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HYDROGEOLOGICAL AND GEOPHYSICAL SURVEY REPORT

CLIENT: JOSIAH OJOWI

P.O. BOX 40010

MOMBASA G.P.O.

PROJECT: GW/2022/05

GEOPHYSICAL AND HYDROGEAOLOGICAL SURVEY

LOCATION: RIAT, KISUMU, KISUMU COUNTY

LAND TITLE: KISUMU

Report by: Geol. Stephen Olang' (R. Geol/Hydrogeol)

Date: September, 2022

Report No: 2022 GWS/05

Table of contents

1. Introduction

1.1 Background

Josiah Ojowi sought for a hydrogeological survey to be conducted at a planned residential development at Riat area, Kisumu, to determine aquifer presence and characterize hydrogeological conditions at the site; with view of drilling for water in event of a successful aquifer strike.

There is presently no piped water serving the area, occasioning great effort by residents to either harvest rainwater or buy water from vendors who commonly cart water within the locality to augment their domestic needs.

1.2 Location

The survey point is within a secured compound which is located at Riat area, Kanyakwar, Kisumu West sub-county, Kisumu county, about 7 km to the North of Kisumu town. Access is via the Kisumu – Kakamega road, turning left at the Riat roundabout, on the tar road that leads to RIAT college. The sounding point was centred on a piece of land, measuring about 1200m2, on open ground with upcoming maize crop; located at – UTM 36M 0695384/9994831.

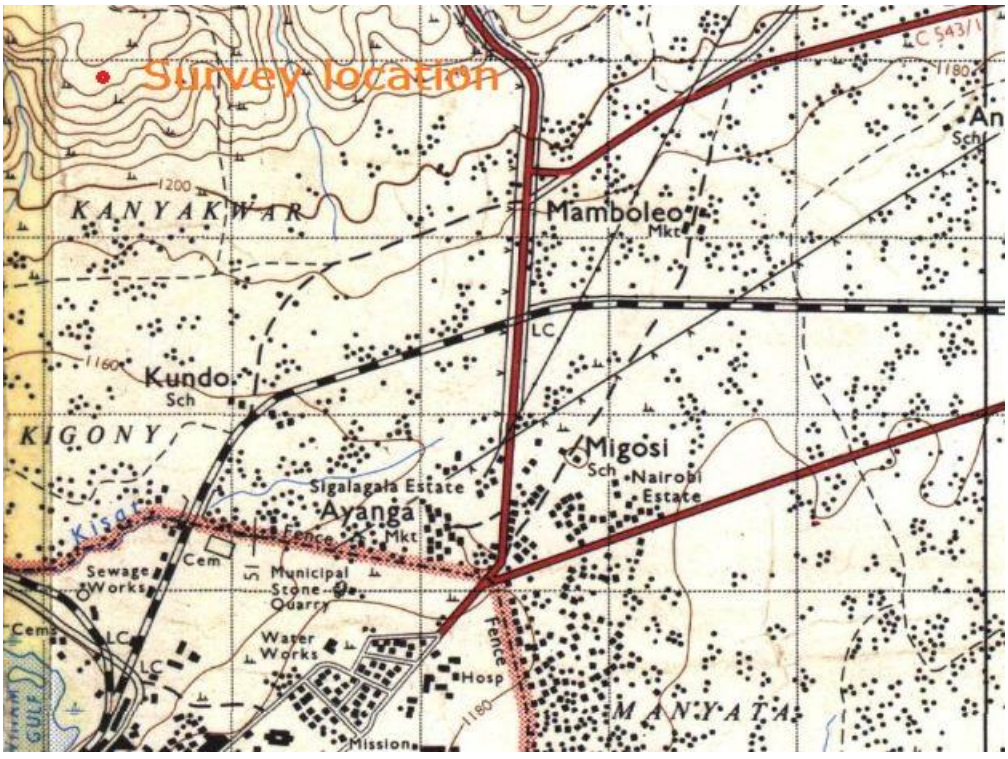

Figure 1: Survey location

1.3 Population

The client's property houses a small worker's dwelling unit within a densely populated peri-urban locality in the outskirts of Kisumu town. The area is typified by secured plots inhabited by a majority of formal sector workers and employees within Kisumu town and possibly other towns.

1.4 Survey date

The field survey was conducted on 23rd September, 2022 under supervision of Stephen Olang – Geologist/Hydrogeologist. At the survey time, Kisumu and environs was experiencing its short rainy season, which lasts almost two months. Conditions were, therefore, moderately dry but soil was moist.

1.5 The problem definition

Riat area, though located in one of the areas receiving a fair amount of annual rainfall, also experiences serious water crises during drought. Expectations of water supply from the local water supply company has not been met in time and reliance on water vendors is currently the norm. Rainwater harvesting is done by a good number of individuals but space and design in the broader area is limiting.

2. Climate

The area experiences a tropical high altitude hinterland type of climate with typical two rainy season pattern, as most Kenya; long rains in March – May and short rains in September – November. The pattern is becoming more and more erratic and unpredictable. Temperatures range from 13^0C at night to a high of 37^0C during hot days.

Mean annual rainfall is estimated at 1500mm.

Lush vegetation of an intermix of subsistence crops such as maize, beans, vegetables, bananas are common in season on farmlands and moderately dense thickets on uncultivated areas are seen most of the year.

3. Physiography

The survey area is located on the northern highs of Riat scarp; which is part of what is commonly referred to as Nandi escarpment. The land slopes moderately gently southwards towards the scarp descent which lies about

700m south of the survey point. The surveyed location is about 120m above the lake Victoria level.

Geology

4.1 Pedology

Located within the northern fringes of the failed Kavirondo rift valley, the survey site lies on a moderately steeply sloping topography covered in, brownish-red, loamy clay soil. The soil is observed to be thin, averaging 0.3m; developed over the bedrock in most places but sometimes on poorly developed saprolite. Where the soil is saturated in water, there appears to be a development of darker matrix, consequent to the leaching of the relatively more mobile ferrous complexes in comparison to Aluminous cations. The soil is rich in plant nutrients and gets sticky after rains but drains and dries fairly fast.

4.2 Tertiary volcanic

Riat area is underlain by a sheet of mafic, fluid basaltic lava which weathers into brownish red clayey soil. There are many exposures in vicinity of the survey area, revealing ubiquitous sub-rounded blobs of pillow-like crusts. The weathering front as well as the pedology indicates an abundant presence of chloritic material in a massive, aphanitic matix. Flow textured portions of the lava are observed at the Kakamega road cut. Adjudging from the topographic map of the area, the dominant rock unit underlying the entire Riat –Kiboswa -Majengo area is Miocene basalt of the olivine-pyroxene paragenesis that accompanied the rift valley formation. Thicknesses and contacts with underlying rocks could not be establish during this survey but is known from regional studies to be in the order of tens to few hundreds of metres.

3.3 Older rocks

Older rocks can only be observed in exposures in the Nandi scarp to the east of the survey area after Wath Orego in Kajulu where exposures of granites and granitic gneisses make very steep drops on the Nandi scarp. These are rocks classed in the pre-Bukoban system and may not warrant detailed exposition in this report.

4.4. Structures

Riat area does not reveal overt mega geo-structures. Save for the major Nandi fault scarp south of the survey area, only a series of north-west to south-east trending minor fractures truncating on the scarp are seen on

exposures. These are limited in length to metres. Basaltic lavas, where and when massive as in this area, will have only fine concordant fractures relating to volcanic flow but possibly a more jugged contact with older rocks below.

4. Hydrogeology

The topmost ground cover is red-brown loamy cley soil, which is known to have moderately poor water transmissivity and low specific retention. The soil develops rich shallow brownish-red saprolite, observed in a few localities where road cuts are located. Within the saprolite, it noted that concretions of ferrous hydro-oxides and manganese hydro-oxides develop prior to development of chlorite and clays. This in turn gives way to brownish to dark-reddish, saprock below. There is occasionally heavy precipitation in Riat, leading to heavy runoff and erosion where there is poor soil cover. Infiltration is thus limited to the aforesaid structures and minor interstitial soil adsorption.

Transient groundwater flow is analogous to the diffusion of heat in a solid material and many of the equations relating to groundwater are treated similarly. Water flow within any aquifer is determined by the aquifer type. The study area indicates an unconfined aquifer and, therefore, specific yield variable shall play a dominant role in release of water for pumping. The water head within this aquifer could, therefore, safely be used for hydraulic head estimation as no other vertical pressure gradient is envisaged.

The observations of site pedology, surrounding geological structures and saprolite properties indicate a largely low porosity.

The hydraulic gradient and direction could not be determined within the one day field trip; though for the purposes of the survey, it can broadly be presumed to be southerly, pertinent with the observed regional drainage.

Presence of an aquifer is realized in the measurements at 23m depth. The values of resistivity indicate a possible clayey deposit on the water front within the basalt.

The results of the VES modelling shows a gradual drop from 725 Ωm through 0.3Ωm; depicting zones of dry soil with boulders of basalt to wet saprolite before fresh basalt.

The weathered interface is supposed to have a good transmissivity unless clay develops during weathering.

5. Methodology

Before carrying out the actual geo-survey, a brief study of the geology, hydrogeology, physiography and existing boreholes in the area was carried out to assist in gauging the potential and borehole density of the area.

The principle applied in sub surface survey for water is electrical resistivity where a known current I (direct or low frequency alternating current) is injected into the ground through a pair of current electrodes A and B, and the potential difference created in the medium between another pair of potential electrodes M and N is measured. The resistivity of the formation is thence given by Ohm's law equation:

$$p = K \frac{dv}{I}$$

Where K is termed the geometric factor of the electrode arrangement.
An aquifer can be located by such geophysical method by taking advantage of the contrast in geophysical properties (resistivity) between water bearing and non-water bearing formations. Here observations are made to obtain information on the variation of the resistivity along a vertical section of a given location (*sounding*). The variation in the resistivity from the normal (*anomaly*) is interpreted in terms of sub-surface in-homogeneities which may include variation in lithology, depth to water table (*aquifer*), quantity of water or water quality.

The schlumberger configuration was employed to distinguish subsurface vertical anisotrophism. In the investigated locality, one vertical electrical sounding was done to probe to 173m depth.

6. Results

The survey data was computer-processed. Raw data, measured and modelled data from the soundings are presented below. Table 1 shows raw data from the sounding location.

The data was inverted using the damped least square method with a damping factor of 100 and a depth factor of 1.1.

Table 1 shows the results of measured data and table 2, the inverting data with an actual modelled profile.

Data#	V (mV)	I (mA)	MN (m)	AB/2 (m)	Ohm-m
1	126.761	93	2.000	3.000	17.13
2	-124.586	108	2.000	5.000	-43.49
3	-102.312	53	2.000	7.000	-145.55
4	-83.173	130	2.000	10.000	-99.49
5	-161.104	154	10.000	15.000	-65.73
6	286.507	47	10.000	20.000	718.16
7	-328.444	95	10.000	25.000	-651.69
8	-218.439	98	10.000	30.000	-612.72
9	-48.151	181	10.000	40.000	-131.63
10	129.497	146	10.000	50.000	689.66
11	117.815	130	20.000	60.000	498.25
12	-38.217	86	20.000	70.000	-335.06
13	416.228	41	20.000	100.000	-15787.10
14	0.833	229	60.000	140.000	89.08
15	-28.661	86	60.000	180.000	-549.67
16	328.555	57	60.000	220.000	14335.91
17	-335.052	113	60.000	260.000	-10355.19
18	-301.788	114	60.000	300.000	-12350.17

Table 1: Raw field data, Riat survey site Day 1

Dat#	V (mV)	I (mA)	MN (m)	AB/2 (m)	Ohm-m
1	3073.064	55	2.000	3.000	702.13

2	532.846	42	2.000	5.000	478.28
3	623.683	98	2.000	7.000	479.84
4	299.609	86	2.000	10.000	541.77
5	189.552	77	10.000	15.000	154.67
6	0.011	49	10.000	20.000	0.03
7	0.015	82	10.000	25.000	0.03
8	0.015	73	10.000	30.000	0.06
9	0.015	133	10.000	40.000	0.06
10	0.015	90	10.000	50.000	0.13
11	0.011	60	10.000	70.000	0.27
12	0.021	60	20.000	70.000	0.27
13	0.015	11	20.000	100.000	2.17
14	0.015	35	60.000	140.000	0.42
15	0.015	69	60.000	180.000	0.36
16	0.015	50	60.000	220.000	0.75
17	0.015	22	0.000	260.000	2.36
18	0.015	112	60.000	300.000	0.63

Table 2: Raw field data, Riat survey site Day 2

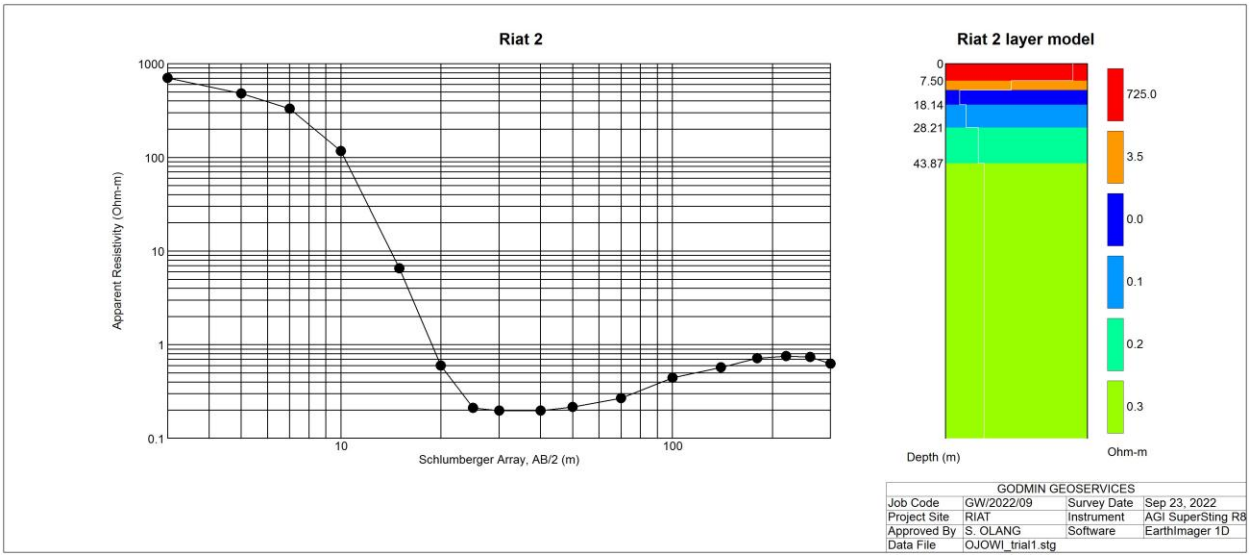

Figure 2: Modelled data Day 2

The results of the data collection and analysis are summarized in the tables below in a seven layer model:

Layer	Thickness (m)	Depth (m)	Resistivity (Ohm-m)	Interpretation
1	16	16	175	Dry soil / boulders
2	12.3	28.3	0.1	Moist rock, clay
3	28.3	171	0.3	Fractured rock

Table 3: Interpretation of the field data

1. The soil/regolith is dry and relatively thick at this point. Possibly encompasses part of the top volcanic layer.
2. The lower resistivity interface depicts either bottom of weathering front and/or earlier generation eruption interface
3. The area is suitable for borehole, yield parameters to be determined at development stage.

7. Recommendations

8.1 Recommended drilling criteria

1. A well be drilled to 75m depth to transect the expected water-bearing intra-volcanic interface. Final decision terminating depth will depend on the supervising hydrogeologist.

2. Any planned septic and waste disposal sites should be located a minimum of 30 from the well location

3. Drilling works to be undertaken and supervised by qualified persons. Care should be taken to note the gravel pack and sieve locations vis-a-viz the resistivity model

8.2 Drilling and related works

(i) Method of drilling & construction are recommended considering the following factors:

- *Quantity of water expected*
- *Geologic conditions*
- *Economic considerations*
- *Time frame*
- *Hydro geologic considerations*

(ii) Borehole diameter – open-hole diameter of 203mm should be drilled up to the recommended depths. However depth can be varied depending on the observations and recommendations of supervising hydro geologist. The first 4m should be drilled with 254mm for installation surface casings.

1. *Surface casing* – Surface casing can be used temporarily in the course of drilling for the first 4m from ground level. However, as per the recommendation of supervising hydrogeologist, the surface casings can be permanently installed.
2. *Permanent casings* – Steel casings of 152mm should be used. This will provide enough annular space for the installation of gravel pack. *The positioning of plain and slotted (screen)*

casings should be designed on site by the supervising hydro geologist.

3. *Gravel pack* – Gravel pack should be of siliceous material grain size 2-4mm diameter to be installed in the annular space. About 3 tons of gravel pack would be required for the borehole.
4. *Borehole development* – After the installation of casing assembly and gravel shrouding, in accordance with the recommended design, a borehole has to be developed to make it sand free and to improve its specific capacity and efficiency. The method to be adopted is the use of compressed air.

7.3 Water quality

International standards for physical and chemical quality of drinking water have been set by the world health organization (1971) as follows

Quality	highest desirable	maximum permissible
Physical		
Turbidity (JTU Units)	5	25
Colour, Hazen-units (on Platinum cobalt scale)	5	50
Taste and odour	unobjectionable	----
Chemical		
PH	7.0-8.5	6.5-9.2
Total dissolved solids (mg/l)	500	1500
Total hardness as CACO3 (mg/l)	100	500
Calcium (mg/l)	75	200

Magnesium (mg/l)	< 30 if SO4 is 250 mg/l, up to 150 mg/l if SO4 is less than 250 mg/l.	150
Iron (as Fe) (mg/l)	0.05	1.5
Manganese (as Mn) (mg/l)	0.1	1.0
Copper (as Cu) (mg/l)	0.05	1.5
Zinc (as Zn) (mg/l)	5.0	15.0
Chloride (mg/l)	200	600
Sulphate (mg/l)	200	400
Fluoride (mg/l)	0.6-0.9	0.8-1.78
Nitrate (mg/l)	-	45

Table 3: W.H.O. water quality data

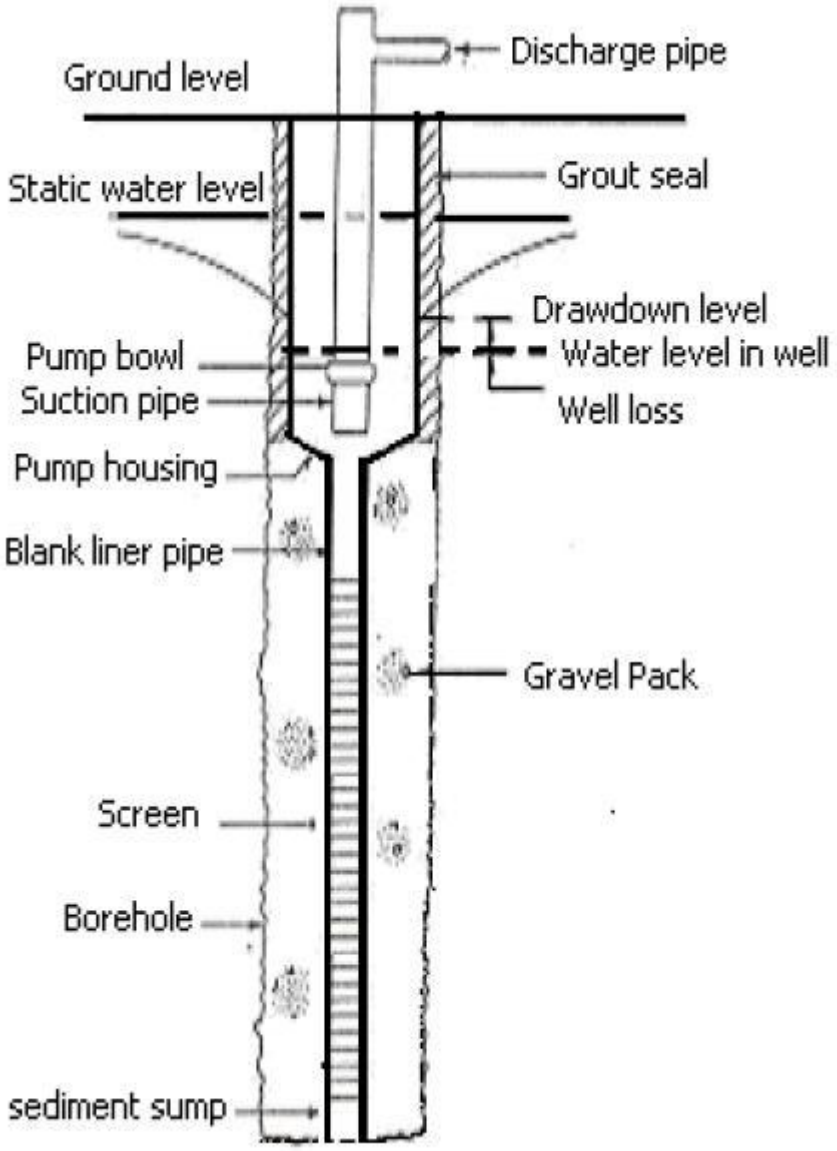

Figure 3: Sketch of a developed borehole

Appendix

Hydrogeology Licence

Form WRP 002

REPUBLIC OF KENYA
(THE WATER ACT)

Reg/Licence No. ***WD/WRP 001/106***

Mr. Olang' Stephen Godfrey,
P.O. Box 166-40104, Koru.

LICENCE

QUALIFIED WATER RESOURCE PROFESSIONAL

Dear Sir, *Rule 135*

I have the honour to inform you that the Ministry of Water and Irrigation has given you a licence to operate as a Qualified Water Resource Professional in the following category:

DETAILS OF QUALIFIED WATER RESOURCE PROFESSIONAL:

Name (Surname first):	***Olang' Stephen Godfrey***
Town:	***Nairobi***
Post Office box :	***166-40104, Koru***
Pin Nnumber:	***A001727113N***
Telephone Contact (Landline):	***N/A***
Telephone Contact (Mobile):	***0734811614***
Email: Contact	***olang73@yahoo.co.uk***
Fax:	***N/A***

DETAILS OF LICENCE: ***Hydrogeologist, Panel III- category 2 only.***

CONDITIONS OF LICENCE:

1. ***Issued subject to annual renewal/gazettement;***
2. ***Can be amended on application when necessary.***

Yours Faithfully,

Signature:

Name: **John Rao Nyaoro, HSC**

Position: *Director Water Reources & Registrar Water Rights*

Date: ***7th January, 2010*** REGISTRAR OF WATER RIGHTS

**This licence is issued without any erasures/alterations whatsoever.*