Water Demand Management in Kuwait

by

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ABSTRACT

Kuwait is an arid country located in the Middle East, with limited access to water resources. Yet water demand per capita is much higher than in other countries in the world, estimated to be around 450 L/capita/day. There are several reasons for such a high demand, but one is certainly the price. Water does have its pricing schedule in Kuwait, but in reality water bills are not collected. The main objective of this thesis is to investigate the impact of water pricing as a tool for managing water demand. The original idea, to construct a water demand model for Kuwait, was modified because of the lack of data about the effect of price increases and household water consumption characteristics in Kuwait. So, water demand models described in the literature for several arid regions were adapted and recalibrated for Kuwait. Simulations describing the influence of block tariffs, constant prices, free allowances followed by various pricing schemes were conducted. A pricing schedule has been proposed that consists of a free allowance followed by a constant price. The proposal has the following logic: if water is consumed wisely, only to satisfy vital needs, it should be free. However, to limit over consumption, the quantity of water over the allowance should be priced. The results showed that this kind of pricing schedule would be efficient in significantly reducing demand. The models show that a price of water of $\$1/m^3$, after a 150L/capita/day allowance, would reduce the demand by about 35 percent (with a range of around 20-40 percent, depending on the demand model used).

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1. Introduction

The quantity of water consumed in Kuwait is estimated to be around 450 L/capita/day (Darwish et al. 2005). When compared to other countries (USA – 333 L /capita/day (EPA); France 164 L/capita /day; Germany 127 L/capita/day (EWA 2005 yearbook)), a need to decrease demand is evident. There are several reasons for such a large demand (temperature, pipeline leakage), but certainly one reason is the fact that water bills are not collected efficiently. Different aspects of water demand management have been studied and an overall approach has been proposed to address Kuwait's large water demand problem.

First, a review of the water resources in Kuwait is presented. Particular attention is dedicated to desalination, since Kuwait gets over 90% of its potable water through desalting plants (Hamoda 2001). The cost to produce water in Kuwait is high, estimated to be around $3/m^3 (Darwish and Al-Najem, 2005)

Next, a literature review of areas that are related to water demand was conducted. A broad review of water demand models found in the literature is presented. Most of the demand models suggest that water consumption is elastic to price increase, with a wide range for elasticity, typically between -0.1 and -0.8. Also a report about water metering and water usage is included. It has been found that water metering has two main advantages: the conservation of water is rewarded, and metering has shown to reduce demand (Lund 1988). Also, studies have shown that around 30% of domestic water use goes for toilets, and about 20% for showering.

The fourth and fifth chapters consist of simulations of water demand in Kuwait using various pricing schemes. The original idea was to develop a water demand model for

Kuwait. However, with the lack of data regarding household water characteristics (water consumption is generally not metered in Kuwait) and the influence that a price increase has on demand (there has not been an increase in the price of water in recent years), the perspective of the research was modified, and water demand models from the literature were adopted for Kuwait.

Chapter four presents the main result of the research. It consists of a price proposal, a free allowance followed by a constant price. The main objective of this proposal is to eliminate the waste of water by pricing it after a certain amount, which would satisfy the basic needs. The quantity of the allowance was proposed to be 150 L/capita/day, an average consumption found in European countries. Simulations of the water demand showed that this pricing schedule would eliminate the waste of water and reduce consumption by about 35% for a price of $\$1/m^3$. Chapter five presents the simulations completed prior the proposal. They were conducted to study the demand models and the influence that various pricing schemes had on demand.

2. Water resources in Kuwait

Kuwait is an arid country located in the Middle East, rich in oil but poor in water resources. The annual average rainfall is around 110 mm, with a variation of 31mm to 242mm. Surface runoff and groundwater recharge from rainfall are rare. This is primary due to factors such as the high potential evapotranspiration rate (Fadlelmawla and Al-Otaibi, 2005).

The main water resources in Kuwait are brackish groundwater, desalination and treated wastewater. Wastewater is treated in three plants in Kuwait to a tertiary level, with an average flow through the plants of 388,000 m^3/day (1999). Depending on the season, between 25-40% of this water is used for irrigation, while the rest is disposed into the sea (Hamoda 2001).

The natural recharge to the groundwater aquifers is smaller than the extraction rate. Fadlelmawla and Al-Otaibi, 2005 cited that the annual groundwater production in 1999 was around 118 million m^3, while under steady-state conditions, the recharge, generated through lateral flow from Saudi Arabia, was estimated to be 44 million m^3/year. Special interest in the thesis was dedicated to desalination in Kuwait, since over 90% of potable water in Kuwait is acquired from desalination (Hamoda 2001).

Desalination

Desalination Technologies

The total desalination capacity of the world is around 37.5 million m^3/day (Abu-Arabi and Reddy, 2005). Based on data from the American Water Works Association (2004) the most frequent desalting technologies are Multistage Flash (44%) and Reverse osmosis (40%), while Electrodialysis represents around 6% of the total capacity. Generally, the processes of desalination can be divided into two main categories: membrane processes (i.e. Reverse Osmosis, Electrodialisys) and thermal processes (i.e. Multistage Flash).

Reverse Osmosis is the dominant approach in the USA. During the process, dissolved ions and water molecules are separated by the use of semipermeable membranes. Based on the dissolved solids' concentrations, desired recovery, and specific membrane performance, a pump provides the required pressure. The technology does not require as large energy consumption as the thermal processes. Electrodialysis is used for salinities smaller than 2000 mg/l, and mainly for smaller facilities.

Membrane processes are mostly used in countries with low energy costs (Middle East). In the Multistage Flash technology (MSF) water is heated in a brine heater, then flows through a number of vessels (stages), where the pressure is lowered, causing water to immediately boil. In every next stage, the pressure is lower, so no additional heat needs to be added. Frequently the MSF plants are combined with electric power plants to reduce energy consumption. Multiple Effect Distillation (MED), similar to the MSF, has a number of vessels with variations in pressure in temperature. MED has a higher performance ratio and works with lower temperatures than the MSF (AWWA, 2004)

Costs

The cost to desalinate water depends on the type of desalination process, energy costs, and labor cost. The AWWA (2004) presents the next information concerning costs.

The costs can be divided into Capital and O&M costs. The Capital costs are construction and incidentals costs. Capital costs are a function of the quality of the source of water, production goals, capacity (bigger capacity- smaller cost), brine disposal, etc. The typical construction costs for a 19,000 m^3/day capacity plant are \$0.8-\$1.5 per l/day installed cap for a sea-water desalting plant and \$0.3-\$0.5 per L/day installed capacity for a brackish water plant. Operation & Maintenance cover the costs of power, labor, chemicals, membrane replacement, etc. A sea-water desalting plant (19,000m^3/day capacity) would have a desalination water cost of \$0.4-\$0.65 per m^3, while a brackish water plant would obtain a cost of \$0.15-\$0.3 per m^3.

Abu -Arabi and Reddy (MEDRC, 2005) cite that for the Multistage flash, the capital cost would be US\$ 1.3 to 1.6 per installed L/day, while the desalinated water cost would be US\$ 0.8 to 1.5 per m^3. For the MED the authors present that the capital costs would be \$0.9-1.2 per installed L/day and O&M costs of \$0.7-1/m3. For other technologies they show smaller expenses. Wangnick (2002) assumes that the total costs could be split up into 40% for interest and depreciation and 60% for the running costs. However, these references do not provide what energy cost is assumed, that is important due to the frequent changes in the cost of oil

Desalination Capacity in Kuwait

The first desalination plant was built in Kuwait in the 1950s. Currently, Kuwait possesses 6% of the world capacity. The following tables represent the total desalination capacities (Table 2.1), the capacities of various desalting processes (Table 2.2), and the capacities of the Multi-Stage Flash plants (Table 2.3), as the dominate technology.

Table 2.1: Total Capacity in Kuwait (Darwish et al, 2000)

Annual Production rate	Average production rate	Maximum production rate	Installed capacity
[M m3/year]	[M m3/day]	[M m3/day]	[M m3/day]
375.17	1.023	1.26	1.6

Table 2.2: Total capacities for various desalination processes (Dr. Al-Sabeeh, 2001)

Type of Plant	Capacity [m3/day]
Multi Stage flash	1,468,750
Multi effect -	11,672
Vapor compression	150
Reverse Osmosis	166,472
Electrodialysis	5,093
Total	1,800,000

Table 2.3: Multi Stage Flash Plant Capacities (Hamoda, 2001)

Plant	CAPACITY [M m3/day]	CAPACITY [M m3/year]	YEAR
Shuwaikh	0.082	29.9	1960
Shuaiba south	0.136	49.6	1971
Doha east	0.437	159.5	1978
Doha west	0.192	70.1	1983
Az-Zour South	0.328	119.7	1988
Total	1.175	428.9	

Darwish, et al. (2002, 2004, 2005) published a number of articles about desalination in Kuwait. He cited that all Kuwait MSF units (except three in the Shuwaikh plant) are combined with electrical power plants to conserve energy (Cogeneration Power Desalting Plants, CPDP). Around 10% of the oil production in Kuwait was used for power and water production, of that 20% of the fuel that is used in the cogeneration power desalting plants in Kuwait in 2003 was used for desalination. Darwish estimated that if the power cost is \$0.06/kWh, then the energy cost to produce one cubic meter of water is \$1.32 (based on 22kWh/m^3 and a price of oil around \$40/barrel). He assumed that if the energy cost is 45% of the total water cost, the cost will be in the range of \$3/m^3 (2002).

The total cost of fuel for water desalination was 612.3 million US dollars in 1999 (Hamoda, 2001)

Zhou and Tol (2005) show that currently water can be desalinated using the MSF technology for 1$/m^3. They also developed a regression model for estimating the cost to desalinate water using various technologies. For the MSF plants, two forms of the model are presented, a semi-log and a double log form. They present that the average unit cost to desalt 1m^3 of water is a function of the total cumulative installed capacity (TIC), the capacity of a single plant (CAP), the contract year of the plant (YEAR), and regional (MENA) and raw water quality dummies (SEA). TIC and YEAR are correlated, so they are not used the in the same model (either one or the other). The regression function (2.1) has the next form when the YEAR dummy is used for the log-log form of the model:

$$Log(UNITC) = \alpha_0 + \alpha_1 \cdot \log(CAP) + \alpha_2 \cdot \log(Year) + \alpha_2 \cdot \log(CAP) + MENA + SEA \quad (2.1)$$

Table 2.4. – Variables and coefficients used in Zhou and Tol (2005) model

coefficient	variable description	Coefficients for the Log-Log model 2
UNITC	average unit cost of desalting water	
α_0	Constant	798.76
α_1	CAP (Capacity of a single plant)	-0.14
α_2	YEAR (contract year of the plant)	-105.02
MENA	ME&NA (regional dummy)	0.05
SEA	SEA(Raw water quality dummy)	0.69

With input data from Table 2.3 (Hamoda, 2001), a cost to desalt water of $2/m^3 was calculated for Kuwait Multistage Flash Plants. This big value was obtained because of the old age of some of the plants. The model does not include changes of oil prices.

3.1 Water Demand Models – Literature Review

3.11. Introduction

With the increase in worldwide water demand over the last few decades, water utilities face problems of supplying the quantity of demanded water. Water pricing, together with other options, showed to be an efficient tool in controlling water consumption. Many studies have researched the influence of pricing. The Journals "Land Economics" and "Water Resources Research" have dedicated much space to this study.

A number of the studies were influenced by or used previous research developed in the study of electricity demand (i.e. Taylor 1975, Nordin 1976). Most of the studies are regression models based on data collected during various surveys, in regions where water prices increased.

In a large number of water demand studies, there are many different approaches. There is no consensus on the correct method to predict the demand for water. This is in part influenced by the fact that every region has its own characteristics regarding water use and socio-economic influences. Most studies find that household characteristics, water prices, climate and seasonal changes and conservation campaigns influence price elasticity.

Water demand studies started in the 1960 and 70s mainly in the USA. In the 1980s, the number of studies increased significantly, mostly encountering regression models based on various data sets in water scarce areas of the US. In the 1990s, conservation methods and water efficient technologies received more attention. Also, a number of studies were done in European and other countries. In addition, some new methods were investigated in order to predict the water demand.

This literature review presents specifications of the models, variables used, technology changes, non-price policies, and some new studies in this field that differ from earlier research.

3.12. Models Specification

Form

Most of the demand models are regression models. They typically use the form Q = f (P, Z) where P are the price variables and Z are factors such as income, household characteristics, weather, etc (Arbues et al. 2003). The most common forms are linear and logarithmic. There is no agreement about which functional form gives better results. Some researchers specify the form by seeing which model better fits their data set. Billing and Agthe (1980) cite that the elasticity in the log model is more useful if the demand is a rectangular parabola, while the elasticity in the linear form is more useful if water demand is linear over a relevant range.

The main flaw that researchers attribute to the linear model is that at some price, the demand for water will be zero, which is not logical as a minimum level of water consumption is needed to survive (Arbues et al, 2003).

Estimation methods

Different estimation methods are used in the studies. The most common are Ordinary Least Squares (OLS), Two and Three -Stage Least Squares (2SLS, 3SLS), and Maximum Likelihood. The choice of the method is somewhat influenced by the data set that the researcher possesses

Data sets

A number of different datasets have been used, ranging from individual household data to aggregate data. A number of the studies used surveys conducted on a sample of households (Rizaiza 1991, Dandy et al. 1997, Renwick and Archibald 1998), other researchers used surveys conducted by the American Waterworks Association (Nieswiadomy - 1984 survey, Foster and Beattie – 1960 survey).

Researches used cross-sectional data (Foster and Beattie 1979, Chicione and Ramammurthy 1986, etc.), times-series data (Billings 1982), and most commonly cross-sectional-times series data (Nieswiadomy and Molina 1989, Renwick and Archibald 1998, Chicione and Ramamurthy 1986, etc.).

3.13. Variables

Household characteristics

Household characteristics are an important factor influencing water demand. All studies include monthly household income as a significant variable that increases water demand. In the deficiency of income data, some demand models use property value as an alternative (Dandy et al 1997).

A number of researchers include lot size as a significant variable (Renwick et al 1998; Dandy et al 1997; Lyman 1992, etc.). Houses with larger lot sizes are expected to have larger outdoor water use (Renwick and Green 1998). Also, household size was frequently used in the demand equation (Nieswiadomy 1992, Renwick et al 1998, Dandy 1997 etc.) as having significant influence on demand. Density of households (Foster, Renwick 1998; Nauges

2000), the number of faucets and age distribution of household members (Lyman1992) are used in some studies too. Table 3.1 presents income and household size elasticities found in some water demand studies.

Table 3.1. : Income and household size elasticity from various studies				
Author	Study area	model	Income elasticity	Household size
Hewitt and Hanemann	Texas	D/C	0.15	
Renwick, Archibald 1998	California	linear	0.36	
Dandy et al 1997*	Australia	Linear	SR: 0.14 | LR: 0.32-0.38	SR 0.04; LR 0.19
Griffin et al(1990)	Texas	linear	0.3-0.48	

*Dandy et al. in his annual model used property value as an indicator of income
(SR –short range; LR – Long range)

Some models include lagged consumption in their models (Dandy et al. 1997, Nieswiadomy and Molina 1991). The Dynamic model, with an included lagged consumption, is used because water use tends to respond slowly to changes in price and other variables, because water-using durables, like washing machines, swimming pools, etc. tend to change only steadily (Dandy et al. 1997).

Price Variables

The most common question in the water demand literature is whether the average price or the marginal price combined with the difference variable should be used as the price variable in the demand equation. Although it has been the subject of a thorough debate in the literature, a consensus has not been reached yet.

<u>The Debate</u>: Howe and Linawever (1967) cited that using the marginal price alone will have invalid results in the presence of block tariffs. Taylor (1975) suggested an alternative method

by including two price-related variables in the estimating model, when block rates are applied. Nordin (1976) modified it, citing that the second price variable should be the difference between the consumers actual bill and what would be paid if all units were purchased at the marginal price (in the case of a declining block tariffs for electricity). Billings and Agthe (1980) implement the difference variable under increasing block tariffs for water demand, showing that it is correct and statistically significant. Economic theory suggests that the coefficients in front of the difference variable and income variables should be the same magnitude, but with opposite signs. However, empirical evidence shows that the coefficient on income and difference should have different signs, but with a bigger coefficient in front of the income variable.

Billings and Agthe (1980, 1982) argue that the use of the average price will generate bigger elasticities when a block pricing schedule is implied, especially when the marginal price increases, while the intra-marginal rates remain the same. In this case the change in marginal price is greater than the change in average price. A possible situation is that with an increase in MP, the AP remains constant or even decreases. Billings and Agthe (1980, 1982) also cite that the effect of a change in rates may have different effects on water use; the use of average price alone ignores this, and produces less accurate results

In many recent studies on water demand, the MP combined with the difference variable is used to show price elasticities (Renwick and Archibald (1998); Renwick, Green, and McCorkle (1998); Dandy, Nguyen, and Davies (1997); Nieswiadomy and Molina (1989)).

However, many earlier studies use the average price (Wong 1972, Young 1973, Foster and Beattie 1979). In their studies Foster and Beattie (1981) recognize that the Nordin specification (the use of MP and difference variable) was not significantly different that the average price specification. They also emphasize questions regarding the knowledge that consumers have on their MP and the way of block pricing and if their reaction is actually set according to the average price.

Shin (1985) constructed a price perception model for electricity demand that describes the response of consumers to MP or AP. He cited that the average consumer does not know the actual rate schedule. Nieswiadomy (1992) gives reasons supporting the average price variable because of the difficulty of determining the actual water usage during the month, as water meters are difficult to read. In addition he cites the difficulty of knowing when blocks have been switched and the fact sewer charges can confuse the consumer.

Shin (1985) defines the price perception parameter as $P^* = MP\ (AP/MP)^k$, where k is the price perception parameter. Thus, if $k = 0$ the consumer responds only to the MP, if $k = 1$ then the consumer responds only to the average price. If $0 < k < 1$ then the price perceived is between AP and MP. Shin finds that electricity consumers react to average prices in his study. Nieswiadomy (1992) tests the Shin model for water demand. His results indicate that consumers react more to average prices than to marginal prices; k is approximately equal to 1 (although in his 1991 study he found that consumers react to marginal prices)

Opaluch (1982) also suggests a test concerning the measure of the price to which consumers respond, for a two block tariff schedule. The hypothesis was conducted through a thorough utility theoretical framework by Opaluch (1981). He suggests a demand equation: $Q = B_3 + B_1 \cdot P_x + B_2 \cdot P_2 + B_3 \cdot \left(\frac{(P_1 - P_2) \cdot Q_1}{Q} \right) + B_4 \cdot (Y - (P_1 - P_2) \cdot Q_1)$ where:

Q – total purchases of the goods subject to block pricing

P_x – price index for other relevant goods

P_1 – price of Q in the first block

Q_1 – quantity of the good which is subject to the initial block pricing (P_1)

Y – total income of the consumer

The average price is $AP = \frac{P_1 \cdot Q_1 + P_2 \cdot (Q - Q_1)}{Q} = P_2 + \frac{(P_1 - P_2) \cdot Q_1}{Q}$. If the consumers react to the block tariff schedule, then $B_3 = 0$, and the demand equation reduces to Nordin's specification. If the consumers react to the average price, $B_2 = B_3$ the equation uses average price as a variable.

<u>The Conclusion:</u> A number of studies accept the idea that the preferences between different price specifications are influenced by empirical rather then theoretical factors. Foster and Beattie (1979, 1981) state that the price schedule to which consumers react should be a subject for testing with available data. Basically, if the consumers think the water bill is significant, they will put in the effort to learn about the pricing schedule and their exact consumption and marginal price. Otherwise, where the water bill represents a small percentage of income, the consumer will react to the average price (Nieswiadomy 1992, Shin 1985)

A review of accounted price elasticities and price variables used in various studies are presented on Table 3.2.

Table 3.2. : Summary of price elasticities in some studies of residential water demand				
Authors		**Study area**	**Price variable**	**Price Elasticity**
Howe and Linaweaver (1967)*		USA	AP	-0.23
Gibbs (1978)*		Miami, Florida		-0.51
Foster and Beattie (1980)	Exponential	USA	AP	-0.35 to -0.76
Billings (1982)	Lin/Log	Tucson, Arizona	MP & D	-0.66/-0.56
Schefter and David (1985)*		Wisconsin		-0.12
Chicoine et al. (1986)*		Illinois		-0.71
Chicoine and Ramamurthy (1986)	Linear	Illinois	MP (AP)	-0.6 on MP
Nieswiadomy and Molina (1989)	Linear	Denton, Texas	MP & D	-0.86
Griffin and Chang (1990)	Linear	USA	AP	-0.16 to -0.37
Riazaiza (1991)	Logarithmic	Saudi Arabia	AP	-0.4 to -0.78
Hansen (1996)*		Copenhagen, Denmark		-0.10
Renwick and Archibald (1997)	Linear	California	MP & D	-0.33
Hoglund (1997)	Linear	Sweden	MP & AP	-0.20 on AP
Dandi et al. (1997)	Linear	Australia	MP & D	-0.63 to -0.77
Renwick, Green, McCorkle (1998)	Logarithmic	California	MP & D	-0.16 to -0.21
Nauges and Thomas (2000)	Linear	France	AP (&MP)	-0.22
Ayadi et al.(2003)	Logarithmic	Tunisia	AP	-0.17

* Data from Nauges and Thomas (2000)

Seasonal and Climate Variables

Most researchers found that seasonal changes and climates influence water consumption. However, they used different variables. Billings et al. (1980,1982) use evapotranspiration from Bermuda grass minus rainfall, Dandy et al. (1997) use moisture deficit (MD = PE-0.6R, where 0.6R = effective rainfall, MD = moisture deficit, but only for the summer demand), Foster and Beattie (1981) use precipitation during growing season, Ajadi et al (2003) used rainfall, while Nieswiadomy and Molina (1991) used weather as a variable.

A Number of studies also use temperature in their models (Nieswiadomy, Renwick et al., Riaza, etc.). Renwick et al. (1998) included the influence of temperature and rainfall in their water demand model. Following Chesnutt and Mcspadden, they present two equations for influences that temperature and climate have on demand. To include the influence of seasonality these equations used sine and cosine Fourier series for the maximum daily air temp (3.1) and cumulative monthly precipitation (3.2). These values are then included into the demand equation.

$$: \ln(DTEMP) = \gamma_0 + \sum_{1}^{6}\left\{\gamma_{1,j}^{tp} \cdot \sin\left(\frac{2\pi jt}{12}\right) + \gamma_{2,j} \cdot \cos\left(\frac{2\pi jt}{12}\right)\right\} + e_{it}^{tp} \quad (3.1)$$

$$: \ln(DPREC) = \gamma_0 + \sum_{1}^{6}\left\{\gamma_{1,j}^{pr} \cdot \sin\left(\frac{2\pi jt}{12}\right) + \gamma_{2,j} \cdot \cos\left(\frac{2\pi jt}{12}\right)\right\} + e_{it}^{pr} \quad (3.2)$$

A number of studies found that summer demand is more elastic to price increase than is winter demand (Lyman 1992, Dandy et al. 1997, Griffin and Chang, etc.). Dandy used seasonal models (winter and summer) in his studies. Also studies have found that outdoor water use is more elastic than indoor.

Nieswiadomy cites that in a log-log model temperature has a nonlinear relationship with demand; the marginal impact of temperature goes up with increases of temperature; he also cites that variations of temperature below 18C have no impact on water demand.

3.14. Effects of Non-Price Policy on Household Demand

Previous studies have shown that non-price policies reduce demand. Renwick and Green (1998) showed that non-price Demand side Management (DSM) policy instrumnets have influence on demand. In their demand equation they included six variables: Public information campaigns (INFO), distribution of free retrofit kits (RETRO), low-flow toilet rebate programs (REBATE), water rationing policies (RATION), water use restrictions (RESTRICT), compliance affirmation policy (COMPLY).

In their study of California Water agencies they find that policies reduce water demand by the percentage presented in table 3.3

Table 3.3. : Influence of non-price policies

Variable	% or reduction
INFO	8%
RETRO	9%
RATION	19%
RESTRICT	29%
COMPLY	Not significant
REBATE	Not significant

Logically, more obligatory policies reduce demand for water more than voluntary policies. As the authors conclude, the outcome is influenced by the quality of the implementation of these policies.

Nieswiadomy (1992), using experience in Tucson cites that a campaign is successful in decreasing demand only for a few years. Yet, after a few years use increases back to its previous level. He cites that only a major public campaign accompanied with a price increase will have success in the long run. Nieswiadomy also suggests that education programs will probably have more effect in water scarce regions, because of the awareness of water scarcity.

3.15. Influence of Technological change on the Demand for Water

Influence of technology changes only recently became evident. Renwick and Archibald (1998) found that increasing the number of low flow toilets in a household by one would decreases household demand by 10%, while Chesnutt et al. (1992) found that it would decrease the demand by 11%.

Regarding the efficiency of low flow showerheads, the next elasticities were perceived:

Table 3.4: Elasticities of low-flow showerheads

Renwick and Archibald	Whitcomb	Chesnutt and McSpadden
8%	6.4 -9.7 %	2%

Low flow toilets and showerheads reduce water by having more efficient technologies and insure significant long term demand reduction with no required changes in the behavior of consumers (Renwick and Archibald 1998). In the same study, they perceive that the elasticity for adoptions of water efficient irrigation technologies for low and high density households is 31 and 10 percent, respectively.

Nieswiadomy warns that even if a water efficient device is installed, the consumer may react by using more water knowing about the conservation effect of the device, therefore offsetting the conservation impact of the device.

Agthe and Billings studied effects that would make consumers install water efficient technologies in individual households and apartments. They found that obligations to save money, income, household size and summer marginal prices effected the decision.

3.16. Recent studies

Maximum-Likelihood Models

Recently, maximum-likelihood models were used to predict price elasticity (Hewitt and Hanemann (1995), Pint (1999), etc.). Maximum-likehood models were previously applied in the labor supply literature. These two models are specified in a two-stage framework, they are based on likelihood functions that show the probability that a household will choose a particular block, in a discrete way, combined with the probability of its particular level of use in the chosen block, in a continuous way. Hewitt (1993) presented three different maximum-likelihood models: the heterogeneous-preference model, the error perception model and the two-error model. The models are structured based on the assumed source of error in estimating household demand. These errors can be errors in data, missing variables or errors in the household's actual consumption relative to its intended consumption. The models directly allow both economic and non-economic influences, they cite that variation in behavior is due to both price and income and influences represented by various socio-demographic variables (Pint 1999).

However, Hewitt and Hanemann using the two-error model got higher elasticities than in previous studies (-1.6), while Pint pointed out that elasticity is bigger in the two-error model (-0.2 to -1.24) than in the heterogeneous - preferences model (-0.04 to -0.29), concluding that the two models might be upper and lower bounds on the estimates for elasticity of demand for water. Also, they mention that these models are very costly to estimate, since they require a large number of socio-demographic observations and have complex non-linear functions.

Stone –Geary Form

A few authors used the Stone-Geary form to predict water demand and price elasticity (Matinez-Espineira and Nauges 2004, Gaudin et al 2001, Al-Qunaibet et al 1985). The function has already been used for food products, durable goods, transportation, and energy. Gaudin et al.(2001) propose this form because it includes a quantity of water that does not respond to price, allows elasticity to decrease as the price increases, and uses only two parameters (γ and β) for each good. γ is defined as a threshold below which water consumption is not affected by prices, while β is the preference variable. Basically, "The consumer is faced with a given level of income and set of prices. The consumers first purchases a minimum acceptable level of each good (the γ_i's) and then portions of each good, for their leftover income, according to their preference parameter (the β_i's)" (Gaudin et al. 2001) Gaudin present the next form:

$Q_w = \gamma_w + \beta \cdot \dfrac{I^* - P_w \cdot \gamma_w - \gamma_z}{P_w}$ where I and P are income and price. SGE (γ,β) are linear combinations of exogenous variables. So, the equation for non-constant γ and β in the Gaudin et al (2001) study is : $\beta_w = (\beta_0+\beta_1 C+\beta_2 SP+\beta_3 APP)$ and $\gamma_w = \alpha o+\alpha_1 C+\alpha_2 SP+\alpha_3 AAP$

(γ_z was excluded from the model, as insignificant to the study)

Where C – days with rainfall; SP – Spanish population; AAP –average annual precipitation)

Gaudin et al (2001) found summer elasticities bigger than winter elasticities, and that more than half of the water demand does not respond to price increase.

Table 3.5: Elasticities in studies that use the Stone-Geary Form			
Author	Study area	Price elasticity	Income Elasticity
Gaudin et al (2001)	Texas	0.19-0.28	
Martinez-Espineira and Nauges (2004)	Spain	-0.1	0.1
Al-Quinaibet and Johnston (1985)	Kuwait	-0.77	0.211

Meta-analysis

Meta-analysis is the use of statistical techniques in a systematic review with a purpose of integrating the results of the included studies. Espey et al. (1997) using meta-analysis studied the factors that affect price elasticity estimates in recent studies in the USA. They tried to explain differences in elasticity using differences in inclusion of variables in the regression models. They found that long-run estimates are more elastic to than short-run estimates; that the inclusion of income, population density, household size, temperature, and seasonable variable do not influence the price elasticity even though they influence the demand; also that evapotranspiration rates, pricing structure (increasing block rates were found to be much more elastic), rainfall and the season influence the elasticity. Also, summer elasticity was found to be bigger than winter elasticity.

Dalhuisen et al. (2003) in their meta-analysis study found that moderately high price elasticities and reasonably low income elasticities are found in studies with increasing block rates. Also, they find that the absolute magnitudes of price and income elasticities are greater for areas with high income, that price elasticities in Europe are bigger than in the US and that elasticities do not change with the date of the study, in other words they did not find differences in elasticities of earlier and more recent studies.

3.17. Conclusion

Studies in water demand prediction and elasticity have come up with a wide range of results. These studies have been conducted using different datasets, regression methods, price increases and variables, that alter the results. Consequently, some correlation parameters have been empirically proven. However, water demand and price elasticity are, no doubt, influenced by local conditions and socio- economic variables. A consensus has not been reached regarding the best methods to predict demand and elasticity. Most researches conclude that more studies have to be done in water demand.

3.2 Water Metering

There are two main benefits of water metering. Water metering has been shown to reduce demand, with a reduction rate generally from 10% to 35% (Lund, 1988). Second, with water metering conservation is rewarded; households that use less water have a smaller water bill.

There are several types of water metering schemes, depending on the pricing specification. Universal metering is when meters are installed at all house connections. In an optimal water metering plan, meters are only installed for consumers where the policy makers conclude that installing a meter will increase the welfare; in other words were more water is spent than the fixed water charge would cover

Prepaid Water Meters

Since one of the problems in Kuwait, is the inefficient collection of water bills, an overview of prepaid water meters is presented.. The main advantage of prepaid water meters is the efficient revenue collection. It is connected with the privatization of water utilities. The World bank specifies that prepaid water meters" facilitate cost-recovery and accelerate private sector participation in provision of water services" (http://www.citizen.org/cmep/Water/humanright/meter/). The references about prepaid water meters are mostly from the internet. Articles are divided into companies that advertise prepaid mater meters and papers strongly opposing it. Prepaid water meters are used in areas in South Africa, Philippines, China, Namibia, Swaziland, Tanzania, Brazil, and Nigeria (http://www.citizen.org/cmep/Water/humanright/meter/). The non-profit organization "Public Citizen" cites that in South Africa, people after being denied clean water went back to collecting water from polluted sources which caused a cholera outbreak. Also, in the USA they are used in areas without access to water infrastructure, and they were declared illegal in UK in 1998."(Public Citizens).

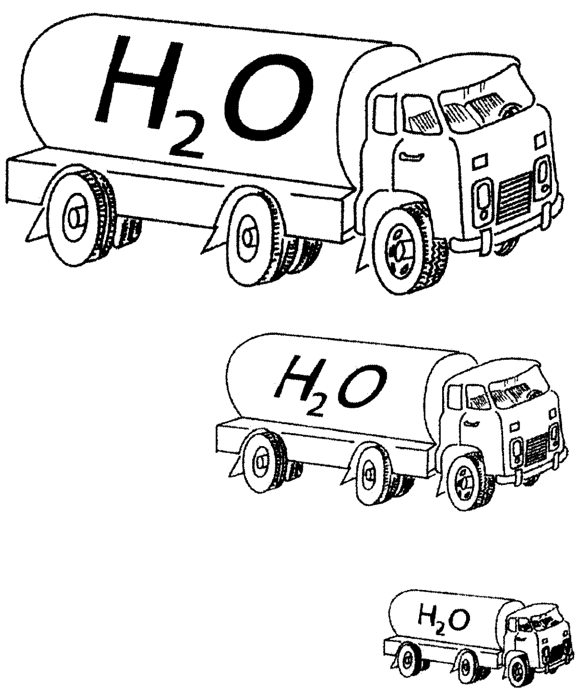
ESI AFRICA (http://www.esi-africa.com/last/ESI_1_2003/031_18.htm) cites that: "Already successfully installed in Mossel Bay, Ladismith and Kuruman as well as in a number of trial sites in Cape Town, the Ecowater prepaid water meter has made significant inroads into the decrease of outstanding water accounts in those municipalities.", and that "Cape Town-based companies Rhomberg and Syntell (formerly Tellumat Electronics) claim to have the answer to the country's problem of recovering hundreds of millions in outstanding water revenues elsewhere".

The Company Hangzhou Jingda advertises a wireless remote water meter, specifying that the water meter will automatically send its data to a concentrator every day at a certain time or after consuming a certain quantity of water. Also, the valve will shut down when all the water is used up, and will reopen when the consumer purchases water again. Water can be purchased by using debit cards that are inserted into the water meter.

3.3 Water Usage

The use of water differs in various regions of the world, with a tendency that higher industrialized countries use more water per capita than developing countries (Falkenmark and Rockstrom, 2004). Figure 3.1 shows non-agricultural water usage by sectors for various regions in the world.

Figure 3.1 NON-AGRICULTURAL USE OF WATER



USA 366 m^3 cap^{-1} yr^{-1}
Household: 100
Service: 140
Industry: 126

EUROPE 232 m^3 cap^{-1} yr^{-1}
Household: 57
Service: 35
Industry: 140

AFRICA 25 m^3 cap^{-1} yr^{-1}
Household: 10
Service: 8
Industry: 7

Falkenmark and Rockstrom, Fig. 3.2, p. 47.

Figure 3.2 (UNEP) presents a breakup of domestic water usage, using data from Swiss households. It shows that 30% of water goes on toilets, while 20% of domestic water is used for showers.

Figure 3.2

How much water do you use?

(data refers to swiss householder)

Activity	water use (l/day)
Toilet	47.7
Bath/shower	31.7
Washing machine	30.2
To cook, drink, to wash dishes (by hand)	24.3
Wash yourself and wash dresses (by hand)	20.7
Dishwashers	3.6
Other	3.8
TOTAL	**162**
Drinking and wash yourself and above all to produce your food (if you are a good farmer and you not waste your water)	2 000

The hidden water use

Commodity	water consumed (l)
1 litre of beer	7
1 litre of gasoline	10
1 cola	70
A single bath	200
1 kg of paper	320
1kg of bread	1 000
1 kg of potatoes	1 000
Television set	1 000
1 kg of meat	4 000 to 10 000
One pair of jeans	8 000

Source: OFEFP, 2003; FAO; Environment Canada

UN Environmental Protection Program – Freshwater consumption in Europe

4. Price Proposal

Water Demand and Water Pricing in Kuwait

Abstract:

Kuwait is an arid country with limited natural water resources. Yet, water consumption per capita is much higher than in other countries in the world and is estimated to be around 450 L/capita/day. Certainly, one of the reasons is the fact that, even though water has a pricing schedule in Kuwait, water bills are not collected efficiently; consequently there is some amount of water that is being wasted. The main objective of this paper is to study the potential impact of pricing as a tool for managing water demand in Kuwait. The original idea was to construct a water demand model for Kuwait, but it was modified, because of the lack of empirical data regarding household consumption characteristics and price influences on demand. Instead water demand models described in the literature were adapted to Kuwait. A pricing schedule is proposed, that consists of a free allowance, followed by a constant water price. This proposal has the following logic: if water is consumed reasonably, only to satisfy vital needs, it should be free. However, to limit over consumption, the quantity of water over the allowance should be priced. Our results indicate that this pricing schedule would be efficient in reducing demand significantly. The models results suggest that a price of water of $\$1/m^3$, for water use in excess of a 150L/capita/day allowance, would reduce the demand by about 35 percent (with a range of around 20-40 percent, depending on the demand model used).

4.1. Introduction

Kuwait is an arid country, rich in oil but poor in natural water resources. The annual rainfall is around 110 mm, and because of factors such as the high potential evaporation rate, surface runoff and groundwater recharge from rainfall are rare (Fadlelmawla and Al-Otaibi, 2005).

The water resources in Kuwait are obtained from groundwater, desalination and treated wastewater. The groundwater is mostly brackish and is not used in a sustainable way, since the extraction from the wells is greater that the natural recharge to the aquifers. The annual groundwater production in 1999 was around 118 million m^3, while under steady-state conditions, the recharge, generated through lateral flow from Saudi Arabia, was estimated to be 44 million m^3/year (Fadlelmawla and Al-Otaibi, 2005).

Kuwait gets most of its potable water from desalination. Multi-Stage Flash is currently the dominant desalting technology. The desalination capacity of Kuwait is 1.65 million m^3/day (Hamoda, 2001), and the estimated cost to produce water is about 3 $/$m^3$ (Darwish and Al-Najem, 2005). This cost was calculated based on a price of around $40/barrel and an assumption that energy costs are equal to 45% of the total cost to desalinate water.

Currently, more water is consumed in Kuwait than is necessary. The water demand in Kuwait is around 453 L/capita/day (Darwish and Al-Najem, 2005), When the demand is compared with other countries (USA – 333 L/day/capita; France 164 L/day/capita; Germany

127 L/day/capita (EWA 2005 yearbook)), a need to decrease water demand in Kuwait is evident.

The main purpose of this study is to analyze the potential impact of pricing as a tool for managing water demand in Kuwait. There may be several reasons for the large demand (pipeline leakage, high temperature, etc.) but one important reason is certainly the low cost of water to consumers. Water does have a pricing schedule in Kuwait; however in reality the water bills are not collected. Darwish (2005) cited that the total income acquired by selling 455 million m^3 (Kuwait's annual water production) was 86 million US$ in 2002. The annual government subsidy was $715 M in 2003.

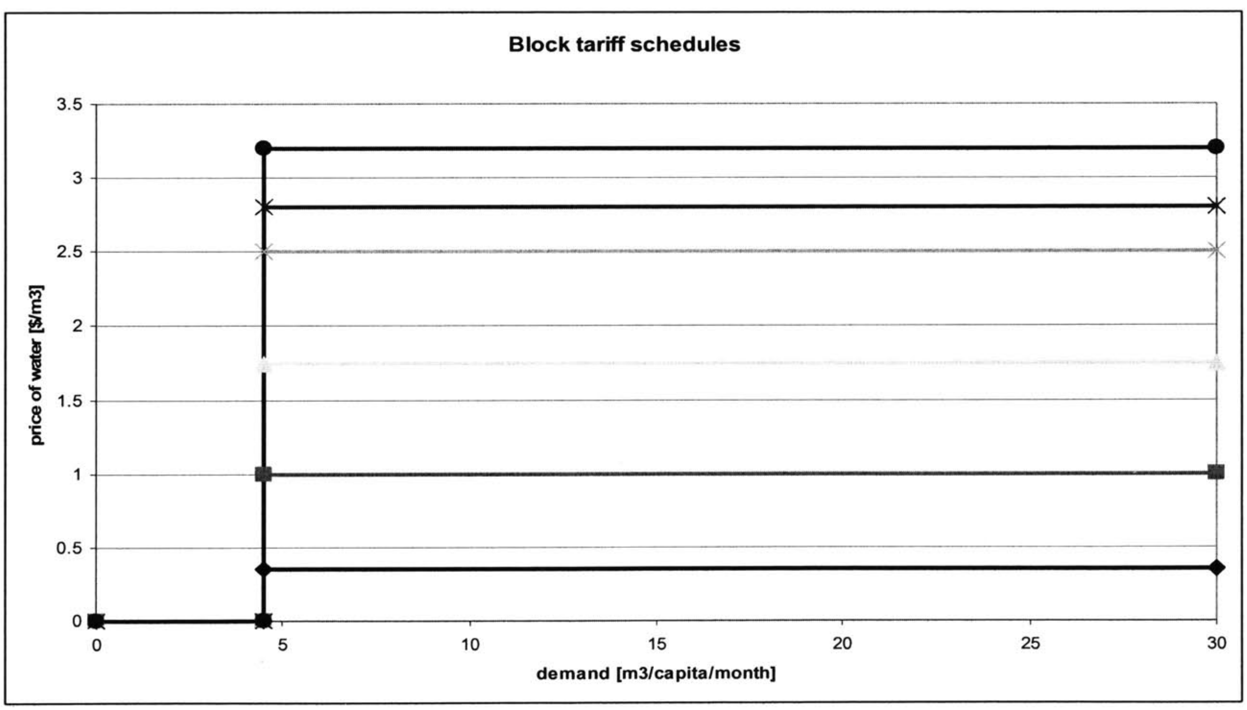
It is known from the literature and from experience of water utilities that water consumption shows certain elasticity to price increase. The original idea was to construct a water demand model for Kuwait in order to quantify the influence of pricing on water consumption. However, assembling a model requires data regarding household consumption characteristics and influences that price increases have on demand. This kind of data is not available, since household water consumption is generally not metered and because there has not been a price increase in recent years. Instead a study was carried out using water demand models reported in the literature and by recalibrating them for Kuwait. Five models were used based on studies in several arid regions: California, Tunis, Australia, Saudi Arabia, and Spain.

A number of simulations analyzing the influences of various pricing schedules on demand were performed including constant prices, block tariffs, and a free allowance followed by various pricing schemes. In this paper, results regarding constant price schedules with and without an initial allowance are presented.

A pricing schedule is proposed that consists of a free allowance (e.g. 150 L/capita/day), followed by constant water charge (Figure 4.1). This pricing schedule has two parameters, the allowance and the constant price. It was concluded that this pricing schedule would be acceptable for Kuwait, economically and politically, and that it would help to eliminate some of the waste of water. Basically, if water is consumed reasonably, only to satisfy vital needs, it would be free. However, consumption of water beyond what is judged by society to be vital need should be priced.

Since countries in the Gulf region have similar socio-demographic characteristics and low water costs, this study would have obtained similar results in some of the other countries in the region.

Figure 4.1: Price Proposal – A free allowance followed by a constant price.



4.2. Literature review

Water demand reduction due to price increases has been extensively studied in the literature. Most of the demand models are regression models. Typically, the demand is derived as a function of price variables and factors such as income, household characteristics, and weather.

Which price variable to use has been the most common question in the literature. A consensus has not been reached about whether to use the average price or the marginal price combined with some other variables. A reasonable assumption, supported by some researchers (Nieswiadomy 1992, Shin 1985), would be that if the consumers think the water bill is significant, they will put in the effort to learn about the exact pricing schedule and their exact consumption and hence would be influenced by the marginal price. Otherwise, where the water bill represents a small percentage of income, the consumer will react to the average price.

All reviewed studies find that household income is a significant variable that increases demand. Also, household size is frequently used in the demand equation (Nieswiadomy 1992, Renwick et al 1998, Dandy et al.1997). Variables such as lot sizes (Dandy et al. 1997, Renwick et al. 1998, Lyman 1992, etc.), density of households, number of faucets (Renwick et al. 1998), and age distribution (Lyman 1992) have also been used. A number of researchers found that seasonal changes and climates influence demand. Summer demand was found to be more elastic than winter demand (Lyman 1992, Dandy et al. 1997, Griffin and Chang). Also, studies have found that outdoor water use is more elastic than indoor.

Renwick and Green (1998) showed that non-price policies (campaigns, restrictions, rationing policies, etc.) have influence in decreasing demand. Nieswiadomy (1992) cites experience from a campaign in Tucson which was successful in decreasing demand only for a few years; after a few years consumption increased back to its previous level; he explains this occurrence by the fact that actual water prices did not rise. Furthermore, Nieswiadomy suggests that education programs will probably have more effect in water scarce regions, because of the general awareness of water scarcity.

Abu Qdais and Nassay (2001) studied the impact of the change of the pricing policy in Abu Dhabi City. Before the change, the water consumption was 636 L/capita/day. However, after changing the price policy from a fixed charge to a constant price per unit volume consumed, the demand decreased. The elasticity was found to be -0.1.

A few authors used the Stone-Geary form to predict water demand and price elasticity (Matinez-Espineira and Nauges 2004, Gaudin et al. 2001, Al-Qunaibet et al.1985). The same function has already been used for modeling demand of food products, durable goods, transportation, and energy. Gaudin et al. (2001) proposed this form because it allows elasticity to decrease as the price increases and uses only two parameters (γ and β) for each product. γ is defined as a threshold below which water consumption is not affected by prices, while β is the preference variable. The form also specifies a quantity of water that does not respond to prices. Gaudin et al. specify the logic of the form in the following way: "The consumer is faced with a given level of income and set of prices. The consumer first purchases a minimum acceptable level of each good (the γ_i's) and then portions of each good, for their leftover income, according to their preference parameter (the β_i's)". Gaudin et al. (2001) presents the following demand function: $Q_w = \gamma_w + \beta \cdot \frac{I^* - P_w \cdot \gamma_w - \gamma_z}{P_w}$ (4.1),

where the subscripts w and z indicate parameters pertaining to water and to other goods, respectively, while I and P represent income and price.

Price elasticities from different studies found in the literature are presented in Table 4.1. As seen, price elasticities vary with in a wide range. This is due to the difference in socio-economic characteristics of the study areas, different price schedules and price ranges, consumption levels, climate, income, awareness of water scarcity, and many other factors that can not all be accounted.

Espey et al. (1997) and Dalhuisen et al. (2003) studied factors that affect price elasticities in demand models. Espey et al. evaluated 24 journal articles, while Dalhuisen et al. examined 64 studies. Both researchers found that studies that are based on regions with increasing block rate structures have bigger price elasticities. Espey et al. (1997) found that the inclusion of evapotranspiration and rainfall results in less elastic demand, while the inclusion of temperature, population density and household size does not affect the elasticity. Dalhuisen et al. (2003) found regions with higher income to have larger price elasticities.

Table 4.1: Price elasticities from studies of residential water demand found in the literature.

Authors	Form	Study area	Price variable	Price Elasticity
Howe and Linaweaver (1967)*		USA	AP	-0.23
Gibbs (1978)*		Miami, Florida		-0.51
Foster and Beattie (1980)	Exponential	USA	AP	-0.35 to -0.76
Billings (1982)	Lin/Log	Tucson, Arizona	MP & D	-0.66/-0.56
Schefter and David (1985)*		Wisconsin		-0.12
Chicoine et al. (1986)*		Illinois		-0.71
Chicoine and Ramamurthy (1986)	Linear	Illinois	MP (AP)	-0.6 on MP
Nieswiadomy and Molina (1989)	Linear	Denton, Texas	MP & D	-0.86
Griffin and Chang (1990)	Linear	USA	AP	-0.16 to -0.37
Riazaiza (1991)	Logarithmic	Saudi Arabia	AP	-0.4 to -0.78
Hansen (1996)*		Denmark		-0.10
Renwick and Archibald (1997)	Linear	California	MP & D	-0.33
Hoglund (1997)	Linear	Sweden	MP & AP	-0.20 on AP
Dandi et al. (1997)	Linear	Australia	MP & D	-0.63 to -0.77
Renwick, Green, McCorkle (1998)	Logarithmic	California	MP & D	-0.16 to -0.21
Nauges and Thomas (2000)	Linear	France	AP (&MP)	-0.22
Ayadi et al.(2003)	Logarithmic	Tunisia	AP	-0.17

* Data from Nauges and Thomas (2000)

4.3. Input Assumptions, Demand Models Used and Adaptations made

First, the assumptions made about the input to the demand models are presented. Then for every model, basic features are presented and the different adaptations made are explained.

Input assumptions made

As discussed in the previous section, a number of models assume that water demand is a function of household income and household size. Based on income and household size, consumers were divided into 40 groups in the following way.

Data regarding household income distribution in Kuwait was not available, so assumptions were made regarding the distribution. The monthly household income was calculated based on the distribution in the USA (U.S. Census Bureau), by dividing the household income distribution in the US by the ratio of GDP per capita in the US and in Kuwait. Non-Kuwaitis were assumed to have half of the GDP per capita as Kuwaitis, and income distribution was calculated in the same way. GDP per capita values for the US, Kuwaiti and Non-Kuwaiti households are presented in Table 4.2.

Table 4.2: GDP per capita in USA and for Kuwaiti and Non-Kuwaiti

	GDP per capita	
USA	$35,721	US Census Bureau, 2004-2005 yearbook
Kuwaiti	$21,300	World Factbook, 2005 (CIA Website)
Non-Kuwaiti	$10,274	

Information was gathered from the U.S. Census Bureau for USA household income distribution and the data was grouped into 5 income categories (Table 4.3). After dividing the

USA income by the ratio of GDP for Kuwaiti and non-Kuwaiti households to the US GDP (ratio = 1.72 and ratio = 3.44, respectively), and the household income groups presented in Table 4.4 were assumed for Kuwaiti and Non-Kuwaiti households and used as input in the simulations.

Table 4.3: Household income USA

Income(1000$/month)		[%]
Under 1.25		15.8
1.25	2.92	25.6
2.92	6.25	36
6.25	12.5	17.9
Over 12.50		4.6

Table 4.4: Assumed Household income For Kuwaiti and non-Kuwaiti

Percent of households in each group[%]	Average income	
	Kuwaiti (1000$/month)	Non-Kuwaiti (1000$/month)
15.8	0.51	0.26
25.6	1.21	0.60
36	2.66	1.33
17.9	5.44	2.72
4.6	11.13	5.56

Table 4.5 presents household size distribution data in Kuwait, acquired from the Economic & Financial Quarterly of the National Bank of Kuwait (1999). This data was used to incorporate the distribution of household size in to the demand models and was adjusted in the following way.

The number of households in every category was transformed into the percentage of the total number of households (Table 4.6). In table 4.5, the distribution of non-private non-Kuwaiti households (households with members that are not related) is not presented. It was assumed that this group has the same distribution as private non-Kuwaiti.

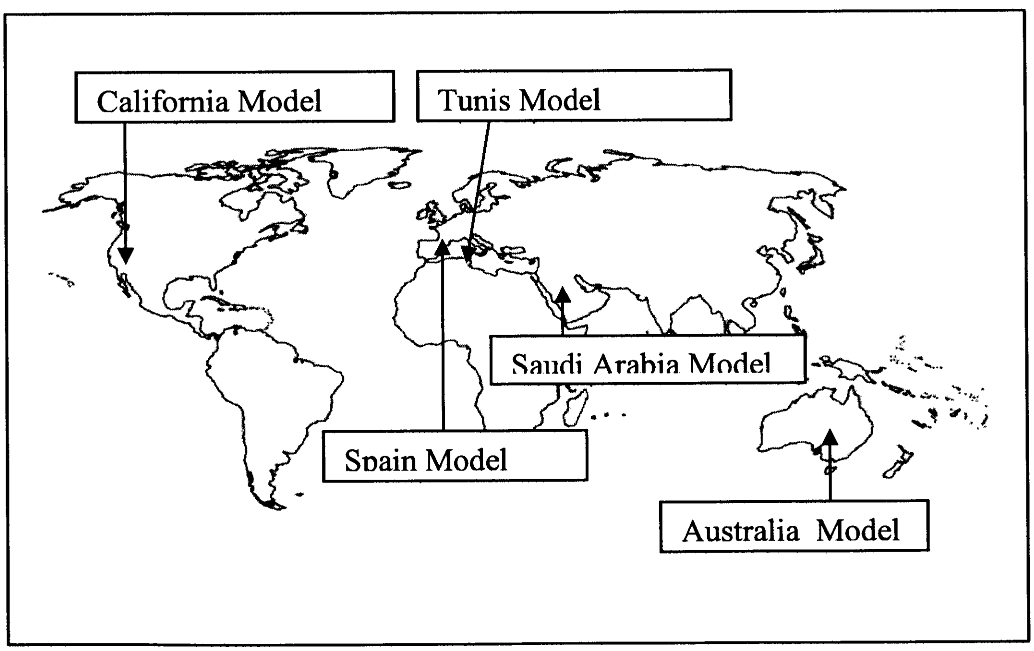
Every income group (specified previously) was assumed to have a household size distribution computed from table 4.6., with respect to nationality. Therefore, following table 4.6, every income group (four Kuwaiti and four non-Kuwaiti) was divided according to household size into four groups. This resulted in a total of 40 consumption groups that were used in the simulations.

Table 4.5: Households in Kuwait National bank of Kuwait (1999)			
Type of Household	Kuwaiti	Non-Kuwaiti	Total
Bachelor (one member)	14,710	96,578	111,288
2-5 members	45,989	80,945	126,934
6-9 members	38,039	21,696	59,735
10+ members	40,645	10,309	50,954
Total private*	139,383	209,528	348,911
Non-private°	--	85,640	85,640
Grand Total	139,383	295,168	434,551

Table 4.6: Household size distribution used in the simulations		
Kuwaiti	Non-Kuwaiti	HH
11%	46%	1
33%	39%	2-5
27%	10%	6-9
29%	5%	>12

Models Used

Models from five continents were used in these simulations. Figure 4.2 shows the locations where the models were estimated



Saudi Arabia Model

Specification

Rizaiza (1991) studied water consumption in four major cities in Saudi Arabia: Jeddah, Makkah, Madinah, and Taif. The study was based on data collected from a socio-economic survey conducted in 1985, water and sewage department circulars from Saudi Arabia, and from other publications. Residents that are supplied from the public water network and tankers were analyzed. Since the public network is the subject of this study, only that part of the paper is reviewed. The price elasticities, for areas connected to the public network, were found to be -0.78 to 0.06. The average demand of water was 350 L/capita/day with a price of 0.08 $/m^3$ for the first 100 m^3/month. The model parameters were estimated using ordinary least square framework.

The water demand equation uses a logarithmic functional form, and calculates annual water demand per household as a function of a constant (city dependent), income, average price, family size, temperature and garden possession according to the following form:

$$Log(Q) = \alpha_0 + \alpha_1 \cdot Log(INC) + \alpha_2 \cdot Log(PRIC) + \alpha_3 \cdot Log(FSIZE) + \alpha_4 \cdot Log(TEMP) + \alpha_5 \cdot GRDN \quad (4.2)$$

Where: Q = annual household demand; INC = household income, PRIC = average price; FSIZE = family size; TEMP = temperature; GRDN =1 if family owns a garden, GRDN = 0 otherwise. In table 4.7 the coefficients for this model are presented.

Table 4.7: Coefficients used in the Saudi Arabia model	
Parameter	Coefficient
GARDEN	0.1
MAKKAH [city]	-0.006
MADI [city]	-0.16
TAIF [city]	0.847
LOG(PRICE)	-0.78
LOG(FSIZE)	0.44
LOG(INCM)	0.090
LOG(TEMP)	1.26

Adaptation

Using the water demand equation (4.2) and coefficients (Table 4.7), demand was computed for every consumption group using different prices. Average temperature was assumed to be 31C; the Garden dummy was not used, since data about garden ownership was not available.

In order to simulate the effect of a free monthly water allowance in the pricing schedule, the first 4.5 m^3/capita/month for every consumption group was computed with a price of \$0.1/m^3 (since the model has a logarithmic from, a zero price could not be calculated), assumed to be close enough to free water. All consumption over the 4.5 m^3/capita/month was priced at the constant price rate.

Next, the model coefficients were adjusted to Kuwait in the following way. Since there has not been a price increase in the recent years, the only point that is known on the demand-price graph is a value around 450 L/capita/day for a situation when water is almost free. Demand was computed to get a value of around 450 L/capita/day for a \$0.1/m3 price of water. The model was modified for this point by changing the constant (city dependent) and a value of zero was obtained.

California Model

Specification

This model, developed by Renwick and Green (1998), was based on data in California for about 7.1 million people from eight water agencies during 1986-96. The model focuses on the influence that price policies and non-price policies have on decreasing water demand. Three kinds of equations are used in this study: water demand equation, price equations and climate equations. Household water demand was derived as a function of price variables, household income, lot size, precipitation, temperature, and non-price policies and has a logarithmic functional form.

Water Demand Equation:

$$\ln W_{it} = \beta_0 + \beta_1 \cdot \ln(MP_{it}) + \beta_2 \cdot \ln(D_{it}) + \beta_3 \cdot \ln(INC_{it}) + + \sum_{i=4}^{11} \beta_i \cdot (NPDSM) + \beta_{13} \cdot \ln(PREC_{it}) + \beta_{14} \cdot LOT$$

(4.3)

i=1,…,8 agencies (cities), t = 1,…,96 months (time)

W_{it} = Household Water Demand per month

MP_{it} = Marginal price

D_{it} =Difference variable (the difference between what would have been paid if all units were purchased at MP and the amount paid under the block pricing schedule)

INC_{it} = Income in $1000

HH_{it} = Number of household members

NP DSM = 8 non-price Demand Side Management (DSM) policies

PREC = precipitation

Values of some of the coefficients for the water demand equation of the California Model are presented in the column named "California" in Table 4.8. Price and climate equations are not presented here, since they are not related to this study.

Table 4.8: Coefficient values for adopting the California Model			
		California	Kuwait
Coefficient	Description	value	value
β0	Interception	2.61	2.35
β1	MP	-0.16	-0.16
β2	Difference variable	-0.01	-0.01
β3	Income	0.25	0.5
β4	Household number	0.18	0.2

In this study a range in marginal prices of \$0.16 – \$1.6 per m^3 was analyzed. The model incorporates: price policies, alternative non-pricing campaigns, and seasonal and climatic variability on demand. The parameters of equation (4.3) were estimated in a generalized least-squares framework. The model estimates 16-20% price elasticity. The authors find that non-price policies have influence on demand. Also, the authors conclude that "price policy may achieve a larger reduction in aggregate demand in lower income communities than in higher income communities".

<u>Adaptation</u>

Since the household allowance was specified to be per capita, that is a function of household size, a household size variable was needed in the model. However, in the original model the household size is not directly incorporated in the demand equation, but it is part of the price equation.

One of the authors of the "California" model, (Renwick) published a similar paper with Archibald (1998) that was based on data also from California, during the same period.

The household size variable was used in the demand model of this paper. However this model (Renwick and Archibald 1998) was not used for this study, since it has a linear form, and coefficients were found to be harder to calibrate. Since a household variable was used for a similar study, the variable was added to the demand equation. A similar value of the coefficient from the price equation was used for the demand equation for household size. In the simulations, the household size did not have significant influence on the price elasticities; it was used to be consistent with the price proposal.

Using the water demand equation (4.3) and coefficients of Table 4.8, demand was computed for every consumption group for a range of prices. Then, the model coefficients were recalibrated for Kuwait. In order to simulate the effect of a free monthly per capita water allowance in the pricing schedule, the first 4.5 m^3/capita/month for every consumption group was computed with a price of \$0.1/m^3, assumed to be close enough to free water. All consumption after that quantity was priced at the constant rate. The income coefficient was increased by a factor of 2, since the GDP in the USA is close to twice the GDP per capita for Kuwaiti and Non-Kuwaiti households (possibly this assumption is not adequate, since the function has a logarithmic form). The constant coefficient was then recalibrated to get a demand of around 450 L/capita/day for a price of \$0.1/m^3. Other coefficients remained the same. Table 4.8 (previous page) shows the values of recalibrated coefficients (Kuwait column)

Australia Model

Specification

This study by Dandy et al. (1997) differs from previous research studies because the influence of a free allowance in the pricing regime is analyzed. It was based on data from the metropolitan area of Adelaide, Australia. The results of this study showed that: "consumption above the allowance is more sensitive to income (or property value), climate variables (summer moisture deficit and winter evaporation), and pool ownership than consumption below the allowance but responds to the need of water as determined by plot size, household size, and number of rooms no differently from consumption below the allowance" (Dandy et al. 1997). There are two variations of the model, static and dynamic. The dynamic model includes lagged water consumption. The two variations also differ because different coefficients are used in the demand equations. The models are linear and are applied on an annual time scale. Also, models with climate variables are included in this article.

The demand model is specified differently for consumers that are above and below the allowance. For consumers below the allowance, water demand is a function of lagged consumption Q_{-1}, property value, and variables such as household size, climate, etc. (Z variables) and D_y (dummy variable for year 1992).

$D = 0$ for $Q < A$:

$$Q = \alpha_0 + \alpha_1 \cdot Q_{-1} + \beta_1 \cdot I + BZ + \theta \cdot D_y + u \quad (4.4)$$

While for consumers above the allowance in addition to the previous variables, demand is also a function of price (MP and D) variables, with different coefficients used, as seen in equation (4.5).

D = 1 for Q > A

$$Q = \alpha_0 + \delta_0 + (\alpha_1 + \delta_1) \cdot Q_{-1} + (\beta_1 + \gamma_1) \cdot I + (B + \Gamma) \cdot Z + \theta \cdot D_y + \Phi P + u \quad (4.5)$$

where:

Q = quantity of water consumed

A = annual allowance

I = property value

P = a vector of price variables (marginal price, difference variable)

Z = a vector of other variables (household size, climate,, etc.)

D = variable showing if demand is above or under the allowance

Q_{-1}= quantity of water consumed in the previous year

D_y=1 for year =1992 and D_y=0, otherwise

In table 4.9 the coefficients used in the annual static consumption model (without lagged consumption) are presented.

Table 4.9: Coefficients used in the Static Annual Australian Model

	Property value	Plot size	No. residents	No. Rooms	Pool	Marginal Price	Difference variable	Constant
D = 0	0.712	0.011	19.51	12.69	69.24			35.73
D = 1	0.751	0.008	2.84	2.72	-56.4	-404.4	-1.37	366.35

Adaptation

The original coefficients were used for the simulations (table 4.9), with the exception of the following. D_y was not used since it is specific to Australia and the lagged consumption was not included since the static annual model was used. Property value was not used in the simulations, because of the lack of data.

The original model used property value instead of income, since not enough data was available to the researchers regarding annual income in Adelaide. However, in the following simulations income was used instead of the property value. The corresponding income coefficient was computed so that the model would produce a demand of 450 L/capita/day for a zero price of water in the simulation of a free allowance followed by a constant price. The property value coefficient was divided by 133, to obtain the Kuwaiti demand for a zero price of water. This would indicate that for an average family, the value of the property that they own would be equal to the income that they earn in 133 months (11.1 years). In table 4.10 the values of the income coefficients are presented. Also, Australian dollars were used in the simulation, and then converted to US dollars.

Table 4.10: Income Coefficient values for adopting the Australia Model

possibility	value
D<A	0.00535
D>A	0.011

The Australia model is based on an annual allowance of 136 m^3 per household. Since the average household in Adelaide is 2.6 members/household (Australian Bureau of Statistics, 1991); the allowance is in average 143 L/capita/day. This is close to an equivalent to the allowance that will be proposed in this paper for Kuwait. However, the average household size used in this paper for Kuwait is five members per household. Because of the fact that the quantity of the allowance in this paper is defined to be per capita, this difference in household size requires adjustments to be made to the model for Kuwait.

Water demand decrease due to price influences in this model is a function of the marginal price (MP) and the difference variable (DV). The part of the demand equation (Eq 4.5) that computes the influence of the price has the form $\beta_1 \cdot MP + \beta_2 \cdot DV$. In a pricing schedule that consists of a free allowance followed by a constant price, the DV variable is equal to the quantity of the household allowance multiplied by the marginal price of water, with a minus sign. If the household allowance (A_H) is specified to be per household member with an allowance of 143 L/capita/day (= 52.2 m^3/capita/year), then:

$$\beta_1 \cdot MP + \beta_2 \cdot DV = -404.4 \cdot MP - 1.37 \cdot DV = -404.4 \cdot MP - 1.37 \cdot (-A_H \cdot MP) = \\ = -404.4 \cdot MP + 1.37 \cdot 52.5 \cdot HH \cdot MP \tag{4.6}$$

where:

MP – marginal price; DV – difference variable; β_1, β_2 coefficients from table 4.10

A_H – annual household allowance; HH – household size

For a household size of 2.6 member/household (Adelaide), equation 4.6 is equal to $-218.08 \cdot MP$. However if the same logic is applied for a household size of 5, equation (4.6) becomes equal to $-142.8 \cdot MP$, resulting in smaller price elasticity, just because of the size of the household; these two factors should not be correlated. For a household with 12 members, the price variables would be equal to $453.70 \cdot MP$, implying that an increase in prices would increase the consumption for big households.

The model was adopted for the household size in Kuwait in the following way. The 1.37 was decomposed: $1.37 = 0.527 \cdot HH$ (for HH = 2.6 in Adelaide), so consequently:

$\beta_1 \cdot MP + \beta_2 \cdot DV = MP \cdot (-404.4 + 1.37 \cdot 52.2 \cdot HH) = MP(-404.4 + 0.527 \cdot HH \cdot APM)$ (4.7),

where APM is annual water allowance per household member and 52.2 m^3/capita/year = 0.143 m^3/ capita/day

The allowance had to be constant in the model; the variations in household sizes would influence the price elasticities. For this model a fixed allowance of 275 m^3/year (or 0.75 m^3/household/day) was used. This amount was chosen because in the model, the average household size is 5 members per household, resulting in an average of 150L/capita/day. So a value for β_2 = -0.527 was used in the simulations. In addition, the household size variable has a much smaller influence than the water price has on demand in the model.

Tunis Model

Specification

This model, developed by Ayadi et al. (2003), was based on water demand data collected in Tunis 1980-1996. The authors first divided the consumers into five brackets based on water demand. Based on similarity in changes in demand for the observed period, the lower two brackets were combined into the lower block, and the higher two brackets were combined into the higher consumption block. The model does not use the middle bracket.

Different coefficients were used for the high and low demand blocks, specifying that the upper block has bigger price elasticity than the lower bracket. The water demand equation (8) is a function of income, average price, network size, rainfall and quarterly dummies. The model also computes household shifting from one bracket to the other (9).

Demand equation:

$$Log(C) = \alpha_0 + \alpha_1 \cdot Log(R) + \alpha_2 \cdot Log(P) + \alpha_3 \cdot Log(N) + \alpha_4 \cdot Log(RL) + \sum_{s=1,2,4} \alpha_{5s} \cdot QD_{st} \quad (8)$$

Portion of households in each bracket:

$$Log(NB/N) = \gamma_0 + \gamma_1 \cdot Log(P) + \gamma_2 \cdot Log(N) + \gamma_3 \cdot Log(RL) + \sum_{s=1,2,4} \gamma_{5s} \cdot QD_{st} \quad (9)$$

Where:

C= average consumption of water per household [m^3/month]

R = average monthly income of households ($1000)

P = average price paid by household ($/month)

N = network size incorporated to capture the effect of network expansion

RL= indicator of rainfall

QD = quarterly dummy

NB = number of consumers in each bracket

Tables 4.11 and 4.12 represent the coefficients used in this model for the Greater Tunis area.

Table 4.11: Water Demand Equation coefficients for the Tunis model

Coefficients	description	Lower Block	Higher block
α_0	interception	3.1	8.65
α_1	Income	0.06	0.05
α_2	Price	-0.08	-0.34
α_3	Network size	0.02	-0.16
α_4	Rainfall indicator	-0.1	-0.1

Table 4.12: Consumers Proportion equation for the Tunis model

coefficient	description	Lower Block	Higher block
γ_0	intersection	3.27	9.84
γ_1	price	0.05	-0.62
γ_2	number of h	0.03	-0.21

Adaptation

The rainfall, quarterly dummies and network expansion variables were not used in the simulations. The first and second Kuwaiti income groups (table 4.4) compose the lower bracket and the fourth and fifth Kuwaiti income groups (table 4.4) create the upper bracket. This led to a smaller percentage of the total population in the lower bracket, and a larger percentage in the higher bracket, which consequently increases the price elasticity, because the model is specified to have a bigger elasticity for the upper block. The α_0 coefficients were calibrated to get a demand similar to Kuwait (about 450 L/capita/day for a situation when the water price is near zero). The γ_0 coefficients were changed in order to match the group breakups specified in the first section (Table 4.4). Tables 4.13 presents the coefficients that were changed in adopting the Tunis model.

Table 4.13: Changed coefficients for adopting the Tunis Model

		Kuwait		Tunis	
Coefficient	description	Lower Block	Higher block	Lower Block	Higher block
α_0	interception	1.25	1.8	3.1	8.65
γ_0	intersection	1.525	2.035	3.27	9.84

Spain Model

Specification

From the three models that are present in the literature that use the Stone-Geary functional form the model developed in Spain was selected since Spain has a GDP similar to that of Kuwait, and because the MP and difference variables were used in the model, which should be a better fit for the price schedule proposed. The model was estimated in Feasible Generalized Least Squares framework (FGLS).

The basic form is: $Q_w = (1-\beta)\cdot\gamma + \beta\cdot\frac{I_t}{P_t} + \alpha_1\cdot BAN_t + \alpha_2\cdot POP_t$ (4.10)

where:

Q_w = average per capita consumption

P_t = the marginal price of water

I_t = virtual income, the difference between the average salaries and the difference variable

BAN_t = binary variable, indicating influence of out-door-use bans

POP_t = daily hours of supply restrictions

γ = the minimum consumption level (not affected by prices)

β = "the marginal budget share allocated to the good considered"

Coefficients used in this model are presented in table 4.14.

Table 4.14: Coefficients used in the Stone-Geary model		
Coefficient	Description	Value
β	Preference variable	0.008
γ	Income*	4.7
α_1	Ban on outdoor use	-0.125
α_2	Restrictions	-0.05

Adaptation

The BAN and restriction variables were not used. The same values of the coefficients (γ_0 and β_0) from the original model were used in simulating demand in Kuwait. Aggregate data was used in the simulation; for income the GDP per capita for Kuwait was used ($20,547).

Model constrains and assumptions

The situation in Kuwait, were water bills are not collected efficiently differs from the situations in the countries were the original demand models were estimated. A clear answer about what is the difference between a free water situation and Kuwait's water pricing situation (water does have a pricing schedule, but bills are not collected efficiently) and how this might influence the water demand can not be found in the water demand literature. Also, in the studies used in the paper, water prices increased initially from a certain price level significantly bigger than a price of zero. Also, simulating a price increase of $2/m^3 (e.g. from 0 to 2$/m^3), is a bigger price range than most of the original models were estimated in.

Also, in lack of data not all of the variables that were specified in the original models were used in simulating water demand in Kuwait. Weather, density of housing, seasonal influences and other variables were assumed constant and incorporated into the constant (intersection); this might have an influence on the demand reduction.

In models that use the marginal price numerical errors occur when due to a price increase, a consumption group shifts from one water price in the block tariff to another. So, when the price of water gradually increases, the water demand of a group gradually decreases. When the demand comes near the border of the blocks tariff (e.g. allowance-constant price), it does not fit, either above the allowance, either under the allowance. In other words, when demand is computed for the lower block (with the MP for the lower block, and therefore a less negative price variable), it exceeds the lower block demand, going into the higher tariff. But, when computed for the higher block (with a higher MP and a more negative price variable), it does not reach the higher block. This numerical problem was solved by putting the consumption group on the border between blocks.

4.5. Results

4.51 Simulation of a Constant Price Schedule

Results regarding the influence of a constant price schedule on per capita demand are presented in Figure 4.3 and show that pricing influences the demand. All models compute different price elasticities, since they are based on data from different studies. The models that have a logarithmic or Stone-Geary functional form show that after a price of around

$\$0.8/m^3$, further price increase does not have influence on demand, proposing that there is a quantity of water that is not influenced by the price.

Government subsidy is shown in figure 4.4. It was simulated for a cost to produce water at $\$3/m^3$. The subsidy was computed for a population of 2.2 million, to be consistent with Kuwait's current population. All models show that water pricing would significantly decrease monthly subsidy by around 60 million USD, for a price of $\$1/m^3$.

Figure 4.3: Decreases in demand for selected models for a constant price schedule without an allowance.

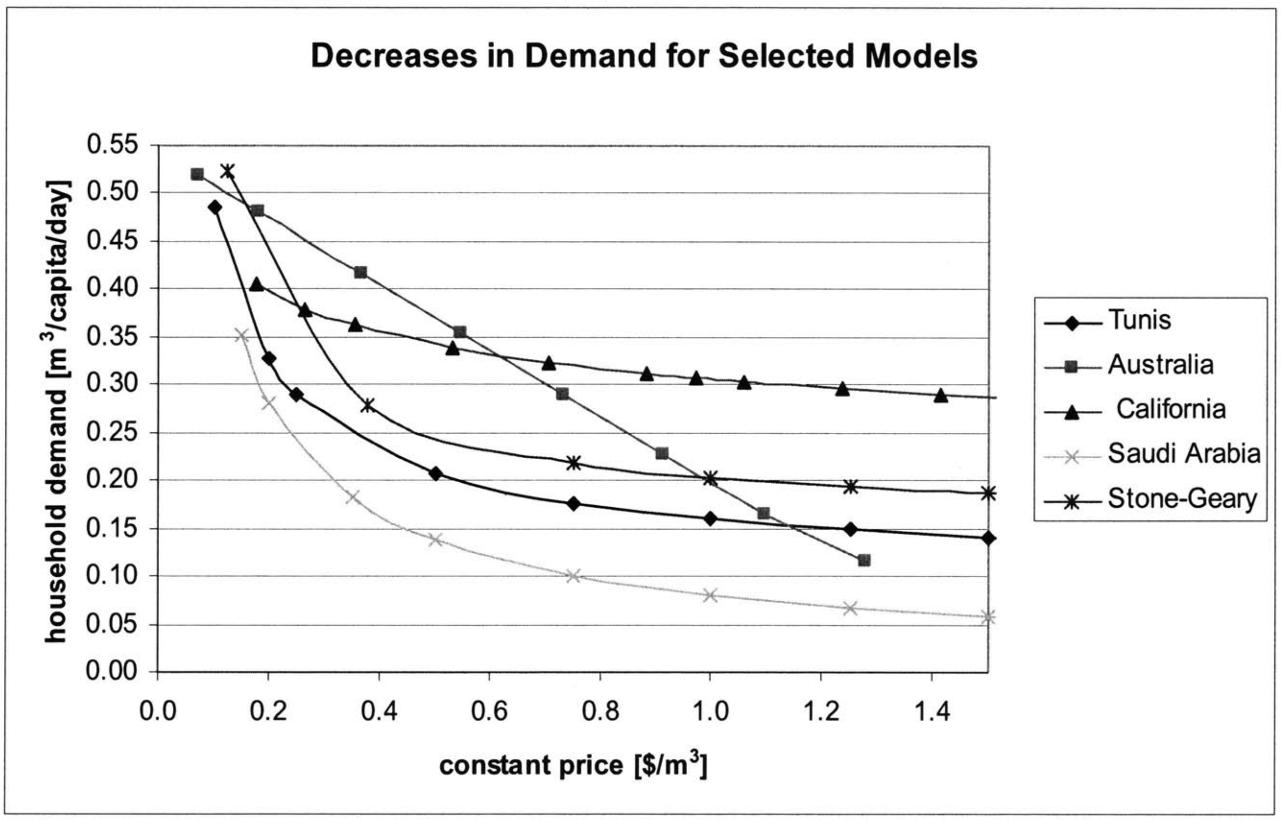
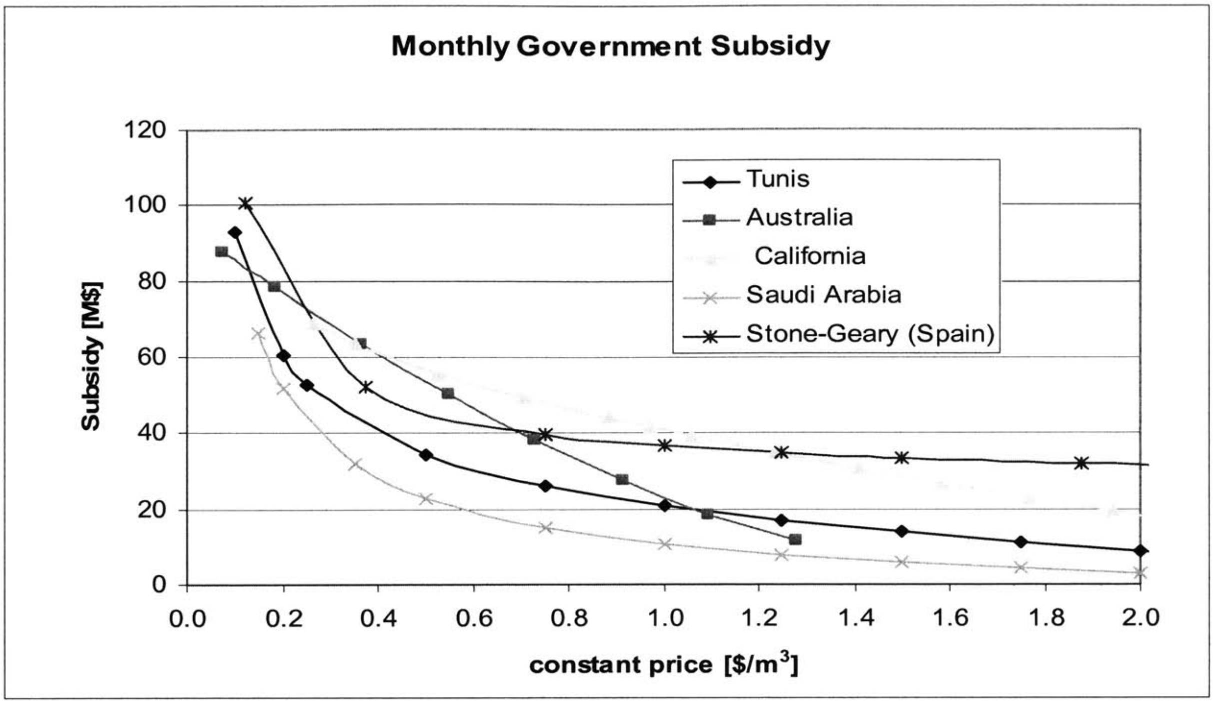


Figure 4.4: Monthly government Subsidy in Kuwait for a constant price schedule without an allowance.



4.52. Simulation of a constant price following a free allowance

As specified earlier, a simple pricing schedule is proposed: a constant price schedule with a free initial allowance (Figure 4.1). It is specified by two parameters, the quantity of the allowance and the constant price per m^3. To specify the quantity of the allowance water demand was in Kuwait was compared to other countries. Most European countries use around 150 L/capita/day. This amount satisfies the need of an average person. Since the goal of any pricing schedule is to eliminate the waste of water, all water above the allowance needs to be priced.

The first 4.5 m^3/capita/month (150 L/capita/day) would be free of charge, while all consumption afterward would be charged by prepaid water cards. Hence, at the beginning of every month the prepaid card would be reset for the meter to accept a new amount of water.

In Figure 4.5, the influence of pricing on demand is presented, indicating that this kind of pricing schedule will decrease demand. Similar to the previous simulation, the Log models and the Stone-Geary model compute that after a price of 0.8 $/m3 the demand does not show much reduction with further increases of the price (Figure 4.4), indicating that there is a quantity of water that is not elastic to prices, while the linear Australian model suggests that a price of $\$1.2/m^3$ would decrease the demand to a consumption level of around 200-300 L/capita/day, depending on the model used (Figure 4.5). So, the models show that a price of water of $\$1/m^3$, after a 150L/capita/day allowance, would decrease the demand by 25%-55% percent, depending on the demand model used, with an arithmetic average of around 40%. The circle on Figure 4 represents the point on the demand-price graph for which the coefficients were recalibrated in the models

Government Subsidy (Figure 4.5) was computed in the same manner as in the simulation without an allowance. All models computed a similar decrease in subsidy, of 40 million dollars per month, for a price of $1\$/m^3$.

Figure 4.5: Decreases in demand for selected models for an allowance followed by a constant price schedule.

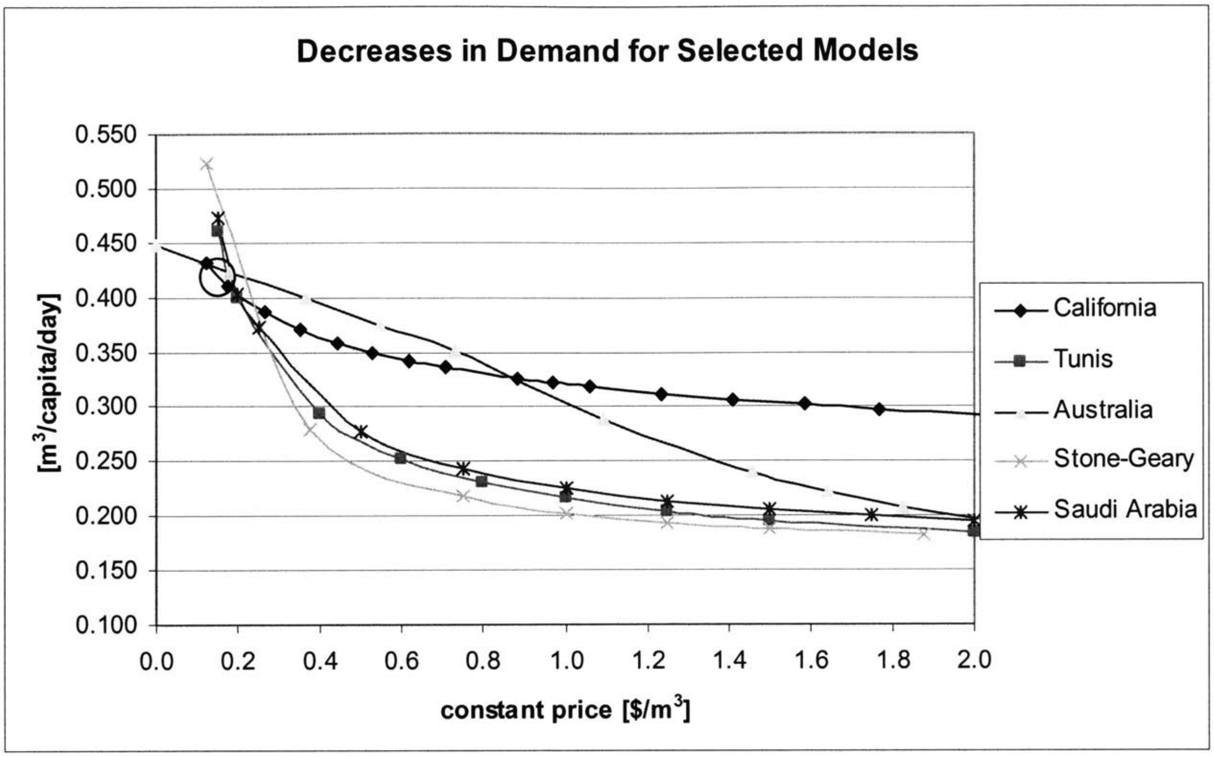
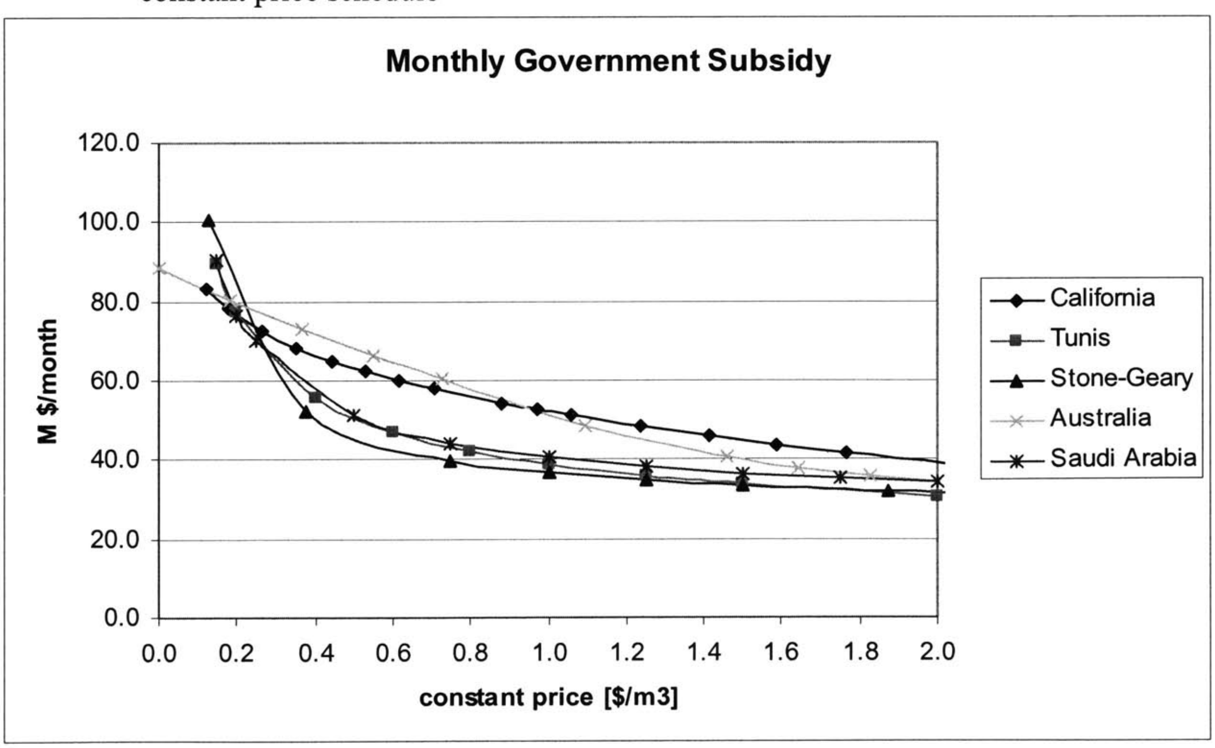


Figure 4.6: Monthly government Subsidy in Kuwait for an allowance followed by a constant price schedule



4.53. Elasticities

Models used in these simulations are based on studies from arid regions in five continents: North America (California), Europe (Spain), Asia (Saudi Arabia), Africa (Tunis) and Australia. Since the models are based on data sets from different regions of the world, they predict different price elasticities. Table 4.15 presents the elasticities for marginal (constant) prices in the original model and those found in the simulations. As can be perceived in table 4.15, elasticities in the simulations differ from original values for some of the models. This divergence might in part be due to the fact that all variables were not put into the models. However, the allowance also makes a significant impact on the elasticities.

Table 4.15: Elasticities obtained in the simulations and in the original models

Model	At price [$/m^3]	Const. prices	Allowance & const price	Original model
California	0.65	-0.16	-0.13	-0.16 to -0.2
Australia	0.73	-0.89	-0.33	-0.63 to -0.77
Tunisia	0.8	-0.41	-0.33	-0.17
Saudi Arabia	0.75	-0.86	-0.35 (AP) -0.78(MP)	-0.78
Stone-Geary-Spain	1	-0.24	-0.24	-0.1

California model: For the simulations without an allowance, the elasticity is in the range of the original model. However, in the simulations with the allowance, the elasticity is smaller. This is partly due to the fact that when an allowance is simulated, a fraction of consumers are consuming water below the allowance quantity, getting water for free, and are not influenced by price increases.

Australia model: The model was based on an allowance; it specifies that a portion of the consumers consume within the allowance, and are not influenced by prices. So, when simulations without an allowance were performed, all the consumers are influenced by price increases, resulting in a bigger elasticity. Simulations with an allowance computed smaller price elasticities, mostly because the allowance in the simulations was bigger than in the original model. Also, the Australia model has a linear form, so elasticities differ with prices.

For the California and Australia Model, income groups that numerically did not fit either above or below the allowance were fixed to be on the border. To check if this would influence the elasticities, a simulation was conducted using only groups that do not have these problems at any price ranges (California–33 groups Australia-27 groups). The results showed almost identical elasticities; the California model showed that the way the shifting between blocks was computed has an insignificant influence on elasticity. For the Australia model, the elasticities were the same; the demand function was totally linear when only groups without errors were used, while when all groups were used there was some non-linearity (Figure 4.4).

Tunis model, the assumed household income distribution (table 4.4) led to a smaller percentage of the total population in the lower consumer block, and a larger percentage in the higher block than in the original model, which consequently increases the price elasticity, because the model is specified to have a bigger elasticity for the upper block.

Computing marginal price elasticities for models that use the average price as a variable might not present the results in the best way; however consistency was the governing principle.

4.54 Influence of the allowance and price on demand reduction

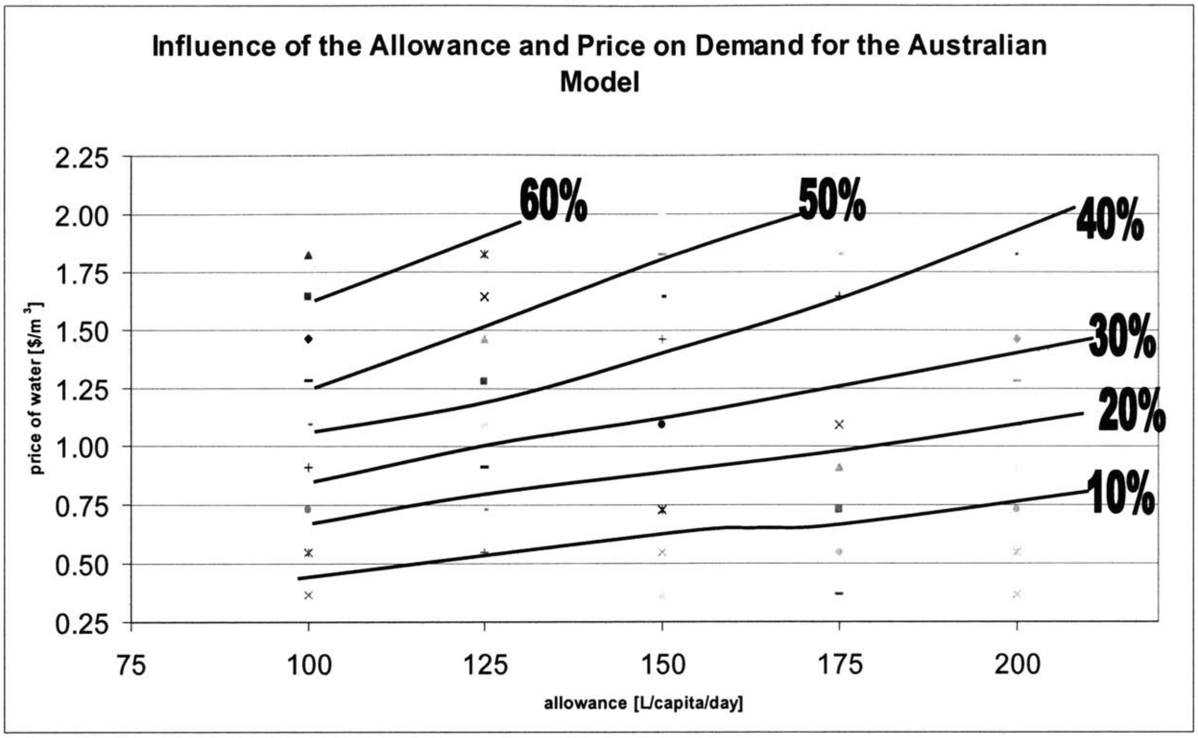
The influence of the allowance on demand reduction for various prices is presented in figure 4.7 for the Australia model and in figure 4.8 for the Saudi Arabia model. In the simulations, the initial demand was computed for prices equal to $0.25/m^3 for the Australian and Saudi Arabia models and reduction percentage was based on the corresponding demand. Both models showed similar results indicating that the price has a bigger influence on demand than the allowance. Also, for different values of the allowance, the initial values of demand slightly differ; however, these initial values have insignificant influence on the demand reduction percentage.

Table 4.16 shows demand reduction in the simulations for all models at a marginal price of $1/m^3 for an allowance of 150 L/capita/day.

Table 4.16 – Reduction in demand in simulations at the marginal price of 1$/m^3

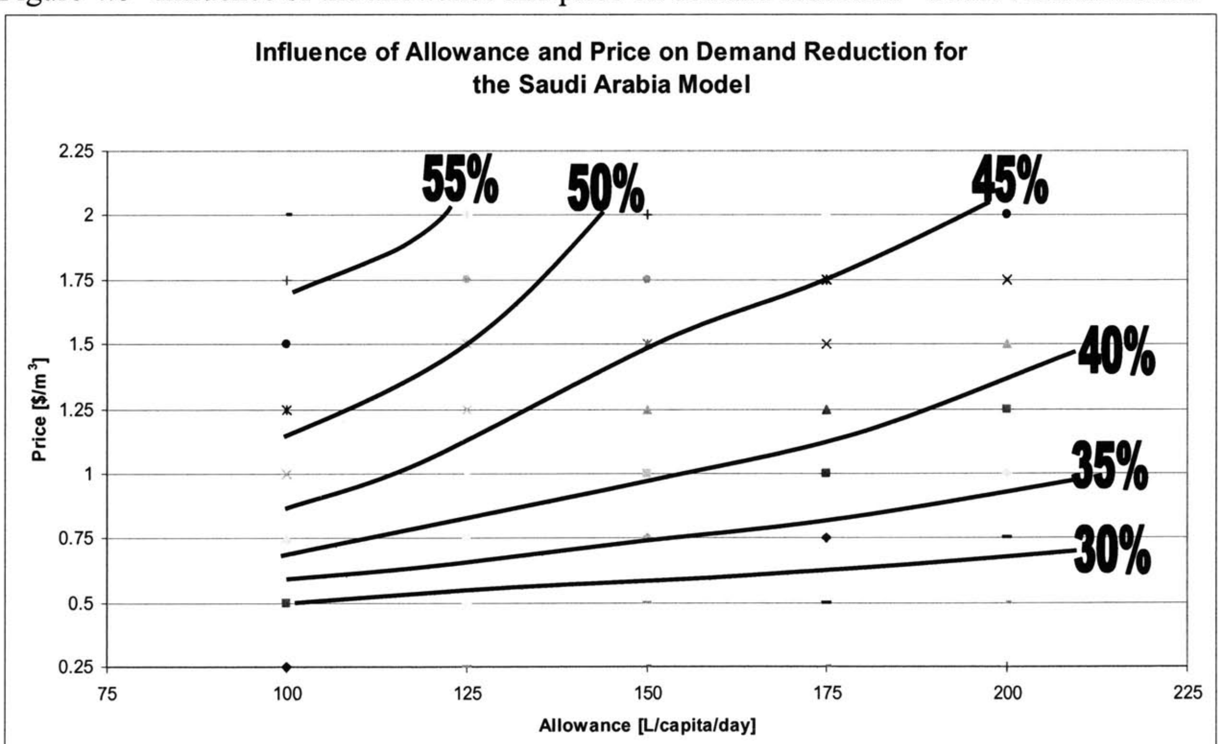
Model	At the marginal pricing of 1$/m3		
	Reduction from an initial price of [$/m3]	Without allowance	With allowance of 150 L/capita/day
California	0.25	19%	17%
Tunisia	0.25	45%	40%
Saudi Arabia	0.25	66%	41%
Australia	0.25	57%	28%
Stone-Geary Spain	0.25	41%	41%
Average		45%	34%

Figure 4.7 – Influence of the allowance and price on demand reduction - Australian Model.



Lines represent areas of equal reduction percentage from a demand computed for a price of \$0.25/m^3.

Figure 4.8– Influence of the allowance and price on demand reduction - Saudi Arabia Model.



Lines represent areas of equal reduction percentage from a demand computed for a price of 0.25\$/m^3.

4.55 Changes in the distribution of the consumption

The distribution of computed water demand, using the Australia model for simulations of a free allowance followed by a constant price, for various prices are presented in Figures 4.9-4.11. The figure shows that at a zero price of water, there will be no households with consumption less than 150 L/capita/day. However, for a price of $\$2/m^3$, over 50% will consume less than that value.

Figure 4.9

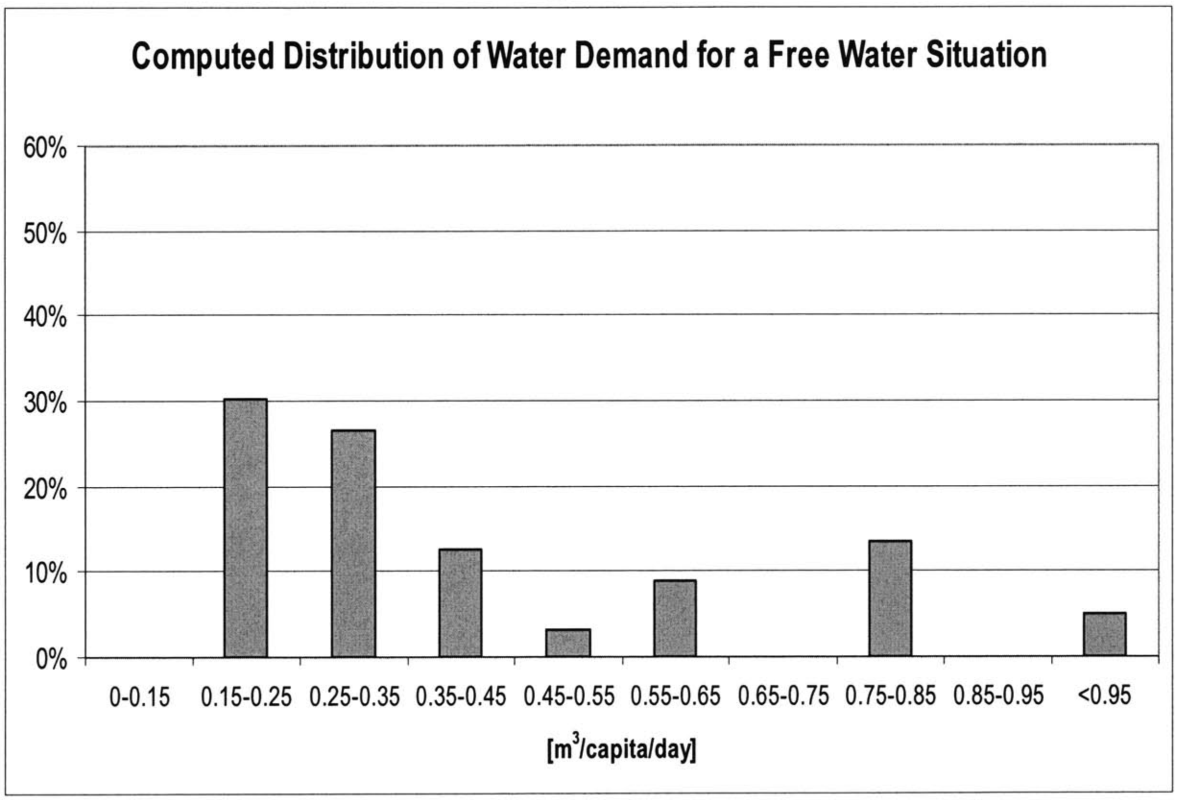


Figure 4.10

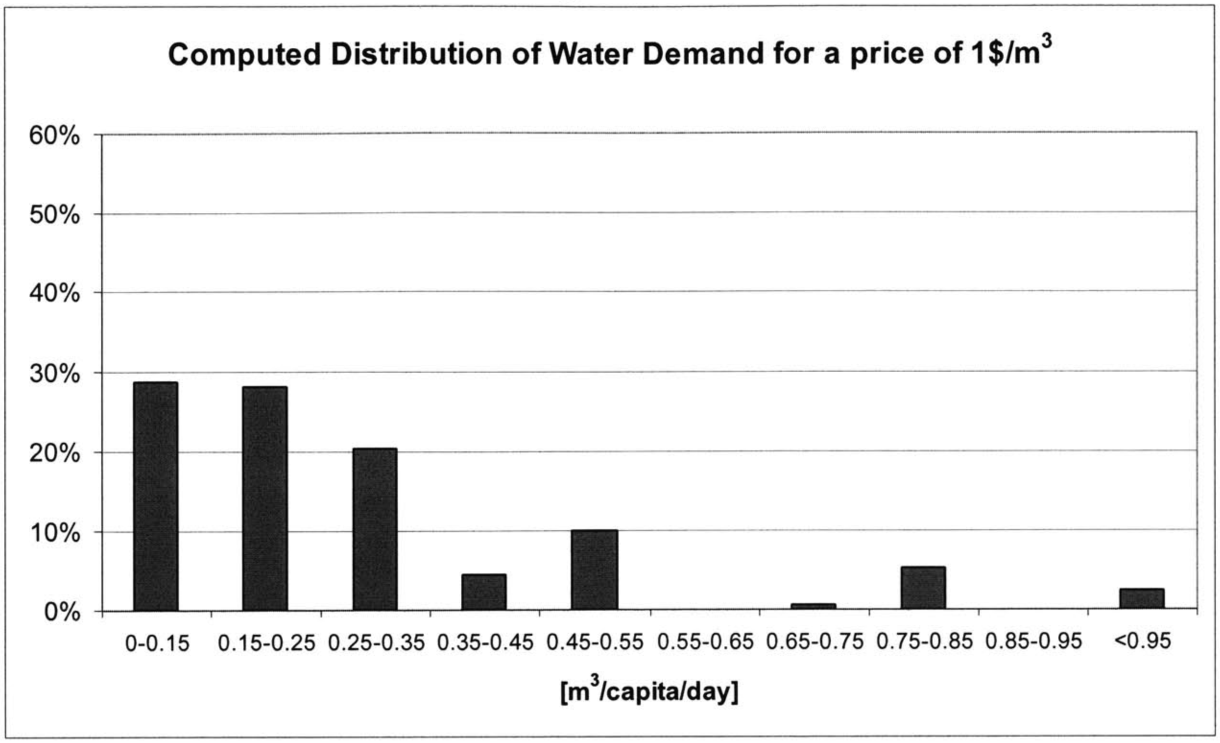
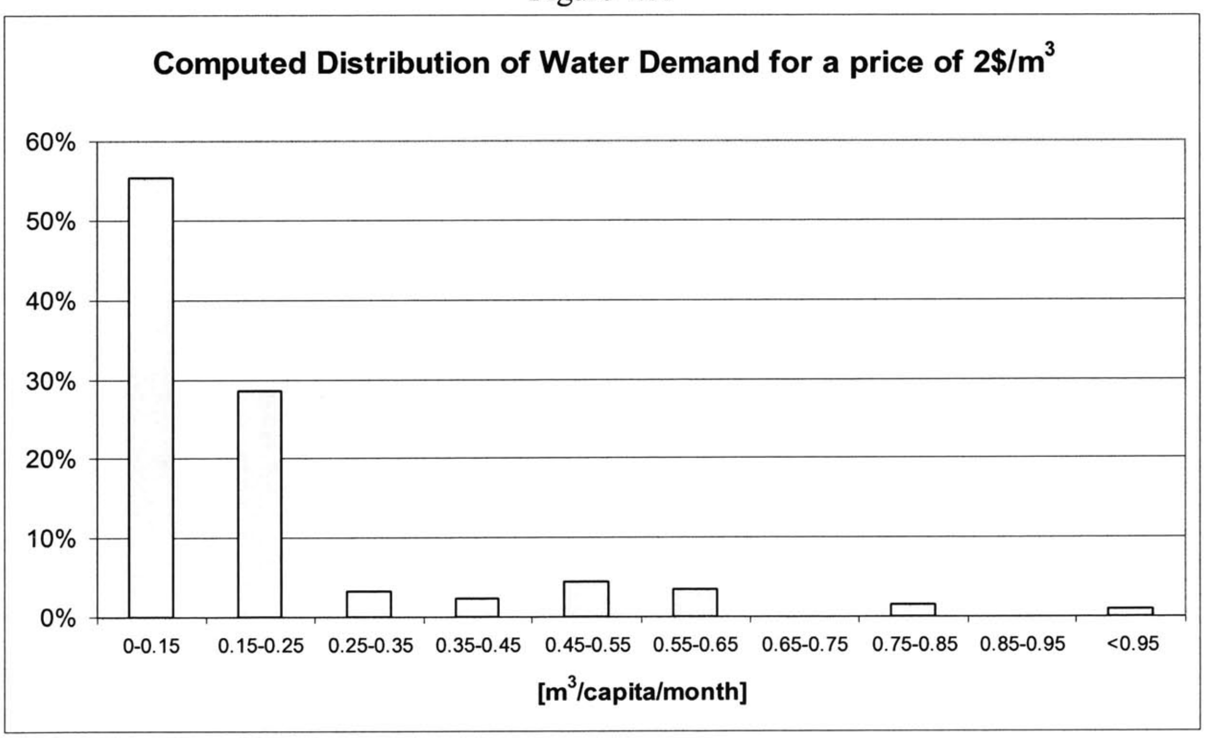


Figure 4.11



4.5. Conclusion

The results showed that pricing water in Kuwait would decrease the demand to an acceptable level. For the simulation of a constant price with an initial free allowance, the models computed that a $\$1/m^3$ price of water, after a 150 L/capita/day allowance, would decrease the demand by 20-40 percent, depending on the demand model used, with an arithmetic average of around 35 percent. For simulations without an allowance, the arithmetic average of the demand reduction for the five models was found to be around 45 percent.

Logically, marginal price elasticities were shown to be slightly larger for a schedule without an allowance. However, paying for water in Kuwait is not the normal practice. So, water bills could be perceived as an unnecessary toll that possibly would not be widely accepted. From a political/socio-economic point of view, a free allowance would certainly be more acceptable solution to address Kuwait's immense water demand problem. It would be for the Kuwaiti government to quantify the two parameters, the price and the allowance, by selecting the most appropriate values.

Since the main objective of charging water after an allowance is to eliminate the waste of water, this kind of pricing would help in addressing this problem. Also, the results presented would be similar for other countries in the Gulf region, where water is generally under priced.

The assumptions abut to the demand models to input should not influence the projected demand reduction. However, since data with actual Kuwait demand characteristics is not available , possible divergence might occur. But, since the models generally have similar results, range of predictions of the influence of the proposed pricing schedule should be accurate enough. More research has to be done in the water demand modeling for Kuwait. Research has to be conducted to see what the water is spent on. Water needs to be metered. Data regarding household consumption characteristics need to be collected, including household income, household size, household water consumption, pool ownership, lot sizes, and landscape irrigation.

5. Simulations of the Influences of Various Pricing Schemes

Prior to the price proposal, other simulations were conducted to see the influence of various pricing schemes on demand. Simulations of the influences of block tariffs and the influence of the percent of household income paid for the water bill were performed. The input assumptions, consumer groups and variables used are the same as in the price schedule proposal of chapter 4. Coefficients used slightly differ from the coefficients in the price schedule proposal, since these simulations had the goal to study the demand models and were conducted in a preliminary phase of this study. This chapter is presented after the price schedule proposal chapter, even though they were conducted before it. In this section only the California and Tunis models were used. The main results of these simulations are that an increasing block tariff schedule will decrease demand more than a constant pricing schedule. Also, simulations showed that a pricing schedule that would result in 1.5% of the total income to be paid for water by an average consumption group would make the demand decrease to a standard consumption level.

5.1 Influence of water pricing and block tariffs on Demand and Government Subsidy

5.11 California Model

Adaptation

The coefficients in the model were adapted to get a value of 430 L/capita/day for a price of water of \$0.75/m^3. The next changes were made. The MP coefficient was increased assuming that because of the lower pay in Kuwait, consumers would show a slightly larger influence on pricing. The income coefficient was increased by a factor of 2.6*1.27 where 2.6 is the GDP ratio for the USA and combined Kuwaitis and Non-Kuwaitis. 1.27 represents the parameters that were not put in the model but are a function of income (lot size...). Also a cost to produce water of \$3/m^3 was assumed. Table 5.1 summarizes the coefficients used in the simulations of block tariffs. The problem of shifting between blocks (explained in the price proposal chapter) was addressed differently than in the price proposal. It was addressed by always taking the lower block. The errors made by this situation increase as the price increases, and can at higher prices influence the demand by 10-15%. But since it was always calculated in the same way, it should have insignificant influence.

Table 5.1. Original coefficients and coefficients used in the California Model Block Tariff and Prohibition simulations

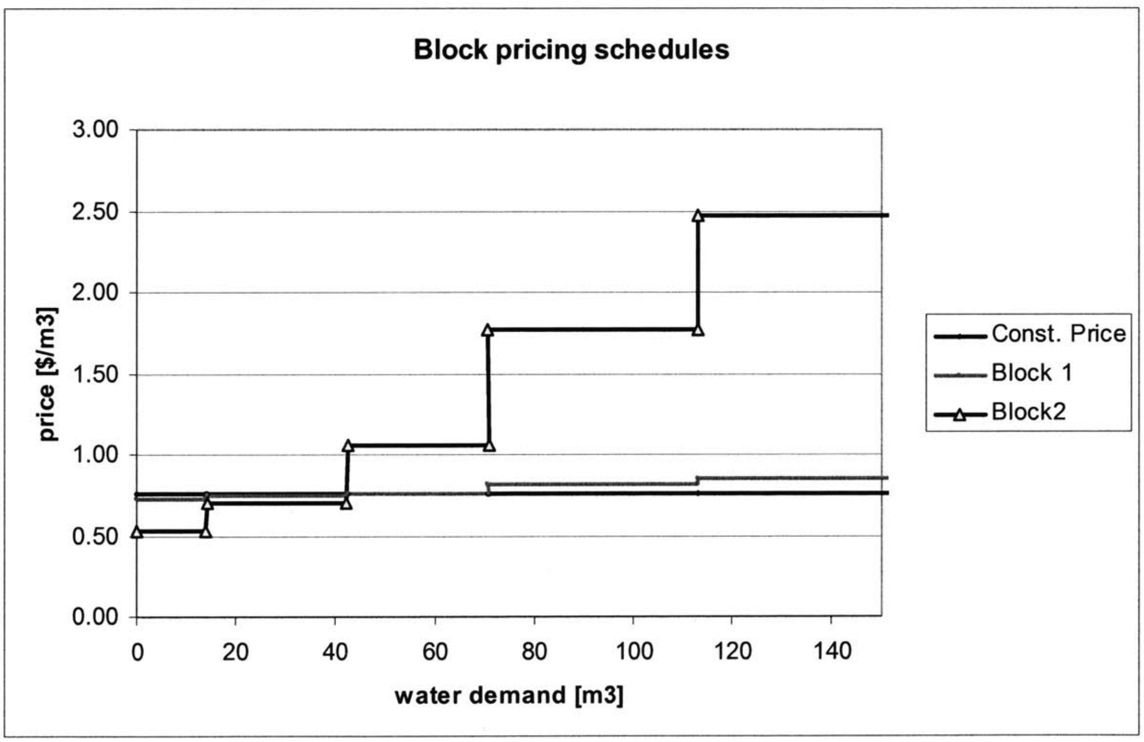
		California	Kuwait
Coeff.	Description	value	value
β0	Interception	2.61	2.48
β1	MP	-0.16	-0.256
β2	Difference variable	0.01	-0.01
β3	Income	0.25	0.85
β4	Household number	0.2	0.24

Results

To show the influence that block tariffs have on water demand, three different tariffs were used. One, with a const price of water, and two with different slopes of marginal price increase (table 5.2 & Figure 5.1).

Table 5.2 Block Tariffs used in the California model					
	Demand [m3]		const.price	Block1	Block2
No	from	to	$/m3	$/m3	$/m3
1	0	14	0.76	0.72	0.53
2	14	42	0.76	0.74	0.71
3	42	71	0.76	0.76	1.06
4	71	113	0.76	0.81	1.77
5	113	453	0.76	0.85	2.47

Figure 5.1 –Block pricing schedules used in the California simulations



Simulations were made for different prices and block tariffs. An average price schedule and a block tariff were compared. Results show that changing the pricing schedule from a constant price to a block pricing schedule will have similar influence on demand as a 50% increase in price for a constant price schedule (Figure 5.2).

The influence that pricing has on demand for Kuwaiti (Figure 5.3) and non-Kuwaiti (Figure 5.4) are presented. Since Kuwaitis have bigger average income, they consume more water than Non-Kuwaitis. So, the decrease in demand for Kuwaitis would have a much bigger influence on the total demand reduction than for Non-Kuwaitis. This suggests that a block tariff schedule will be more efficient in decreasing demand.

The influences of the average price of water on total cost to produce water, total price paid by consumers, and total subsidy by the government are presented, for a const price and the third block tariff schedule in figure 5.5 for a total population of 1.9 million. Since block tariffs compute smaller demand for the same average price of water, consequently they reduce the cost to produce water and the total price paid by consumers. However, as the subsidy is the difference between these two categories, the subsidy has a similar value for all pricing schedules. The figure shows that pricing water an average rate of $1.5/m^3, would reduce the subsidy by 30 million dollars (the cost to produce water was assumed to be $3 /m^3).

Figure 5.6 shows the influence on demand for: 5 prices in block 3 (for MP & D), 5 income groups, 4 household size groups, and basic demand (constant). It shows that the income and constant variables have the biggest influence in the demand equation.

Figure 5.2 - Influence of block tariffs for the California model

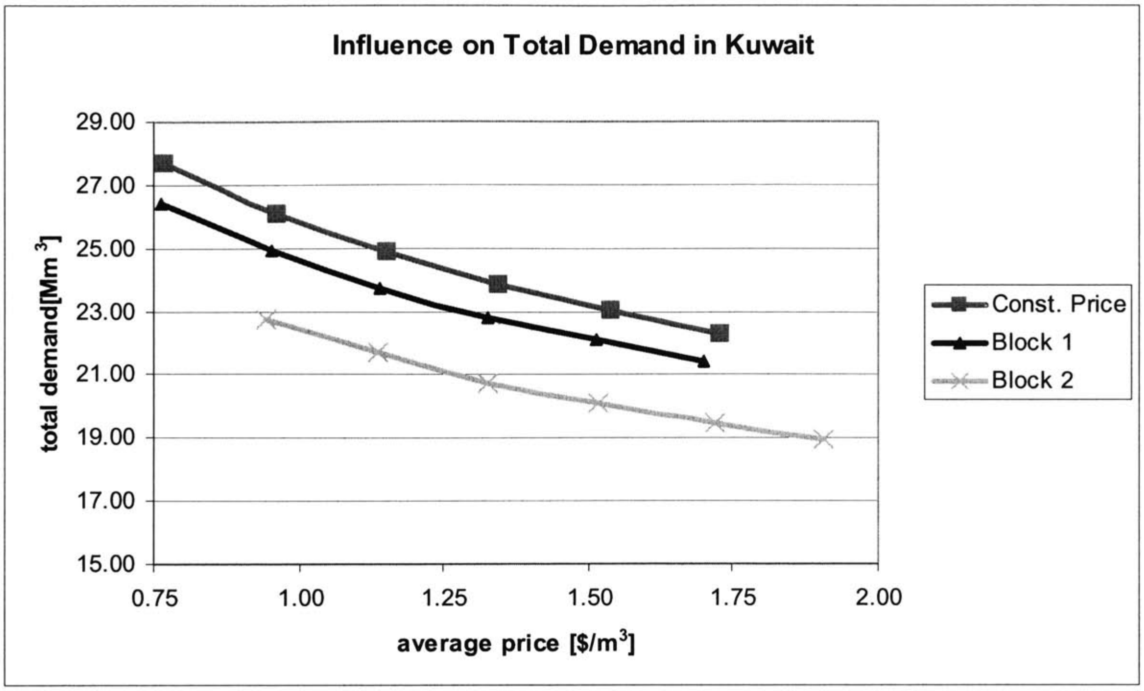


Figure 5.3 - Influence of pricing on Kuwaiti (California model)

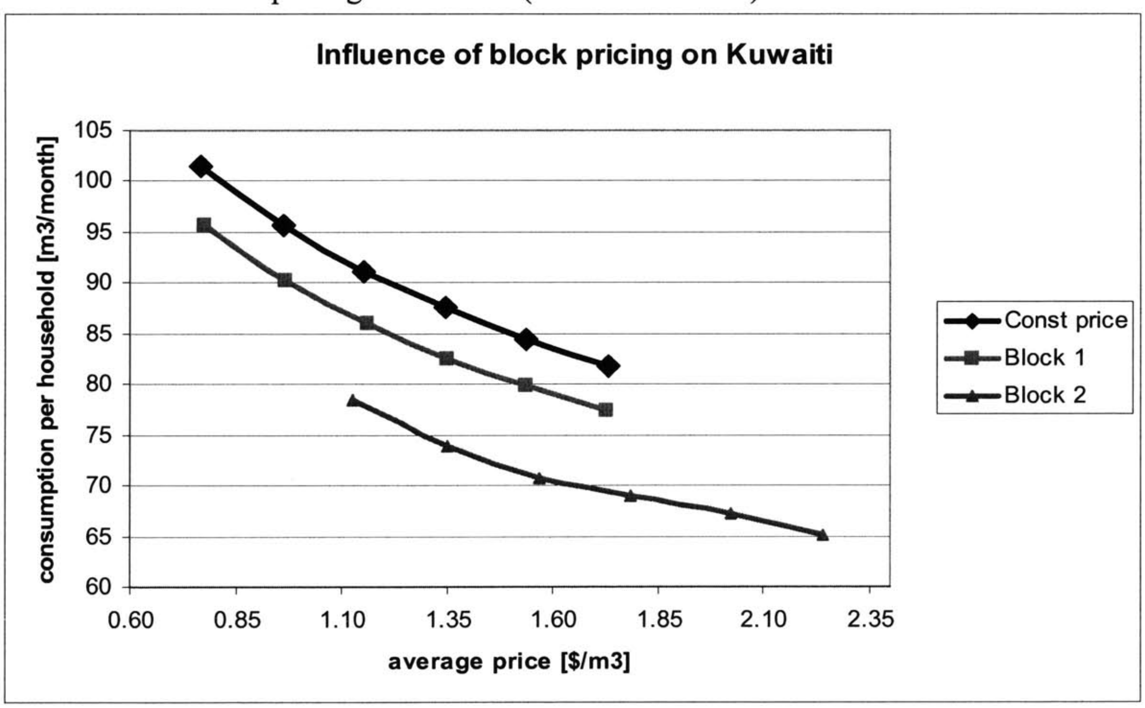


Figure 5.4 - Influence of pricing on Non- Kuwaiti (California model)

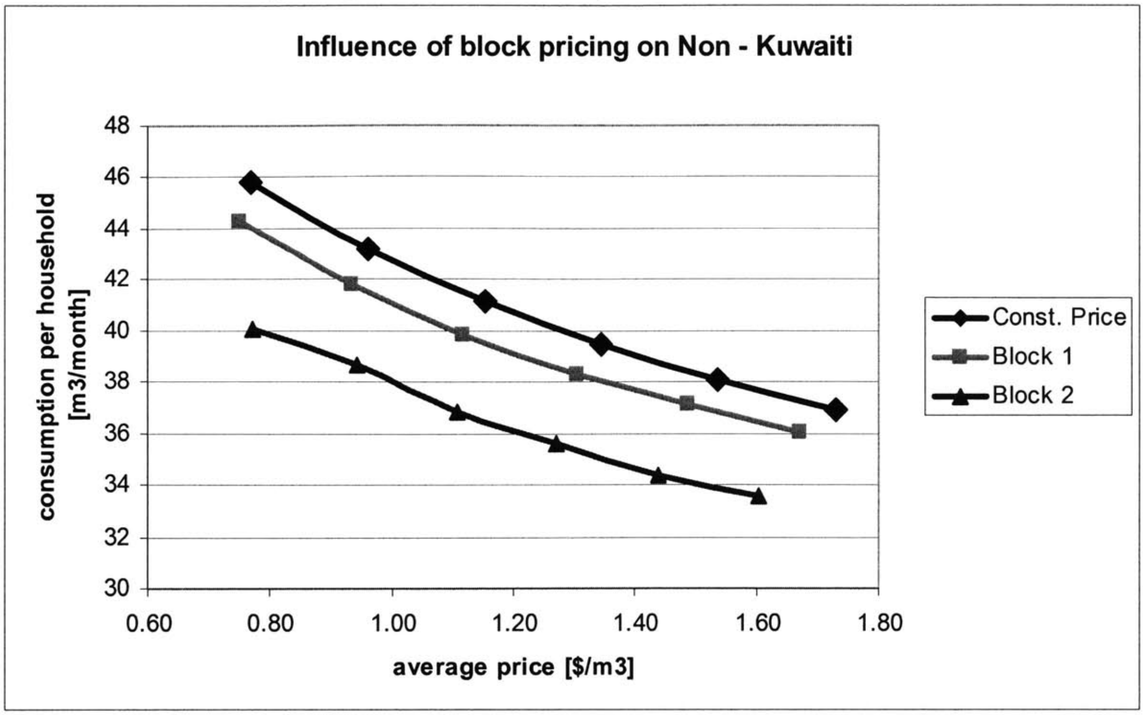
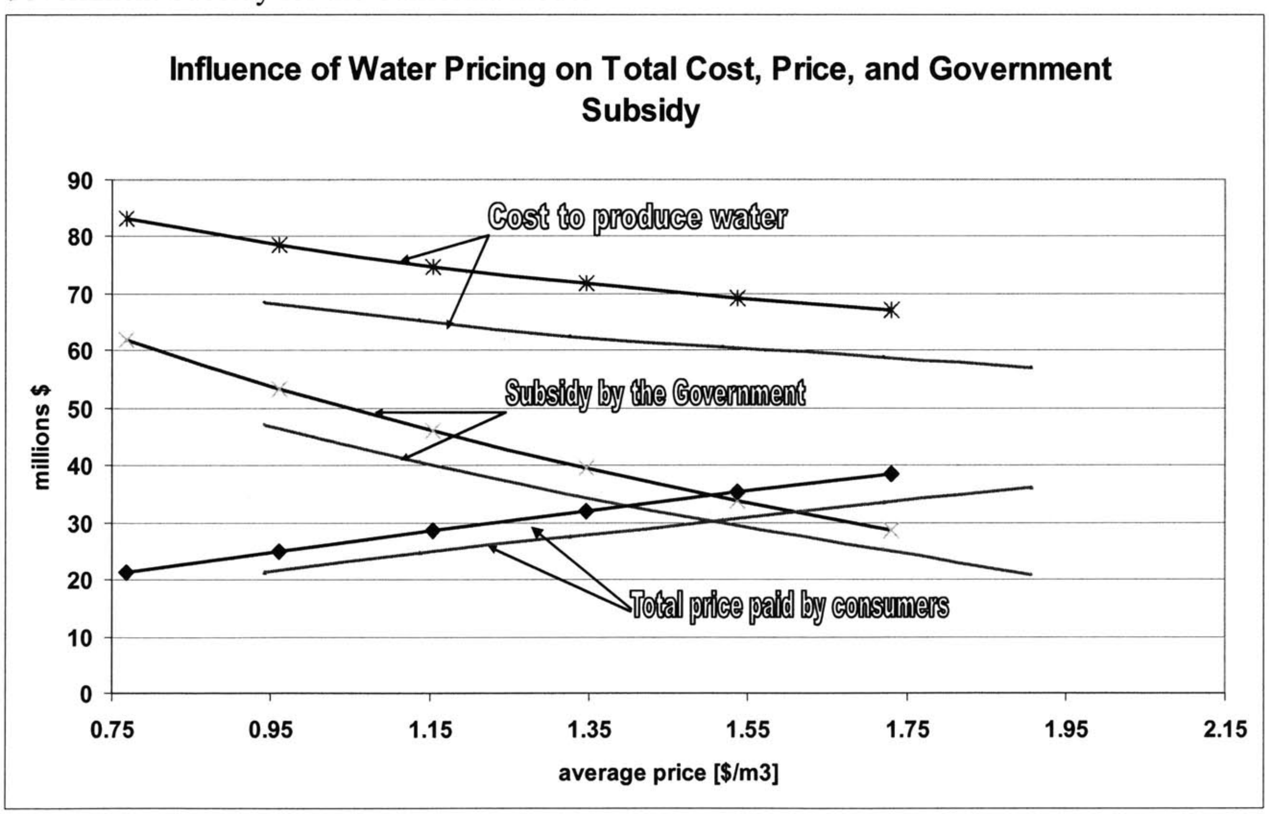
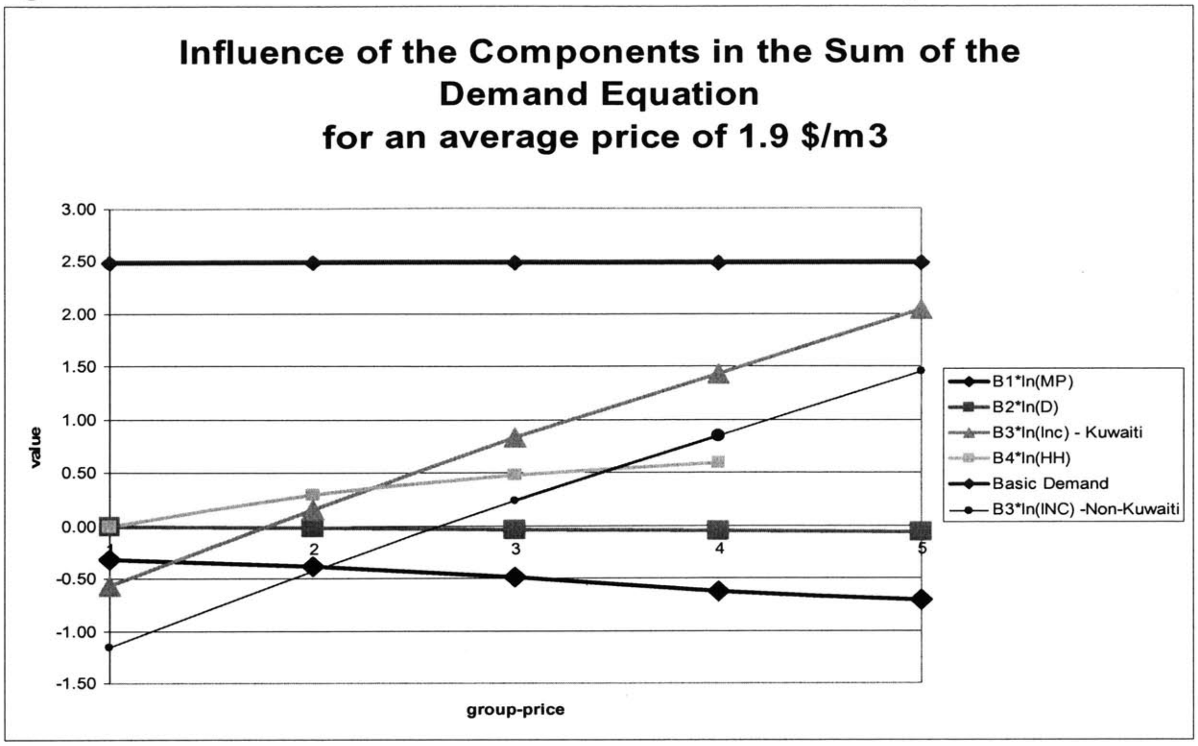


Figure 5.5_– Influence of Constant pricing and a block tariff system on the Total Cost, Price and Government Subsidy for the California model



(Upper lines(blue) – Constant pricing Lower lines (red) – Block 2 pricing)

Figure 5.6 - California Model- influences of variables in the demand equation



5.12 Tunis Model - Block Tariffs

<u>Adaptation</u>

Table 5.3 presents the coefficients used in the water demand equation in the Tunis simulations for block tariffs. In this simulation the coefficients were calibrated to get a demand of 430L/capita/day for a price of 0.75 $/m3. The intersection coefficient was changed, while other coefficients remained the same.

The γ_0 coefficients were changed in order to match the group break ups specified in the first section. The first and second groups compose the lower bracket and the fourth and fifth groups make the upper bracket. This led to a smaller percentage of the total population in the lower bracket, and a larger % in the higher bracket; which consequently increases the price elasticity, because the model is specified to have a bigger elasticity for the upper block. Values are presented in table 5.4

Table 5.3 – Coefficients used in the Tunis model water demand equation for block tariffs and prohibition simulations					
		Kuwait		Tunis	
Coeff	description	Lower Block	Higher block	Lower Block	Higher block
$\alpha 0$	interception	1.5	2	3.1	8.65
$\alpha 1$	Income	0.06	0.05	0.06	0.05
$\alpha 2$	Price	-0.08	-0.34	-0.08	-0.34

Table 5.4 - Coefficients used in the Tunis model consumers proportion equation for block tariffs and prohibition simulations					
		Kuwait		Tunis	
	description	Lower Block	Higher block	Lower Block	Higher block
γ_0	intersection	1.454	2.462	3.27	9.84
γ_1	price	0.05	-0.62	0.05	-0.62
γ_2	number of h	0.03	-0.21	0.03	-0.21

Simulation

In order to compute the response of various blocks on water demand, the tariffs presented in table 5.5 & Figure 5.7 were used in simulations.

Table 5.5 – Block tariffs used in the Tunis Model Simulations

	Demand [m^3/household/month]		const. price	Block1	Block2	Block3	Block4
No	from	to	$/$m^3$	$/$m^3$	$/$m^3$	$/$m^3$	$/$m^3$
1	0	14	0.76	0.72	0.6	0.53	0.01
2	14	42	0.76	0.74	0.72	0.71	0.53
3	42	71	0.76	0.76	0.8	1.06	2.12
4	71	113	0.76	0.81	1.3	1.77	2.82
5	113	453	0.76	0.85	2	2.47	3.53

Figure 5.7 Block Tariffs used in the Tunis Simulations

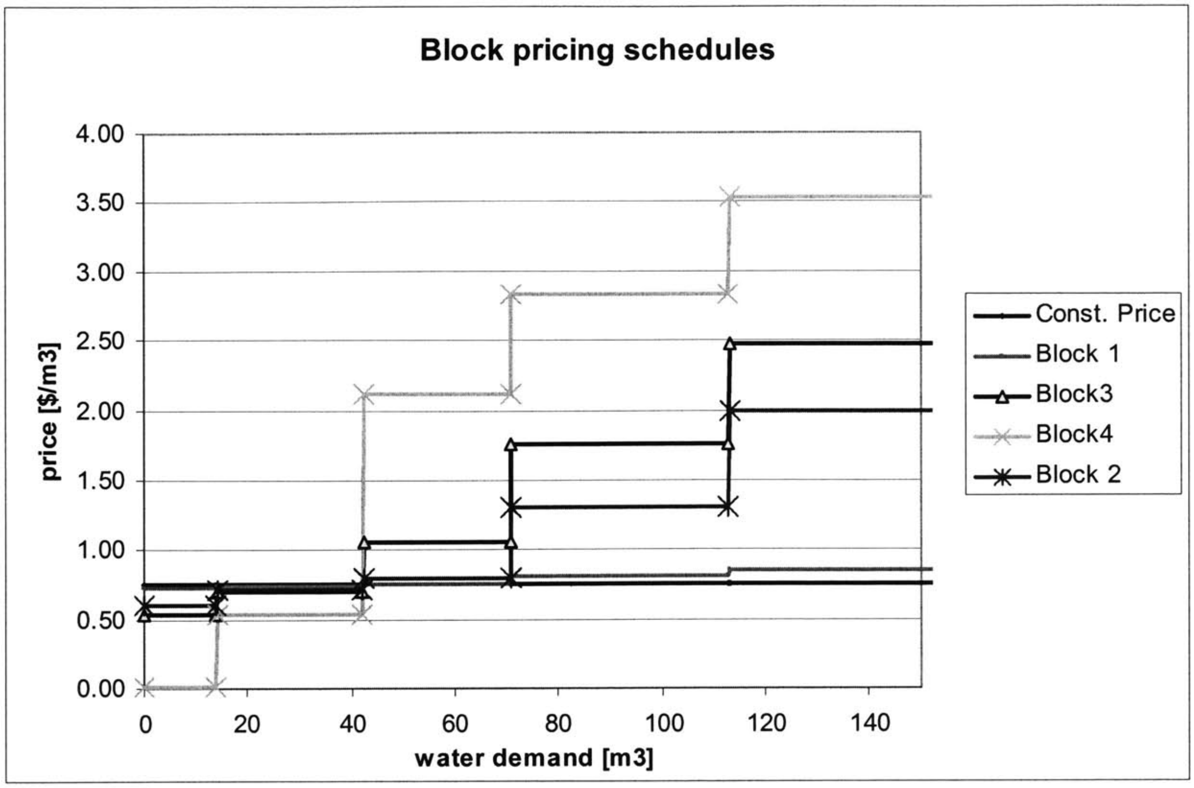
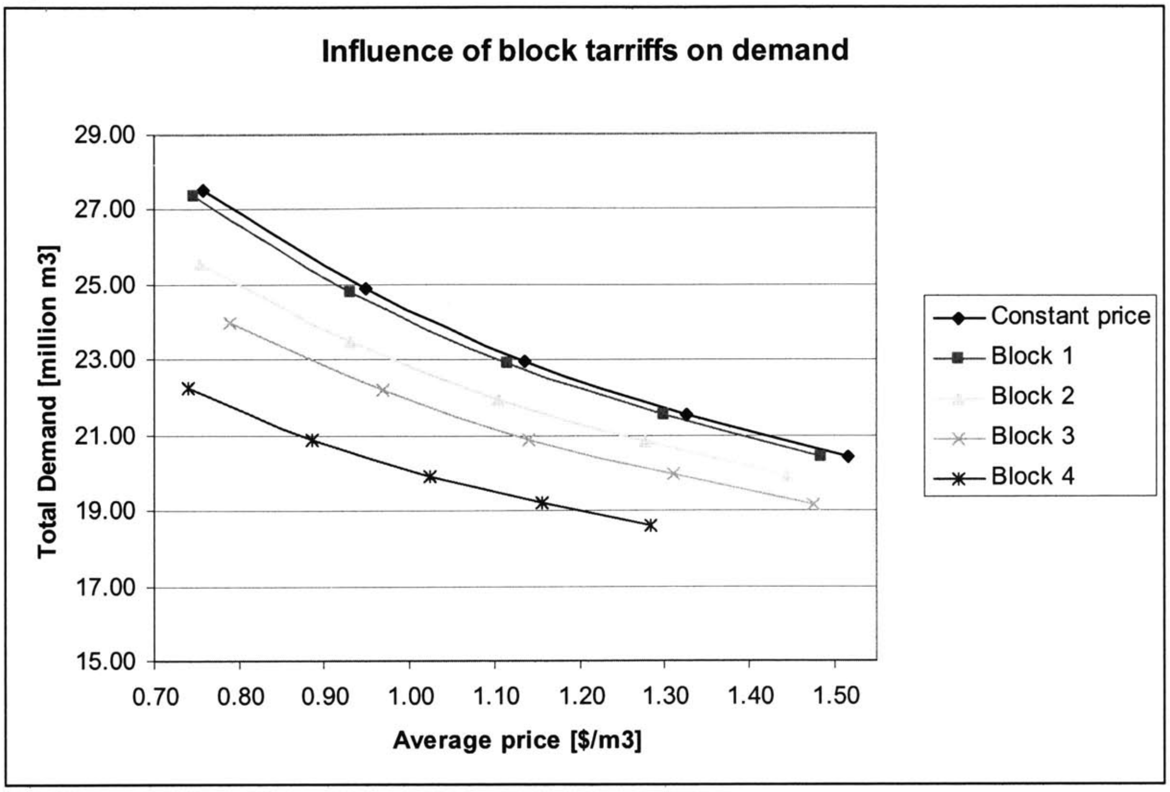


Figure 5.8 shows the influence that block tariffs have on demand. A more increasing tariff lowers the demand more. This is because an increasing block schedule influences the higher consumers more, making the higher bracket have a higher average price.

Figure 5.8 - Influences of block tariffs on demand in the Tunis simulations



As can be seen on the next two Figures the higher bracket shows a significant decrease when the average price paid by the bracket is increased (Figure 5.9), while the lower bracket only slightly decreases (Figure 5.10). Figures are the same for all tariffs because water demand is computed using the average price paid in considered bracket

Figure 5.9 – Responds of the Higher Bracket in the Tunis Model

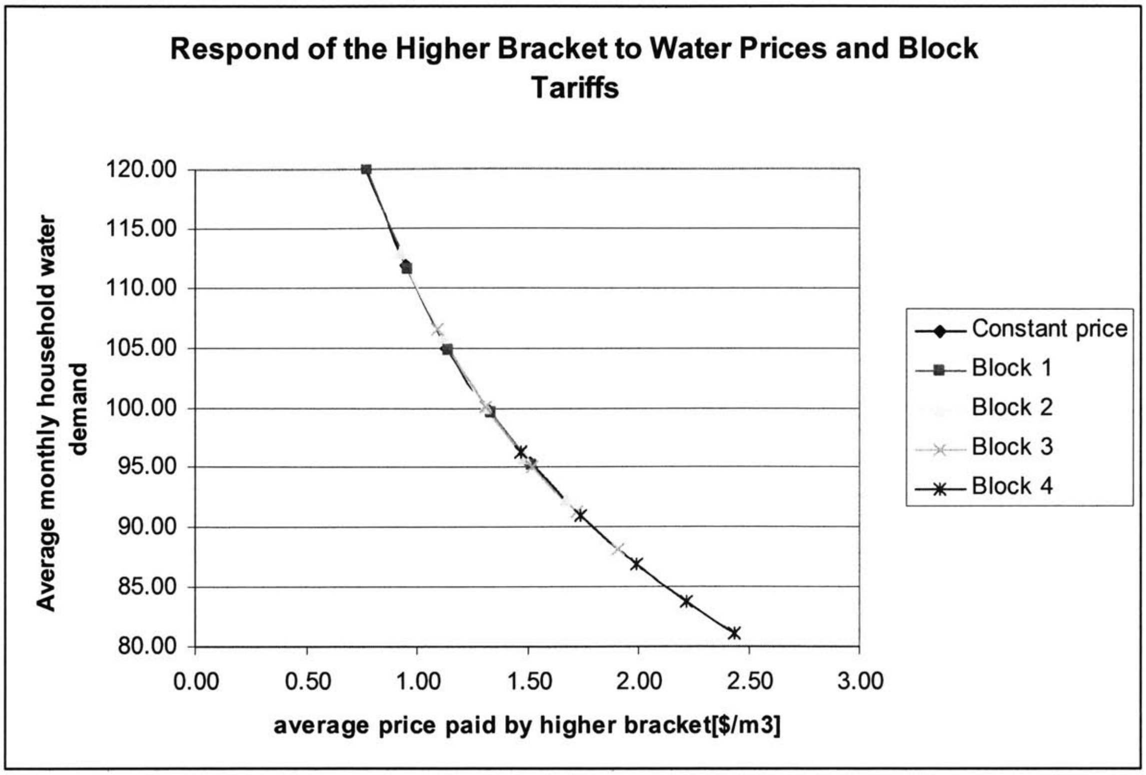
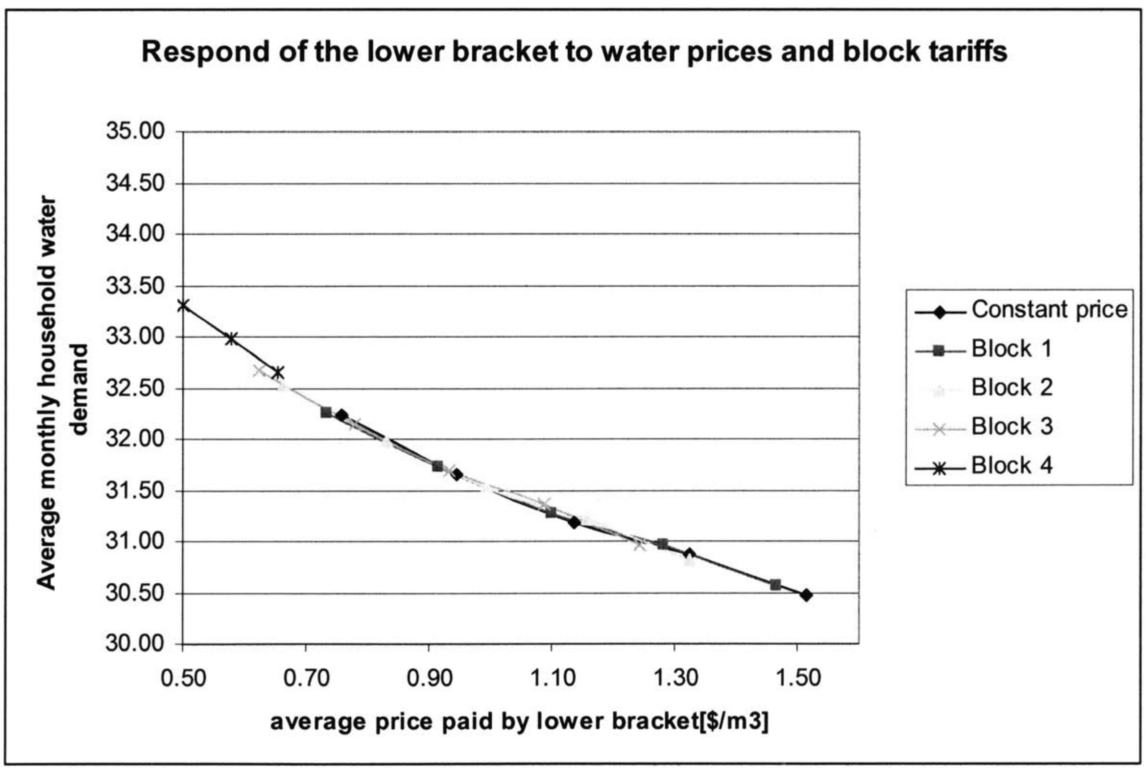


Figure5.10 - Responds of the Lower Bracket in the Tunis Model



This Figure (5.11) shows the influence of both block pricing and price increase on the total cost to produce water, total price paid by consumers, and total subsidy by the government. As can be seen, the higher block schedule, decreases demand the most, influencing all parameters (for the same average price paid by consumers).

Figure 5.12 shows shifting between blocks when prices increase. The increase of water price will make consumers shift from the higher bracket to the middle one (not calculated), and from the middle to the lower bracket.

Overall, the results for this model show that the Lower bracket demonstrates a small decrease in demand as a result of a price increase of $1/m^3$ (8%), while the higher bracket expresses a significant reaction to a $1\$/m^3$ price raise (up to 25%). Price increasing makes consumers from the higher bracket shift to the lower, therefore decreasing the total demand.

Figure 5.11 –The Total Cost and Price of Water and Government Subsidy in the Tunis model

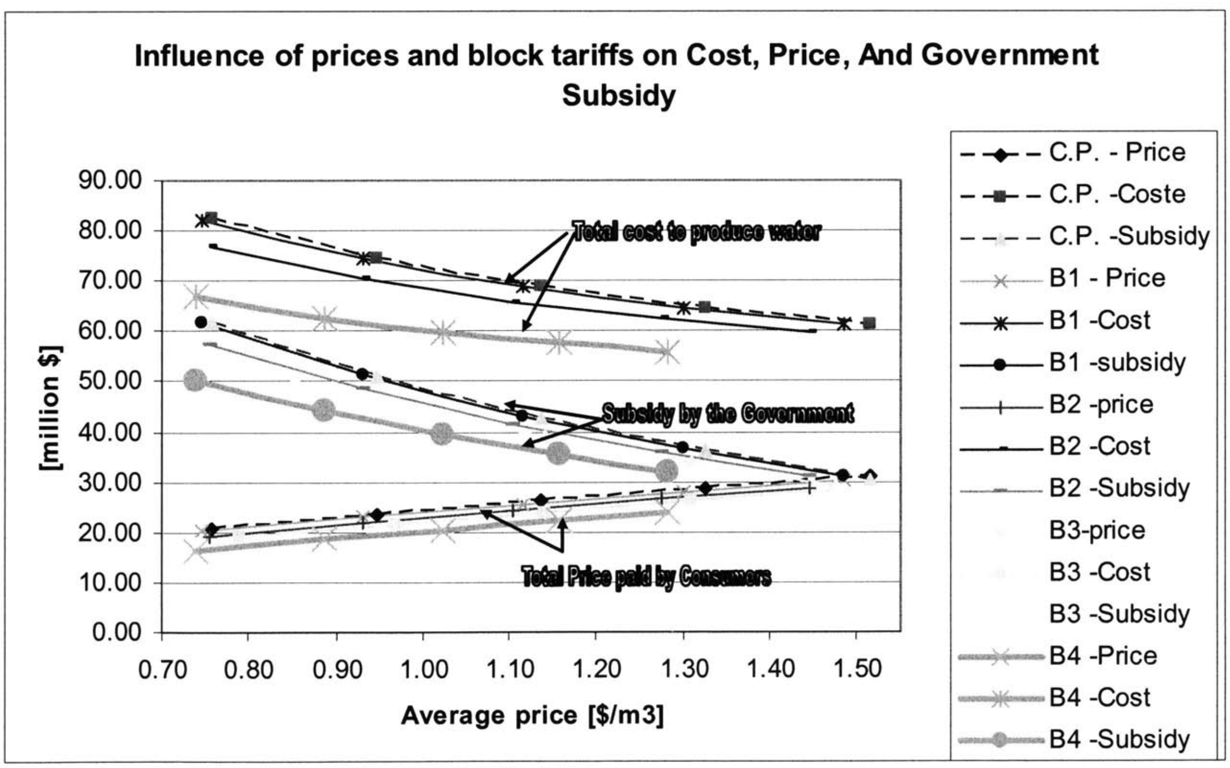
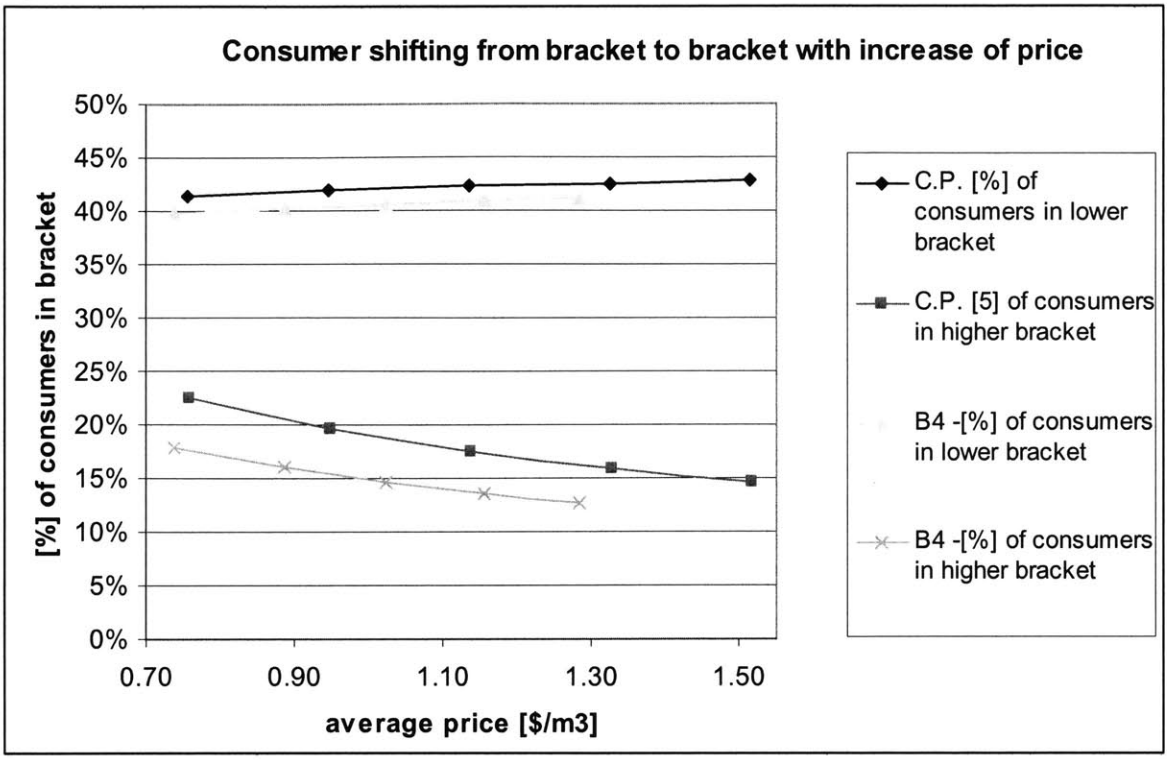


Figure 5.12 – Shifting between block in the Tunis model



5.2. Influence of the percent of household income that is paid for the water bill on demand

California model adaptation

In order to get a reasonable model for Kuwait, some of the coefficients were altered in the following way:

- Overall, coefficients were adjusted to get a consumption of 375 L/day/capita with a water price of \$0.15 m3 (currently in Kuwait water bills are not efficiently collected; since the model has a logarithmic form a zero price is not computable).
- The coefficients remained the same as in the previous simulations (Table 4.1), with an exception of the intersection. It was calibrated to get a value of 375 L/capita/day for a price of \$0.15/m^3. Also, a cost to produce water of \$3/m^3 was assumed. Coefficients used in this simulation are presented in table 5.6.

Table 5.6 - Coefficients used in the California Model simulations of the influence of the percentage of the household bill on demand

		Original	Kuwait
Coeff.	Description	value	value
$\beta 0$	Interception	2.61	2.1
$\beta 1$	MP	-0.16	-0.256
$\beta 2$	Difference variable	0.01	-0.01
$\beta 3$	Income	0.25	0.85
$\beta 4$	Household number	0.2	0.24

In this simulation, block tariffs were constructed as a function of the percent of the household income that is spent on the water bill by an average household. This was analyzed to show how much an increase in water charging would influence the average consumer's budget. Also, the decrease in demand was shown, and government subsidy was calculated.

The following Figures represent:

- Block tariffs that will produce a water bill that will be equal to a certain percentage of income for an average household (Figure 5.13)
- The decrease in water demand, as a function of percent of income that an average household has to pay for water (Figure 5.14)
- The government subsidy for various ratios of the water bill and income. (Figure 5.15)

Figure 5.13 – Block Tariffs constructed to have a certain percentage of the Total income

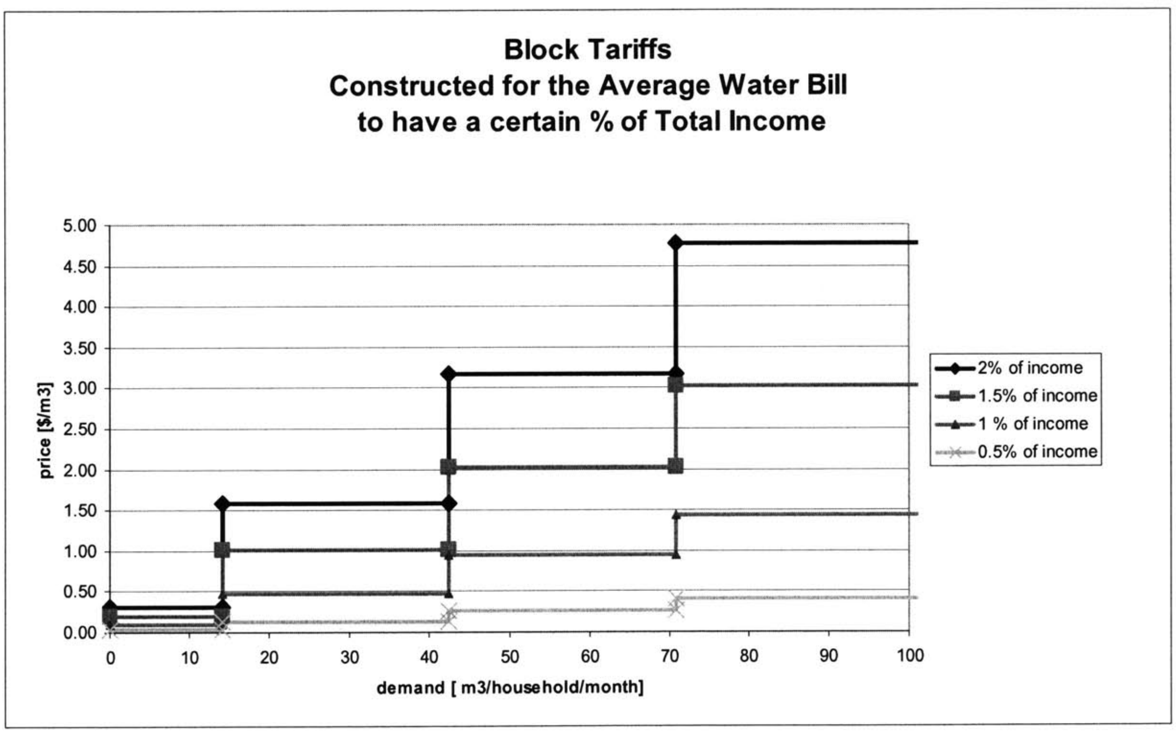
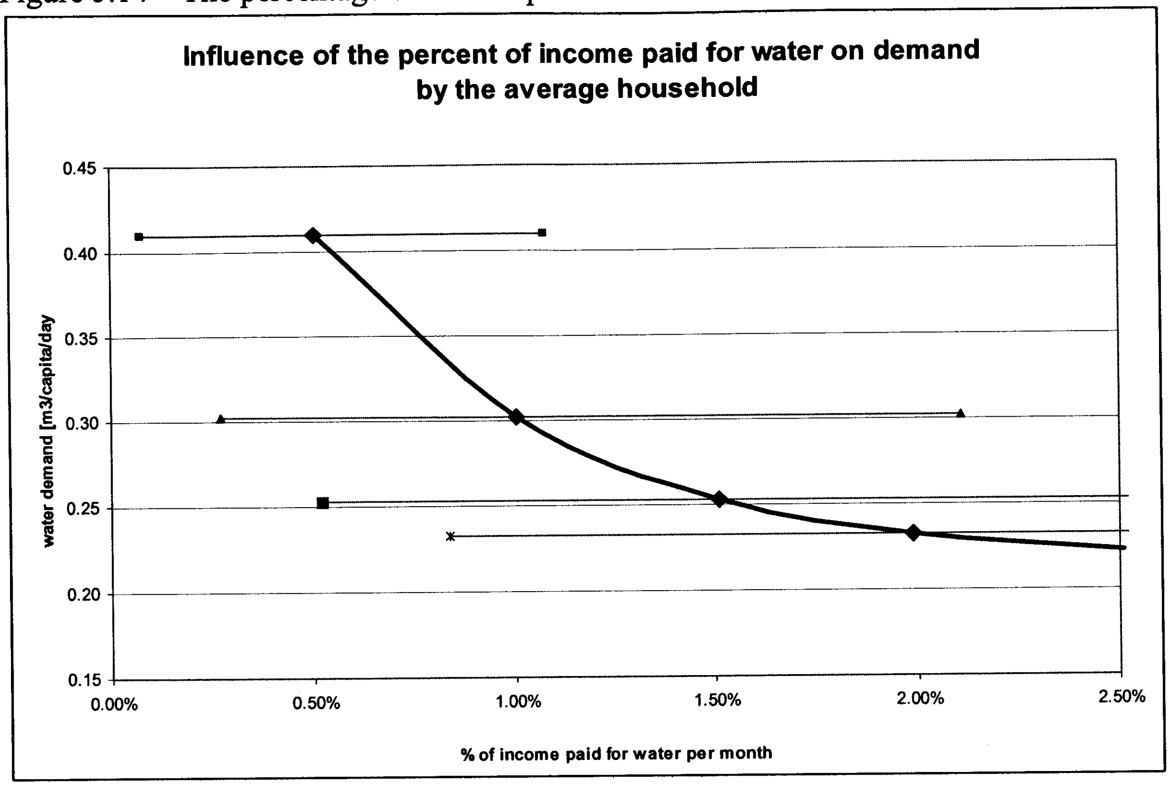
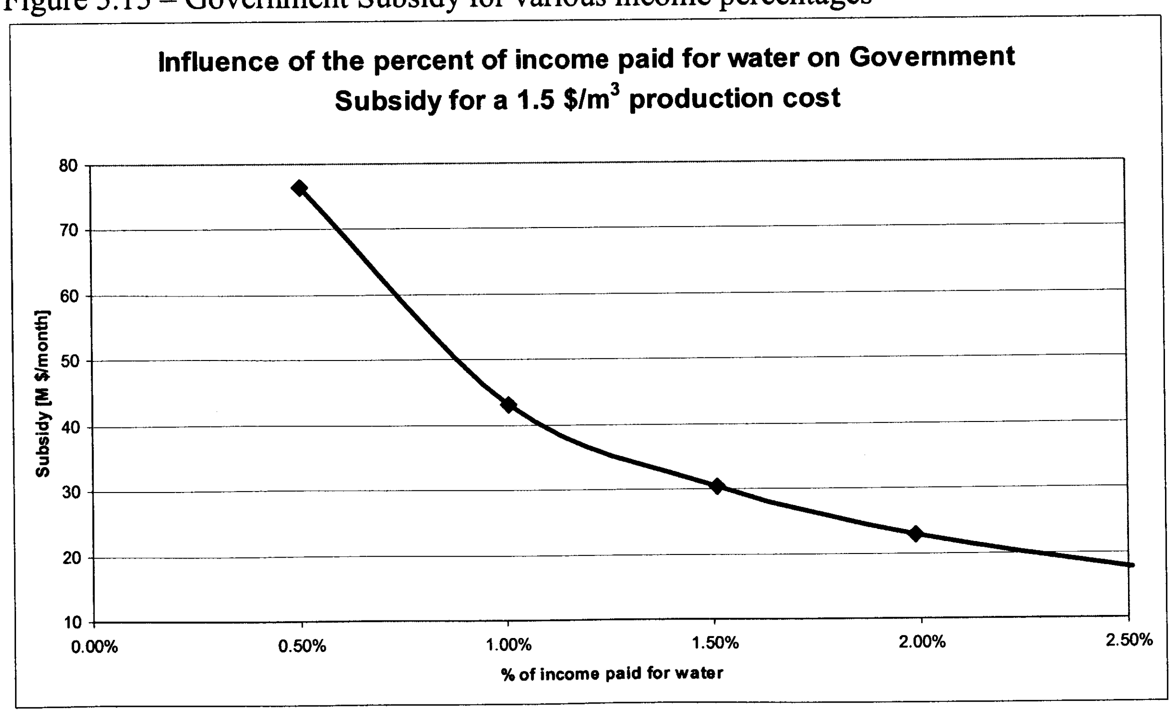


Figure 5.14 – The percentage of income paid for water



Red (horizontal) lines represent min and max values
1% of income equals average price of 0.5 $/m3 || 2% of income equals 1.28 $/m3

Figure 5.15 – Government Subsidy for various income percentages



6. Conclusion

In order to address to the immense water consumption problem in Kuwait, the water demand literature was extensively studied, and evidence that water demand is influenced by prices was found. Due to lack of data concerning influences of price increases and household consumption characteristics, the original idea of constructing a water demand model for Kuwait was modified. Water demand models for several arid regions were adapted from the literature and recalibrated for Kuwait.

Simulations of various kinds of pricing schedules were conducted. Input assumptions were made, however it was concluded that these assumptions have an insignificant influence on the predictions. Results showed that increasing block pricing schedules would be the most efficient in reducing the demand in Kuwait. However, this kind of pricing schedule would not be the best fit for Kuwait, from a socio-economic point of view, since paying for water is not a custom in Kuwait and increasing block tariffs might not be widely accepted. Instead a free allowance, followed by a constant price schedule is proposed. Results showed that this kind of pricing schedule would be sufficient in reducing the demand to a reasonable level and will eliminate the waste of water. Also, simulations showed that a price schedule that would make the water bill a very small portion of the household income (1-1.5%) would be beneficial in reducing demand.

Since an actual demand model was not assembled, the range of the prediction is large, (between 20-40 % of demand reduction, depending on the demand model used). Generally the California and Australia model have similar results; they predict smaller elasticities and demand reduction. It can be assumed these two models represent the lower boundary of the demand reduction. While, the Tunis, Saudi Arabia and Spain model have very similar results, and represent the upper boundary in the demand reduction.

Also, results presented here would be similar for other countries in the Gulf region, since they have similar characteristics. Certainly, more research has to be done in the water demand modeling for Kuwait.

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