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Future Domestic Water Demand for Jeddah City

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Abstract. The paper discusses the present and future (1431-1460 A.H.) water demand and water resources for the domestic use in Jeddah city. Projection of both water demand driven by population as well as water resources are illustrated. Three scenarios are presented representing high, moderate and low cases for the population. Under each case, the level of water shortage problem is addressed and it is shown that without water conservation Jeddah city will face significant water shortage.

Keywords: Jeddah city, domestic water, water shortage, water shortage problem, water resources.

Introduction

The National Development Plans for the Kingdom of Saudi Arabia entail the provision for water of adequate quality to meet public health standards and quantity to provide for the total requirements of the population. Previous surveys (Abu-Rizaiza *et al.,* 1988) have shown that the Jeddah-Makkah-Taif area to be the most water deficit area in the Western Region. Jeddah city is one of the seven large cities in the Kingdom. It has the largest airport and seaport in the Kingdom as it is the major and pivot point en route to the Holy Mosque in Makkah. The population of Jeddah has increased from 916000 capita in 1980 (Allehaibi, 1996) to 2801481 in 2004 (Central Department for Statistics and Information, 2008). In the same period the water supply from Jeddah desalination plant increased from 56.688 million m^3 per year to 142.78 million m^3 per year. Despite the significant increase in the capacity of the

desalination plant, the demand increased substantially due to the large increase of population.

The objectives of this paper are to present the current and future (1431-1460 A.H.) water resources and demands for the domestic water supply. The current water resource is Jeddah desalination plant which will be used to forecast the future water supply as the present rate of development will be retained. The current water demand is decomposed into the population and the demand rate. Based on the current population, three population projection are investigated, namely, low, moderate and high cases. The current demand rate will be retained and then it will be used as one measure for water conservation in order to bring the supply and demand in balance.

Water Supply

Domestic water supply to Jeddah city is mainly from Jeddah desalination plant. Table 1 shows the amounts of desalinated water produced by this plant from 1405 A.H. up to 1416 A.H. (Ministry of Planning, 1995). The rest of the data up to 1429 A.H. was obtained from annual reports of the Saline Water Conversion Cooperation (2004-2009).

Table 1. Water production in thousand m^3 for Jeddah desalination plant.

Year	Production	Year	Production	Year	Production
1405	111568	1414	143474	1423	140777
1406	109347	1415	154335	1424	146234
1407	107760	1416	150049	1425	136377
1408	109380	1417	149731	1426	140352
1409	116837	1418	150603	1427	148896
1410	133056	1419	152574	1428	151231
1411	131011	1420	154544	1429	147715
1412	134861	1421	150503	1430	145648
1413	134818	1422	142110	1431	122273

Projected water production is predicted based on extrapolation of the present production data using linear function as it gives the best fit. Figure.1 illustrates the present and future projection of the desalinated water.

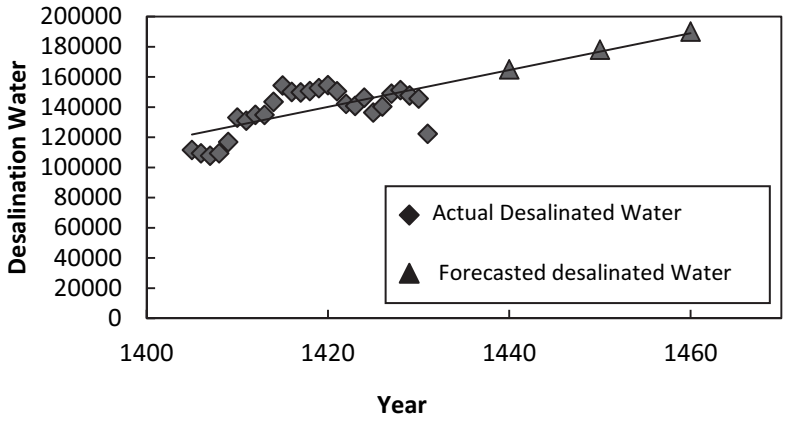

Fig. 1. Actual and forecasted desalinated water in 000' m^3.

Table (1) shows a steady rate of increase of water production. Starting from 1423, Al-Shoaibah desalination plant started diverting about 85 million m^3 of its production of water to Jeddah to improve the supply and combat the shortage.

Water Demand

Water demands are classified into two categories, municipal and industrial. However, as the industrial demands in Jeddah represent about 4% of the total demands, so it will be incorporated within the municipal water demands (Ministry of Economy and Planning, 2008). Municipal water demands can be decomposed into population and rate of water consumption. Population of Jeddah city obtained from data collected from its different municipalities for the years 1980, 1985 and 1990 (Allehaibi, 1996) were found 916000, 1076662 and 1475990 capita respectively. It is to be noticed that these figures include the non-Saudi citizens. Further census at 1413, 1425 and 1431 were conducted. Future estimates of population can be obtained using various methods (Steel and McGhee, 1985). However, due to the lack of lengthy data to conduct a proper population forecast, three simple methods have been used; one that gives high rate of growth, one that gives low rate of growth and an average between the two results to represent a moderate case. The first method that gives a high rate of growth is the Geometrical Progression Method. Under this method, it is assumed that the population growth rate is proportional to the population, *i.e.*

$$\frac{dY}{dt} = K_g\, Y \qquad (1)$$

Where dY/dt is the change in population, Kg is the geometric rate of increase and Y is the population. Integrating Eq. 1 and setting the limits yields;

$$K_g = \frac{lnY_2 - lnY_1}{t_2 - t_1} \qquad (2)$$

Where Y_1 and Y_2 are two consecutive censuses and t_1 and t_2 are the years of these two censuses. Thus the population estimate is given by:

$$lnY_2 = lnY_1 + K_g(t_2 - t_1) \qquad (3)$$

The second low growth rate method is the Arithmetic Method which assumes that the rate of population change has been and will remain constant,

$$\frac{dY}{dt} = K_u \qquad (4)$$

Where K_u is the uniform growth rate. By integrating Eq. 4 and setting the limits, then the population estimate can be written as,

$$Y_2 = Y_1 + K_u(t_2 - t_1) \qquad (5)$$

Finally, the population estimates by the two previous methods along with the average values are given in Table 2 and are shown in Fig. 2.

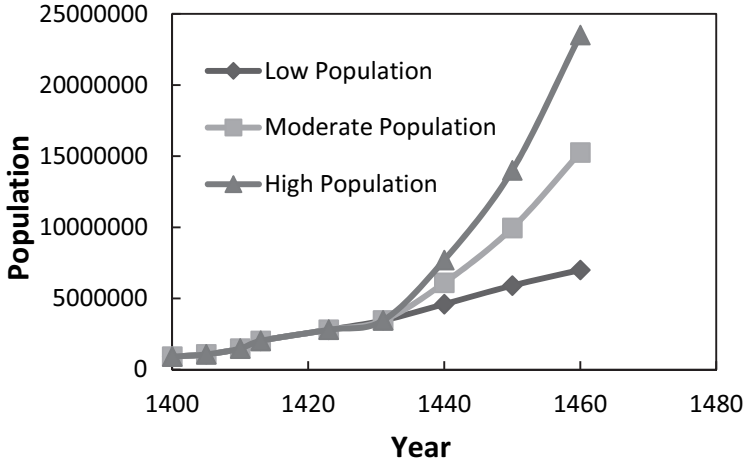

Fig. 2. Actual and forecasted population of Jeddah City.

Table 2. Actual and forecasted future population (Capita) of Jeddah City.

Year	Low Population	Moderate Population	High Population
1400	916000	916000	916000
1405	1076662	1076662	1076662
1410	1475990	1475990	1475990
1413	2021095	2021095	2021095
1423	2801481	2801481	2801481
1431	3456259	3456259	3456259
1440	4381369	5958699	7536028
1450	5310714	9399232	13487750
1460	6240060	15190008	24139956

Water consumption rate is not known as a figure for Jeddah city, however, it can roughly be estimated based on the population and the actual domestic water consumed (Statistics Yearbook, 1995, 2008). The values for years 1413 and 1423 were shown since actual population census were known. The latest Statistics Book 2009 did not show consumption for year 1431. Table 3 shows the estimated water consumption rate. It can be seen that the rate increased substantially in 1405 then it decreased in 1410. A rate of 250 lit/cap/day will be assumed based on engineering judgment.

Table 3. Consumption rate (lit/cap/day).

Year	Population	Water Consumed (m^3)	Consumption rate (lit/capita/day)
1400	916000	68086924	204
1405	1076662	115792000	295
1410	1475990	134309000	249
1413	2021095	141330000	192
1423	2801481	237127000	232

Results, Discussion and Analysis

The results are presented as a comparison between the available water resource and the domestic water use. Figures 3 through 8 illustrate the output resulting from the three different cases high, moderate and low of population growth.

i) Low Case

As shown in Fig. 3, the available water will satisfy the water demand up to year 1435. It is to be noticed that the sudden rise in the water resources at year 1423 is due to the introduction of the new source from Al-Shoaibah desalination plant. After that year, water shortage is

expected. Therefore, conservation measure must be implemented to alleviate the problem. If the rate of consumption is reduced to 200 lit/cap/day, which is a reasonable figure that can be attained, the water will cover the demands to the end of the simulation period, year 1460 as shown in Fig. 4.

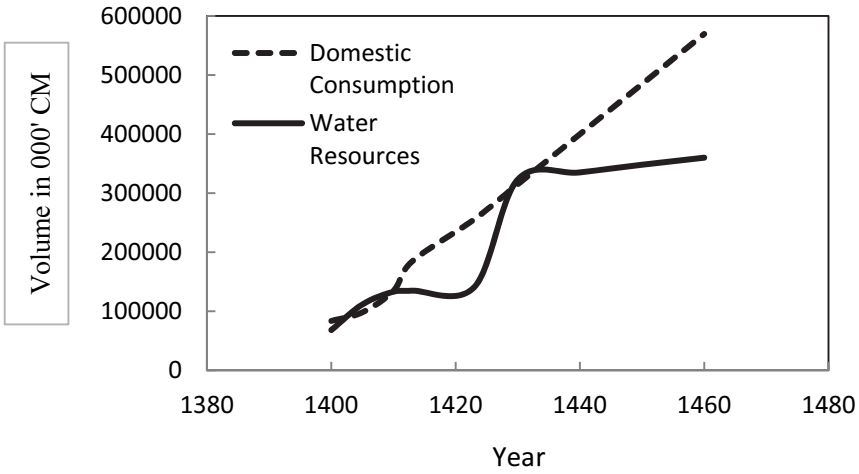

Fig. 3. High case (250 l/cap/day).

ii) Moderate Case

Figure 5 shows that the water shortage problem will be present at year 1432. By reducing the rate of consumption to 200 lit/cap/day, water will cover the demand till year 1442 as shown in Fig. 6.

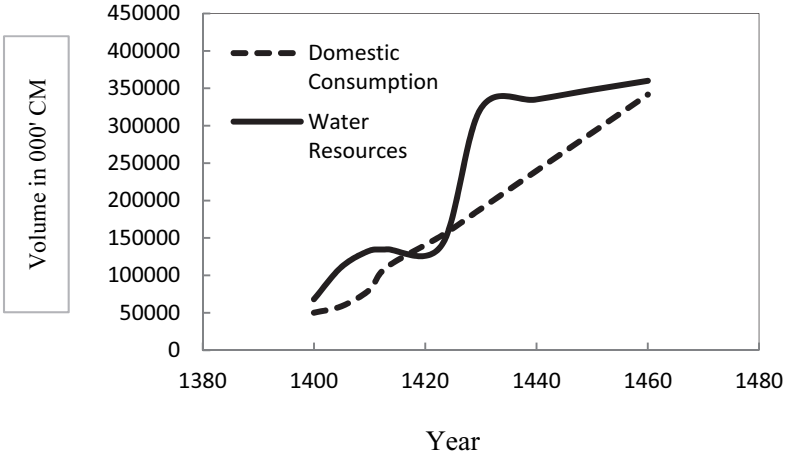

Fig. 4. High Case (200 l/cap/day).

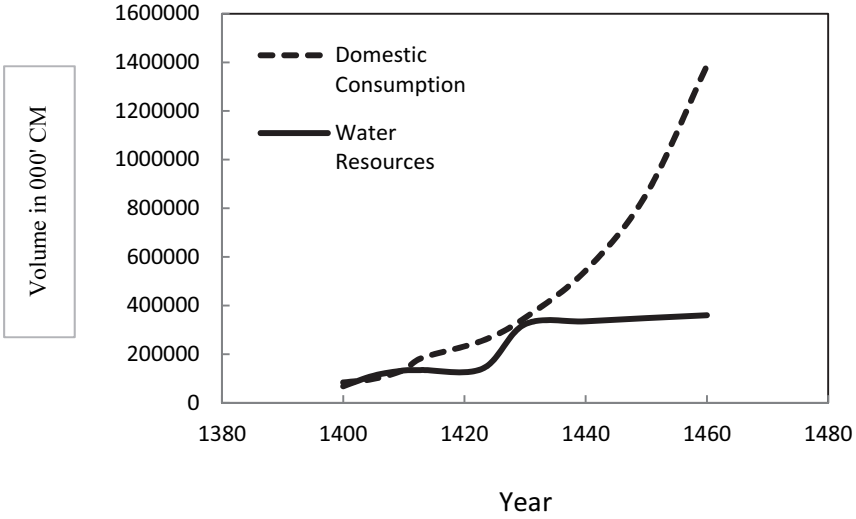

Fig. 5. Moderate case (250 l/cap/day).

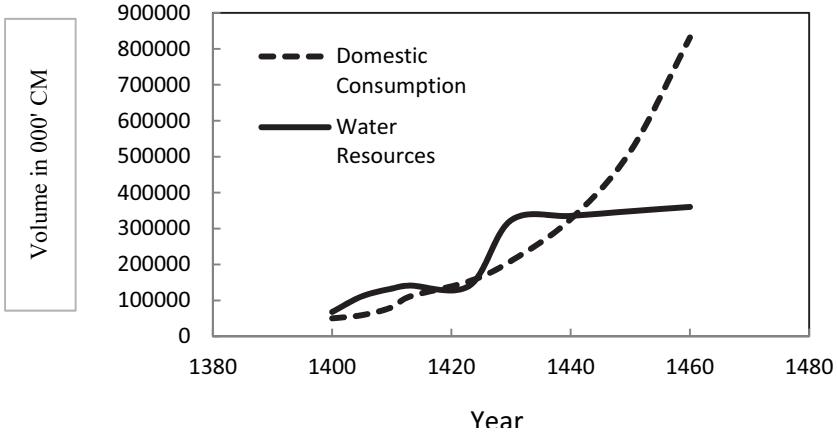

Fig. 6. Moderate case (200 l/cap/day).

iii)High Case

Figure 7 illustrates that water shortage already occurs in this case. While, if the rate of consumption is reduced to 200 lit/cap/day shortage will be delayed up to year 1438 as shown in Fig. 8.

The results point out that water shortage is pound to occur in future even under the moderate case. Therefore, now is the time for earlier planning as the present rate of development of desalination water production is not coping with the rate of increase of population. In fact it

is fortunate that a national campaign is launched to conserve water and it is hoped that this will lead to the reduction of the rate of water consumption.

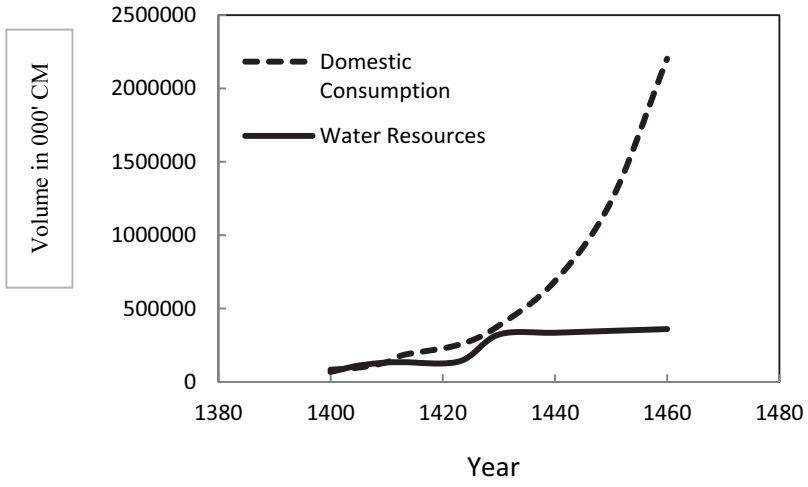

Fig. 7. Low case (250 l/cap/day).

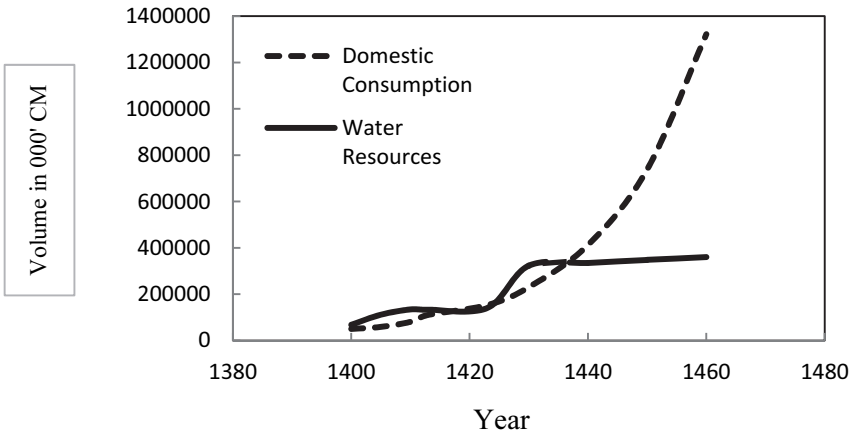

Fig. 8. Low case (200 l/cap/day).

Conclusion

In this paper, it is demonstrated that the current development plan for desalination water for Jeddah city will not cope with the population

increase in the near future. Three cases; high, moderate and low rate for Jeddah population increase are explored. Even under the moderate case it was shown that the current plan can not cover the domestic requirement if the current rate of water consumption is remained unchanged. However, if this rate is reduced to 200 lit/cap/day, the current plan will satisfy the demand up to year 1460 AH only under the low case. If the current conservation plan is successfully carried out, the current development plan will satisfy the demand up to year 1442 AH under the moderate case. Therefore, it is suggested that an increase in the desalination production is needed to satisfy the demands up to year 1460 AH. This is based on the successful execution of the conservation measures being undertaken in the meantime.

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الاحتياجات المستقبلية لمياه الشرب لمدينة جدة

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المستخلص. يناقش البحث الاحتياجات الحالية والمستقبلية (١٤٣١-١٤٦٠) لمياه الشرب لمدينة جدة. حيث تم الاستفادة من البيانات السابقة في توقع الزيادة السكانية وتطور مصادر المياه للمدينة. وبالنسبة للمستقبل فقد تم عرض ثلاثة حالات تمثل الزيادة السكانية المتوقعة (نسبة عالية، نسبة متوسطة ونسبة منخفضة). وفي كل حالة من الحالات الثلاثة، تم استخدام المعدل الحالي للاستهلاك للفرد والمعدل المتوقع في حالة نجاح حملات الترشيد القائمة. وبناء على هذه التوقعات تم تحديد مقدار النقص في المياه المتوقع واستخلاص أنه بدون نجاح خطط الترشيد الحالية واستمرارها فإن مدينة جدة ستعاني من نقص كبير في احتياجات مياه الشرب في المستقبل.

الكلمات الدالة: مدينة جدة، مياه الشرب، نقص المياه، مشكلة تخزين المياه، مصادر المياه.