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Groundwater Rising as Environmental Problem, Causes and Solutions: Case Study from Aswan City, Upper Egypt

Sayed A. Selim[1], Ali M. Hamdan[1], Ahmed Abdel Rady[2]

[1]Geology Department, Faculty of Science, Aswan University, Aswan, Egypt
[2]Aswan Water and Sanitation Company, Aswan, Egypt
Email: alielaraby1@yahoo.com

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Abstract

This paper examines the rise in the level of the groundwater in the Quaternary aquifer at Aswan city, Upper Egypt. Since the 1960's, the areal extent of Aswan City and the urban populations are growing at a high pace which introduces new sources of water that increase groundwater recharge. As a result of leakages or infiltrations from different sources, the natural groundwater balance is overturned into an unbalance where the input to water table is comparatively much more than the natural groundwater flow towards the Nile River. The present study shows a variation in the groundwater level, from 1971 up to 2014, where the water table rising ranges between 12.55 and 13.69 m. Also, it shows an abrupt increase in the water levels in 2010 continuing up till now. The groundwater rising phenomena that happened in 2010 can be directly refereed to the cessation of groundwater pumping from El-Shallal wells, and to the reduction of pumping from KIMA factory wells. Generally, the rate of water rising is much higher in the western side of the city and in Kima factory area, where they are characterized by low relief and dense population. The most troublesome groundwater mounds under urban areas are likely to develop in low-lying areas of relatively high permeability aquifer, which is not exploited for water supply. These damages will become more widespread if the rising groundwater table remains uncontrolled. The environmental impact of the water rising includes: forming ponds in low lying areas (Kima and El Shallal ponds), flooding building's basements, and inundating underground infrastructure. A general deterioration in groundwater quality was identified.

Keywords

Aswan City, Groundwater Level Rising, Quaternary Aquifer, Urban Areas

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1. Introduction

The area under investigation (Aswan City) is situated along the Nile Valley in the southern part of Egypt. It is located adjacent to the east bank of the Nile River, bounded by latitudes 24˚01'30" and 24˚06'30"N and longitudes 32˚52' and 32˚56'E (**Figure 1**).

Over last few years, a rise in groundwater levels has been observed in several parts. Raising groundwater levels have the potential to inundate underground infrastructure, flooding basements and submerging sewer pipes and utility lines that deliver water and electricity. The magnitude of anthropic impacts upon their environment makes humans the major geologic agent on the surface of the planet [1].

This work aims to review the causes of changes in groundwater levels in Aswan region which is under the subtropical arid region conditions. The geo-environmental impact of the rising water-level and their consequences on the built environment will be considered.

Over the last few years, a steady rise in groundwater levels has been observed in several parts of Aswan City. This reflect environmental problems existing in many areas of the city, where it creates swamps and ponds and affects the basement of many buildings as it is shown in El-Seil, KhorAwada, Phatemic graves, El-Aqad buildings, Blood Bank, Military building, El Shallal and KIMA factory area (**Figure 1** and **Figure 2**). Rising groundwater levels are expected to be a chronic problem and will likely be a major issue for residential areas of Aswan city.

2. Study Area

Geomorphologically, Aswan City area can be divided into three main units: low elevated lands (Aswan plain); high elevated lands; and the Nile River channel (**Figure 1**).

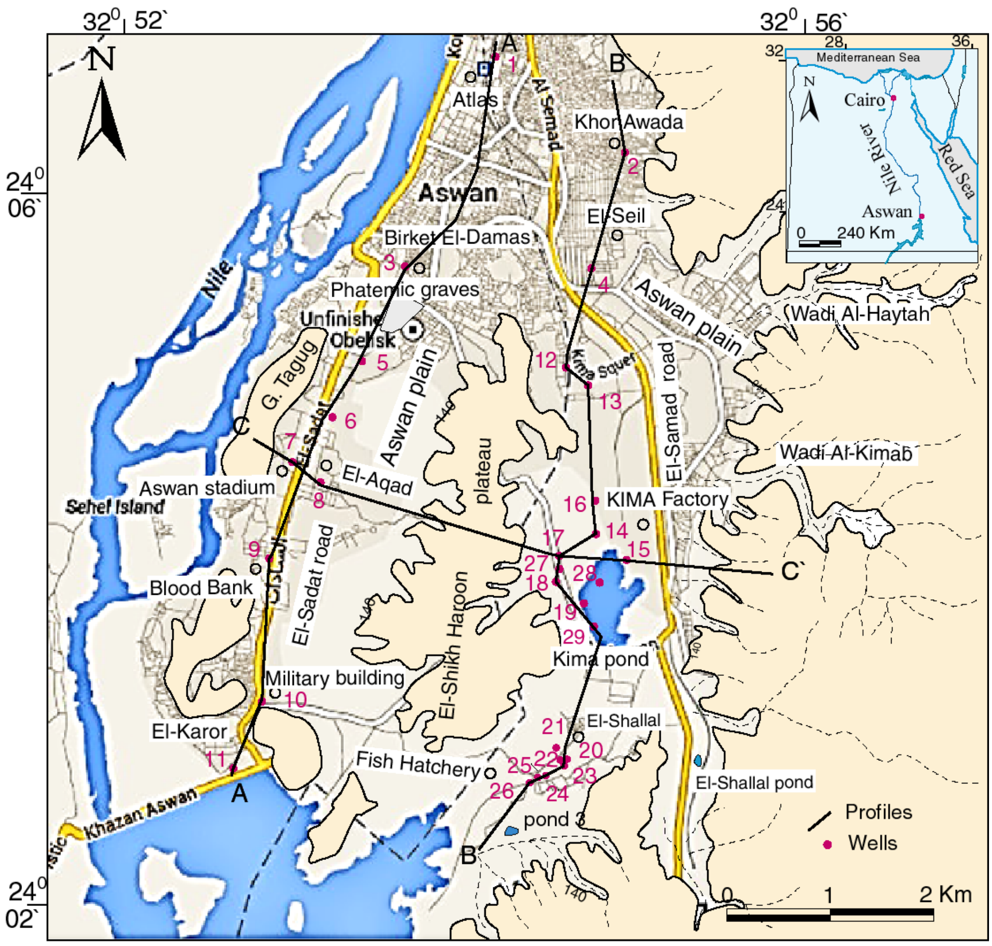


Figure 1. Location map of drilled wells and profiles in the study area.

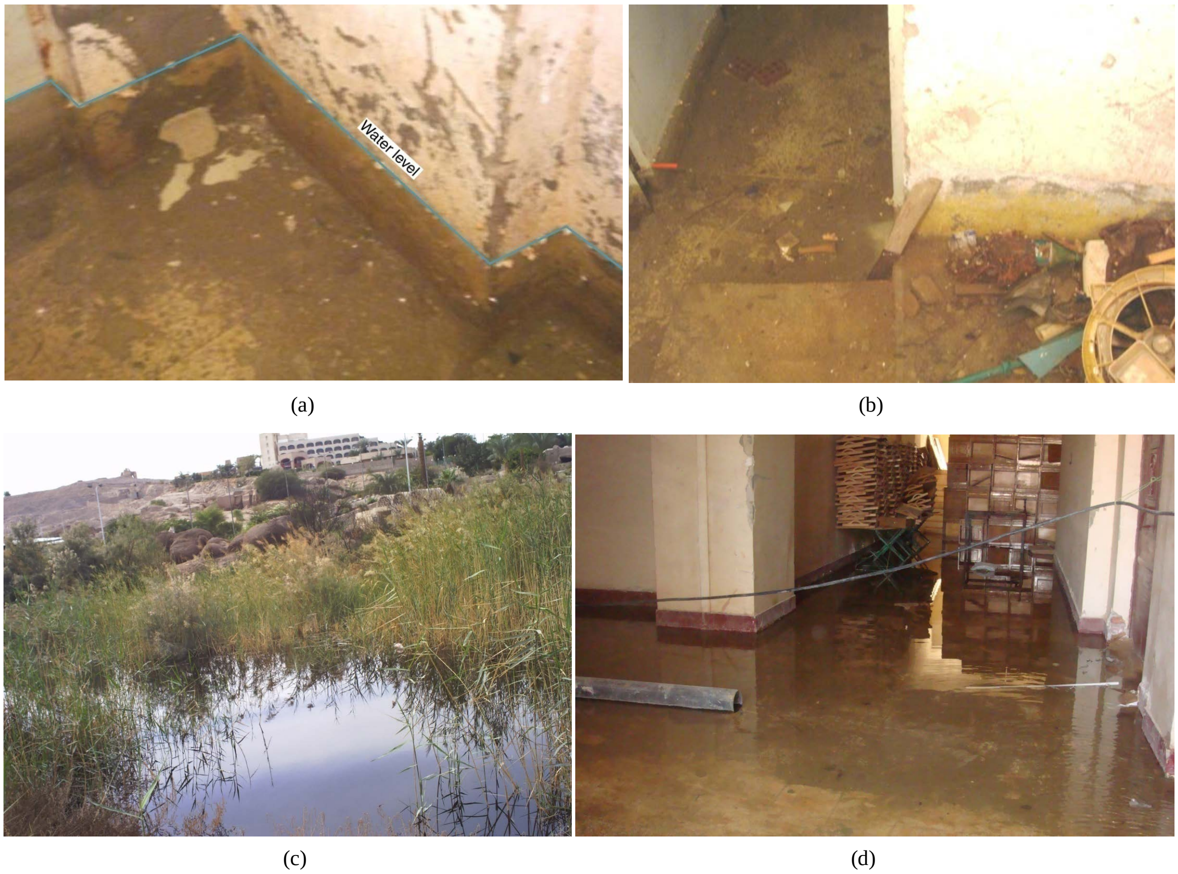


Figure 2. Rising groundwater level affecting areas: (a) KhorAwada, (b) El-Seil, (c) Phatemic graves area, and (d) Aswan stadium.

1) Low lands (Aswan plains): are underlain by the urban areas of Aswan city and can be divided into two main parts. The western plain that extends along El Sadat road up to Atlas area northward, while the eastern plain extends along El Samad road (**Figure 1**). These two plains were the location of the old channel of the Nile River and their width determined the original width of the old Nile gorge. The maximum width of these plains is encountered near the center of the town (about 3.5 Km), and the minimum one is along El Sadat road (less than 1 kilometer). Generally, these plains are characterized by great variation in ground elevation and show a general slope from south to north (**Figure 3**).

2) The highlands: the more extensive one bounded the study area from its eastern side (elevations vary from 164 to 188 m). Few wadis incise this highland and directed from east to west, W. El-Keimab and W. Al-Haytah (**Figure 1**). The second main highland occupies the central parts of the study area and represented by El-Shikh Haroon plateau (elevations vary from 142 to 167 m). Other small highlands are located to west of the study area close to the Nile River as Gebel Tagug (150 m) and El Karor (135 m). The high land areas are underlain either by basement rocks and or by Nubian sandstones.

3) The Nile River Course forms the western limit of Aswan City area (the approximately water level is +85 m). Aswan Dam (Khazan Aswan) with its water reservoir is situated to the south of Aswan city where the water level ranges between 106 and 118 m.

The general geology of Aswan area is relatively well known and has been studied by several investigators [2]-[10].

The following lithological units were exposed in the study area (**Figure 4**).

- The basement rocks represent the oldest rocks (Precambrian age) and mainly exposed in the many parts of the study area (**Figure 4**). They are characterize by the presence of many fissures and joints, and can play an important role in accumulation of water in many parts of the study area.
- The Nubian Sandstone rocks of Cambrian to cretaceous age [11] are exposed in the central and eastern parts of

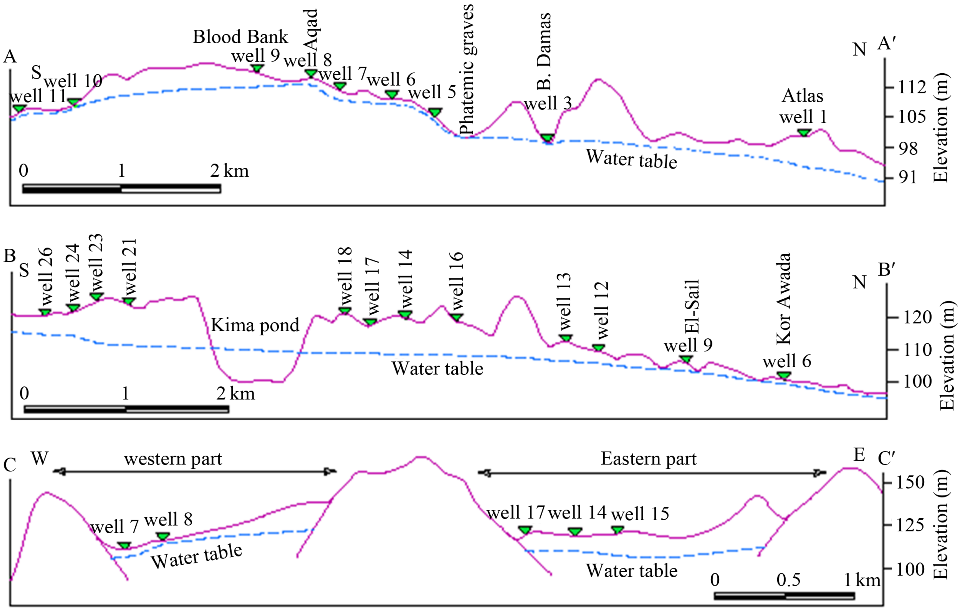


Figure 3. Hydrogeological profiles along the study area (2014).

the study area. It exposed at high lands in the central part (El Shikh Haroon plateau) and the eastern part and unconformably lies over the basement complex (**Figure 4**). It is made of ferruginous sandstone, sandstone and clays and composed into three Formations from base to top, Abu Agag Formation; Timsah Fomation; and Um Barmile Formation and has a total thickness ranges between 20 and 85 meters [12].

- The Quaternary sediments are represented by sands, gravels and clays of the Pleistocene time, and by mud and Aeolian sediments of the recent. They are underlain by a thick bed of Pliocene clays [13]. These sediments are well exposed in the area through El-Samad and El Sadat roads with a thickness reached up to 248 m. The Quaternary gravels are composed of coarse well-rounded pebbles, ranging from 15 to 20 centimeters in diameter. The recent deposits comprise a small portion of the surface of the study area and are represented by alluvial and Aeolian deposits. The alluvial deposits, sand and mud form the cultivated land in the northern part of the study area. The Aeolian deposits are represented by blown-sand.

Hydrogeologicaly, few has been published on the hydrogeology of Aswan city area due to the limited amount that groundwater used for public water supply. The Quaternary sediments represent the main aquifer in the studied area and outcropped in two geomorphologic low lands (Aswan plains) which will be outlined in the following.

At the western plain (along El Sadat road): The quaternary aquifer is consists of unconsolidated sediments of sands, gravels, and clays enriched of smectite minerals group of the Pleistocene time. These sediments are unconformably overlies the basement rocks and fill the floor of the low lands with a thickness vary from few meters to less than 20 m. basement rocks outcrops in many parts along the western part of the study area as in El Karor and G. Tagug.

The eastern border of the aquifer is El-Shikh Haroon plateau (basement rocks caped by The Nubian Sandstone rocks), but westward is bounded by G. Tagog and El Karorplateaux. The width of the aquifer is relatively small and varies from 1.5 km (at Blood Bank) to 1.67 km (at El-Aqad). It reached 4.52 km at the central part of the city and 1.13 km at the northern extreme (Atlas).

At the eastern plain (along El-Samad road): The quaternary aquifer in the eastern part of the study area studied by [14] [15]. They concluded that the Quaternary aquifer in the eastern part is mainly composed of unconsolidated material of sands, gravels, and clays intercalation. It is not covered by impermeable layers in the major part of the area; therefore, it is under unconfined condition. They stated that the transmissivity (T) values of the Quaternary aquifer range between 1996.4 and 3029 m^2/day which means that the aquifer is of high potential class (more than 500 m^2/day) according to the classification of [16].

The thickness of the Quaternary aquifer vary from 100 m in the southern part to 137 m in the central part and it underlined by the Pliocene clay, as detected from the lithological log of deep well No. 27 (**Figure 5**). The east-

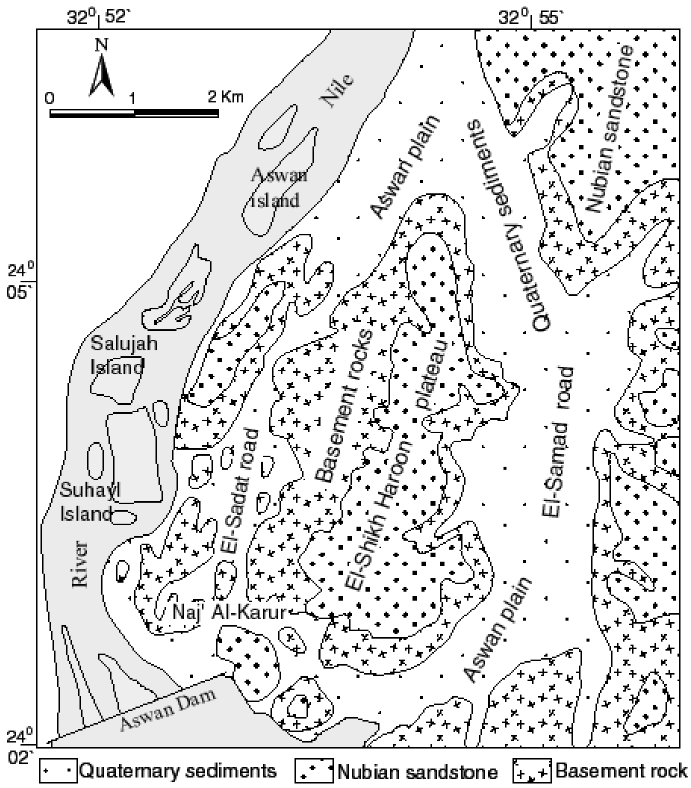


Figure 4. Geological map of the study area.

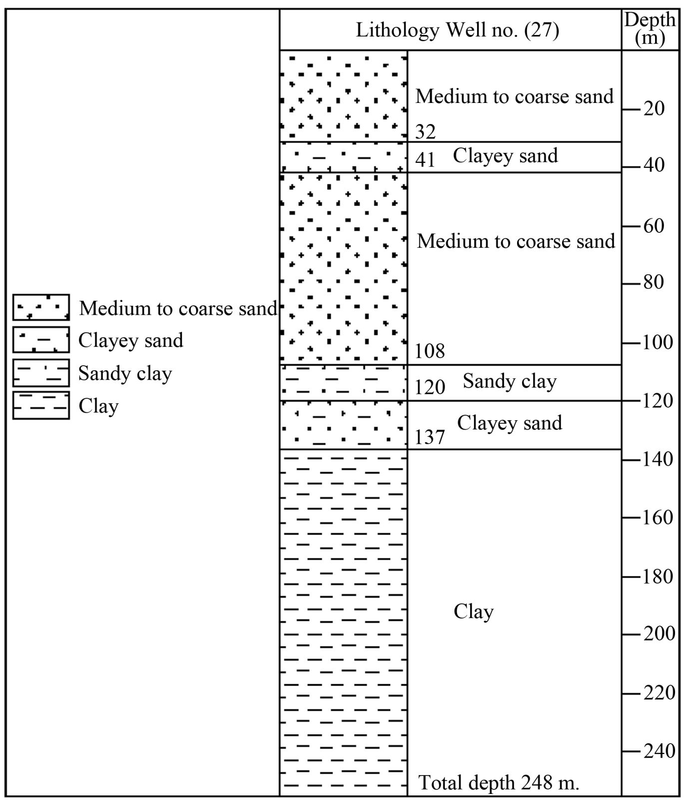


Figure 5. Lithological log of well No. 27.

ern border of the quaternary water-bearing sediments represented by the basement rocks which caped with Nubian sandstone, while westward is bounded by high land of El-Shikh Haroon plateau. The width of the aquifer is small and ranges between 2.05 km northward and 1.37 km southward.

The natural recharge to the Quaternary aquifer is from the Aswan Dam Lake, which has water level ranges between 108 and 118 m asl, towards the urban areas of the city.

The aquifer discharged through the natural groundwater outflow to the Nile River, in the northern part of the city in addition to groundwater abstraction by pumping at Kima and El Shallal areas.

3. Materials and Methods

During this study, the data recorded from 1971 to 2014, from six wells at Kima area are evaluated to determine the general trend in groundwater levels and the change in the water-table over a 43-year period (**Table 1** and **Figure 6**). These data also helped to identify general and local groundwater flow directions, where the groundwater level contour map is prepared (**Figure 7**).

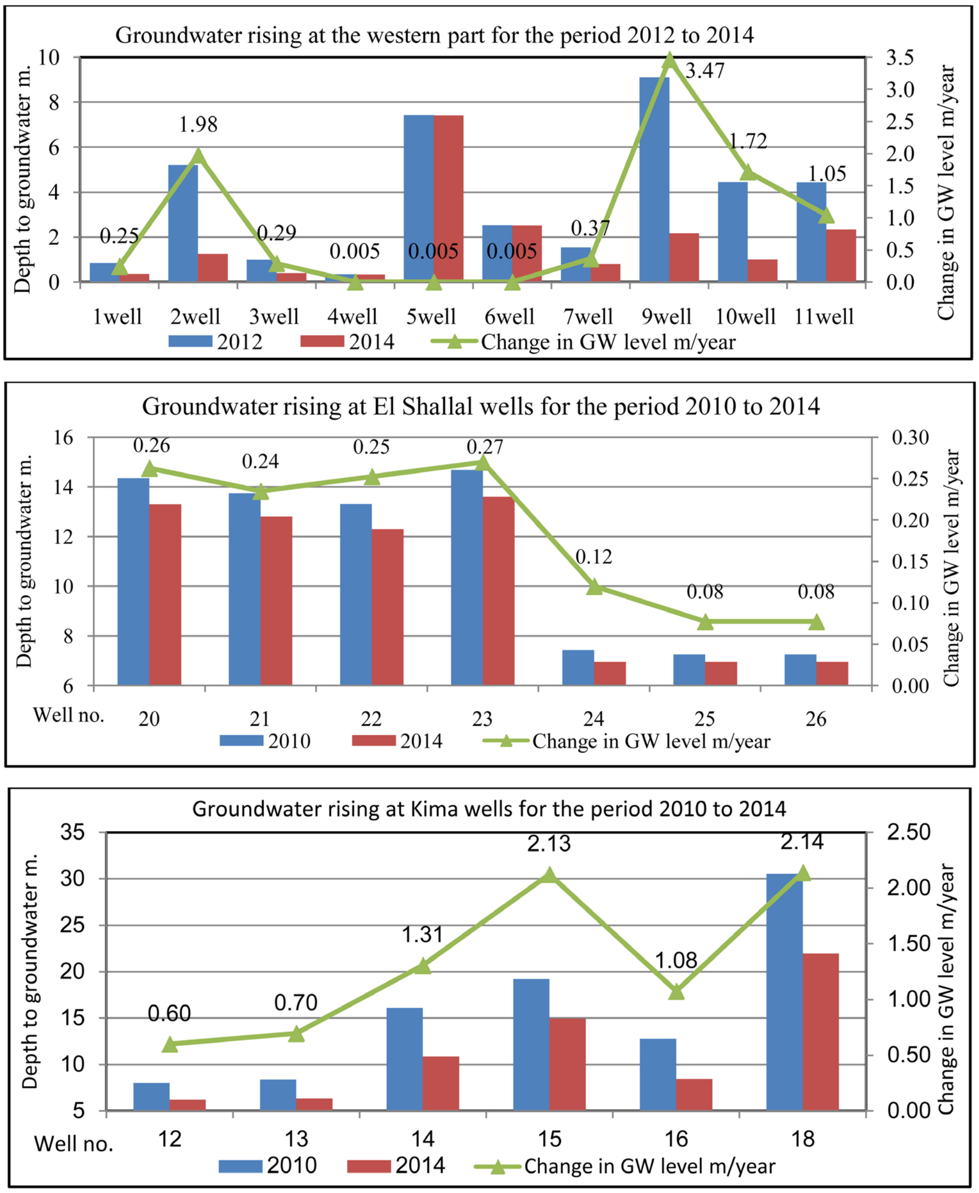


Figure 6. Groundwater rising and changes in GW level per year in the study area.

Table 1. The hydrogeological data of drilled wells of the study area.

Date	Water depth	Water Level	Date	Water depth	Water Level	Date	Water depth	Water Level
	Well No. 1			Well No. 26			Well No. 13 (continue)	
1/6/2012	0.85	101.86	18/7/2010	7.26	113.74	20/10/2012	6.49	114.51
22/2/2014	0.36	102.35	15/1/2014	6.95	114.05	3/11/2012	6.42	114.58
	Well No. 2			Well No. 12		1/12/2012	6.37	114.63
1/6/2012	5.21	104.74	17/10/1971	19.0	91.0	21/1/2013	6.42	114.58
22/2/2014	1.25	108.70	26/6/1975	18.75	91.25	16/2/2013	6.4	114.6
	Well No. 3		16/1/1978	15.5	94.5	16/3/2013	6.36	114.64
1/6/2012	0.98	99.01	14/8/1979	15.9	94.1	13/4/2013	6.33	114.67
22/2/2014	0.4	99.59	5/1/1980	15.4	94.6	25/5/2013	6.31	114.69
	Well No. 4		18/11/1981	16.1	93.9		Well No. 14	
1/6/2012	0.35	91.82	2/1/1982	14.6	95.4	24/11/1981	26.0	93.0
22/2/2014	0.44	91.73	28/7/1984	16.3	93.7	3/1/1982	25.0	94.0
	Well No. 5		2/4/1985	15.6	94.4	25/10/1983	26.0	93.0
1/6/2012	7.42	84.86	31/5/1986	16.3	93.7	2/7/1984	27.0	92.0
22/2/2014	8.23	84.05	1/10/1987	16.05	93.95	1/4/1985	24.57	94.43
	Well No. 6		25/1/1988	15.47	94.53	29/9/1987	22.6	96.4
1/6/2012	2.53	98.44	18/1/1989	14.9	95.1	24/1/1988	22.0	97.0
22/2/2014	2.52	98.45	14/3/1990	14.7	95.3	8/2/1989	22.8	96.2
	Well No. 7		21/9/1991	13.33	96.67	9/12/1989	23.2	95.8
1/6/2012	1.53	97.05	17/12/1992	11.94	98.06	12/2/1991	22.23	96.77
22/2/2014	0.8	97.78	16/5/1993	11.77	98.23	5/2/1992	21.35	97.65
	Well No. 8		15/2/1999	11.8	98.2	18/12/1993	20.67	98.33
1/6/2012	8.76	95.56	6/2/2001	12.0	98.0	5/8/1996	21.65	97.35
22/2/2014	closed	104.32	8/3/2004	11.8	98.2	11/7/2001	22.0	97.0
	Well No. 9		15/2/2010	8.0	102.0	19/5/2010	16.1	102.9
1/6/2012	9.1	90.03	19/5/2010	7.5	102.5	28/6/2010	15.98	103.02
22/2/2014	2.17	96.96	28/6/2010	7.4	102.6	5/7/2010	15.87	103.13
	Well No. 10		8/1/2011	6.28	103.72	28/4/2011	13.68	105.32
1/6/2012	4.44	94.97	21/6/2011	6.45	103.55	15/9/2011	13.0	106.0
22/2/2014	1.0	98.41		Well No. 13		3/1/2012	12.4	106.6
	Well No. 11		6/6/1971	20.0	101.0	7/2/2012	12.9	106.1
1/6/2012	4.43	109.91	9/2/1985	16.27	104.73	25/8/2012	14.55	104.45
22/2/2014	closed	114.34	17/11/1986	17.02	103.98	20/10/2012	14.37	104.63
	Well No. 20		24/9/1992	12.48	108.52	16/2/2013	13.93	105.07

Continued

18/7/2010	14.35	107.65	18/5/1993	12.25	108.75	13/4/2013	13.96	105.04
15/1/2014	13.3	108.7	28/8/1994	14.0	107.0	8/2/2014	10.87	108.13
	Well No. 21		29/9/1998	13.75	107.25		Well No. 15	
18/7/2010	13.74	108.26	4/4/1999	12.5	108.5	8/6/1972	27.5	89.5
15/1/2014	12.8	109.2	17/2/2000	12.0	109.0	18/11/1975	27.87	89.13
	Well No. 22		8/4/2004	12.4	108.6	26/1/1976	28.0	89.0
18/7/2010	13.31	108.69	15/5/2010	8.4	112.6	28/3/1984	28.8	88.2
15/1/2014	12.3	109.7	28/6/2010	7.77	113.23	7/9/1984	29.0	88.0
	Well No. 23		5/7/2010	7.77	113.23	2/7/1985	27.32	89.68
18/7/2010	14.68	107.32	6/7/2012	6.73	114.27	4/2/1985	27.4	89.6
15/1/2014	13.6	108.4	2/7/2012	6.68	114.32	18/7/1985	28.2	88.8
	Well No. 24		28/7/2012	6.61	114.39	12/1/1990	28.77	88.23
18/7/2010	7.43	113.17	25/8/2012	6.58	114.42	16/10/1994	27.7	89.3
15/1/2014	6.95	114.05	29/9/2012	6.58	114.42	24/10/1994	27.5	89.5
	Well No. 15 (continue)			Well No. 16 (continue)		28/6/2010	16.7	100.3
11/1/1994	28.19	88.81	7/4/1993	16.86	100.14		Well No. 18	
13/11/1994	28.29	88.71	13/7/1994	17.3	99.7	16/8/1988	36.15	88.85
19/12/2002	28.5	88.5	5/4/1995	16.8	100.2	30/1/1989	36.34	88.66
15/5/2003	28.4	88.6	7/11/1995	17.4	99.6	24/9/1990	36.87	88.13
15/5/2003	28.4	88.6	29/8/1996	17.59	99.41	4/3/1992	35.0	90.0
15/5/2003	28.4	88.6	22/1/2000	17.5	99.5	7/2/1999	35.8	89.2
25/8/2012	19.2	97.8	13/6/2004	17.75	99.25	9/5/2006	36.2	88.8
29/9/2012	19.01	97.99	16/5/2010	12.75	104.25	9/10/2007	35.4	89.6
20/10/2012	18.9	98.1	5/7/2010	12.2	104.8	31/5/2008	35.4	89.6
1/12/2013	18.73	98.27	8/2/2014	8.45	108.55	25/1/2009	30.5	94.5
3/16/2013	18.59	98.41		Well No. 17		5/1/2010	30.85	94.15
16/3/2013	18.62	98.38	22/11/1990	23.75	93.25	19/5/2010	30.85	94.15
5/4/2013	18.65	98.35	2/1/1991	23.7	93.3	28/6/2010	30.5	94.5
2/8/2014	14.95	102.05	6/2/1991	23.65	93.35	5/7/2010	30.52	94.48
	Well No. 16		11/5/1992	24.41	92.59	19/3/2012	26.5	98.5
5/1/1971	21.0	96.0	23/9/1996	22.3	94.7	8/2/2014	21.95	103.05
26/3/1977	20.3	96.7	4/11/1997	22.93	94.07		Well No. 19	
7/3/1983	20.9	96.1	21/2/1998	22.49	94.51	29/8/2008	3.71	92.29
4/8/1987	21.1	95.9	13/4/2006	22.4	94.6	15/8/2009	0.0	96.0
6/10/1992	17.12	99.88	19/4/2007	22.3	94.7	5/7/2010	−2.0	98.0
13/10/1992	17.02	99.98	19/5/2010	17.3	99.7	5/12/2013	−5.0	101.0

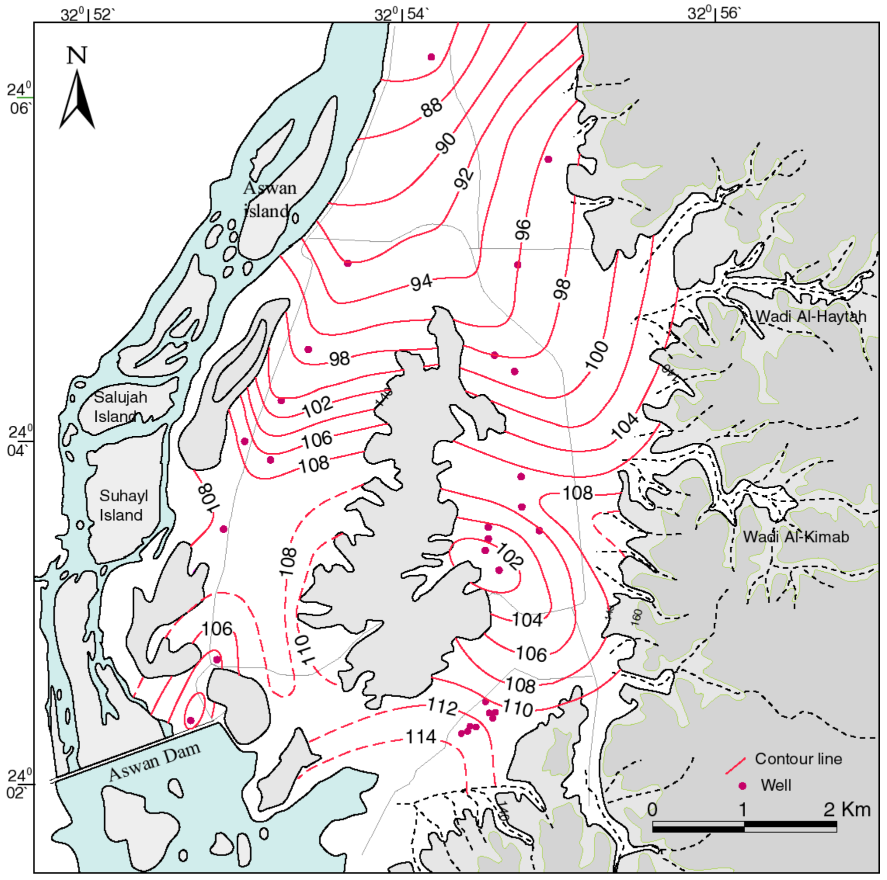


Figure 7. Groundwater level map in the study area (2014).

In order to assess the rate of groundwater rise, the present authors measured the hydrogeological data (depth to water, groundwater level, ground elevation, and total depth) from the drilled wells through many trips from 2010 up till now (Table 1). The collected data covered all affected areas through monitoring the cases of groundwater rising and their environmental impact and the illustrations were prepared (Table 1 and Figure 8, Figure 2, and Figures 9-14).

To achieve the causes of this problem in Aswan city, hydrogeological data were collected from 11 wells drilled along the study area for the period from 1971 to 2009 (Figure 15).

A total of 13 water samples were collected from some of affected areas and bore wells from various localities of the city and chemical and microbiological analyses carried out to assess the groundwater quality. They analyzed for different physio-chemical parameters (TDS, pH, E.C, TH), major cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}), major anions $\left(HCO_3^-, SO_4^{2-}, Cl^-\right)$, and some trace ions as (PO_4), (NO_2), (NO_3), Fe, and Mn (Table 2).

The present work studied the causes of the groundwater level rising, the environmental impact of the problem on the city and gave recommendations for solving it.

4. Results and Discussion

Groundwater level rise results provide a basis for the characterization of groundwater variation within the Quaternary aquifer in the studied area. It is possible to interpret different processes that may occur within the aquifer.

In this study, the data recorded between 1971 and 2014, from five wells at Kima area, are evaluated in order to determine the general trend in water levels and the change in the water-table over 43-year period (Table 1).

Figure 15 shows a noticeable variation in the groundwater level, from 1971 up to 2014, where the water table rise ranges between 12.55 and 13.69 m which means that there is about 1.37 m groundwater table rise in each year. Also, the figure shows an abrupt increase in the water levels in the 2000's and reached its peak in 2010 and continuing up till now.

(a) (b)

Figure 8. Rising groundwater level creating ponds: (a) Kima pond, (b) El Shallal pond.

Figure 9. Increase population and Urbanization activity at the study area.

Figure 10. Rash of sewage network system on streets.

From the groundwater level contour map for the year 2014 (**Figure 7**) the following points can be identified.

- The general groundwater flow direction is generally from the south towards the north, *i.e.* toward the Nile River, Other direction of water flow comes from the highlands, which is characterized by high urbanization.
- The highest water level is recorded at El Shallal area, close to the area of recharge (Aswan Dam Lake), and the lowest water level is noticed at the northern part of the city, close to the area of discharge, the Nile river.
- The contour lines are more or less regular in the northern part of the city, while they are condensed in El Shallal, Kima and El Aqad areas where these areas are characterized by dense population and industrial activities.

(a) (b)

Figure 11. Satellite image for KIMA factory pond before flooding (a) 2009 and after five years of flooding (b) 2014.

Figure 12. Salt crystals cause the building materials to split, flake and crack (Khor Awada and El Sail areas).

- Two water depressions are noticed in Kima and El Karor areas, these two areas are characterized by low ground elevations.

The authors measured the depth to groundwater in 26 piezometers, all over Aswan city, for the period from 2010 up to 2014 to assess the rate of the water rising in the city (**Table 1** and **Figure 6**).

(a) (b)

Figure 13. Examples from different locations where algae growth in the rising water at the affected areas. (a) Khor Awada; (b) El Sail.

(a) (b)

Figure 14. Groundwater rising and their environmental impact: (a) Displacement occurs between two buildings, (b) Example of flooding buried basements of many buildings. (a) El Aqad; (b) Aswan stadium.

The table and figure show that the rise in groundwater level ranges between 8 cm/year (wells 25 & 26) and 27 cm/year (well 23) at El Shallal area, and it ranges between 0.60 cm/year (well 12) and 2.14 m/year (well 18) at Kima area, while it reached 3.46 m/year (well 4) in the western plain and 0.01 cm/year (well 1) at the northern side of the city (**Figure 6**). We can concluded that the rate of the water rising is much higher in the western side of the city, along El Sadat road, and in Kima factory areas where they are characterized by low relief and by dense population. The minimum rising of the groundwater is noticed in the northern part of Aswan city because this area is of low population and represents the discharge area for the Quaternary aquifer; to the Nile River. During the last five years of monitoring, some wells at KIMA factory area are submerged under the rising water (wells No. 19, 28 and 29).

In 2009, 40 productive wells at El Shallal area were turned off, as a result of deteriorated water quality, they were pumped an amount of 12.44×10^6 m^3/year. Moreover, groundwater withdrawals from KIMA factory wells were reduced from 13.23×10^6 m^3/year to 9.12×10^6 m^3/year. The former discussion proves that the phenomena of groundwater rising that happened in 2009 at Aswan city, can be directly refereed to the cessation of groundwater pumping from El-Shallal wells, and to reduction of pumping from KIMA factory wells.

4.1. Causes of the Water Level Rising Problem

The problem of increasing the groundwater level and flooding over the ground surface is observed in many

Table 2. Chemical analysis of the surface and groundwater samples in the study area.

Sample No.	Physio-chemical parameters				Major Cations (ppm)				Major Anions (ppm)			Trace ions (ppm)					e%
	pH	EC µmho/cm	TDS (ppm)	TH (ppm)	Ca	Mg	Na	K	HCO_3	SO_4	Cl	(PO_4)	NO_2	NO_3	Fe	Mn	
well 1	7.65	540	454	231.9	50	26	16	7.4	275	22.8	15.2	0.11	0.1	3.52	0.016	0.005	0.93
well 2	7.86	5250	3383	993.8	277	73.4	700	14.5	908	550	860	0.13	0.15	3.74	0.011	0.006	0.07
well 3	7.9	8800	5632	1482	424	103	1320	50	360	1650	1700	0.15	0.14	0.19	0.012	0.004	0.05
well 4	8.4	6510	4166	1198	320	97	925	20	340	1382	1068	0.19	1.12	86.4	0.151	0.053	0.15
well 5	7.45	4760	3046	900.2	250	67	650	14.3	320	1042	690	0.17	0.13	0.16	0.017	0.006	0.21
well 6	7.84	4360	2812	833.3	248	52	620	14.8	321	900	657	0.177	0.16	14.3	0.537	0.036	1.66
well 7	8.36	1170	748	270.1	62	28	120	7.4	200	128	160	0.21	0.13	0.19	0.173	0.044	1.58
well 9	7.6	2530	1619	442.3	98	48	340	19	395	332	375	0.19	0.17	0.18	0.113	1.038	0.29
well 10	7.63	3940	2568	522.6	145	39	640	26	380	685	653	0.18	0.17	0.14	0.02	0.006	0.03
well 11	7.39	1250	845	338.8	78	35	135	7.4	265	155	170	0.2	0.18	8.7	0.02	0.004	1.80
Phatemic graves	7.85	9150	5856	3146	530	443	603	42.3	1827	1181	1255	3.49	0.08	2.12	0.085	0.09	0.13
Khor Awada	8.09	4420	2828	763	106	121	636.4	37.3	792	538	597.5	0.81	0.37	15.8	0.18	0.21	3.33
Aqad	8.03	3810	2418	659	114	91	530.8	35.8	628	456	562	0.72	0.48	14.1	0.11	0.25	2.09

lowlands along the study area as El-Seil, Khor Awada, Birket El-Damas, Phatemic graves, El-Sadat road, El-Aqad, Aswan stadium, Blood Bank, Military building, Kima, El Shallal (**Figure 1** and **Figure 2**). The main causes of the water rising at the Aswan city can be related to the following.

4.1.1. Variation of Direct Groundwater Recharge and Discharge

The principal cause is the great variation of the difference between the recharge and discharge to and from the main aquifer under Aswan city area, where a big and continues recharge amount of water regardless to a small discharge amount of water by time lead to increasing the water level and appear in low elevated lands in the study area causing a concern problem. The groundwater recharge from potable and different supplies may exceed both the natural rate of recharge from Aswan Dam Lake and the natural rate of groundwater discharge. So that, less discharge of groundwater indirectly leads to increase the water level.

4.1.2. The Hydrogeological Parameters of the Quaternary Aquifer

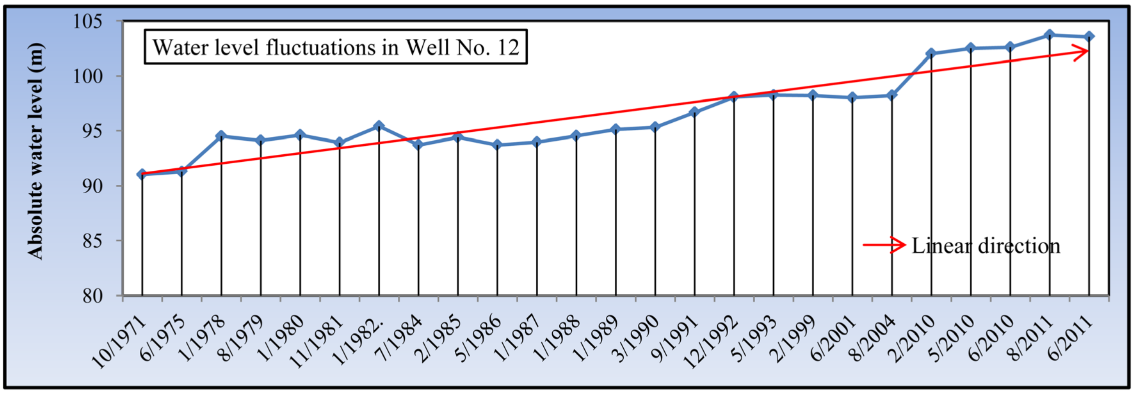
The hydrogeological parameters of the Quaternary aquifer, in Aswan area, play significant role in the calculations of groundwater rise. The pumping tests analyses reveal that the Quaternary aquifer at Aswan area has high hydraulic conductivity (ranges between 0.0001 and 0.0004 m/s), and high transmissivity values (0.02 to 0.04 m^2/s), [14]. Increasing hydraulic conductivity and transmissivity lead to increasing the rate of groundwater flow which act as an important role in the problem of water rising.

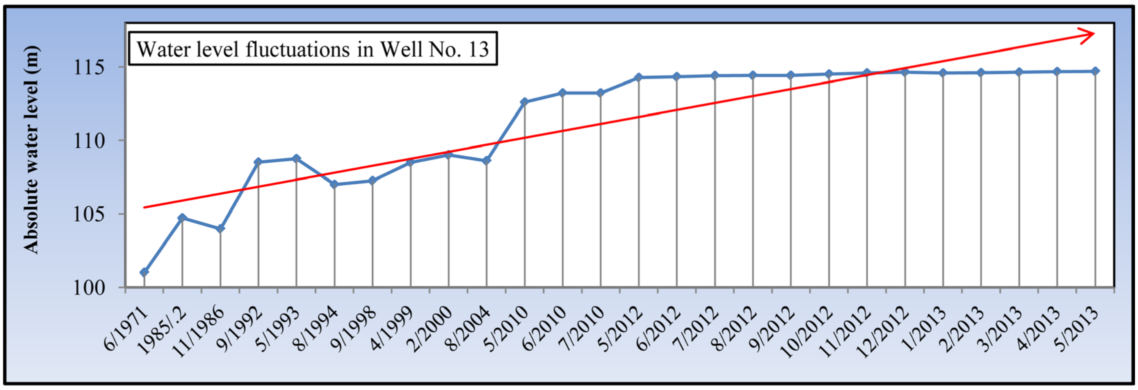
4.1.3. Cessation of Groundwater Pumping

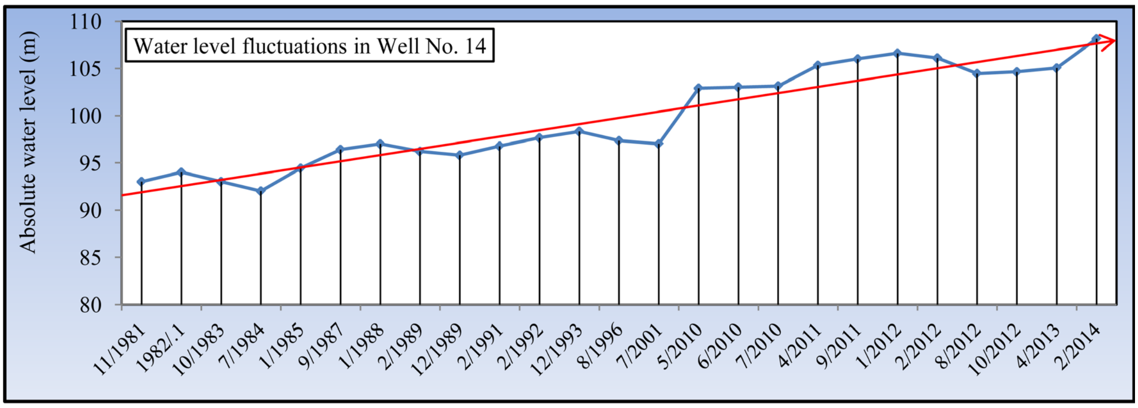
In 2009, 40 productive wells at El Shallal area were turned off, as a result of deteriorated water quality, they were pumped an amount of 12.44×10^6 m^3/year. Moreover, groundwater withdrawals from KIMA factory wells were reduced from 13.23×10^6 m^3/year to 9.12×10^6 m^3/year. This proves that the phenomena of groundwater rising that happened in 2009 at Aswan city, can be directly refereed to the cessation of groundwater pumping from El-Shallal wells, and to reduction of pumping from KIMA factory wells.

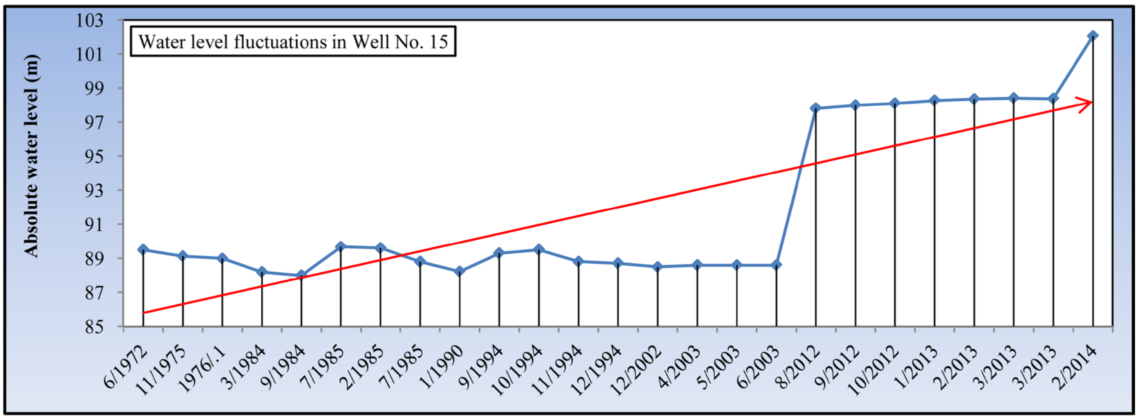
4.1.4. Groundwater Recharge from the Urban Activities of High-Land

Urbanization has a great effect on the groundwater regime especially to subsurface components of infiltration


Water level fluctuations in Well No. 12
Absolute water level (m)
Linear direction
10/1971
6/1975
1/1978
8/1979
1/1980
11/1981
1/1982.
7/1984
2/1985
5/1986
1/1987
1/1988
1/1989
3/1990
9/1991
12/1992
5/1993
2/1999
6/2001
8/2004
2/2010
5/2010
6/2010
8/2011
6/2011


Water level fluctuations in Well No. 13
Absolute water level (m)
6/1971
1985/.2
11/1986
9/1992
5/1993
8/1994
9/1998
4/1999
2/2000
8/2004
5/2010
6/2010
7/2010
5/2012
6/2012
7/2012
8/2012
9/2012
10/2012
11/2012
12/2012
1/2013
2/2013
3/2013
4/2013
5/2013


Water level fluctuations in Well No. 14
Absolute water level (m)
11/1981
1982/.1
10/1983
7/1984
1/1985
9/1987
1/1988
2/1989
12/1989
2/1991
2/1992
12/1993
8/1996
7/2001
5/2010
6/2010
7/2010
4/2011
9/2011
1/2012
2/2012
8/2012
10/2012
4/2013
2/2014


Water level fluctuations in Well No. 15
Absolute water level (m)
6/1972
11/1975
1976/.1
3/1984
9/1984
7/1985
2/1985
7/1985
1/1990
9/1994
10/1994
11/1994
12/1994
12/2002
4/2003
5/2003
6/2003
8/2012
9/2012
10/2012
1/2013
2/2013
3/2013
3/2013
2/2014

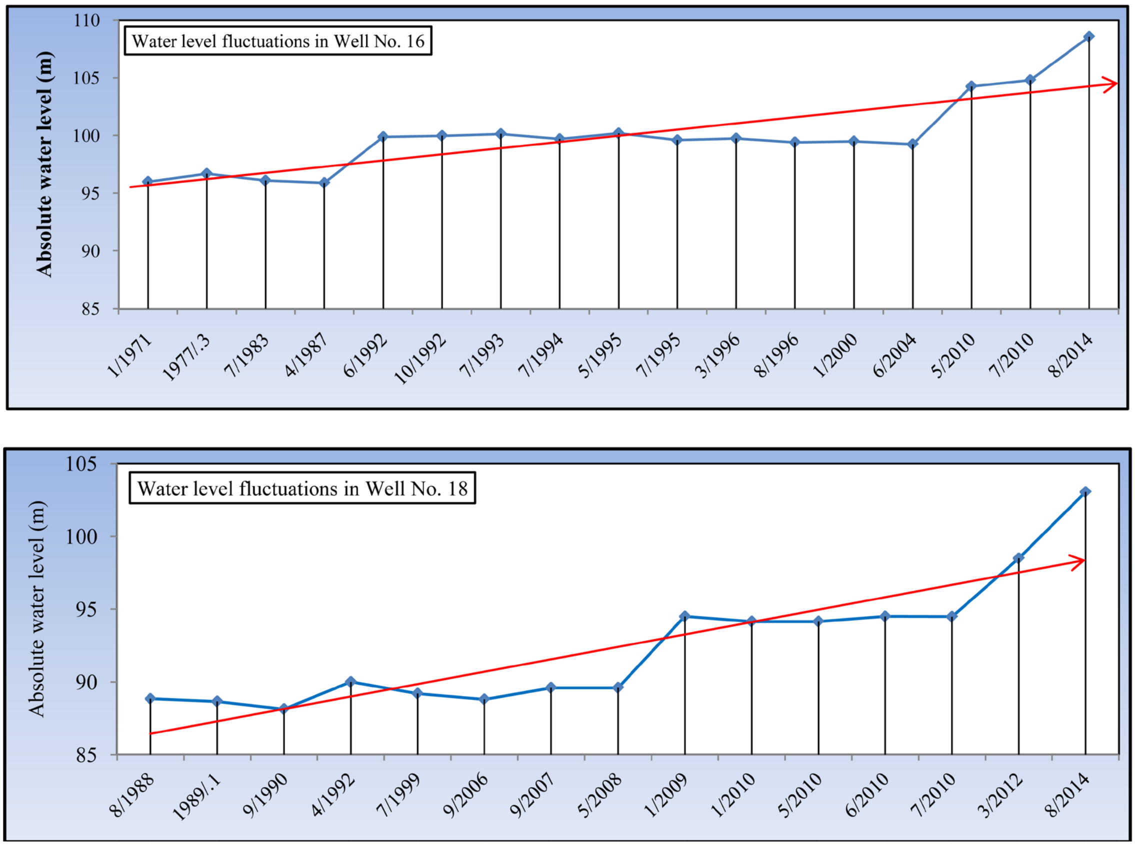


Figure 15. Water level fluctuations in different wells from 1971 till now.

and percolation leading to groundwater recharge. In any urbanization, sanitation and drainage arrangements are of fundamental importance. Quantifying groundwater recharge in urban areas is especially challenging because the urban environment is quite complex as a large variety of land uses coexist and overlap and because of the heterogeneity of the shallow underground.

Aswan city expanded both vertically and horizontally due to unprecedented rapid economic growth after 1970 (**Figure 9**). Unfortunately, neither geological nor hydrological features are taken into consideration in such developments. Water supply from alternative sources and their distribution through the mains cause to water leakages within urban areas, which enhance groundwater table rise. Moreover, the aquifer beneath the urban area is unexploited which leads to continuous groundwater level rising under these areas.

4.1.5. Leakage from Wastewater Sewers, Septic Tanks, and Water Supply System

When sewer lines are located below the water table, they may infiltrate groundwater, and when located above the water table they may leak. Therefore, the seepage from sewage network system itself conceder another problem. Recently in Aswan city area a phenomena of rash of sewage network system on streets (above ground surface) for many times leads to raise the water level and become as other recharge source (**Figure 10**).

Septic tanks, in the parts that are not served by a sewage network system, lead to infiltration of a considerable amount of water to the aquifer and increase the water level. In many parts of the study area, seepage water from water supply networks, even if small amount, give another reason of water rising and flow water to accumulate and appear in low lands.

4.2. Environmental Impacts of Water Level Rising

The magnitude of anthropic impacts upon their environment makes humans the major geologic agent on the surface of the planet [1]. These effects are most severe where population concentrates, today, half of the world's populations live in urban areas. Water quality is a prime issue in urban settings as shallow aquifers and surface waters in cities are subject to pollution by a multitude of point and non-point sources. At Aswan city, the environmental impact of the water level rising includes the following points.

4.2.1. Forming Ponds in Low Lying Areas

In many areas of Aswan city, the continuous increase in the groundwater rising leads to creation of new ponds e.g. Kma, El Shallal, and pond 3 (**Figure 1** and **Figure 8**). These ponds have bad environmental impact to the area, where theymay threaten the community public health. At KIMA factory area, the continuous rising of groundwater level leads to increasing its area and covering new lands (**Figure 11**).

4.2.2. Impact on the Groundwater Quality

A total of 13 water samples were collected from some of affected areas and bore wells from various localities of the city and chemical analyses carried out to assess the groundwater quality.

They analyzed for different physio-chemical parameters (TDS, pH, E.C, TH), major cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}), major anions $\left(HCO_3^-, SO_4^{2-}, Cl^-\right)$, and some trace ions as (PO_4), (NO_2), (NO_3), Fe, and Mn (**Table 2**).

In the study area, the average value of TDS is 2798.1 mg/l (**Table 2**). The relatively high TDS of the analyzed water samples have a bad environmental impact on the infrastructures of the area. The capillary action draws the salty groundwater to the surface and into the porous walls and foundations of the buildings. The dry desert heat causes the evaporation of the water from the walls material leaving behind salt crystals that cause split, flake and crack of these walls (**Figure 12**).

The salt crystals combinations are calculated for both the surface and groundwater samples along the study area. They revealed the presence of different groups of salt assemblages (**Table 2**). The hypothetical salt combination revealed the presence of different salts arranged in terms of their predominant as NaCl, $Ca(HCO_3)_2$, Na_2SO_4, $MgSO_4$, $CaSO_4$, $Mg(HCO_3)_2$, and KCL; where the average of equivalent percentage is 42.18%, 19.16%, 13.68%, 10.42%, 9.01%, 4.34%, and 1.37% respectively. In many spots of the study area, high nitrate, sulphate, chloride and sodium concentrations indicate anthropogenic aquifer pollution and it is most severe where population concentrates.

4.2.3. Growth of Micro-Organism and Algae

Some of the collected water samples were subjected to microbiological measurements for the total bacteria and total Coliform in the study area (**Table 3**). The total Bacteria vary from 20 to 1000 no of colony/100 ml. The total Coliform ranges between 0 and 470 no. of colony/100 ml. In Phatemic graves and KhorAwada, the total bacteria and total Coliform are too numerous to count. The results obtained from the microbiological analysis reflect a presence of bacterial activity in the accumulated water due to rising groundwater level in the study area.

Once a building has been exposed to a large volume of water, may species of micro-organism and algae can growth (**Figure 13**). They are causing bad environmental impact on building and human health. In addition of directly environmental effect on building and human health of pollutants water of micro-organism, the probability of pollutants water to seeps to the drinking fresh water pipes network increase.

4.2.4. Flooding Building's Basements and Inundate Underground Infrastructure

In many locations of the study area, water level rising leads to inundation of the basement of many buildings (**Figure 2** and **Figure 14(b)**). In any urban area, presence of the groundwater for long time has bad environmen-

Table 3. The analytical of total bacteria and total Coliform in some water samples.

Sample No.	Total Coliform (colony/100 ml)	Total Bacteria (colony/100 ml)	Sample No.	Total Coliform (colony/100 ml)	Total Bacteria (colony/100 ml)
well 2	0	20	well 10	470	1000
well 4	0	20	well 11	20	40
well 5	10	50	Aqad	273	400
well 6	250	450	Phatemic graves	Too Numerous to count	Too Numerous to count
well 7	0	500	KhorAwada	Too Numerous to count	Too Numerous to count

tal impact on building, where it causes direct damage to building. **Figure 14(a)** shows clear displacement occurs between the two building as result of water level rising and flooding their basements for long time.

Underground infrastructures that lie beneath many parts in Aswan City, as Communication networks, wastewater sewers system, pipes of drinking water distribution networks, high voltage electrical cables, and others, are flooded by rising groundwater level.

5. Conclusions

Aswan city expanded both vertically and horizontally due to unprecedented rapid economic growth after the year of 1970. Unfortunately, neither geological nor hydrological features are taken into consideration in such developments. As a result of leakages or infiltrations from different sources, the natural groundwater balance is overturned into an unbalance where the input to water table is comparatively much more than the natural groundwater flow.

In this study, the data recorded between 1971 and 2014, are examined in order to determine the general trend in water levels and the change in the water-table over 43-year period. It shows a noticeable variation in the groundwater level during this period, and the water table rising ranges between 12.55 and 13.69 m, which means that there is about 1.37 m groundwater table rise in each year. Recently, an abrupt increase in the water levels is noticed and reached its peak in 2010 continuing up till now. This study proves that the phenomena of groundwater rising can be directly refereed to the cessation of groundwater pumping from El-Shallal wells, and to the reduction of pumping from KIMA factory wells. During these last five years, all the low-lying areas of Aswan city are suffering from groundwater rising. The continuous increase of groundwater level can lead to appearance of new affected areas in other parts at Aswan city.

The environmental impact of the water rising includes: forming ponds in low lying areas (Kima and El Shallal ponds), flooding building's basements, and inundating underground infrastructure. A general deterioration in groundwater quality was identified. Much higher sulphate and alkali and alkaline earth metal concentrations were found in many spots of the study area and it is most severe where population concentrates. Furthermore, the bacteriological investigations show that the total Bacteria vary from 20 to 1000 no. of colony/100 ml and the total Coliform range between 0 and 470 no. of colony/100 ml indicating that local sources are strongly influencing the observed bacteriological data. In some locations (Phatemic graves and KhorAwada), the total bacteria and total Coliform are too numerous to count.

6. Recommendation

The necessary recommendations to decrease and/or prevent water rising problem at Aswan City include re-exploitation of groundwater from El Shallal and Kimawells. Leakages from the networks must be controlled and necessary maintenances are obtained. In the future continuous monitoring of the water level in all the available drilled wells should be taken into consideration where, the continuous increase of groundwater level can lead to appearance of new affected areas in other parts at Aswan city. Moreover, all urbanization activities in the high elevated lands should be under control to decrease water seepage and/or flow to the low elevated lands.

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