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Integrated Water Management in Mala Omer, Erbil, KRI

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***Abstract*- Mala Omer is a small community about 16 km from center of Erbil. Mala Omer faces a rapid population growth.**

The current conducted study was to examine the current situation of water management.

The incremental rate of the population was estimated to be 7.98%. The annual rainfall was estimated to 518 mm. 63.3% is consumed as Evapotranspiration, and 10% as evaporation. While only 18.7% is recharged into the ground and the remainder 8% run to out of the research area as runoff. The abstraction amount of water was estimated to be 3641 m^3/day. The facts showed deficit in water balance estimated to 406485 m^3. More than 80 m water table drawdown has been observed in less than two decades. More research is needed where participation is touted as the best approach in the urban environmental management.

Keywords-component; Water Management, Hydrology, Water Supply

I. INTRODUCTION

Humankind cannot survive more than few days without water. No developments and human achievements would have been achieved without water. Aligned with growth of civilization and population, the required amount of water for human survival increases [1]; however, the water management is complicated. Water management faces rising challenges across the world – from urbanization and increased consumption [2-3], from underinvestment and lack of capacity, from poor management and waste, from the demands of agriculture, energy and food production [4]. Growing demand for freshwater is being challenged [3] and it is not being used sustainably according to needs and demands. Accurate information remains disparate, and management is fragmented. In this context, the future is increasingly uncertain, and risks are set to deepen [4].

The current conducted research dealt with the grounded implemented methods for water management assessment, and gaps were identified and analyzed, comparing with the new trends in water management for solving the problems of water and control the situation for restoration of the quantity and quality of water resources [5].

There are some problems with water, in general, in Asian countries. The water problems in Asia's cities are similar. These include sources and uses of raw water, the large proportion of water loss in distribution networks, intermittent supply, and the quality of tap water. In some cities, the excessive use of groundwater resources has caused serious environmental problems, including rapid depletion of groundwater, deterioration of water quality, and land subsidence. Many cities suffer from inadequate sewerage networks and wastewater treatment systems, while a large majority still depends on septic tanks and other on-site sanitation facilities. As a result, pollution loads in freshwater bodies and groundwater sources have increased substantially [6]. Efforts have been attempted to solve these problems. Some studies had a great success in achieving their goal while others were not as successful as required [7]. On the other hand, there are several instances of water crises. For instance, in Gujarat, India, the groundwater crisis in North Gujarat is severe and likely to become worse. Farmers are already suffering [8]. Therefore, the present study examines the current situation of research area, Mala Omer, regarding water management.

II. MATERIALS AND METHODS

II.I Research Location and Catchment Area

Mala Omer community is the selected site to be implemented for water management and its related environmental concerns research. It is located in the KRI in the North-Northeast of Erbil Governorate, Dashty Hawler District, and it belongs to Kasnazan sub-district. It extends between latitudes 36°17' 0" and 36^{0}19' 0" N and longitudes 44°6'30" and 44°11' 0" E as shown in figure 1. More than 50% of the area is defined as non-cultivated area, however about 30% is agricultural land. In addition, the gardens and ponds are only about 3% of the total research area (Table 2).

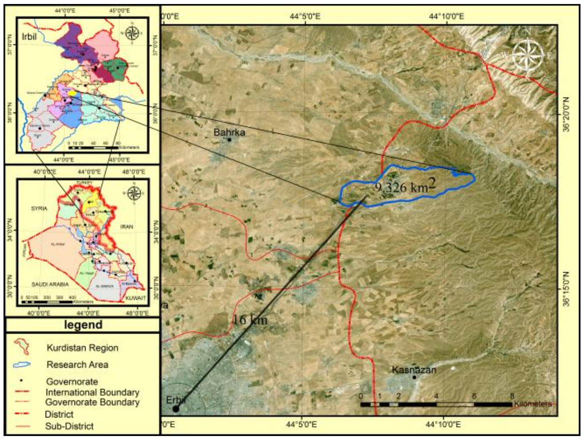

Figure 1: Location map of the research area regarded Kurdistan Region of Iraq.

II.II Data Collection

In terms of information collection a number of sources are used, including written material, interviews with stakeholders and field inspections. For this research journey, there were several decisions to be made: firstly, assessing the problems about the factors that are responsible for ineffective management of water and degradation of water resources and environments, and then to answer it through analyzing the current situation of the area.

II.III Data Analysis

The sources of water were determined by personal interviews with Mala Omer water wells operators and private owner wells. GPS was used to determine wells location, and then, GIS was used to determine the location, topography, watershed delineation, drain pattern network, research area basin contribution to the main river basin, climate interpolation, depth to water level contour map, distance measurement between wells, and land use map. Penman-Monteith equation was used to determine evapotranspiration consumption and then [9]; they were rechecked using Crop-Water Program. Soil Conservation Service Method (SCSM) was used for runoff determination. Thereafter, water that is recharged into the ground was determined by simple mathematical calculations. Future water table drawdown was forecasted in Microsoft Excel. Exponential equation was used for population growth rate forecast.

III.RESULTS AND DISCUSSION

III.I Watershed Delineation

A watershed could be defined as a geographic region, within which hydrological conditions are such that water becomes concentrated within a particular location [10]. Digital data generated by automated techniques also have the advantage that they can be readily imported and analyzed by GIS [11].

The spatial resolution and quality of the Digital Elevation Model (DEM) data are important considerations when deriving hydrographic data from DEM [11-12]. The network and drainage divides were driven form DEM (26x26) m resolution and it is adequate for the present study [12]. The option of spatial analysis tools to select hydrology and watershed delineation through the following steps have been conducted [13].

i. Through site visits and GPS points of the main streams of research area, whose watershed boundaries were identified (Figure 2).
ii. In this step, the mouth of the watershed has been identified. The mouth of the watershed is located just where the two streams meet each other and flow into another stream.
iii. Starting from the mouth of the watershed, and through field visits, and GIS through contour line maps of the research area and surroundings the highest elevations to represent the borders of the catchment as shown in figure (3).

Figure 2: Drain patterns of the research area.
Note: The figure is drawn by the researcher depending on DEM data by GIS 10.2.

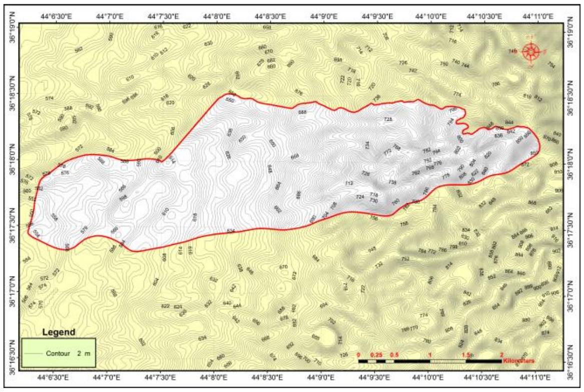

Figure 3: Contour line map of the Research Area with 2m interval.
Note: The figure is drawn by the researcher depending on DEM data by GIS 10.2.

Research area characterized by annual rainfall amount reaches to 500 mm and part of this water evaporate, and some is used by plants in evapotranspiration, some infiltrate to the ground, and the remainder leaves the area as surface water runoff and represents a third order stream for Greater-Zab river drain patterns as shown in figure (4).

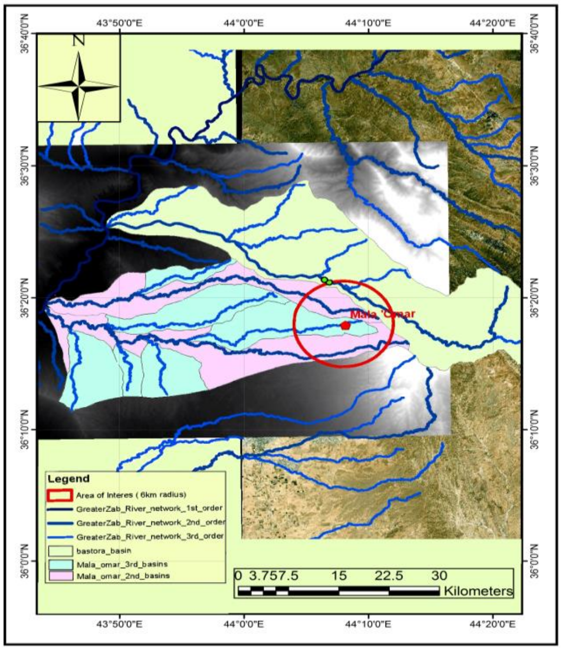

Figure 4: Research area contributed basins.
Note: The figure is drawn by the researcher depending on DEM data by GIS 10.2.

III.II Water Balance:

III.II.I Climate Elements, Evapotranspiration, and Runoff

Catchment area is un-gauged and its climate elements have been resulted from interpolation of the climate elements between Salahaddin and Hawler (Erbil) stations of twenty one years between (1993-2013) using program Arc GIS 10.2[14]. See table 1.

Table 1: Mean monthly climate elements values of the research area.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Evaporation (mm)	42	52	103	135	232	319	349	320	236	158	73	50
Relative Humidity (%)	72	70	61	56	41	32	32	32	36	47	60	67
Daylight (hours)	5	5	6	7	9	12	11	11	10	8	6	5
Wind speed (m/sec)	2	2	3	3	3	3	2	2	2	2	2	2
Vapor pressure (mbar)	8	7	9	11	12	13	15	15	13	11	9	7
Rainfall (mm)	104	92	79	58	21	2	1	0	4	33	49	76
Maximum temperature (°C)	10	12	16	21	29	34	39	38	33	27	18	13
Minimum temperature (°C)	3	4	7	12	17	23	26	26	21	16	9	5

Climate change is a central external driver that affects water demands for all uses directly. Its mitigation and controlling factors, by adaptation means of planning and preparing for increasing hydrological variability and extreme weather events, including floods, droughts, and storms [4]. Figure 4.5 represents the amount of evapotranspiration in the research area which is increasing until reaching its maximum in July and that amount is decreasing after that. This flowing in temperature is related to temperature of the area. The mean temperature riches it's maximum to 39 °C in July (table 1), and therefore, evapotranspiration is maximized to more than 250 mm. see table (4).

The SCSM was used for runoff calculation that was developed by US Army Corps of Engineers uses the following equations:

$$Pe = (P-0.2S)^2/(P+0.8S) \quad (1)$$

$$S = (25400/CN)-254 \quad (2)$$

Where:

Pe: Depth of direct surface runoff in [mm]

P: Depth of rainfall in [mm]

S: is maximum potential difference between rainfall and runoff in mm, starting at the time when the storm begins.

CN: Curve number varying from zero to 100. When CN= 100, S=0 and Pe= P

CN can be obtained from special tables, in which, the values apply to antecedent rainfall condition II (Table 2) for soil type (A), which is an average value for annual floods. According to above factors, SCSM classifies soil into four hydrological soil groups (A, B, C, and D) for condition II, correction factors for other antecedent rainfall conditions should be done using special equation [15].

$$CN = (4.2\,CN2/\,(10-0.058(CN2))) \quad (3)$$

$$CNIII = (23CN2/\,(10+0.13(CN2))) \quad (4)$$

Condition I: Moisture content from wilting point to about lower plastic limit. For this study, September, October and November were considered as condition I, where the soil is dry and it is the beginning of rainfall.

Condition II: Average value for annual floods, where the soil is almost wet. For this study, December, January and February were considered as condition II.

Condition III: The soil is almost at high moisture content and soil potential for infiltration is at low, so runoff increases. For this study, March, April and May were considered as Condition III [15]. Table (4) shows estimated monthly runoff.

Table 2: Antecedent rainfall conditions, CN and correction factors.

Type of land use	Area (Km^2)	Area (%)	CNII	Weighted CNII
Commercial	0.022	0.24	89	0.21
Agricultural	2.933	31.45	67	21.07
Pond	0.029	0.31	0	0
Streets	0.255	2.73	98	2.68
Gardens	0.283	3.04	64	1.94
Non-cultivated areas	4.859	52.10	49	25.53
Residential	0.945	10.13	77	7.80
Total	9.326	100		59.23

III.II.II Current Water Consumption in the Research Area

The amount of the consumed water in the research area is frequently difficult to be accurately estimated. This is due to the absence of any measuring meters, storage tanks with specified times and also missing records of daily amount abstracted from wells; because the main source of water is ground-water wells for supplying water for domestic purposes, agricultural and commercial purposes .

For domestic water supply within the research area there are about 28 wells for water supply for public and 18 of them are operated by government and the other are personnel by public people. For commercial purposes, six wells are operated, two of them for Bafrin apartments and four wells for Khanzad hotel. The other remained 41 wells are used for agricultural, gardens watering and for livestock requirements. The estimated abstracted amounts for different water use sectors are shown in table (3). Most of abstracted water is for domestic uses followed by agricultural and commercial uses [16].

Table 3: Water consumption estimated amounts.

Water occupation	**Abstracted amount (m^3/day)**
Domestic Use	2071
Commercial	671
Agricultural	900
Total	3642

Table 4: Calculated monthly water available and losses elements.

Month	**Rainfall (mm)**	**ET$_0$ (mm)**	**Actual* Runoff (mm)**	**Actual* ET$_0$ (mm)**	**Evaporation (mm)**	**Actual* evaporation (mm)**
Jan	104.1	39.4	19.6	39.4	41.7	42
Feb	92	48.5	14	48.5	52.1	52
Mar	78.6	83.7	0	78.6	103.4	78.6
Apr	57.9	119.5	0	57.9	135.4	57.9
May	21.4	187.7	0	21.4	231.7	21.4
Jun	2.4	229.8	0	2.4	318.7	2.4
Jul	0.8	252.3	0	0.8	348.9	0.8
Aug	0	236.6	0	0	319.6	0
Sep	4	181	0	4	236.1	4
Oct	32.5	129.8	0	32.5	157.8	32.5
Nov	49	69.2	0	49	72.8	49
Dec	75.8	44.2	7.7	44.2	49.7	49.7

* Actual means available rainfall water for evaporation and evapotranspiration, and the remained of precipitation, evapotranspiration and evaporation then available for runoff.

The difference between water precipitation, evapotranspiration, evaporation, and runoff is estimated to be recharged into aquifer as shown below:

$$\text{Aquifer Recharge} = \text{Rainfall} - (\text{Evapotranspiration} + \text{Evaporation} + \text{Runoff}).$$

$$\text{Aquifer Recharge} = 4834598.4 - (3057356.5 + 488265.3 + 385163.8)$$

$$\text{Aquifer Recharge} = 903812.8\ m^3$$

$$\text{Aquifer Recharge} = (903812.8 / 4834598.4) * 100\% = 18.7\% \text{ of precipitation}$$

The annual water abstraction was estimated to be $((3642 m^3/\text{day}) * 365 \text{day} = 1329298\ m^3)$

Then, the water balance condition in the research area is calculated as: see figure (5).

$$\Delta S = 4,834,598.5 + 19,000 - 3,057,356.5 - 488,265.3 - 385,163.8 - 1,329,298$$

$$\Delta S = -406485\ m^3$$

Where 19,000 m^3 are water brought by trucks to the research area.

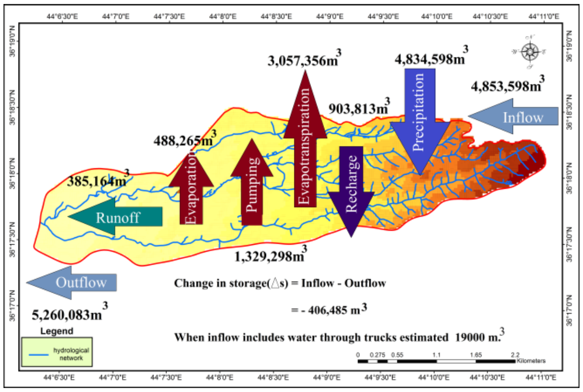

Figure 5: Estimated amounts of water reach and leave research area in m^3/year.

This deficit is equal to 0.31 of the water abstraction which is estimated to 1329298 m^3. Therefore eliminating equivalence rate of pumping of the total wells the watershed balance will be satisfied. In addition it will restrict the groundwater drawdown of the research area.

Worth to mention that the availability of daily climate data could have a significance improvement to the calculation of runoff amounts.

III.III Groundwater and Wells Condition in the Catchment Area

III.III.I Water Abstraction Wells

Sustainable development is achieved when the quality and quantity of the available water from the wells remains unaffected over many years [4]. However, drilling of new wells within research area have never been stopped to protect the yield of the existing, private, and irrigation wells, because this amounted to of a scarce resource are being captured and others are being permanently denied an equitable share of the resource [17]. Not all ground water is readily recharged as in the research area aquifer. Many aquifers have built up their water reserves over millions of years and receive very little infiltrating rainfall annually [12]. The use of ground water at high rates led to ground water depletion [4]. The total 85 wells are in the research area, based on site investigation and government's directorates [16, 18-19] which include legal and illegal wells for public distribution, agricultural and projects that exist there, for supplying water to a hotel called khanzad, which is away from the research area of about 2.5 km to the north-northeast of research area.

III. III. II Groundwater Level

Due to the huge pressure and topography of the research area, the groundwater level faced an extensive lowering of the water table based on the available data for monitoring wells within the research area and surrounded it, 80 meter drawdown was observed in the research area between 2000 and 2014[18]. The expected drawdown reaches to about 65m in average between 2014 and 2030.

III. III. III Groundwater Condition

Groundwater wells were used for supplying water. Seventy-five wells were observed for water to abstract water from the groundwater within the research area. This is a large number of wells to be existed in a small area, which is barely 9.326 km^2, and it is being used in unmanaged ways that have caused a lot of problems in water resources in the research area.

According to the present study findings and as a result of improper water resources management, it has been experienced that the problem of failing to supply water from aquifer with current water management and wells constructed within the research area. In addition, ground water table has been dropped down significantly in 2014, compared to 2000. This is a big threat because it will have huge impacts in the near future. The reasons for this depletion are the reliance of unmanaged use of groundwater; lack of water planning that affected the water losses in the system. This requires strategic protection plans in order to be sustained.

The quantity of water was continuously decreasing in efficiency until it became unable to provide the required water, due to improper planning and water losses through inadequate water network and leakages. The water is pumped out of the well at too high rate, in such an extensive number, in addition to insufficient water wells screening and casing that caused water to not flow through the geologic formation fast enough, [20] to keep the well filled at a required level. Beside over pumping of groundwater would cause significance land subsidence [21] and contamination movement fastening increases towards wells.

Accordingly, it is indispensable to eliminate the number of existed wells to the minimum number of wells. Thus it is easier also to control wellhead protection zone area that should be provided to protect against contamination. Even though, groundwater protection is complex, it should have a potent coordination and commitment on multidisciplinary institutional level and regulatory requirements, environmental and socio-economic impacts as well as its technical requirements [22].

The population of Mala Omer was estimated to 3000 by 1997[23], increased to reach 11855 by the end of 2013 [16], using exponential equation the increment in population estimated to be 7.98%.

Exponential Function
Continuous Change Model [24]

$$\mathbf{A(t) = Pe^{rt}} \qquad (5)$$

A(t) = population after t years
P = initial Population
e = exponential constant
r = annual growth rate
t = time in years
r= 7.98%

It is extreme when compared to Erbil population incremental rate, which equals 2.32% [25]. This difference in the population increase is due to the location of the research area, which is close to Erbil city that made people settle to the research area. Therefore, the government should take serious actions to balance the development in urbanization. As well as controlling the population growth by considering that all parts of the KRG require to be planned on basis of providing the same welfare and entertainment. Hence, people can obtain their life requirements equally.

Land, which has the first priority, was in the development within the research area with no planning and management. This is the first step that should be taken in order to distribute water and plan for future [26]. Aligned with water and other natural resources, our ultimate objectives and sustain production of desired outputs in water and related environment management should be carried out in an integrated approach. The community land use agency should practice land use planning tool to control urban growth. Decisions on these matters affect the future of the urban water demand and economy, for instance, water and livestock, irrigation, commercial and any other water consumption type.

However, to distinguish integrated water management from other land management practices is its holistic consideration of all affecting factors, linking them to each other.

In the research area, integrated water management is mistaken by the most, if not all. The extreme requirement is often missing on the issues that concerns about integration of the water resources with other resources for optimal return of integrated resources. IWRM approach should be implemented within the research area, connecting as much as possible crosscutting requirements in an integration management framework for more equitable, efficient, and sustainable emergence.

The required water, generated waste and runoff waters, aligned with deficit in water supply are important tasks for urban hydrologists to act for integrated and lasting solution of groundwater depletion problems not only to satisfy running municipal water needs. Also to restore depleted (groundwater levels. In addition, storm-water can be used for restoration of the groundwater levels. Wastewater can be, after an adequate treatment, also used for this purpose. In agricultural production of non-consumption crops, wastewater could be used without or after primary treatment only. For crops' consumption, wastewater would be carefully treated to calculate the standards depending on risks for crop uptake of chemical and bacterial pollution [27].

Accordingly, waters should be used in the research area to provide economic well-being to people, without compromising social equity or environmental sustainability. In addition, to fully understand the generic problems of water management, it is necessary to consider water basins as whole units, with stakeholder participation and under the prevalence of good governance. In this way, IWRM aims at enhancing good governance and promoting a balanced development in relation to the social equity, economic growth and environmental sustainability. A strong political commitment is indispensable for decision making and planning process to achieve the balance of all naturally water and environment relevant factors.

IV. CONCLUSIONS

From the present study, it was concluded that the water management strategies implemented within the research area were inadequate, and water supplied to the community was in continuous deterioration. In addition, the most affecting water factors were not taken as integrated part in the water management system and lacked sustainable solutions. Many gaps are existed within the information management system, and what made it more complicated, was the variety of institutions in charge of water and water management with no clear responsibilities.

In addition, over-consumption of groundwater abstraction resulted in a huge depletion in water table level in the research area. Moreover, there was no significance use of waste water and runoff that could be used in the environmental enhancement, irrigation, and groundwater restoration. More research is necessary where participation and legal frameworks are touted as the best approach in the integrated water management.

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