RESIDENTIAL WATER DEMAND IN THE HEBRON DISTRICT

BY

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ABSTRACT

Water demand in the Hebron district like in other West Bank districts is continuously increasing due to the continuous increase in population and industrialization. In this study, an attempt is made to develop several models to estimate the residential water demand for different categories of houses in the Hebron city and major villages of the city, taking into consideration the differences in socio-economic and climatological factors among the city and villages. A socio-economic survey was conducted to collect the relevant needed data.

The study show a number of important conclusion. The present average consumption of water for domestic use in the Hebron district is low and does not represent the present actual demand of water. Some areas in the district has a high water use and other has a low water use because of the difference in way of supplying by water. The total water demand for domestic use in the Hebron district for year 1992 is around 9,000,000 cubic meter per year, 15,500,000 m^3/year for year 2002 and 25,000,000 cubic meter per year for year 2012. The study further show that there are differences in residential water uses among different areas due to different in family size, annual income, water price and water services. The study may be used to predict domestic water use for different type of houses in the Hebron district of West Bank.

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INTRODUCTION

Hebron district is located in the south of the West Bank. It is a mountainous area with an average height of 800 m with respect to sea level. The temperature is moderate in the Summer (20-30 °c) and Winter temperature is low. The Hebron district has a population of approximately 250,000 for 1992.

The wide expansion and accelerated development of the Hebron city, villages and camps had led to an increase in amount of water consumption for domestic, public, irrigational and industrial water uses. At the same time, water supply has not increased in any appreciable manner. The development of the additional water supplies by the Palestinian people is not presently possible because the Israelis Occupation Authorities prevent the digging of new wells. The average consumption of water in the district per capita for all purposes dose not exceed 100 cubic meter per year due to limited quantities of water. This water demand was mostly met by ground water and partially by surface water.

The average annual rainfall in the Hebron district of West Bank under the natural climatic conditions is 550 mm. About 40-50% of this quantity evaporates and the rest stored as either surface water or ground water. In the Hebron district underground water (springs and municipality water) is the main source of water, hence, the amount of ground water recharge from surface water is quite good. In spite of this, the amount of water is not sufficient to meet the present demand of water.

In view of this condition, there is no alternative but to make most efficient utilization of the available water. Making the utmost use of the water resources and promote scientific studies and researches related to water resources. The first step in planning is to estimate the water demand in two dimensions, time and space, and this is the interest of this research.

Previous researches show that the residential water demand rises as the standard of living increases through the establishment of new uses and through the intensifications of old ones. The historical data of water uses of the Hebron district and the dramatic socio-economic changes that started in the last twenty years conform to the above statements. This incredible increase in water use was not only due to increase in population, but due to increase in per capita water use as well. Now the average per capita water use in Hebron city and Halhul village are around 75 and 55 liters per day respectively.

Socio-economic and climatological data of the Hebron-city and some villages were collected and an attempt is made to estimate the residential water in the study area by developing several models. The choice of the independent variables in the proposed model was based on the theoretical background which correlates residential water demand with the socio-economic and climatological variables, the availability of the data, and the cridibility of relationship between the selected independent and dependent variables. The developed models correlate the residential water demands with the family size, annual income, and the availability of garden within the house. Several models were derived to estimate the residential water demand for different types of houses in the study areas of Hebron district of West Bank.

Study Areas

This study covered the Hebron city and four villages. These four villages are: Halhul, Beet Ommar, Dura, and Yatta. Hebron city is divided into five relatively homogeneous areas: Area A, Area B, Area C, Area D, and Area E.

Population

The Population of the Hebron district is increasing rapidly from year to year. As mentioned earlier, the estimated population is 250,000 for year 1992. The population of the Hebron city are 120,000 and the population of the Hebron villages are 130,000.

SOCIO-ECONOMIC SURVEY

In order to estimate the residential water demand for the Hebron city and villages of the West Bank, a socio-economic survey was conducted by the research team. The socio-economic survey was covered the Hebron city and the four major villages of the Hebron city as mentioned earlier. the questionnaire (see Table 1) was designed according to appropriate statistical criteria, using stratified and probablistic sampling. Randomly a street and a starting point where choosen and then every seventh house was selected in the sample, another street was randomly selected and the same procedure were adopted. The process was stepped when the total number of houses in the particular area was completed. A total of 300 questionnaire was used to study all the villages and the city.

The survey started on the first day of August 1992. The survey took three months to complete. A pilot test of 30 application forms was conducted in different places to check the effectiveness (understandability) and reliability of the form and the response of the samples. Some modifications were made as a result of the pilot test. All questionnairs were studied, out of which 30 were rejected (liberty of refusing to answer) due to incomplete and/or contradictory answers. The remaining 270 questionnaire were studied, analyzed and the information was coded and transferred to computer files to detailed analysis.

The climatic and socio-economic factors considered in the study for the Hebron city and the four villages of the Hebron district of West Bank are presented in Table 2. A brief discussion of these factors is presented in the following paragraphs. This discussion highlights how one place differs from another in different levels of income, living standards and the availability of essential services such as water, sewer,etc.

Tabel (1)

QUESTIONNAIRE

EVALUATION OF THE RESIDENTIAL WATER DEMAND

1. Zone:
2. Elevation: - Up - Middle - Down.
3. Address:
4. Method of obtaining water:
   - connected to public network - cisterns - by tankers - others
5. Agreement No.:
6. Average monthly use of water from public network: m^3.
7. Average monthly use of water from cisterns: m^3.
8. Size of cistern: m^3.
9. Average monthly use of water by tankers: m^3.
10. Size of tankers: -8 m^3 -10 m^3 -12 m^3.
11. Price of one cubic meter of water: JD.
12. Monthly expenditure on water: JD.
13. Disposal method of wastewater:
    - Connected to sewerage system - Septic tanks - By tankers - Others.
14. Does the house have a garden? - Yes - No.
15. Number of persons in the family:
16. Type of house:
    - Villa - Apartment - Traditional - Others.
17. Number of rooms:
18. Number of bathrooms:
19. Average yearly income: JD.
20. Do you have objection of reusing wastewater in agriculture or industrial after the treatment?
    - Yes - No - Do not know.
21. If the price of water is highly increased, your water consumption will be change?
    - Yes - No - Do not know.
22. Do you have problem with your water network in the house (i.e. leakage in the pipe)?
    - Yes - No.
23. Do you teach your children to economic water use?
    - Yes - No.
24. Annual Consumption of water (m^3) "Data collected from the Municipality"

- Jan:
- Feb:
- Mar:
- Apr:
- May:
- Jun:
- Jul:
- Aug:
- Sep:
- Oct:
- Nov:
- Dec:

Tabel (2)

CLIMATOLOGICAL AND SOCIO-ECONOMIC DATA FOR STUDY AREAS

City /Village	Hebron City						Villages		
Variables	Area A	Area B	Area C	Area D	Area E	Halhul	Beet Ommar	Dura	Yatta
Average Annual Temperature (°C)	16	16	18	17	18	15	15	18	20
Average Annual Railfall (mm)	550	550	500	500	500	650	650	450	350
Average Family Size	6.0	6.0	6.5	6.5	7.0	6.5	7.0	7.5	8.0
Family Average Annual Income (NIS)	11000	10000	9500	7500	8000	7000	8000	8000	5000
% of Houses Connected to Public Water Network	90	70	60	80	50	90	90	70	90
% of House Connected to Public Sewerage System	90	70	50	95	90	0	0	0	0
% of Houses Having Garden	70	65	45	40	25	20	25	25	5
Per Capita Average Monthly Water Consumption (m^3)	2.9	2.5	2.25	2.0	1.7	1.95	1.95	1.5	1.15

The data show that more or less the average temperature is same for all the places which have a moderate temperature in the Summer (20-30 °c) and the Winter temperature is low. Yatta has a highest average temperature and Halhul has the lowest temperature due to the height with respect to sea level. Rainfall in the Halhul and Beet Ommar is high around 650 mm where in Yatta is comparatively low 350 mm. The average annual rainfall in the Hebron city areas and Dura village are almost same which is about 500 mm.

The average family size in the villages and old places in the Hebron city seems to be more. This may because the people in the other places are more educated and usually they are not going for more children due to the difficulties of life.

The standard living of the people in Area A and Area B of the Hebron city is high due to more average annual income compare to other areas. In the villages the average income of the people is low because most of them are workers or farmers.

Inspite of the almost availability of water networks in all the places as shown in Table 2 (% of houses connected to public network), the water which comes through the networks is not enough and the different places supplement their supply through cisterns or tankers. This condition is because the development of additional water supplies by the Palestinian people is not presently possible because among other restrictions the Israeli Occupation Authorities prevent the digging of new wells. According to that, the data show that Area A, Area B of the city, Halhul, And Beet Ommer are mainly supplied with water through a public network (70-80%) while Area C and Area D of the city are supplied by water through public networks (60%) and through tankers and cisterns (40%). Yatta village is mainly supplied by water through tankers (80%). Area E and Dura village are approximately served by tankers/cistems and network system.

Regarding the sewerage system , 90% of Area A, Area D, and Area E are served with a sewerage system. Area b and Area C are served with only 60%. All the villages are served with septic tanks.

The socio-economic survey showed that Area A and Area B among the city areas and Halhul and Beet Ommer among the villages have the highest water use per household while Yatta has the lowest. This is probably because Yatta village is mainly supplied by water through tankers where the price of water is high around 10NIS/m3 while Area A, Area B, Halhul, and Beet Ommar are mainly supplied by water through public networks and in the same time, these places are located in the way of the main line of water (where the water is always available). Annual water use in Area C and Area D are almost same hence both areas are depend on tankers and public networks equally. Area E and Dura village have low water use for household due to the less water obtained through public networks and depend on tankers.

Only 20-25% of the houses in the villages and Area E have gardens and these are more or less villas. In Area C and Area D around 40% of the houses have gardens where in Area A and Area B the percentage of the houses which have gardens is 65%.

The Average annual income over all the villages is around 8000 NIS per family per year except Yatta which it is little less. The family average annual income in the city is more than the villages which is between 8000-12000 NIS.

As mentioned earlier, the average family size in the villages is more than the city which is around 7.5 where in the city is 6.5 with a narrow range of one within the different places of the city.

RESIDENTIAL WATER DEMAND MODEL

The dependent variable in the proposed model is the annual residential water consumption per household (QYH) in any of the study areas. Residential water use in this study represents the interior and exterior uses of household. The independent variables are: family size of household (FS), average total annual income per family head (IN), average annual temperature (TE) and average annual precipitation (PR). In addition to the above mentioned independent variables, three dummy variables may be utilized to distinguish among different types of houses. The dummy variables were as follows:

GR = 1 A house with a garden.
GR = 0 A house without a garden.

CN = 1 A house supplied by water through the public water system.
CN = 0 A house supplied by water through tankers.

SW = 1 A house connected to the public sewerage system.
SW = 0 A house uses a septic tank as a final disposal.

Symbolically the model can be represented as:

QYH = (FS, IN, TE, PR, GR, CN, SW).

The ordinary least squares (OLS) method was used to find relation between the dependent and the independent variables. The coefficient of determination were to check the significance of the whole model and of each variable in the estimated model. The regression analysis were done with the help of LOTUS software and IBM personal computer.

Different trials were made to develop a different models to estimate the annual residential water consumption per household for each study area using the relevant data of the independent variables of the concerned area. Several predictive equations from different combinations of independent variables for each study area were developed, but some of the independent variables such as temperature and precipitation were find to have inproper signs or statistically insignificant because the average of these two variables are more or less same for all the houses. Transformation of the data to the natural logarithms of the variables resulted in better models. These models have high coefficients of determination (R^2), all the independent variables have the appropriate sign. Several trial equations were estimated to get the best models using the family size (FS), annual income (IN) and garden (GR) variables. The models for Hebron city are:

Area A:

$$QYH = 1.533\ e^{0.16GR}\ FS^{0.44}\ IN^{0.47} \quad \text{.....(1)}$$

Area B:

$$QYH = 2.350\ e^{0.12GR}\ FS^{0.32}\ IN^{0.44} \quad \text{.....(2)}$$

Area C:

$$QYH = 1.370\ e^{0.23GR}\ FS^{0.38}\ IN^{0.47} \quad \text{.....(3)}$$

Area D:

$$QYH = 0.580\ e^{0.19GR}\ FS^{0.43}\ IN^{0.54} \quad \text{.....(4)}$$

Area E:

$$QYH = 2.400\ e^{0.10GR}\ FS^{0.34}\ IN^{0.41} \quad \text{.....(5)}$$

The models for Hebron villages are:

Halhul:

$$QYH = 0.180\ e^{0.13GR}\ FS^{0.63}\ IN^{0.66} \quad \text{.....(6)}$$

Beet Ommar:

$$QYH = 0.860\ e^{0.21GR}\ FS^{0.46}\ IN^{0.49} \quad \text{.....(7)}$$

Dura:

$$QYH = 0.030\ e^{0.15GR}\ FS^{0.75}\ IN^{0.80} \quad \text{.....(8)}$$

Yatta:

$$QYH = 0.190\ FS^{0.59}\ IN^{0.63} \quad \text{.....(9)}$$

The models are also shown in Table 3. To estimate the water consumption for any of the study areas, one simply substitutes the appropriate values of the independent and dummy variables in the above equations.

The derived models show a positive relationship between annual residential water consumption and the family size and the annual family income. It further shows that houses which have gardens use more water than ones without them.

Tabel (3)

ANNUAL RESIDENTIAL WATER CONSUMPTION MODELS IN THE HEBRON DISTRICT

Dependent Variable QYH

Study Areas		Family Size FS	Income IN	Garden GR	Constant	No. of Observation	R.square
Hebron City	Area A	0.44	0.47	0.16	1.53	30	0.95
	Area B	0.32	0.44	0.12	2.34	30	0.91
	Area C	0.38	0.47	0.23	1.37	30	0.93
	Area D	0.43	0.54	0.19	0.58	30	0.94
	Area E	0.34	0.41	0.10	2.40	30	0.87
Halhul		0.63	0.66	0.13	0.18	30	0.88
Beet Ommar		0.46	0.49	0.21	0.86	30	0.89
Dura		0.75	0.80	0.15	0.03	30	0.92
Yatta		0.59	0.63	0.00	0.19	30	0.87

Estimated average residential water use for different types of houses in each area was calculated using the mean values of the independent variables for each area. (see Table 4). The estimated values of the residential water uses were found to be close to the sample values.

In developing several models, 20% of water use were added to the present annual residential water consumption to allow better living standard and economic condition. The addition is made to each house and to all the places before developing the models . So, actually the data given in Table 4 represent the present estimated annual residential water demand per house for different types of houses in the Hebron district in cubic meter. Tables 5 and 6 show the data of the estimated residential water demand per capita in the study areas and estimated total water demand for domestic use in the study areas of the Hebron district. The data obtained from the developing models using the mean values of the independent variables for each area and omiting the variable GR in some cases due to low independent on it.

Tabel (4)

ESTIMATED ANNUAL RESIDENTIAL WATER CONSUMPTION FOR DIFFERENT TYPES OF HOUSES OF HEBRON DISTRICT OF THE WEST BANK IN CUBIC METER PER HOUSE

Study Areas		With Garden	Without Garden
Hebron City			
	Area A	314	268
	Area B	271	240
	Area C	260	207
	Area D	194	161
	Area E	205	185
Hebron Villages			
	Halhul	229	201
	Beet Ommar	212	172
	Dura	209	180
	Yatta	140	140

Tabel (5)

ESTIMATED RESIDANTIAL WATER DEMAND PER CAPITA IN THE STUDY AREAS

Study Areas		m^3/month	m^3/year	liter/day
Hebron city				
	Area A	3.70	44.70	122
	Area B	3.33	40.00	110
	Area C	2.88	34.45	95
	Area D	2.48	29.80	82
	Area E	2.20	26.40	72
Hebron Villages				
	Halhul	2.67	32.00	88
	Beet Ommar	2.52	30.30	83
	Dura	2.00	24.00	66
	Yatta	1.46	17.50	48

Tabel (6)

ESTIMATED TOTAL WATER DEMAND FOR DOMESTIC USE IN THE STUDY AREAS OF HEBRON DISTRICT

Study Areas		Pobulation	Annual Demand	Total Water Demand (m^3/year)
Hebron city				
	Area A	24,000	44.70	1,072,800
	Area B	21,000	40.00	840,000
	Area C	32,000	34.50	1,104,000
	Area D	23,000	29.80	685,400
	Area E	20,000	26.40	528,000
Hebron Villages				
	Halhul	15,000	32.00	480,000
	Beet Ommar	7,000	30.30	212,100
	Dura	30,000	24.00	720,000
	Yatta	23,000	17.50	402,500
Total		195,000		6,044,800

The data of Tables 5 and 6 are the estimated water demand for domestic use in the study areas of the Hebron district which show that Area A of the Hebron city has the heighest residential water demand among the city areas and Halhul village has the heighest residential water demand among the Hebron villages, this condition is due to many factors as mentioned earlier. Now, in order to calculate the actually presently water demand for domestic purposes for the Hebron district of West Bank using the proposed model, the equations of Area A were adopted for Hebron city and aquations of Halhul village were adopted for Hebron villages. Susequently the following models were employed for the Hebron city and Hebron villages and camps which allow adequate (minimum) present water demand:

Hebron city

$$QYH = 1.53\ e^{0.16GR}\ FS^{0.44}\ IN^{0.47} \quad \text{.....(1)}$$

Hebron villages

$$QYH = 0.18\ e^{0.13GR}\ FS^{0.63}\ IN^{0.66} \quad \text{.....(6)}$$

Using the above equations, the data of present residential water demand for the Hebron city and villages were obtaind using the mean values of the independent variables. A figure of 46.5 cubic meter per capita per year were obtained for the Hebron city and 32.0 for the Hebron villages taking into account that most of the villages do not have gardens.

Due to the difficulties in estimating the future family size, average annual income, the availability of water, economic conditions, etc, simple calculation were used in order to calculate the future residential water demand for the Hebron district using the proposed model, the following assumptions have been made:

1. Present annual demand {using equations (1) and (6)}
   - 46.5 cubic meter per capita for the Hebron city.
   - 32.0 cubic meter per capita for the Hebron villages.
2. Rate of increase in the annual water demand per capita = 2%.
3. Design period (time of calculation) = 25 years.
4. Preasent population
   - Hebron city population = 120,000.
   - Hebron villages population = 130,000.
5. Population growth rate = 3%.

Rate of increase in annual water consumption for the design period 2% were adopted according to the expected better economic condition and high standard of living in West Bank and Gaza Strip. In the same time, the rate of increase in water consumption in the other countries ranges from 1%-4%. Of course this rate is decreases and expected to be only 1% in the year 2020.

The population of the Hebron city and villages were estimated at year 2002 and 2012 using the above assumptions. The residential water demand per capita for the same years were calculated. The data obtained were listed in Tables 7, 8, 9 and 10.

The total water demand for domestic porposes in the Hebron district for year 1992 is "9,740,000" cubic meter per year, "15,702,000"cubic meter per year for year 2002 and around "25,320,000" cubic meter for year 2012, which means that water demand will be two and half times in year 2012.

Tabel (7)

RESIDENTIAL WATER DEMAND IN THE HEBRON DISTRICT FOR THE YEAR 1992 (PROPOSED MODEL)

Region	Population	Water Demand (m^3/year)	
		Per Capita	Total
Hebron City	120,000	46.50	5,580,000
Hebron Villages and Camps	130,000	32.00	4,160,000
Total	250,000		9,740,000

Tabel (8)

RESIDENTIAL WATER DEMAND IN THE HEBRON DISTRICT FOR THE YEAR 2002 (PROPOSED MODEL)

Region	Population	Water Demand (m^3/year)	
		Per Capita	Total
Hebron City	160,000	56.70	9,072,000
Hebron Villages and Camps	170,000	39.00	6,630,000
Total	330,000		15,702,000

Tabel (9)

RESIDENTIAL WATER DEMAND IN THE HEBRON DISTRICT FOR THE YEAR 2012 (PROPOSED MODEL)

Region	Population	Water Demand (m^3/year)	
		Per Capita	Total
Hebron City	210,000	69.00	14,490,000
Hebron Villages and Camps	228,000	47.50	10,830,000
Total	438,000		25,320,000

Tabel (10)

RESIDENTIAL WATER DEMAND PER CAPITA FOR THE HEBRON DISTRICT (PROPOSED MODEL)

Region	Year					
	1992		2002		2012	
	l/day	m^3/year	l/day	m^3/year	l/day	m^3/year
Hebron City	127	46.50	155	56.70	189	69.00
Hebron Villages and camps	88	32.00	107	39.00	130	47.50
Total Water Demand for Hebron District (m^3/year)	9,740,000		15,702,000		25,320,000	

SUMMARY AND CONCLUSION

The main conclusions drawn from the present study are summarised below:

1. Restrections on the Palestinian use of the annual ground water resources of the West Bank led to limited quantities availability of water and due to this condition the average consumption of water in the West Bank cities in general is very low and does not represent the present actual demand of water.
2. The socio-economic survey shows that some areas in the Hebron district has a high annual water use per household while the other has low water use. This is because many areas in the Hebron ditrict are mainly supplied with water by tankers where the price of water is high due to low quantities of water run through public water networks.
3. The total water demand for domestic use in the Hebron district for year 1992 is around 9,500,000 cubic meter per year, 15,500,000 cubic meter per year for year 2002 and 25,000,000 cubic meter per year for year 2012 (see Table 10) which means water demand will be three time in year 2012 which is also possible to arranged from our natural water resources as mentioned eariler.
4. The study shows that the residential water uses in houses, within the city or village, which are supplied by water through the public water network are more the residential water uses in houses supplied by a combined system (tankers or cisterns and public water network). This difference in residential water use are mainly due to differences in the price of water supplied by network and tankers.

5. The study further shows that, there are differences in residential water uses among the city areas and villages and between the city and villages (see tables 5 and 6). The differences are due to different family size, income, water price, and water services. The differences for example between the residential water uses in house served by the public network in Yatta and Halhul are mainly due to differences in average annual income.
6. The study also shows that 80-90% of the total annual residential water demand is used within the house (interior use) while 10-15% of the annual entire residential water demand is used for lawn irrigation in the houses have gardens (exterior use). It is assumed the exterior residential water use is equal or close to the differences between the total and interior water uses.

Finally, this study may be used to predict water use as well as to direct water policies towareds conservation of water resources for different types of house in the Hebron distrect of West Bank.

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