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Economical Feasibility for the Utilization of Groundwater Model in Kuwait.

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The aim of this technical paper was to design a conceptual system to provide a sustainable water source at a feasible cost. The conceptual design system was developed to address the problem of water scarcity and sustainability in general, and specifically to represent the Kuwaiti water quality and quantity limitation problem. The conceptual design system consists primarily of utilizing brackish groundwater in conjunction with treated wastewater augmentation and a reverse osmosis unit. The economical analysis was based on the calculations of the net present worth value of the cash flows for the capital cost, the operation and maintenance costs, and the revenues of the crop yields (alfalfa) for the 40 years of operation. The benefit-cost ratios for the base case of the general conceptual design system using the lump model approach and the areal distribution model for the three orientation layouts were calculated for ranges of different interest rates. The benefit-cost ratios were feasible for the Middle East condition in general and to the GCC countries in particular, especially at low interest rates.

INTRODUCTION

Water scarcity is the predominant issue in the arid and semi arid countries. In particular, most Middle East countries and the Gulf Cooperation Council (GCC) countries (Kuwait, Saudi Arabia, Bahrain, Qatar, United Arab Emirates, and Oman), in particular, are characterized by extremely arid climate and limited surface water supplies. The major water resource for these countries is groundwater (91%) and desalination of seawater (7.2%). The lack of freshwater resources in these regions constitutes a major deterrent to their sustainable development. In Kuwait, one of the GCC countries, natural resources of fresh water are very limited. Kuwait is situated in an arid coastal region characterized by high temperatures, low humidity, sparse precipitation rates, and high evaporation and evapotranspiration rates with no rivers or lakes. Therefore, Kuwait has always relied on other secure freshwater to meet its growing demands. The water supply in Kuwait can be obtained from three main sources: brackish groundwater, water reuse (treated wastewater), and seawater desalination.

Brackish groundwater exists in reasonable quantities. During 1999, the daily production of brackish groundwater was around 400 million imperial gallons per day (MIGD), which is almost 3 times the annual groundwater inflow (MEW, 2000). Thus, the production of brackish groundwater is exhausting the one and only vital natural water source.

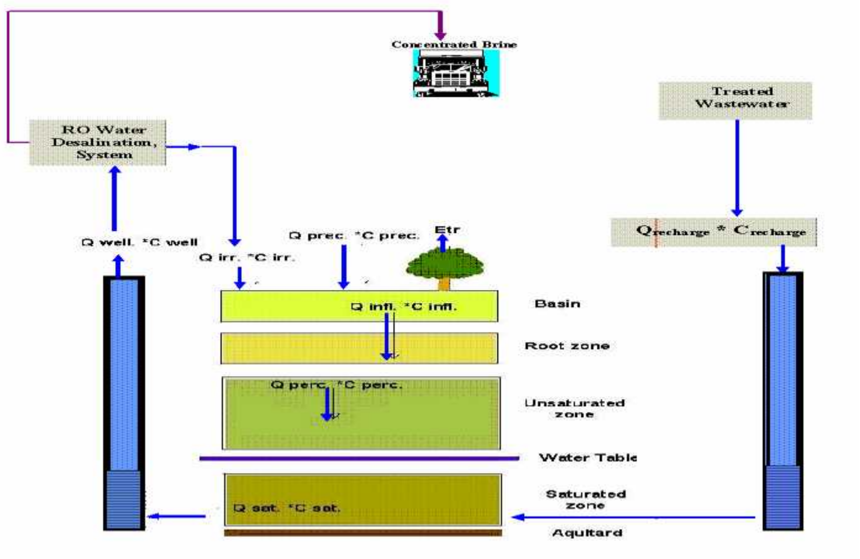
In Kuwait, treated wastewater is an almost unused water source. Urban wastewater is collected, treated and returned to the sea; limited quantities are utilized for landscaping purposes. In Kuwait, wastewater effluent is treated to a secondary or tertiary level. The relatively low salinity of the treated wastewater (1000 mg/l) compared with brackish water of 4000-10000 mg/l makes it a potentially excellent source of good quality water.

The purpose of this paper is to evaluate the feasibility of a conceptual design system utilizing brackish groundwater in conjunction with treated wastewater augmentation and a reverse osmosis unit to achieve water sustainability for crop production (alfalfa). To fulfill this purpose, two main approach models were utilized (lump and areal distribution model) and compared for the most economic feasibility.

MATERIAL AND METHODS

The technical paper considered two types of simulation models for the conceptual design system approach. These models are the lump model approach, and the areal distribution model approach. The lump model approach was carried out through the construction of a simplified model approach utilizing the Visual Basic model. On the other hand, the areal distribution model approach was carried out through the utilization of the Visual MODFLOW and MT3D simulation model approach. The economical feasibility of the general conception design system was analyzed for the lump model simulation approach and for the three orientation layouts of the areal distribution model approach. The economical analysis was based on the calculations of the net present worth value of the cash flows for the capital cost, the operation and maintenance costs, and the revenues of the crop yields for the 40 years of operation. The benefit-cost ratios for the base case of the general conceptual design system using the lump model approach and the areal distribution model for the three orientation layouts were calculated for ranges of different interest rates.

Figure 1 Conceptual design system of implementing a treated wastewater recharge technique and R.O. unit system for water sustainability.



The lump model for the general conception design system was designed to calculate the overall the treated wastewater injected and the system total operation power requirements, within the unconfined saturated aquifer while utilizing the Visual Basic model. On the other hand, the orientation of the pump and injection well location in the areal distribution model (Visual MODFLOW and MT3D model) simulation is very essential. Moreover, the location of the area relative to the groundwater salt concentration is another element of concern in designing the simulation of this model. Furthermore, several layout combinations can be oriented between the pump well locations relative to the injection well location in the hypothetical area. Hence, the location of the pump well to the injection well and the location of the hypothetical field area relative to the groundwater concentration may cause a significant discrepancies in the overall power consumption and total costs of the conceptual design system. Therefore, three orientation layouts for the areal distribution model (Visual MODFLOW and MT3D) simulation will be put under consideration. The simulation layout with the least power consumption and least total cost will be considered for design purposes.

The orientation layout (1) will consist of one pumping groundwater well and one treated wastewater well. The separation distance between the groundwater pump well and the wastewater injection well is 210 m. This large separation distance between the two wells was chosen to resemble the longer time residing and mixing of the inlet and outlet sources salt mass concentration within the groundwater zone. The orientation layout (2) is analogous to the orientation layer (1) except for the location of the hypothetical field area relative to the groundwater salt concentration. Due to the close locations of the groundwater pumping well and the treated wastewater injection well to the location of the field boundary, 48 m, the groundwater salt mass concentration on the adjacent immediate vicinity of the field area will have an affect (if it is different from the salt mass concentration under the field area) on the salt mass concentration of groundwater under the field area. This effect is caused by the mixing and the movement of the groundwater from the immediate adjacent vicinity of the field area to the groundwater under the field area and vise versa, due to pumping and injection practice. .The orientation layout (3) will consist of one pumping groundwater well and one treated wastewater well. The separation distance between the groundwater pump well and the treated wastewater injection well is 20 m. This 20 m is the minimum separation distance between the two wells that will be accepted by the public with regard to practicing simultaneous treated wastewater injection and groundwater pumping.

The economical feasibility of the base case of the general conceptual design system using the lump model and the areal distribution model approach will be based on the calculations of the net present worth value of the cash flows and the benefit-cost ratio theme for the capital cost, the operation and maintenance costs, and the revenues of the crop yields for the 40 years The benefit-cost ratio for the general conceptual design system using the lump model approach and the areal distribution model for the three orientation layouts were calculated for ranges of different interest rates (2%, 4%, 6%, and 8%). These benefit-cost ratios values were calculated for USA and Kuwait conditions. Moreover, calculation of the Kuwait benefit-cost ratio was calculated for electrical power consumption with and without the government electrical power subsidy.

RSULTS

From Table 1, it is obvious that the areal distribution model (orientation layout (3)) simulation approach was the most benefit-cost ratio efficient for all possible ranges of interest rates. Moreover, the second most efficient benefit-cost ratio is the areal distribution model (orientation layout (1)), then, the areal distribution model (orientation layout (2)), and finally the lump model for all possible ranges of interest rates. The benefit-cost ratio was almost equal for both the areal distribution model’s orientation layout (1) and orientation layout (2) for the ranges of interest rates. The percent decrease in benefit-cost ratios for the USA condition between the lump model and the areal distribution model orientation layout (1) is 0.70%, 0.58%, 0.51%, and 0.43% for the interest rates of 2%, 4%, 6%, and 8% respectively. Moreover, the percent decrease in benefit cost ratios for Kuwait with the electrical power subsidy condition between lump model and the areal distribution model orientation layout (1) is 0.0.09%, 0.07%, 0.06%, and 0.06% for the interest rates of 2%, 4%, 6%, and 8% respectively. Furthermore, the percent decrease in benefit-cost ratios for Kuwait without the electrical power subsidy condition between the lump model and the areal distribution model orientation layout (1) is 0.80%, 0.64%, 0.53%, and 0.46% for the interest rates of 2%, 4%, 6%, and 8% respectively. Therefore, the variation difference between the areal distribution orientation layout (1) model and the lump model benefit-cost ratio is minute for all the interest rate ranges. In a conclusion, the lump model approach can safely be substituted for the areal distribution orientation layout (1) and/or orientation layout (2).

Table 1. Benefit-Cost ratios for ranges of different interest rates.

Method	Interest Rate %	Benefit –Cost Ratio USA	Kuwait [a]	Kuwait [b]
Lump Model	2	0.9219	1.1159	1.0261
Lump Model	4	0.8063	0.9525	0.8849
Lump Model	6	0.7054	0.8161	0.7650
Lump Model	8	0.6208	0.7058	0.6665
Areal Distribution Model, Orientation Layout (1)	2	0.9284	1.1169	1.0341
Areal Distribution Model, Orientation Layout (1)	4	0.8110	0.9532	0.8906
Areal Distribution Model, Orientation Layout (1)	6	0.7090	0.8166	0.7691
Areal Distribution Model, Orientation Layout (1)	8	0.6235	0.7062	0.6696
Areal Distribution Model, Orientation Layout (2)	2	0.9277	1.1168	1.0332
Areal Distribution Model, Orientation Layout (2)	4	0.8105	0.9531	0.8900
Areal Distribution Model, Orientation Layout (2)	6	0.7086	0.8166	0.7687
Areal Distribution Model, Orientation Layout (2)	8	0.6232	0.7061	0.6692
Areal Distribution Model, Orientation Layout (3)	2	0.9375	1.1184	1.0453
Areal Distribution Model, Orientation Layout (3)	4	0.8192	0.9544	0.9004
Areal Distribution Model, Orientation Layout (3)	6	0.7161	0.8176	0.7774
Areal Distribution Model, Orientation Layout (3)	8	0.6296	0.7070	0.6766

[a] With electrical power cost subsidy ($0.0066 per Kwatts-Hr); [b] Without electrical power cost subsidy ($0.0595 per Kwatts-Hr).

DISSCUTION AND CONCLUSION

The benefit-cost ratios for all the simulation approaches methods were less than 1, except for the Kuwait condition at interest rate of 2%. As an initial conclusion, from the benefit-cost ratio results, the general conceptual design system is unfeasible for most of the simulation method approaches when the interest rate is higher than 2%. The conceptual design system simulations may not be feasible in the United State of America due to the benefit-cost ratio (less than 1). But for Kuwait, specifically, and the Middle East, in general, food-self efficiency is one of the main aspects of the government's higher political strategy. For that reason, oil wealth is used as a highly valuable commodity traded for food. Thus, the general conceptual design model for the base case simulation can be strongly economically feasible, especially if utilizing the orientation layout (3) design with the 2% interest rate and the electrical power subsidy, where the benefit-cost ratio = 1.1184. Of note, now a day, the government of Kuwait provides long period loans (up to 50 years) with 2% interest rates for small to medium size projects (Industrial Bank of Kuwait). Personally, I strongly recommend the utilization of the orientation layout (1) design, particularly for the low interest rate, where the benefit-cost ratio for 2% is equal to 1.1169. The utilization of orientation layout (1) will give us the benefit, to a larger extent, of enhancing the groundwater salt concentration, which will reduce the vulnerability of possible lateral reduction of the operation system due to emergencies or cost effects. Furthermore, the enhancement of groundwater salt concentration will have a positive impact on the ecosystem and the environment.

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