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Contribution of geophysics in hydrogeological prospecting of the Nkoup watershed (Nun plain-Cameroon)

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Abstract
The Nkoupwatershed (174 km^2) islocated in the Nun plain, between longitudes 10°35''-10°47''E and latitudes 5°27''-5°42''N. 73,918 of the 92,818 inhabitants in this area don't have direct access to a drinking water. Wells equippedwith HMP are the mostwidelyuseddrinking water structures aftersprings. Agricultural activities and sanitation structures scatteredaround the area make the quality of water drawnfromgroundwaterdoubtful. Boreholes are preferred, but theirscarcitytestifies to the caution of investorsgiven the number of dry wells and the high failure rate duringdrilling. It isimperative to find an aquifer in whichitis possible to install structures producing a good quantity of drinking water to meet the needs of the population. This workaimis to identify a productive aquiferproviding water of excellent quality. Itsrealizationrequiredgeologicalprospecting, carrying out geophysicalsurveys, evaluating flow rates, collectingpiezometric data. The resultswereobtainedafterprocessing and interpreting the data in Excel, ArGis and EPANET. The groundwaterisdistributed in five geological formations (recentbasalts (64 km^2), gneissicbedrock (49 km^2), oldbasalts (31 km^2), pyroclasts (16 km^2) and rhyolites (14 km^2)). Resistivitiesvarydepending on the aquifers; the following maxima werenoted: pyroclasts (1745 Ω.m), gneissicbedrock (1725 Ω.m); oldbasalts (631 Ω.m); recentbasalts (333 Ω.m) and rhyolites (231 Ω.m). The depths of the water tables are variable: 5 to 11 m in recentbasalts, 10 to 11 m in rhyolites, 12 to 18 m in gneisses, 18 m in pyroclasts and 18 to 26 m in oldbasalt. Recentbasalts have a fracture layer located at a depthvaryingfrom 45 to 70 m. The aquifers of oldbasalts, rhyolites and gneisses are discontinuous and localized in theirlowerparts. The piezometric levels are also variable, lower in recent basalts and higher in the old basalts defining the flow of groundwater from the north to the south of the watershed. The flow rates vary according to the aquifers and the type of water structures: -pyroclasts (wells (4 m^3/h), springs (186 m^3/h)); - recent basalts (boreholes (3 m^3/h), wells (4 m^3/h), springs (87 m^3/h)), - old basalts (wells (1 m^3/h), springs (8 m^3/h)); - rhyolites (well (1 m^3/h), springs (5 m^3/h)), -gneissicbedrock(well (1 m^3/h), springs (2 m^3/h)). Recent volcanic formations constitute the most important aquifer in terms of resource availability. This resource deserves to be protected to ensure sustainable access to water in Foumbot and its surroundings.

Keywords: *watershed, geophysics, aquifer, flow rate, piezometry*

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I. Introduction

The Nkoup watershed (173.7 km^2) is located to the South-East of the Nun plain, between longitudes 10°35''-10°47''E and latitudes 5°27''-5°42''N (fig.1a). In this area 73,918 people don't have access to water and there is an upsurge in water-borne diseases. The level of access to sanitation is low and sanitation facilities are located alongside drinking water points. Wells equipped with Human Motricity Pumps (HMP) are the most widely used drinking water structures after springs. The agricultural activities and the sanitation structures (full-bleed latrines) distributed anarchically in the area compromise the quality of surface water and groundwater. The scarcity of boreholes is linked to the difficulty of identification, access and variations in flow rates over time. It is imperative to find suitable places for the installation of good quality, productive water structures that can meet the long-term water needs of the population. The objective of this work is to identify a productive aquifer providing excellent quality water in the Nkoup watershed. Carrying out this work required a multidisciplinary approach drawing on knowledge of geology, hydrology, geophysics, GIS, cartography and hydrogeology.

Geological Context

Located on the Volcanic Line of Cameroon, the Nkoup watershed is marked by the following geological formations: Migmatitic Gneiss, Rhyolite, Basalts, Pyroclasts and Alluvium (fig.1b).

Alluvial formations are found in the flooded Baïgomvalley which stretches from Mfa'chekwet to Ngoundoup. They consist of a mixture of weathering products (mud and sand) and partly cover the gneissic bedrock.

Rhyolites are located on the Mbapit Massif and on the Baïgom-Koutaba road section. They surface in the form of domes and present a porphyritic texture made up of an arrangement of potassium feldspars (Or_{97-89}),sodium feldspars (Ab_{99-88}), quartz and Fe-Ti oxides (contents between titanohematite and hemo- ilmenite) (Wandji*et al.*, 2010).

Basalts are present in two types: ancient basalt or plateau basalt which occupies the Far North of the area. It has a porphyritic microlitic texture consisting of olivine and pyroxene phenocrysts. The recent basalt which is to the southwest of the zone and outcrops in places at the level of the summits. Recent basalt has a porphyritic microlitic texture with olivine and pyroxene phenocrysts. This basalt is vacuolar; what differentiates it from plateau basalts. Recent basalts are partially covered by pyroclastic formations. On the microscopic level, the mineralogy of these basalts is homogeneous: olivine, clino-pyroxene, plagioclase, Fe-Ti oxide and chromite. The geochemistry of these lavas shows an enrichment in SiO_2 (41.2-46.4%), Al_2O_3 (11.4-17.1%), Na_2O (2.4-3.9%), K_2O (1.0-1.9%) and a depletion of MgO (13.8-4.6%), CaO (11.9-7.6%) (Wandji*et al.*, 2010).

The **pyroclastic formations** composed of Pumice, Slag, lapilli and volcanic ash occupy about a third of the watershed with thicknesses varying from 01 to more than 15 m. They have two colors (red and black) and are strongly concentrated around the craters forming cones.

The **bedrock** consists of strongly fractured migmatitic gneiss and presents quartzo-feldspatic veins with orientations N25°- 40°E. It has a migmatitic texture made by the following mineralogical composition: Quartz, Feldspars, Biotite, Amphibole and Muscovite.

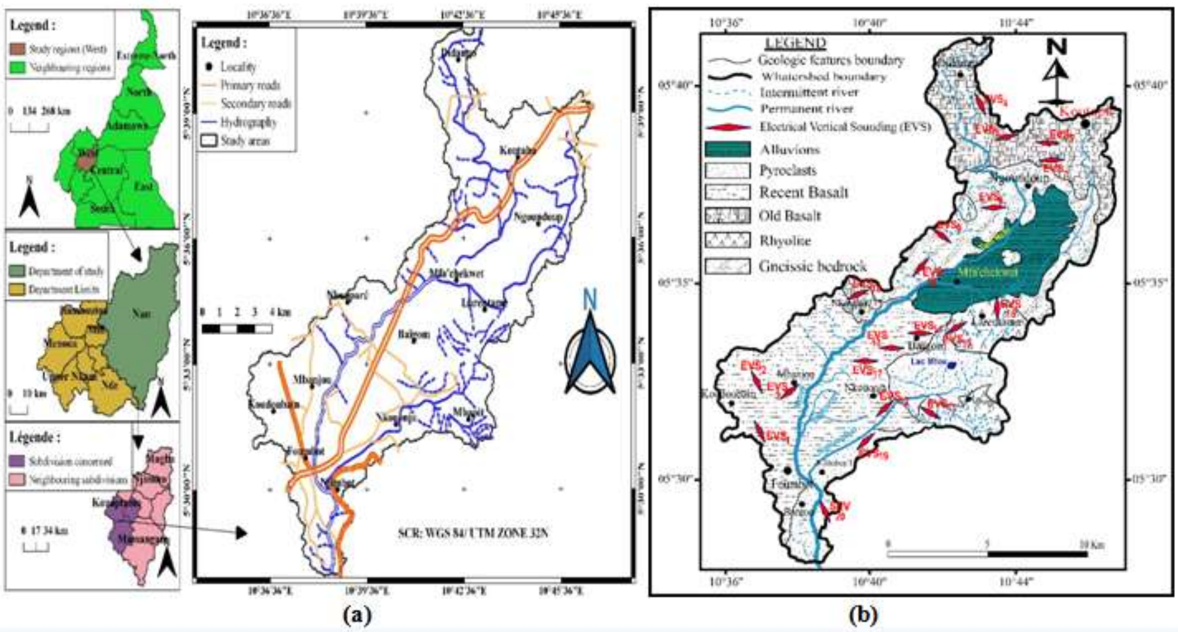


Figure 1:(a) Location **(b)** and geophysical survey point according to the geological formations of the Nkoup watershed (modified from Wandji, 1995 and Moundi*et al.*, 2007)

II. Methodology

The maps of the study area were obtained from satellite images, SRTM, Landsat ETM +. Twenty (20) Vertical Electrical Soundings (VES) were carried out according to the following distribution: -seven (07) in recent basalt; - five (05) in the old basalt; - three (03) in rhyolites; - three (03) in the gneissicbedrock; - and two (02) in the pyroclasts (**fig.1b**). The Schlumberger device was adopted for the sounding using a digital multifunction resistivity meter WDJD-3 which displays on its screen the values of resistivity, the potential difference (ΔV), the current intensity (I_{AB}), spontaneous polarization and error. After several measurements over each distance considered, the values retained are those obtained with a margin of error less than or equal to 5%. The results obtained are represented on bilogarithmic diagrams with the values of AB/2 (m) on the abscissa and the resistivity values (Ω.m) on the ordinate. The shape of the curve obtained depends on the apparent resistivity and the thickness of the layers of soil crossed.

The interpretation of VES consisted in analyzing the curves ρa = f (AB/2) of the semi-logarithmic diagrams. The aim is to identify and determine the number, thicknesses and real resistivities of different layers of land at the sampling point (Degallier 1963, Gasmi*et al.,* 2004). In the exercise of interpretation, in addition to knowing the resistivities of the different geological formations, it's necessary to know the type of VES curve, because the aquifers are identified according to the resistivity anomalies on the curves. Kousoubé*et al.,* 2003 working in basement area with n-layers, defined seven (07) types of VES curves denominated by successive letters of the alphabet from A to G. SomboAbé*et al.*, 2011 based on the forms of resistivity anomalies curves, also propose seven (07) types of VES curves whose name is made by capital letters referring to the shape of the curve.He distinguishes between the curves of types C, H, K, M, U, V and W. Chapellier, 2001 proposes four types of curve of VES therefore the curves of type "A" which go up in stages, the curves of type "H" which present a conductivity anomaly between two relatively more resistant terrains, the "K" type curves which present a more resistant layer between two relatively less resistant (more conductive) terrains and the "Q" type curves which present stepped conductive anomalies. The VESs were grouped according to rock's type and classified according to the typology of Chapellier (2001). The succession of different layers was determined using the Hummel method which consists of the simple superposition of the 2 CH1 plot chart from the General GeophysicCompagny and the diagram ρa = f (AB/2). The values (ρ1 and h1) read under the left cross of the abacus CH 1 are the resistivity and the thickness of the first terrain, obtained after a double translation from the abscissa 1 and the ordinate 1. The value of ρ2 is the value reached by the asymptote of the chosen curve. The following parameters were taken into account for the determination of the layers: - the shape of the curve which depends on the type of device and AB/2; - variations in the thickness "h1" and the resistivity "ρ1" of the first layer; - variations in the thickness "h2" and the resistivity "ρ2" of the second layer.To determine the depth and power of aquifers, the method of Boudoukha (2008) used proposes 5 scenarios based on the original abscissa "A" of the abacus CH1 and the value AB/2 = 100 m for "H" and "K" type curves:

"H" type curves: here the method makes it possible to determine just the apparent depth "Adr" and the real depth of the roof "Rdr" of the aquifer. Two scenarios arise:- if 1 m < A < 100 m, Adr = A and Rdr = 0.9 Adr + 7;- if A > 100 m, Adr = A / 3 and Rdr = 0.9 Adr + 6.

"K" type curves: in this particular case, the method makes it possible to determine the apparent depth "Adw" and the real depth of wall"Rdw" of the aquifer.Here, three cases arise:- if 1 m < A < 100 m and ρa > 50 Ω.m; Adw is read directly on the abscissa axis of the diagram ρa = f (AB/2) and Rdw = 0.8 Adw + 6;- if 1 m < A < 100 m and ρa < 50 m, Adw = A/3 and Rdw = 0.8 Adw + 3;- if A > 100 m, ρa no longer has any influence.Adw = A/3 and Rdw = 0.9 Adr + 10.

The interpretation was supplemented by observations made at road trenches, wells and boreholes.

The piezometric levels are obtained through measurements carried out using a piezometer on 147 selected reference wells and during four periods of the year: March, June, September and December 2018. The piezometric level "H" (m) is determined by the following formula: H = Z - P; with Z = altitude of the soil surface at the entrance to the well (m) and P = empty space between the soil surface and the piezometric surface (m). The flow rates of the wells were evaluated during the flow test sessions using a graduated bucket, a container with 5 m^3 capacity, a piezometer, a stopwatch and a pump. The Nkoup watershed has 55 developed wells and nearly 200 traditional wells mainly concentrated in recent basalts. In each type of aquifers, four reference wells were chosen for these tests. The approach by ascent tests was adopted due to the instability of voltage which influences the pumped flow. The container was used to quantify the water pumped from the wells because the irregular walls of the wells does not allow a direct estimation of the volume of water in the structure. The container also offers the advantage that it retains the pumped water avoiding infiltration that would quickly feed the water table through any crack. The measurements were carried out in two periods (March and September) of the year 2018 on 30 wells. The pumped water is discharged into the container of known volume and the time required for the water to rise in the well to the starting level is recorded. The flow rate is obtained by dividing the volume of water in the container by the ascent time. The results were obtained after processing the data in Excel, interpolation in ArGis and EPANET software followed by interpretation.

III. Results And Interpretation

Types of aquifers

The Nkoup watershed has five (05) main aquifers: -recent basalt aquifers (64.29 km^2); - the aquifers of gneissic bedrock (48.9 km^2); - the aquifers of old basalts (31.43 km^2); - aquifers ofpyroclasts (15.58 km^2) - and aquifers of rhyolites (13.48 km^2).

Analysis and Interpretation of VESs

Case of VES on recentbasalts

The seven (07) VESs made on recent basalt have 02-03 layers and are grouped according to the shapes of the curves in three classes:

- **Class 1**

This class includes the VESs from areas influenced by a weak pyroclastic cover (VES1, VES13 and VES17) (fig.2). According to the classification of Chapellier, 2001, these curves correspond to type H VES curves.

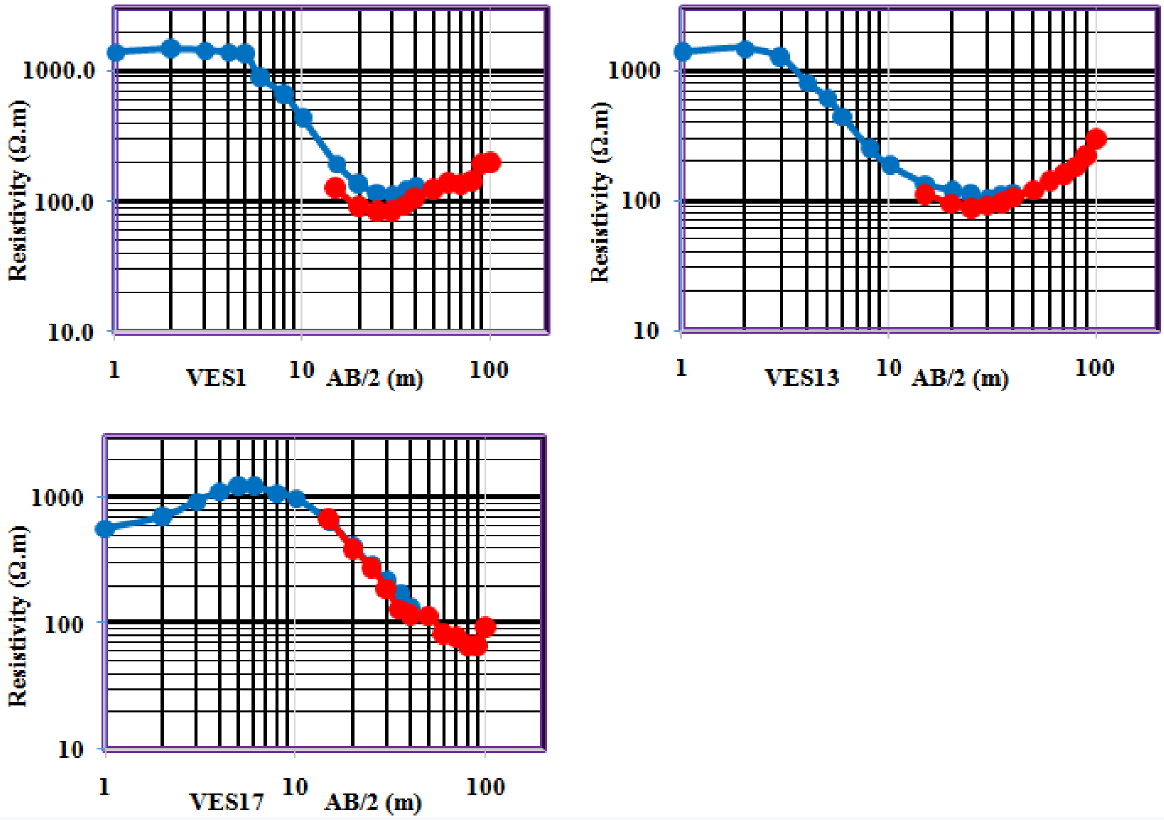


Figure 2:VES curves of recent basalts under weak pyroclastic cover

These VESs have three layers of different resistivity according to Hummel's interpretation: - a pyroclastic layer with resistivity varying between 1300-1500 Ω.m with a thickness of 4 to 5 m; - a conductive zone made up of less humid weathered basalt with a resistivity of 80-100 Ω.m included in the wake of the resistivities of fresh water and 15-25 m thick; - and a less conductive zone with resistivities of 300 Ω.m made up of basalt which isless or not weathered. Here, the apparent depth of the aquifer roof (Adr) determined from the CH1 abacus varies from 4 to 5 m. Thus the real depth Rdr is given by the following formula: Rdr = 0.9 x Adr + 7. The roof of the water table is at a depth of 10 to 11 m while the wall is between 15 to 25 m with a power "**e**" from 5 to 10 m.

- **Class 2**

This class combines the curves VES2 (GHSKoudoubain) and VES14 (GHSBaïgom) (fig.3). These are “H” type VES curves according to the Chapellier classification (2001).

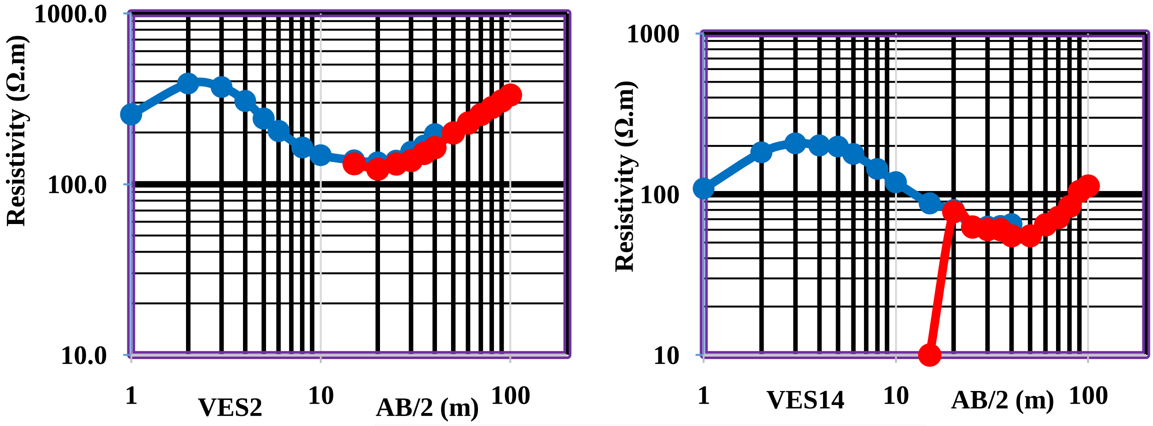


Figure 3:VEScurves of recentbasaltswithoutpyroclasticcover

These curves show two layers surmounted by agricultural soil with a resistivity of 200-300 Ω.m and 2 m thickness. The VES2 has a dry weathering 11 m thick, resistivity 150 Ω.mwhich sits on compact basalt. No water table was detected in this area. VES14 has a thick wet weathering layer with a resistivity of 50 Ω.m and a thickness of 27 m. At the base of this layer, a less altered humid zone of resistivity 125 Ω.m which extends over 100 m. The weathered basalt represents the suitable aquifer with a roof 10.6 m deep and a wall 27 m. However, we can still have water up to a depth of 90 m but with relatively low flows.

- **Class 3**

This class takes into account the VES3 and VES12 (fig.4). They are characterized by the succession of severalgeoelectric anomalies.

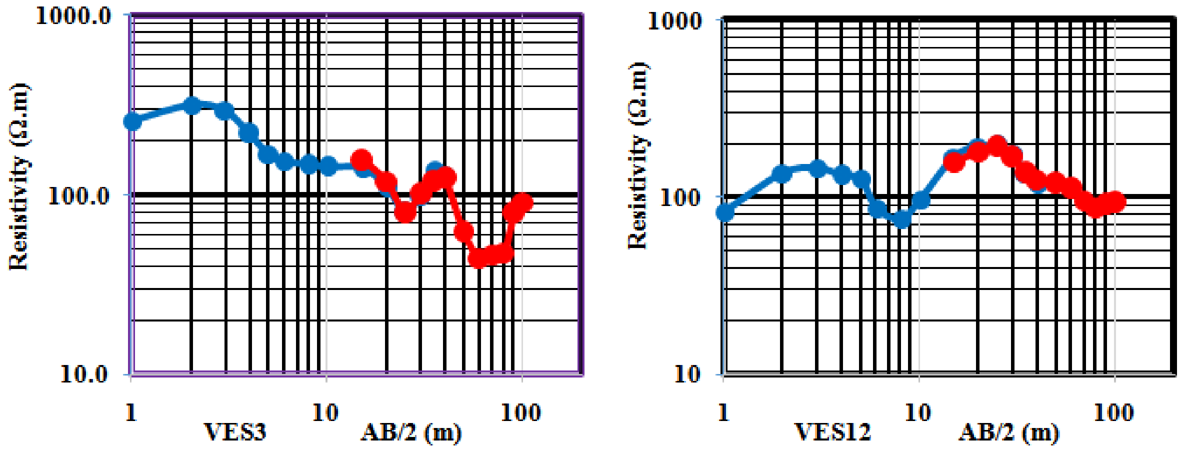


Figure 4:VEScurves of recentbasaltswithoutpyroclasticcovershowing anisotropies

VES3 has an agricultural soil with a resistivity of 300 Ω.m and a thickness of 1 m, dry weathering layer with a resistivity of 150 Ω.m located between 1 to 15 m dotted with blocks of vacuolar basalt. From 15 to 30 m, there is a humid altered layer showing the resistivity of 70 Ω.m with a water table between 22 and 30 m. From 30 to 45 m, there is a weakly weathered basalt and from 45 m, a fracture zone of resistivity 40 Ω.m sheltering a water table that extends to more than 100 m. The VES12 has an agricultural soil at the surface with a thickness of 2 m and resistivity 150 Ω.m, a dry weathering (130 Ω.m) which extends from 2 to 4.5 m, a wet weathering (75 Ω.m) from 4.5 to 12 m and more or less weathered basalt which extends up to more than 100 m. Two layers can be noted: a water table perched between 6 and 12 m and a fracture layer that starts from 65 m and extends to more than 100 m. It emerges from the preceding description that these two VESs show the existence of two layers: - an alteration layer with variable depth and power: 15 m deep and a power of 15 m in the VES3; 4.5 m deep and 7.5 m power in the VES12; - and a fracture sheet with variable depth and indeterminated power over the depth of investigation: 45 m in VES3 and 70 m in VES12.

Case of VES on plateau basalts

The VESs on plateau basalts have four parts. Agricultural soil (80-300 Ω.m), a thick layer of dry weathering (460-630 Ω.m), wet weathering (150-200 Ω.m) and more or less weathered or cracked rock (510-535 Ω.m) (fig.5).

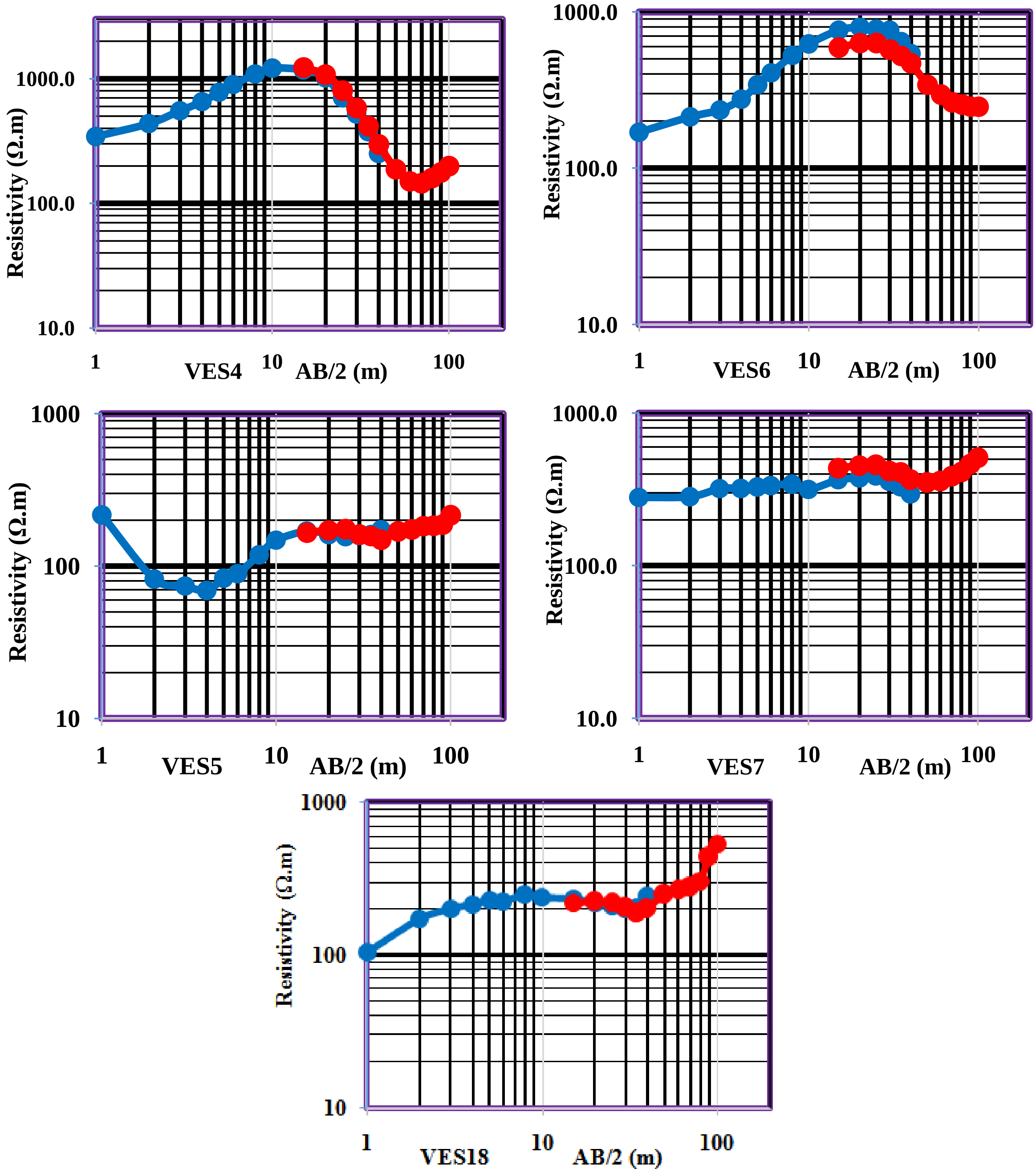


Figure 5:VES curves of plateau (old) basalts (VES4 to 7 and VES18)

These curves are of type "K" (Chapellier, 2001) and present the following four layers: agricultural soils have thicknesses varying from 1 to 2 m; the dry weathering zone (not very conductive) with thicknesses between 19 and 23 m; a highly conductive wet weathering zone located between 15-19 m downstream and 20-25 m upstream; and an area consisting of resistant lessweathered, more or less cracked basalt which begins at depths of 35-70 m up to the limit of investigation. In the basaltic aquifers, within the limit of the depth of investigation, an alteration sheet is identified located at different apparent depths from 15 m downstream to 25 m upstream. This aquifer is discontinuous, almost non-existent upstream. Its real depth according to Boudoukha's formula (2008) is Rd = 0.8Ad + 6; are 18, 21.1 and 26 m respectively for the apparent depths of 15, 19 and 25 m.

Case of VES on rhyolites

The VESs on rhyolitic formations have three parts: a rising part that is not very conductive (150 Ω.m), a descending part that is very conductive (60-80 Ω.m) and a rising part that is more or less resistant (125-230 Ω.m) (fig.6).

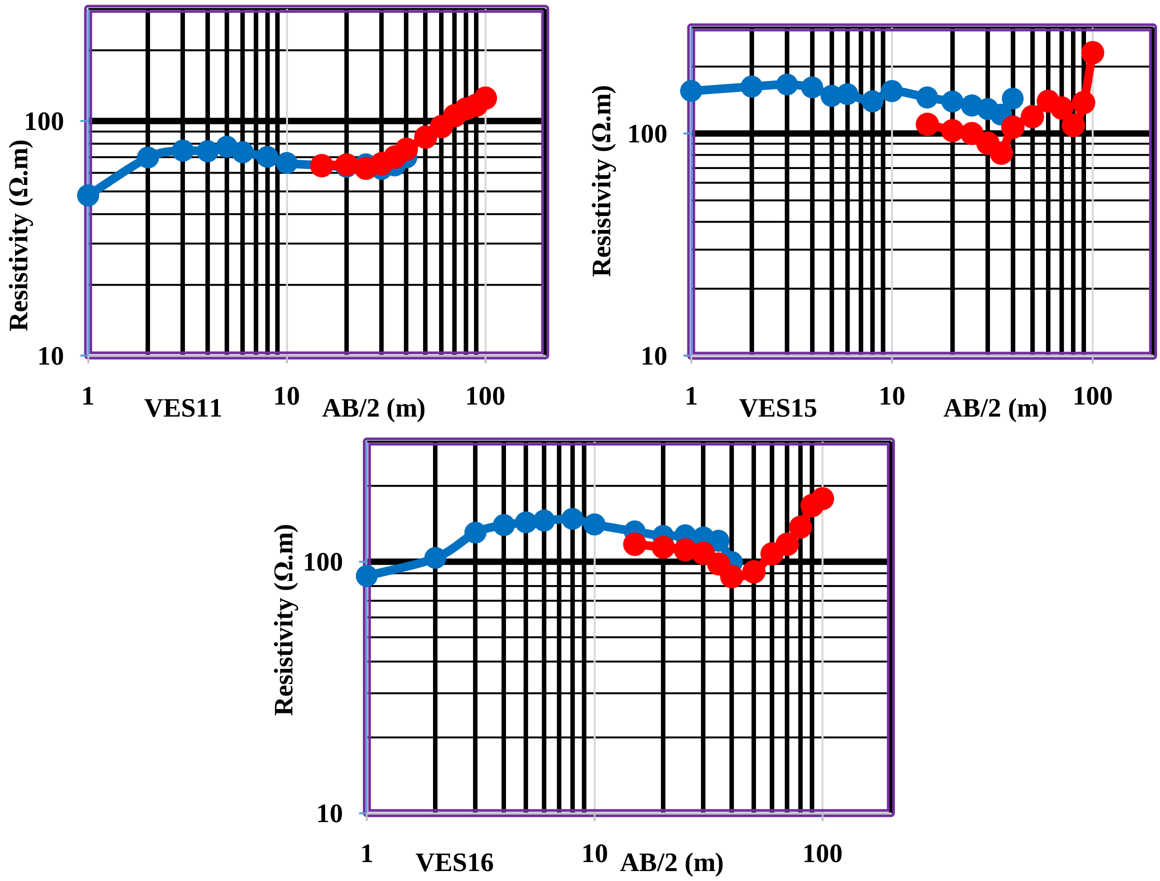


Figure 6:VEScurves of rhyolites (VES11, VES15 and VES16)

According to the Chapellier, 2001 classification, these VESs correspond to "H" type curves. Four layers are identified: - agricultural soil varying in thickness between 2 and 3 m; -a thin dry weathering zone (5 m) present in the VES16 located a little higher up, -a wet weathering zone between 2 and 8 m deep, 20 to 32 m thick; -and an area made up of clay and slightly altered rock, more or less cracked, with a depth varying between 20 to 40 m.The aquifer potential of the rhyolitic formations of the Nkoup watershed is marked by an alteration layer located at a theoretical depth (Ad) of 3 to 8 m. The real depth according to the formula Rd = 0.9Ad + 7 of this aquifer is between 10 m and 14 m deep and a power of 29 m.

Case of EVS on a base

The VES curves on gneissic bedrock have three parts: a rising part that is not very conductive (90-2000 Ω.m), a descending part that is very conductive (60 Ω.m) and a rising part that is resistant (250-500 Ω.m) (fig.7).

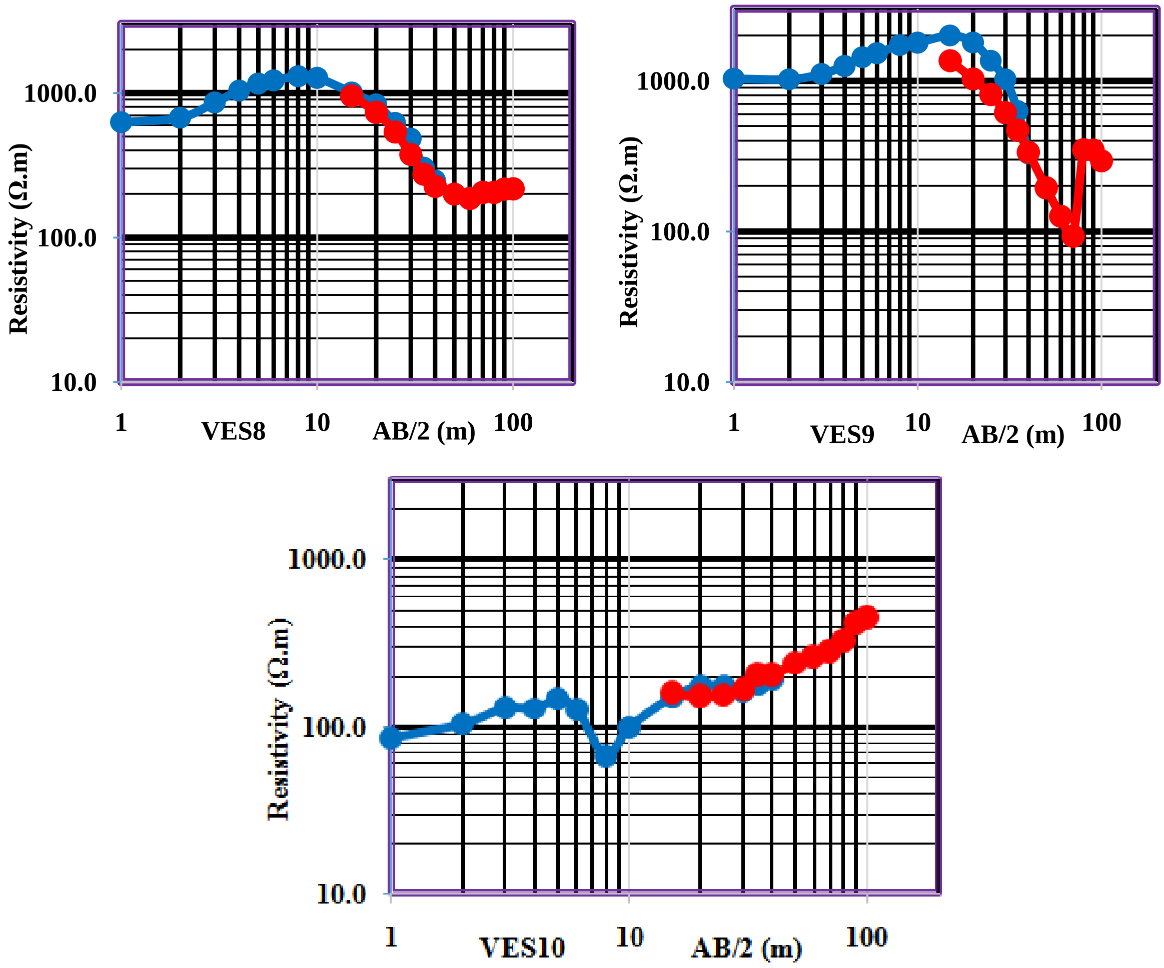


Figure 7:VES curves of the base formations (VES8 to 10)

TheseVEScurvesbelong to two types according to the classification of Chapellier(2001): the “K” type VEScurves (VES8 and VES9) and the “H” type (VES10).Theyreveal four layers of terrain: - agricultural soil of varyingthickness (1 to 2 m) with a resistivity of (100-673 Ω.m); -a dry weatheringthatbegins at a depth of 2 m and extends over 3 to 13 m with a resistivity of 1300-2000 Ω.m; - a wetweatheringwhichbeginsaround 5 to 15 m with a thicknessrangingfrom 60 to 70 m downstream and 3 m towards the summit; we note resistivities of 60-90 Ω.m. -a slightlyaltered more or lesscracked zone located at a depth of 8 m towards the summits and between 60-70 m downstream. The resistivityhereisratedbetween 200-440 Ω.m. The gneissicbedrock of the Nkoupwatershed has a discontinuousweathered layer located in itslower zone. This water tablelocated at a real depth of 12.4-18 m has a power varyingbetween 42 and 44 m.

Case of VESs on pyroclasts

Pyroclastic formations behave like gravels and have a lot of voids. In dry conditions, they have resistivities greater than 1000 Ω.m. Their VES curves have three parts: a less conductive rising part (1725 Ω.m), a very conductive descending part (280-315 Ω.m) and a more or less resistant rising part (345-370 Ω.m) (fig.8).

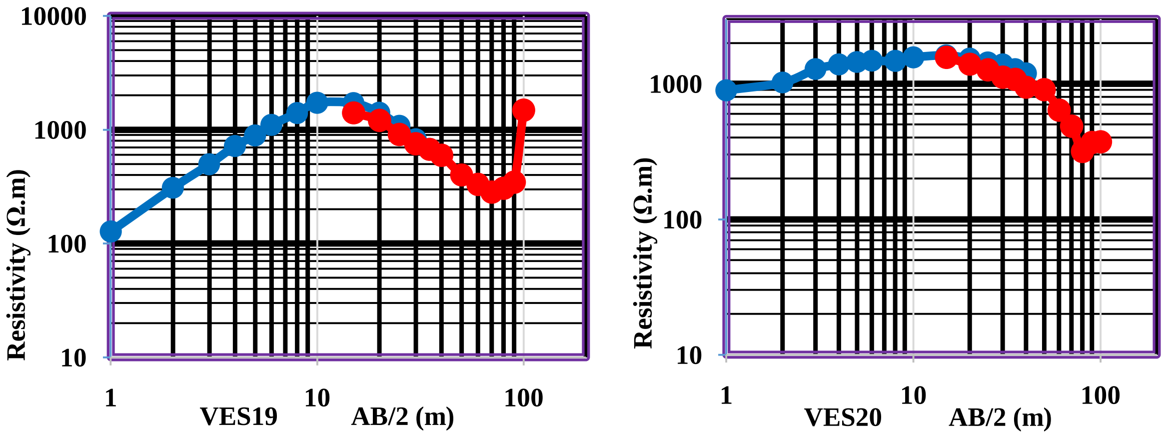


Figure 8:VES curves of pyroclasts (VES19 and VES20)

According to the classification of Chapellier (2001), these VES curves are of "K" type composed of four layers: - agricultural soil with a thickness of 1 m which only appears on the VES20 m; - a layer of dry pozzolana 14-15 m thick; -a layer of wet pozzolana varying in thickness from 55 to 65 m; -a layer of compact boulders spaced with voids located at a theoretical depth of 70-80 m. It emerges from this analysis that there is a slick in the pyroclastic formations at a real depth of 18 m with a power of 44-52 m.

HYDROGEOLOGICAL STUDIES

Water works operating flow rates

Flow measurements were performed on 11 springs (04 on recent basalt, 02 on pyroclast, 02 on old basalt, 02 on rhyolite and 01 on plinth); 30 wells (10 on recent basalt, 05 on pyroclast, 05 on old basalt, 05 on rhyolite and 05 on gneissic bedrock) and on the 06 boreholes in the area, only installed on recent basalts. The flow rates vary depending on the type of structure; the highest flows are observed in springs, and low in wells and boreholes (Table 1). In order of decreasing flow of spring, the aquifers of the Nkoup watershed are classified as follows: Pyroclastic formations (186 m^3/h), Recent basalts (87 m^3/h), Old basalts (8 m^3/h), Rhyolites (5 m^3/h) and the gneissic bedrock (2 m^3/h) (fig.9). The pyroclastic cover positively influences the infiltration of water into the underlying fractured basalt aquifer.

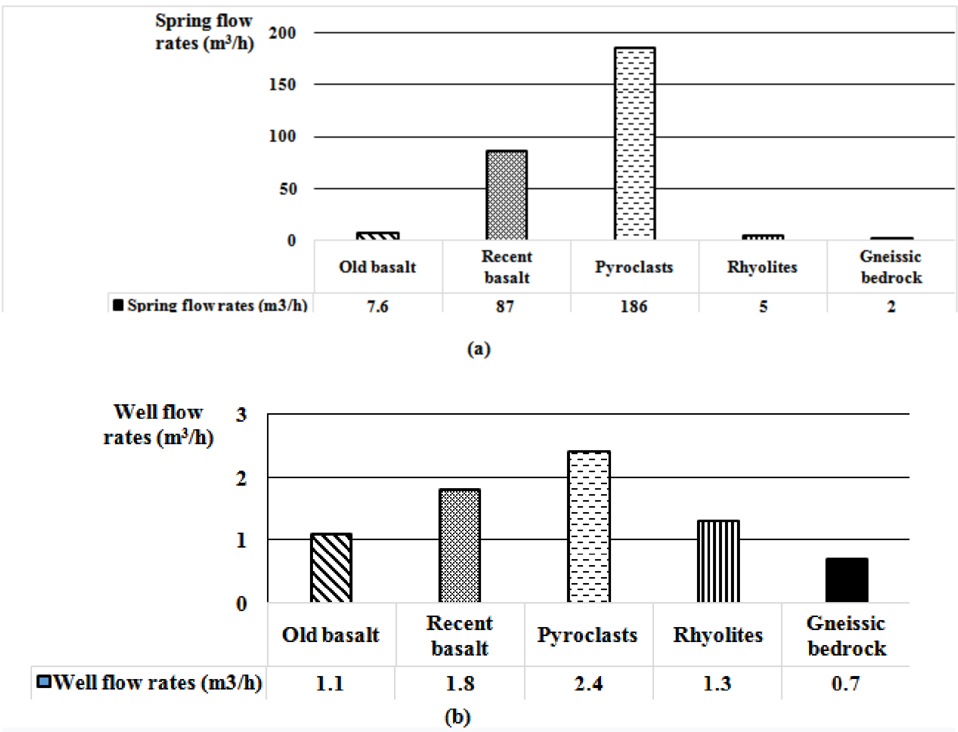
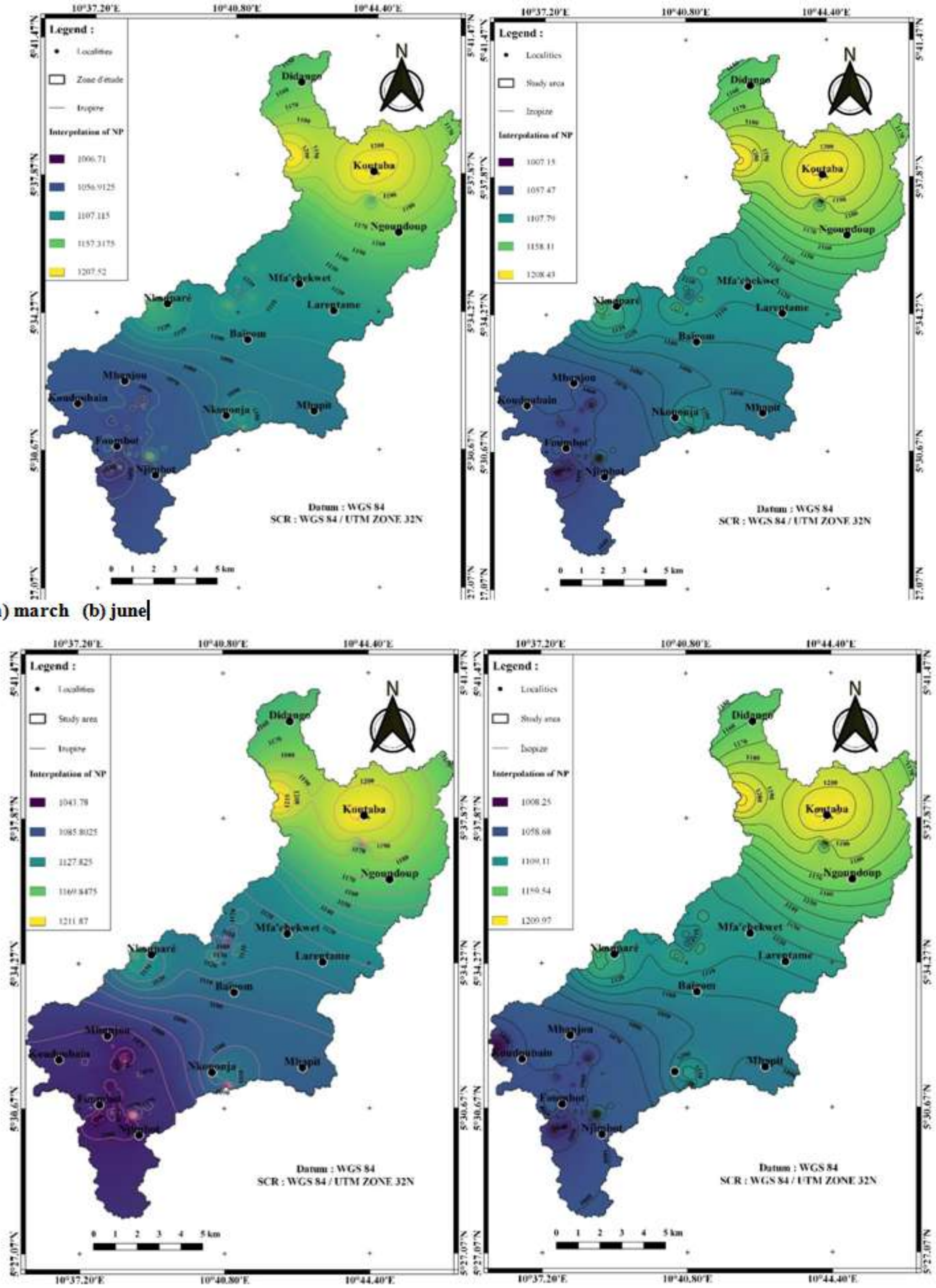


Figure 9: Spring and Wellflow rates in the Nkoup watershed

Piezometry of the water table

The measurements of the piezometric levels were carried out on 147 wells. Figures 10 show the variations in piezometric levels and flow direction according to the periods of the year (March, June, September and December 2018).



(a) march (b) june

(c) september (d) december

Figure 10: Piezometric maps (a) March, (b) June, (c) September, (d) December of the year 2018 in the Nkoup watershed

The piezometric levels show variation from one season to another. These variations do not depend on the type of aquifer and are located between 2 to 7 m depending on the structures. These variations have very little influence on the direction of groundwater flow. The highest piezometriesare observed in the northern part (Koutaba) while the lowest piezometries are found in the southern part of the watershed. The underground flow follows a North-South direction.

INTERPRETATION

In short, five (5) aquifer formations are identified in the Nkoupwatershed. Each of these aquifers has an alterationsheet. The aquifers of oldbasalts, rhyolites and gneissic bedrock are discontinuous and located in the lowerpart (low altitudes) of thesedifferent formations. The recentbasalt has in addition to the weathering layer, a fracture layer located at a depthvaryingfrom 45 to 70 m (Table 1).

Table 1: Summary of resistivities, depths and average flow rates of aquifers in the Nkoup watershed

Aquifer	Resistivity interval (Ω.m)	Weathering table (water table)		Flow rate (m^3/h)		Deep water table			
		Aquifer roof depth (m)	Aquifer wall depth (m)	Spring	Well	Aquifer roof depth (m)	Aquifer wall depth (m)	Nature and structure of aquifer	Flow rate (m^3/h)
Recentbasalt	**40-333**	**5-11**	**12-27**	**87**	**3.8**	**40-70**	**90 - …**	**Fracturedbasalt**	**2.9**
Old basalt	**70-631**	**18-26**	**40-80**	**7.6**	**1.1**	**/**	**/**	**/**	**/**
Pyroclasts	**280-1745**	**18**	**45-50**	**185.7**	**4.4**	**/**	**/**	**/**	**/**
Rhyolites	**60-231**	**10-14**	**40-45**	**4.9**	**1.3**	**/**	**/**	**/**	**/**
Gneissicbedrock	**60-1725**	**12-18**	**55-60**	**2.2**	**0.7**	**/**	**/**	**/**	**/**

Resistivities vary from aquifer to another, higher in pyroclasts and bedrock, lower in recent basalts and rhyolite. The groundwater resource is available in all aquifers. The shallow water depths and the presence of several functional water structures in recent basalt aquifers indicate that the resource is easily accessible and exploitable. The underground flow favors the concentration of water in the recent basalt. The recent basalt therefore constitutes the most important aquifer in the Nkoup watershed. But the shallow depth of its water table can make it vulnerable to microbiological pollution (Tita, 2008; Mouncherou*et al.,* 2018).

IV. Conclusion

The Nkoup watershed has five main geological formations which have the capacity to store water. They have variable resistivities and all have a more or less discontinuous weathering layer. The recent basalts constitute the most important aquifer, because they are quite extensive and have two productive, accessible and exploitable aquifers. The shallow water depths make it vulnerable to pollution. Measures to ensure its protection must be taken to ensure sustainable access to water in the town of Foumbot and its surroundings.

Table 2 : Synthesis of geophisic datas

AB/2 (m)	Resistivityrrecentbasalt (Ω.m)							Resistivity of oldbasalt(Ω.m)					Resistivity of gneissicbedrock (Ω.m)			Resistivityof Rhyolite (Ω.m)			Resistivity of Pyroclasts (Ω.m)	
	VES$_1$	VES$_2$	VES$_3$	VES$_{12}$	VES$_{13}$	VES$_{14}$	VES$_{17}$	VES$_4$	VES$_5$	VES$_6$	VES$_7$	VES$_{18}$	VES$_8$	VES$_9$	VES$_{10}$	VES$_{11}$	VES$_{15}$	VES$_{16}$	VES$_{19}$	VES$_{20}$
Dir.	NW-SE	NW-SE	NE-SW	NE-SW	E-W	E-W	SNE-NSW	NW-SE	E-W	NSW-SNE	E-W	SW-NE	E-W	NW-SE	NE-SW	NW-SE	NE-SW	N-S	E-W	SNW-NSE
1	1403	256	260,3	83,0	1385,8	108,6	571,6	344,4	216,3	169,6	279,9	103,7	627	1032,2	84,5	48,1	155,4	87,6	127,5	892,4
2	1479,4	388	317	136,9	1503,9	182,3	706	437,3	82,1	212,8	283,1	171,4	673,6	1022,1	103,3	69,8	162,5	103,4	308,8	1020,7
3	1464,5	370,1	294,8	147,6	1263,8	207,3	946,1	553,7	73,9	235,6	319,8	200,9	858,8	1107,1	128,8	74,7	166	130,4	496,8	1282,3
4	1397,8	306,7	219	132,8	814,9	201,1	1136,7	655,4	69,2	276,2	320,9	211,1	1036,3	1250	128,3	74,3	161,3	139,6	717,1	1388,5
5	1348,4	242,2	169,4	129	623,4	198,1	1226,9	780,3	83,1	342,2	327,9	225,4	1156,7	1660,9	146,2	77,5	147,5	143,2	890,5	1446,5
6	889,7	204,8	154,1	87,2	446,8	178,2	1233,5	898,4	89,1	407,3	335,2	221,1	1217,6	1519,7	126,4	73,5	150,4	145,6	1100	1478,3
8	655,4	163,7	146,9	76,2	251,3	143,7	1094,9	1092,6	118,4	527,8	341,7	250,7	1301,2	1725,3	67,1	70,3	139,6	148	1397,2	1473,8
10	432	147,7	117,7	97,2	187	118,7	1011,1	1217,4	147,8	624,2	315,8	238,9	1270,1	1389	100	66,2	155,1	180,6	1744,6	1564,2
15	126,6	131,6	86	146.9	92,3	115	677,3	1231,6	165,7	591,7	535,5	219,6	954,8	1160,2	156,3	64,5	110,2	117,3	1407,7	1569
20	91	122,4	87,6	169,7	74,1	77,9	389,3	1080,1	171,4	630,9	453,2	223,7	734,6	929,2	150,1	65	103,2	114,1	1209,8	1395,8
25	82,5	131,3	92,8	193,2	88	60,6	276,7	805,3	174,7	632,2	459,4	216,8	536,4	610,9	156	62,8	100,2	111,5	909,1	1270,3
30	87,6	137,4	101,2	170,1	91,7	61,3	156,6	583,1	161	573,7	417,5	203,8	375,5	514,1	164,6	65,8	90,5	108,1	754,3	1120,4
35	85,5	151,5	109,5	137,4	94,7	28,4	128,9	416,4	157,5	522,3	409,2	156,1	274,1	400,2	200,5	70,2	71,8	81	673,7	1077,2
40	110,5	164	123,4	154,8	106,6	55,3	116,2	297,7	149,2	469,2	367,3	188,8	225,5	335,7	203,7	75,7	106,8	87,3	596,3	943,3
50	112,4	198,6	62	221,5	120,2	55,2	164,1	188,2	169,1	341,9	351,8	249,7	199,8	194,5	243,3	85,3	119,1	91,3	401,5	904,6
60	137,4	228,37	44	103,4	149,7	64,7	83,3	150,8	174,3	296,1	359,2	264,7	186,4	226,3	257,2	94,7	140,1	107,5	330,9	639,7
70	133,3	256,1	46	94,8	158,3	71,9	87,1	145,6	182,9	263,9	387,1	276,2	205,1	93,2	278,1	105,4	130,4	117,3	283,5	487,8
80	121,6	281,3	94	86,7	162,4	74,3	66,7	160,1	184,4	255,4	412,7	305	205,5	348,9	321,6	112,6	108,9	137,3	306	216,8
90	190,8	307,6	49	61,5	221,5	114,1	66,7	177,9	187,4	247,8	464	434,1	216,2	47	409,7	116,7	137,9	127,3	246,6	368,6
100	167,4	332,9	90	93,7	300	102,6	94,1	199,8	215,7	247,5	511,2	334	217,5	194,2	342,4	125,1	231,3	178,2	1488.8	273,3
Alt.	1078	1098	1081	1106	1125	1137	1114	1237	1208	1229	1143	1165	1123	1146	1130	1137	1146	1155	1064	1073
Lat.	05°30'26,36 ''N	05°31'29,43 '' N	05° 31'25,75'' N	05°31'16,28'' N	05°33'28,25'' N	05°34'12,75 '' N	05°33''10,91 N	05°38'17,63'' N	05°37'41,97'' N	05°38'00,24 '' N	05°37 '14 '' N	05°34'27,34 '' N	05°36'24,46'' N	05°36'00,48 '' N	05°34'45,13 '' N	05°31'13,55 '' N	05°34 '25,01'' N	05°33'58,85 '' N	05°30'27,92'' N	05°30'19,16 '' N
Long.	10°37'24,91'' E	10°36'52 '' E	10°37 '35,4 '' E	10°39 '41 '' E	10°40 '05,61'' E	10°40 '58,41 '' E	10°39 '37,12 '' E	10°43'44,4 '' E	10°44'16,93'' E	10°44 '07,3 '' E	10°44 '08,4 '' E	10°38 '36,00 '' E	10°43'23,2 '' E	10°41 '23,7 '' E	10°40'45,2 '' E	10°40 '52,90 '' E	10°42'51,53 '' E	10°44 '13,8 '' E	10°38 '37,91 '' E	10°38 '10,2 '' E

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