Report No. WD/OS/81/6 March 1981

PROPOSALS FOR SUDAN-IGS-ACSAD WATER RE-SOURCES PROJECT IN THE BUTANA AREA, SUDAN.

Report of visit to Khartoum, 26.2.81-7.3.81

by

W M Edmunds

PROPOSALS FOR SUDAN-IGS-ACSAD WATER RESOURCES PROJECT IN THE BUTANA AREA, SUDAN.
Report of a visit to Khartoum, 26 February-7 March 1981.

1. BACKGROUND TO PREVIOUS WORK

Research into improved methods of recharge estimation in arid and semi arid zones has been identified as a high priority, based on various water resources projects carried out by IGS during the last decade. Recharge can take place by various routes: (1) vertical direct recharge through the unsaturated zone, (2) recharge by surface runoff via wadis, (3) lateral recharge between adjacent aquifers, (4) recharge from rivers into adjacent aquifers. There is also the important question of recharge variability with time both on short time scales (1-10 years) and on longer time scales (10^2-10^4 years) which may be important in estimating the evolution of the resources and in the projection of long term usage. In some areas artificial recharge via dams or storage ponds may also be important.

A project funded by ODA to study the direct recharge component was initiated in 1976 in Cyprus and field work carried out 1977-80. This project in collaboration with Cyprus Water Development Department was intended to investigate the use of lysimeters and geochemical methods for estimating recharge and to compare the results with more conventional methods of calculating recharge. The preliminary results of this work have been given in Edmunds and Walton (1980), Kitching et al. (1980). The detailed results of the geochemical investigations are reported in Edmunds et al. (1980).

The results of the work in Cyprus have demonstrated that geochemical methods, notably the use of the chloride balance in the unsaturated zone, supplemented by tritium analysis can give reproducible recharge estimates for unconsolidated aquifers where the rainfall regime varies between 300-600 mm/year. Comparisons with other methods must await several years of data from lysimeter studies.

The advantage of the chloride profile technique is that an integrated (10-30 year) value for recharge is obtained and that the approach used is relatively unsophisticated and inexpensive and should be adaptable to other terrains. Following the Cyprus experiments therefore, it was desirable to apply and develop the technique in a country which was more typical of semi arid zones.

2. RELATIONSHIP WITH ACSAD AND THE SUDAN GOVERNMENT

Contacts between ACSAD (Arab Centre for the Studies of Arid Zones and Dry Lands) based in Damascus and UK were initiated in 1977 by the visit of Dr J Khouri (Director of Water Resources) to London. Aquifer recharge research was identified as a potential area of collaborative study, especially the extension of the Cyprus studies to Arab countries.

ACSAD contacted various member countries to solicit interest in recharge studies and received a favourable reply from the Democratic Republic of Sudan. A tentative project document was prepared by ACSAD in February 1979 and submitted to ODA for approval; the specific project area was the Saag el Naam basin in Darfur province. This proposal (ACSAD 1979) proved unacceptable to IGS and ODA on grounds of cost (mainly of lysimeter work) and the British Embassy in Khartoum advised strongly against the project in view of the remoteness of the area and related logistic grounds.

Further discussions were held in Damascus in February 1980 between Dr Edmunds and ACSAD (Edmunds, 1980) at which further possibilities for collaboration on recharge studies and other research were discussed. A further visit was made by Dr Khouri to London in June 1980. It was agreed to prepare outline conditions for a recharge project based either in Sudan, or in Tunisia or Morocco.

The approval of ODA was given for work in Sudan to be further explored. A brief report was prepared by Sudanese geologists on a project area in the Butana region (Appendix A). The present report is thus an outline for collaboration between the three organisations to work on a water resources project in this region, with special emphasis for IGS recharge aspects. The area is described in the review by Nash (1979).

3. PROGRAMME OF VISIT

The visit by W M Edmunds was made between 26 February and 7 March 1981. Dr J Khouri, Dr Nabil Roafil and Sd. Mohamed El Hassan El Tayeb represented ACSAD, respectively Syrian, Egyptian and Sudanese nationals. Discussions were held with staff of the National Water Administration, the organisation of which is given in Table 1. Principal contact was Dr Rameses Salaama, Head of Research. The following was the itinerary of the visit.

26.2.81	London-Paris-Khartoum
27.2.81	Initial discussions IGS-ACSAD
28.2.81	Meeting with staff of National Administration for Water (NAW) to explore objectives. Meeting with British Embassy staff (C Hayward, 1st Secretary Development; J James, 3rd Secretary Arid). Further discussions NAW-IGS-ACSAD.
1.3.81	Technical discussions ACSAD-IGS-NAW
2.3.81	Field trip to Wad Hassani - Abu Delayq - Wadi Hawad - Shendi.
3.3.81	Shendi - Wadi Bannaga - As Saffra area - Khartoum.
4.3.81	Discussions on field area between ACSAD-IGS-NAW. Meetings with Director General NAW.

5.3.81 Definition of project with NAW. Meeting with the Minister for Energy and Mining. Further discussions with British Embassy.
Official Dinner with Director General NAW and staff-ACSAD-IGS-British Embassy.

6.3.81 Further IGS-ACSAD discussions and writing of a project outline to be left with NAW.

7.3.81 Khartoum-London.

4. PROJECT AREA

4.1 Geographical.

The Butana area lies between the Blue Nile and Atbara rivers with Atbara town in the north and Gedaref in the south extending towards the Ethiopian Highlands (Figure 1). The land is generally flat lying but dissected towards the Nile and Atbara valleys. Highland areas occur in the NW of the region. An area of some 30,000 km^2 was defined as the main research area, including the principal wadi, Wadi Hawad.

4.2 Rainfall and Climate.

The rainy season is from June to September with rain occurring principally in several heavy storms. Rainfall is 600 mm in the south of the area, grading to 100 mm in the north. The exact distribution is likely to be very variable and contours must only be used as a rough guide. At Abu Delayq, the maximum rainfall has been 256 mm and minimum 120 mm over the past 12 years. Basic meteorological stations exist at Abu Delayq and Shendi with good control from Khartoum.

4.3 Natural Vegetation.

The southern Butana area provides good grassland for grazing and rainfed agriculture. East and north of Khartoum there is open country with acacia and scrub and seasonal grassland. In the wadis the vegetation is denser.

4.4 Population, Land Use.

The population is sparse in the northern area and only two market towns - Abu Delayq and Shadida - with approximately 10,000 inhabitants are found away from the Nile. These towns support the nomadic population of the rangelands. At present there is no agricultural tradition except for basic seasonal rainfed agriculture. Small seasonally cultivated areas are found on the black cotton soils and along the Wadi Hawad. No irrigation is practiced at present although the soils are promising over much of the area.

4.5 Surface Water.

The Nile and Atbara rivers support alluvial development at many places along their lenths. During the rainy season, surface runoff is significant along wadis where floods of 1-5 days duration may occur bringing water generally south to north across the area. Some areas of standing water remain for considerable time after the floods along the Wadi Hawad,

4.6 Groundwater Occurrence.

The probable occurrence of groundwater is shown schematically in Figure 2. A deep water table (80-100 m) exists in the Nubian sandstone; lateral recharge to the Nubian probably takes place from the Basement Complex to the south. The extent of regional direct recharge is not known. The basal Nubian near Abu Delayq is sandy and conglomeritic in general with some mudstone interbeds and is probably a site of direct recharge along its outcrop and is likely to be a good aquifer although aquifer properties are unknown. In the south (Gedaref) the Nubian is mainly mudstone and does not constitute a good aquifer.

There is a shallow aquifer related to the Wadi Hawad of which the exact relationship to the Nubian is unknown, although it probably recharges the Nubian vertically and laterally. The water table in the wadi is usually less than 5 m.

The Nile supports an alluvial aquifer, important around Shendi. The water table decreases to the regional Nubian water table within a distance of some 10 km.

Several deep hand dug wells exist in the Nubian, dating from Roman times which are still in use with camel and donkey power. Only a handful of new boreholes exist to the deep aquifer over the whole area. Yields of 1,000-10,000 g/hr are obtained. There are a considerable number of shallow wells along the Wadi Hawad.

5. PROJECT OBJECTIVES

The proposed project will be considered as a combined Sudan-ACSAD-IGS study whose overall objectives are defined below.

The region is important hydrogeologically as a typical recharge area for the Nubian aquifer of North Africa. It extends across a major climatic boundary with rainfall in the range 600-100 mm and can be considered as a typical area for study of the Sahel belt of variable climate and desertification. Nationally, the region represents an almost undeveloped area quite close to the capital. It is important as an area at the boundary of rainfed agriculture and pastoralism, where the priority is to stabilise the population, prevent migration to the towns, yet provide an improved living standard. This would be accomplished by developing water resources to guarantee fodder during drought and to encourage other limited forms of perennial agriculture.

The current recharge to groundwater is likely to be small even though the overall reserves in the deeper system could be quite large. Definition of current recharge is therefore important within the overall project objectives, although recharge from several sources may be important in the area.

The project will be known as the Butana area water resources project. A main project area in the north has been defined and within this area it is likely that one or more detailed research sites will be chosen.

The project is envisaged to last five years. Phase 1 will provide sufficient information on which to base the proposals for development. Phase 2 will then proceed with any development, bearing in mind the relation to existing development schemes in adjoining areas and the overall ecology.

In Phase 1 the project will provide basic knowledge on the water resources. In the first year ACSAD would emphasise data collection and regional studies, whilst IGS would include detailed work in year I. ACSAD's regional studies would be supplemented by surface geophysics and some drilling. It is important that a joint effort, particularly involving Sudan NAW be devoted to providing a data base for the project in year I.

6. ACSAD CONTRIBUTION

ACSAD form both an important catalyst in the project and are to provide considerable staff and resources. They will also seek financial support from the Arab Fund. The provisional material contribution of ACSAD is given below but the financial allocation or staff commitment cannot be made before June 1981.

- Hydrogeological field equipment including downhole logging
- Hydrometric equipment (automatic water level recorders)
- Meteorological stations (automatic)
- Resistivity (surface) equipment
- Some chemical analysis (non-routine)
- Cartographic/photographic facilities (Damascus)
- Satellite imagery interpretation
- Report preparation printing
- 2 Field vehicles
- Pumping Unit (diesel 60-70 hp)

ACSAD would provide expertise as required in the following fields:

- Surface water hydrology
- Hydrogeology
- Hydrochemistry
- Modelling
- Geophysics
- Training
- Land Use Surveys

7. SUDAN GOVERNMENT (NAW) CONTRIBUTION

The Sudan NAW clearly welcomes the concept of this project and from the discussions held it is clear that their contribution will be at least equal to the other two participants. They have agreed provisionally to provide the following:

All basic data on the area including maps

Aerial photographs (expensive in Sudan £20K)

Automatic water level recorders

Topographic survey equipment

Routine chemical analysis

Digging of wells

Observation well drilling/test well construction

Neutron probe supply

Fuel supply

Basic services and logistic support

Construction of rainfall and hydrometric stations

They would provide the following staff.

Consultant senior staff

Topographic team

Topographic engineer

Photointerpreters

Hydrologist

Project Hydrogeologists (2)

2 Hydrogeological Assistants

Geophysics field team

Labour, drivers, driller(s)

8. IGS PROJECT COMPONENTS

The IGS input is designed to investigate recharge aspects based on geochemical techniques as proposed originally to ODA. However additional work by UK would be welcomed and possible areas are given below. The programme outlined below is intended to last for at least 2 years.

8.1 Recharge Assessment (Geochemical) - see Figure 2.

(a) Rainfall chemistry. Supervise the collection of rainfall samples at three stations - Khartoum, Abu Delayq, Shendi - (1981-84). Supply equipment from UK. Analysis of Cl and major constituents in UK together with $\delta^{18}O$, $\delta^{2}H$.

(b) Direct recharge. Side-wall sampling from new dug wells using auger; plans for dug well construction to be sent to NAW. On-site determination of moisture content, SEC, bulk density with collection of elutriate samples for Cl^- and some major ions. At least one tritium profile will be sampled and a technique developed for $\delta^{18}O$, δ^2H profile measurement at selected localities. Sampling concentrated in Abu Delayq.

Since the unconsolidated deposits are not very thick, it will be necessary to consider adaptations of the method to cover large terrains overlying Nubian/Basement. Auger techniques using L/R power take off (or rig) will be considered to sample to depths 2-5 m.

The method developed in Cyprus will also be tested in this terrain for unsaturated zone sampling particularly in wadi sediments.

(c) Wadi recharge. Trial drilling to be carried out in wadi sediments to determine geochemical regime - sampling of moisture and related saturated zone for Cl, ^3H. Observation well network across wadi to be used to assist geochemical study. Sampling (if possible) of wadi flows, standing water.

(d) Hafir recharge. Possible study of extent of artificial recharge via hafirs (collecting ponds).

(e) Lateral recharge - Basement Complex/Nubian. This includes a regional study of the hydrogeochemistry of the system to examine inter-relationship of the various groundwater regimes. Sampling and analysis for major, trace inorganic, ^3H, $\delta^{18}O$, δ^2H,$\delta^{14}C$, $\delta^{13}C$ as appropriate.

(f) Nile Valley/Atbara River recharge. The extent of infiltration of the surface water into the groundwater system will be determined.

8.2 Related Studies.

In addition to the main objectives above, the possible involvement of IGS in the following activities was proposed, to be discussed further in UK.

(a) Soil Physics Studies. Soil temperature/moisture movement in key areas for qualitative study of moisture movement in semi arid zone soils. Quantitative studies might be difficult. Neutron probe in Sudan. Access tubes needed.

(b) Photogeological work. Enquire what photo cover available in UK and whether interpretation has been carried out. Supply of photos (or mosaics) would help, especially if MOD can supply free.

(c) Satellite imagery. Carry out studies related to recharge estimation. Vegetation desnity, drainage patterns, rainfall intensity, standing water, wadi flood area. Moisture retention by different rock types. Complimentary to ACSAD studies.

(d) Aquifer modelling. At a later stage of the study regional digital modelling or modelling of certain components (river-groundwater) would be desirable. Some modelling proposed by ACSAD; coordination required.

(e) Palaeohydrology. Although within a rainfall belt, evidence exists of former more humid episodes - evidenced by Egyptian settlements e.g. for elephant training. Also possible lake deposits (cherts) in north of area.

(f) Training. 1 or 2 x 3 month training visits to UK by Sudanese staff would be relevant in fields of soil physics/hydrochemistry; it is hoped to arrange these via the British Council/British Embassy Khartoum.

8.3 Input of Resources by UK (IGS, and ODA).

It was agreed provisionally that IGS (UK) would supply the following:

1 long wheel base L/R (Pick-up) } British Embassy Khartoum

1 Station wagon

1 Power take-off for fixing to above

1 Augur attachment

1 Pilcon 1500 (reconditioned) rig with 6", 8" casing. Rotary attachment (?), Tools

Lengths (as many as possible) UPVC 3" liner

Portable 100 cc generator

Air photos

Satellite photos

Neutron access tubes/platform

Field equipment (including tents - 4 no.)

Fridge (gas), Oven

Gas bottles

Miscellaneous items relating to chemical sampling

Specialist equipment would be brought in - balance, conductivity meter, small centrifuge(?), distilled water, rain sampling equipment, field pH, HCO_3, chemical, bottles etc. etc.

IGS would supply expertise in the following fields:

Hydrogeochemistry

Drilling methodology

Soil physics (?)

Digital Modelling

Photogeology, satellite imagery

8.4 Timing (provisional). First of two years

1981	April/May	:	Send rainfall sampling equipment to Sudan
	June/September	:	Rain collection
	April/August	:	Visit by EPW to Sudan or ACSAD
	September	:	Discuss final plans in Rabat (WME/ACSAD)
	October/November	:	Well digging (NAW)
	November/December	:	3/4 week field visit (IGS)
1982	February/March	:	3/4 week field visit (IGS)

9. GENERAL OBSERVATIONS/LOGISTICS

Importation via PORT SUDAN allow 4 months; customs and port clearance not expected to present undue problem. Use Ratcliffe International (UK) and Trans Inter or Trans Sudan. Petrol is rationed but for our use no problems should exist.

Related studies are being carried out by Green Deserts, a charity organisation based in UK to establish shelter belts in the north of our area.

HRS have been involved with Sudan Government (Dr Wooldrige) in design and construction of inflatable dams. These might be useful in Wadi Hawad.

If IGS supply tents etc. all other supplies are available in Khartoum which is 3-7 hours driving from project area. Estimate 3 days mobilisation in Khartoum. No serious logistic problems are envisaged at this stage. By splitting the field visits into two phases, it is hoped to cater for (a) the inability to make very detailed field plans for this large area during the present visit and (b) the chance to obtain additional data based on experience gained during the first field visit.

10. ACTIONS

The provisional proposals contained above are to be confirmed with IGS/ODA and a detailed programme forwarded to ACSAD/Sudan Govt. A costed proposal will be prepared by IGS within the funds allocated (61K) by ODA over 1981-83. ACSAD will prepare a final project document by mid-1981. Follow-up visit to Damascus or Sudan by Dr Wright would help to cement the concepts of collaboration especially with ACSAD. There is scope for bilateral UK/Sudan Aid projects in water resources although the Embassy have indicated that there is little change of serious consideration of these before 1983-4. However there is scope for growth within the present project.

ACKNOWLEDGEMENTS

The generous hospitality of the Sudan Government (NAW) is gratefully acknowledged and their constructive attitude will considerably assist this project. The valuable assistance of Ms Janet James and Mr Chris Hayward of the British Embassy is also acknowledged.

REFERENCES

ACSAD (1979) Water balance and aquifer recharge in arid zones (Sudan). A tentative project document. ACSAD Report HS/PD13, Damascus.

EDMUNDS, W M (1980) Report on a visit to ACSAD, Damascus, February 1980. IGS Unpubl. Report WD/OS/80/7.

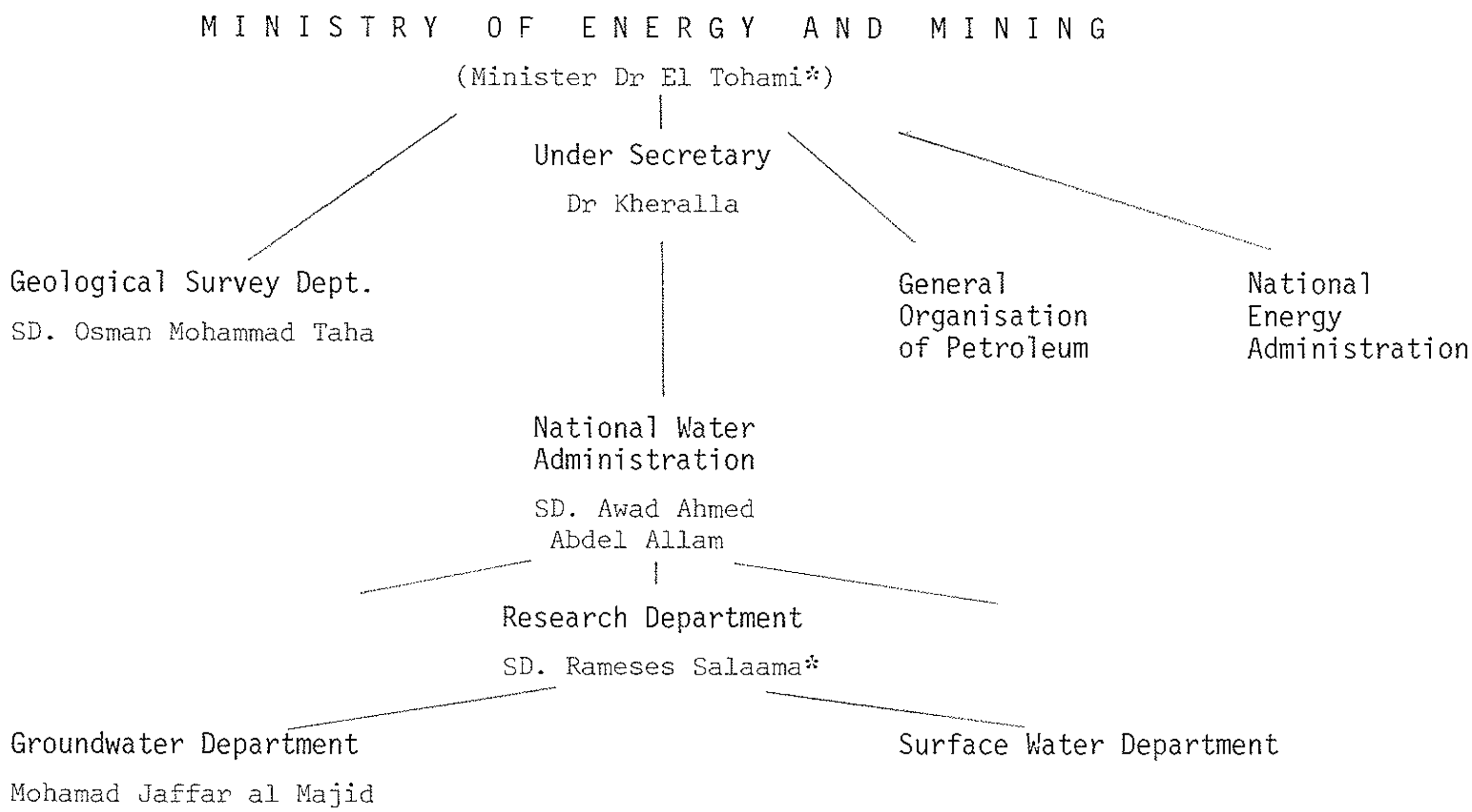
EDMUNDS, W M and WALTON, N R G (1980) A geochemical and isotopic approach to recharge evaluation in semi-arid zones - past and present. IN 'Arid Zone Hydrology: Investigations with isotope techniques'. IAEA (Vienna) AG-158/4, pp 47-68.

EDMUNDS, W M, WALTON, N R G, HOWARD, M P J and JACOVIDES, J (1980) Geochemical estimation of aquifer recharge. Final Report of Semi Arid Zone Aquifer Recharge Project, Cyprus. IGS Report WD/OS/80/17.

KITCHING, R, EDMUNDS, W M SHEARER, T R and WALTON, N R G (1980) Assessment of recharge to aquifers. Hydrological Sciences Bulletin, 25, (3) 217-235.

NASH, H G (1979) Review of hydrogeology of groundwater resource studies in the Sudan. IGS Report No. WD/OS/79/23, Unpubl.

TABLE 1. SUDAN ORGANISATION IN WATER RESOURCES.



* Ex London (UCL) Hydrogeologists.

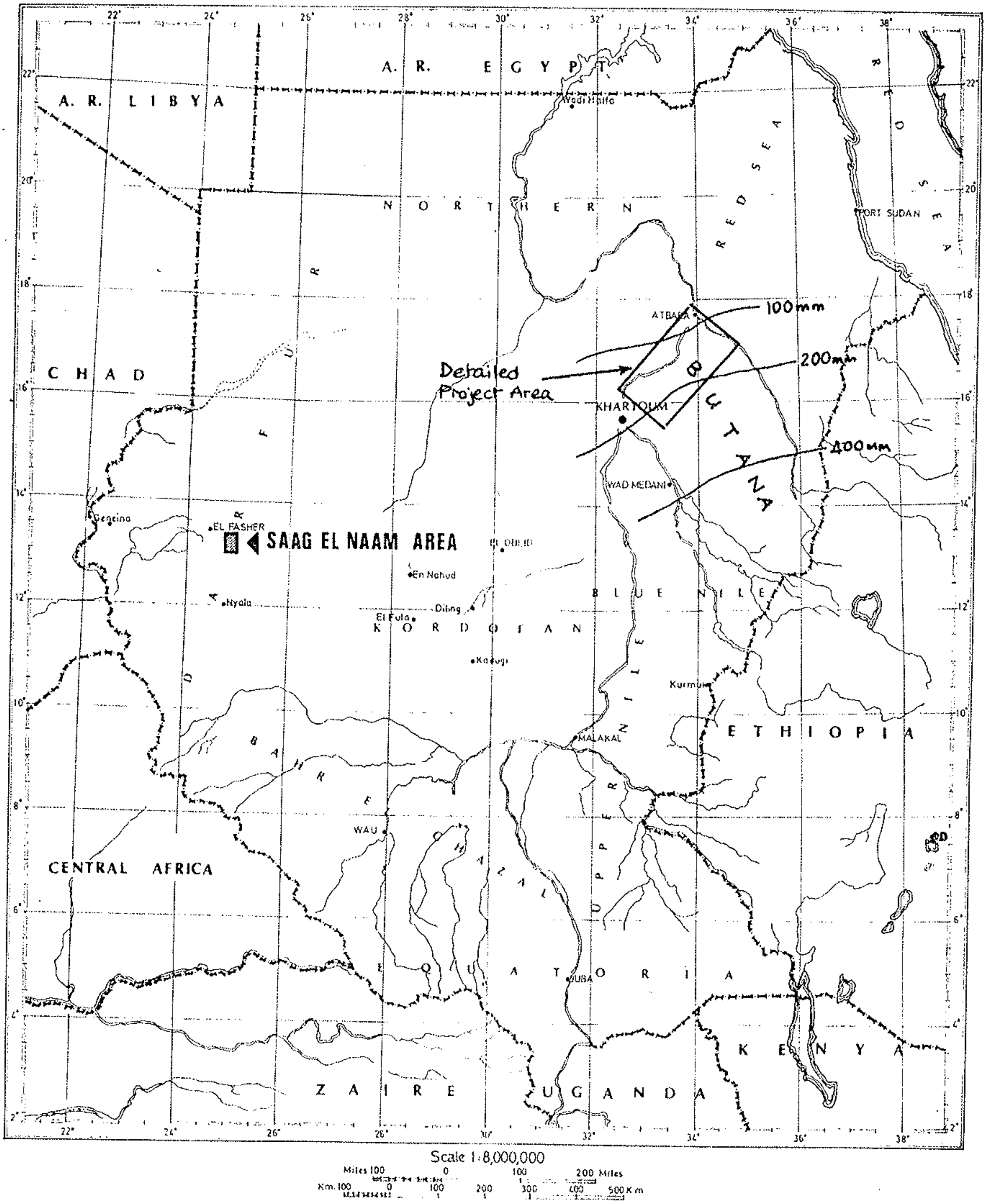


Figure 1. Location of Butana area in relation to Khartoum. The detailed project area is shown in outline with approximate rainfall contours. Most of the Butana area is underlain by Basement Complex but the detailed area is mainly Nubian Sandstone Series. The earlier Saag el Naam project area is also shown.

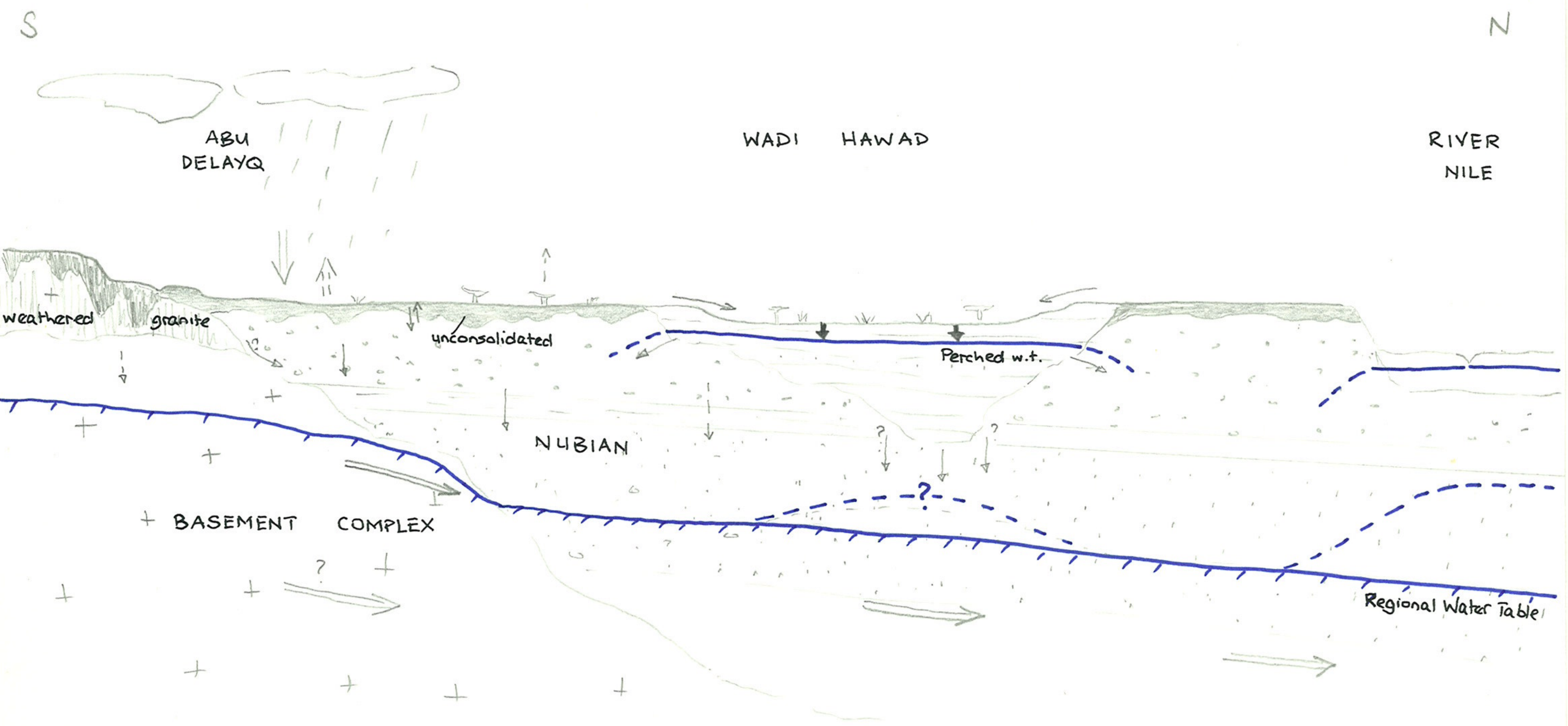


Figure 2. Schematic hydrogeological cross section through project area showing the relationship of Nubian to Basement Complex. Lateral recharge probably occurs from the Basement Complex. A recharge zone some 10 km wide is known for the River Nile. Recharge from the Wadi Hawad perched aquifer to the deeper Nubian is probable. Direct recharge through the unsaturated zone is probable, especially in the sandy lithologies of the Nubian Sandstone.

APPENDIX

Report about the area below River Atbara

Location :

The area embraces by the triangle shape which is extended from the function of Atbara River with the River Nile at Atbara Town and Southwards to Khartoum Town and somewhat eastwards to El - Gadaref Town.The whole area comprises by the sheets 45-K,L,O,N,P and sheets 55 - B,C,D .

Topography :

The middle of the triangle is open flat country of sandy - clay with occasional clays,this is a typical scenery of theButana plain The area along the River Nile is dominated by isolated hill masses (Jebel Um Ali) and flat topped plateau of the Nubian formation and gorege plateau.The Northern part of sheet 36-0 is characterized by the vast Nubian plateau .That rise up to 250 feet above the ground surface.

The area is dissected by numerous surface drainage lines, due to rather poor rainfall in the upper part of the area.The drainage system is mostly represented by ill defined Khors,that are generally in the form of shallow elongated depression with relatively dense vegation.In general the drainages in the NW part are flowing from South to North and mostly they are fasted to reach the Nile .

The largest drainages are wadi El Hawad,wadi ElMukabrab and Khor Abu Deleig.Wadi El Hawad has a well developed bed that extends as a clay rich North-South strip for about 50 miles with width of 2-4 miles.The wadi drained an area of about 133 sq - miles plus its teributeries and received an average annual rainfall of about 213 mm. The Khor bed is about some tens ft. deep and about 300 feet in Abu Deleig.It is filled with very coarse gravelly clean sand,grits,pebbles and clayey Nubian formation.Along the wadi water supply from shallow dug wells,some of these are produce saline water .

Climate :

The climate of the area is mainly Tropical continental type The winter is between December and March is pleasently cool. The Summer is hot and dusty. The period of last month in winter and the first monthes of summer the area subjected to strong local winds as the re-result of the fast Northern winds. The max., min. temperature, relative humidity, rainfall and evaporation of the major towns in the area are given below in the climatological normals. The rainfall ranging from (227 mm) at Atbara town to (500 mm) at El Gadaref. The area is somewhat arid to semi - arid zone, some trees and shrubs are only being along the Khors and wadis .

Geology of the area

Stratigraphy :

1 - Recent superficial deposits including soil types and Khor deposits .

2 - Nile and Atbara rivers alluvial deposits Quaternary-Recent age .

3 - Tertiary laras flows.Upper tertiary .

4 - Ferricret beds on present Nubian surface.Mid-Tertiary age.

5 - Hudi cherts and associated ironstone.Lower Tertiary-propably Oligocene .

6 - Nubian Sandstone Formation.Jurracic-Cretaceous age .

7 - Basement complex . Precambrian age .

I - The basement complex rocks :

The basement complex rocks are the major rock type in the eastern and the northern part of the triangle area.They are of Precambrian age.They were divided according to their age as follows :

1 - Basal schists : It is mainly of quartz chlorites schist and graphite schist.Itis known to be oldest rock.It is covered by Butana clays and other superficial deposit at the middle part of the triangle (west part of sheet 55-D)

2 - Granitic gneisses and foliated granite : Well foliated and banded with mica rich and feldspare alternating bands.The pegmatites veins are invaded the granitic gneisses as well as the amphibolite bands.These formation appeared in Sabaloka gorege,Gebel Geili,wadi Bannaga exposures at long 33° 07 and lat 16° 31 and South-West shendi town which join those of Sabaloka gorege.

3 - The acid extrusive series : Rhydite,younger intrusion of granite,Syenite (Jebel Geili),Ignimbrites,Agglomerates and tuffs. They are scattered as small hills in the northern part of Sabaloka gorege.They are highly jointed and fractured.The ring dyke of porpheritic micro granite which drived from Rhydite nagma.The central hill masses at Sabaloka,cut through by the Nile in a gorege some 320 feet deep and in places only

1300 feet wide,is composed of Rhydite lavasand Ignimbrite tuffs...etc resting on metamorphosed basement of granitic gneisses.It partially enclosed by a ring-dyke consisting of porpheritic micro-granite which intruded into the zone of fracture .

Jebel Geili composed of basement complex at the central plug (Qalat Geili) is Syenite and three associated ring - shaped bodies intruded into the quartzite,schist and altered andesite lavas . As the result of the defferential erosion the Syenite and granite are formed a group of hills that rise about 260 ft. above the ground surface .

II - The Nubian Sandstone Formation :

The Nubian sandstone formation rest unconformably above the basement complex.It is covered the area east of the River Nile and down to South of Khartoum town.It is represented by a monotonous succession of mudstone and sandstone with occasional intercalation of conglomerat beds.The mudstone is less dominated the Nubian formation .Depth of saturated zone ranging from 40 - 750 feet related to defferent lithology as well as the distance from the River Nile.

There is a continouty between the Khartoum basin amd Nagara basin West of the Nile which is broken at the east of the Nile by sabaloka - wad Hassuna-Jebel Geili ridge,which is form a subsurface barrier extending broadly east-west acroos the area. Boreholes drilled along it are dry.Along the fault-planes the sandstone tends to be compact of hard quartzitic rocks due to thermal effect followed by later silicification .

The thickness of the Nuvian is deffer from place to another , the Max. depth reach in well No. 5837 at Emahmeia which is 1059 feet.The thickness reduces towards the basement contact,or the border of the Nubian in the middle part of the area.

The Nubian also recorded west and east south Esshowak and Gedaref towns which overlain by the basaltic rocks.The Nubian in this area is dominated by the mudstone which is impervious medi ,many boreholeswere drilled west of esshowak,they were failed.This Nubian in this area was classified by (white-man 1970) as El Gadaref Nubian formation.He has recorded that it is older than the Nubian in the west part of the area.

III - Hudi cherts :

It is associated with ironstone and ferricrete beds,which are rest above the Nubian formation.(Jebel El Guweir,16°-46 , 33°-29).In general they form low lying plateau(Jebel Suweirig el Bafalil)20 miles S. East of shendi.The Hudi chert occurs in the Nile valley,wadi Mugaddam and wadi el Melik area near Hudi station.It is also recorded at Zeidab area and N. East of Saba-loka plateau.The Hudi boulders are mostly irregularly ellipsoidal in shape ranging to nearly a foot diameter.It is a lacustrine deposit.

IV - Tertiary lavas flow :

These formation are extruded as a multiple sheets and irre-gular intrusion.It is contemporaneous with the Ethiopian plateau voleanic seriesat the eastern part.These formation are recorded around esshowak and Gadaref towns,which is overlies the Nubian formation and overlies the Hudi chert in the area North-East Shendi town.The sequence of the basaltic flows are feldspatic basalt,Trachite phonolite and olivine basalt.The basalt intruded by dolesite dykes (north Gadaref town) running North-South direc-tion.The weathered horizon is soft and deeply fractured.It attair thikness of 400 meters at the middle part of the outcrop north-west Esshowak town.The basalt formation in the eastern region is is of limited importance as an aquifer due to its low productivit and low quality.The investigation done west of Esshowak shows tha the fissures and cracks decreases with depth and during summer period the recharge decreases while alkalinity (Ca Co_2) increases

V - Superficial deposits :

- Butana clays
- Residual soils
- Sand dunes
- Transported soil
- Alluvial deposits

The Butana clays differ in colour from place to another due to the rocks types surround the area.It is heavely dark in the eastern region to light brownish in the middle of the triangle and light grey in the western part and the Northern part .

The residual soils are drived by the weathering processes from the rocks of the basement complex . They are mainly made of clay,clayey sand surrounding the basement complex hills in th middle and the eastern part of the area.Thickness and extension depend on the slope and the rock type of the hills.The transported soils are alluvial soils which drived from far distance by rivers wadis and tribularies in the area.Which is composed of clay , clayey sand , sandy clay and silts.

The alluvial sediments fill the Khors,wadis and river valley , wadi El Mukabrab , wadi El Hawad River Nile and Arabo river,which is composed of clay,sandy clay and gravels,pebbles, of rock fragments and silt along the terraces of the river Nile.

Extensive gravel spread occurs in the Atbara river terraces Many wells were dugged at wadi El Hawad they produce ample amount of water and some of them become dry during summer perioc

References

1 - 1959 M. O. Mansour
A. Samuel and Omar A. Mohd .
Geology and Hydrology of sheet 45 - 0 .

2 - 1960 M. Keiralla
Groundwater Geology of the Nile valley in Nile province.

3 - 1965 A. M. Saeed
Short Note about El Damer area .

4 - 1966 Short Report on water problem in wad Hassuna
Mohd. Sirag el Din .

5 - 1970 Whiteman
Geology of Sudan .

6 - 1971 Salah M. Nour
Habib George
Omer Khogali
Mohd. Abbas
Geology of El Kamlin sheet No. 55c .

Nile Province

	Locality	Well No.	Sheet	Depth ft	Filter depth ft	S-W L ft	Q g/hr
1	Kabosheia	382	45-0	150	-----	60	496
2	Shendi	444	45-0	148	77-148	22	12800
3	=	445	45-0	202	96-202	25	13800
4	=	446	=	414	328-419	25	13000
5	Kabosheia	383	=	175	-----		
6	Hederba	907	45-K	140	70-140	22	-----
7	==	908	=	160	68-160	21	2000
8	El Nagaa	926	45-0	304	257-304	251?	880
9	==	928	=	316	269-316	250	=
10	Al Temaid	956	45-0	404	246-338 317-362	215	1320
11	AlT-Hag Tahir	990	=	435	340-435	215	13200
12	Umm Raboul	993	=	306	202-306	189	1050
13	= =	1020	=	312	-----	187	1200
14	W. Al Hamid	1000	=	357	308-346	298	880
15	= =	1010	=	336	279-336	300	1320
16	U. Durwa	1012	=	446	336-446	310	1150
17	= =	1021	=	446	333-446	300	1000
18	U. Arda	1029	45-K	440	338-440	220	1300
	= =	1042	=	421	338-421	199	1300
19	Qala el Tour	1961	45-0	482	382-482	Abondon	
20	Wad El Habash	1959	45-N	100	-------	=	
	= =	1959	=	32	-------	=	
21	Al Teibna	2841	45-A	462	354-447	115	5000
22	Wadi el Areif	2842	45-D	760		Abondon	
23	Al Gewair	2843	=	590	440-485 460-505	65	4000
24	Al Norab	2844	45-0	419	-------	43	8000
25	Keli	2845	=	755	688-755	65	8000
26	Abu Ushar El Hassaneia	2986	45-K	480		Abondon	
27	Umm Maraheik	3037	=	154			
28	Kemail Al Awadeia	3039	45-A	506	420-486	73	2000
29	Jebel AlRakami	2987	45-K	941	830-290	165	7000
30	Saial El Maleik	2528	45-D	295	215-285	180	

	Locality	Well No.	Sheet	Depth ft	Filter depth ft	S-W L ft	Q g/1
31	Al Makaylab	2991	45-G	65	31-51	24	1440
32	Al Bawga	2990	=	75	30-60	24	1440
33	Al Bagraweia	3429	45-0	380	306-361 341-381	19	5000
34	Qot Badur Al-Mashaik	3567	=	102	50-90	38	6000
35	Taybat al Kawad	4001	=	440	64-361 100-421	48	3000
36	Al Makneia	4002	45-K	524	53-433 90-513	22	3000
37	Al Mutmar	3565	=	210	30-140 30-195	28	1440
38	Sagadi AlMahmeia	3568	=	205	40-128 58-183	43	1330
39	Ageidat AlSalamab.	3569	=	260	105-207 160-232	44	1440
40	Qoz Al Fung	3570	=	190	35-124	32	1330
41	Banaza	4194	45-O	354	250-315	40	7000
42	Al Gehaid	4197	=	419	245-365 340-400	280	900
43	Sherasha	4760	=	527	400-510	280	5000
44	Um AGAGA	4195	=	410	310-370 340-410	140	3000
45	Al Matamâ	4846	=	340	228-316	60	2000
46	Al Fayahssain	4200	=	892	757-874	120	2000
47	Al Nehud	4196	45-K	434	310-350 330-410	120	1400
48	Um Ali	4825	=	255	86-196 126-235	25	1400
49	Al Aliab	4824	=	260	72-162 91-236	55	1200
50	Al Baglail	5023	45-O	270	253-140	160	1200
51	Um Shagal	5024	=	160	24-145	35	1440
52	Um Bah	5043	=	440			
53	Kadabas	4210	45-K	140	52-77	15	1200
54	Al Takawar	4296	45-G	155	63-130	20	1200
55	Cement Factory	4209	45-K	175	64-140	82	720

	Locality	Well No.	Sheet	Depth ft	Filter Depth ft	S-W L	Q g/l
56	Adamer	5649	45-K	310	200-267	35	10000
57	=	5650	=	297	207-274	35	13000
58	=	5651	=	302	251-281	35	4000
59	Al Makabrab	5654	=	350	148-315	83	3000
					214-348		
60	Tenaideba	5652	=	999	760-944	83	5000
					811-977		
61	Al Kaker	5678	=	120	19-101	30	2400
62	Atbra	5648	=	421	312-370	76	10000
					346-387		
63	Wad Hamid	5671	=	55		Abon.	
64	El Mahmia	5837	45-K	1059	990-1040	90	7500
65	Al Hafian	5838	45-O	412	301-338-375	91	7400
					318-355-391		
66	Falag elSawad	5839	=	412			
67	= =	5839	=	481	410-465	350	960
					443-481		
68	Dein el Grai	5841		518	324-376	62	7500
					357-392		
69	el Gablab	5842	=	684	598-664	65	7500
70	Al Mgameer	5843	=	460	368-421	70	8000
					401-438		
71	AL Tkagma	6219	=	220		Abon.	
72	Al Sayal	7098	=	240	166-216	20	10000
73	Gado	7354	=	905	797-869-742	75	2000
					847-885-775		
74	Al Saloab	7095	=	293	-----	106	8000

KH . Province

Locality	Well No.	Sheet	Depth ft	Filter depth	S-W-L	Q g/l
K. North	22	55-B	350	---------	70	4500
Lizergab	175	=	101	---------	80	1200
Shambat	269	=	152	---------	65	4120
Wad Hassuna	581	55-C	505	185-400	368	720
	594	=	400	400-220	189	300
Kabashi	615	55-B			257	
Al Debaiba	1097	=	230		115	3000
El Dafor	1504	55-C	630	350-456	275	1680
				232-450		
El Hagiz	1522	55-B	553	499-541	494	1100
Abu Zleig	1549	55-C	402		200	1150
Um Duban	1692	55-B	596			
Abu Gronr	3118	55-B	305	128		1440
Wad Abu Salih	2161	55-C	388	279-366	252	1500
Esalat	2164	=	285	185-230	110	1440
				220-255		
Sayal El Faki	2791	=	355	242-342	233	12000
Wad El Basal	5828	55-B	52		18	1440