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THE HYDRAULIC AND HYDROCHEMICAL IMPACTS OF THE NILE SYSTEM ON THE GROUNDWATER IN UPPER EGYPT

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ABSTRACT :

The Nile system in Upper Egypt includes the River Nile, the irrigation canals and drains nets. The Quaternary groundwater aquifer represents the main aquifer in the area. It is essentially recharged locally from the Nile system water.

During the last four decades the water levels in the river were nearly controlled. However, the water levels in the main irrigation canals are periodically fluctuated and are more higher than the water levels in the Nile River at the same latitudes. They are fluctuating continuously but with different amplitudes and manners.

In the present study a trial has been made to detect the hydraulic and hydrochemical impacts of the Nile system on the groundwater in some selected localities in Upper Egypt. The study depends mainly on the analysis of the available measured and collected data concerning the surface and groundwater levels and composition in the area.

It was concluded that the fluctuations in the groundwater levels are strongly related with the surface water fluctuations in the main irrigation canals, while the chemical impact of the surface water on the groundwater is limited.

INTRODUCTION:

Egypt is located within the arid zone of North Africa, where the fresh water quantity is limited and it is mainly extracted from the River Nile and its system. The groundwater represents the second source for the fresh water. It is mainly originated in Upper Egypt from the local surface water bodies.

The sharp population growth leaded to increase in the water demands, which in turn leaded to the necessity to manage all the available water resources and to re-use the drained water. The quality factor is generally taken into consideration. Both the surface and the ground waters in Upper Egypt are used mainly for irrigation and drinking purposes. During the last few decades the surface water levels and fluctuations were generally controlled. On the other hand, the groundwater in Upper Egypt shows a slight increase in its level and a decrease in its fluctuation amplitudes.

The study area includes the low flat alluvial plain of the Nile Valley extending from latitude 26^{o} southwards till Aswan (Fig. 1). The surface water bedies in that area include the Nile River

and a complete net of irrigation canals and drains. Not to mention, the groundwater in the area is essentially related to the Quaternary aquifer.

The study of the hydraulic and hydrochemical relationships between the groundwater and the Nile system water in the area is based on the analysis of the data collected from the two water systems. The data include the periodical water level fluctuations at selected points. The second part of the data is concerned with the chemical composition of some collected surface water and groundwater samples. A quick reference is given later for the water quality evaluation taken into consideration the international standards required for the main water uses.

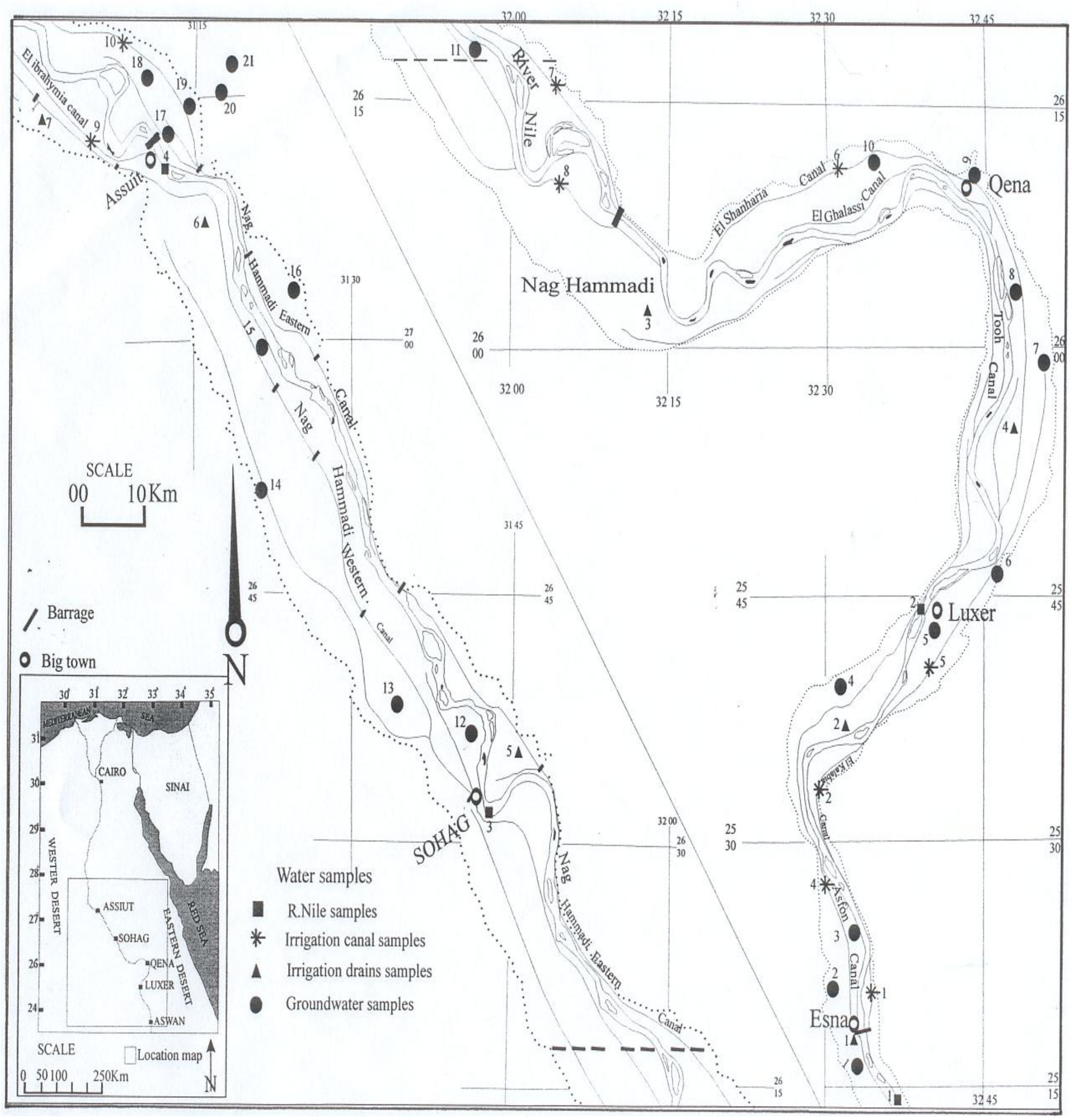


Fig. (1): Location map of the studied surface water streams and groundwater wells in Upper Egypt.

Physiography of the Area:

Upper Egypt is charchterized by arid climate. Aridity increases southwards. East and west the study area desert climatic conditions prevail. The air temperature ranges between 12.5 C^o and 35^0 C^o with annual average of 25^o C^o. The relative humidity ranges between 40% and 60%. The monthly evaporation rates were estimated between 10 cm and 95 cm with mean value of 39 cm/month. The evapotranspiration rate was estimated as 185 cm/year (Farrag, 1982). The rainfall is not significant throughout the year, nevertheless, some rare and irregular storms take place over scattered localities during the winter season.

Regarding the morphology of the area, five land features are recognized (Farrag, 1982). These are 1) The young alluvial plain of the Nile which is traversed by the River Nile. 2) The old alluvial plains of the Nile which comprise the terraces found at various heights on both the eastern and western sides of the Nile Valley. They were formed as a result of the aggradation and degradation of the Nile Valley relative to the change in the Mediterranean Sea level. 3) The calcareous structural plateau and its bounding slopes. The plateau is underlain by Eocene limestones. It lies on both sides of the Nile Valley with cliffs overlooking the flood plain at the northern part of the area. 4) The structural plains which occupy the southern portion of the area. They are essentially underlain by the Nubian Sandstone, and 5) The desert hydrographic basins which include the dry drainage lines directed into the Nile Basin and traversing the structural plains and the calcareous plateau.

Geology of the Area:

Geology plays an important role in determining the location and availability of the groundwater. Stratigraphy controls the groundwater situation and its connection and interaction with the surface water bodies. The location and characteristics of the aquifers depend mainly on the rock types. Moreover, the chemical composition of the water-bearing rocks or sediments affects the groundwater quality.

Egypt is a portion of the northward overlap on the Arabo-Nubian Massive. In the southeastern part of the country, the basement rocks are exposed and constitute a portion of the African craton. Rocks belonging to the Paleozoic are exposed in Lake Nasser area. The section is dominated by sand and shale facies of epicontinental origin deposited in a fresh water and/or near-shore environment. These rocks constitute a portion of the Nubian Sandstone.

During the Triassic Period Egypt has became a part of a continental plain, while, during the Early Jurassic marine transgression occurred.

The main Nubian Sandstone was deposited all over Egypt at Lower and Midde Cretaceous Period. This period was followed by a major marine transgression which extended southward as far as latitude 23^0, with subsequent deposition of the lower carbonate layers belonging to the Upper Cretaceous.

During the Paleocene and Eocene Periods thick deposits mainly calcareous rocks accumulated. They are composed of chalky shales, and followed by calcareous shales (Esna shale). These shaly layers separate the lower carbonate layers (Upper Cretaceous) from the upper carbonate layer (Eocene).

The Late Miocene was a period of uplift and folding, during which lagoonal sediments as well as continental sands and gravels were deposited. During this period a canyon was formed by the Nile (Eonile of Said, 1981).

During the Pliocene and Late Miocene uplifting continued. The sea transgressed along the Eonile Valley, leaving a series of moderately thick layers of clay, sandy clay and gravels.

The Pleistocene Period was characterized by a fluviatile phase, caused by succession of several pluvial phases. The sea finally retreated and intense erosion took place with subsequent formation of thick raised gravel terraces along the Nile Valley.

The Quaternary and Late Tertiary sand and gravel beds, which are intercalated with clay lenses form the Nile Valley aquifer in Upper Egypt. The aquifer is underlain by Pliocene clays, generally considered as the impervious base of the aquifer (aquiclude).

Surface Water and Groundwater Systems:

A brief account of the surface water and groundwater situation in the area is given here, after Farrag, 1982, Attia, 1985, Abu-Zeid, 1992, Abu-Zied and Hefny, 1992, Hefny and Shata, 1992 & 2004 and Idris, 2004.

A-The Surface Water System:

The surface water system in Upper Egypt includes the River Nile and the main and small irrigation canals and drains.

The River Nile flows northward more than 500 km with an average width of one kilometer. The discharged water volume through the river changes daily and seasonally. The water level fluctuations are limited and nearly constant after the construction of Aswan High Dam.

The discharged water in the river ranges between 50 and 250 million m^3/day (mm^3/day). It increases during summer periods and decreases during winter periods. The river water volume decreases northward due to the water taken for recharging the main irrigation canals. Several irrigation canals are present, the most known main canals in upper Egypt are Nag-Hammadi, Eastern and Western Canals and El-Ebrahymia Canal. The discharged water through these irrigation canals is seasonally fluctuated but it reaches its maximum during the summer. The water discharge in these main canals is nearly stopped during the winter closing period. The small irrigation canals are recharged from the main irrigation canals and their water levels fluctuate periodically each 40 days (Fig. 2).

B-The Groundwater System:

The Quaternary water-bearing sands and gravels represent the main groundwater aquifer in Upper Egypt. The aquifer has semi-confined condition at its central part, however, it is present in free condition at it's eastern and western boundries. The groundwater level decreases gently northwards, where it is in the range of + 85 m at Aswan and about +45 m at Assiut. The aquifer has a various thickness and width. It's thickness exceeds 300 m at Sohag and decreases north and southwards. The transmissibility of the water-bearing sediments ranges between 5000 and 20,000 m^2/day. The aquifer is underlain by the Pliocene impermeable clays and overlain by the silty clay layers which range from 3 to 20 m thick. At the eastern and western sides, the aquifer is bounded by Upper Cretaceous Nubian Sandstone at the south and by Eocene Limestone at the north.

The groundwater flows generally toward the north. Other local trends are found either from or toward the River Nile. Adjacent to the new reclaimed areas on both sides of the Nile Valley, the groundwater flows toward the old cultivated lands if the irrigation depends on the uplifted surface water. On the contrary, the groundwater flows toward the new reclaimed

areas if the irrigation depends on the groundwater only.

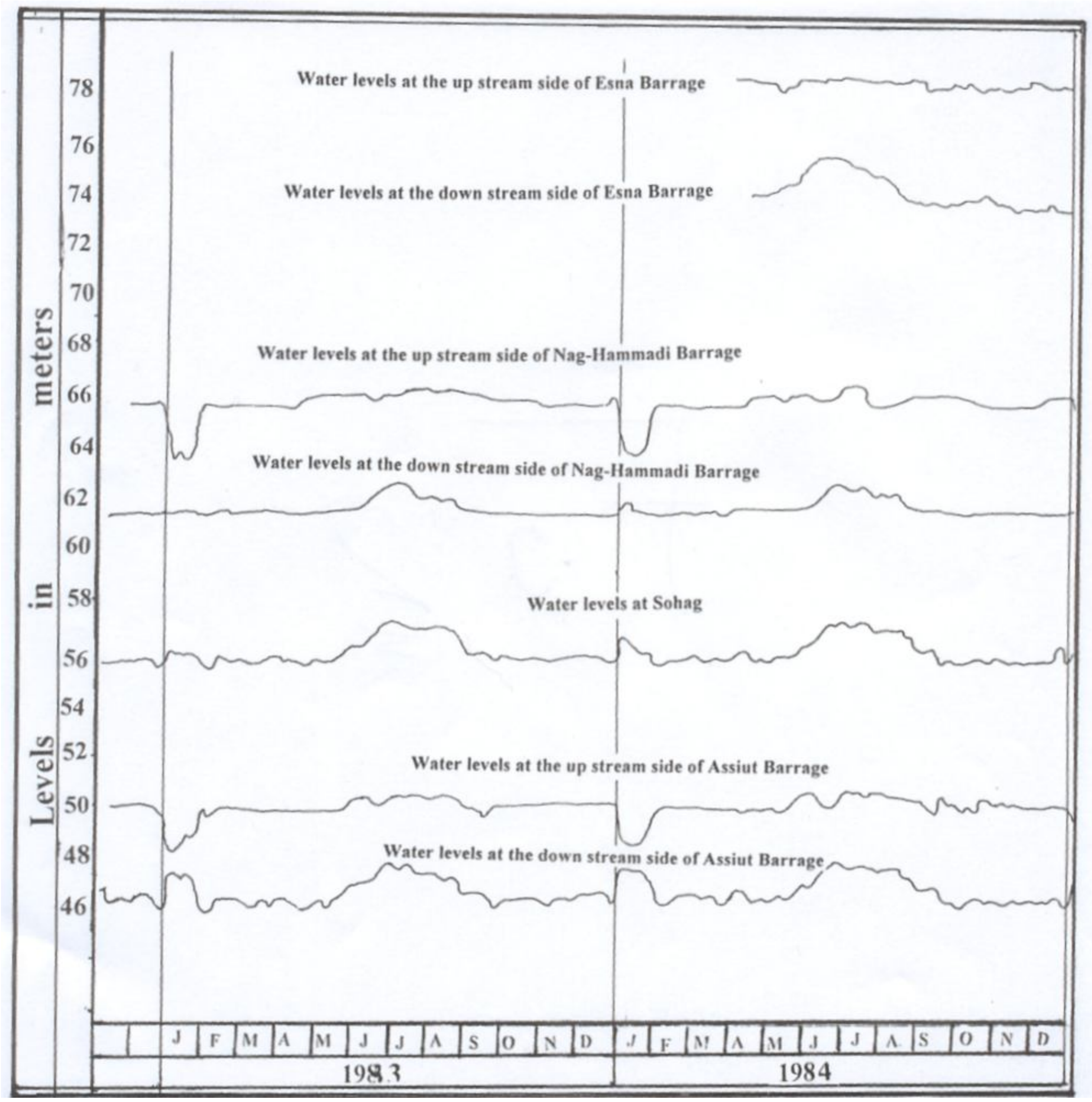


Fig. (2): Water level fluctuation of River Nile in Upper Egypt. (after Farrag,1992)

The Surface Water and Groundwater Relationship:

A- The Hydraulic Relationship:

The Nile flood plain slopes gently northwards and towards the river. The River Nile course represents the lowest part traversing Egypt from south to north. The local surface water represents the main recharging source of the groundwater. The main irrigation canals act as influent streams, except in some parts, where they act as effluent streams during the winter closed periods. The River Nile has a variable behaviour as it acts essentially as effluent stream. However, it acts as influent stream

close to the southern sides of the barrages traversing its course.

In Upper Egypt the annual surface water used for irrigation in Upper Egypt is more than 15 milliard cubic meter. The drained water to the River Nile includes the excess of the irrigated water in addition to the municipal and industrial drained water. These drained waters have a negative effect on the river water quality, especially at their outlets; but these bad effects decrease and in many cases disappear a few distance away from the river.

The annual groundwater recharge in Upper Egypt reaches 5.3 miliard cubic meter, while the groundwater losses to the river through the surface drains or by evaporation reach 2.1 miliard cubic meter. Consequently, the net annual groundwater recharge in the area is about 3.2 miliard cubic meter. Other recharge is comming from the rainy storms or floods through the adjacent wadies. The annual pumped water from the groundwater in Upper Egypt alone attains 1500 million cubic meters.

The drained water in the study area comes from an area of about one million feddan. The estimated drained water to the river from Aswan to Esna is about 3.4 mm^3/day, while from Esna to Nag-Hammadi it is about 1.01 mm^3/day. From Nag Hammadi to Assiut the drained water to the river is about 2.79 mm^3/day. The drained water to the River Nile in Upper Egypt is, therefore, about 7.2 mm3/day, i.e about 2.6 miliard cubic meter annually or about 15% of the total irrigation water.

The groundwater levels are continuously fluctuated with time. The fluctuation amplitudes of the groundwater levels in each well depends mainly on the distance separating the surface water sources from the groundwater wells (Fig. 3).

The hydraulic relationship between the groundwater and the surface water is locally variable. The correlation between the groundwater and the surface water levels in the area shows a remarkable variation in their fluctuation intensity. Generally, the groundwater in the area can be distinguished into three categories according to their hydraulic responses to the surface water bodies:

1-The first division represents the groundwater bodies situated close to the main irrigation canals. In this part, the groundwater levels are fluctuating similar to the water levels in these canals (Fig. 4 and well No. 8 & 11). It represents the dominant part of the groundwater in Upper Egypt. In most cases the excess of this groundwater discharges to the River Nile, where at the same latitude the water levels in the main irrigation canals are more higher than those in the River Nile.

2-The second division represents that part of the groundwater situated close to the upstream sides of the barrages constructed on the river course (wells 1, 4, 12 & 17 Fig. 3). In this division the groundwater level fluctuates with the water level in the river.

3-The third division of the groundwater fluctuates slightly but without clear relation with surface water bodies (well No. 4 & 14, Fig. 3). It seems to be present in semi-static state and is feeded mainly from the excess irrigation water. In many cases, this part of groundwater is present close to the eastern and western borders of the Nile Valley.

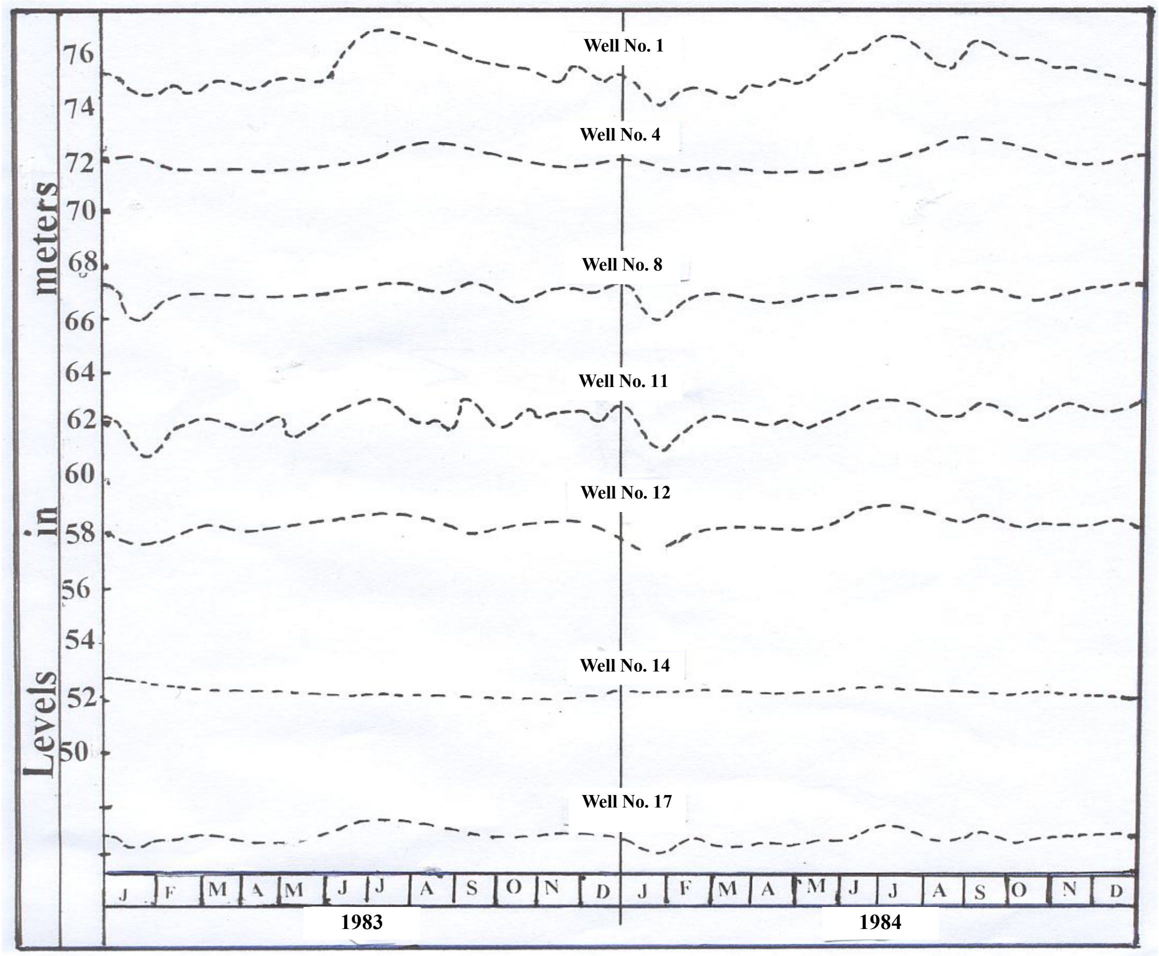


Fig. (3): Groundwater levels fluctuation in some groundwater wells in Upper Egypt.

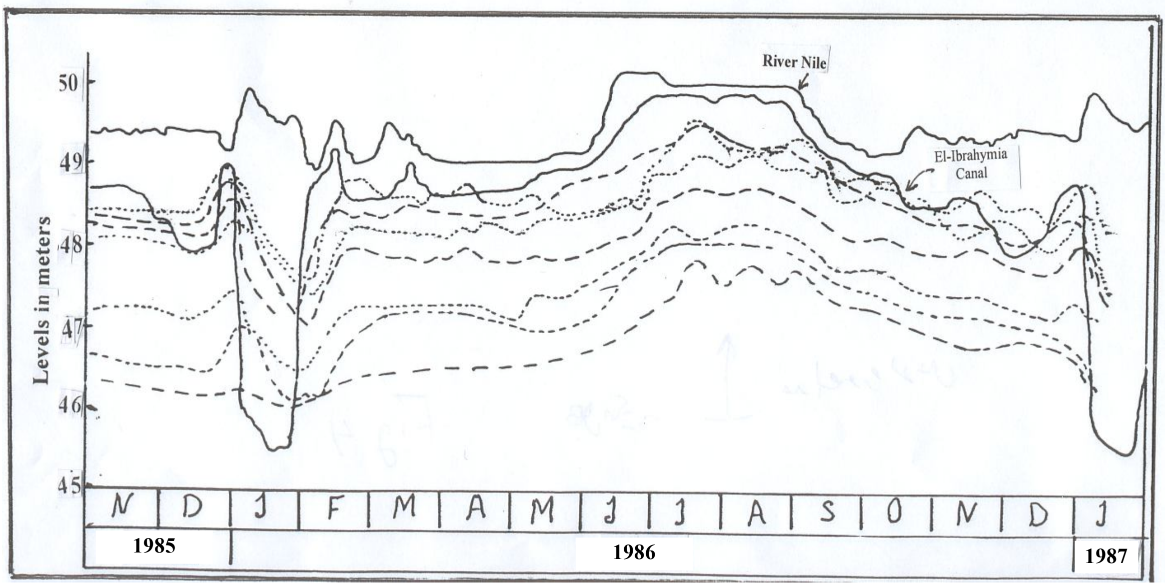


Fig. (4): The water fluctuation in the River Nile, El-Ebrahymia Canal and in some shallow wells at Assiut City.

B-The Surface and Groundwaters Composition:

Fortytwo water samples were collected and chemically analyzed in order to show their chemical characteristics and to calculate their quality indices. The analyzed samples comprise 4 from the River Nile, 10 from the main irrigation canals, 7 from the surface drains and 14 from the groundwater (Tables 1,2,3 and 4).

The chemical analysis shows clearly that the water type in the river and in the irrigation canals is mainly Na, Mg, calcium – bicarbonate. The magnesium and sulfate ions increase in some irrigation canals. In most of the drains the water type is Mg, Na, calcium –bicarbonate, while in some drains it is Na, Mg, calcium- Cl, HCO_3 sulfate.

In the groundwater, the water types differ according to the distance separating the wells from the surface water bodies. Close to the river and the main irrigation canals, the bicarbonate ratio increases, while chloride and sulfate ratios increase as the distance increases. The cations ratio depends on the soil and rock types and composition.

A comparative view to the chemical data shows that both the total salinities and ionic contents differ according to the sample sources and locations; the ions concentration in the water differs slightly through the river course and in the individual canals. On the other hand, a considerable variation in the individual ionic concentration is present in the drains and groundwater samples. Both SO_4^{-2} and Cl^- concentrations in the drains are more than those in the river and canals waters. This is mainly due to the fertilizers and contamination.

In Schoeller and Piper diagrams (Fig. 5a&b) the samples representing the chemical composition means of the studies water sources are situated closed to each other with gradual variation. The drains representing sample (2=DW) is located between the representative surface water samples of the river (4=RW) and the canals (1=CW) and the groundwater representing sample (3=GW).

It is noticed that the fine grained sediments play a considerable role in the groundwater and drained water composition where Na^+ ions concentrations are higher than that in the river and canals water. On the other hand, Ca^{++} and Mg^{++} ions decrease due to the ionic exchange.

C-The Water Quality Index:

The water quality index (Tiwari and Manzoor, 1987 and Saha *et al.*, 1991) is expressed as

$$q_i = 100\ V_i/S_i \quad \text{where,}$$

q_i = the quality rating for the ith parameter.

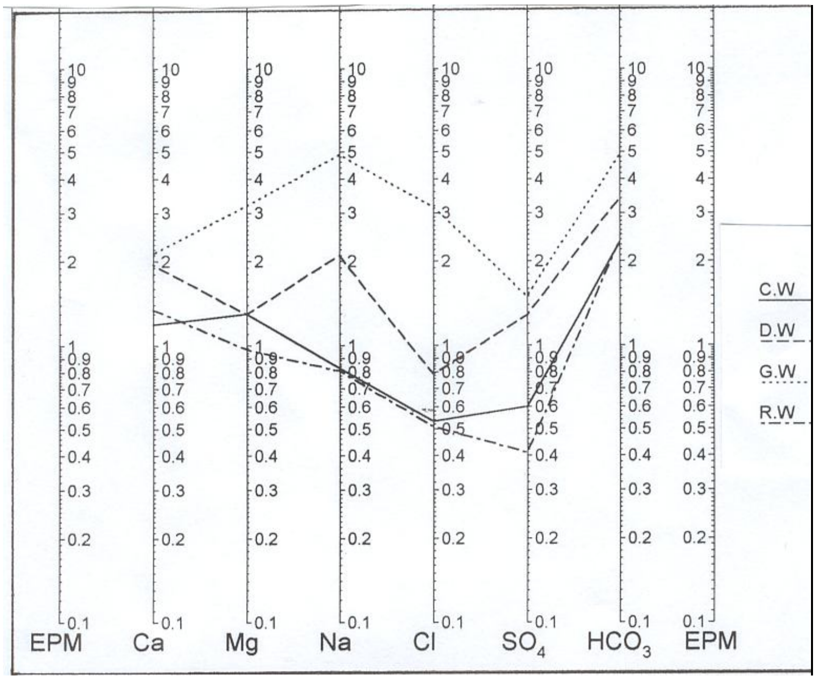
V_i = the observed value of the ith parameter.

S_i = water quality standard.

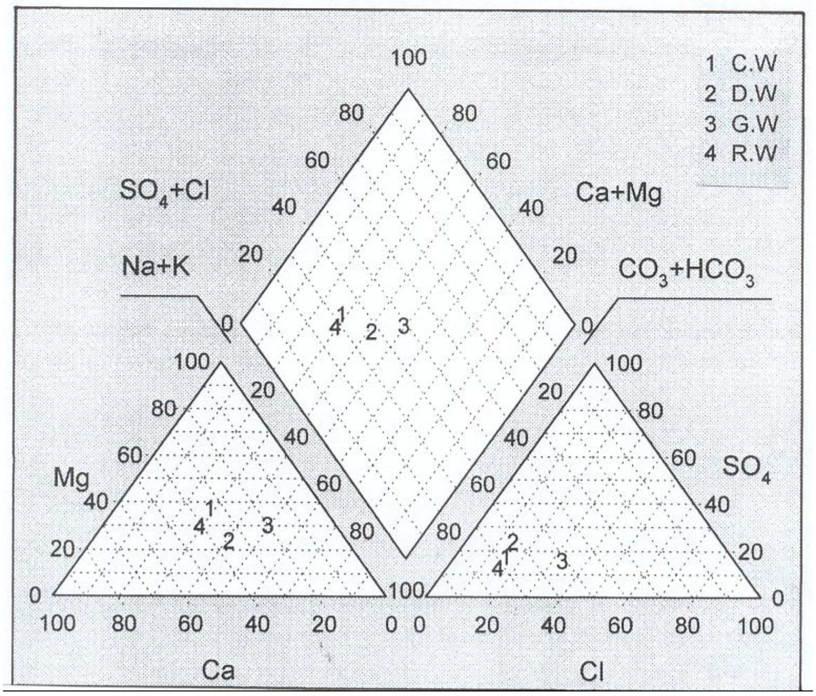
The average water quality index "Q" for the studied parameters is

$$Q = \frac{\sum_{i=1}^{n} q_i}{n}$$

For drinking purposes 6 parameters were considered (n=6) which are; TDS (total dissolved solids), Ca^{++}, Mg^{++}, SO_4^{-2}, Cl^- and TH (total hardness) values. For irrigation purposes 5 parameters were considered (n=5) which are: TDS, Na^+, HCO_3^-, Cl^- and SAR (sodium adsorption ratio) values. The World Health Organization (WHO) standards (1984) for drinking water were considered, while for irrigation purposes Ayers guide lines (1975) were applied.



(A)



(B)

Fig. (5): Plotting of mean chemical composition of the studied water in Scholler Diagram (a) and Piper Diagram (b).

1(CW): Irrigation canal sample **2(DW) : Irrigation drains sample**
3(GW) : Groundwater sample **4(RW): R. Nile Sample**

When the mean quality index value reaches 100, it means that the analyzed water sample is saturated regarding the measured parameters, compared with their standards for a certain use. If the resultant mean quality index is less than 100 it means that the examined water is of good quality. On the other hand, if the mean quality index is more than 100, it means that the water is over-saturated or polluted.

The calculated quality index values in addition to the chemical analysis results are presented in Tables 1 to 4. The individual examination of the cations and anions contents show an increase in HCO^-_3 content in the Nile and in the irrigation canals than its standard values required for drinking purposes. In the drains water an increase in TDS and HCO_3^- values is observed.

The quality indices of the water in the Nile and in the irrigation canals, show that they can be used safely for irrigation and drinking purposes. For the drains water, the quality indices show that they have higher content of the studied parameters than their standard values required for using in drinking and irrigation purposes. However, most of the groundwater samples have quality indices more than 100 specially for irrigation purpose. For drinking purposes, some groundwater wells can be used safely.

CONCLUSIONS:

The present study reveals the following;

1- The groundwater levels and compositions in Upper Egypt are highly related with the surface water in the River Nile and its system.

2- The hydraulic and the chemical impacts of the River Nile system on the groundwater decreases as the distance separating them increases.

3-The water quality in the Nile River and in most of the main irrigation canals in addition to some drains is good and can be accepted for drinking and irrigation purposes regarding the concentrations of their main ionic contents.

4-The huge fresh water discharged daily through the River Nile and the main canals and the capability of Nile silts and clays to adsorb the pollutant components conserve the river water quality in good and/or acceptable level.

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التأثيرات الهيدروليكية والهيدروكيميائية لنظام النيل على المياه الجوفية بمصر العليا

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تشتمل منظومة النيل بمصر العليا على مجرى نهر النيل وما يرتبط به من قنوات رى وصرف رئيسية وفرعية، ويمثل خزان صخور العصر الرباعى أهم خزانات المياه الجوفية بالمنطقة.

وخلال العقود الأربعة الأخيرة وبعد إنشاء السد العالى أصبحت مناسيب المياه بنهر النيل محكومة وتتغير تغيراً موسمياً طفيفاً، بينما فى الترع الرئيسية تتذبذب مستويات المياه دورياً وتظل أعلى من مستوى المياه فى النيل فى نفس المنطقة وتتباين تذبذبات مناسيب المياه الجوفية من موقع لآخر.

وبمقارنةتذبذبات مناسيب المياه السطحية والجوفية فى المنطقة تبين وجود ارتباط قوى بين النطاقين، وا ِن ظل لقنوات الرى الرئيسية الدور الأكبر المؤثر على المياه الجوفية بالمنطقة.

ومن دراسة التركيب الكيميائى لعينات من المياه السطحية والجوفية بالمنطقة تبين وجود تدرج فى تركيز مكونات المياه بنهر النيل والترع والمصارف والمياه الجوفية، وبحساب معامل الجودة اتضح صلاحية مياه النيل والترع وبعض المصارف الرئيسية للاستخدام فى الرى والشرب، إلا أن المياه الجوفية فى كثير من الآبار تحتوى على تركيز لبعض العناصر أعلى من المسموح به عالمياً لأغراض الرى والشرب .