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GROUNDWATER PROTECTION IN THE NILE DELTA

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الملخص العربى:

تعتبر المياه الجوفية من أهم مصادر المياه خاصة في المناطق القاحلة وشبه القاحلة، وتعد المياه الجوفية في مصر مصدرا هاما للمياه في الصحراء وفي دلتا ووادي النيل، وتستخدم لأغراض عديدة منها الشرب والاستخدامات المنزلية والري؛ لذا من المهم حماية هذا المصدر من التدهور من حيث الكمية والنوعية، يهدف هذا البحث إلى شرح كيفية حماية نوعية المياه الجوفية في دلتا النيل من التلوث وبالتحديد في الجزء الأوسط الجنوبي بمركز أشمون بمحافظة المنوفية.

تم تقييم نوعية المياه الجوفية الضحلة والعميقة عن طريق قياس الأس الهيدروجيني، التوصيلية الكهربية ، الأملاح الكلية الذائبة ، الكاتيونات القابلة للذوبان ، الأنيونات القابلة للذوبان ، المعادن الثقيلة والبكتيريا وذلك عن طريق أخذ عينات مياه جوفية من آبار سطحية وعميقة طبقا لمعايير ضبط الجودة وتم تحليل هذه العينات بمقر المعامل المركزية التابعه للمركز القومي لبحوث المياه. كما اوضحت النتائج ملائمة المياه الجوفية الضحلة والعميقة للري، كما أظهرت أيضا تواجد المنجنيز والحديد بنسب كبيرة في المياه الجوفية الضحلة والعميقة، ومن ثم تم اختيار بئر بعمق (110 متر) لغرض الشرب، وكانت نوعية المياه به مطابقة لمحددات منظمة الصحة العالمية لاستخدامات مياه الشرب.

ولحماية نوعية المياه بهذا البئر ، تم استخدام النماذج الرياضية العددية عن طريق برنامج الحاسوب (Visual MODFLOW Pro.V.4.6) لتحديد منطقة الحماية مع الأخذ في الإعتبار أن التصرف المسموح به هو 125 لتر/ ثانية، وأظهرت النتائج أن استخدام مياه هذا البئر لمدة عشرة اعوام بنفس التصرف مع الأخذ في الاعتبار أنيون الكلوريد كمثال لاستقبال الملوثات فإن الحرم الآمن لنطاق البئر يقع في دائرة نصف قطرها 33 متر.

Abstract:

Groundwater is considered one of the essential sources, particularly in arid and semi - arid areas. Groundwater is an inherent water source in the desert and Nile delta and valley used for drinking, domestic uses, and irrigation, so it is vital to protect this source from the point of quantity and quality from deterioration. This study aims to protect the Nile delta's groundwater quality from pollution in the Ashmon district at Menofia governorate.

Fourteen groundwater samples from shallow hand pumps and deep production wells were collected and analyzed for the following:

- LOG H **(pH)**, Electrical Conductivity **(EC)**, Total Dissolved Salts **(TDS)**, soluble Cations and soluble Anions.
- Heavy Metals such as Iron **(Fe)**, Manganese **(Mn)**, Cupper **(Cu)**, Cadmium **(Cd)**, Lead **(Pb)** and Zinc **(Zn)**.
- Total coliform and fecal coliform.

Two surface water samples were collected from the irrigation canal and surface drain and analyzed for the former parameters. The data clear that the quality of the shallow and deep groundwater is available for irrigation. The heavy metals, mainly Fe and Mn, violated the permissible limits of World Health Organization **(WHO)** except the water. The well SDW, which is depth 110 m. The Numerical model **(MT3D)** was calibrated and run for one scenario considering the discharge of the well 125 L/sec, chloride represents the pollutants, and the prediction time of pollutant transport is 50 years. The results of the models precise that the pollutant will not transport to circle its diameter is meters, which is considered the safeguard zone 33 m for the studied well.

Keywords: Groundwater protection, Water Quality, Visual MODFLOW, Numerical Models.

Introduction:

Water scarcity is considered the main challenge for many countries all over the world, the balance between the development requirements and the wise management of water resources now has considerable attention from scientists and researchers [1].

The largest available source of freshwater lies below the surface of the earth. Groundwater is a crucial source of water supply, especially in arid and semi-arid areas. In such regions, assessment of groundwater recharge for renewable aquifers is one of the critical challenges in determining the aquifers sustainability [2].

The Nile delta aquifer is a vast renewable groundwater reservoir. It is, hydro geologically, of great interest for the economic development of Egypt as the Nile delta aquifer is one of the most critical renewable groundwater reservoirs in Egypt. The Nile water is no longer sufficient for the rising water conditions for the various growing projects in Egypt [3].

Therefore, groundwater plays an inherent function in the economy of Egypt because of its significance for the domestic, agricultural, and industrial water supply. Nevertheless, many wariness and disturbances are frequently being voiced on the hazards that enclose groundwater supplies. The principal components of these upsets are related to consumption due to over-abstraction and quality degeneration brought by numerous forms of pollution from point and non-point sources such as agriculture, industries, and domestic wastes [4].

Groundwater in Egypt is a strategic and significant water source; most rural population activities are primarily dependent on untreated shallow groundwater from hand pumps as a source of drinking and other domestic aims and for irrigation from groundwater wells. Groundwater, meanwhile, suffers from contamination in rural areas such as private septic tanks, field drains, animal feedlots, leakage from treatment lagoons, and municipal sewage systems are contaminated in these areas. Water quality is connected to changes in physical, chemical, and microbiological factors and changes in the concentrations of many components. These sources of contamination predominantly include suspended solids, nutrients, heavy metals, organic matter, and bacteria carried by microorganisms leads to a decline in the quality of groundwater such that it does not become sufficient for the operation of irrigation and other human activities [5].

The present research aims to review the Nile delta's groundwater status and evaluate the influence of possible contamination sources on groundwater quality in the study area to protect the groundwater quality.

2. Hydrogeological conditions and physical setting of the study area:

This part represents hydrogeological conditions and the physical setting like Location, Topography, Land Use, Geology and Hydrogeology , and detailed them as follows:-

2.1. Location:

Study area located in the south delta between latitudes 30 11' 38" and 30 25' 43" N and between longitudes 30 48' 34" and 31 8' 12" E with a total area approximately about 800 km2. it belongs to the Menofia governorate. Figure (1) shows the location map of the study area.

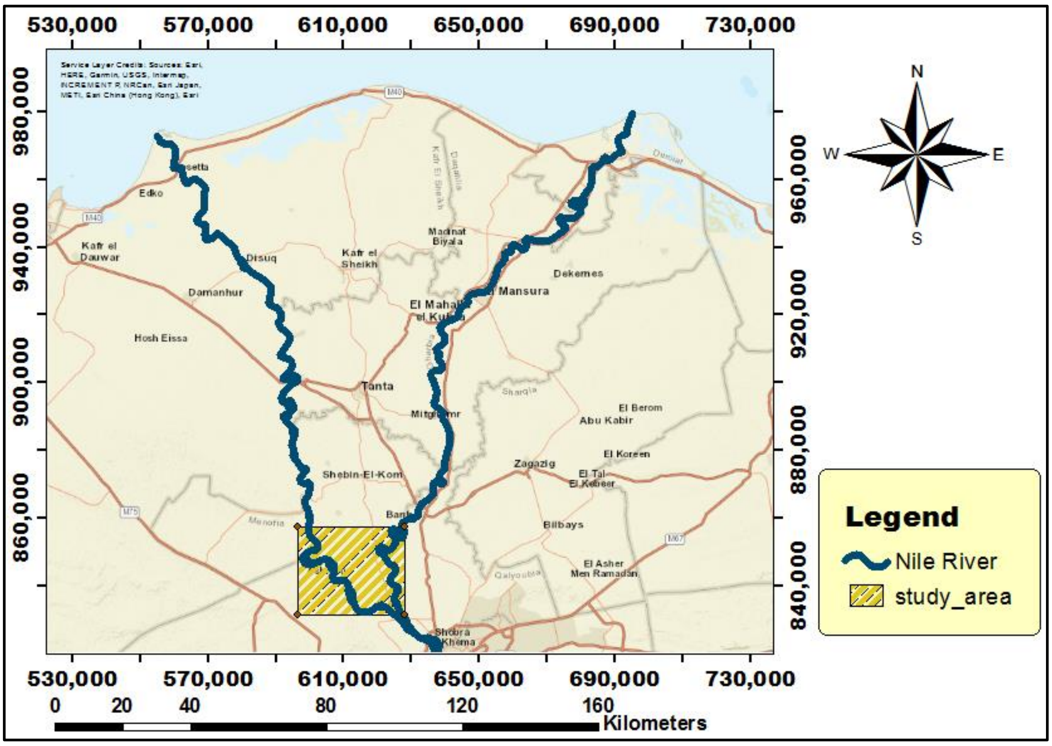

Figure 1: Location map of the study area.

2.2. Topography:

The ground elevation of the study area is almost flat. its ranges between 15m to 20m in all areas except southwestern area reaches to 80m above mean sea level based on data from two topographical map produced by (EGSA,1998) of scale (1:50000); Cairo West sheet (NH36-13a) and Cairo East sheet (NH36-13b) as shown in figure (2)[6].

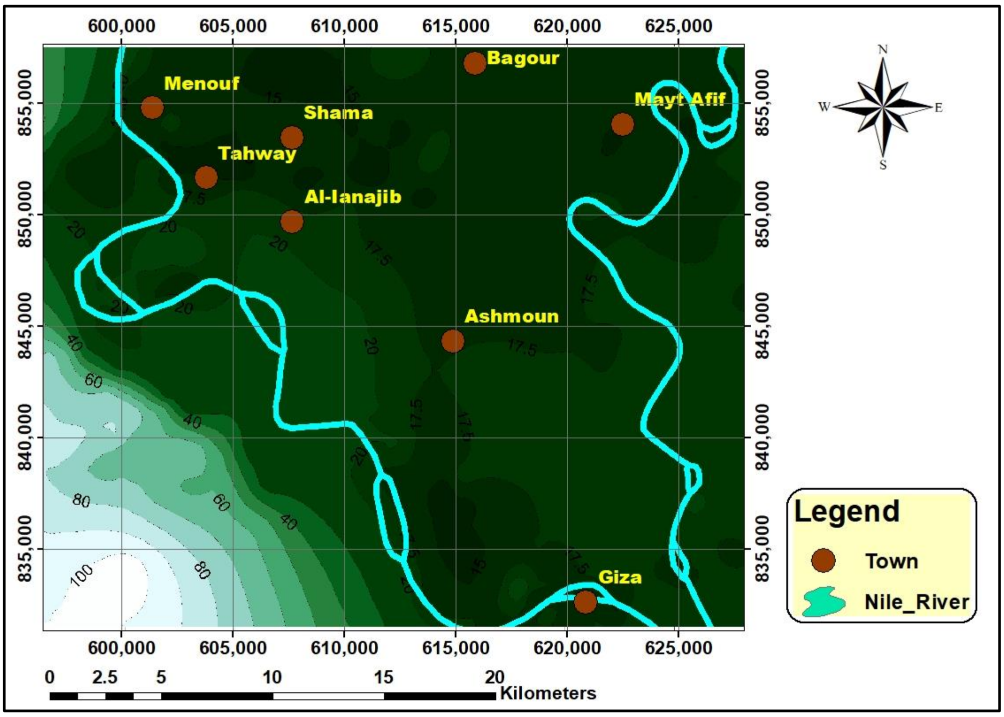

Figure 2: Topographical map of the study area.

2.3. Land Use:

Agricultural area is settled in the center and west of the area, while the residential areas concentrates on the edges of River Nile. The residential area is commonly sub-served with a piped sewerage system while the dispersed agricultural areas and some unplanned settlements are unless unserved or served with limited channels or septic tanks, and contaminated water infiltrates cause pollution in the aquifer [7] as shown in Figure (3).

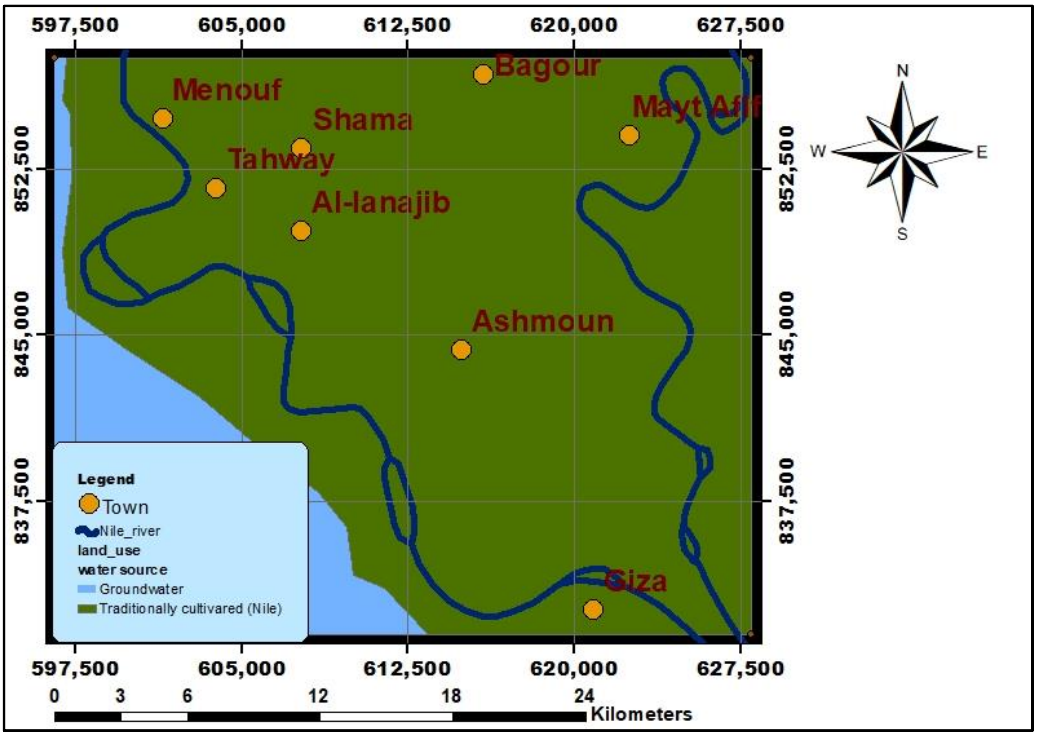

Figure 3: Land use of study area

2.4. Geology and Hydrogeology:

The water resources involve both surface water represented in the Nile river and groundwater eliminated from the quaternary aquifer, divided into two hydrogeological layers; the uppermost part is the Holocene, and the below one is the Pleistocene aquifer. A layer of silty clay covers the aquifer acts as a semi-pervious layer (aquitard) of thickness ranges between 10 m to 20 m, and it increases more than 20m in the center of the study area. However, the thickness of the aquifer reaches 200 m [8] as shown in Figure (4).

The surface water system in the study area has comprised a set of canals (el-rayyah el-menofy, el-rayyah el-behary, canal, and el bassiya canal) and drains as (sable el kebli drain). Surface water systems are led into significant community frequencies and initiated manufacturing regions. Untreated fluid wastes and effluents are instantly discharged into channels, drains, and on the land surface. Because of the medium thickness of the clay cap, contaminated water infiltrates and maybe cause pollution of the Pleistocene aquifer as shown in Figure (5).

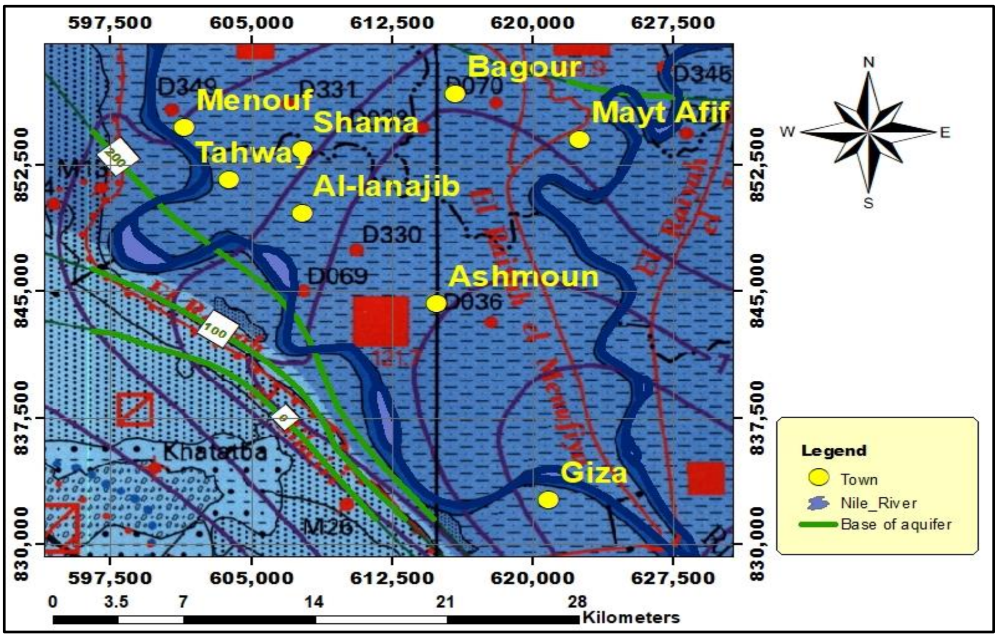

Figure 4: Aquifer base of the study area

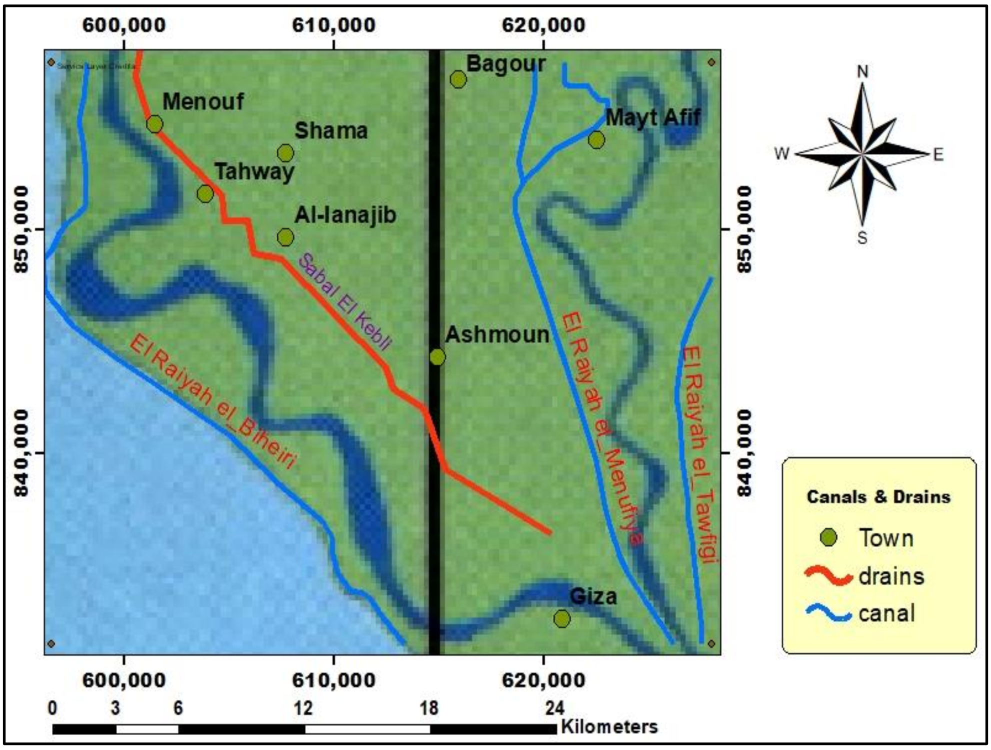

Figure 5: Canals and Drains in the study area

3. Water sampling in the study area:

To evaluated groundwater quality, fourteen water samples were collected from different locations in the Ashmoun district. Figure (6) and Table (1) presents coordinates of the studied wells and their depths. These samples were analyzed for different chemical, physical and microbiological parameters in the Central Laboratory for Environmental Quality Monitoring (CLEQM) at the National Water Research Center in Egypt, including the following:

- pH, EC, TDS soluble Cations and soluble Anions.
- Heavy Metals such as Fe, Mn, Cu, Cd, Pb and Zn.
- Total coliform and Fecal Coliform.

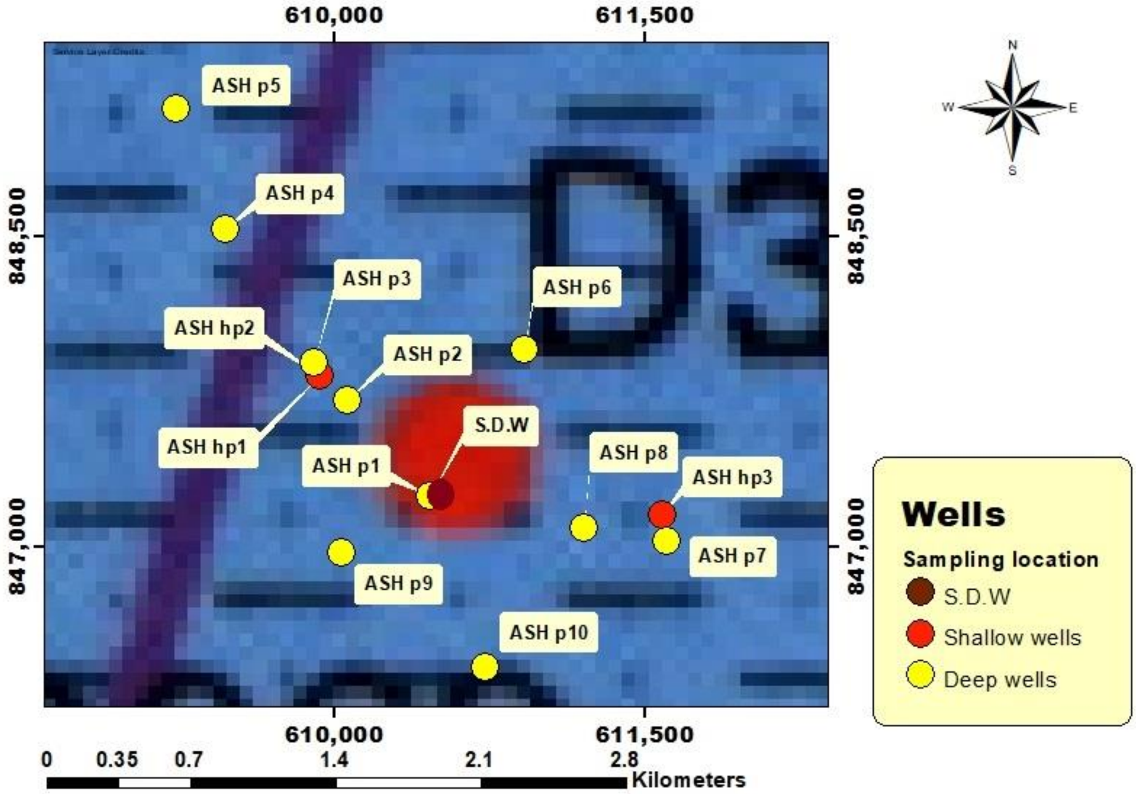

Figure 6: Water sampling locations in the study area

Table 1: Groundwater wells and hand pumps locations in Ashmoun district

Well name	East	North	Depth of well	
ASH hp1	30° 56' 56"	30° 20' 29"	15	Shallow Groundwater wells
ASH hp2	30° 56' 56"	30° 20' 29"	15	
ASH hp3	30° 57' 58"	30° 20' 07"	15	
S.D.W	30° 57' 16"	30° 20' 10"	110	Studied well
ASH p1	30° 57' 16"	30° 20' 10"	70	Deep Groundwater wells
ASH p2	30° 57' 01"	30° 20' 25"	70	
ASH p3	30° 56' 55"	30° 20' 31"	70	
ASH p4	30° 56' 39"	30° 20' 52"	70	
ASH p5	30° 56' 30"	30° 21' 11"	70	
ASH p6	30° 57' 33"	30° 20' 33"	70	
ASH p7	30° 57' 59"	30° 20' 03"	70	
ASH p8	30° 57' 44"	30° 20' 05"	70	
ASH p9	30° 57' 00"	30° 20' 01"	60	
ASH p10	30◦ 57' 26"	30◦ 19' 43"	55	

4. Numerical modeling of the flow system:

A numerical model was generated to simulate the flow system in the study area. The groundwater flow modelling is carried out to understand the flow system and then support the environmental hazard for the water accumulation from wells correlated to possible pollution origins identified in the study area. The better understanding gained from numerical modelling will form the basis for recommendations that would enhance the environmental control of the study area [9].

4.1. Modeling methodology:

The used methodology for the numerical simulations of the groundwater movement can be summarized as follows as shown in figure (7): select a suitable simulator (numerical model MODFLOW 2000), construct a conceptual design of the flow mode, simulate the numerical design (surface layers, hydrogeological parameters, and boundary conditions), perform a pre-calibration and check if the pre-calibrated model parameters allow the best calibration to get final calibrated model. Finally, define the groundwater flow patterns in three dimensions, estimate a mass balance and apply a quality model.

Figure 7: Modeling methodology

4.2. Conceptual model and input data:

The groundwater aquifer system of the study area was studied based on the geology and the hydrogeology of the study area to build the conceptual model. the geological and hydrogeological settings and inherent pollution origins of the conceptual model present the primary aquifer system in the Menofia locality as shown below.

Geological context: the topography of the study area is almost flat, with elevation varies between 15m to 20m over most parts of it. the upper layer of the aquifer is the clay cap aquitard layer with an average thickness evolution between 5m to 20 m, and it increases more than 20m in the center of the study area and vanishing towards the eastern area. the principal aquifer is quaternary, represented as a sandy gravel aquifer with an average thickness of 200m.

Hydrogeological context: the aquifer system is recharged essentially by the Nile river, excess water infiltration, and main canals. Groundwater piezo meter head varies between 5m as a minimum level in the northern and 12m as a maximum level.

4.3. Model layers, grid and boundary conditions:

The study area, which the Numerical model will represent, was determined in the village of Samadun, Ashmoun District, Menofia governorate, in the middle of the delta region, between latitudes 845200 m to 849600 m in the north, and between longitudes 608500 m to 611850 m in the east. it covers an area of about 14 km^2. The study area model dimensions are 3.3 km in x-direction and 4.4 km in y-direction; columns and rows are 55 and 98, respectively, also the hydrological boundary of the groundwater flow model is shown in Figure (8).

Boundary conditions are Numerical statements specifying the head or fluxes of the problem domain. As per the model boundary conditions, the northern and southern assigned as "constant head", the western and eastern boundaries represented as a "No flow" (perpendicular to flow lines), in addition to main canals and drains (El-Neania canal, Sabal and Abu Aoualy drain).

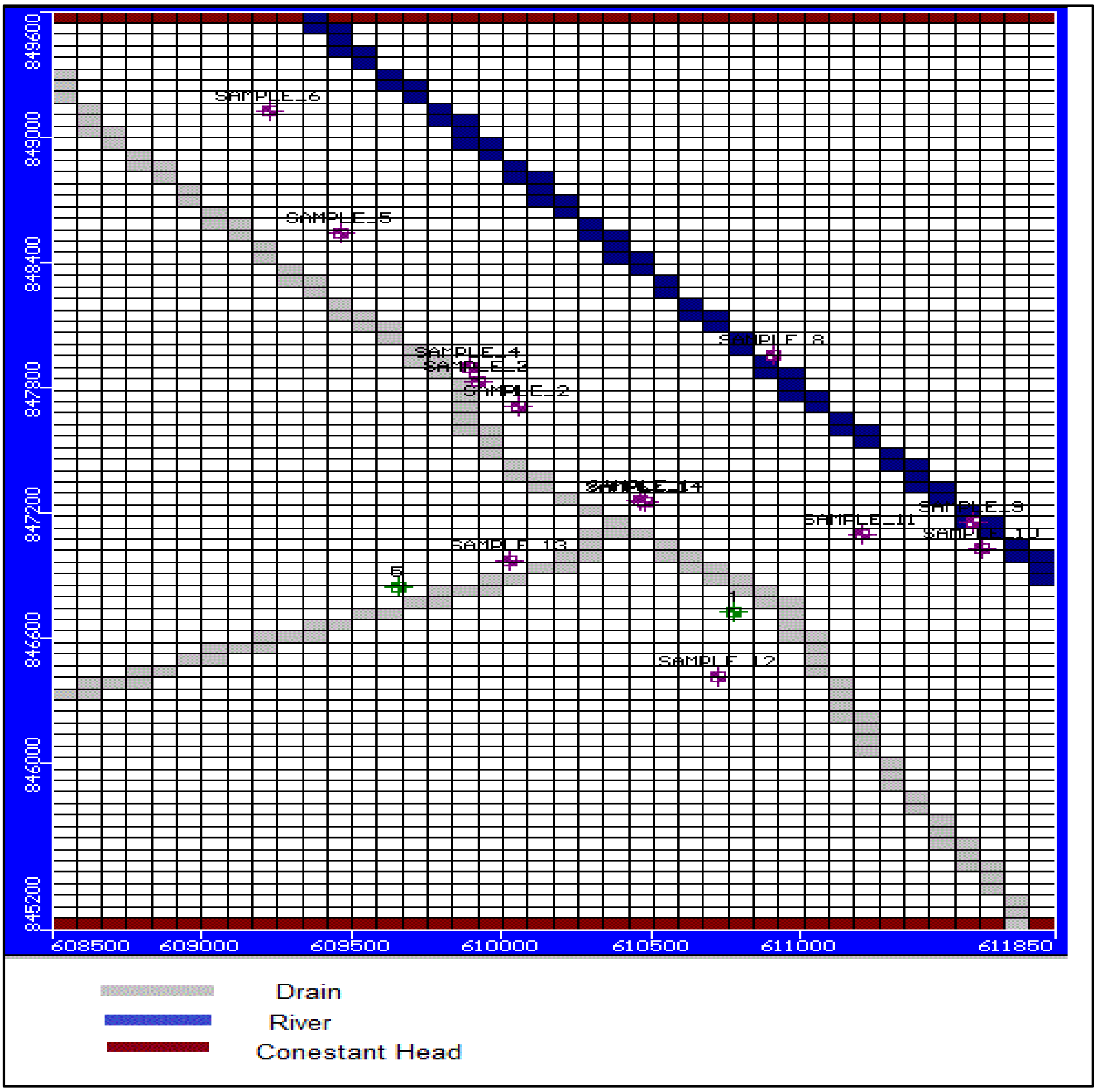

Figure 8: Boundary conditions of study area model

5. Results and discussion:

5.1. Samples analysis and standards:

Groundwater samples were obtained from near-surface and profound groundwater wells, these samples were examined for different chemical, physical and microbiological parameters in the central laboratory for environmental quality monitoring (CLEQM) at the national water research Centre in Egypt, including the following:

Determination of the electrical conductivity in mm hos/cm and the pH values, cations and anions, and acidified samples for the analyses of the trace metals.

All these parameters concentration values were compared with **(WHO)** standards and the Food and Agriculture Organization of the United Nations **(FAO)** limits to recognize pollution sources and classify water type and its ability for different human uses [10-11].

The results of the water samples analysis collected are presented as following. Table (2) shows the concentration of different deep groundwater samples and the shallow groundwater samples, Table (3) **(WHO)** limits for drinking water and Figures from (9) to (14) show the concentration of certain parameters and its limit according to **(WHO)** standards limit.

Table (2): Groundwater quality at Ashmoun district

	ASH hp1	ASH hp2	ASH hp3	ASH P1	ASH P2	ASH P3	ASH P4	ASH P5	ASH P6	ASH P7	ASH P8	ASH P9	ASH P10	SDW
pH	7.95	7.98	7.71	7.46	7.75	7.81	7.58	7.85	7.8	7.33	7.74	7.66	7.4	7.22
EC mmhos/cm	2.49	0.967	0.84	1.044	1.43	2.12	1.966	1.701	0.545	1.119	1.146	1.622	1.654	0.978
TDS ppm	1600	619	538	668	918	1355	1262	1089	349	717	733	1038	1063	626
Na ppm	215	59	54	80	120	210	104	145	22	65	80	115	130	82
K ppm	6	5	4	7	14	13	8	9	5	10	11	9	13	5
Ca ppm	204.16	57.05	55.97	84.36	120.18	159.12	191.04	139.97	37.64	84.21	84.21	131.52	131.49	72.29
Mg ppm	63.18	59	21.89	27.49	32.63	42.92	61.57	145	12.25	25.85	26.32	50.6	38.1	45.54
HCO_3 ppm	309.2	253.1	253.3	261.1	239.9	255.8	408.7	289	157.9	305	306.7	338	334	177
SO_4 ppm	48.2	42.3	42.9	116	243	365	349	314	21.7	78.4	116.9	250	247	133
Cl ppm	316	67	57.9	106.2	170	305	159	175	23	72.7	78.8	166	164	101
NO_3 ppm	9.8	1.44	3.4	209	2.2	4.9	6.5	5.2	3.6	15.7	2.6	5.8	2.9	0.2
PO_4 ppm	0.2	0.2	0.2	0.7	0.5	1.9	5.1	4.2	0.2	0.2	2.5	4	4.5	0.2
Fe ppm	0.068	0.149	0.056	0.381	0.319	0.114	0.348	0.505	0.196	0.063	0.192	0.157	0.245	0.002
Mn ppm	3.306	1.78	1.712	1.888	2.509	3.319	3.319	3.25	3.129	0.111	1.103	2.457	2.979	0.106
Cd ppm	0.001	0.001	0.01	0.001	0.001	0.003	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Cu ppm	0.069	0.066	0.056	0.068	0.064	0.062	0.059	0.058	0.062	0.062	0.061	0.074	0.061	0.011
Pb ppm	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.062	0.063	0.192	0.003	0.003	0.001
Zn ppm	0.013	0.041	0.001	0.007	0.008	0.006	0.101	0.008	0.122	0.003	0.036	0.032	0.103	0.001
Total coliform	0	32	$53*10^2$	4	0	98	35	74	$170*10^2$	21	27	76	$14*10^2$	0
Fecal coliform	0	0	$13*10^2$	0	0	55	0	0	$61*10^2$	0	1	11	$4*10^2$	0

Table (3): Inorganic constituents for drinking water quality (WHO)

Characteristic	Health-based guideline
Antimony (mg/l)	0.005
Arsenic (mg/l)	0.01
Barium (mg/l)	0.7
Boron (mg/l)	0.3
Cadmium (mg/l)	0.003
Chromium (mg/l)	0.05
Copper (mg/l)	2
Cyanide (mg/l)	0.07
Fluoride (mg/l)	1.5
Lead (mg/l)	0.01
Manganese (mg/l)	0.5
Mercury (mg/l)	0.001
Molybdenum (mg/l)	0.07
Nickel (mg/l)	0.02
Nitrate (mg/l as NO_3)	50
Nitrite (mg/l as NO_2)	3
Selenium (mg/l)	0.01
Uranium (µg/l)	140
Consumer acceptability level	
Aluminium (mg/l)	0.2
Chloride (mg/l)	250
Hardness as $CaCO_3$ (mg/l)	500
Hydrogen Sulphide (mg/l)	0.05
Iron (mg/l)	0.3
Manganese (mg/l)	0.1
pH	6.5 - 9.5
Sodium (mg/l)	200
Sulphate (mg/l)	250
Total dissolved solids (mg/l)	1200
Zinc (mg/l)	4

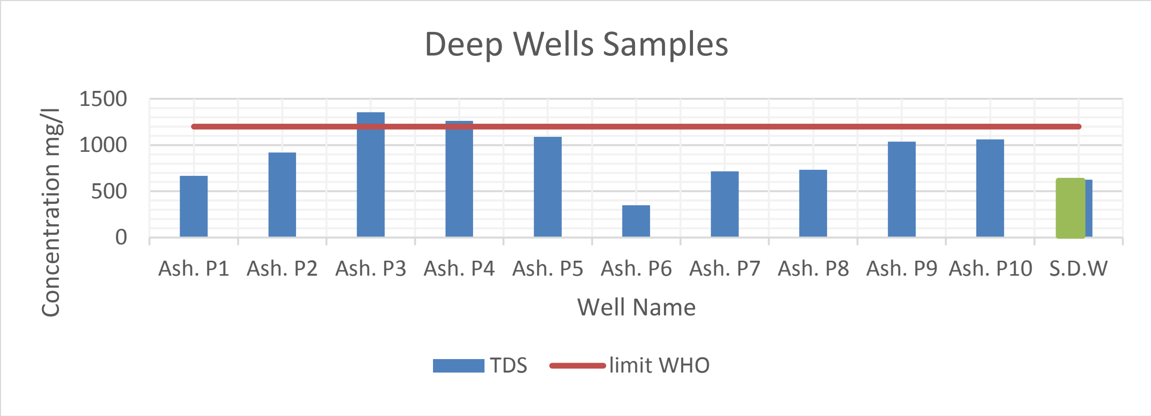

Figure 9: TDS concentration for deep wells and its limit according to (WHO)

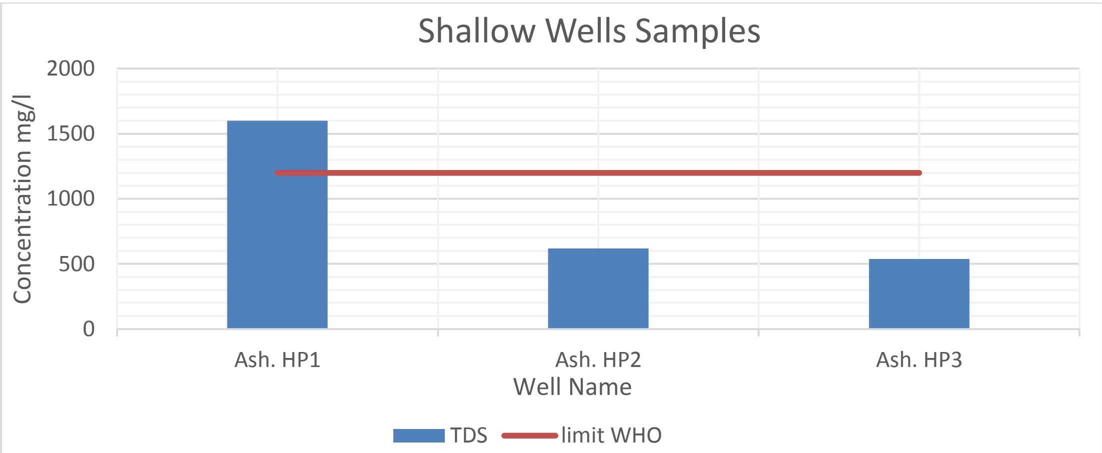

Figure 10: TDS concentration of shallow wells and its limit according to (WHO)

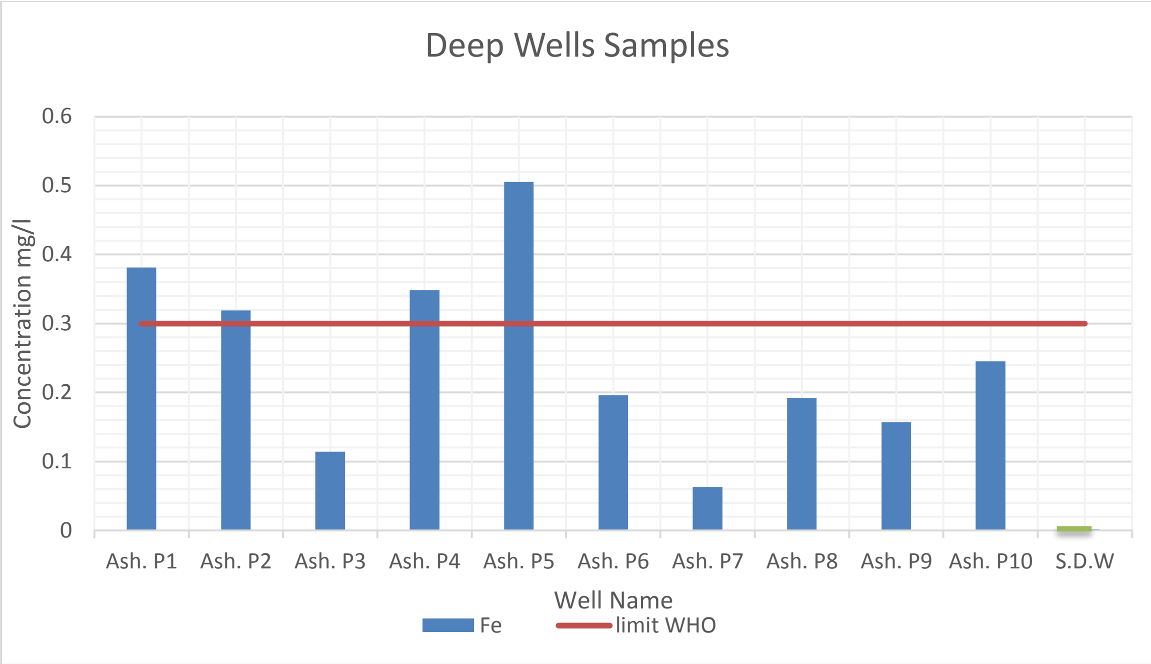

Figure 11: Fe concentration of deep wells and its limit according to (WHO)

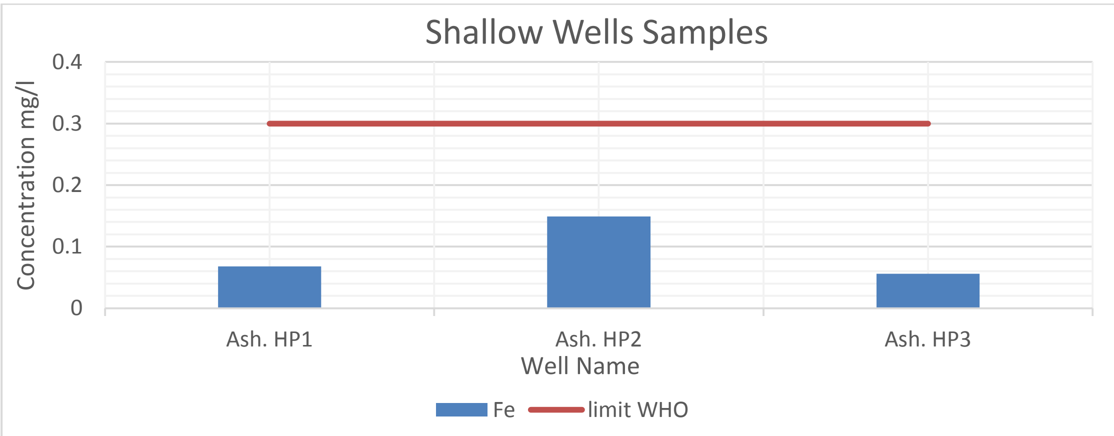

Figure 12: Fe concentration of shallow wells and its limit according to WHO

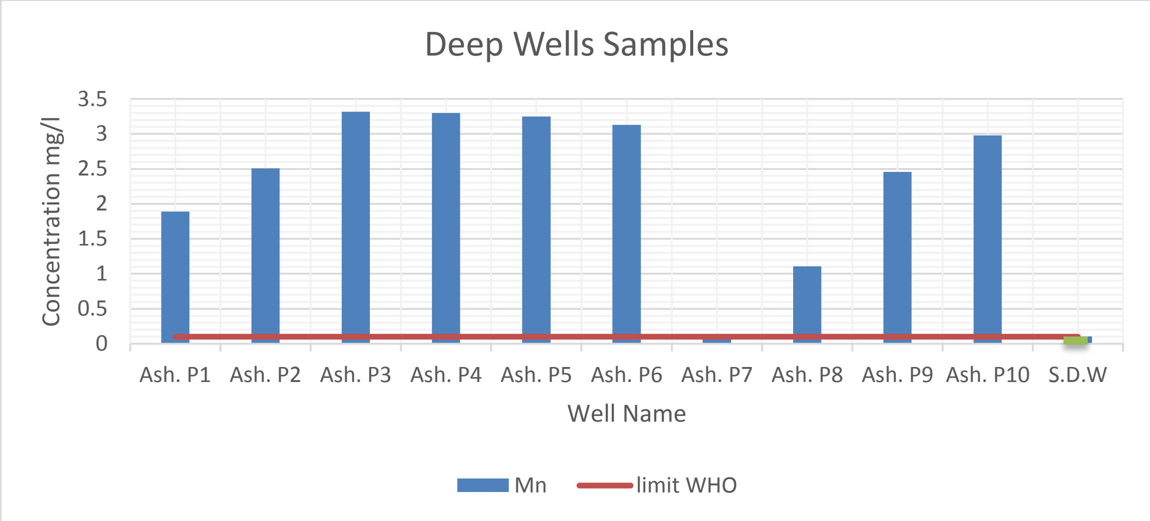

Figure 13: Mn concentration of deep wells and its limit according to (WHO)

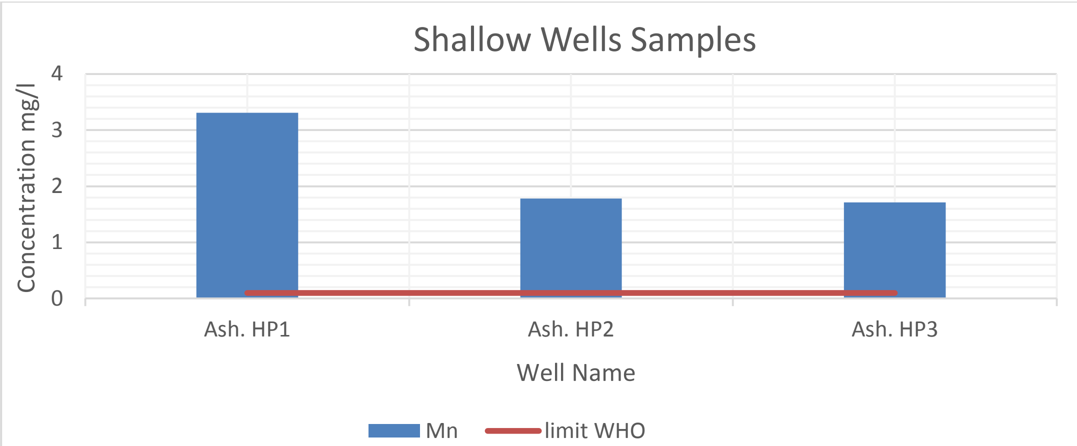

Figure 14: Mn concentration of shallow wells and its limit according to (WHO)

5.2. Water quality description according to analyses and result

The chemical analysis results of groundwater samples indicate that groundwater has quality problems due to natural and human-related factors. High frequencies of total dissolved solids and trace components are recognized in the water samples. So, water is an obligatory treatment before drinking.

5.2.1. Water quality parameter indication:

Salinity is a measure of the number of dissolved salts in the water, metals concentrations increase can be used as an indicator of toxic wastes impact.

5.2.2. Water quality survey in Samadon-Ashmoun District:

The data of the hand pumps (ASH hp1- ASH hp2- ASH hp3) which represent the surface groundwater clear the following:

The pH values were ranged between 7.71 and 7.98, which means that the groundwater is natural. The surface water salinity was expressed in EC, ranging between 0.84 and 2.49 **mmhos/cm**, and TDS, between 538 and 600 ppm.

The results of cations including Na, K, Ca, and Mg clarify that the dominant cations were Na, and Ca are followed by Mg. the data of anions, including HCO_3, Cl, SO_4, NO_3, indicates that the dominant cations were HCO_3 and cl followed by so4. in contrast, the CO_3 anions disappeared, which coincides with the neutral values of pH.

The results of the heavy metals show a precise high concentration for Mn and Fe. the concentrations of Mn violated the permissible limits of drinking water of who, while the concentrations of Fe violated the allowable limits of who in two wells (ash. hp1) and (ash. hp3).

The data of the deep groundwater (ASH p1-ASH P2- ASH P3- ASH P4- ASH P5- ASH P6- ASH P7- ASH P8- ASH P9- ASH P10) of the production wells indicate the following:

The production well that used for irrigation with a depth of 55 m has the following quality data: the pH was 7.66, EC was 1.622 **mmhos/cm**, TDS was 1038 ppm, Na and Ca were dominant cations, while HCO_3, SO_4, Cl were dominant anions. Mn and Fe violated the allowable limits of who. the well is lightly polluted with total and fecal coliform.

The production well that used for irrigation with a depth of 60 m. the data of that well followed almost the same trend of water quality data where the pH was 7.4, the EC was 1.654 **mmhos/cm**, TDS was 1063 ppm, Ca and Na were the dominant cations followed by Mg. while the HCO_3 was the dominant anions followed by SO_4, then Cl. the Fe and Mn violated who is allowable limits, where the values were 0.245 and 2.979 ppm for Fe and Mn, respectively. especially in the deepest well, which is located in the Samadon treatment plant.

5.3. The solute transport Model MT3D:

After calibration of flow and quality data analysis, it can be used to test the impact of groundwater abstraction from the groundwater wells of the studied plant of samadon village on the groundwater levels and study the pollutants transportation from their different sources. The solute transport package (MT3D) is used to predict the change in groundwater quality. MT3D model is considered one of the available engines in the visual Modflow. The model was run under the following conditions:

The well of the drinking plant discharged 125 l/sec; It assumes the presence of the pollutants, which is presented by (Cl) anion as 350 mg/l. This concentration of Cl in the domestic sewage water can percolate to the groundwater in the study area, and the concentration of Cl is present in the surrounded open channels such as canals and drain.

The model was applied to follow up the pollutants movement and transport for ten years with a constant concentration of 350 mg/l, as mention before.

MODPATH used to illustrates the movement of the contaminate with time due to continuous pumping from drinking supply well and its direction. Also, the concentration of future groundwater contaminants after specific years under different scenarios.

5.3.1. Particle tracking direction

MODPATH engine was applied to track the movement of the contaminant elements distributed above the first layer and track their migration through the aquifer layer. Figures (15-16) shows section view for migration of path lines through aquifer layer and source of groundwater was pumped from supply wells. The movement of pollutants may reach the screen zone of the well during the next ten years, up to a depth of 110 m, which confirms the need to deepen the drinking wells shortly, and the situation is considered this well is critical, which requires periodic monitoring and collection of samples and chemical and bacteriological analysis.

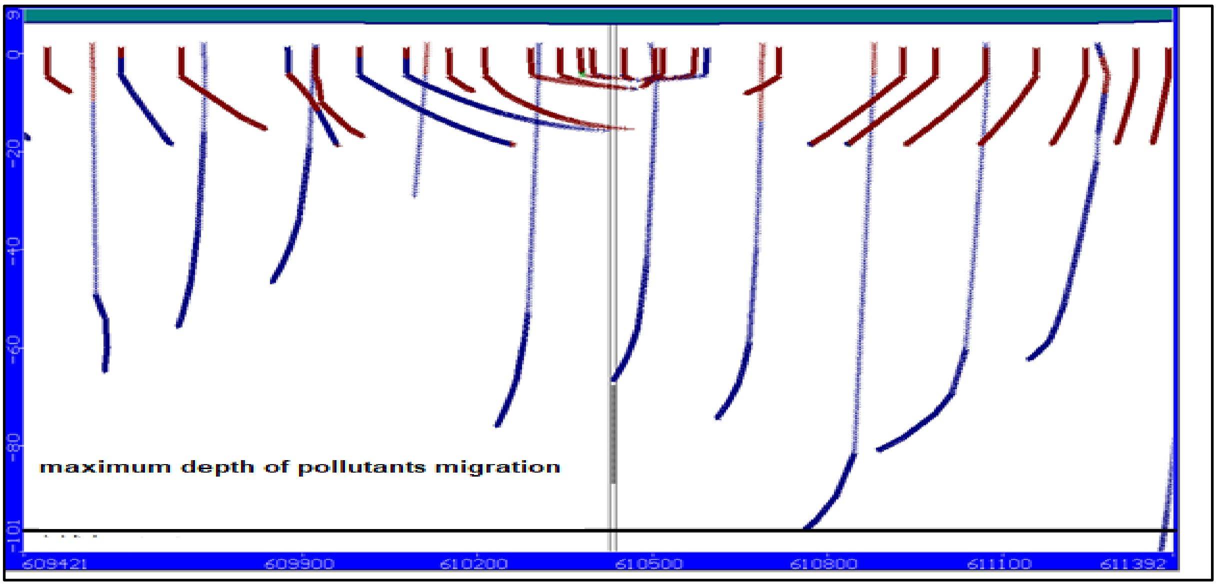

Figure 15: Cross-section for Path lines migration through aquifer layer

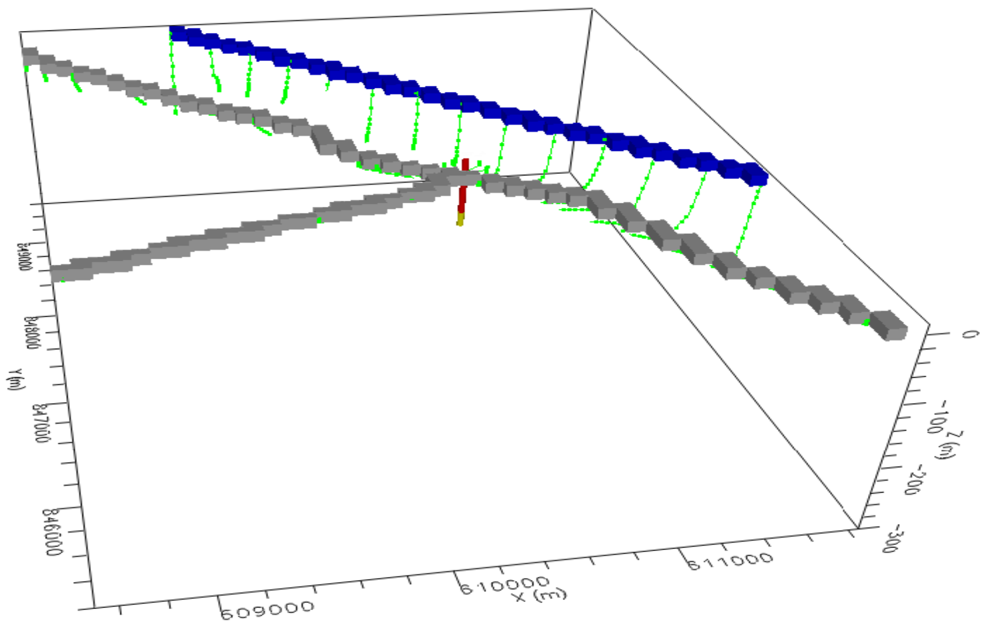

Figure 16: 3DPlan view of pollutant distribution surrounding studied well

5.3.2. MT3D model scenarios results:

The Numerical model results showed that the scope of the well precinct was calculated by determining the transition time of the pollutant (10 years). The result of the model running clears the following:

The safeguard zone (protection zone) that has been calculated from the time of pollutants transportation due to the international standard, preventing any microbiological pollutants to the ground reservoir will not exceed a circular it is half diameter 33 meter.

This zonation range ensures that no pollutants arrive within ten years, which is the period tested in the Numerical model, under the influence of the current conditions of population area and population density.

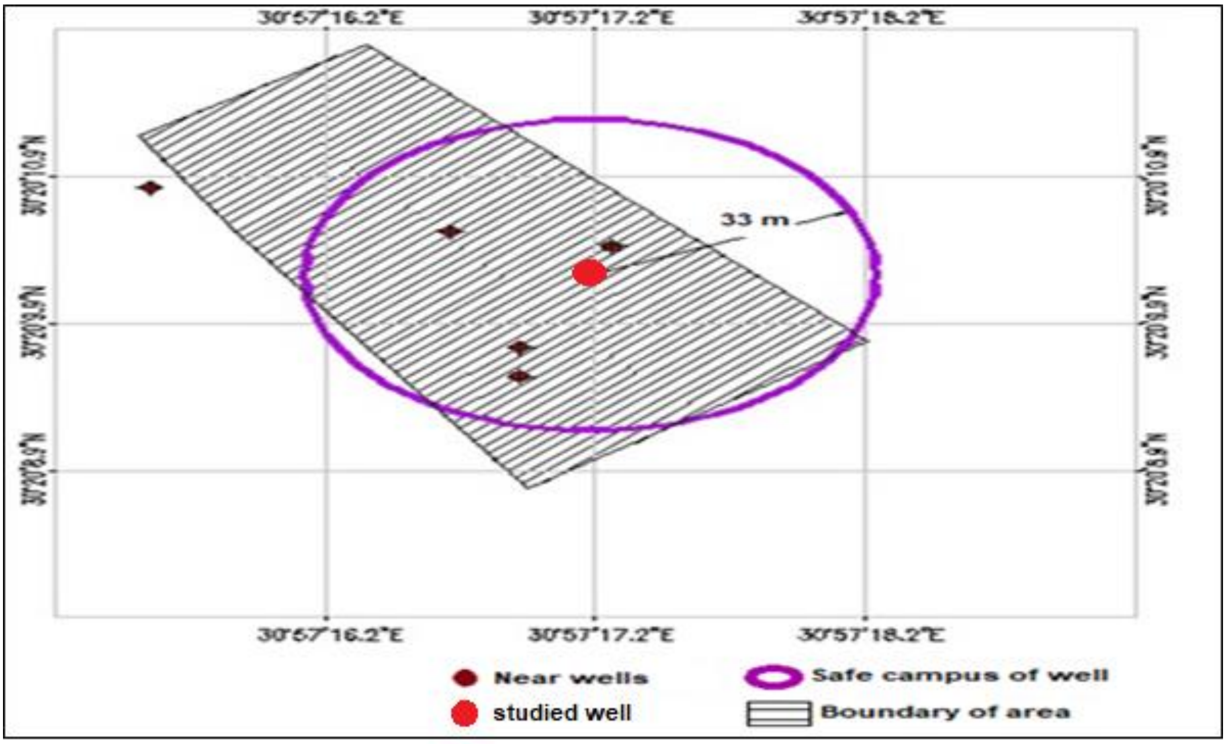

Figure 17: The safe campus around the well according to the numerical model

6. Conclusion:

From the previous discussion of this study can be concluded as the following:
The water quality of the shallow groundwater in most of the study areas is suitable for irrigation, while the water quality parameters pass the allowable boundaries for drinking water.
The future increase of pollutants concentrations will deteriorate groundwater quality to the degree that it will not be suitable for irrigation.
The groundwater in the area of Samadun - Ashmoun in the Centre of the Menofia is fresh water. The total dissolved salts content is within the allowable boundaries and does not have bacterial contamination in the deep wells; this indicates that a mixture of sewage water did not reach deep wells. Groundwater is a rare element (heavy metals) in the allowable boundaries for drinking water, except manganese, which in some old wells exceeds the permissible limit. Water always needs manganese treatment before being pumped into the drinking water network to the consumer. The new well at the station does not contain any pollutants, and the water must be analyzed periodically.
There is no microbiological contamination of the deep water in drinking wells, at the same time there is bacterial contamination in other shallow wells, which indicates the contamination of shallow water in wells implemented by non-engineering and non-standard methods, which allowed the contamination to reach shallow groundwater to a depth of about 50 meters from the surface of the earth.

The withdrawal and replacement experiments conducted on the well of the smadoun station showed that the efficiency of the well reaches 80%, and the conductivity factor is 407 m2/day.

The Numerical model results showed that the wells are operated at the planned withdrawal rates (125 l/s) for fifty years. The final concentration of chloride (Cl), which was used to study the movement of pollutants after ten years in the withdrawal layer of drinking water, is less than 143 mg/l, which is much less than the permissible percentages in drinking water for chloride, which is 250 mg/l.

The Protection Zone of drinking well (the area where it is not allowed to carry out any polluting activities) was determined through Numerical model calculations, which showed that the protection zone represented as circle around well with radius of 33 meters. Continued monitoring for groundwater quality highly recommended for protecting drinking water wells from any contaminations.

List of Abbreviations:

<table>
<tr><td>pH</td><td>LOG H</td><td>SO_4</td><td>sulphate</td><td rowspan="3">CLEQM</td><td rowspan="3">Central Laboratory for Environmental Quality Monitoring</td></tr>
<tr><td>Ec</td><td>Electrical Conductivity</td><td>Cl</td><td>Choloride</td></tr>
<tr><td>TDS</td><td>Total Dissolved Solids</td><td>Fe</td><td>Iron</td></tr>
<tr><td>Na</td><td>Sodium</td><td>Mn</td><td>Manganese</td><td rowspan="2">WHO</td><td rowspan="2">World Health Organization</td></tr>
<tr><td>K</td><td>Potassium</td><td>Cu</td><td>Cupper</td></tr>
<tr><td>Ca</td><td>Calcium</td><td>Pb</td><td>Lead</td><td rowspan="3">FAO</td><td rowspan="3">Food and Agriculture Organization</td></tr>
<tr><td>Mg</td><td>Magnesium</td><td>Cd</td><td>Cadmium</td></tr>
<tr><td>HCO_3</td><td>bicarbonate</td><td>Zn</td><td>Zinc</td></tr>
</table>

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