

## **Artificial Recharge to Alluvial Aquifer, Northeastern Nuba Mountains, Sudan.**

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**Abstract:** Many engineering geology and structural geology aspects have been used in this study, to point out the suitability of the site for artificial recharge to alluvial aquifer, such as; rocks and soil types, seepage rate, structures and lineaments. The area is under lied by basement rocks with considerable thickness (10 to 15 m) of alluvial deposit. Overall soil type is sandy soil and its seepage rate is 34.56 Liter per hour. The most existing lineaments are trending toward NW direction while rocks foliation dipping toward WNW direction. The site is satisfied to be artificial recharge.

**Key words:** Artificial, Recharge, Alluvial, Aquifer, Nuba Mountains

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### **I. Introduction**

Fresh water, renewable but limited sources, is scarce in many areas of the developing world because of unplanned withdrawal water from rivers and underground aquifers causing severe environmental problems like arsenic contamination. In many countries, the amount of water being consumed has been exceed the annual amount of renewable creating a non-sustainable situation in addition to that, rainwater run-off during heavy rain is leading to accumulated in many countries like Sudan where the drainage system was not designed including the volume rainwater runoff. The area of Nuba Mountains –which located southern Sudan, South Kurdufan state (Fig. 1)–annually receives high rate of rainfall during rainy season making flooding in many areas as Khor el awai close to Abu Gibeiha, unfortunately people suffer from draught and resettled in neighboring Cities, because of unavailability of water in their areas due to unplanned water management and use.

The area of Nuba Mountains is suffering from lack of water for both domestic and irrigation demands, due to:

1. Shallow basement complex (limited groundwater aquifers).
2. High inclination of mountains slope towards the White Nile (causes the whole rain fall received flow to White Nile).
3. The area under investigation is located very far from the Nile system.

In this regard rain water harvesting should be done to provide enough water for drinking and irrigation to people over there, to get a bright life, because water displayed the base of everything.

The purpose of this study is to provide rainwater harvesting solution in both surface and subsurface storage in Nuba mountains area using geotechnical aspects.

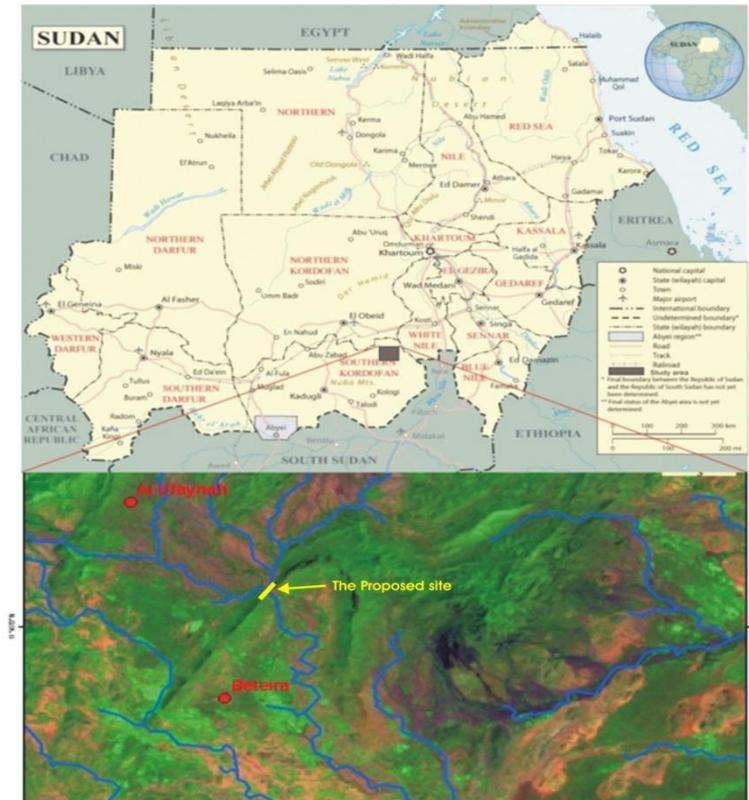


Fig. (1): Location map of study area

## II. Materials and Methodology:

In this study many engineering geology and structural geology aspects has been used to clarify the final view of the plan of artificial recharge in the proposed site; geological map was drawn to identify rocks and soil types, topographic features and drainage pattern have been created for dam site selection, soil classification test has been carried, structural analysis was done in form of fractures and lineament for groundwater flow. Landsat 7 images were used to drive base map, shuttle Radar Topographic Mission (SRTM) data have been used in topography and drainage system analysis. May software were used in completion of this work; ENVI for satellite images processing, global mapper for shuttle SRTM data, stereonet for structural modeling and Arc map for data base and maps layout.

## III. Results

**Geology:** from Geological point of view, Northeastern Nuba Mountains region represents one of the most important basement complexes in Sudan. The area is underlain by high-grade gneisses and low-grade meta-volcano-sedimentary sequence of the Nubian Arabian shield (both are intruded by alkaline and post to anorogenic intrusions) and paleozoic sediments. Kabus Ophiolitic mélangé separates the two terrains as a suture zone demarking an old subduction zone. The proposed site is within the low-grade meta-volcano-sedimentary sequence. The Wadi Alluvial includes: clays, silt, fine- to medium-grained sands of the lower parts of the Wadis, and coarse-grained sands to fine gravels of the upper parts of the Wadis. Alluvium deposits in the site are confined to the Wadis and Khors where they provide an agricultural land and shallow ground water aquifers are sandy soils and its thicknesses are variable from 10 to 15 meter.

**Topography:** the study of the proposed dam site showed that, the site lies in the north- eastern edge of a gentle topographical swell in the central plain of the Sudan and it represented in different topographic terranes varying from hilly to peniplains (fig. 2) and it rises to a height of 600m above mean sea level. And the streams are flowing between the hills which make the selected sites very suitable to be dam sites.

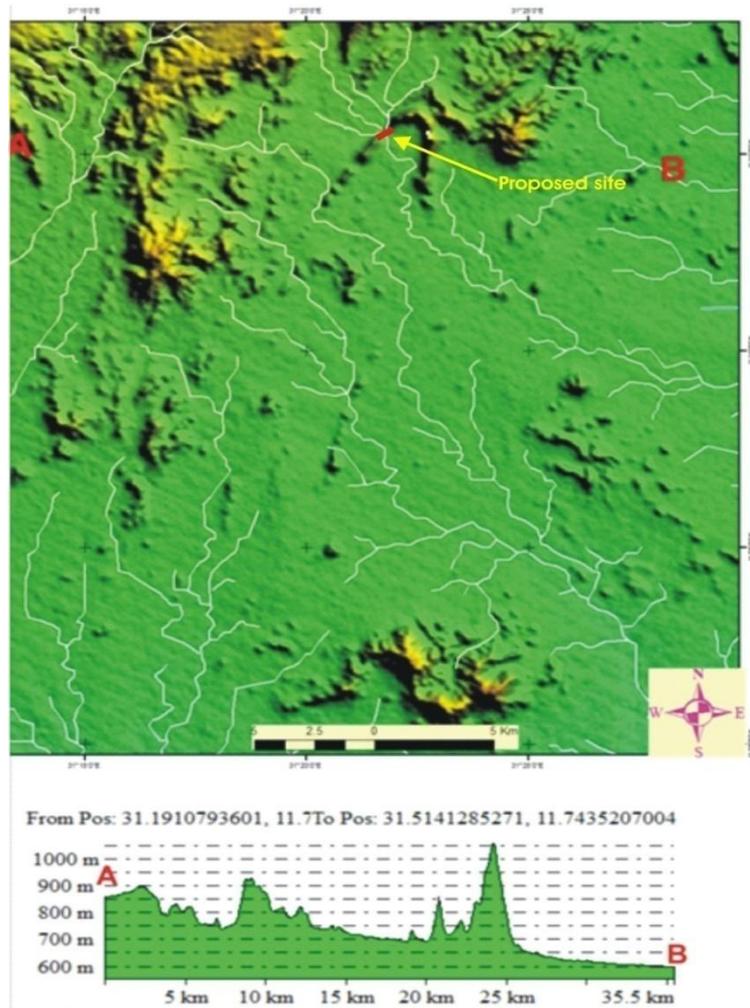


Fig. (2): topography and drainage pattern and elevation cross section of the area. This figure display the variation of topographic features the overall inclination toward the east direction to River Nil.

**Soil Type:** soil texture tests are carried out to determine soil types. The relative proportions of sand, silt and clay are used to determine the textural class of a soil. The internationally accepted and most used tool for initially identifying soils for dam building is the United States Department of Agriculture (USDA) texture diagram. The mechanical or sieve analysis was performed to determine the distribution of the coarser, larger-sized particles, and the hydrometer method was used to determine the distribution of the finer particles.

Table (1): soil classification test of eight samples; the result shows that all samples are sandy types of soils.

Sample No.	Sand %	Clay %	Textural class	Soil Group	Soil Name
1	46.4	44.1	Sandy Clay	SP	Gravelly Silty Sand
2	80.0	16.5	Sand Clay loam	SM	Silty Sand
3	75.3	–	Loamy Sand	GP	Gravelly Sand
4	50.4	35.2	Sand Clay Loam	CL	Silty Clayey Sand
5	60.0	15.8	Sandy Loam	SM	Silty Sand
6	75.7	25.3	Sand Clay Loam	CL	Silty Clayey Sand
7	70.1	10.5	Sandy Loam	SP	Gravelly Silty Sand
8	65.6	15.8	Sandy Loam	SC	Clayey Sand

**Seepage Test:** seepage losses are affected more by the prevailing groundwater conditions than by permeable soils. For example, if an excavation is cut into sandy soil, which lies well above the water table, water will tend to seep out of the excavation. On the other hand if the water table is higher than the floor of the excavation, then

obviously water will seep in. However, because most storage is built well above the water table, sands and gravels are likely to be sources of seepage. There is a simple test was used to evaluate a site. During the site exploration, several soil-sampling test holes has been dug in the borrow pit areas, these holes are done by hand (30 cm diameter and at least 70 cm deep) for the seepage tests which resulted high rate (34.56) of seepage table (2).

Table (2): Test bits of three samples; the average result is 34.567 liter per hour which thought to be too permeable for a dam

Test bit No.	Seepage loss rate (L/hr)	Average seepage loss rate
1	28.5	34.56
2	36.8	
3	38.4	

**Structural analysis:** the site which is outlined by quartzite ridges has an axis extends in NNE direction (about 30°). This fold axis plunges 70° in the same direction. The dip values of the limbs range between 70° and 75° westward. The intersection of two foliations S1 and S2 at right angle produces a lineation of D2. This lineation can be observed in the closure of D2 fold. Most of lineaments trending more or less north to west direction (fig. 5) and related to  $\sigma_2$  of strain ellipsoid (fig 4). These types of fractures are close fractures, therefore cannot act as water bearing. By using the strain ellipsoid; the fold axis parallels the greatest strains axis ( $\sigma_1$ ) has a 30°; therefore the smallest strain axis ( $\sigma_2$ ) has a 300° direction (D2 forces direction). When the folding forces increased, the middle stress axis will act in a direction of 75° - 90° ( $\sigma_3$ ) producing a refolding, so any fold with an axis in a 75° - 90° direction can be attributed to D2 forces. Extensional fractures parallel to D2 forces direction (300° or 120°) may be formed. In the last stage of deformation, release fractures perpendicular to the folding forces direction could be resulted (Fig. 4).

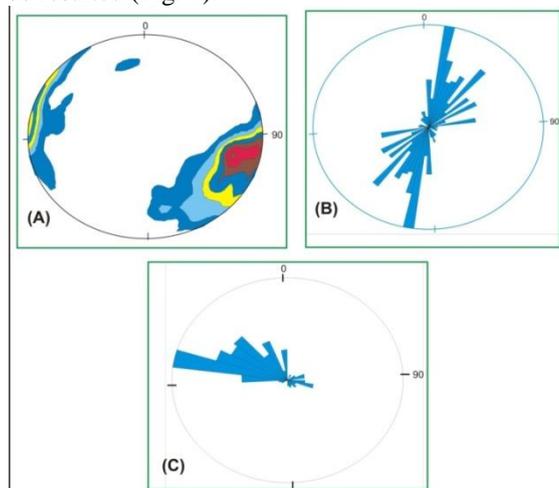


Fig. (3): Stereographic projection of Study area; (A): Contour diagram of dip & strike of foliation, (B): Rose diagram for strike of foliation, (C): Rose diagram for dip direction of foliation. The general trend of foliation is in NNE direction (30° approximately) and the general dip direction on both two limbs is about 300° (WNW).

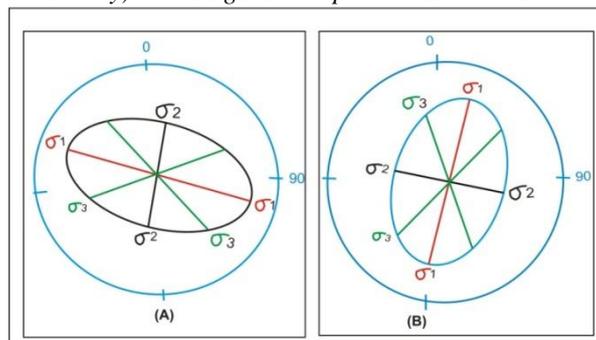


Fig. (4): stress and strain ellipsoids of Study area. A: Stress, B: strain.

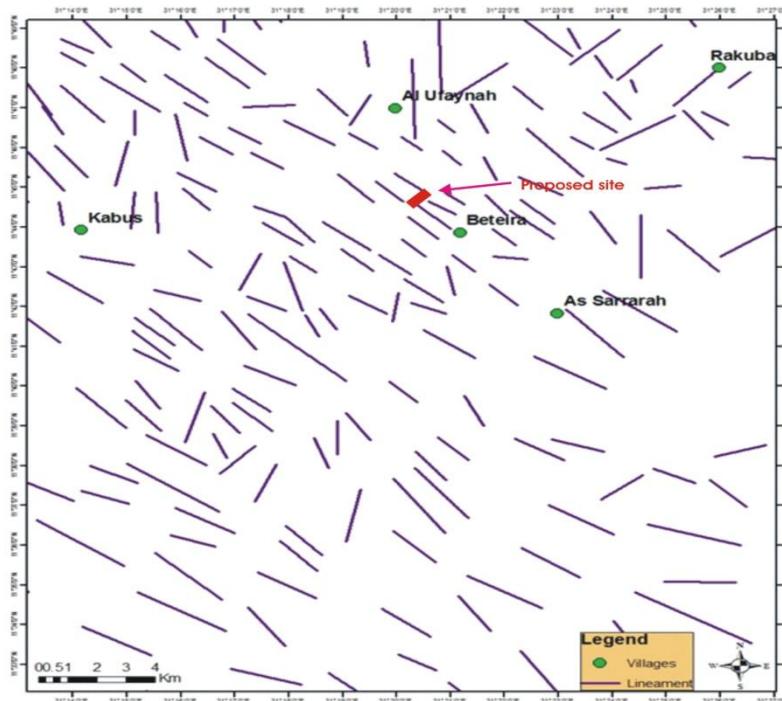


Fig. (5): Lineaments of study area are trending more or less toward northwest Direction.

#### IV. Conclusion

Topographically, the site is very satisfying for surface storage, but soil texture showed the existence of sandy soils which seep the water, and this has been ensured by seepage test ( $> 30$  L/hr). For this reason the site has been proposed to be artificial recharge to alluvial aquifer. Detailed structural analysis has been done to know the rock foliation, dip, fractures and lineaments; then subsurface water flow. The results shows that; the foliations of rocks at the site are dipping towards the west direction generally and lineaments of area are trending more or less to WNW direction, so the water will flow to this direction and the boreholes must be drilled northwest of the dam site.

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