclusions

- The water and sanitation sector in Uganda has a comprehensive legal, policy and institutional framework, however, there is need for enforcement in order to systematically manage contemporary issues in the sector.
- Lukaya TC has a population that has decreased from 2002 to 2014 by about 5% (rural to urban migration?) although the population of Lukaya town has increased (due to urbanization?).
- The main economic activities in Lukaya TC are services (~13%), trade (~9%) and agriculture (~9%). Beans are the most grown crop (~49%) and cattle are the most kept livestock (~66%).
- Rainfall is variable and follows a bimodal (March-May and September-November) pattern amounting to 709-890 mm per annum with potential evapotranspiration exceeding rainfall. Monthly minimum and maximum temperatures in the area range from 10-25 ^{o}C.
- Lukaya town is a low (<1,238 masl) relief region, with wetlands and sluggish flowing streams. River Katonga drains through wetlands on the northwestern part into Lake Victoria with a bimodal peak discharge seasonally varying from 0.008 m^3s^{-1} to 17.6 m^3s^{-1}.
- Soils in the area are generally ferrallitic including red-yellow loams all underlain by soft laterite and grey coarse sands in wetlands towards the lake.
- Geology includes sediments and rocks that comprise slate, phyllite, mica schist, gneiss, granite, mudstone, shale, quartzite, conglomerate, sandstone, siltstone and gritstone.
- Hydrogeological formations include shallow alluvial and lake sediments, weathered zone through the interface with fractured zone as well as the fractured zone. A shallow static water level (up to 0.5 mbgl) is exhibited by the area with depth to bedrock up to 33 mbgl, and generally low borehole yield (0.5-1.5 m^3h^{-1}). Long-term (since 1999) groundwater level monitoring at Nkozi indicate shallow and sharp, seasonal responses to rainfall recharge fluctuating between 1.5 and 4 mbgl.
- Lukaya TC has specific water and sanitation issues that include inadequate composition of the water board; dormant water and sanitation committees; insufficient groundwater sources for water supply which requires chemical treatment and is costly for users; insufficient water storage reservoir and small coverage of reticulated grid; drilling contractors invariably determining site of water sources without regard for sanitation facilities; waste disposed into surrounding wetlands posing a critical waste management problem; boreholes with turbidity problems during the wet season; poor maintenance of water infrastructure.
- Groundwater is the dominant source of water in Lukaya TC with high variability in well yields and inconsistent performance which lead to intermittency in supply to meet rising demands.

- Water for drinking (32.5%) and other household uses (35.5%) is mainly from public taps, however, use of unprotected springs for both drinking water and other household uses also features prominently (>9%).
- Across Kalungu district to access water for various uses 23% of households cover <0.5 km, >43% cover 0.5-1.5 km, 21% cover 1.5-3 km, and >13% cover >3 km; waiting times for access of water are >30 minutes for 56% of the households, <30 minutes for 18% of the households with 25% not having to wait; 52% do not pay for water.
- The background groundwater quality is largely fresh (<1,000 mg/l TDS) of Ca-Mg and HCO_3-SO_4 types except for variable total iron concentrations.
- Sanitation facilities are generally limited, elevated due to the shallow groundwater, proximate to water sources, emptied into surrounding wetlands which increases associated health risks.
- Malaria prevalence rate for 0-4 years was 32% and ≥5 years was 26%; diarrhea has a prevalence rate for 0-4 years of 10% and ≥5 years of 4%; >45% of children aged ≤4 years had completed full immunization schedule whereas 20% had partial completion and 3% had none.

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