Water Resources in the State of Qatar: Toward Holistic Management

Hassan Ibrahim Al-Mohannadi BA MA

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School of Applied Sciences
Department of Environmental and
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DECLARATION

I declare that no material in this thesis has previously been submitted for a degree at this or any other university.

ABSTRACT

This project deals with water resources issues in the State of Qatar from a holistic viewpoint. It analyses the factors which have led to the present heavy dependence on desalinated seawater and to aquifer salination problems. The present position is inherently unstable and unsustainable: the project will explore policy options to resolve these issues holistically.

Different approaches to water management exist. The Islamic view considers water as a public commodity and tends to frugal consumption. Traditional approaches are often strongly linked with religion and water is considered a communal resource. In the social or statist view, the state should control water management equitably, sometimes with popular participation. Recently, because of the high cost of water production, the economic view and market approach would suggest covering costs by raising tariffs. The technological approach is to use modern science for water resources development. Because environmental damage is caused by water resource development, the environmental approach looks to minimise this encroachment. Finally, developing sustainable approaches look to involving the public in decision-making as stakeholders, with due respect to the environment so that resources are not depleted by the present generation.

Studies of water management for Qatar are few, usually short articles or reports focusing usually on changes in groundwater quality and quantity. Other factors, such as drinking water quality, social, socio-economic, administrative and legal conditions are lacking from these studies.

Fresh water is considered the most important natural resource, as there is no life without water. Although global fresh water is less than 3% of total water, more than half can not be consumed directly, since it is inaccessible or frozen. Scarcity of water is a growing international problem, but countries located within the arid zone suffer most. Qatar is among the arid countries suffering from a serious water resources problem. After the first commercial production of oil in 1949, Qatar experienced rapid socio-economic development and a massive increase in population, some natural but with enormous labour immigration to satisfy an ever-expanding economy. The increase in per capita income led to lack of awareness of the importance of water. The absence of strict laws and water fees also contributed to waste. The Government lacked a clear water strategy, with a technological approach leading to dependency on desalinated water for the domestic sector. Desalination is costly and dependent on the availability of cheap energy (oil and gas). Furthermore, the Government policy of food self-sufficiency caused a massive drain on groundwater, without actually being able to achieve its aims.

Research has obtained detailed statistics from secondary data and five surveys. Firstly, old people were interviewed, in order to understand water management before the 1950s. Secondly, 77 stakeholders were interviewed, covering all aspects of water management. Thirdly, a public questionnaire (of 724 respondents chosen to represent Qatari social groups) aimed to measure people's behaviour and attitude towards varied water issues. Fourthly, domestic hydrology was assessed, to measure the amounts consumed by the individual for all purposes. Fifthly, 53 samples were collected from the water consumed directly from the three main sources in order to test 11 chemical parameters of quality.

The results from these surveys showed that water management policy has not adapted well to the changes brought with the oil era. The Qatari people before the oil era were more understanding of their limited water and managed sustainably. The present use of the limited groundwater is unsustainable. Lack of regulation of abstraction is causing groundwater problems to worsen rapidly, especially because most irrigation is wasteful. Moreover, the high costs and pollution from desalination technology are important obstacles to expansion of desalination for different sectors. Recycling requires improved quality to be suitable for wide use. Importing water from other countries is not suitable policy due to political and economical difficulties. There are serious problems with water quality, especially groundwater used for agriculture, because conductivity is high and chloride, sodium, iron, calcium, magnesium, sulphate are above the maximum concentration recommended.

Current consumption behaviour, especially among people with a high standard of living, is not appropriate for a water-poor country. Efforts to control consumption by using different tools such as awareness, laws and tariffs have been ineffectual due to half-hearted and incomplete enforcement. Many stakeholders could identify many of the problems facing water supply in Qatar, but few had a clear idea of how to deal with the issues. Most respondents wished to manage water in the public sector but there is some acceptance for partial privatisation under the management of water institutions. Importantly, the public would be willing to accept tariffs if laws were implemented on all groups in society and services improved, especially quality.

The institutional framework for water management in Qatar does not encourage people to address problems. Moreover, the water institutions are suffering from lack of co-ordination, power, funding, qualified decision-makers and staff, so policies are partial or incompletely implemented. Therefore, the water sector situation in Qatar requires a holistic and sustainable management policy, which should to give water supply, quality, demand and institutions similar concern and attention. Firstly, Qatar should depend completely on desalination for the domestic sector with efforts to improve this technology in order to reduce its cost and pollution. The limited fresh groundwater should be limited to commercial farms with efforts to improve recycled water quality so it can be used for irrigation and feasibly be used in other sectors. Secondly, water quality should be improved by establishing strict standards and continuous monitoring. Thirdly, water demand should be controlled by application of different tools, especially encouragement of consumers to use new irrigation and domestic technology. Moreover, a rigorous tariff should be enforced on all groups in society without exception. Indirect tools, especially raising public awareness and participation in water management, should also be used and cover all groups in society. Fourthly, a new water institution should be established with full power and financial resources for overall policy design, monitoring, studies, co-ordination and improvement of decision-makers and staff skills. The water sector should be regulated by Government. Conceptual models for public and private ownership of the water industry are finally explored.

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Dedication

In the name of God, Most Gracious, Most Merciful

"Verily, my *Salat* (prayer), my sacrifice, my living, and my dying are for Allah, the Cherisher of the Worlds"

(Qur'an, 6:162)

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CHAPTER ONE:

INTRODUCTION

Chapter One:

Introduction

1.1. Introduction:

Water is one of the most essential elements of life, and yet freshwater constitutes less than 3% of the world's total water supply, and less than half is in a usable form (e.g. McDonald and Kay, 1988; Moss, 1992; Kandiah, 1999). Because of the importance of water in maintaining civilization, it is essential that a reliable supply of usable water is available to meet human need. Meeting this need becomes a problem because water supply and demand are subject to variations through time and space. This is related to the many issues concerning the extraction of water from the environment and to its many uses which require water of specific quality. In the 21st century, with increased water consumption, many countries face shortages, which threatens development (e.g. Gilley, 1985; Tolba, 1995; Abu Samur and al-Khatib, 1999). It is clear that, in a country where water shortage is immediate and ongoing, almost any economic or social initiative must be constrained by the water supply situation.

This thesis is an investigation and analysis of the environmental, technical, economical, decision-making, legislative, administrative, religious, and social aspects of water in the State of Qatar. The water resource crisis in Qatar is particularly severe compared with those experienced in much of the developing and developed world (e.g. FAO, 1981; al-Alawi and Abdulrazzak; 1994; Kotoub and Abdulrab, 1995; al-Mohannadi, 1997a). Water resource problems in Qatar have been little studied and researched, compared with the large body of literature dealing with water resource problems in the Levant (e.g. Bakour and Kolars, 1994; Merrett, 1997; Biswas *et al.* 1997; Khalil, 1998) and many developed countries (e.g. Ericksen, 1990; Rogers, 1993; Gray, 1994; Grigg, 1996).

1.2. Water Resources in Qatar:

The State of Qatar is located east of the Arabian Peninsula, halfway along the west coast of the Arabian Gulf (Figure 1.1) (el-Mallakh, 1985; Ashour, 1987).

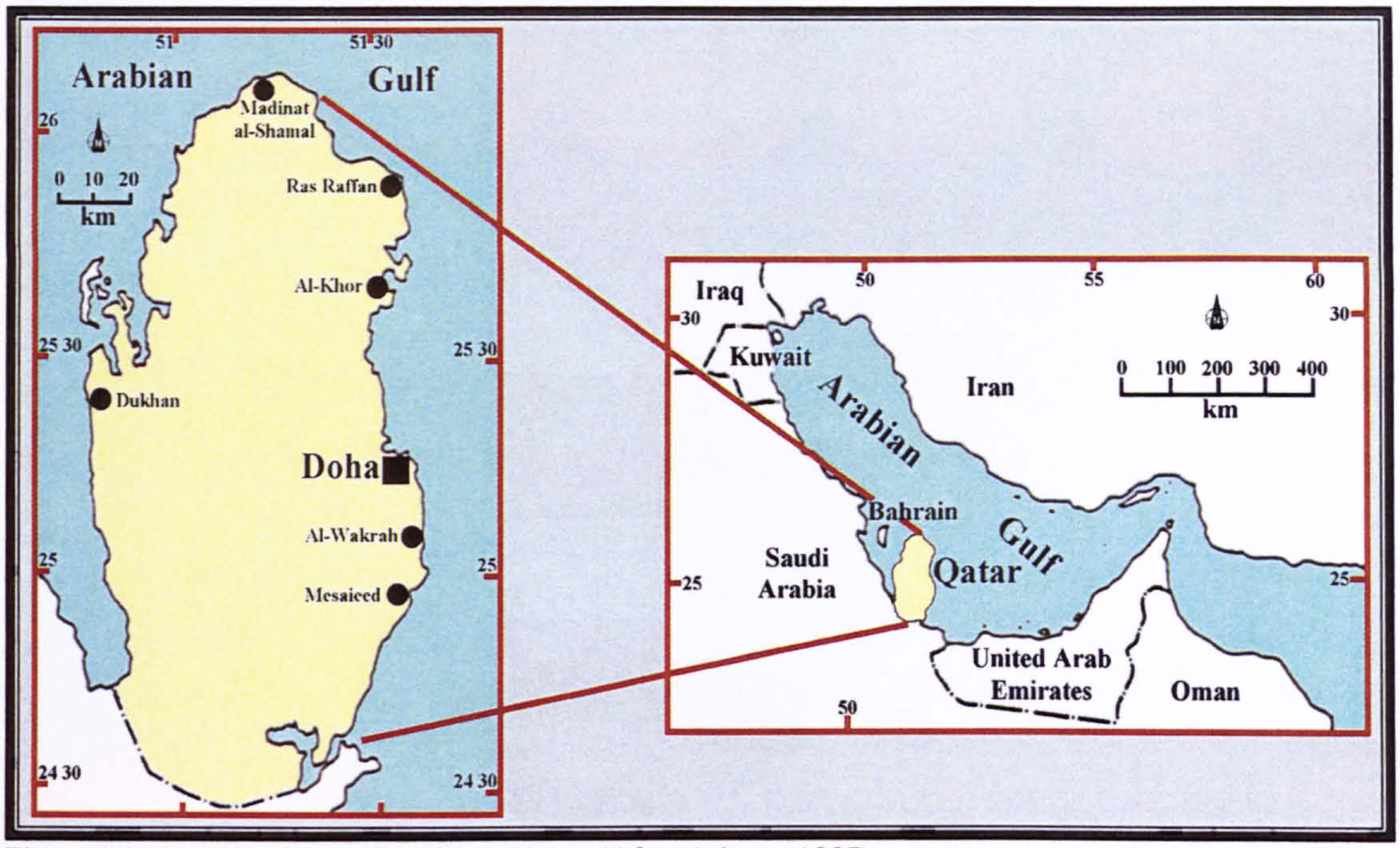

Figure 1.1. Location Map of the Study Area (After Ashour, 1987).

The climate overall for Qatar is arid, with hot summers and relatively warm winters. The average rainfall is about 73 millimetres per year (mma^{-1}) (Babikir, 1998a; al-Nasr and al-Sheeb, 1999). According to the Third Census, the population was 522,023 in 1997 (PC, 1999a), having grown from 111,133 inhabitants in the First Census in 1970 (al-Kuwari, 1996). It was estimated in 1998 at 560,000 inhabitants (PC, 1999a).

The complexity of the current water resources systems in Qatar is summarized in Figure 1.2. In general, desalination of brackish water and seawater has become a prime component of the water supply, together with groundwater and recycled water. With increasing development in both the urban and rural sectors in Qatar, pollution and groundwater deficit have become a distinct probability and signs of this are already apparent (FAO, 1981; Rukin *et al.*, 1995; Agnew and Anderson, 1992; MMAA, 1997a; al-Mohannadi, 1998).

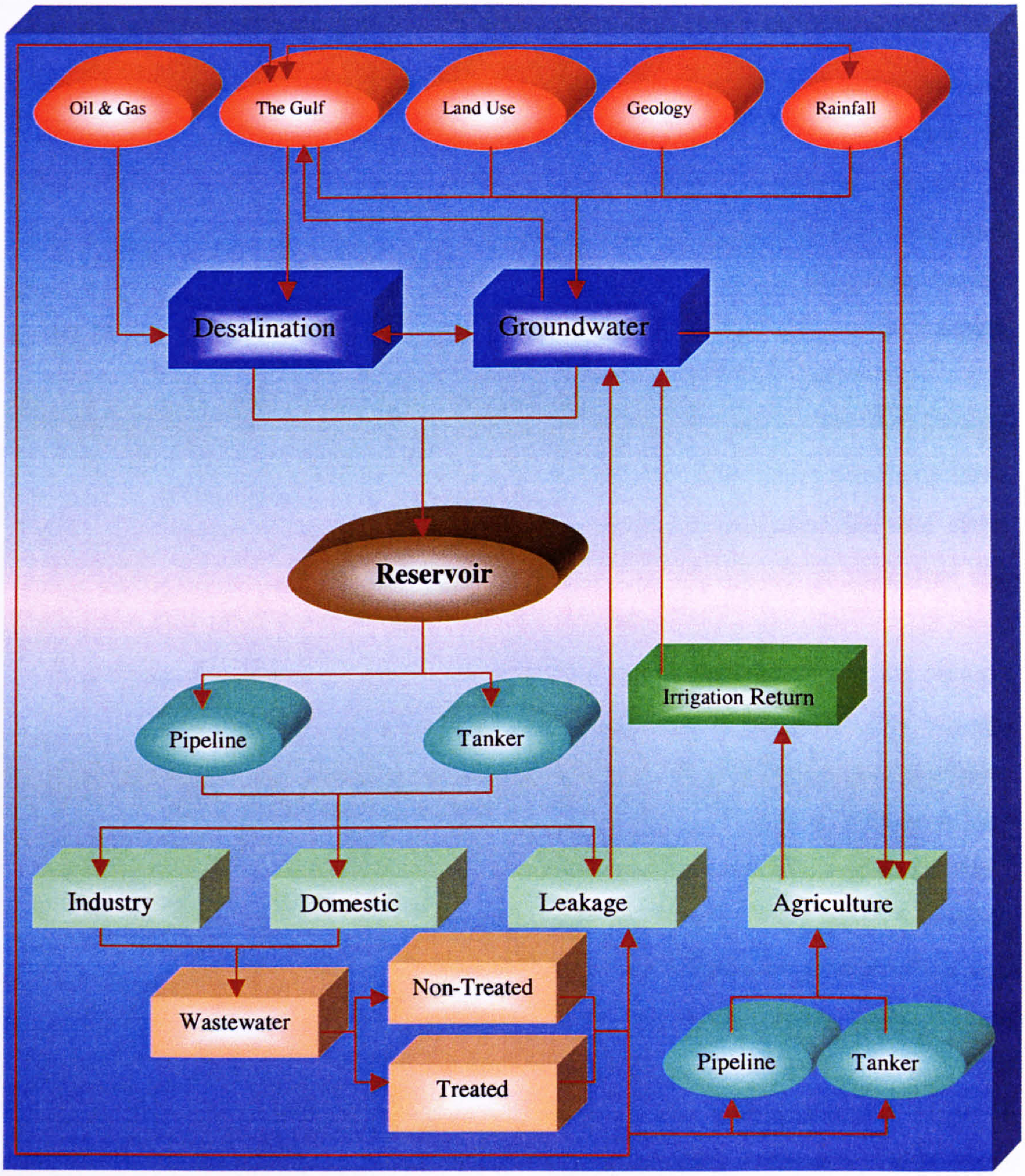

Figure 1.2. Water System in the State of Qatar (Based on Several Sources).

During the pre-oil period, before the 1950s, water supplies were based on shallow groundwater obtained from small local wells (Lormer, 1978; el-Mallakh, 1985; al-Nasr and al-Sheeb, 1999). During this period, almost every house had a water well, which was sufficient for the small number of inhabitants and simple life style (al-Othman, 1981; al-Mohannadi, 1997a). After the beginning of oil production in Qatar, the population grew at a high rate, resulting from both high birth rates and immigration (Fakro, 1998). Increased revenues and urbanization led to improvements in the standard of living (al-Alawi and Abdulrazzak, 1994; Zahlan, 1989; Arthur, 1997; Khuraibet and al-Attar, 1997; Ahmad and al-Faqeh, 1999) and this increased the demand for water. In addition, a policy of agricultural self-sufficiency led to a dramatic increase in agriculture through irrigation in the heart of the Arabian desert. Finally and most important is the non-existence of a clear and comprehensive water management policy. In fact short-term water management policies did not provide long term planning (Abdulrazzak, 1995; Arthur, 1997; Kotoub and al-Mahmoud, 1997; Judah, 1994). All of these factors put pressure on the existing groundwater and on the increasingly expensive desalination seawater resource. Water supply became especially problematic after the oil crises in during 1970s, with oil price rises (Campbell and Laherrere, 1998) making desalination an expensive option. Furthermore, the limited oil resources will eventually make desalination based on oil unsustainable.

Despite considerable ongoing investment and multiple initiatives toward addressing the issue of water resources in Qatar, efforts to make this country independent and secure in its water resources are beset with difficulties and problems. It seems clear that reliance on water supplies from outside sources (e.g. Turkey or Iran) cannot be a totally viable solution, given that independence is one of the goals (al-Akry, 1994; Mukemer and Hijazy, 1996; Kotoub and al-Mahmoud, 1997; MMAA, 1998d). The substantial increase in agricultural water demand and population growth alone, with the limited national sources of freshwater, demand that a systematic, coherent water management policy is developed in Qatar. However the establishment of a new water management policy must take into consideration the environmental, technical, economical, decision-making, legislative, administrative, religious, and social circumstances. In a world where resources (even Qatar's abundant oil and gas) are limited, it is of critical importance that Qatar's use of water is sustainable.

1.3. Purpose of the Study:

The main goals of this study are:

I- Examine the current water resource situation in Qatar using secondary data, with special attention to:

1- Level of water production.
2- Level of water consumption.
3- Institutional organisation for water management.
4- Policies and plans.
5- Issues and debate.

II- Test chemical water quality, with attention to:

1- Different sources of water in Qatar (groundwater, desalination and recycled).
2- Geographical distribution of relative aspects (e.g. people, farms and industries).

III- Explain water management in pre-oil era. The aim of this part of study not only to fill a gap in this kind of research but also to examine the possibility of applying some old experience, especially when the oil and gas resources run out.

IV- Explain, evaluate, and assess management and public responses to the water resource situation using personal interviews and surveys, with attention to:

1- Environment.
2- Technical aspects.
3- Economics.
4- Decision-making.
5- Legislation.
5- Administration.
6- Religious aspects.
7- Social aspects.

V- Make proposals for a new, holistic and sustainable water management system for the State of Qatar.

1.4. Outline of Thesis Structure:

The results of this work, when integrated, will enable these aims to be met. The thesis falls into thirteen chapters. The first is this general introduction to the overall thesis and is designed to acquaint the reader with the issues concerned and the purpose of the study. The detailed theoretical context of the study is set out in Chapters Two and Three but from different angles. Chapter Two discusses the water resources problem in arid countries and is focused on the balance between water supply and demand. Chapter Three examines water management in arid countries, firstly, focussing on problem conception and solutions from different views, Islamic, traditional, social, economic, technical and environmental. Secondly, its focuses on different approaches to water management including traditional, state, market and technical. Thirdly, it examines the most important water supply and demand management tools including traditional, economic, legislation, decision-making and social. Finally, it discusses different water management institutional frameworks and the development of water policies. The research methods are described in Chapter Four, including the methods of data collection, sampling, analysis process and problems confronted during the fieldwork. The study area is described in Chapter Five, focussing on the most important aspects of land, climate, population, agriculture and industry.

Chapter Six analyses the available water resources in Qatar (groundwater, desalination and recycled) first focusing on production levels. The second section discusses water demand and the various uses of water (agricultural, residential, government, commercial and industrial). Chapter Seven provides a broad context for the study. The first section of this chapter gives a general background on water management before the oil era; in the second section the discussion focuses on the current water management problems in Qatar in all its aspects: environmental, decision-making, legislation, technological, economic, social, and the institutions responsible for water management in Qatar. The results of water quality tests are set out in Chapter Eight. This part of the study concentrates on water quality and comparisons with published standards. Water quality tests were undertaken for 11 parameters: pH, magnesium (Mg), iron (Fe), nitrate (NO_3), chloride (Cl), conductivity, sodium (Na), sulphate (SO_4), calcium (Ca), potassium (K) and phosphate (PO_4). The results of interviews with stakeholders are set out in Chapter Nine. In this chapter stakeholders opinions about 22 issues related to water resources including environment, technology, economic, decision-making and legislation, society, administration, religion is documented. The results of domestic hydrological measurements are set out in Chapter Ten. This establishes the daily per capita consumption of water and its distribution among domestic uses in Qatar. In addition, it aims to establish the peak times of water consumption during the day. The results of a public questionnaire are set out in Chapter Eleven. The first section of this chapter is about public behaviour and opinion related to different water issues, service, laws, quality, recycling, consumption, tariffs, awareness, administration, privatisation, and knowledge of water. The second section is about public behaviour and opinion related to different groups, nationality, gender, education, age and income. The third section deals with reasons for public behaviour and opinions. This information is synthesized, interpreted and commented on in relation to the regional literature in Chapter Twelve. Suggestions for new sustainable water management policy using a holistic approach are then set out. The thesis concludes in Chapter Thirteen.

CHAPTER TWO:

WATER ISSUES IN ARID COUNTRIES

Water Issues in Arid Countries

2.1. The Importance of Water:

Water is essential for all facets of life. It constitutes 70% to 90% of the volume of all living things on earth, including humans (natural water in Appendices 1 and 2, untraditional water in Appendices 3, 4, 5 and 6). Additionally, the importance of water to human existence and activities is incomparable with any other resource (amongst others Pearson, 1999; Kandiah, 1999; al-Tarabulusi, 1999).

In the holy books this is recognised. The holy Qur'an contains over 60 verses mentioning the importance of water. Many verses which consider water as the essence of life on earth "*...And We have made from water every living thing....*" (Qur'an, 21:30). Also "*Allah has created every moving (living) creature from water....*" (Qur'an, 24:45). Many verses consider water as source of maintaining vegetation such as "*...And you see the earth withered up then when We send down water upon it, it was freshened and swelled up and grew every beauteous pair .*" (Qur'an, 22:5). Also "*And do they not see that We send water toward dry land, and produce thereby crops of which their cattle and they themselves eat....*" (Qur'an, 32:27). "*It is He Who sends down water (rain) from the sky, and with it We bring forth vegetation of all kinds....*" (Qur'an, 6:99).

Water is the most important natural resource, since extinction is the destiny of those who can not have it. It makes life possible on earth while other natural resources help make life more comfortable (amongst others Beekman, 1998; Polevoy, 1996).

Water played an essential role in the progress of society and the development of industry, agriculture, transport and the generation of energy (amongst others Fang and Xie, 1994; Liebaert, 1997; al-Sofi, 1999; Sadik and Barghouti, 1997). Metualy (1981b); Walton (1969); Abu al-Fatih (1997); Smethurst (1988) attest to the significance of water to any settled human life on earth and indicate that the relationship between man and water might not be so evident in areas where rain is abundant, but it is extremely noticeable in arid areas.

2.2. Sustainability:

There are numerous definitions of sustainability (e.g. Newson, 1992; Conway and Edward, 1990; Barrow, 1995; DE, 1996). Most recognise the principle of inter-generational equity – using resources in a way that does not prejudice the access to these resources by the following generations (WCED, 1987). In Islam, unsustainable resources management is considered as corruption "...*Each (group of) people knew its own place for water, eat and drink of that which Allah has provided and do not act corruptly, making mischief on the earth*" (Qur'an, 2:60). Also "*And when he turns away, his effort in the land is to make mischief therein and to destroy the crops and the cattle, and Allah likes not mischief*" (Qur'an, 2:205). Many traditional societies have evolved sustainable resource management systems (e.g. Crook, 1997; Jones *et al.*, 1998), but it can be argued that much of the modern global system and much development is unsustainable, with rapid resource depletion occurring (e.g. Fernie, 1985; Miller, 1992; Tolba, 1995). In this thesis, it is argued that the current water management system in Qatar, because it depletes groundwater and energy resources and degrades the environment, is not sustainable (e.g. al-Kuwari, 1996). The final chapters of the thesis address the issues critical to making Qatar's water management sustainable.

2.3. Water Problems in Arid Countries:

Arid areas cover a third of the earth and have a population more than 400 million (Figure 2.1 and Table 2.1). Limited rainfall, seasonal aridity and high rates of evaporation represent a serious problem in these areas. Moreover, many developing countries - in Asia, Africa and South America - are geographically located in the arid zone. Their water problems are exacerbated because of their high population growth. These twin problems put some of these countries in the category of countries threatened by 'thirst' (amongst others Arthur, 1994; Walton, 1969; UNESCO, 1999).

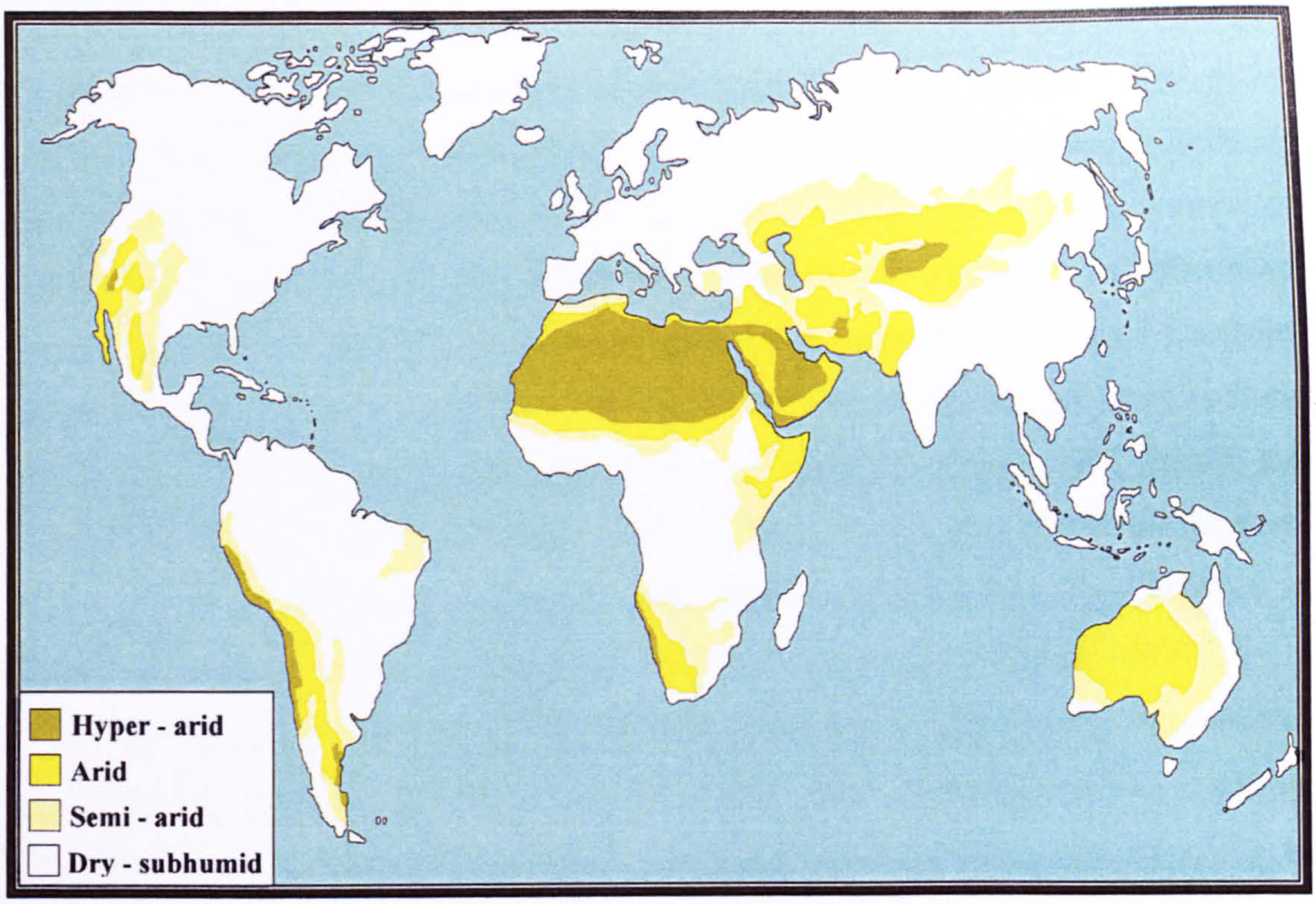

Figure 2.1. The Global Distribution of Drylands (After Thomas, 1997).

Table 2.1. Distribution of Dry Lands by Country (After Paylore and Greenwell, 1979).

Group	Description	No.	% of Nation Arid/semi-Arid	Countries
1	Arid	11	100	Qatar, Bahrain, Kuwait, UAE, Oman, KSA, Djibouti, Egypt, Mauritania, Somalia, Yemen
2	Predominantly arid	23	75-99	Afghanistan, Algeria, Australia, Botswana, Burkina Faso, Cape Verde, Chad, Iran, Iraq, Palestine, Jordan, Kenya, Libya, Mali, Morocco, Namibia, Niger, Pakistan, Senegal, Sudan, Syria, Tunisia
3	Substantial parts arid	5	50-74	Argentina, Ethiopia, Mongolia, South Africa, Turkey
4	Some parts arid	9	25-49	Angola, Bolivia, Chile, China, India, Mexico, Tanzania, Togo, USA
5	A small proportion arid	18	< 25	Benin, Brazil, Canada, Central Africa Republic, Ecuador, Ghana, Lebanon, Lesotho, Madagascar, Mozambique, Nigeria, Paraguay, Peru, Sri Lanka, Venezuela, Zambia, Zimbabwe, Former USSR

Consequently, a considerable proportion of the people in arid countries suffer from water problems. These problems take a number of forms. In many cases, these include a lack (seasonal or permanent) of drinking water, or of drinking water of adequate quality. They may also include a seasonal or permanent lack of water – or water of adequate quality - for domestic animals or for irrigation. Furthermore, salinisation caused by inappropriate irrigation threatens agriculture in several countries. There may be insufficient water (seasonal or permanent) for industrial or agricultural development, or to accommodate expanding populations (Kandiah, 1999; Agnew and Anderson 1992). The people in some arid countries are prey to water-borne diseases, such as bilharzia. Water in the wrong place causes severe engineering difficulties in some arid countries through corrosion of foundations (Pickering and Owen, 1997).

Technical 'fixes' to the problems of lack of water and lack of water of sufficient quality are available but these are expensive, often cause considerable environmental degradation or disruption, cause conflict with indigenous peoples and are vulnerable to terrorist activity. The long-term sustainability of such 'fixes' is questionable, since many are energy-intensive. The use of fossil fuels to power, for instance, desalination plants, is undesirable in the context of their limited availability in the longer term as reserves are exhausted and, moreover, their contribution to global warming (for example Lindh and Gilbrich, 1996; Faillace, 1990; Gleick, 1997). Several countries, such as Libya, are effectively mining their fossil groundwater resources – this option is also unlikely to be sustainable for any length of time since these are not recharged (Abu al-Fatih, 1997; Salem, 1992; el-Asswad, 1995). These issues are dealt with in detail in Chapter 3.

2.4. Causes of Water Problems:

Figure 2.2 shows the causes of water resources problems in the arid countries, following the analysis by Falkenmark (1989a). The arid climate and growing population cause both an increasing demand and a need for water security in the agricultural, domestic and industrial sectors (Appendix 7). This leads to decreasing per capita water availability. The growth of residential and industrial areas and agricultural extension or intensification driven by population growth tends to lead to land degradation, and the necessity of food security leads to more irrigation. Population growth and growth in irrigation increase the needs for water storage and distribution, which in turn puts more pressure on scarce land. The arid zone is characterised by seasonality and intermittent and unpredictable drought years, which means that expensive storage to cover these periods is essential (Falkenmark, 1989a).

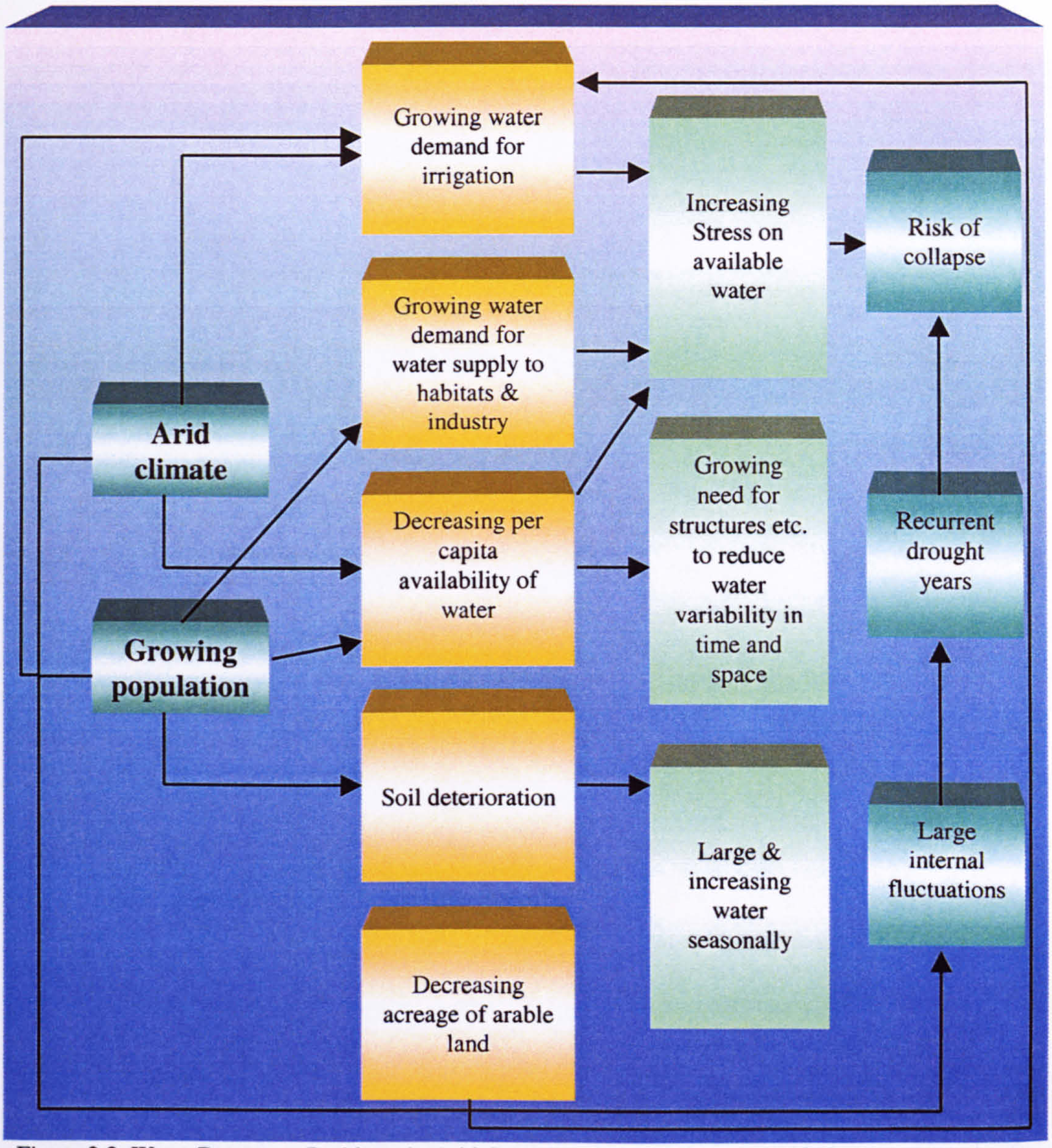

Figure 2.2. Water Resources Problems in Arid Countries (After Falkenmark, 1989a).

Besides climatic reasons and population increase (Table 2.2), mismanagement, inefficient and unsustainable utilisation of water have contributed to the emergence of water shortages in countries of the arid zone (amongst others el-Ashry, 1995; Zubari, 1999; Sayed, 2000). According to Agnew and Anderson (1992); Beekman (1998); Arthur (1997), the real problem lies in the uncontrolled increase of population and subsequent increase in household and municipal demand.

Table 2.2. Arid Land Populations (Millions) (Agnew and Anderson, 1992).

Region	1960	1985	% Increase
Asia	151	271	79
Africa	50	97	95
North America	16	26	68
South America	10	18	75
Europe	1	1	0
Australia	1	1	0
Arid lands total	229 (7.6%)	414 (8.6%)	81
World	3,019	4,818	56

Countries in the arid zone will face immense problems concerning water if they do not control population growth and urban development. The accelerated and massive growth of cities as well as the increase in the number of big cities has caused serious domestic water shortages. Growing population also causes rising agricultural demand. These together push these countries into carrying out large expensive water projects (amongst others Allan, 1995; Cohen, 1997; Arrhenius, 1992).

The gap between water resources and water demands is thus continuously increasing in arid areas. This is causing serious concern to governments and international institutions because of its effect on economic growth and potential political instability (amongst others Allan, 1992, al-Yahiawi, 1998; Young, 1997; Berkoff, 1994).

The water crisis in arid areas will take a central position over all other crises that these countries face. The doubling of the population in the developing countries within twenty years has increased the level of poverty and suffering. This will be further exacerbated by shortage of water, which is the essence of economic growth. Such aggravation of the human condition might possibly lead to political instability (for example Agnew and Anderson, 1992; Arthur, 1997; Evans, 1997; Falkenmark, 1990;

Abdulwahab, 1999a). For instance, in the Middle East (which has only 1% of the global total amount of freshwater - Young, 1997; Jones, 1997; Abdelmageed, 1997; Mahmoud and Sadeqi, 1997) in the past thirty years the population doubled and it is expected to double again in the coming thirty years. This has led to water disputes in the region, and might eventually cause the eruption of destructive wars (Mohammed and Abu Sleem, 1998; Cowan and Johnson, 1985; Sayed, 1999; Abu Riyyan, 1999).

The Arabian Gulf countries have had an unique experience (al-Akry, 1994; Arthur, 1997; Khuraibet and al-Attar, 1997; Abdulqafar, 1999). Exceptional growth took place in a variety of economic activities so their population expanded rapidly due to the influx of foreign labour, which in some of these countries far exceeds the local population (al-Hajri, 1997; al-Kuwari, 1996; al-Kubaisi, 1986; al-Mohannadi, 1997a; Othman, 1999). With the increase in per capita income, especially after the boom in oil prices in the during 1970s and early 1980s, the life style and standard of living changed also drastically (al-Khayat, 1988; Riad, 1992; Khuraibet and al-Attar, 1997). This, in addition to industrialisation and an emphasis on the development of agriculture for the purpose of achieving food security caused a remarkable depletion of already limited water resources (al-Biati, 1998a; Abdulrazzak, 1994; al-Mohannadi, 1997a).

Many countries have a poor record of managing their water resources. Even countries with abundant rainfall, such as the UK, are not immune to this problem (Porter, 1978; Smith, 1972; Arthur, 1994; Herringtom, 1996). According to el-Ashry (1995); al-Ibrahim (1991); Vohra (1975); Brown *et al.* (1996); Lees (1994); Shadi (1999); Young (1991); Sadik and Barghouti (1997), the most important factor behind water problems is the bad management of water which leads to inefficient use.

In the West, water technology (e.g. seawater desalination, irrigation, dams and pipelines) has provided adequate water and has been a strong force behind social progress. The success of technology in the West has led planners and engineers in the developing countries to believe that through technology their problems will be solved. It has also led Western decision-makers to feel that the best way to help developing countries is to provide technology (Welford, 1997; Katko, 1992; Niemczynowicz, 1991). This has in turn provided opportunities for Western Multinationals and educational institutions (Arthur, 1997).

So far, however, the implementation of technological solutions has in many cases been unsuccessful due to the inappropriate nature of Western technology for many developing world problems. There have also been problems with mismanagement. Large sectors of the population of many countries are still in need. Technology has in effect created other problems, such as the spread of water borne diseases through the construction of reservoirs (amongst others Clarke, 1993; Kay, 1990). At the same time, countries found themselves incapable of paying for imported technology after the failure of these projects. Usually, the technology used in developed countries appears to be of limited value. This opinion is widely adopted by recent research. The importance of using local technology more suitable to local conditions, traditions and customs is now emphasised (amongst others Niemczynowicz, 1991; van Schilfgaarde, 1994).

In the same context, al-Mugran (1992); Rondinelli (1991); al-Hajri (1997) emphasise the success of desalination technology in many arid countries such as the Arabian Gulf states, which are rich in energy sources, in meeting the needs of these states, especially municipal ones. These states have become huge markets for Western companies specialising in water technology, equipment and tools, water pumps, spare parts and the plants themselves etc. Thus al-Mugran (1992) sees the need to fight aggressive marketing policies by increased co-operation among concerned countries to develop and use local technology. This view is shared by Uqba (1991); Cullis and Pacey (1992); Hamdan (1989); Judah (1994) who show that import of technology has included equipment but also labour. They address the need to utilise local labour and to train it in the use of modern technology.

It is also argued that the developing countries (Mukemer and Hijazi, 1996; Niemczynowcz, 1991; al-Hajri, 1997; Beaumont, 1993) suffer from a lack of modern technology in the field of water development, besides the obvious lack of local technical skills. Some rich developing countries compensate for the lack of local technology by importing it, but they can not import all types of technology. Some developed countries put restrictions on the transfer of such technology and prohibit its vertical transfer also.

It is indicated (Lindh and Gilbrich, 1996; Faillace, 1990; Gleick, 1997) that the high cost of modern technology is one of the biggest constraints in its widespread use. An example is desalination plants and modern irrigation systems whose use is restricted to some countries such as the Arabian Gulf states, Libya and the US. These countries are able to utilise the technology because of the availability of energy sources, hence reducing costs immensely, but very few countries in the developing world can afford such technology.

In the arid zone, climate change - especially in the Sahel and Middle East - has had an effect on the available freshwater. This has led to the exacerbation of the problems these regions face (Bazzaz, 1994; Agnew and Anderson, 1992; Tolba, 1995; Houghton, 1997; Moore *et al.*, 1996; Jones, 1997). Many of the technical issues raised by these problems are further dealt with in Appendices 3, 4, 5, 6 and 7.

2.5. Conclusion:

Water is considered one of the most important natural resources and the reason behind the existence of mankind on earth. Arid and semi-arid regions have very little surface water and are increasingly dependent on groundwater. Even in countries (e.g. Egypt and Iraq) where rivers flow they can not guarantee the continuous flow of water, since they are under threat from upstream countries. Some arid countries attempted to solve this problem by depending on non-traditional sources of water (e.g. desalination) but without much success due to its high cost. In many cases water management is now unsustainable in arid countries.

Therefore, a rigorous water management policy should be implemented to control the problem. This policy should take in account all factors, which may affect water management. This is because the issue of scarcity of water cannot be treated from a single perspective, ignoring other direct and indirect factors. These factors are environment, technology, economy, decision-making, legislation, administration and society. Chapter Three will discuss these issues in detail.

CHAPTER THREE:

MANAGEMENT OF WATER IN ARID COUNTRIES

Chapter Three:

Management of Water in Arid Countries

3.1. Introduction:

Water Management is the balance of supply and demand through a variety of strategies. It is emphasised by Gillam and McCoy (1966); Mather (1984); Agnew and Anderson (1992) that water is vital in all aspects of social and economic life. In the arid zone it is essential to develop water resources to delineate the prospects and the challenges for the short and long terms and to manage the resources appropriately and sustainably. Kotoub and Abdulrab (1995) point out that the word "manage" means that people should be able to predict, prepare, operationalise and correct policies and actions. The management of water entails the provision of the necessary amount of water for all at the right time and place. The essential elements in such a process are the institutions and management responsible for carrying out the water policy, the availability of technology and trained personal, the availability of finance, social acceptance and support and the legal framework. For a project to be successful in the long term, it should have minimal environmental impact.

According to Berkoff (1994); ReVelle and ReVelle (1981); Kandiah (1999); Mason (1981) water management deals with two parts: the management of supply and demand. Management of supply deals with the sources and distribution of water and their development. Management of demand involves finding ways to predict and influence the level of water consumption. These issues are explored in this chapter, which deals with concepts, principles, approaches, tools and institutions.

3.2. Conceptualising the Water Issues:

3.2.1. Introduction:

In this section the principles, views and beliefs which guide management of water are explored. It should be noted that the conceptual framework tends to govern the types of institutions and tools for water management.

3.2.2. Traditional View:

Most traditional societies world-wide have ways of managing water. In arid countries these are/were often highly developed. In many cases water is seen as a communal resource. Often control over water supply is vested in those using it. The traditional view is actually a plethora of views, since all traditional water management system are unique. Often the ethical framework of these systems is strongly religious (e.g. Crook, 1997). Traditional water management systems usually have a body of formal or informal rules and bye–laws, which are founded in principles of equity and proportionality (Spiertz, 1991; Mahendrarajah and Warr, 1991; Smith, 1990; Ericksen, 1990). A strong concern for the future well being of the system is generally apparent since memberships of systems is inheritable. This is one of the key reasons (together with the equity approach and the detailed knowledge of the local environment) for the sustainability of these systems over long periods (Jones *et al.*, 1998; Crook, 1997).

3.2.3. Islamic View:

In the Holy Qur'an there are many of verses about the use of water such as "*Tell them that water is to be divided between them*" and " *...And eat and drink and do not cross the limit. Undoubtedly, the persons crossing the limit are not liked by Him*". Allah also mentions that his love is withdrawn from those who consume more than they need because they are depriving the needy of water and food. He also indicates that wastefulness is an ugly character and it is one of the traits of the devil and not human, because wastefulness is a type of godlessness with Allah's gifts to man *"No doubt, the extravagant are the brothers of the Devils (Satan). And the devil is very ungrateful to his Lord"* (e.g. al-Qarrdauy, 1995; al-Tarabulusi, 1999; al-Najar, 1999).

The prophet Mohammed (peace be upon him) emphasises this importance of water by indicating that water is a right of every human being which should not be monopolised and must be shared by everyone in society "*mankind are co-owners in three things: water, fire and pasture*". He also encourages the provision of water to the weakest in society and confirms that those who do so will find their reward in heaven "*he who withholds water in order to deny the use of pasture, Allah withholds from him his mercy in the Day of Resurrection*". He also said " *excess in the use of water is* *forbidden, even if you have the resource of a whole river*". In fact most water legislation which is still applicable today in some arid areas was coded thirteen centuries ago, based on the Holy Qur'an and the Prophet's sayings (e.g. Hamed, 1993; Naff, 1994; Norvelle, 1985; Bouguenaya, 1995; Bucaille, 1989).

3.2.4. Social View:

Fernie (1985); Cvjetanovic (1986); Pearson (1999) define water management as the provision of water for the utmost benefit to everyone while simultaneously protecting the sources of water. They emphasise that more plans are needed which balance the resources and the demand for water.

This viewpoint is essentially utilitarian, and came from the writings of John Stuart Mill in 1848 (Acton, 1972) and Jeremy Bentham in 1818 (Rosen, 1985). In its most developed, this viewpoint is manifest in the Marxist World view. It is the underpinning for most state - controlled water management systems (Smith, 1996; al-Nabhani, 1990; Carling, 1989; Wood, 1986; Reiss, 1998; Kolakowski, 1978; Smart, 1989).

According to Linsley and Franzini (1972); Sewell *et al.* (1985); Rees (1990); Clarke (1993); UNESCO (1999), the problem of water shortages became more marked in the middle of the twentieth century as a result of unprecedented population expansion and spreading industrial activities. They emphasise that inefficient water management and inability to control floods has resulted in a great number of people losing their lives. They argue that water, just like any other natural resource is bound to be misused or depleted by humans. Despite technological advancements water problems and the inefficient utilisation of water are still pervasive.

In recent years, a social solution - popular participation - in water management is becoming increasingly favoured in the developed countries, while most developing countries are still far away from granting such rights to individuals.

3.2.5. Economic View:

In recent years, shortage of water has become a fact facing all countries, leading to the emergence of new concepts in water management. Water will increasingly become an economic commodity (Sadik and Barghouti, 1997; Abdulqafar, 1999; Rogers, 1993; Arthur, 1994; Leopold and Davis, 1971; Postel, 1992).

According to el-Ashry (1995); al-Ibrahim (1991); Vohra (1975); Brown *et al.* (1996); Lees (1994); Shadi (1999); Young (1991), there are two factors behind the water problem. The first is the bad management of water, leading to inefficient use. The second is the failure to consider the economic value of this vital resource, hence its deterioration and depletion.

Developing and producing water needs massive amounts of capital, feasibility studies, well drilling, building of distribution networks etc. Many people are unaware of this high cost, since the water rates they usually pay are nominal rates which do not cover the cost of production (al-Mugran, 1992; Biswas, 1978; Smethurst, 1988; Mather, 1984; James and Lee, 1971; al-Sofi, 1999; Sayed, 2000).

The economic solution is historically linked to shortages of water. It has become increasingly important due to unprecedented growth in demand for water. The production and distribution of water is expensive and many governments are not willing to raise taxes to pay for it. Other solutions must be found. The adoption of a policy of charging results. This affects the distribution of water, since not all regions and individuals are capable of paying. Consequently, there is a tension between social and economic considerations. It is difficult to achieve the success of the economic solution without adverse effects on equitable distribution (Whittington, 1992; TCWPP, 1992; Le *et al.*, 1992; Cairncross and Kinnear, 1991; Biswas *et al.*, 1997; James and Lee, 1971; Liebaert, 1997).

3.2.6. Technical View:

Technology is defined by Sarre and Reddish (1996) as "the totality of all the practical ways a particular society provides for its needs". Sometimes this is synonymous with engineering, while in other instances it means the skills or the science that increases knowledge. Technical fixes, according to Rogers (1990), are merely the result of the wrong use of technology, and hence correction is through more technology. On the other hand technology is known by engineers as the trusted method of solving problems. Rogers (1990) emphasises the immense dependence on technology in modern development of water resources - construction of dams and canals, purification plants and control of floods.

The technical view is not an ideologically based view in quite the same way as, for instance, the Islamic view or the social view. Its practitioners necessarily will have some level of faith in the efficiency of modern sciences in solving problems (Polevoy, 1996). Technology is effectively the application of scientifically determined methods, usually through a scientifically - literate bureaucracy (Benian, 1994; Rogers, 1993).

Under all systems, technologists are administering water resources to find sources, store and transport water from source to consumer and in the management and reuse of wastewater. Nevertheless, some countries are still deprived of modern technology. According to Gray (1989), technology has become integrated in societies and is hard to avoid, although that does not stop societies from inventing new methods and ignoring old ones. Lynn (1989); Speight (1996) argue that mankind has learned in the past twenty years that technological solutions are not infinite or enough in the long run and that unreasoning optimism about technology's ability to overcome all difficulties has actually reduced human wisdom and efficiency. They argue there should be more interaction between nature, man and technology to find practical solutions.

It is argued by Biswas (1978); Mather (1984); Grigg (1996); Mukemer and Hijazi (1996) that technological advancement has been instrumental in improving water resources through forecasting weather, reducing rates of evaporation, flood control, gathering surface water, water quality, water conservation and in finding new sources including desalination, rain-making and utilising icebergs. Technology also has a part to play in reducing water use, through improved design and even simple expedients such as the "Hippo Bag". Despite all this, they emphasise that improvements and advancements in order to solve water problems and reduce costs are still necessary. This approach emphasises the key role of developed countries in the technological field.

3.2.7. Environmental View:

The environmental views is relatively modern, with roots in the writings of authors such as Thoreau (1884); Jacks and Whyte (1939) Leopold (1949); and John Muir (Fox, 1981), more recent times, writers such as Carson (1962) and Udall (1963) highlighted the dangers of unrestrained use of technological solutions. Hardin (1968) pointed out that in a finite world, it was impossible for everyone to take all the resources they wished without environmental collapse and mutual impoverishment. This argument was extended by Meadows *et al.*(1972). Another hugely influential contribution was the Gaia hypothesis (Myers, 1984). Over the last fifteen to twenty years, the environmental view has gathered power and has become pervasive in Western society, even influencing Government decisions (e.g. Tulba, 1995) and the Rio Earth Summit Agenda (Johnson, 1993; Park, 1997). Since then, environmental thinking has become ever more pervasive. The catchword has become sustainability (O'Riordan, 1993).

Ideas of the environmental perspective on water should be considered. According to Biswas *et al.* (1997); Kano and Saha (1995); Reuss (1992); Mamo (1997); Balba (1986), halting environmental deterioration caused by water projects should be addressed by long-term solutions related to water quality and its protection, soil destruction, earthquakes, climate, diseases etc.

The weakness in the management of water projects in the developing countries, especially concerning dams (Table 3.1), is highlighted by many authors. Park (1997); Biswas (1993); Sadek *et al.* (1997); Chesworth (1990), enumerate environmental damage caused by water projects; concerns are expressed about management of risk and water level variations.

Table 3.1. People Problems Associated with Large Dams (Goldsmith and Hildyard, 1984).

Dam	Displaced People	Area (in Hectare)
Aswan High Dam (Egypt)	120,000	400,000
Volta Dam (Ghana)	78,000	848,200
Kariba Dam (Zimbabwe)	50,000	510,000
Kainji Dam (Nigeria)	42,000	---
Keban Dam (Turkey)	30,000	---

Typical is the case of the Aswan High Dam in Egypt (Figure 3.1) which has caused serious damage to the environment (e.g. Newson, 1992).

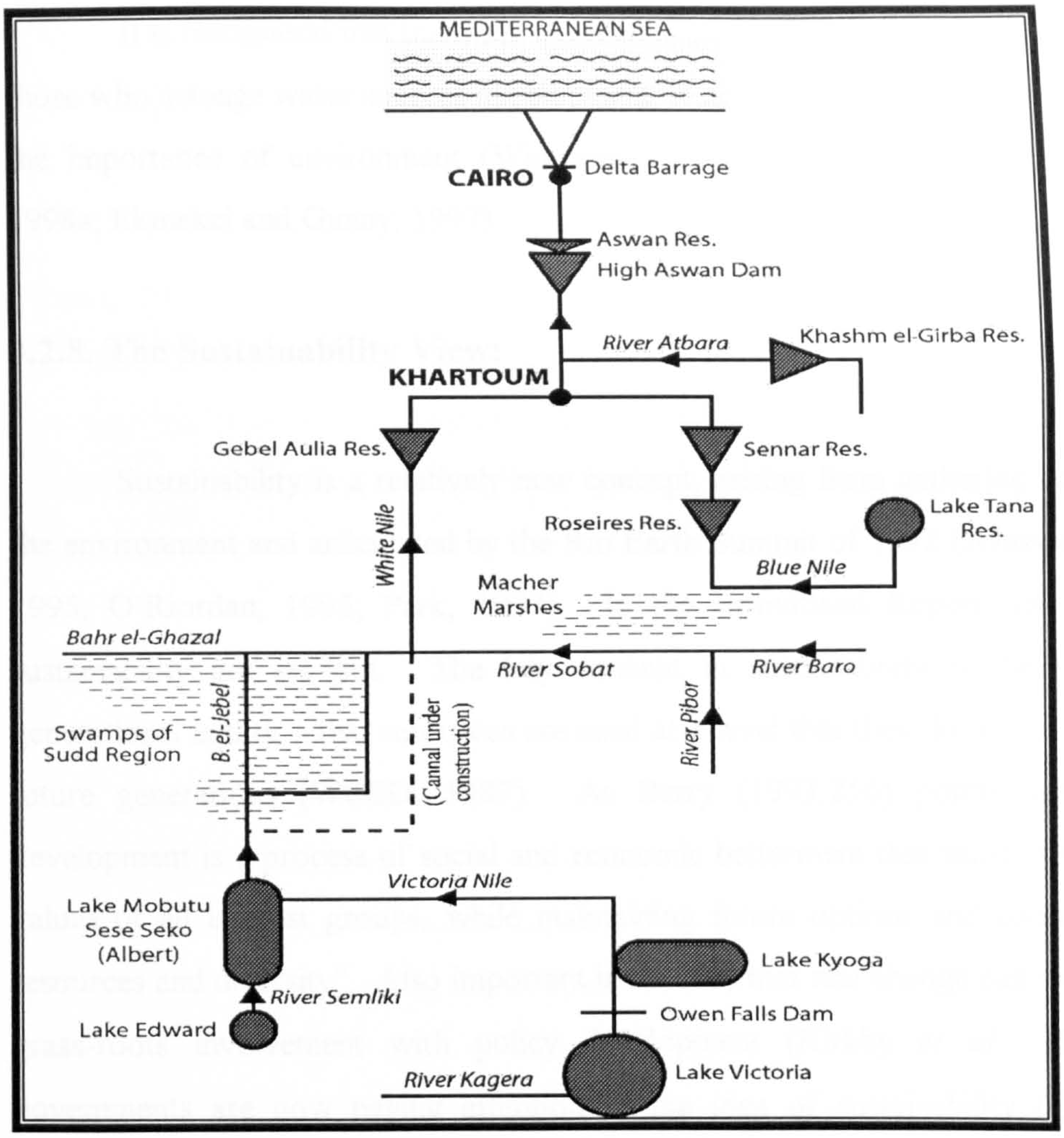

Figure 3.1. Schematic Representation the Aswan Dam in the Nile River Basin (After Abdelmageed, 1994).

Concerns have been raised by other water projects, which have damaging impacts on the environment. These include projects for the development of groundwater, which are essential to many countries. Although mankind has depended on this source since ancient times, high levels of pumping did not take place until the second quarter of the 20th century. Over-exploitation has led to pollution and sometimes to groundwater depletion, especially in countries that are focusing on food production (Brown *et al.*, 1996; Micklin, 1996; Mohanty and Ebrahim, 1995; Leusink, 1992; Bouwer, 1994b; Agnew and Anderson, 1992; Williams *et al.*, 1995; Gray, 1994; el-Asswad, 1995). In some arid countries, especially the Arabian Gulf states, increased pumping of groundwater has caused changes in water quality as groundwater depletion and seawater incursion have occurred (e.g. Gore, 1997; Streetly and Kotoub, 1998; Othman, 1999; Abdulqafar, 1999).

It is recognised that many environmental problems are due to lack of attention by those who manage water sources development, in addition to lack of public awareness of the importance of environment (Winpenny, 1994; Thanh and Tam, 1990b; al-Biati, 1998a; Ekmekci and Gunay, 1997).

3.2.8. The Sustainability View:

Sustainability is a relatively new concept, arising from gathering concerns about the environment and articulated by the Rio Earth Summit of 1992 (Johnson, 1993; Gao, 1995; O'Riordan, 1995; Park, 1997). In the Brundtland Report, the principles of sustainability are set out. The key concept in sustainability is the idea of inter-generational equity – that resources are used at a level that they do not prejudice use by future generations (WCED, 1987). As Berry (1993:256) points out "sustainable development is a process of social and economic betterment that satisfies the needs and values of all interest groups, while maintaining future options and conserving natural resources and diversity". Also important is the idea that real change can only come from grass-roots involvement with policy development (Kirkby *et al.*, 1993). Many governments are now paying attention to the idea of sustainability (Chatterjee and Finger, 1994). The UK, for instance has policies of sustainable development strategy published in 1994 (DE, 1996). Although the concept of sustainability is now fashionable, the application of the concept is often not very strong (Kuylenstierna *et al.*, 1997). As the Brundtland Report (WCED, 1987: 8) states "The concept of sustainable development does imply limits – not absolute limits but limitations imposed by the present state of technology and social organisation on environmental resources and by the ability of the biosphere to absorb the human activity. But technology and social organisation can both be improved to make way for a new era of economic growth".

3.2.9. Conclusion:

As can be seen in the preceding section, water management is underlain by a variety of perspectives. In the following sections, it will be seen how the conceptual approach used tends to condition the tools used to manage water.

3.3. Approaches to Water Management:

3.3.1. Introduction:

There is not one effective model for management (Okun, 1991; Lee, 1992; Biswas, 1978; McDonald and Kay, 1988) since a number of models have proved successful in achieving their aims and each country has its specific conditions. Thus choosing the type of management must be rooted in the prevalent socio-economic conditions of the society. Okun (1991) identifies governmental administrations, national and local quasi-governmental agencies, and the local public, for instance.

3.3.2. Traditional Approaches:

Traditional societies in the Mediterranean countries often have sophisticated water management systems. Here, typically, certain people, usually farmers, invest as a group in the development of water supply. The water is divided equitably, usually pro - rata with the size of the initial investment. Important decisions are usually made communally, with the weight of a person's opinion dependent on the size of this investment (Jones *et al.*, 1998). Very often a communal organisation controls water (Jones *et al.*, 1998; Crook, 1997). In most cases, water rights are inheritable in perpetuity. This encourages those who own water rights to invest time and resources in maintaining the system, and thus furthers sustainability over periods of time as long as 2,500 years (Hunt and Gilbertson, 1998; Gilbertson, 1986). The members of the organisation possess water rights, often in accordance with their investment. Such organisations often have complex and highly-developed bye-laws, with sanctions for those who transgress. In some cases, these organisations employ various officers to maintain the systems, allocate the water and prevent unauthorised abstraction. Such systems are widely seen in the Mediterranean countries (e.g. Jones *et al.*, 1998; Netting, 1981; O'Neill, 1987; Crook, 1997).

3.3.3. State Approach:

In most developing countries water management is a state responsibility. This effectively follows from the social view (Section 3.2.3). The state determines the effects of water projects on the environment, secures funding, determines the technology to be used and sometimes considers people's opinions (Jellali and Jebali, 1994; Agnew and Anderson, 1992). A major mistake can bring down governments, as happened in Jordan in the mid 1998 (Mansour, 1998; Anon, 1998b). The Minister of Water had to resign, followed by the resignation of the whole cabinet, due to their inability to explain and manage the pollution that occurred in a major water distribution network.

Any country, according to the OECD (1977); Grigg (1996), needs three levels of management to guarantee smooth operation. Firstly, the central government, is responsible foremost for executive decisions, laws and policies. Secondly, the regional level is concerned with water management. Thirdly, the local level is concerned with the employees involved in operation, maintenance and follow up. This is discussed further in Section 3.5.

3.3.4. Market Approach:

In this approach water resources and distribution systems belong to companies, which in turn are owned by shareholders. The companies make money for the stakeholders by selling water. The objective of most private companies is to make a profit. This approach follows from the economic view (Section 3.2.4).

According to Moore and Diner (1995); Bolding *et al.* (1995); Sayed (2000); Biswas (1990); Beekman (1998); Rogers (1993); Allan (1995); Sewell *et al.* (1985) the most important tool is the consideration of water as an economic commodity. This gets rid of the idea that water is a gift from Allah, so man can use it freely, without any controls other than availability and ability to pay. It teaches people that water has a high value, which equals or exceeds the cost of the same amount of oil. The economic value of water will not be realised unless fees are charged according to the cost of providing the water. It may not be necessary to consider the amounts charged on water as income as much as a way of protecting water from irresponsible uses in all sectors, though in many privatised water industries it is necessary to make a profit for shareholders.

Historically, water has often been considered a free commodity, especially in water-rich areas, where this is often enshrined in law. Even in countries where people pay for water, the rates are often much lower than the actual costs. The consequences are that people living in isolated areas, or people using water in peak times or people using great quantities of water pay the same as people living in areas where the cost of water is very little, or those using water at off-peak times or those who use small amounts of water. Thus, it is important to consider the economic and geographic factors when appraising pricing policies (Sewell and Bower, 1968; Knapp, 1992; Woo, 1992).

According to al-Yahiawi (1998); Sadik and Barghouti (1997); Altaf (1994); Biswas (1978); Shadi (1999); Badauy (1999) water has become a commodity just like other commodities, and its scarcity will increase its price, making it unavailable to poor communities. Developing countries are following developed countries in the spread of private companies for producing and marketing water and making profit. Some developing countries, which are cautious about providing water at economic rates, are coming under pressure from developed countries to privatise their facilities. This will benefit companies from the developed world, who compete with local companies for these contracts.

The natural consequence of unfettered capitalism is the maximisation of profit and minimisation of cost. The consumer may suffer grievously if this is the case as price will be high (al-Qarrdauy, 1986; al-Nabhani, 1990; Jessop, 1982; Kolakowski, 1978; Pierson, 1989; Brenner, 1986). Consequently, in some countries, such as the UK, a regulator determines the cost of water to the consumer, so there is a measure of equality and excess profits are not made (Porter, 1978; Parker and Penning-Rowsell, 1980; Gray, 1994).

3.3.5. Technical Approach:

The Technical approach is a produced of modern science and bureaucracy. It is highly ordered and organised - its proponents would say, on a scientific basis (Polevoy, 1996; Kassas, 1997). Virtually, all modern development projects operate in this way and analyses of many development possibilities (e.g. by the World Bank) are on this basis (Biswas *et al.*, 1997).

3.3.6. The Sustainable Approach:

The sustainable approach revolves around the idea that local communities are often the best judge of how to ensure long-term viability of resource use – from Agenda

21 (Boyle, 1995; Mehta, 1997; Bowers, 1997). If local communities are not engaged in the management of resources, they will not care if they are depleted (Oad and King, 1991; Mukemer and Hijazi, 1996). Local communities therefore have to be empowered, so that individuals have a stake in their future – and the futures of their descendants (Kassas, 1997; Carley and Christie, 2000). Approaches are shown in Table 3.2 and Figure 3.2. A degree of local democracy and autonomy is therefore necessary before sustainable solutions can be found (Paehlke, 1995; Carley and Christie, 2000). Local democracy and autonomy often manifests itself through local councils and local participation in decision-making (Bowers, 1997).

Table 3.2. Guidelines to Sustainable Development (Kassas, 1997: 66-67).

Action	Requirement
Development policies	Should incorporate population and demographic objectives that aim at maintaining - in the long term – a balance between resources and national basic needs.
National policies	Should envisage education (and training) as a national machinery for human-resource development and aim at ensuring that education transforms men and women into societal resources (and not, as at present prevalent in many countries, societal liabilities).
Plans for the development of natural resources (renewable and non-renewable)	Should be set within time horizons that satisfy the requirements of the present generation and that anticipate the requirements of future generation.
Programmes for the development of resources	Should include the means and conditions that ensure equal opportunities to men and women and the positive participation of all people concerned in all phases of planning and implementation. Special programmes for environmental education and public awareness need to be designed and implemented.
Land-use policies	Should aim at ecologically sound utilisation of biosphere resources and at reducing conflicts between different uses and be based on nationally accepted priorities.
Institutions for the development of natural resources	Should include components for the management of environmental and natural hazards including recurrent droughts, floods, etc.; such components may include environmental monitoring and early warning facilities and insurance mechanisms.
National policies	Should provide support for regional co-operation in the management of shared natural resources and for collaborative programmes for the protection of the regional environment and conservation of its elements and should accept the reality of global interdependence.

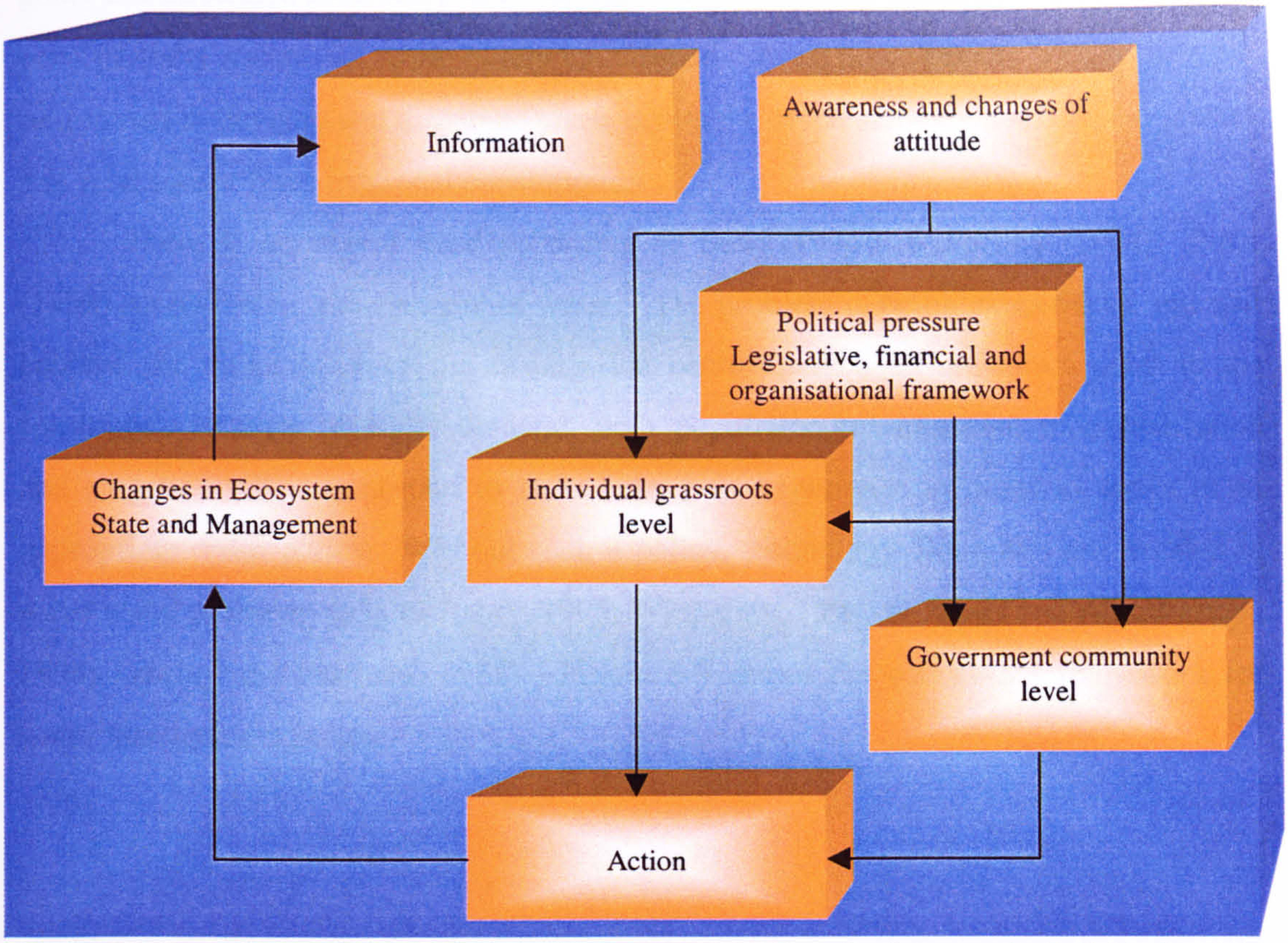

Figure 3.2. Towards Sustainable Ecosystem Management: the Interplay between the Individual and the Community (After Barkham, 1995).

3.3.7. Conclusion:

Again, it is the context - conceptual and practical - in which water management is embedded is critical to the type of approach taken. The type of approach taken in turn governs the types of tools, which are appropriate.

3.4. Tools for Water Management:

3.4.1. Introduction:

It has been imperative for people, states and international organisations to find mechanisms to balance demand and supply, hence the establishment of water management. This is not a modern phenomenon, since ancient people managed water, but the second half of this century has witnessed an acceleration in preparation of water plans and strategies to develop and manage water resources. Some arid countries have been partially successful while others have failed. Water management tries to find the best means to develop and distribute water equitably, at the same time it needs to protect this vital source from irrational consumption.

There is an urgent need according to Bear (1996); Winpenny (1994); Shadi (1999) for the better management of water. The problem is being exacerbated and will become the major issue of the twenty-first century, since all indicators point to the continuous increase of water demand, with population urbanisation, industrialisation and irrigation. It is important to learn from past experience in order to arrive at an appropriate water policy. Without such a policy, technology alone will not be able to solve water problems (e.g. el-Ashry, 1995; Winpenny, 1994; al-Alawi and Abdulrazzak, 1994; Linsley and Franzini, 1972). Figure 3.3 shows the conceptual framework for water management policy.

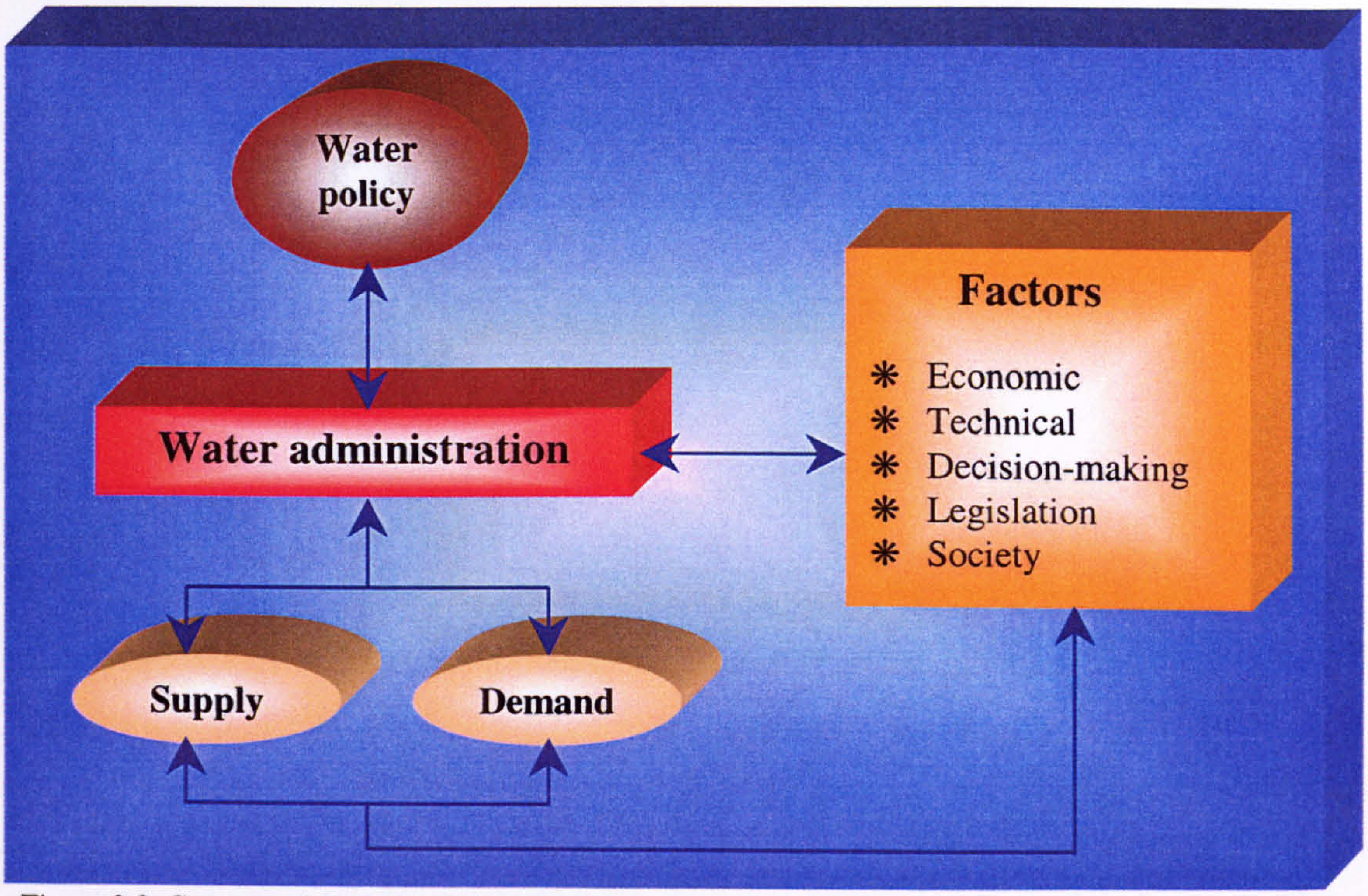

Figure 3.3. Conceptual Framework for the Water Management System.

3.4.2. Management of Supply:

3.4.2.1. Technical Tools:

The development and production of water started with the simplest and most primitive of methods and tools to raise or store water. Today technology is capable of constructing giant dams for reservoirs, as well as sophisticated treatment of water and desalination. This is underpinned by engineering and the sciences (Polevoy, 1996).

Technologists often have the upper hand in water resources management from the finding and protection of sources, transport, storage and management to reuse of wastewater (Figure 3.4), since they retain the specialised information enabling these tasks to be completed (Rogers, 1990). In traditional societies, the equivalent information is more widely distributed.

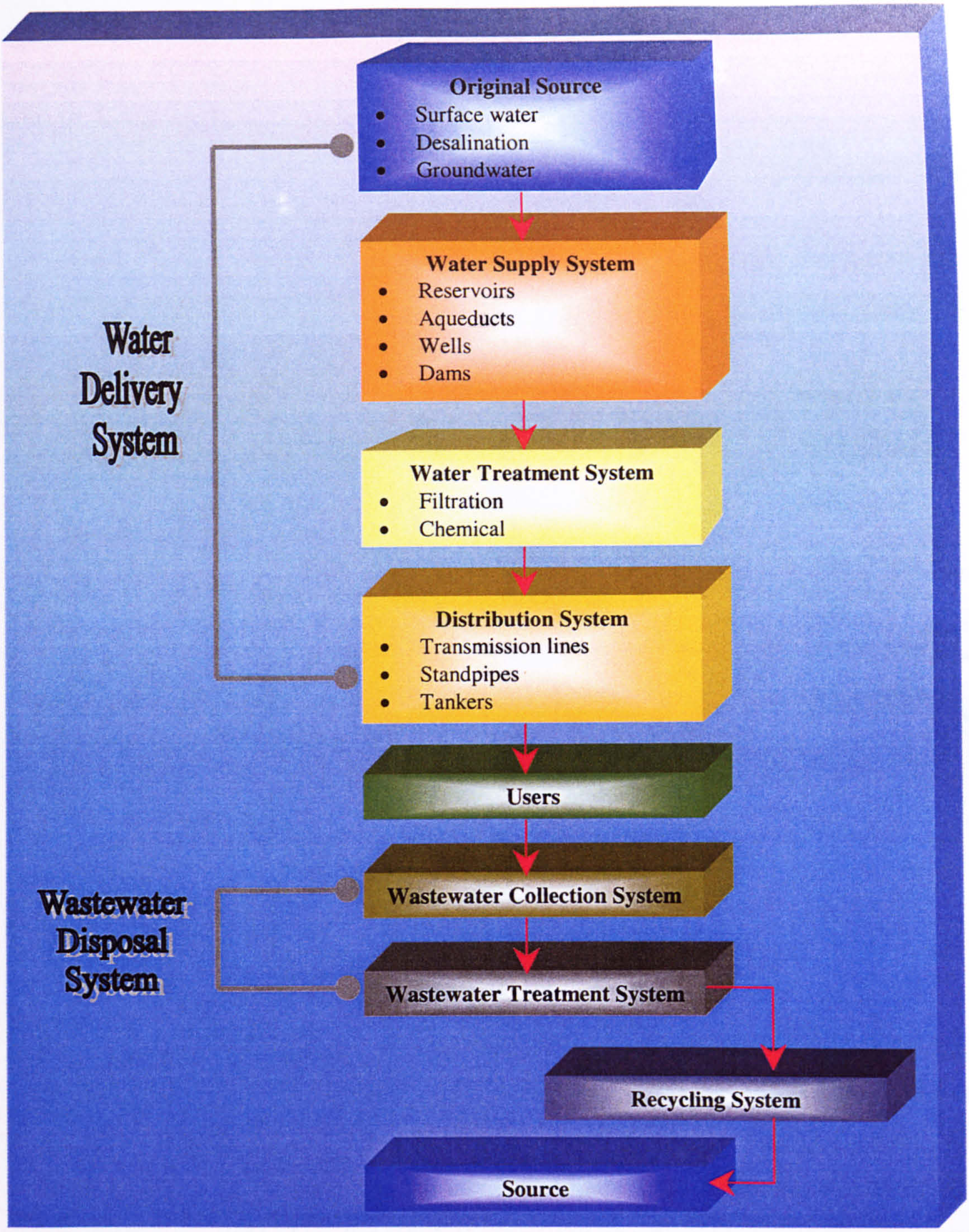

Figure 3.4. Water Systems Technology (After Rogers, 1990).

Technical tools used in modern water resources management in the arid zone are summarised in Table 3.3.

Table 3.3. Some Technical Tools used in Groundwater, Surface and Non-traditional.

Sources	Technical Tools (Examples)	Authors (Examples)
Groundwater	Fossil groundwater aquifers development	Alam (1989); Tsur *et al.* (1989)
	Groundwater monitoring (quantity and quality)	Jones (1997); Miles and Chambet (1995)
	Monitoring of pumping	Moore *et al.* (1995)
	Building dams and barriers in order to recharge groundwater and compensate some of the loss from pumping	Meldrum (1995); Bouwer (1994b)
	Use recycled water to recharge groundwater	Soliman *et al.* (1995); Bouwer (1991)
Surface Water	Catchment management techniques (e.g. modification of hillslopes to achieve unimpeded rapid runoff	Hunt and Gilbertson (1998); Arar (1997)
	Use of barrages to encourage shallow subsurface storage	Jones (1997); Mukemer and Hijazi (1996)
	Use of dams to store runoff	Black (1996); Abu Zeid and el-Shibini (1997)
	Water transfer systems (pipelines and canals)	Grigg (1996); Biswas *et al.* (1997)
	Flood water farming technology	Hunt and Gilbertson (1998)
Non-traditional Resources	Brackish and seawater desalination by using different techniques (e.g. MSF)	Dabbagh and Faraj (1997); Porteous *et al.* (1993)
	Use recycled water for some purposes such as irrigation	Boller (1997); Mahmoud and Sadeqi (1997)
	Transfer water from area to another by pipelines, ships and balloons	Gleick (1997); Hadad (1994)
	Rain-making	Mather (1984); Mussa (1993)

3.4.2.2. Economic Tool:

The economic factor plays a subsidiary role in the management of water and is closely tied with the other elements of management. Economic tools are not generally very effective in expanding supply. In economies open to the capitalist system, or in receipt of foreign cash aid, engineering companies will build new water facilities if there is sufficient recompense. The economic tool can thus be used to expand water supply, given that even the most water-poor countries can have access to desalination plants and similar advanced technology if they have the resources to pay. Payments must then be made to sustain production. Every water development project has a specific cost regardless of size (James and Lee, 1971; Arar, 1997; al-Sofi, 1999; Abdulqafar, 1999). This cost increases according to the required levels of production, and the technical difficulty of the project.

The cost of water production for domestic supply must be discussed (Table 3.4). It appears there is no relation between cost of production and water availability (Dabbagh *et al.*, 1994). For instance, Singapore which depends on water importation from Malaysia has low production costs, around \$0.24 l^{-1}, while Cameroon which is water rich (rivers and rain) has production costs around \$2 l^{-1}. This clearly points to the importance of management in reducing the cost of developing and producing water. Thus Singapore keeps the cost low despite including all costs incurred in the process, while some Third World countries have high costs, although not all costs incurred in the process are included. The cost of water production is thus closely tied to the management of water and not to the quality of the source that is produced or needs developing.

Table 3.4. Unit Cost of Water Production in Some Countries (Dabbagh *et al.*, 1994).

Country	Cost $/m³	GNP per Capita ($)	$ Cost per Capita (%)
Cameroon	2.0	800	0.25
Mexico	1.5	2,080	0.07
Argentina	1.5	1,929	0.8
Netherlands	1.25	9,290	0.01
Zambia	1.05	390	0.3
Saudi Arabia	1.0	8,850	0.01
Sierra Leone	0.9	200	0,45
Malawi	0.6	170	0.35
Tunisia	0.5	1,277	0.04
Cyprus	0.4	3,572	0.01
Bahamas	0.37	7,556	0.01
Ghana	0.35	420	0.08
Switzerland	0.33	14,764	0.002
Afghanistan	0.3	163	0.18
Spain	0.22	4,256	0.005
Zaire	0.22	271	0.08
Iraq	0.118	2,964	0.004
Philippines	0.05	585	0.008
Singapore	0.24	7,420	0.003

The high cost of producing and developing non-traditional sources of water has not stopped wealthy countries, such as the US and Arabian Gulf states, from developing these sources, most importantly desalination. The energy required in the desalination process is 2.8 J per 1 m^3 of water. Yet, it is possible to reduce ten-fold the necessary energy with the future development of desalination plants (Dabbagh and Faraj, 1997;

Arthur, 1997; Hoehn, 1972; Agnew and Anderson, 1992; Duetch, 1999). The cost of producing 1 m^3 from desalination is between \$1 and \$8. According to a study by the World Bank it should have been possible to reduce this cost to \$0.70 by the year 2000 through improving operation (Braverman, 1994).

It is possible to reduce costs by switching to solar energy. Further research is needed, however, to make it available world wide (al-Hajri and al-Misned, 1994; al-Ismaily and Probert, 1995; Ali, 1993; Ayoub and Alward, 1996; Braverman, 1994).

Recycling is another non-traditional alternative resource, but its acceptance for human consumption is very limited and its use is restricted to irrigation or recharge of groundwater. Recent expansion in use is due to low costs from \$0.20 to \$0.50 per m^3, especially in comparison with other sources - desalination is from \$1.5 to \$3.0 per m^3 (Table 3.5). Use of recycled water for irrigation and industrial purposes is considered the most economical solution for shortages of water in arid areas (e.g. Arar, 1997; al-Mohannadi, 1997a; al-Alawi and Abdulrazzak, 1994).

Table 3.5. Non-tradition Water Production Costs (Arar, 1997).

Source	Cost (\$/m^3)
Desalination (Seawater)	1.5 - 3.0
Desalination (Brackish Water)	0.25 - 0.40
Recycling	0.20 - 0.50
Rain-making	0.02 (Syrian Experience)
Cloud Gathering	0.30 (Chilean Experience)

The import of water is another non-traditional source. It is usually considered a last resort solution because of the political difficulties associated with dependence on another country for water and the high cost. An example is the Peace Pipeline project which aims to transfer water from Turkey to most of the Middle East. The project consists of two pipelines. The first, to Gulf States costs \$12.5 billion and the second, to other countries in the Middle East costs \$8.7 billion. That means the cost of one litre in the Gulf will be \$1.07 and in the other states \$0.84 (Biswas *et al.*, 1997; Gregory, 1991; Luelmo, 1996; Mukamer and Hijazi, 1996). Another water transfer example is the Jordanian-Iraqi project. The cost is estimated at \$1.8 billion despite the short distance between the two countries. This emphasises the high cost of such projects, in addition to political and environmental factors (Biswas *et al.*, 1997).

Hence, water production requires funds that are not easily available in most developing countries. Table 3.6 shows possible ways to meet these costs are:

Table 3.6. Example Sources of Fund to Meet the Cost of Water Development.

Source of Funding	Country (Examples)	Author (Examples)
Cost control by minimising or eliminating wastewater	Cyprus	Van Tuijl, 1993
Taxes and public (state) investment	USA	Rogers, 1993
Printing money (not a good idea but widely used)	China	Tong and Zha, 1996
Public subscription	Chile	Sadik and Barghouti, 1994
Raising capital through borrowing from commercial banks or international organisations	Morocco, Algeria and Tunis borrowed from the World Bank	Sadik and Barghouti, 1994
Assistance from developed countries or regional and international organisations	Yemen	Mahmoud, 1992
Raising capital by share or debenture issues	France	Buller, 1996
Water tariffs which recover the costs of operation and maintenance	Morocco	Tuijl, 1989
Reinvesting profits	UK	Brewster *et al.*, 1999

3.4.2.3. Legislation:

Legislation is often a pre-requisite for the expansion of supply, but it can be a crude tool. The privatisation of the British Water Supply Industry, which has led to considerable investment in the supply side, has a legal basis (e.g. Ogden and Glaister, 1996; Neto, 1998; Buller, 1996). The legal control of the British water industry continues through the Regulator, who has statutory powers. Legislation thus provides the framework in which other tools can operate (Gray, 1994; Parker, 1997).

"Legal control of water sources has been ones of the most compelling issues facing individuals and government throughout history" (Mather, 1984). Legislation provides a legal framework, which governs the actions of people and organisation. It provides (Harris, 1997; Denham, 1999):

- rules to establish the limits of behaviour in a society,
- rules about how behaviour and procedures should occur,
- sanction for those who transgress.

The constitution (which may be unwritten) determines the legislative body within the state. In states with an absolute ruler, laws are effectively the utterances of the ruler, though these may be codified and administered by a bureaucratic apparatus. In a constitutional monarchy, although law-making power is theoretically with the ruler, laws are usually made by an elected assembly (Harris, 1997; Yardley, 1978; Herling, 1997; Jones and Kavanagh, 1994). In a republic, laws are made by on behalf of the people by an elected assembly (Banks and Muller, 1998; Conradt, 1993; Schopflin, 1994; Preston, 1997).

Supra-national legislation is governed by treaties between sovereign states. It takes the form of an agreement regarded as legally binding and ratified by the legislative body of each country concerned. Treaties may be between just two states, but much supra-national legislation is at regional level (e.g. the Gulf Co-operation Council) (GCC, 1996a; GCC, 1998b) or at the level of the European Community (EC) or United Nations (UN) (Kratochwil and Ruggie, 1997; Denham, 1999).

For surface water the International Law Society confirmed four principles. The first is the principle that considers river basins as one unit that should not be treated in parts. The second guarantees the right of states to invest in the water that flows through their territory unless an agreement stipulates otherwise. The third principle requests countries that share the same river basin to abide by international agreements. Lastly is the principle of solidarity among the countries that share same basin and the adherence to international law (Hassan, 1990; Gleick, 1996; Mukamer and Hijazi, 1996).

These principles still needed explanation; for instance how to decide that the planned project is beneficial or harmful. The Helsinki Rules did this in 1966. These rules made these principles very clear, by stipulating for instance that the just share for each country does not necessary mean an equal share, but rather that the needs of each country should accord to its economic and social level (Shuval, 1995; McCaffrey, 1991; Agenw and Anderson, 1992; Douman, 1996; Biswas *et al.*, 1997; Naff, 1994; Abu Zeid, 1999).

In 1980, an International Law Commission was appointed to prepare a draft document of law for non-maritime utilisation of international waters. The draft prepared included 17 items to organise the rules that have been mentioned above (Hassan, 1990; Gleick, 1997; Falkenmark, 1989b; Naff, 1994; Overman, 1976).

For groundwater the situation is complicated by the frequent absence of aquifer data. Laws have not seen much development, despite the need for it, except the Bellagio Draft Treaty. According to this treaty, which appeared in 1988, groundwater is similar to surface water in the sense that the development of water in one country affects the quality and amount of water for others, with the exception that with groundwater these effects are unseen. Therefore, groundwater should to be treated as surface water (Hayton and Utton, 1989; Barberis, 1991; Naff, 1994).

3.4.2.4. Decision-making:

Decision-making can occur at a number of levels in society (Table 3.7).

Table 3.7. Some Levels of Decision-making Examples.

Decision-making Levels (Example)	Authors (Example)
Local administration (e.g. local councils)	OECD (1977); Grigg (1996)
Regional administration	OECD (1977); Grigg (1996)
Central government	OECD (1977); Grigg (1996)
Companies (small, large and multi-national)	Gilpin (1987); Vietor (1994)
Non-governmental organisations (NGOs) (e.g. charities, pressure groups, political parties and religions organisations)	Villeneuve (1996); Natsios (1997)
Quasi non-governmental organisation (QUANGOs) (e.g. semi-privatised government and national organisations)	Cavadino (1995); Mallett (1993)
International and supra-national bodies (e.g. the EU and the UN)	Backstrand *et al.* (1996); Luard (1994); Strange (1997)

Experience shows that decision-making is only efficient where the group making the decision is very small, usually less than five. This can be seen, for instance, with the UN, where decision-making is very difficult. Even the much smaller Security Council has difficulty making decisions (Appling, 1995; Luard, 1994; Wallensteen, 1997; Ghali, 1997).

In many cases decision-making is actually done by small groups of people - the executive - who derive power from their position in their organisation. Thus, in the UK government, decision-making is done by the Prime Minister and Cabinet, who are the elected leaders of the majority party in the legislature (Parliament) but who are legally appointed by the sovereign (Herling, 1997; Yardley, 1978; Keenan, 1992; Elliott and Quinn, 1998; Jones and Kavanagh, 1994). In Bahrain, decision-making is done by the Amir (Rule in Bahrain is hereditary, whereby power is transferred from father to son) and in some cases sharing with the Prime Minister or the Advisory Council (whose members are chosen by the Amir) (Zahlan, 1989).

In most companies, decision-making is done by a Managing Director and Board of Directors, who are appointed by the shareholders to make decision on their behalf (Mintzberg, 1996; Martino, 1975; Johnson and Scholes, 1993; Jauch and Glueck, 1988).

3.4.2.5. Social Tools:

Introduction:

Society participation (Willeke, 1976; Syme and Nancarrow, 1992; Cernea, 1991; Whitland and ReVelle, 1990; Bultena, 1974; Mazmanian, 1976; Hunter, 1998; House, 1996; O'Rourke, 1992; McDonald and Kay, 1988; Sewell *et al.*, 1985) has become one of the mechanisms of development of water resources. The main reason is to allow people a chance to understand the projects and to hasten the speed of implementation. It started in the most developed countries. In the USA, for example, in 1960 a series of federal laws called for popular participation in projects concerning water development, especially concerning shared waters, the quality of water, and its protection from pollution. Planners felt an improvement in planning for these projects with popular participation. For example, some of the disputes that existed between individuals and groups could be solved or at least discussed during the planning stage rather than leaving it to legal action, in addition planners benefited immensely from the information exchanged with the public. The effect of considering costs and profits among the different groups of society seemed to be more just.

There are no over riding reasons preventing popular participation in the management and development of water, since projects aim at serving the people, who pay for them directly through taxes or indirectly through the exploitation of their natural resources. These projects may cause harmful effects, if constructed near settlements, as with dams, which cover large areas of land. Desalination plants damage sea life, which is a livelihood for some people. Considering all this, it is argued to be wrong to deprive society from expressing views on these matters (Willeke, 1976; Syme and Nancarrow, 1992; Cernea, 1991; Whitland and ReVelle, 1990; Bultena, 1974; Mazmanian, 1976).

Today, the major problem facing most developing countries is the expense in providing the required amounts and quality of water. On the other hand, high costs can be reduced by allowing popular participation in these projects, using local workers, materials and technology. In addition, costs can be spread by permitting non-governmental organisations to participate in these projects as well as using the expertise of international institutions such as the World Bank (al-Mugran, 1992; Biswas, 1978; Smethurst, 1988; Sadik and Barghouti, 1997).

Participation:

The following sheds light on the manner in which people participate in water management (Table 3.8).

Table 3.8. Steps a Manager would go through in a Process of Public Participation (Following Willeke, 1976 and Hendee *et al.*, 1976).

Steps	Explanation
Issue definition	This concerns the planning process and the tools used such as the laws, politics, economics and the environment which should be clarified in order to guarantee a well informed opinion on the part of the people.
Public input collection	This includes summary and data presentation.
Public input evaluation	This involves the analysis of people's opinions and their integration with the rest of the information and suggestions.
Public input analysis	This includes the efforts exerted to inform the public on distribution of water resources, matters of water management and the recording of their opinions.
Decision implementation	This involves taking decisions on all that has been discussed and done.

Sustainable approaches require a high level of participation by all parts of society. According to Pimbert and Pretty (1995) there are varieties of manners for public participation (Table 3.9).

Table 3.9. A Typology of Participation (Pimbert and Pretty, 1995, 24p).

Typology	Components of Each Type
Passive participation	People participate by being told what is going to happen or what has already happened. It is unilateral announcement by an administration or by project management, people's responses are not taken into account. The information being shared belongs only to external professionals
Participation in information given	People participate by answering questions posed by extractive researchers and project managers using questionnaires surveys or similar approaches. People do not have the opportunity to influence proceedings, as the findings of the research or project design are neither shared nor checked for accuracy
Participation by consultation	People participate by being consulted, and external agents listen to views. These external agents define both problems and solutions, and may modify these in the light of people's responses. Such a consultative process dose no obligation to take on board people's views
Participation for material incentives	People participate by providing resources, for example labour, in return for food, cash or other material incentives. Much *in situ* research and bioprospecting falls in this category, as rural people provide the resources but are not involved in the experimentation or the process of learning. It is very common to see this called participation, yet people have no stake in prolonging activities when the incentives end
Functional participation	People participate by forming groups to meet predetermined objectives related to the project, which can involve the development or promotion of externally initiated social organisation. Such involvement does not tend to be at early stages of project cycles or planning, but rather after major decisions have been made. These institutions tend to be dependent on external initiators and facilitators, but may become self-dependent
Interactive participation	People participate in joint analysis, which leads to action plans and the formation of new local groups or the strengthening of existing ones. It tends to involve interdisciplinary methodologies that seek multiple perspectives and make use of systematic and structured learning processes. These groups take control over local decisions, and so people have a stake in maintaining structures or practices
Self-mobilisation	People participate by taking initiatives independent of external institutions to change systems. Such self-initiated mobilisation and collective action may or may not challenge existing inequitable distributions of wealth and power

The means for facilitating popular participation include public meetings, field visits, workshops, direct meeting and through post and media. It is emphasised (Gray, 1989; Blachmore, 1995b; Bultena, 1974; Johnson and Burdge, 1974) that public awareness of environmental issues is on the increase and this is helping to stimulate interest in the water problem, especially the quality of water. Although people notice the lack of information about water resources and quality, they have the desire to participate in the responsibility for water management. Participation can be facilitated through exchange of views and education as well as interaction between those working in the field of water development and consumers. Gray (1989) points out that transferring responsibility to the private sector has achieved progress in that direction.

Raising the awareness of people (Doerksen and Pierce, 1976; Biswas, 1990; Pyrovetsi, 1997; Arreguin *et al.*, 1996; Curran, 1971; Vainio, 1996; Curtis *et al.*, 1995; Mamo, 1997; Othman, 1999), must be the first step when considering water projects, in order to bridge the gap between those who implement the project and the people living in the area of the project. They enumerate the ways to achieve popular participation such as public suggestions, surveys, secret ballot boxes, public meetings, and pressure groups. In this context Sewell *et al.* (1985) points to the increased environmental awareness of societies which encouraged some groups to participate in the operation of specialised administrations, such as water. The period between 1960 and 1965 witnessed a mobilisation of interest groups, especially in Europe and North America, in order to influence decision-makers. Various governments reacted differently, but mostly there has been an acceptance of the rights of the people, not just in raising their awareness about projects but also in expressing their views and suggestions.

There are, however, many obstacles, such as determining the extent of participation. The most important part of planning is gaining acceptance and support from people. Sometimes people are not helpful, especially when values such as honesty and trust are lacking. People co-operate only when the other party is equally co-operative and shows integrity. Laws of environment and land have guaranteed, in most of the developed countries, the right of the public to be consulted prior to the implementation of public projects. But experience shows the difficulty of implementing this, since it is very hard to include all sectors of the society, while choosing some sectors does not achieve the required fairness (Grigg, 1996; Jordan and Wagner, 1993; Mamo, 1997; Blackmore, 1995a; Lee, 1993; Jeffery and Chooye, 1991).

People living in the project area know sometimes better than planners the socio-economic conditions of the area, and hence the extent of the cost and benefits that might accrue from the project. Society has an immense pool of expertise and knowledge that might help governments in their efforts to protect and develop natural resources. A mechanism is needed to guarantee the use of beneficial opinions, including the view of the youth, women, inhabitants of the project area and non-governmental organisations. The participation of all must be secured, thus when the government permits the participation of the young it is in effect helping towards bringing up an aware generation ready to shoulder responsibility. The same applies for the rest of the society (James and Lee, 1971; van Veelen and van Zyl, 1995; Schafer, 1974; Moaren and Dent, 1995; Brokensha and Riley, 1989; Zhou, 1996; Biswas, 1978; Smyth, 1997).

It is important that people accept projects, especially if new technology is used, as with desalination plants or modern irrigation systems. In order to guarantee social acceptance, it is necessary to allow people the chance to participate in the decision-making process. Thus the importance of popular participation in the management of water resources is clear. In democratic countries, this is available directly or indirectly through the election of representatives who legislate and implement projects on behalf of the electoral body. In countries where democracy is absent, people complain about their lack of power over projects carried out by the government. This leads to the failure of some projects, even if technology and finance is available (Oad and King, 1991; Fordham *et al.*, 1991; Ross and Rowan, 1994; Mukemer and Hijazi, 1996).

3.4.3. Management of Demand:

3.4.3.1. Introduction:

This side of water management focuses on the control of water demand in order to achieve a balance between demand and supply (Figure 3.5). There are many tools that can be used to bridge the gap between demand and supply of water in all consuming sectors. Some believe that considering water an economic commodity helps in controlling demand. Others focus on technology, through which transport or irrigation methods are developed, thus providing more efficient use of water and reducing the deficit between the demand and supply. Focus on the decision-making and legislative aspects helps reduce the gap by making laws that control conspicuous consumption and limit the consumption of water in general. Those concerned with the social aspects call for a change in the behaviour of consumers in order to conserve water.

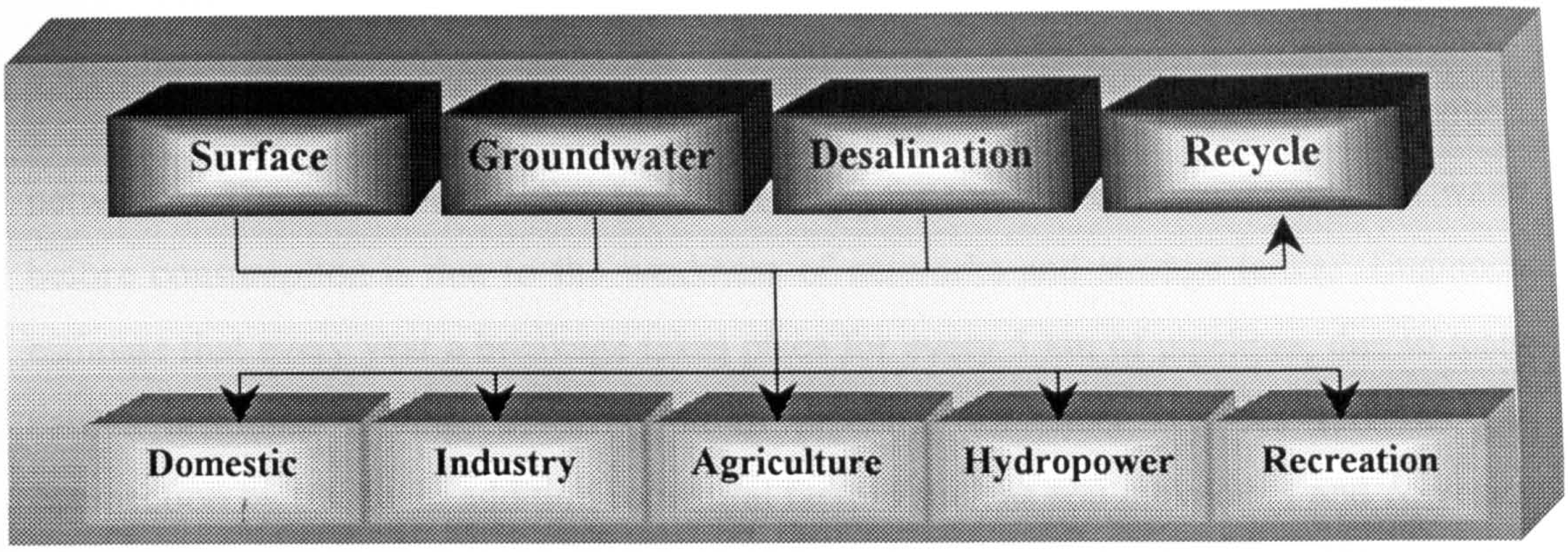

Figure 3.5. A Model for Water Resources and Demand (After Biswas, 1990).

Water demand is defined as the need for water. Water demand is also defined by Sewell and Bower (1968) as "the amounts of water or waste assimilation services for which individuals would sacrifice resources rather than go without". This sacrifice can be estimated through the price paid, for instance, or through willingness not to use these resources. They give an example of high consumption of water when prices are low, but consumption is reduced when prices are increased (van Der Graaf *et al.*, 1997; Anon, 1996; Somlyody, 1993; Rossi, 1990).

A variety of tools and methods are used to control consumption in the domestic, industrial and agricultural sectors, water loss through water distribution networks. Broadly, this is done by charging fees on consumption or the reuse of water or the utilisation of technology that consumes less water. Such measures should be taken before thinking about finding new water sources or developing of existing sources (al-Mugran, 1992; Judah, 1994; Sadik and Barghouti, 1994; Mukemer and Hijazi, 1996).

3.4.3.2. Technical Tools:

Introduction:

Technical fixes can be divided into four types: Distribution and sectorally into domestic, agriculture and industry.

Distribution:

Much focus, in most references is on the technology used in distribution networks. The reason, according to Gray (1994) for the loss of huge amounts of water before consumption is due to the weakness of networks and storage tanks. Engineers estimate that every year a breakage takes place for every 5 km of pipelines, due to many causes including drilling, construction of pipelines for other services such as gas, compaction by traffic, in addition to natural factors such as soil movement and corrosion of pipes, especially steel ones. Estimates for loss of water varies between 25% to 35%. The necessity of technological development of water distribution networks is apparent because of the loss of water - between 40% to 50% and sometimes as high as 60% - in the transport process in some developing countries. It represents a serious problem and a huge pressure on resources, thus it is important to deal with it to achieve more modern and efficient transport. In addition, it will facilitate the use of central methods of control in order to trace leakage and record and control water pressure, so overpressure does not destroy networks (Mukemer and Hijazi, 1996; Kugler, 1995; Iwaki, 1990; Rudolph *et al.*, 1989; Morrison, 1997; Sharaf, 1997)

Mamo (1997) notes that the type of technology used in the distribution network of the Saudi Arabian capital, Riyadh, has led to loss of very costly water produced by desalination. The foundations of buildings are threatened by an increase in groundwater level, and the appearance of a belt of salty water is fed by leakage. It would be possible to avoid such a loss and protect the environment if the right technology were used in the design and construction of the network.

Rogers (1987) gives the example of Boston City in the USA where the loss of water was reduced from 30% to less than 12% between 1978 and 1983 through an effective system for detecting leakage.

Domestic Consumption:

According to Cameron and Wright (1990); Henze (1997); Shelef (1991); Beekman (1998); Othman (1999) the technological solution plays a role in reducing the amount of water consumed directly in households, although more progress is still needed at present. The technological weakness in the design of equipment and lack of maintenance especially in lavatories is considered a serious problem, since water dripping from taps, breakage in pipelines and floods from water tanks are among the main reasons for loss of water (Abu Hggag, 1981; Porteous *et al*., 1993; Cryer, 1995; Othman, 1999).

Technological improvements will help immensely in reducing that loss. Porteous *et al*. (1993) indicated that the individual consumes for washing and bathing about 62% (87 litres) of his total consumed water (140 litres). Much will thus be saved if technology of bathing and washing in households becomes more efficient. Other efforts aim at producing high quality water after treating to be used in the domestic sector (Cisneros, 1995; Nurizzo and Nezzanotte, 1994).

Industrial Consumption:

The industrial sector rates second, after the agricultural sector, in terms of its share of world consumption of water (around 23%). Most water is utilised for cooling, in energy production or in industrial processes themselves, for instance paper manufacturing. The technology of reusing of water in this sector has developed and factories are not geographically linked to areas with surface water as they once were. Water used is often reused many times until its quality is longer acceptable for the sector (Mather, 1984; Clarke, 1993; Biswas, 1978).

According to Mather (1984); Willums (1995); Skellet (1992); Taylor and Denner (1985); Asano and Levine (1995), there are general technological methods that can control increased consumption in the industrial sector (Table 3.10).

Table 3.10. Technical Tools Used in Reduce Industrial Water Consumption (Mather, 1984).

Technical Tools	Reduce Consumption (Examples)
Reducing loss due to leakage	Use of technology that conserves water by, water pipelines that are not in operation and the water used for moving products from one place to another. For instance, instead of using water for transporting vegetables during production the use of moving belts.
Reuse of water several times for the same purpose	Cooling in factories. The use of more advanced technology will reduce the adverse effects on water quality, beside decreasing usage. Dilation of re-used water may make it suitable for reuse.
Re-use of water from one process	In some industrial activities that do not require high quality water. In this case caution is very important during the transportation of water.
Resource shifting	Many factories do not require good quality water and can use recycled water or even brackish water in production without influencing quality.
Treatment of water inside the factory, so it can be used several times	This operation appears costly, but in the long-run, is more efficient. Factories pay huge sums for freshwater, far exceeds the cost of constructing a small treatment plant within the factory.

Agricultural Consumption:

The agricultural sector (e.g. Williams *et al.*, 1995; Clarke, 1993; Cantor, 1970; Olivier, 1972; Abdulwahab, 1999a) consumes more than two thirds (around 70%) of the world's consumption and is the main reason for water shortages in developing countries with high population density and food shortage. Attention has focused primarily on finding technological means to help reduce high levels of consumption.

Persistent efforts to purify recycled water for reuse in irrigation have already been mentioned (Appendix 4). Many countries, especially those that are located in the arid zone, have successfully utilised water treatment technology to obtain water of appropriate quality for irrigation, especially of crops consumed by animals or those that are not eaten directly (e.g. Diamant, 1985; Petrov and Kathijotes, 1996; Shuval, 1987; Arar, 1997; al-Salum, 1999).

Other efforts have focused on the development of irrigation technology and methods (e.g. Abramovitz *et al.*, 1996; Jensen *et al.*, 1993; Minhas, 1996) crops breeding (Jiusheng and Kawaro, 1996; Jensen and Malter, 1995; Mather, 1984; Grigg, 1996) or shifts to new crops that consume less water. By using a more advanced technology (e.g. Gilley, 1985; Stansfield, 1997; Beekman, 1998; Sayed, 1999; Vaux *et al.*, 1990) large quantities of water will be saved in the agricultural sector in region that have severe shortages of water (Table 3.11 and Figure 3.6).

Table 3.11. Some Modern Irrigation Methods.

Irrigation Technology	Methods	Authors (Example)
Sprinkler irrigation	Water is released under pressure from overhanging pipe or through rotating hoses that can cover an area of 30 ha in diameter. The benefits of this method other than saving water is that there is no need for digging canals or for labour as well as reducing evaporation.	Sadik and Barghouti (1994); Rawitz (1973); Rolland (1982)
Bubbler	Where openings are constructed which allow the appropriate amount of water to pass and hence controls and saves water.	Sadik and Barghouti (1997); Arar (1997)
Drip	Irrigate through an underground network and can save up to 80% of the water used by traditional irrigation technologies (furrow, border, and flood irrigation).	Mukemer and Hijazi (1996); al-Ibrahim (1991); Mustafa *et al.* (1989)

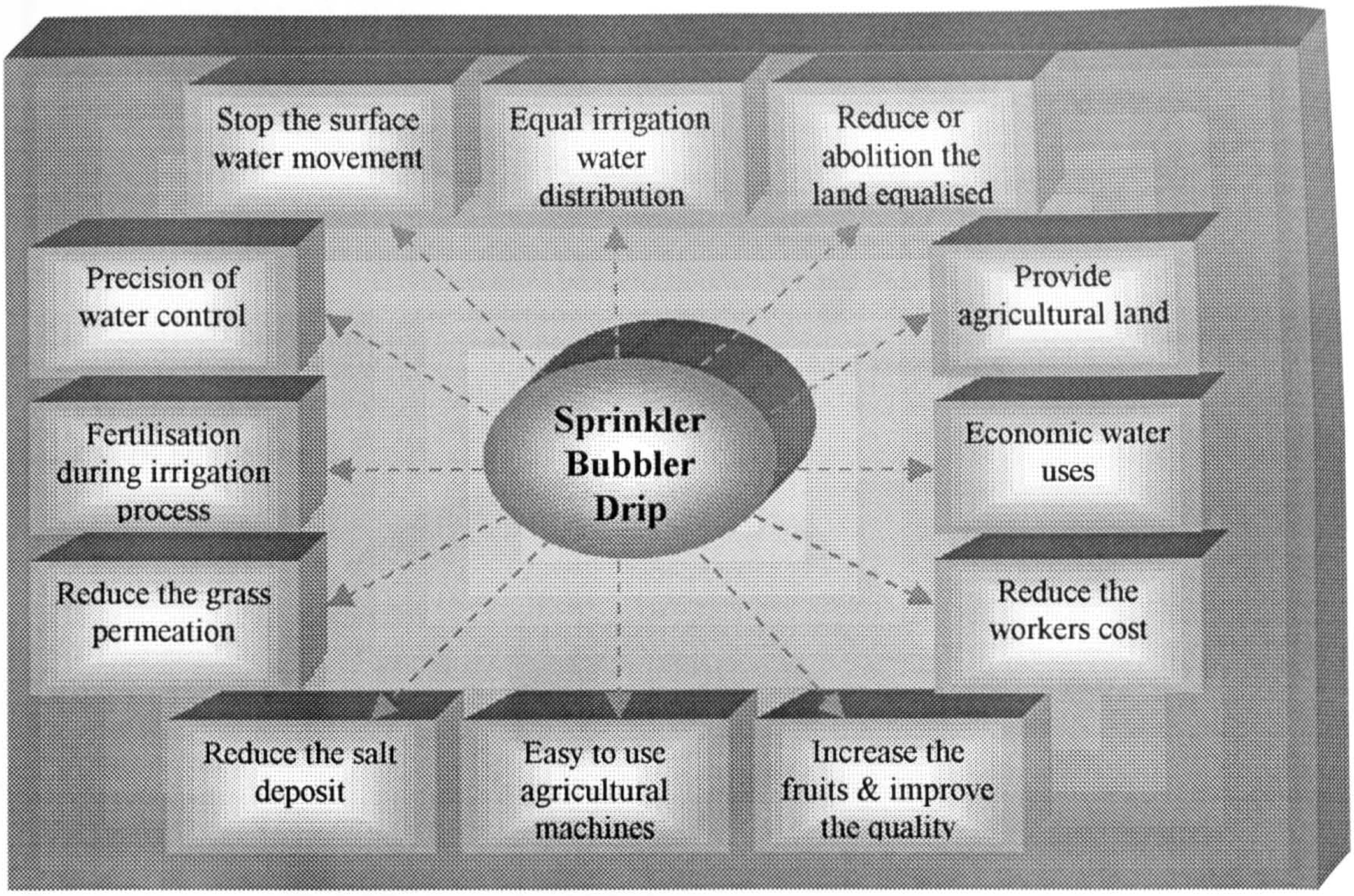

Figure 3.6. The Benefits of Modern Irrigation Methods (After Ismail, 2000).

In Saudi Arabia for example, drip and sprinkle (Figure 3.7) methods have reduced water consumption significantly, in the case of the former by 62% and in the case of the latter by 42% (Ibrahim, 1991). Also as indicated by Sadik and Barghouti (1997), the sprinkle and drip methods proved very successful in Jordan. Water consumption was reduced by 70% especially in fruit and vegetables.

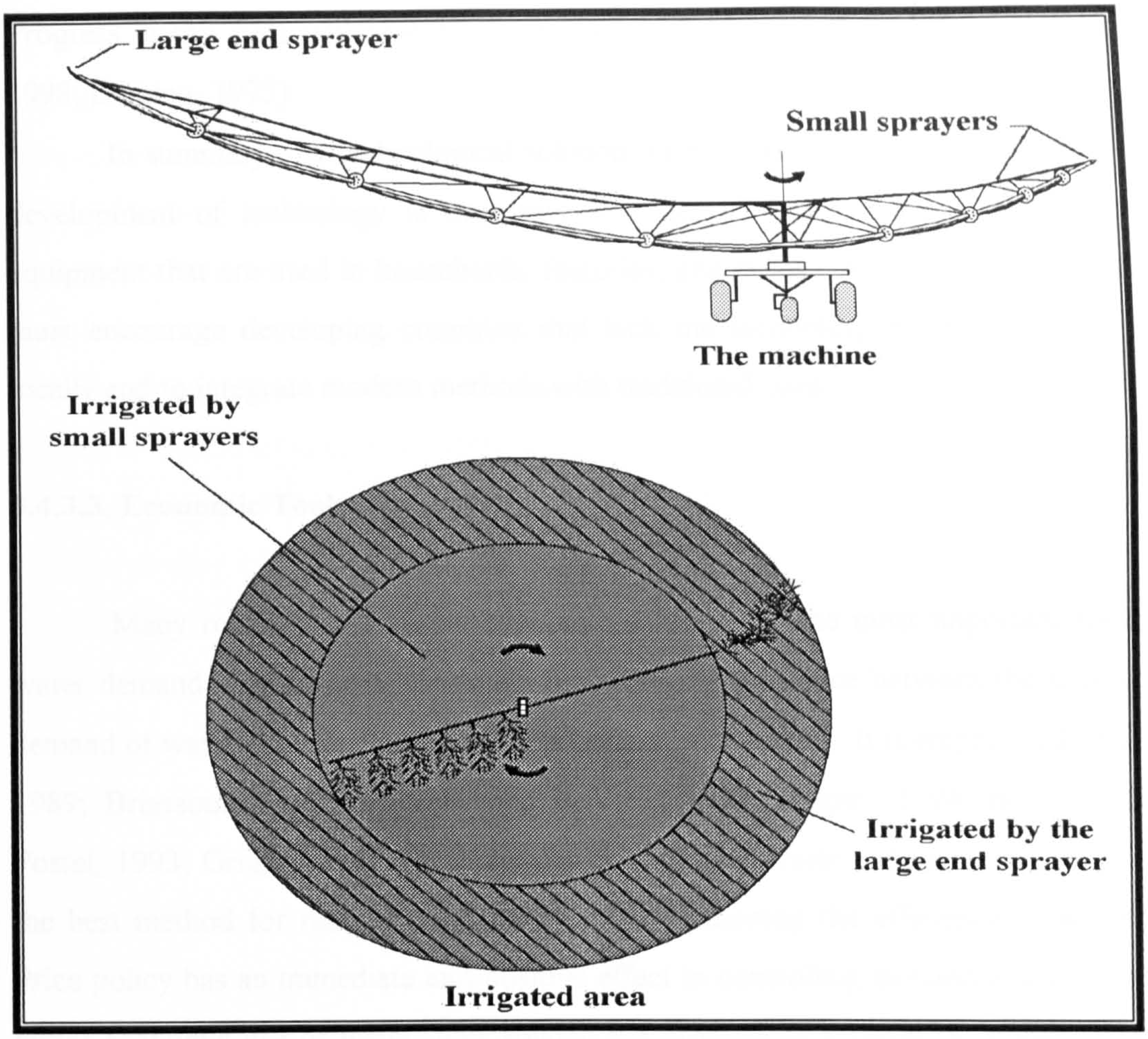

Figure 3.7. Boom-sprinkler Irrigation Technique (After Rolland, 1982).

Advancements made in genetic engineering have started to filter into the agricultural field, especially in producing plants that need very little water (Joumah and Abu al-Ainian, 1990; UNESCO, 1999). Some of the technology aims to find plants that have a short life span but high productivity, leading to a reduction of water need by 15% to 25%.

The use of modern irrigation technology will help to use water that is of medium to low quality and salty. The technological advancements made in finding new lineage of plants will increase crops ability to bear salty water. Thus it may be possible to use seawater or brackish groundwater in irrigation (Fang and Chen, 1997; Arar, 1997). There are many experiments aiming to reduce the effect of salty waters on soil fertility. Some experiments have indicated that the use of 2% of the remain of chicken farm fertilisers help reduce salinity by 30% (Mukemer and Hijazi, 1996). The use of Ammoniac Acids sprayed on plants helps increase their ability to bear salty water.

Progress in this field will save huge amounts of freshwater (Liu, 1997; Nasr Aldeen, 1998; Deming, 1975).

In summary, the technological solution on demands is at present essential. The development of technology is necessary in order to increase the efficiency of the equipment that are used in households, factories, and farms. Also, developed countries must encourage developing countries that lack the technology to develop their own locally and to integrate modern methods with traditional ones.

3.4.3.3. Economic Tools:

Many references focus on economic solutions as the most important tools for water demand management, especially for achieving a balance between the supply and demand of water, and for finding the appropriate price policy. It is emphasised (OECD, 1989; Briassoulis, 1994; ReVelle and ReVelle, 1981; Draper, 1994; Bouwer, 1993; Postel, 1993; Grigg, 1996) that increasing the value of water and increasing its price is the best method for reducing consumption and enhancing the efficiency of water use. Price policy has an immediate and positive effect in controlling demand and achieving a better economic use of water, thus solving the problem of a relatively stable supply of water and a demand that is increasing continuously. This naturally means that water use must be metered, or that the rate paid is in same other way linked to the scale of consumption.

The importance of conserving natural resources does not mean only protecting them from misuse, but also using them more economically. For that reason, the best way to achieve that is to make people pay rates that will make the user think about the resource and its conservation before consuming it. People will consider the conservation of their wealth and this will discourage, especially in water shortage areas, the spread of wasteful practices like garden irrigation (e.g. Winpenny, 1992; Clarke, 1993; Mukemer and Hijazi, 1996; Sulaiman, 1999; Hejab, 1999).

It is indicated (Rogers, 1987; Biswas, 1978; Grigg, 1992) that the economic solution - through using price policy - aims first at conserving water by reducing uneconomic uses of water and second to increase the amount of water produced, since the increase in price will encourage investment in costly sources. The pricing policy must be linked to the overall policy of water development as well as being flexible and able to change if necessary. Thus, it is argued this method can be effective in the management of water as well as encouraging consumers to behave in a more economical manner without adversely influencing the poor segments of society and regions.

The economic solution for the water problem is historically linked to shortages of water. It has become increasingly important at present due to unprecedented growth in demand for water by mankind, which has necessitated the adoption of high price policies. This, however, affects the distribution of water since not all regions and individuals are capable of shouldering such a policy. Consequently, it is important to take into account all social and economic considerations to achieve the success of the economic solution without adverse effects on equitable distribution (Whittington, 1992; TCWPP, 1992; Le *et al.*, 1992; Cairncross and Kinnear, 1991; Biswas *et al.*, 1997; al-Sofi, 1999; Abu Zeid, 1999).

Prices must reflect at least the cost of production and distribution. Such a policy is capable of reducing consumption and conserving water. At the same time it provides the funds for the development of water sources, besides being more equitable among consumers. It is not possible for the economic solution to succeed unless the rate paid for water is relatively equal to the cost, which is very high in most countries, especially for the agricultural sector. This includes the cost of developing water, pumping it as well as treating it, and the distribution networks (Martin and Kulakouski, 1991; Juhasz, 1989; James and Lee, 1971).

It is emphasised by Sadik and Barghouti (1997); Badauy (1999) that all social and economic conditions must be taken into account when appraising pricing policy and that the policy must aim at conserving demand and controlling consumption, and not at preventing people from getting the water they need. Also, the different situation of people must be considered, since sometimes poor people pay prices inappropriate to their income and standard of living.

The policy of distributing water without charging fees or charging a nominal fee (e.g. Kotoub and Abdulrab, 1995; Abdulrazzak, 1992; al-Mohannadi, 1997a) led to the use of this vital resource without any controls. al-Mugran (1992) doubts whether the individual in the Arabian Gulf, for example knows the real cost of water production and asserts that he only pays 5% to 15% of its real cost. The same applies to the agricultural sector where there are no controls on well drilling, which sometimes reaches 75% of the total amount consumed. Farmers do not know the value of this water and the effect of high consumption on groundwater, since they do not pay for it. At the same time, the state provides assistance in drilling equipment and in some cases the fuel. Thus, the perceived insignificance of water is rooted in these practices. In order to control consumption it is necessary to appraise pricing policies in a manner that reflects the importance and the value of water.

The pricing policy in some developing countries such as the Arabian Gulf states (Othman, 1999; al-Alawi and Abdulrazzak, 1994; al-Mugran, 1992; al-Mohannadi, 1997a) despite its variation, did not achieve its objective in controlling consumption. Prices are too low and do not reflect the real cost of water production on one hand and the high economic level in most of these countries on the other. People find it very easy to pay water rates and hence do not have any sense of the significance of water. It is necessary to change and develop this policy. For instance, people can be encouraged to reduce consumption if rates are kept low for those that consume small quantities, while higher rates are imposed on those that use more, as well as a strict policy for settling bills.

According to al-Yahiawi (1998); Biswas (1978); Shadi (1999), water has become a commodity just like other commodities, and its scarcity will increase its price making it unavailable to poor communities. The time when water was free is gone. Developing countries are following the footsteps of developed countries in the spread of private companies for producing and marketing water and making profit. Some developing countries, that are cautious about providing water at rates comparable with the living standards of users, are coming under pressure from developed countries to privatise their facilities. This will benefit companies from the developed world, who compete with local companies for these private contracts.

In summary, the economic solution, which is based on pricing water as an economic commodity, is one of the important tools of water management which can be used to reduce and control consumption. But also there has to be consideration for socio-economic conditions in order to achieve equity. Pricing policy must be based on standards of livelihood. There are many people in the developing countries who can not pay high rates. Another factor that has to be considered is geographical differences. It is not easily acceptable for someone living in an area that produces water at low costs to pay similar rates to the one who lives in far away areas that need long distribution networks. Pricing policy must be flexible and dynamic, capable of conserving the resource and controlling consumption, simultaneously covering the cost of production. Lastly the policy must take into account local and regional conditions within the country.

3.4.3.4. Legislation:

It is emphasised by al-Mugran (1992); Hassan (1995); Patrick (1994); Mingay (1990) that neglect of water demand management led to the misuse and depletion of water. Without strict application of punishment for the misuse of water, people consider water an inalienable right, and to behave as they wishes. Thus the attention of legislators to water management might lead to laws and directives that help in to control demand.

Hames (1996); Daudi and Heimlich (1996); Platt (1995); Muttamara and Sales (1994); Brown *et al.* (1996); Postel (1992); McDonald and Kay (1988) emphasise that strict laws and directives will make the individual think before using water. They emphasise the importance of water legislation to regulate the relationship between consumers and water resources. Thus, legislation is one of the main tools, which maintains water resources from irresponsible depletion. What is important is not the abundance of laws, but their implementation and rigorous enforcement.

According to Zubari *et al.* (1993); Shatanawi and al-Jayousi (1995); Uys (1992); Biswas (1978); al-Alawi and Abdulrazzak (1994); Hejab (1999) the lack of application of laws, especially in developing countries, led to the ineffectiveness of water policies, since without implementing laws, the policies are rendered ineffective. There is an urgent need for strong political decision to support water laws in order to reap their benefits. For instance, strict legislation according to Abu Hggag (1981) is a necessity to control agricultural demand. The lack of such laws led farmers act negligently, for instance pumping all day when a farm only needed 5 hours. To stop such practices a strict regulation regime and monitoring is necessary because the law conflicts with the operation of market forces point out problems for personal freedom-would need a police state to enforce it (Mamo, 1997). On the other hand, it is unpopular solution to government because this action may lead to political cost (Allan, 1994).

Laws must be easily applicable and acceptable to the public. It is recommended by Naff (1994); Mamo (1997) that countries exchange experience in this field and that specialised international institutions help countries to improve and activate their laws and help in co-ordinating the exchange of information and experts.

It is emphasised by Rogers (1987); Rosegrant (1995); Low and Balamurugan (1991); al-Kuwari (1996) that decision-makers can introduce change through enacting laws, but that process is not easy. According to Rogers (1987) "it may be a strength of the system that once legislation is passed it is very difficult to reverse the process, but in settings where the original for the legislation has changed, this is a major weakness". An example is the Clean Water Act in the USA in the early seventies. The law was passed, but upon application it became clear that many issues referred to in the law were difficult to deal with.

In summary, laws must be adapted to local conditions and must stem from society to be successful. Hence decision-makers must convince people of the reasons behind new laws. At their worst, new laws are imposed on vulnerable segments of society only; equity must be achieved by not allowing powerful forces or interest groups in the society to make these laws ineffective.

3.4.3.5. Decision-making:

The prospect of this happening on an international level depends on the issuing of guidelines by international institutions and international agreements about controlling water demand. Such guidelines might include a call for states to adopt a water policy for the management of water resources or the establishment of special programmes to improve water efficiency (Fernie, 1985; Clarke, 1993; Berkoff, 1994).

The UN organisations encourage countries to make plans and policies for water use. Such calls are not obligatory, but depends on influencing local decision-making, which is expressed through laws and directives (Goodman and Edwards, 1992; Majeed, 1993; Biswas, 1978; Clarke, 1993; Berkoff, 1994; Brown *et al.*, 1996).

Decision-makers can impose or increase water rates or ration water, for instance restricting water to consumers to certain times or days. These measures help to save water and preventing activities that cause over use of water but are unpopular. It is indicated by Allan (1994); Allan (1995) that decision-makers in the developing countries, including the Arab countries, have neglected water programmes and focused on the micro level rather than the macro one, especially concerning the efficient use of water. Most policies adopted by decision-makers are rejected by the public, while other urgent matters are left without solutions. Powerful forces in society can exert pressure on decision-makers to negate such important decisions.

Changing the behaviour of consumers requires massive effort and perseverance. The success of decision-makers is linked (Salanes, 1992; Berkoff, 1994; Mather, 1984; al-Yahiawi, 1998; Abu Zeid, 1998; Hejab, 1999; al-Saqar, 1999) to appropriate laws and directives. Thus these laws must be in accordance with the overall legal framework, in addition to the religious, social, cultural, environmental and other considerations prevalent in the society. Also important are estimates of future demand, the cost of production and distribution, and the overall government water policy.

Decision-makers (Winpenny, 1994; Abu Hggag, 1981; Judah, 1994; Grigg, 1996) have the potential to manage water issues effectively, especially when the user they are attempting to regulate is not a powerful force in society. For instance, they can cut water to consumers or shift consumption from one use to another - shifting water from agriculture to household consumption. They also have the tools to put pressure on consumers to change their water consumption behaviour especially during shortage seasons. Despite the relative effectiveness of these means, they still need the co-operation of society to make them totally successful, and that depends on the extent of people's understanding of water issues.

In summary, decision-making is some of the most difficult tools of water management to apply, since they must take into account the prevalent views and customs of society to ensure people's acceptance to ensure success during implementation.

3.4.3.6. Social Measures:

Introduction:

Social measures are considered some of the most difficult in water management (Smith, 1974; Filho, 1985) but are essential in a sustainability approach. Developing countries can import or develop technology, find funds to cover the costs of production and distribution of water, make public policies, enact laws, issue directives and impose them on society by force (Figure 3.8). These measures can quickly provide the required expertise and structures for a water industry. However, work in the social field, changing people to be economical consumers of water and especially influencing their behaviour is thought to be extremely slow and difficult (al-Mugran, 1992). Costs can be high and there are no guarantees of success. Consequently, it is a solution that requires patience, wisdom and knowledge of social conditions and traditions. It is argued that social policies must stem from the local society, its customs and traditions if success is to be achieved (Winpenny, 1994; Shah, 1991; Vedeld, 1992; Othman, 1999). On the other hand, without change in behaviour, all the other ways of addressing water issues are unsustainable. People have to be encouraged to think and behave in sustainable ways (Ekmekci and Gunay, 1997; Hames, 1996; Jellali and Jebali, 1994).

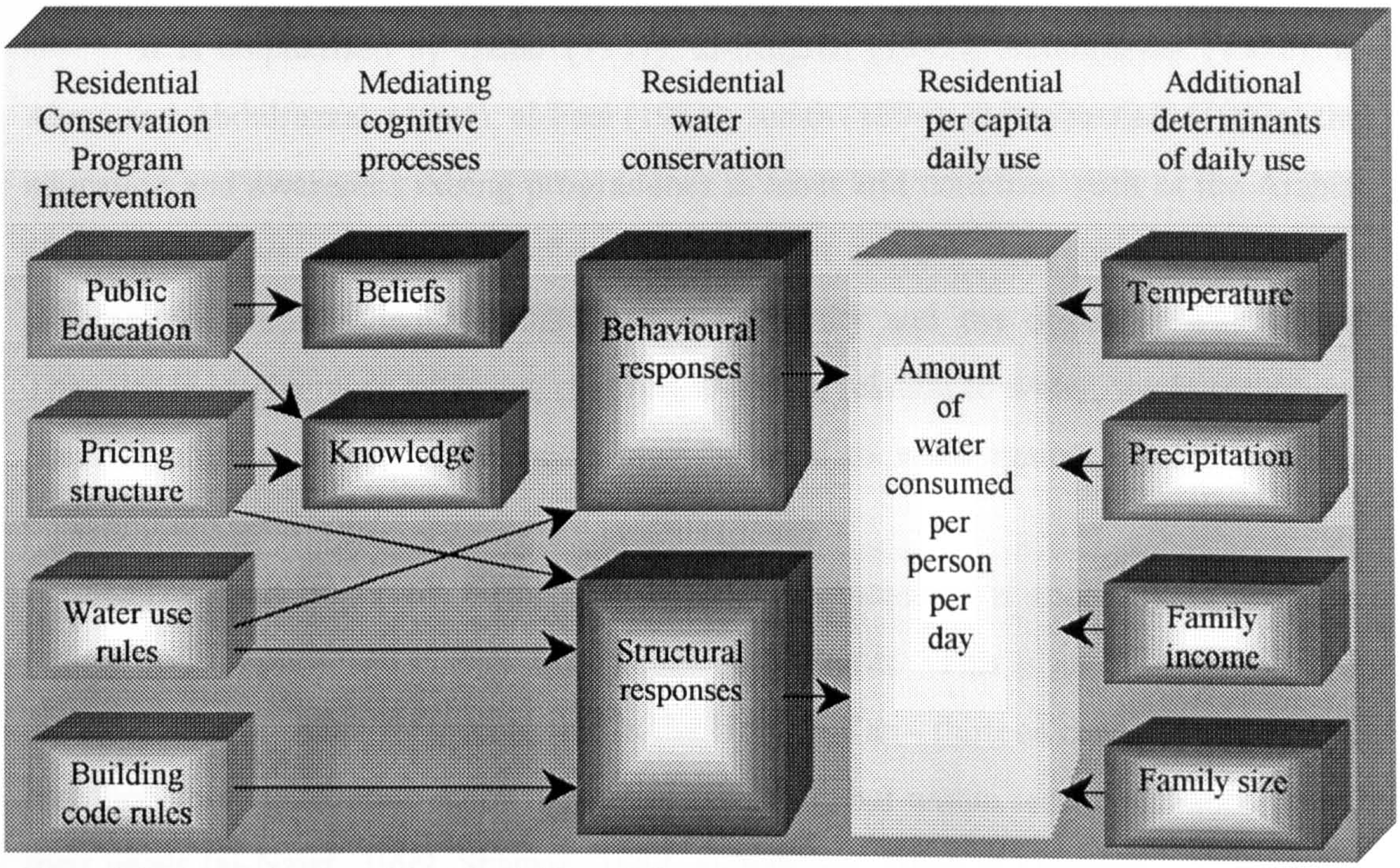

Figure 3.8. Determination of Residential Water Conservation (After Grigg, 1996).

For instance the introduction of new technology might increase or decrease water consumption. In the many areas utilisation of new technology resulted in an increase of demand. Changes also in standard of living usually increase demand. The presence of more than one lavatory in houses has become very common as well as daily baths, while washing machines, swimming pools, gardens are on the increase in both arid and rainy areas. Knowledge of these changes is essential in order to be able to choose the right method to control change and redirect it so water demand decreases rather than increases (Sewell and Bower, 1968; Shelef, 1991; Fittschen and Niemczynowicz, 1997; OECD, 1989; Cryer, 1995).

The necessity to consider education as part of the structure of water management is emphasised by Winpenny (1994). Raising people's awareness must not focus only on education and giving advice but must include convincing people. Other administrative tools will not be successful if isolated from the issue of people's awareness. He gives an example of what happened in the dry city of Tucson in southern United States. Water fees were used as the method to overcome a water deficit, but unsuccessfully, because of lack of programmes for raising the awareness of people and for convincing them of the necessity of the action taken.

It is emphasised by Bahar (1997); al-Mugran (1992); Abdulrazzak (1992); al-Alawi and Abdulrazzak (1994); al-Feel (1981); Judah (1994); al-Mohannadi (1997a) that education and awareness raising programmes in most arid countries such as the Arabian Gulf states have not been beneficial and did not achieve their objectives. These programmes were inadequate, they lacked continuity and the coverage was limited. They needed to be more extensive covering all issues relating to water, water conditions, costs of production etc. The media must be used to warn against certain unwanted consumption behaviour.

The most important element amongst social measures is encouraging people to reduce consumption and change their behaviour patterns. This is an old issue between man and nature. Allah referred to that in the Holy Qur'an - thirteen centuries ago - when he called upon mankind to enjoy their food and drink, but within reason and according to their needs (al-Najar, 1999; Shamah, 1988; al-Nabhani, 1990; al-Qarrdauy, 1995; Zidan, 1987).

" ...And eat and drink and do not cross the limit. Undoubtedly, the persons crossing the limit are not liked by Him" (Qur'an, 7:31).

As mentioned in Section 3.4.3.5, popular participation in the management of supply and permitting people to express their opinions is encouraged by some governments and is critical for sustainability. Different social groups can be participate to minimise water consumption (Table 3.12).

Table 3.12. Some Social Groups that can Participate in Water Management to Encourage the Public to Reduce their Consumption.

Group (Example)	Method (Example)	Author (Example)
Religious leaders	Can be encouraged to exhort their congregation to act responsibly with water and other resources	Filho (1995)
Celebrities	Can be used to give good examples of water conservation and responsible behaviour, and social opprobrium leaped upon the irresponsible	Geisler *et al.* (1994)
Architects	Can be encouraged to consider water conservation, perhaps by the annual award of a prestigious prize for a "water friendly" house	al-Feel (1981)
Planners	Must be instructed to refuse planning permission for developments, which do not involve water conservation	Doerksen and Pierce (1976)
People	Should be encouraged to feel ownership of the water resources of the country through consultation of elected representation of lay people onto water management bodies	Geisler *et al.* (1994); Willeke (1976)
Fee payers	Fees for water use will encourage responsible use, especially if there is strict but equitable enforcement and high-profile penalties for those who attempt to circumvent the rules. Well-publicised prize for those who use very little water may also encourage people to behave responsibly	Simpson (1994); al-Feel (1981)

In order to protect natural resources from depletion, new generations must be brought up well educated about the protection of nature and not necessarily through formal education, informal education can be beneficial. Messages about water conservation (as part of general messages about environmental sustainability) should be built into all aspects of the curriculum (e.g. Smyth, 1997; Wilson, 1996; Holl *et al.*, 1995; House, 1996).

Four social elements are indicated important in changing people behaviour and increasing their understanding of the significance of water. These are decision-makers, women, farmers and the young. Raising the level of awareness of decision-makers will influence their final decisions and increase their appreciation of the importance of water and the need to put it on top of their list of priorities. Women have great influence on domestic consumption especially in most developing countries. It is possible to raise their awareness by providing information to women's association, women's magazines, seminars, setting special women's associations concerned with water and lastly by providing information to state schools. Women have a big role in disseminating information with the family (e.g. Filho, 1995; Pre, 1997; Sangodyin, 1993; Foster *et al.*, 1998; Othman, 1999).

According to al-Ibrahim (1991); Lopes and Meyer (1993); Brough (1991); Kromm and White (1991), in most countries, farmers are the biggest consumers of water, hence it is vital to organise special awareness programmes for workers in the sector, including seminars, instruction about the best means of utilising water efficiently. Dissemination can be through the media, as well as field visits to farms. Water conservation should be a major curriculum item in courses dealing with industry, agriculture, architecture and town planning.

Entertainment programmes and entertaining literature can be used to convey serious information in a light-hearted way ("infotainment") (Todesq, 1991; Gooch, 1994; Ahmad and el-Hassan, 1995; Pescod, 1990). The popular soap opera "the Archers" has been used by the British Government to influence farmer's behaviour since the Second World War, and similar programmes have been widely adapted world-wide.

Abu Hggag (1981) considers the media the most important tool to raise awareness about water and to control wastefulness in its uses. al-Mugran (1992); Pescod (1990) calls for intensification of broadcasting programmes, to continue for long periods nationally. Advertisements in newspapers, on the radio and on television can inform people about the perils of wasteful use and encourage good behaviour. Documentary programmes and semi-learned articles can inform people in grater depth and enable them to reason better ways of behaviour.

Such efforts - Field visits, educational programmes, television and radio broadcasts, workshops etc. - for raising the awareness of the public, as consumers, of water issues needs government and popular support in order to be successful and not to be halted during implementation. For instance, a million dollars have been pledged in Saudi Arabia in order to raise the awareness of the public about water in the coming five years (Othman, 1999; al-Ibrahim, 1991). Although the amount is relatively very small, many developing countries can not pledge similar amounts. Politicians in these countries are concerned with more pressing matters and will not see such expenditure as necessary. Hence, developed countries must assist, not by exporting ready-made programmes and ideas, but through covering the cost of local programmes. The preparation of awareness raising programmes must precede any other effort, because without it efforts are destined to fail. Special budgets and plans must be adopted over many years in order to guarantee continuity and success to these programmes (Assaad *et al.*, 1994; Ervin, 1993; Wolf and Mohood, 1997).

3.5. Institutional Frameworks for Water Management:

3.5.1. Introduction

State management of water is one of a number of possible models which can be adopted - others being management by an independent but state - run organisation and management by private companies organisations (Sewell *et al.*, 1985; Winpenny, 1994; Bakour and Kolars, 1994). State management is the model currently prevalent in Qatar and is likely to continue, in some form, for some time, given the value of the society and its level of institutional development (al-Kuwari, 1996; al-Mugran, 1992). Water management regimes globally are exceedingly varied. In general, highly regulated, tightly controlled systems are characteristic of places where water is scarce, where as in places were water is easily to obtain laissez-faire systems are prevalent (Agnew and Anderson, 1992).

The development of water resources has shifted from the sphere of the individual to specialised administrations and specialised institutions overseeing the operation that have serious consequences on society (Sewell *et al.*, 1985; Ghooprasert, 1990). Administration is the overall frame that includes all the elements of water management (Figure 3.3). Administrators gain the approval of politicians, determine the effects of water projects on the environment, secure funds for projects, determine the technology to be used and determine people's acceptance for these projects (ODCE, 1989; Mitchell, 1990; Grigg, 1996).

3.5.2. Institutional Frameworks:

Water administration, according to Helmer and Hespanhol (1997); Giannias and Lekakis (1997); Mohorjy and Grigg (1995), is defined as a special type of administration that includes a group of people that have similar specialisation. It may be a public institution with a separate budget and staff, such as the water administrations in the various ministries or the administration for environment protection or a non-governmental institutions.

According to Biswas (1990); James and Lee (1971) for water development plans to be successful a large number of people many be involved. It is necessary to organise their work through a management structure. There are four types of organisations:

- According to the geographical location they serve.
- According to the functions they carry.
- According to the group they serve.
- According to the expertise required.

According to the OECD (1977), every country needs three levels of water administrations:

- Central government.
- Regional.
- Local.

According to Muckleston (1990); Sewell *et al.* (1985) the state can organise institutions for water management in different ways. Often, because of historical accident, they are complex and sometimes rather inefficient. In some cases, state and private - sector institutions work in partnership. A broad hierarchy of organisation is apparent. Table 3.13 shows some water administrations characters.

Table 3.13. Some Water Organisations Character.

Organisation Character	Country (Example)	Authors (Example)	Advantages (Example)	Disadvantages (Example)
Central Government control and implementation of water management through a national body	Hong Kong	Holmes (1996); Chau (1993)	1- Centralised decision-making	1- Problems of nationalised industry 2- Excessive bureaucracy 3- Remoteness from people
Central Government control and implementation of water management through a series of regional organisations	The UK (England & Wales) water industry until the 1990s (Figure 3.9)	Parker and Penning-Rowsell (1980); Porter (1978); Mitchell (1971); Pitkethly (1990)	1- Centralised control and planning 2- Low Tariff	1- Lack of accountability 2- Lack of co-operative 3- Lack of consumers affect policy 4- Waste 5- Quality
Regional/local government control under supervision of a national authority	France (Figure 3.10)	Grigg (1996); Anon (1994); McDonald and Kay (1988); Drouet (1990); Buller (1996)	1- Restrict power 2- Supply, wastewater and pollution control 3- Public participation 4- Public and private partnership	1- Tariff 2- Services not cover all population
Multiple institutional management under government	Kuwait (Figure 3.11)	al-Mugran (1992); Abdulrazzak (1992)	1- Government financial support 2- Suitable tariff	1- Absence of co-ordination 2- Conflicts 3- Bureaucracy 4- Lack of public participation 5- Waste 6- Lack of tariffs affect 7- Quality
Multiple institutional management under government with water resources council	Oman (Figure 3.12)	al-Mugran (1992)	1- Co-ordination 2- Government financial support 3- Suitable tariff	1- Bureaucracy 2- Lack of public participation 3- Waste 4- Lack of tariffs affect 5- Quality
Management by private companies under state regulation	The UK (England & Wales) after 1990s (Figure 3.13)	Grigg (1996); Buller (1996)	1- Consumers affect policy 2- Quality 3- Services cover large percentage of population	1- High Tariff 2- Monopoly
Management by private companies in a lightly regulated regime	The USA	Muckleston (1990); Rogers (1993); Miller (1992)	1- Cover large water issues 2- Public participation	1- West 2- Absent of central authority 3- Conflicts 4- Boundaries problems 5- Paralysis of the policy process 6- Finance problems 7- Environment mismanagement

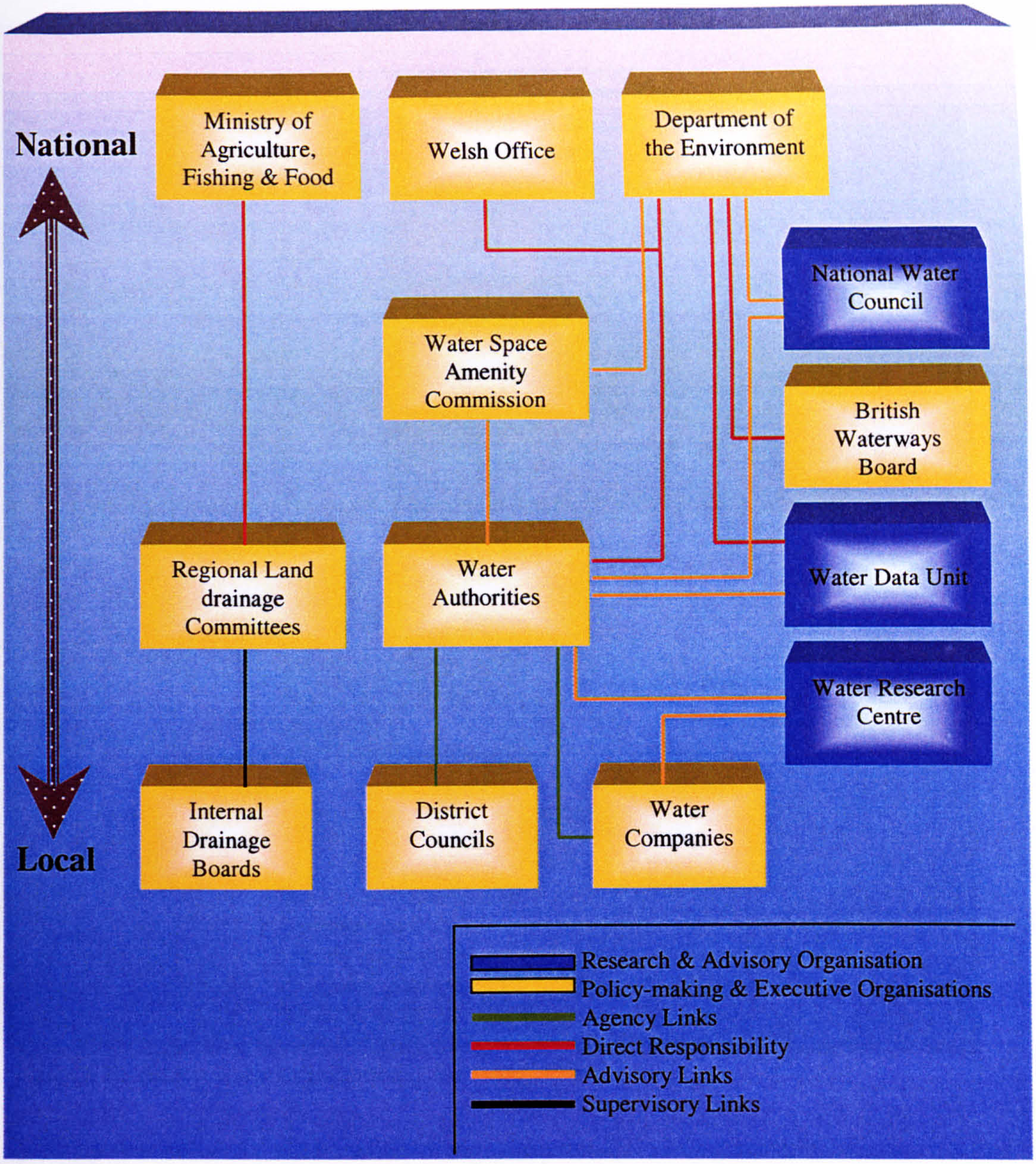

Figure 3.9. Water Organisations in England and Wales before the 1990s (Parker and Penning-Rowsell, 1980).

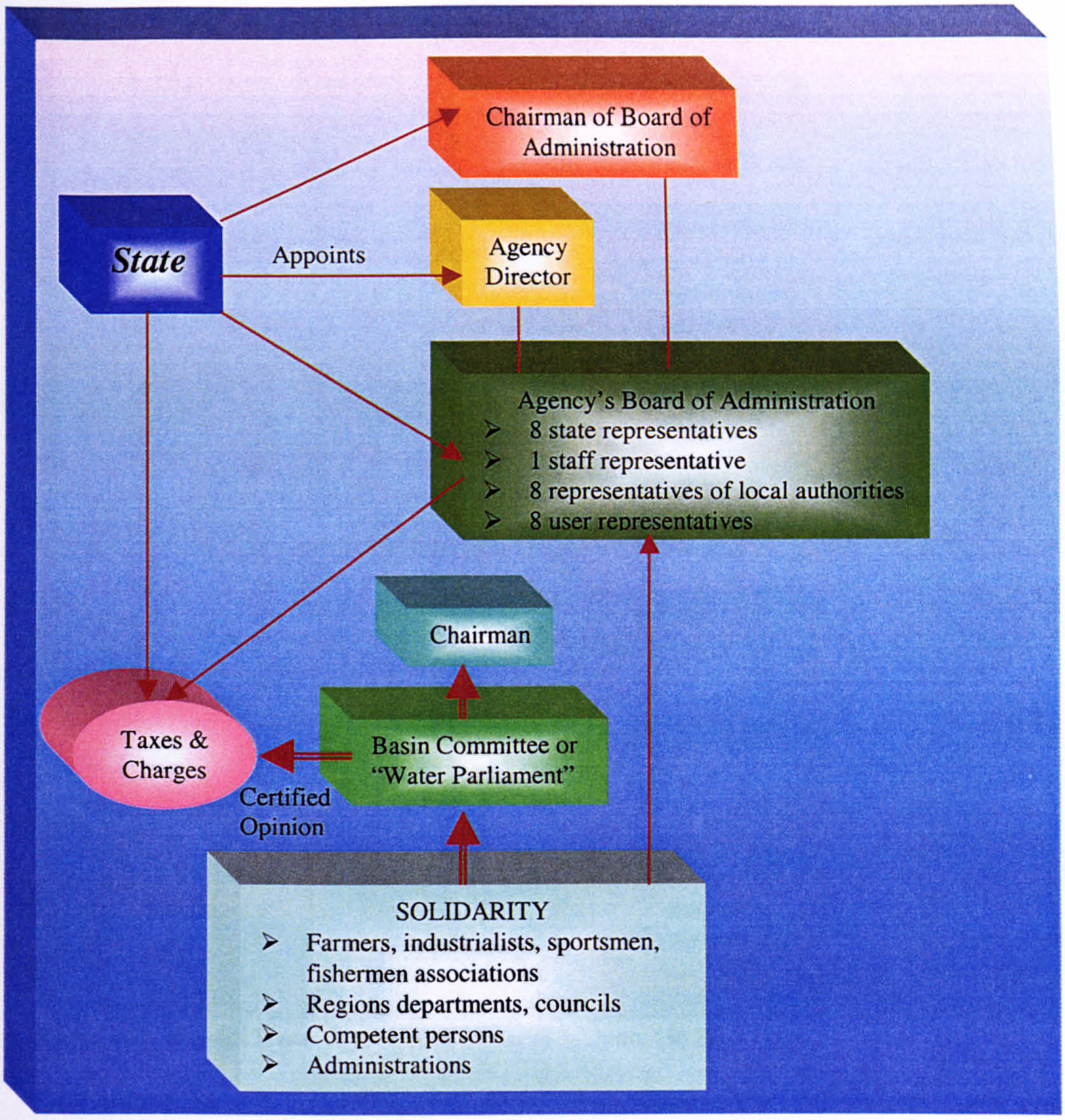

Figure 3.10. French Water Organisation (After Grigg, 1996).

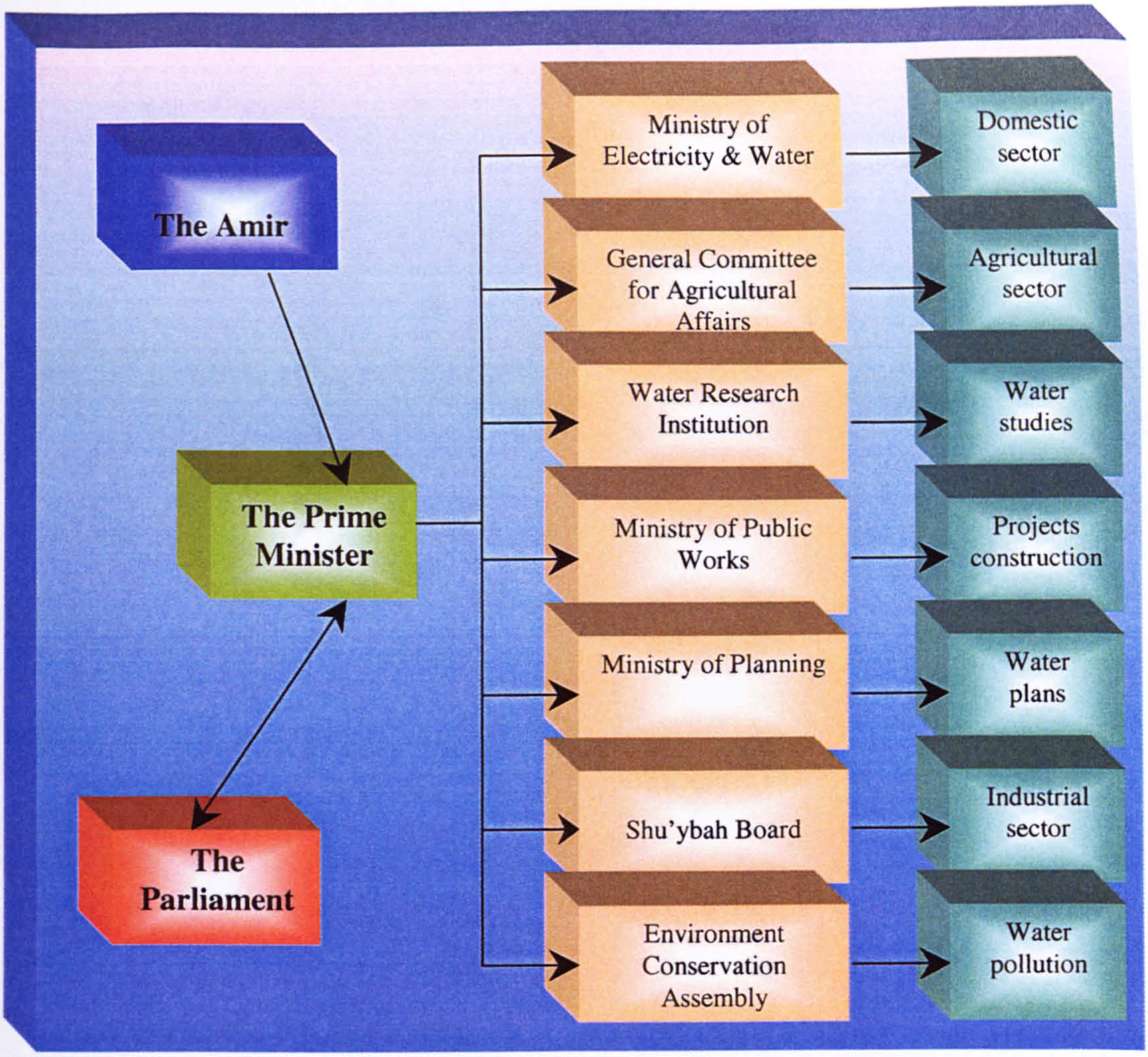

Figure 3.11. Kuwaiti Water Organisation (After al-Mugran, 1992).

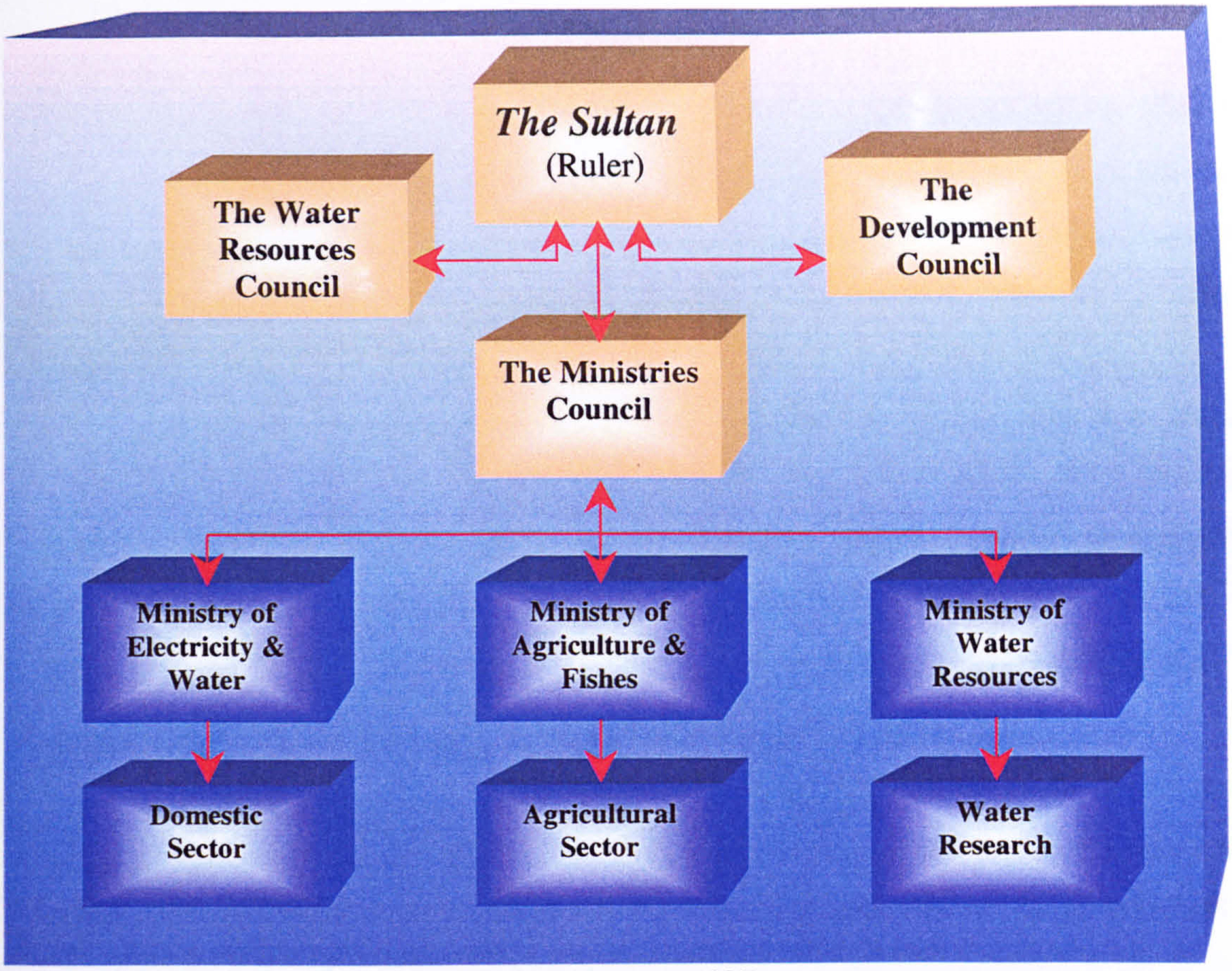

Figure 3.12. Omani Water Organisation (After al-Mugran, 1992).

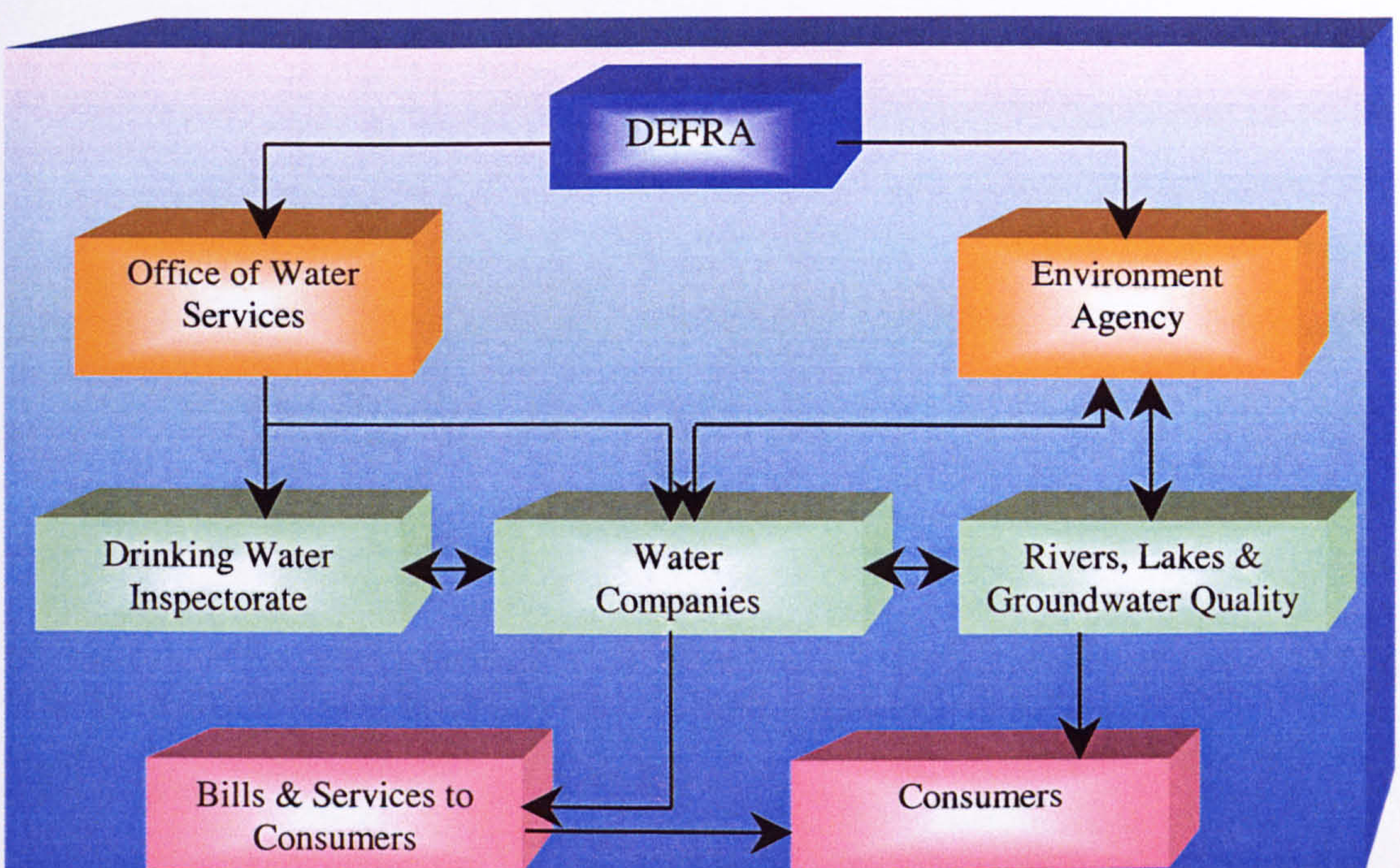

Figure 3.13. British Water Organisation in the early 1990s (After DEFRA, 2001).

It should be noted that once management of the water issue is divided between a number of regional or single - function organisations, overall control and co-ordination is extremely difficult to achieve. Although single - function organisations may be efficient at carrying out their task, and regional organisations may be responsible to local needs, it is probable that conflict between organisations will cause significant problems unless there is extremely strong overall co-ordination (Mitchell, 1990; Muckleston, 1990; Rogers, 1993).

An administration concerned with the management of resources (e.g. Grigg, 1996; Quick, 1995; Helmer and Hespanhol, 1997; Giannias and Lekakis, 1997; Mohorjy and Grigg, 1995), must identify the problems caused by demand and ways to overcome them, must subsequently enact directives to implement solutions and must continue to monitor and respond to changing circumstances. It must provide the qualified staff to operate the programmes, and the budget for these programmes.

The traditional understanding of water management, as indicated by Sewell *et al.* (1985) which included specialists in the fields of engineering, chemistry and biology and to lesser degree specialists in law must change to create a team that includes specialists in economics, sociology and geography. The progress and development of society necessitates giving attention to both social and applied sciences in order to find comprehensive solutions and to create comprehensive administration structures. The importance of taking care of water management is highlighted (e.g. Rogers, 1987; Delage and Tiret, 1990; Davis *et al.*, 1993; Masschelein, 1992b; Judah, 1994; Berkoff, 1994), because it is the tool for implementing the directives and instructions of decision-makers. The size of these administrations must correspond to the size of the problems they face, they must have the qualified staff to be able to implement laws and directives and they must be able to understand natural, social and legal changes and be able to prepare the appropriate plan.

3.5.3. Operational Procedures:

The operational procedures of an organisation are the internal (and some times external) rules and regulations, which govern the ways in which its personnel can act (Table 3.14).

Table 3.14. The Six Major Functions of Water Management (Grigg,1996).

The Functions of Water Management
The identification of the problems and solutions.
The stipulation of rules and regulations.
The development of programmes according to the rules and regulations.
The provision of funds and staff to run these programmes.
The supervision and the execution of the programmes.
The development of rules for the monitoring of implementation of programmes and the necessary revision of rules and regulations.

The water management system (Figure 3.3) must address three issues using the structure about - production (supply), quality and demand (OECD, 1989; Abu Samur and al-Khatib, 1999; Turan, 1996; Brimberg *et al.*, 1993). Most systems globally - and most of the literature - concentrate on the former two, and this is a significant weakness.

3.5.4. Management of Production:

In most water administrations, management is aimed to maximise production. It must be pointed out that this is not necessarily a policy conducive to sustainability (Gao, 1997; Abdulrazzak, 1995).

Development of water resources is essentially driven either by actual demand - by consumers (private citizens, companies or state institutions) who require more water - or by estimated future demand. Future demand is often estimated by extrapolation from the growth of consumption in the past and often embodies unreasonable assumptions about population growth and rates of industrial development (OECD, 1989; Sewell and Bower, 1968). Thus, in the UK, Kielder Water Reservoir was built to supply heavy industry in the North East of England a region that had succumbed to the recession of the 1980s (Pitkethly, 1990).

Following the identification of demand, feasibility studies will be commissioned to explore options for developing new water supplies. This may be done by "in - house" technical staff of by outside contractors (Jones, 1997; Mukemer and Hijazi, 1996; Rogers, 1993; Mather, 1984). Once a potential permission resource is identified, political approval must be obtained, funds must be raised, through taxation, borrowing and current revenue will normally be extremely complex, with the development of the resource, links to the water distribution scheme, purification plants etc. (Sadik and Barghouti, 1994; Lado, 1997; Briscoe and Garn, 1995).

Alternatively, licences may be allocated to the private sector to develop a water resource (Grigg, 1996). In some very undevelopment countries, water resource development is usually done by NGOs funded by charities undeveloped via the international community (Mancy, 1993; Sadik and Barghouti, 1994). For example, there is possibility to establishing a Regional Development Bank will enhance the prospects of investing billions of dollars in water development in the Middle East (Bartholet, 1994).

3.5.5. Management of Quality:

Management of Quality is essential for public health. Potential conflicts of interest occur if the body monitoring quality is part of the system, which supplies the water. In this case, the water supply system is often unresponsible to the customer's concerns about quality. An independent regulatory body can address these concerns, providing it can operate within a strong legal framework and can enforce its judgement (e.g. Rogers, 1993; Whipple, 1996; Brunnee, 1995; Mamo, 1997; Hames, 1996).

3.5.6. Management of Demand:

Management of demand is often neglected by water administrations, but is essential in area where water is scare (Gao, 1997; Abu Samur and al-Khatib, 1999; Winpenny, 1994). Demand management has neglected knowledge of production and quality management in many places.

The functions of the water administration (Figure 3.14) control the uses of water is carried out by regulation. The importance of regulation is emphasised (James and Lee, 1971; Leopold, 1990; Arreguin *et al.*, 1996; Winpenny, 1994) are identified as follows: the control of supply, the control of consumption (conservation), control of pollution and control of the different uses of water. Controlling pollution, whether direct or indirect uses similar tools - licenses or prohibition. Controlling consumption requires the use of tools such as licenses or metering, priority rights, especially in sectors that have high level of consumption such as agriculture.

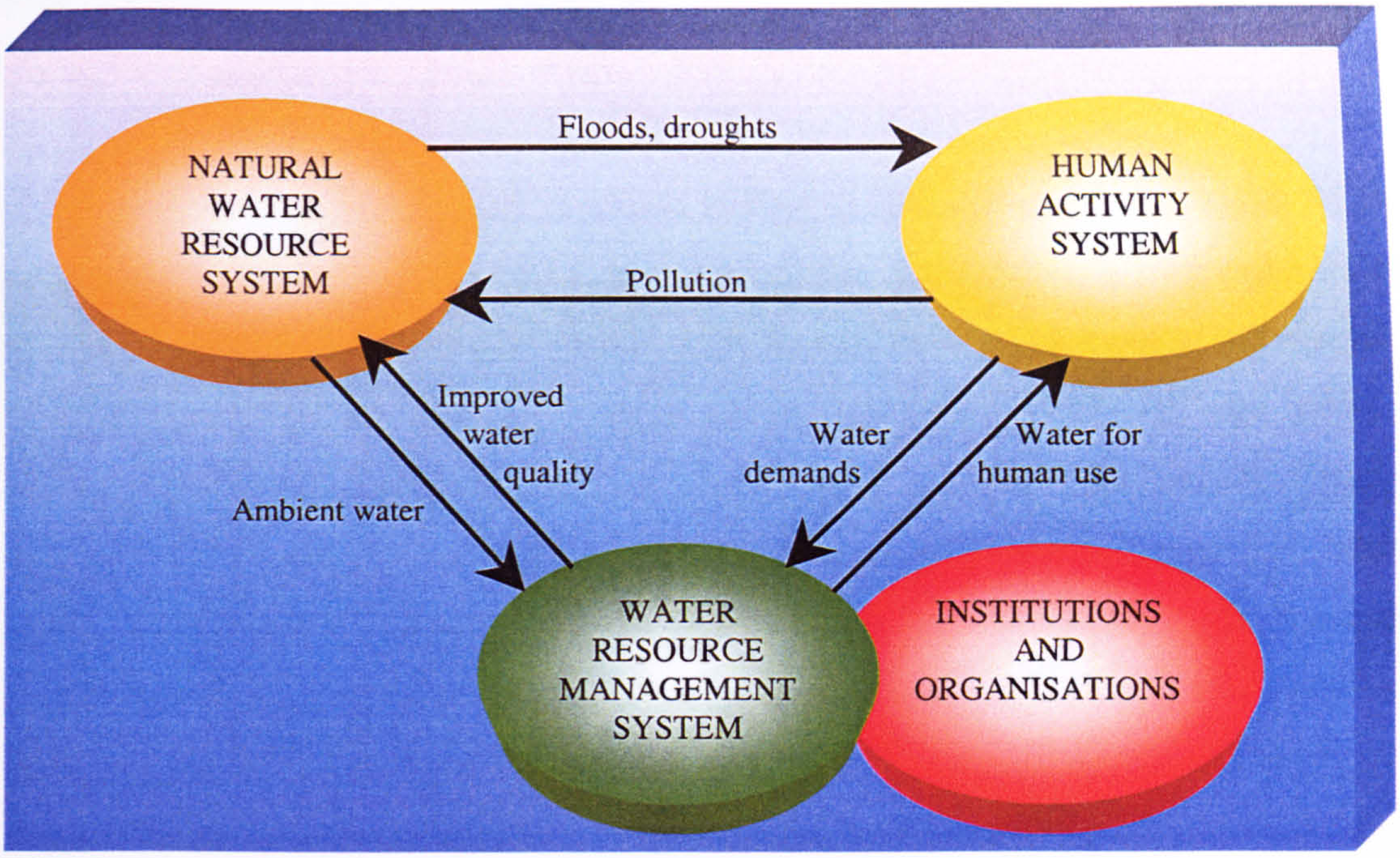

Figure 3.14. The Framework for Institution an Organisation Water Resources Management (After Jones, 1997).

Biswas *et al.* (1997); Brown *et al.* (1996) identify the tools that can control consumption, especially in developing countries where population growth is the main reason behind the increase in water demand in the municipal sector. This problem is very difficult and slow to solve because it is rooted in society and has religious, historical and economic dimensions, not easily contained. A second strategy is to determine the amounts consumed, so it is possible to identify those that are wasting water and those who are using it efficiently. A third strategy - sustainability - concerns raising the awareness of people, which requires knowledge of local conditions so they can address particular problems. A fourth strategy is charging appropriate fees to cover costs and also limit demand. All these require qualified staff and a budget.

3.6. Issues in the Development of Policy for Water Management:

3.6.1. Introduction:

Water is a critical resource in arid countries (Winpenny, 1994; Jones, 1997; Allan, 1992). Policy must be developed to guide the development and management of the water resource. Within the policy framework, institutions can develop and operate. A policy framework must take account of the environmental, social and political conditions of the country concerned (Kuylenstierna *et al.*, 1997; Warford and Partow, 1990). It must address the needs of the stakeholders concerned - the political, water industry professionals, industrial consumers, agricultural consumers and domestic consumers. A suitable policy framework will enable problems to be addressed early and thus worked around or avoided (OECD, 1989; Mitchell, 1990; Sewell *et al.*, 1985). In the following section, some of these issues are explored in depth.

3.6.2. Politics and Decision-making:

In some countries, water is a political issue. From among the most prominent of conflicts is the Arab-Israeli dispute over the river Jordan. The river Jordan basin, according to Mejcher, 1996; Naff, 1994; Beaumont, 1993; Abdulrahman, 1999; Abdulwahab, 1999b, is shared by Israel and three other Arab countries. The problem has risen when the State of Israel was created in 1948. When the Arabs tried to divert the waters of the river Jordan and deprive Israel of its waters, the 1967 war erupted.

Another example is the dispute over the river Nile, which flows in nine African countries. The nature of the river and its flow in dry areas necessitated the construction of dams and reservoirs (Newson, 1992; Abu Zeid, 1990; Flint, 1995; Abu Atta *et al.*, 1985). Egypt and Sudan signed an agreement in 1959, which gave Egypt 55.5 bm^3 and Sudan 18.5 bm^3. But the dispute extended to other countries especially Ethiopia - which was not party to the agreement -. It has attempted to utilise the part of the river that flows within it territory (Beaumont, 1993; Caponera, 1996; Rowley, 1993; Clarke, 1993; Abu Zeid, 1999).

In Kuwait, a refusal to pay water and electricity rates by the large group of consumer led to a change in Government policy (Anon, 1998c; al-Shamari, 1998; Salem, 2001).

A number of forces, political, economic, social, and in the Arabic Countries, religious, drive or affect water policy (Biswas *et al.*, 1997; Allan, 1992). In state - run water industries, poor performance, manifested by rationing or the appearance of water - borne diseases, or high water rates, can cause the public to become unhappy with the politicians who run the system (Rogers, 1993; Bultena, 1974; Fordham, 1992). One of the factors leading to the privatisation of the British water industry was the unpopularity of politicians who seemed unable to deliver an adequate service (Cryer, 1995; Richardson *et al.*, 1992; Schofield and Shaoul, 1997). By privatising the industry, politicians could claim they were no longer responsible for any problems (Buck *et al.*, 1996; Tanzi and Schukncht, 1996).

Socio-economic forces can also guide policy development. A supply of good - quality water is essential for the development of industries such as food and beverages (Rogers, 1993; Gray, 1994). The development of water resources is thus necessary to underpin economic development. Historically, in some countries (e.g. UK), water resource development was drive by industrial development, particularly of mining, textiles, ferrous metallurgy and chemicals (Pitkethly, 1990; Parker and Penning-Rowsell, 1980). Rising standards of living, globally, also drive water resource development. At a basic level, there is a need for clean water supplies and sewage treatment. With increasing affluence, demand growth for water supply for shower, washing machine, garden irrigation and to forth (Rogers, 1993; Niemczynowicz, 1992; Abu Samur and al-Khatib, 1999; el-Ashry, 1991; Schliephake, 1992; Kandiah, 1999).

In the Arab World, religious imperatives are also important. There is a necessity for clean water to wash before prayers. According to the Holy Qur'an "*O you who believe, what rise to pray, wash your faces and your hands as far as the elbow, wipe your heads, and your feet to the ankle. If you are polluted, cleanse yourselves...*" (Qur'an, 5:6). Religious principle also guide the treatment and re-use of wastewater, which should not enter the human food chain (Abu Hggag, 1981; Diamant, 1985; Helmer and Hespanhol, 1997).

3.6.3. Policy Development:

Water policies differ from country to another related to their political, economic, social, cultural, environmental and technical situations (Long and Field, 1974).

In Libya, for example, the increase oil income derived from oil in 1970s increased the Government to establish a high cost water project to transfer between 2 to 3 bm^3a^{-1} from fossil groundwater in the southern desert to the northern cities (Allan, 1989; Salem, 1992; Abu al-Fatih, 1997). The Great Man-made River project was embarked upon with a first phase costing $23 billion (about 15% of the year's oil revenues earned in 1980), and the following phases cost at least four times this sum (Allan, 1994; Khalil, 1998). The Libyan Government devoted about 12% of GDP over a period of a decade to water projects in order to find a long-term solution. With the oscillation in the price of oil during the 1980s, the Libyan revenues declined to one-quarter of their 1980 levels. Therefore, the long-term policy of strategic investment in water security began to dominate the national economy and the construction schedule was extended to two decades rather than one (Allan, 1994).

Another example is Britain. Historically, water policy in Britain was developed in variety of ministries, principally the Ministry for the Environment and the Departments of Health and Trade and Industry. There was then faster development at regional level by the nationalised Water Authorities, in consultation (on occasions) with Local Government and large industries. Industrial consumers and those affected by aspects of water policy had little opportunity to affect policy (Pitkethly, 1990; Parker and Penning-Rowsell, 1980; Cryer, 1995). In some recent times, since privatisation, government policy may still originate in one of a number of ministries - Environment and the Regions, Health, Trade and Industry, which will act via the Water Industry Regulator or via the Environment Agency, as appropriate. These bodies will then issue directives to the Water Companies, who will then modify their policy (and consequently actions) accordingly. Water companies will also make their own policy initiatives, according to commercial and operational imperatives (Grigg, 1996; Richardson *et al.*, 1992; Schofield and Shaoul, 1997).

Agenda 21 - Principle 10 (Chatterjee and Finger, 1994; Boyle, 1995) suggests that for sustainability, the people themselves must become stakeholders and take part in policy formulation. This requires a radically different type of approach, which may require the re-engineering of society (Welford, 1996). This is dealt with more in the next section.

3.6.4. Stakeholders and Participation:

Stakeholders are all those involved in an enterprise, the owners, the people that work there, the suppliers, the customers and those who are affected by the actions and by - products of the enterprise in every way. In a nationalised industry, all citizens are stakeholders, but most are unable to participate in any way on decision-making (Bultena, 1974; Sewell *et al.*, 1985; Abu Samur and al-Khatib, 1999; Doerksen and Pierce, 1976). This leads to feelings of hostility and alienation, as seen, in extreme form, during the break - up of the old the USSR. Lack of participation leads to lack of engagement in the enterprise, and these workers and citizens not feeling responsible for its success. This in turn leads to low work - rates and shoddy work (al-Nabhani, 1990; Palei and Radzivanovich, 1990; Standing, 1991). Policy development in nationalised industries tends to be by politicians and by technical specialists or managers in the organisations and their imperatives will be largely internal to the organisation rather than external, to the customers and the citizen at large (Parker and Penning-Rowsell, 1980; Pimbert and Pretty, 1995; Allan, 1994).

In a private industry, the stakeholders are the owners, the people who work there, the suppliers and the customers and people affected by the actions of the industry. Only the owners and the consumers tend to have significant power in this relationship, and usually only the owners representatives and senior management have the ability to initiate policy development (Grigg, 1996; Barron and Rotherham, 1991; Tanzi and Schukncht, 1996). In the privatised British water industry, policy can be initiated by Government, through the Industry Regulator, or by the Regulator, or by the boards of Directors of the companies themselves (the Directors are responsible for upholding the interests of the consumers, and of the wider community (Pitkethly, 1990; Schofield and Shaoul, 1997; Buller, 1996; Richardson *et al.*, 1992). It is notable that many people are denied participation by this arrangement (OECD, 1989; Konig, 1996; Kavanic and Humber, 1995).

In many traditional societies, groups of citizens form organisations, in which they are stakeholders, to manage water resources. Participation in these organisations is usually equitable and often proportional to the investment of the individual (e.g. Crook, 1997; Najita, 1996). The sustainability approach (Chatterjee and Finger, 1994; Barrow, 1995; Carley and Christie, 2000) requires the re-creation of this type of organisation, with local groups of stakeholders taking responsibility for their actions.

3.6.5. Policy Practice:

3.6.5.1. Introduction:

Policy, once formulated, must be implemented. In sophisticated systems, monitoring should then be used to judge the action of the policy. In many organisations, policy is made but implementation is ineffective. This will not be discovered unless effective monitoring occurs (Simpson, 1994; el-Ashry, 1995). There are some general reasons for ineffective implementation of policy. All organisations have institutional inertia - the nature and structure if organisations and the people who work in them are all resistant to change. Many members of the wider population are also instinctively conservative and deeply resistant to the adoption of new practices (Yaffee, 1997; al-Alawi and Abdulrazzak, 1994).

3.6.5.2. Conflicts Between Organisations:

One particular reason for policy failure is conflict between agencies. When the policy of one agency impacts on the areas controlled by another, the resulting conflict can completely paralyse effective action (Rogers, 1993; Winpenny, 1994; Sewell *et al.*, 1985; Manring *et al.*, 1990; Jellali and Jebali; 1994).

The need for institutions is emphasised by Calvo, 1990; Burak *et al.*, 1994; OECD, 1977; Mitchell, 1990, they note that they must operate efficiently in preparing plans and implementing and following them up. Sometimes the large number of these institutions become an obstacle and hence they call for the establishment of an institution that co-ordinates between all the different institutions dealing with water development resources.

In the same context, the numerous institutions supervising the water sector is an unhealthy phenomenon. In developing countries such as the Arabian Gulf states there is more than one institution responsible for water distribution and development with very weak linkages between them, making this the most important obstacle facing the management and development of water in the Gulf. It is possible through common laws to co-ordinate the functions and specialisations of each management and suggests the establishment of one institution that supervises the rest, such as a water management board with a branch in each state. Such an institution should be equipped with the power to achieve co-ordination locally and regionally as well as the power to solve disputes among the various institutions (Abdulrazzak, 1992; al-Mugran, 1992).

This direction is supported by al-Mugran (1992) but he calls for the unification of all institutions and managements working in the water field. It is possible to keep some decentralised branches and sections to supervise the execution of projects locally as well as following up operations. The reduction of the number of institutions in the field has become one of the main aims of governments, as indicated by Bauer (1997); Sadik and Barghouti (1997). In Chile for example - which is considered one of the leading countries in the world in the field of economic policies - the number of institutions have been reduced to the minimum in its effort to create what is known as free market concerning water rights.

The importance of knowing the circumstances of a society is emphasised by Winpeeny (1994) as an important factor in forming these management structures as well as the integration of new ideas with old ones. In addition the variation in the work of these managements imposes on them the necessity of co-operation and co-ordination. It is pointed out by Rogers (1993) that what is required is not the formation of a big administrative structure but a small board with the needed powers will be enough to co-ordinate the work of all water management structures. Another problem discussed by al-Kuwari (1996) is the ease in which water administrations fall under the influence of powerful consumers in the society, hence impeding the work of these institutions and reducing fairness.

3.6.5.3. Conflicts with Consumers and "Neighbours":

Another reasons for policy failure is conflicts between the outcomes of a policy and the interests of consumers and other people affected by the policy such as the conflict between fisheries and hydropower development in Canada (OECD, 1989) or between Israeli water policy and Palestinian people (Biswas *et al.*, 1997; Abdelmageed, 1997; Abu Maylah, 1999; Bakri, 1999). In this use, protest action or non-co-operation can causes abandonment of policy (Abu Samur and al-Khatib, 1999; Cox, 1994; Geisler *et al.*, 1994; Grimble and Man, 1995; McKinney, 1988; Blahna and Yonts, 1989; Manring *et al.*, 1990).

In Qatar, for example, during 1950s, the Government tried to collect fees on governmental services including water. Water rates were set at \$0.084 gal^{-1}, but the citizens resisted and refused to pay, partly because they believed that water is owned by everyone and partly because of their limited economic situation in that time (al-Kuwari, 1996).

3.6.5.4. Administration Staff:

The necessity of preparing technical staff to work in water management is emphasised by Judah (1994); Zubari *et al.* (1993); Arar (1997). Most developing countries suffer from a lack of trained personnel in that administrations. There are few incentives for employees this is partly because investment, in programmes for personnel training and development is lacking. According to al-Mugran (1992); Abdulrazzak (1992); Zubari *et al.* (1993); Hamdan (1989) in some developing countries, such as Arabian Gulf states, local universities do not focus on providing the training needed to manage water resources. These countries therefore depend on foreign labour.

The existing education programmes are often old-fashioned. For the higher levels of management, training on negotiation and discussion skills, modern management methods is often lacking (Biswas, 1978; Seacrest and Herpel, 1997; Niemczynowicz, 1993; Okun, 1991; Lloyd and Helmer, 1991).

3.7. Overall Conclusion:

Chapter Two focused on water problem in arid countries. This chapter dealt with possible views (Islamic, social, economic, traditional, technical, environmental and sustainable), approaches (state, market, traditional, technical and sustainable) and supply and demand tools (economic, technological, decision-making, legislation and society). The role of the administration is the overall frame within which all solutions operate. Countries have given special attention to the creation of organisational structures that can carry the responsibility of water management. Despite this there are still, especially in developing countries, inefficiencies in water management where by specialisations are duplicated, responsibilities blurred and a lack of qualified personnel. Much policy developed today is not sustainable.

It is necessary to evolve clear policies to control water management. A variety of type of policy are available, but it must be stressed that not all policies can be applied successfully in any given environment or society. Clear lines of policy development and rigorous implementation and monitoring are necessary.

The success of a water strategy on a local, regional or international level requires paying attention to all aspects and not concentrating on one only. It is important to implement policy that stems from the local conditions in the society, so it can be accepted socially and its chances of success enhanced. The sustainability approach suggests that policy is best at gross-roots level. It is clear that like problems, effective solutions are often local - which will work in a developed country like the USA will not necessarily work in a developing country. Therefore, methods to establish the scale and nature of water problems in the research area - Qatar - will be considered in Chapter 4.

CHAPTER FOUR:

RESEARCH METHODOLOGY

Research Methodology

4.1. Introduction:

The overall aim of this thesis is to design a new holistic and sustainable water resources management policy for the State of Qatar. This policy should take account of all the factors involved directly or indirectly with water resources management. This research, therefore, considers the factors affecting water resources management and water resources in general in Qatar, in the light of environmental, technological, economic, decision-making, legislative, administrative, social, and religious circumstances. The issue of scarcity of water can not be treated from a single perspective, ignoring other direct and indirect factors. The aim of this chapter is to discuss the types of data, manner in which was collected, analysis process and the problem arising the nature of the data.

The research depends on two kinds of data, primary and secondary (Figure 4.1). First, extraction of secondary data is dealt with.

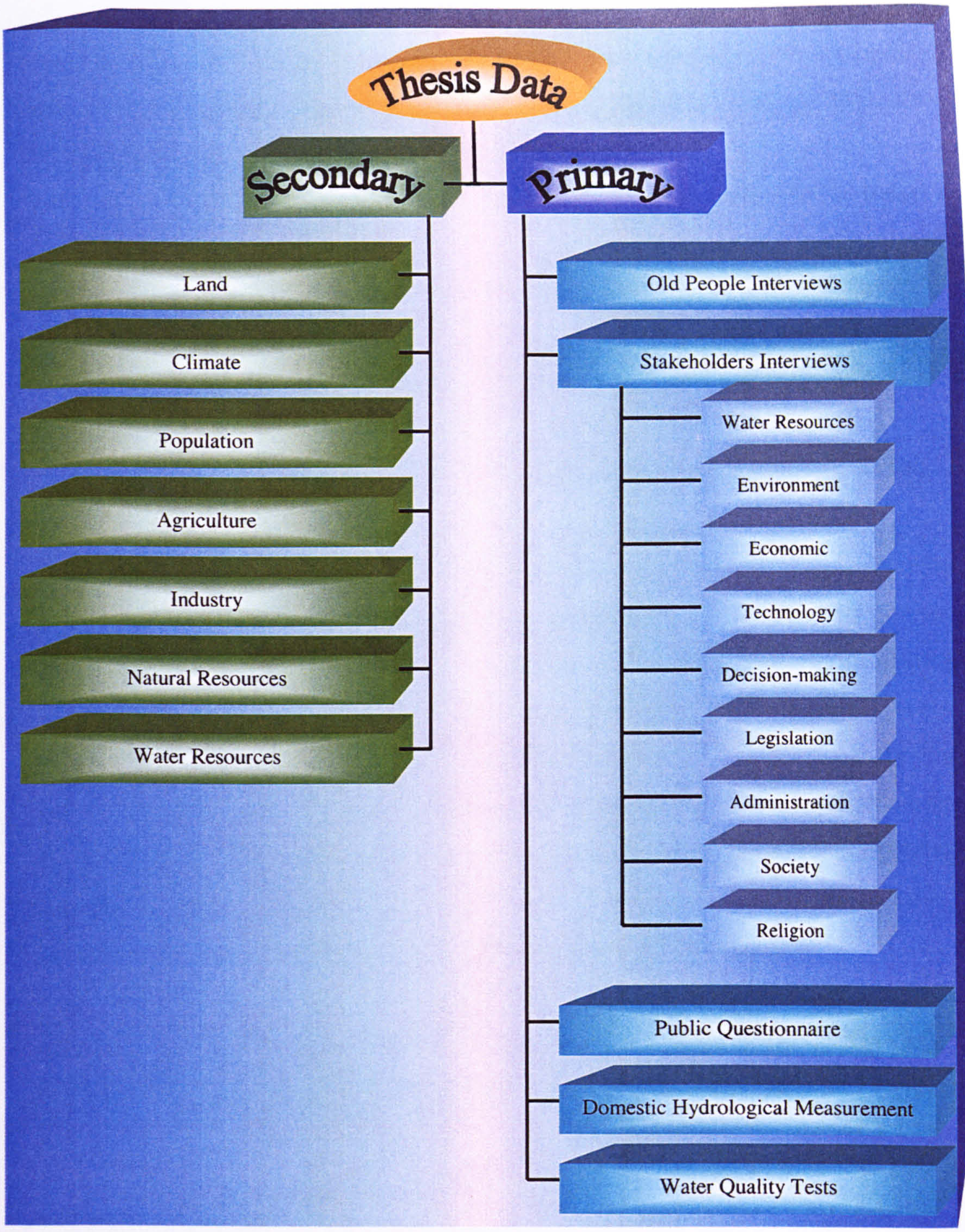

Figure 4.1. The Thesis Data.

4.2. Secondary Data:

In the beginning, it was necessary to obtain what was written about the State of Qatar, the land, climate, population changes, and people's industrial and agricultural activities. In addition to production and consumption figures for water for different years and different sectors, dependence was on reports and pamphlets from responsible administrations. The first secondary source of data was the administrations responsible for water. Information from this source consists of the following:

- Reports from the Desalination Section, focusing desalination process and its water production.
- Reports from the Groundwater Section, including data on water wells production and groundwater pollution.
- Reports from the Distribution Section, including data about water demands by different sections.
- Reports from the Laboratory Section, including data about domestic water quality.

The second secondary data source was the administrations responsible for agriculture. Information includes data concerning agricultural water demands, current groundwater balance, and number and size of farms. The third data source was the Administration responsible for planning and development. Information includes government plans and policies for water resources management. The fourth source was the Gulf Collaboration Council at Riyadh, Saudi Arabia and the Gulf Organization for Industrial Consulting at Doha, Qatar. These sources provided information including agreements about regional water collaboration and co-ordination among the countries, especially about groundwater pollution and common groundwater aquifers.

The secondary data is used as appropriate, throughout the thesis, especially in chapters 5 (The Study Area), 6 (Water Resources, Production and Demand in Qatar) and 7 (The Water Management Problems in Qatar).

4.3. Primary Data:

4.3.1 Introduction:

The primary data comes from a number of sources. These include interviews, questionnaires, domestic hydrological measurements and water quality surveys. The rationale and methods are described below.

Different groups provided different types of information. These could not all be accessed in the same way. For some groups, personal interviews were necessary. For others, public questionnaire was more appropriate. Both methods are considered as excellent approaches to obtain data directly (Sarantakos, 1994; al-Zamat, 1998; Smith, 1991; Schutt, 1996; Porter and Coggin, 1995; May, 1997), though both have problems (Sarantakos, 1994; Robson, 1993; Judd *et al.*, 1991) (Figure 4.2. for the advantages and disadvantages of questionnaires and interviews).

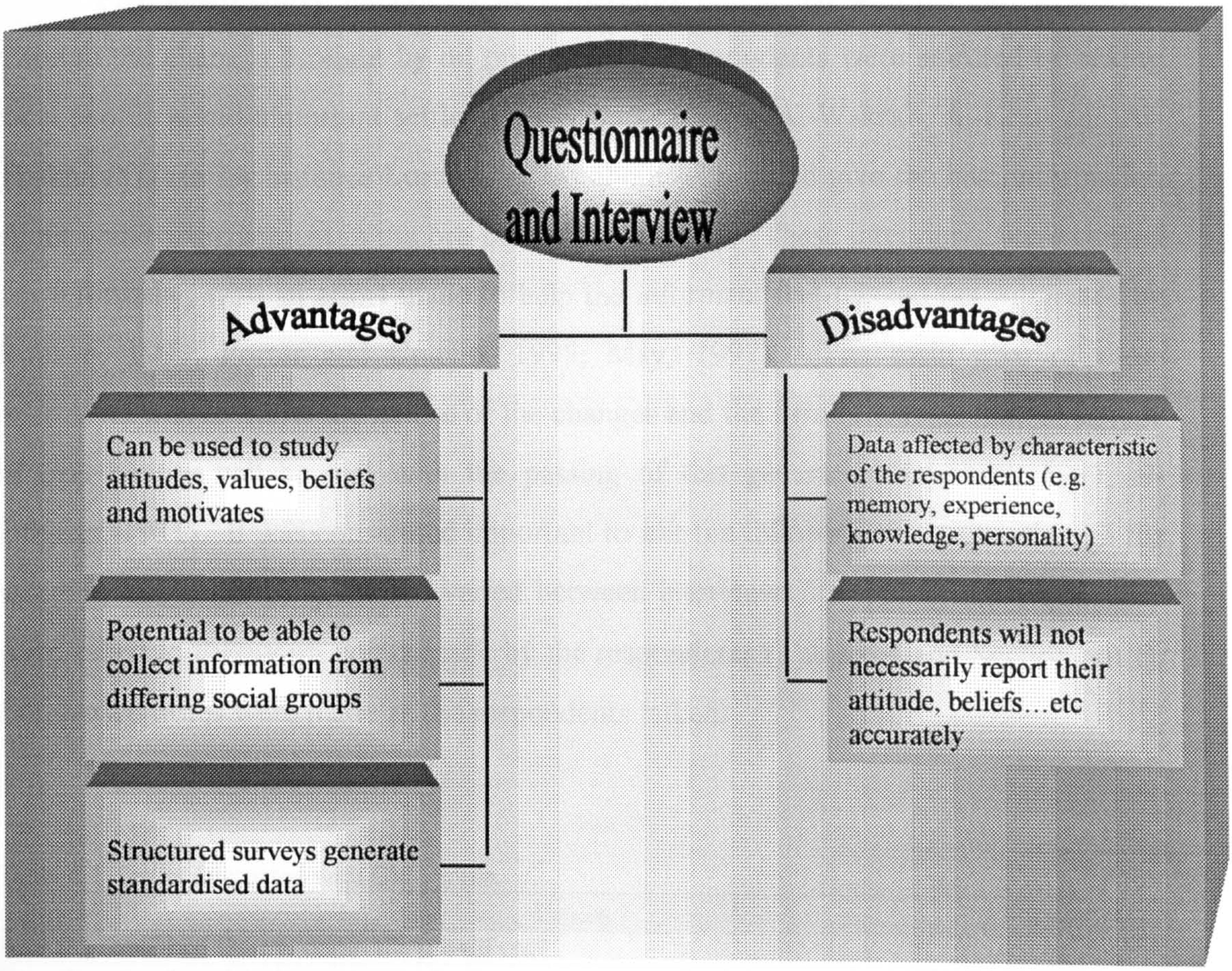

Figure 4.2. The Main Advantages and Disadvantages of Questionnaire - and Interview - Based Surveys (After Robson, 1993).

Two types of personal interviews were carried out. The first was with old people, to obtain oral history; the second was with eight groups of expert stakeholders in different specialisations in close relation with water management. The third type of primary data was generated by a questionnaire for the public. The fourth type was a survey of domestic hydrological measurements, a fifth type was a survey of water quality.

4.3.2. Oral History:

It was necessary in the beginning to know the nature of water production and consumption in the pre-oil period, before the 1950s. Written information, found in some historical studies about the old society in Qatar, did not exceed a few lines or words (Section 7.2 and Appendix 8). Therefore, an alternative source of information was needed.

Five unstructured interviews were therefore conducted with persons who lived through the changes brought by oil production. Respondents were selected by asking local people in old important settlements in Qatar (Doha, Al-Wakrah, Al-Khor and Al-Thakhirah) (see for instance Lormer, 1978) about who could give the best information about water management in the pre-oil era in their city. These interviews were carried out informally, with an effort made to help the informant feel relaxed (as suggested by Robson, 1993; Porter and Coggin, 1995; May, 1997). The main goal of these interviews was to know the nature of the changes and the former way of life. This type of oral history will be lost with the passing of this generation (al-Hajri, 1997; al-Othman, 1981). It was considered important to ask the following questions, though the wording and order of questions varied between interviews. Supplementary questions were asked to follow up points made by the respondents (Table 4.1 and Section A8.1). Condensed notes were made as the respondents talked.

Table 4.1. Issues Discussed with Old People.

Issues
How they obtained their water in the pre-oil era?.
How they distributed and stored water?.
What difficulties they faced to obtain water?.
How was water consumed?.
How all these styles changed in the period that followed oil exploitation?.
Was there a real change in their consumption of water, or was the change only with the new generation?.

4.3.3. Interviews with Stakeholders:

As was pointed in the Chapter Three, the process of water management must rely on a variety of perspectives. The Water Industry in Qatar, as in most other countries, is effectively run by a variety of specialists. These are stakeholders in the Qatari Water Industry, because their jobs depend, to a greater or lesser extent, on it. Personal interviews with expert stakeholders were therefore of importance.

Interviews were therefore conducted with 77 experts in water resources, environment, technology, economic, decision-making, legislation, society, administration, and lastly with religious scholars (Table 4.2). These were based in Government, Government Agencies and the private sectors, including the University of Qatar, petroleum corporations and other bodies. In this case, to ensure comparability and a uniform collection of information, structured interviews were needed (Robson, 1993; May, 1997; Stangor, 1998; Porter and Coggin, 1995; Sarantakos, 1994; Schutt, 1996; Judd *et al.*, 1991). Each respondent was asked ten open questions relating to the research arising out of issues identified in Chapters 2 - 3 and from secondary sources in Chapters 6 - 7 (Appendix 12). It would be normal, in an exercise of this type, to pilot the interview questions in a population different from the study population (Robson, 1993; Porter and Coggin, 1995; May, 1997; Sarantakos, 1994; Smith, 1991; Stangor, 1998). In this case, because of the nature of Qatari society and its Water Industry, there was no analogue population on which a pilot could be conducted. The following tables give detail about the purposes and nature of the questions, which were addressed through these personal interviews.

Table 4.2. Number and Field of Stakeholders Interviews.

Field	**Water Resources**	**Environment**	**Technology**	**Economic**	**Decision-making and Legislation**	**Administration**	**Religion**	**Society**
Water Management	5	1		2	6	7		
Water Engineering	3		4					
Geology	2	2						
Chemistry	1							
Desalination	1		1					
Physical Geography	1	1						
Irrigation Engineering	1							
Environment		4	3					
Agriculture		1						
Water Quality		1						
Agricultural & Development Geography		1						
Mechanical Engineering			2					
Academic & Government Economists				4				
Economic Geography				1				
Law					3			
General Management					2	2		
Political Geography					1			
Islamic Law (*Shari'a*)							4	
Qur'an Sciences							2	
Islamic Economy							1	
Sociology								5
Human Geography								2

Table 4.3 shows the nature and purpose of questions asked of different stakeholders.

Table 4.3. The Interview Subjects and Reasons for Asking.

Issue	Subjects							
	Water Resources	Environment	Technology	Economic	Decision-making and Legislation	Administration	Religion	Society
Perception of problem	Existence and size							
Groundwater	Quality Change and Depletion	Impact and control						
New resources	Comparison between desalination and importation	Environmental impacts of new sources	Possibility of new technology	Economic framework for new resources and comparison between desalination and importation				
Recycled water	Possibility to expand	Environmental possibility to expand	Technological possibility to expand				Religious viewpoint about possibility to expand	
Quality	If there problem in Domestic water	Pollution sources						
Water network	Its situation and suggestions to improve it							
Water research	Availability and benefit from post studies							
Co-ordination	Availability with GCC countries				Availability with GCC countries	Interaction between them and with international institutions		
Water development and environment		Impact of water development on local environment						
Desalination		Pollution and its impact on sea life	Kind of technology	Economic possibility to expand				

Table 4.3. The Interview Subjects and Reasons for Asking (Continued).

Issue	Subjects							
	Water Resources	Environment	Technology	Economic	Decision-making and Legislation	Administration	Religion	Society
Awareness		The level of environment awareness efforts				Level of efforts to change the public behaviour		Institution involvement to change the public behaviour
Water technology			Appropriate to the local condition and manufacture locally					
Modern irrigation			Technical possibility to expand uses					
Consumption			Impact of domestic modern technology and control	Economic reasons and control	Use of law for control		Viewpoint about waste water and control it	Social reasons and control methods
Manpower			Level of technical availability		Availability of local experts	Availability of skilled staff		
Tariff				Level of the current tariff				
Privatisation				Possibility to apply in future		Possibility to apply in future	Religious viewpoint	
The current economic situation				Impact on water sector				Level of impact on individual behaviour
Water management					Current policy problems			
Public participation					Possibility to apply	Possibility to apply		Possibility to apply
Laws					Availability and equity when applying			
Water institution						Availability, independence and Government support		
Recommendation	Improve current policy	Improve current policy	Improve current policy	Improve current policy	Improve current policy	Improve current policy	Improve current policy	Improve current policy

4.3.4. Public Questionnaire:

The questionnaire of members of the public was the third way of producing primary data. Research into this sector has three reasons:

- This sector saw great growth in the oil period. Natural population growth and immigration caused great pressure on limited water resources.
- This sector consumes highly expensive water: most of the population consume desalinated water and its expense is more than five times greater than groundwater which is consumed in the agriculture sector and in rural areas. Water misused in this sector is expensive to the treasury.
- The Government gives priority to water conservation in this sector by any means and at any price, because the other sectors, such as the agriculture sector, which is considered the first consumer of water, did not produce more than a very small percentage (<1%) of the national income.

For all these reasons, the study of the domestic sector and its water consumption is critical. A public questionnaire was used to assess people's interest in the importance of water and the position of water in the state generally (Table 4.4 and Section A14.1). Respondents were selected purposively to form a stratified sample of Qatari society. Random sampling might have missed some groups. The sample was stratified by group - Qataris, foreign workers of various origins, and by education, income, age, occupation and sex (Table 11.1). Respondents were selected by visiting a large variety of localities chosen randomly out of those localities where if would be likely to found a certain group and asking respondents to participate in the survey.

The questionnaire concentrated to a great degree on people's customs and behaviour in different uses of water: drinking, washing, cooking, toilet uses, and house garden irrigation. Also, the questionnaire tackled the extent of people's understanding of the importance of conserving water and reaction to guidance or advice. The survey ascertained if people are ready to participate directly or indirectly in the management of water, to increase their interest in this resource. Response to water tariffs was also assessed and an estimate made of their potential to reduce the consumption of water. As indicated in Section 7.3.5.4, water is free of charge for citizens and costs \$1.2 m^3 for non-citizen, commercial, and industrial sectors (al-Alawi and Abdulrazzak, 1994; al-

Attiyah, 2000; al-Sumori, 2001a). Lastly, the public opinion on current water management policy, decision-making processes, laws were recorded and recommendations to improve water resources management in Qatar were sought.

Table 4.4. The Questionnaire Subjects and Reasons for Asking.

Subject	Reasons for Asking Question
The Service	Test the level of public satisfaction toward the water service
Water Laws	Test the publics attitude to current water laws
Water Issues	Test the public feeling toward quality, recycling and importation
Consumption	Test the public water consumption behaviour
Water Tariff	Identify public opinion towards water tariff
Public Relation	Examine the level of public awareness of public relations efforts by the Water Industry
Water Administration	Identify the public opinion toward water administration and possibility of participation
Privatisation	Test the degree of public acceptability for water sector privatisation
Knowledge of Water	Examine the public water knowledge
Finally	Public Recommendations

The questionnaire was aimed at different classes in the society, considering nationality, gender, education, age, income and occupation. Therefore, the questionnaire was in three languages, Arabic (A), English (E) and Urdu (U). The sample was selected to answer a representative cross - section of Qatari society was sampled (Table 4.5).

Table 4.5. The Questionnaire Distribution Methods and Responses.

Methods and Language	Distribution		Responses		Completed		Uncompleted	
	No.	%	No.	%	No.	%	No.	%
Face to face (A)	211	16	211	100	211	100	0	0
By hand (A, E & U)	507	39	396	78	283	71	113	29
Group (A)	383	29	271	70	193	71	78	29
Mail (A & E)	160	13	15	9	14	93	1	7
Telephone (A)	39	3	39	100	23	59	16	41
Total	**1,300**	**100**	**932**	**71**	**724**	**78**	**208**	**22**

4.3.5. Domestic Hydrological Measurements:

This way of collecting primary data is considered important to help understand the results of the public questionnaire. It was done to understand rates of water consumption in the house for different purposes; to know the real consumption of members of the house and what purposes consume more than others (Appendix 13).

The calculation of consumption of water in the house for different purposes is not new, as there are many studies such as Gray (1994); OECD (1989); Fittschen and Niemczynowicz (1997); Leopold (1974); Herringtom (1996), which calculated the individual's consumption of water in different societies. Most did not mention the method of calculation, so this study of the Qatari society may be considered new.

All the purposes that may consume water in the house were covered, but measuring the use of water in domestic swimming pools was not indicated because personal experience suggests that this is very limited. Measuring amounts of water consumed in the house was completed by choosing samples from twenty persons who had indicated a willingness to participate in further research in the first questionnaire. The survey was aimed at different classes in the society, considering nationality, gender, education, age, income, occupation and number in the household (Table 10.1). Therefore, the questionnaire was in three languages, Arabic, English and Urdu (Table 4.6).

Table 4.6. The Domestic Hydrological Measurements Distribution Methods and Responses.

Methods and Language	Distribution		Responses		Completed		Uncompleted	
	No.	%	No.	%	No.	%	No.	%
By hand (A, E & U)	42	70	31	74	19	61	12	39
Mail (A & E)	18	30	3	17	1	33	2	67
Total	**60**	**100**	**34**	**57**	**20**	**59**	**14**	**41**

Estimates for the consumption of water was arrived at through several ways (Table 4.7). For instance drinking water was calculated, based on the capacity of drinking glasses in Qatar. A second approach was to estimate the amount of water flowing from the tap for one minute by catching the water in graduated buckets. The researcher then had to multiply that number by the time the water was run. This is a good method for calculating the water used in a shower. When such water use was for the whole family, a third method is calculating the water flowing for a minute, multiplying that number by the time used and then multiplying the result by the number of family members. This is useful for finding out amounts used for irrigating gardens or car washing since all family members benefit. Capacity of machines such as dish washers, washing machines and toilet systems was found by reference to manufacturers figures for popular models. The main difficulty was the different amount of consumption of water of the appliances used, such as washing machines and cooking equipment.

Table 4.7. Methods for Measure Daily Per Capita Water Consumption.

Use	Litre	Methods
Drinking	0.3	Per once
Toilet	16.5	Per once
Clothes washing	85	Per once
Showers	11	Per minute
Personal Washing	8	Per minute
Cooking	16	Per once / No. Household
Dish washing	8	Per minute / No. Household
Floor washing	10	Per minute / No. Household
Car washing	10	Per minute / No. Household
Watering Gardens	10	Per minute / No. Household

In general, the benefit of this study was great, since it shows how much domestic activities consume water. Generally, it can be said that the outcome of studying domestic hydrological measurements is to use the results as information and guidance to concentrate on certain types of consumption behaviour in order to develop methods to reduce them. Also, the study is beneficial to the consumer, as it enables him or her to compare consumption with the average. This may help to raise the general interest in water and its conservation.

4.3.6. Water Quality Tests:

This study is concerned primarily with the scarcity of water in Qatar and how to manage it. It is however necessary to study water from the quality side to know to what extent the water is suitable for the different kinds of consumption and its compliance with international standards. Therefore, the quality of water consumed in the domestic, industrial and agricultural sectors was measured and samples taken to judge the quality of water and the extent of its validity for consumption. Replicated samples were taken from each source to give confidence in the results.

The samples were collected from water sources that are consumed directly by the domestic, industrial and agricultural sectors. For the domestic sector, samples were taken from brackish groundwater and seawater desalination plants for the capital and some distant and important areas such as the army camp and oil production areas (Figure 4.3 and Table 4.8). In addition, samples were taken from groundwater tanker filling stations for villages and rural areas. For the agricultural sector, samples were taken from farm wells, with attention paid to the geographical distribution of the farms to cover all parts of the state. Samples were also obtained from two sewage treatment plants, one in the capital and other one at al-Khor, to ascertain the quality of this water and its utility. Great care was taken to obtain the samples and store them, so as not to expose them to high temperatures, which may affect the water quality.

Water samples were taken in acid-cleaned 100 ml plastic bottles. Two bottles were filled at each sampling site. Sampling was between November and December 1998 and samples were analysed between January and March 1999.

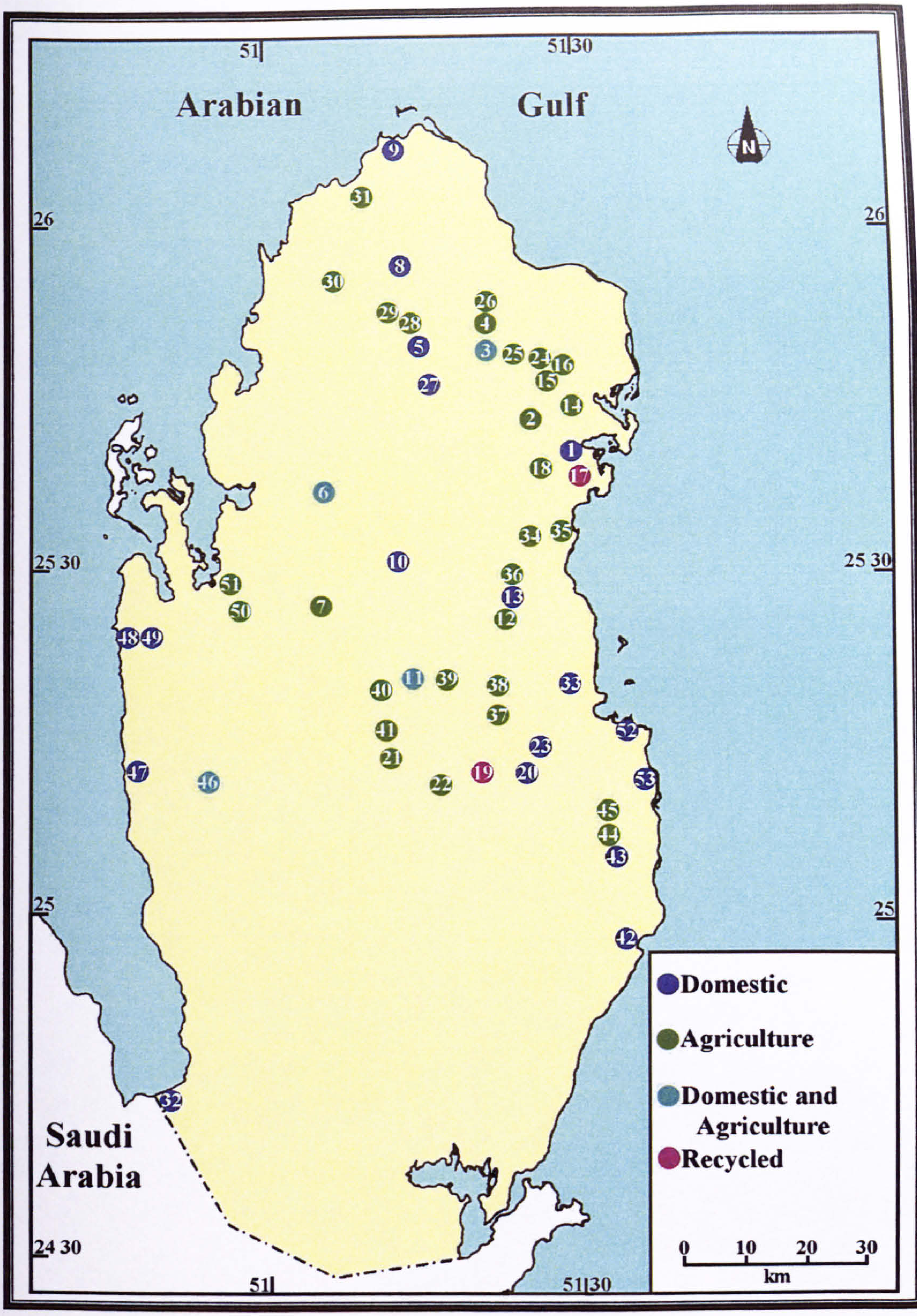

Figure 4.3. Source and Location of Water Samples.

Table 4.8. The Number and Source of Samples (Drinking water indicated in Bold).

Sample No.	Area	Source	Purpose
1	**Al-Khor**	**Groundwater**	**Domestic**
2	Umm al-Shukhut	Groundwater	Agriculture
3	**Rawdat al-Faras**	**Groundwater**	**Domestic and Agriculture**
4	Farm	Groundwater	Agriculture
5	**Al-Ghuwayriyh**	**Groundwater**	**Domestic**
6	**Al-Jumayliyah**	**Groundwater**	**Domestic and Agriculture**
7	Farm	Groundwater	Agriculture
8	**Al-Judaiyah**	**Groundwater**	**Domestic**
9	**Madinat al-Shamal**	**Groundwater**	**Domestic**
10	**Al-Latariyah**	**Groundwater**	**Domestic**
11	**Al-Shahaniyah**	**Groundwater**	**Domestic and Agriculture**
12	Al-Mazruah	Groundwater	Agriculture
13	**Umm Slal Ali**	**Groundwater**	**Domestic**
14	Umm Gain	Groundwater	Agriculture
15	Abu Slailah	Groundwater	Agriculture
16	Al-Qattarah	Groundwater	Agriculture
17	Al-Khor Sewage Treatment Plant	Recycled	Agriculture
18	Umm Sawayah	Groundwater	Agriculture
19	West Doha Sewage Treatment Plant	Recycled	Agriculture
20	**Al-Sayliyh**	**Groundwater**	**Domestic**
21	Rawdat Rashid	Groundwater	Agriculture
22	Abu Nakhlah	Groundwater	Agriculture
23	**Muaydhir**	**Groundwater**	**Domestic**
24	Umm Birkah	Groundwater	Agriculture
25	Simsimah	Groundwater	Agriculture
26	Madinat al-Kaban	Groundwater	Agriculture
27	**North Camp**	**Desalination (RO)**	**Domestic**
28	Al-Majidah	Groundwater	Agriculture
29	Sulaymi Qasim	Groundwater	Agriculture
30	Umm Quraybah	Groundwater	Agriculture
31	Umm Jassim	Groundwater	Agriculture
32	**Abu Samra**	**Desalination (RO)**	**Domestic**
33	**Al-Duhayl Camp**	**Groundwater**	**Domestic**
34	Poultry Farm	Groundwater	Agriculture
35	Simsimah	Groundwater	Agriculture
36	Umm Slal Mohammed	Groundwater	Agriculture
37	Al-Wajbah	Groundwater	Agriculture
38	Umm al-Afaiy	Groundwater	Agriculture
39	Al-Sammiryah	Groundwater	Agriculture
40	Al-Wabrah	Groundwater	Agriculture
41	Umm al-Mawaqa	Groundwater	Agriculture
42	**Mesaieed**	**Desalination**	**Domestic**
43	**Farm**	**Desalination**	**Domestic**
44	Farm	Groundwater	Agriculture
45	Al-Wukayr	Groundwater	Agriculture
46	**Ummahat al-Anz**	**Groundwater**	**Domestic and Agriculture**
47	**Umm Bab**	**Desalination**	**Domestic**
48	Dukhan	D. Before Treatment	Industry
49	**Dukhan**	**Desalination**	**Domestic**
50	Al-Uwaynah	Groundwater	Agriculture
51	Khuwzan	Groundwater	Agriculture
52	**Ras Abu Abbud (Doha)**	**Desalination**	**Domestic**
53	**Ras Abu Funtas (Doha)**	**Desalination**	**Domestic**

There are several methods to test water quality (chemical, biological, physical and thermal). This study concentrated on chemical tests, because other tests link strongly with surface water which is not available in Qatar. Tests were undertaken for 11 parameters: pH, magnesium (Mg), iron (Fe), conductivity, sodium (Na), calcium (Ca), potassium (K), nitrate (NO_3), chloride (Cl), sulphate (SO_4) and phosphate (PO_4) (see for instance Clesceri *et al.*, 1998; De Zuane, 1997).

The main aim of this part of the study is compare the results with international water quality standards (e.g. World Health Organization "WHO" and European Community "EC") (see for example Gray, 1994; WHO, 1984; De Zuane, 1997; Appendix 9) to assess health in the relation to the water consumed in the domestic sector. The results of agricultural and industrial samples compared primarily with irrigation and industrial water quality criteria given by Zajic (1971) and Train (1979) to assess the sustainability of soil, agricultural and industrial production.

The samples of water were examined in the laboratory for their chemical characteristics: pH, conductivity, chloride, sodium, sulphate, calcium, magnesium, potassium, nitrate, phosphate, and iron (Figure 4.4) (see for example Clesceri *et al.*, 1998).

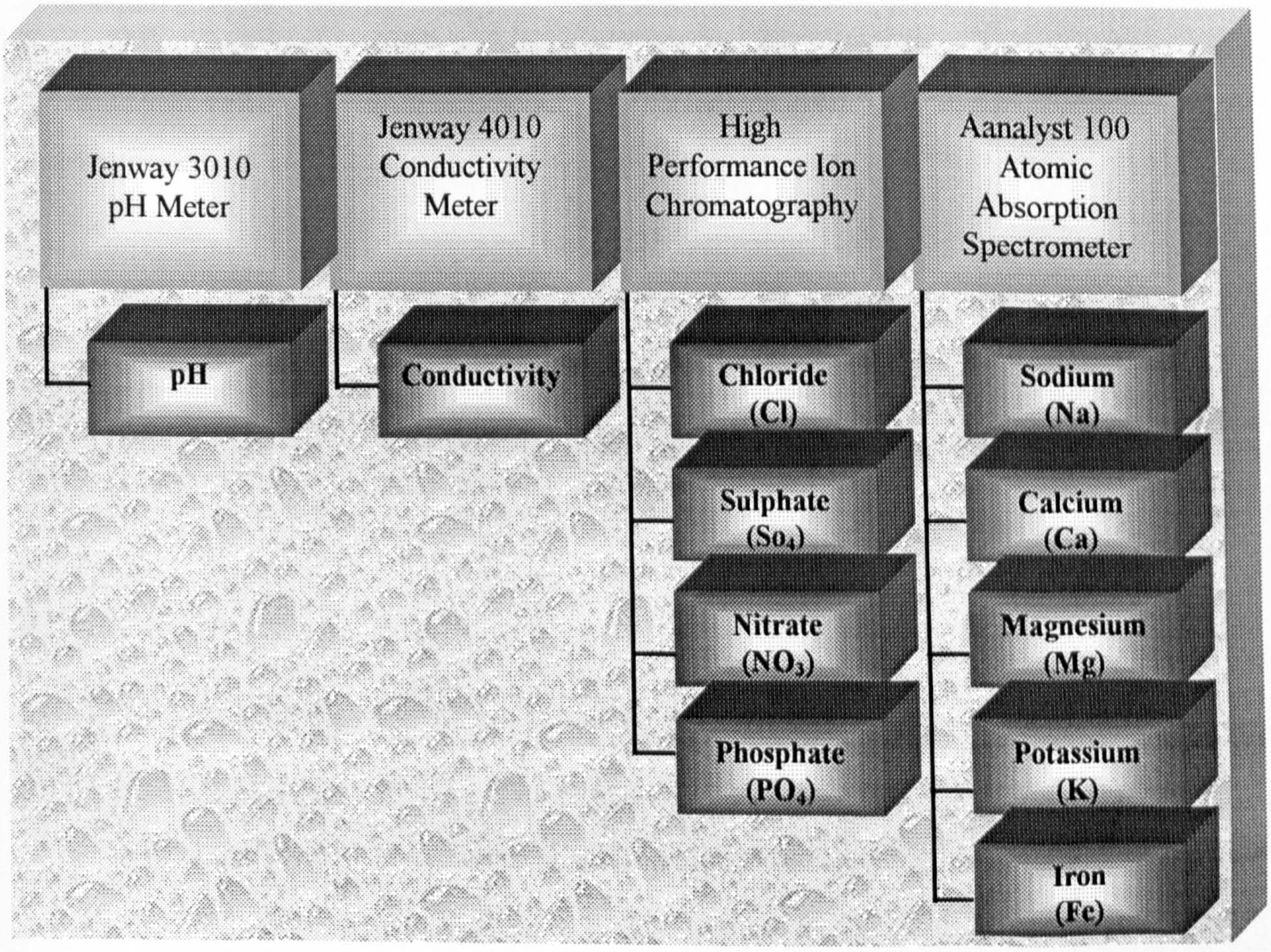

Figure 4.4. Water Quality Test Methods.

4.4. Analysis Process:

After carrying out two kinds of interviews: with old people, and experts; the public questionnaire; together with measuring the chemical quality of water and the domestic hydrological measurements, the resulting data were subject to different analysis (Figure 4.5).

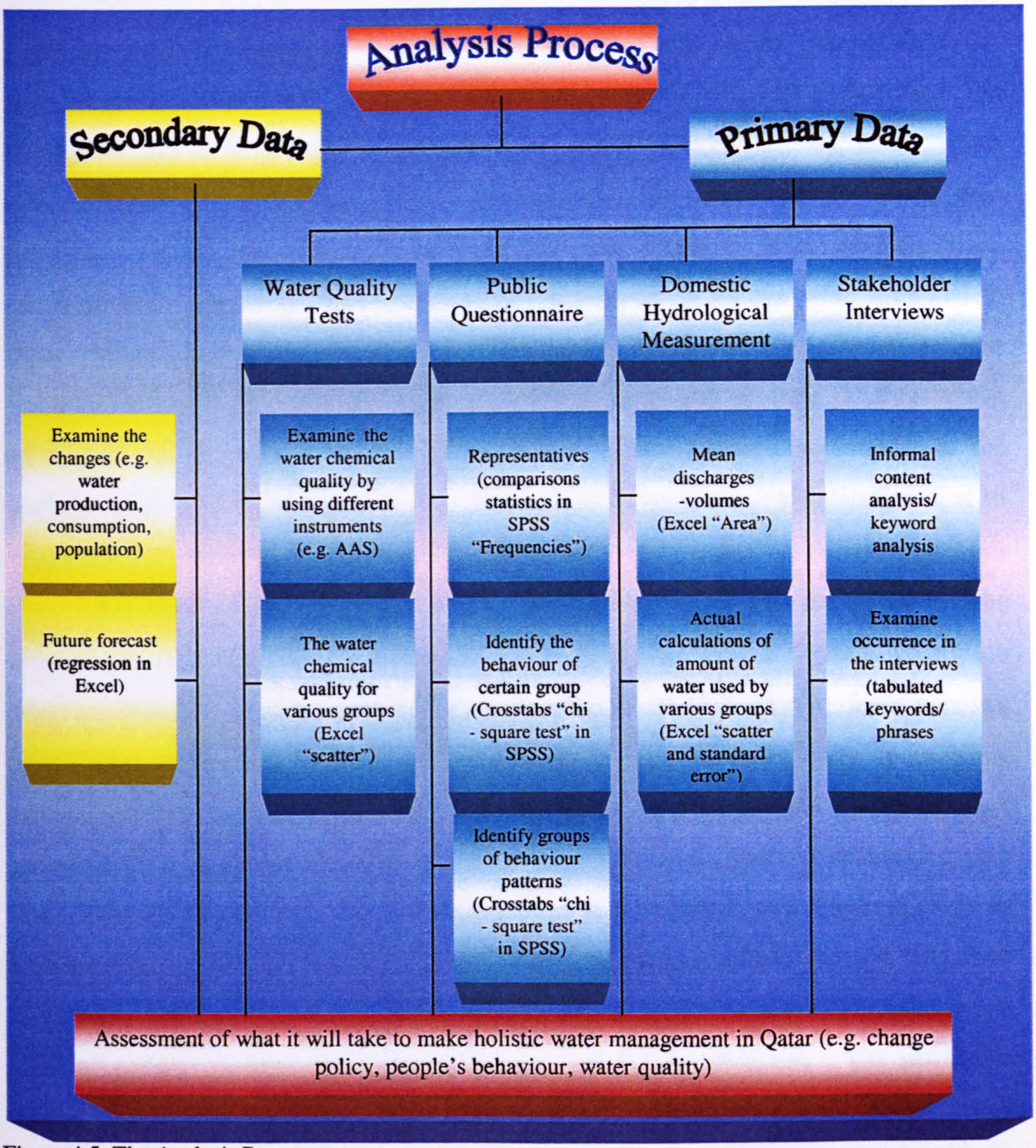

Figure 4.5. The Analysis Process.

Analysis of stakeholder interviews, public questioner, house hydrology and water quality results used EXCEL and SPSS (crosstabs, frequencies and chi-square in crosstabs) where appropriate, results were presented using the graphic capabilities of EXCEL.

4.5. Data and Sample Survey Problems:

Naturally, the process of collecting data is not free of problems and difficulties, and these problems differ with different people and countries. In the State of Qatar, in spite of great progress since the discovery of oil, obtaining data and presenting it for scientific research is still difficult. Zarkovich (1993); al-Zamat (1998), confirm that data collection is very difficult. Even when secondary data are available, a long time and great efforts are needed to obtain them. For example, in an administration responsible for water production, the latest data about its doings were prepared in 1994. When the researcher asked about that report, the question was "what are you going to do with it ?!!". There is unjustified fear about preparing data. There is a lack of respect for scientific research. There is also a semi-undemocratic aspect to the society, where information is for a limited group of 'responsible people' and denied to the public and researchers.

For primary data collection, it is not easy to identify samples for research. The response of the sample is also often poor. Because this research depends greatly on personal interviews and questionnaires, the difficulty here is greater, from personal experience while researching this thesis. There was great difficulty in reaching intellectually all these experts. This was especially so because the questions were mostly of an open nature. For example, when you meet an expert in economics, they may have no idea about water economy. Another problem was the restriction of knowledge. Thus, when meeting some experts in water technology we find their knowledge is confined to one issue such as desalination. Because their experience was restricted, they did not understand other parts of water technology. The researcher found this matter with experts working in Government and private sector water administration. An other difficulty was political difficulties perceived especially with interviews with Government administrators. For example, the application to make interviews with employees in an administration was rejected without a clear reason. In this case, it is probable that the administration was reacting to previous press coverage. On the other hand, when asking a question about the possibility of importing water from outside, a responsible person said "that this matter is related to politics and I can not answer it", although the question was about the possibility, not the actuality.

In spite of all these difficulties, the information obtained through personal interviews was useful to a great extent. Despite these difficulties, the opinions of all these influential stakeholders are known in relation with making a comprehensive and inclusive water management policy.

Generally, it can be said that this kind of collecting primary data is considered difficult in developing countries (Zarkovich, 1993; al-Zamat, 1998; al-Qubaisi, 2000; al-Kazim, 2001), especially if it relates to interviews with experts to give a holistic overview of water management.

The questionnaire to measure the behaviour of the public also faced difficulties. The first difficulty was to put questions with an easy and clear nature, as there are different levels of education and culture in the sample chosen. The second difficulty is to obtain a response. In many cases it took personal interviews. The third is distributing the questionnaire to all members of the society, especially women. In Qatari society it is difficult or impossible to obtain a response from women because of the conservative nature of the two genders. The problem is that women are the greatest consumers of water inside houses, so it is necessary to obtain data from this important source. The fourth is Qatari society is still conservative and it is difficult to ask personal questions, such as about using water in toilets. The fifth is the public, also, were not motivated to answer the questionnaire, as there is insufficient interest in the importance of water. The water tariff does not cost families much of their high income. It would seem that guidance and information by responsible water administrators has little effect on the public. But on the other hand, there was a recognition of the importance of the questionnaire from some cultured people and the results were acceptable, especially regarding their consumption habits and their interest in the importance of water.

A major difficulty was to specify the nature of the sample. Citizens do not exceed a quarter of the population. Foreigners form the three-quarters of the population, but their presence is temporary and their stability can not be measured (al-

Khayat, 1988; al-Kuwari, 1996; al-Mohannadi, 1997a). Moreover, most foreigners are from different cultures and their behaviour is different, behaviour of women is also likely to be different, occupations with different income and education groups. Therefore, careful stratification of the sample was thus necessary.

Lastly, some difficulties were faced while taking water samples from different sources. The difficulty was how to reach and obtain permission to sample some important sources, such as big desalination plants, which are guarded strongly. Thus was especially the case for the security centres (e.g. the army camp) which use some desalination plants for their own consumption. In addition, there was difficulty in taking samples from water production and distribution facilities for domestic consumption in small cities and villages. It took time ask permission and for responses to take samples.

4.6. Conclusion:

The aims of this chapter were twofold. The first was to show the research methods used in this study. The second goal was to describe methods of obtaining secondary and primary data and to assess the difficulties and obstacles that accompanied the process of data collection. The primary data for this research depends on two kinds of interviews (old people and stakeholders), public questionnaire, domestic hydrological measurements, and water quality tests. The results of these data collection analysis are discussed in the next chapters.

CHAPTER FIVE:

THE STUDY AREA

Chapter Five:

The Study Area

5.1. Introduction:

The aim of this chapter is to provide a background on the geography and economy of the State of Qatar. In particular the discussion will cover the most important aspects of land, climate, population, agriculture and industry.

5.2. Land:

Qatar is one of the smaller Gulf states, located between latitude 24° 27′ and 26° 10′N and longitude 50° 45′ and 51° 40′ E, situated halfway along the western coast of the Arabian Gulf and surrounded by it on three sides. Saudi Arabia borders it to the south (Figure 5.1). It consists of a peninsula 160 km long and 88 km across at its widest point, while its coastline is 55 km long. Its total land area is 11,437 km^2 (Ashour, 1987; al-Mansour, 1979; Drost *et al.*, 1995; el-Mallakh, 1985; al-Khayat, 1998). Qatar's islands include Halul, Janan, Al-Ashat, Al-Safiliyah, Rakan and Al-Bashiriyah (al-Sheeb, 1998).

Figure 5.1. Qatar and other Arabian Gulf States (After al-Khayat, 1998).

Most of the country is a flat desert terrain interrupted by a line of hills along its west coast and mesa-type hills in the west and south (Figure 5.2). Sand dunes encircle the inland of Khor al-Udaid and run into the Rub al-Khali (Empty Quarter), that is the massive sand desert that covers almost much of the Arabian Peninsula. The highest hill in Qatar is in Dukhan in the middle of the east coast which reaches about 35 m above sea level (el-Mallakh, 1985; al-Nasr and al-Sheeb, 1999). The land surface is mainly limestone and dolomite overlaid by a few centimetres of broken material. Collapse structures below the surface have resulted in depressions in which sands and soils have collected in depths of several meters. Qatar's central and northern parts are characterised by surface rainwater-draining basins known as *Al-Riyad* (the gardens). In these areas the land is fertile and suitable for agriculture. Another of Qatar's unique features is the presence of huge salt flats (*Sabkhah*) that extends between Salwah, on the border with Saudi Arabia in the south, and Khor al-Udeid on the eastern coast (Ashour, 1987; Bohairi and al-Fara, 1976; Drost *et al.*, 1995; Fisher, 1971). Extended land reclamation has added miles to previously shorefront land at Doha (Pereira *et al.*, 1977; Nyrop, 1984).

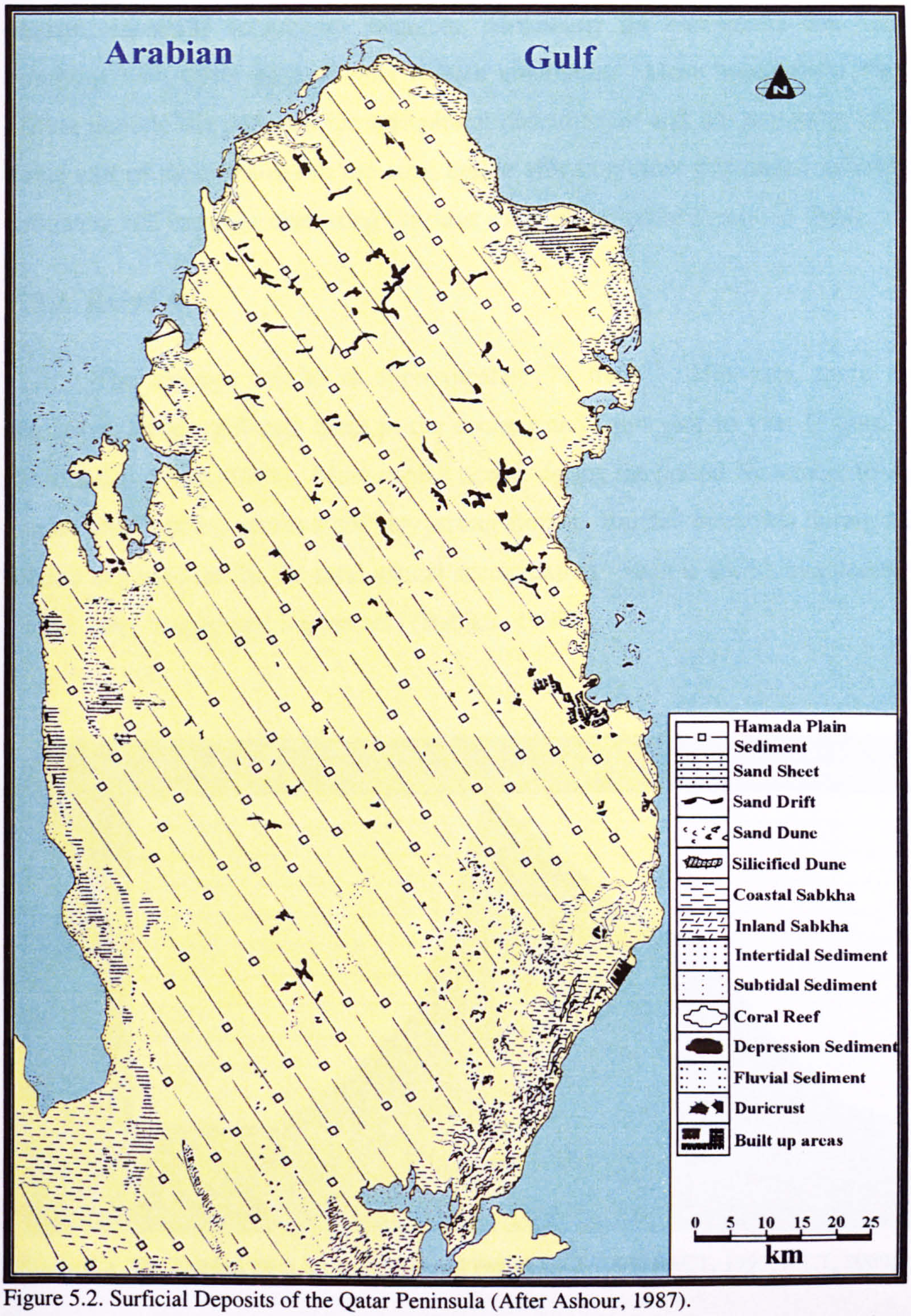

Figure 5.2. Surficial Deposits of the Qatar Peninsula (After Ashour, 1987).

5.3. Climate:

5.3.1. Introduction:

Qatar climate in general is hot and arid, but sometimes with high atmospheric humidity and always very limited amounts of rainfall. The general usage of air conditioning in Qatar has made life much more comfortable and made the severity of the climate, especially in summer, bearable, particularly for immigrants that come from countries with either cold or mild climate conditions. More importantly, the climate affects directly the potential for agricultural development and the possibility of reaching some sort of food security in the area, beside affecting other population activities. The following will focus on discussing the most important specific climate in Qatar.

5.3.2. Rainfall:

The average rainfall is approximately 73 mma^{-1}. However, there are wide variations among different areas in the country and from year to year (Figure 5.3) (al-Nasr and al-Sheeb, 1999). Most rainfall occurs during the period November to April and sometimes flooding results from very strong storms. Rainfall occurring during a 24 hour period can account for the total annual accumulation. Rain is absent in summer months (June, July, August and September) (Babikir, 1998a).

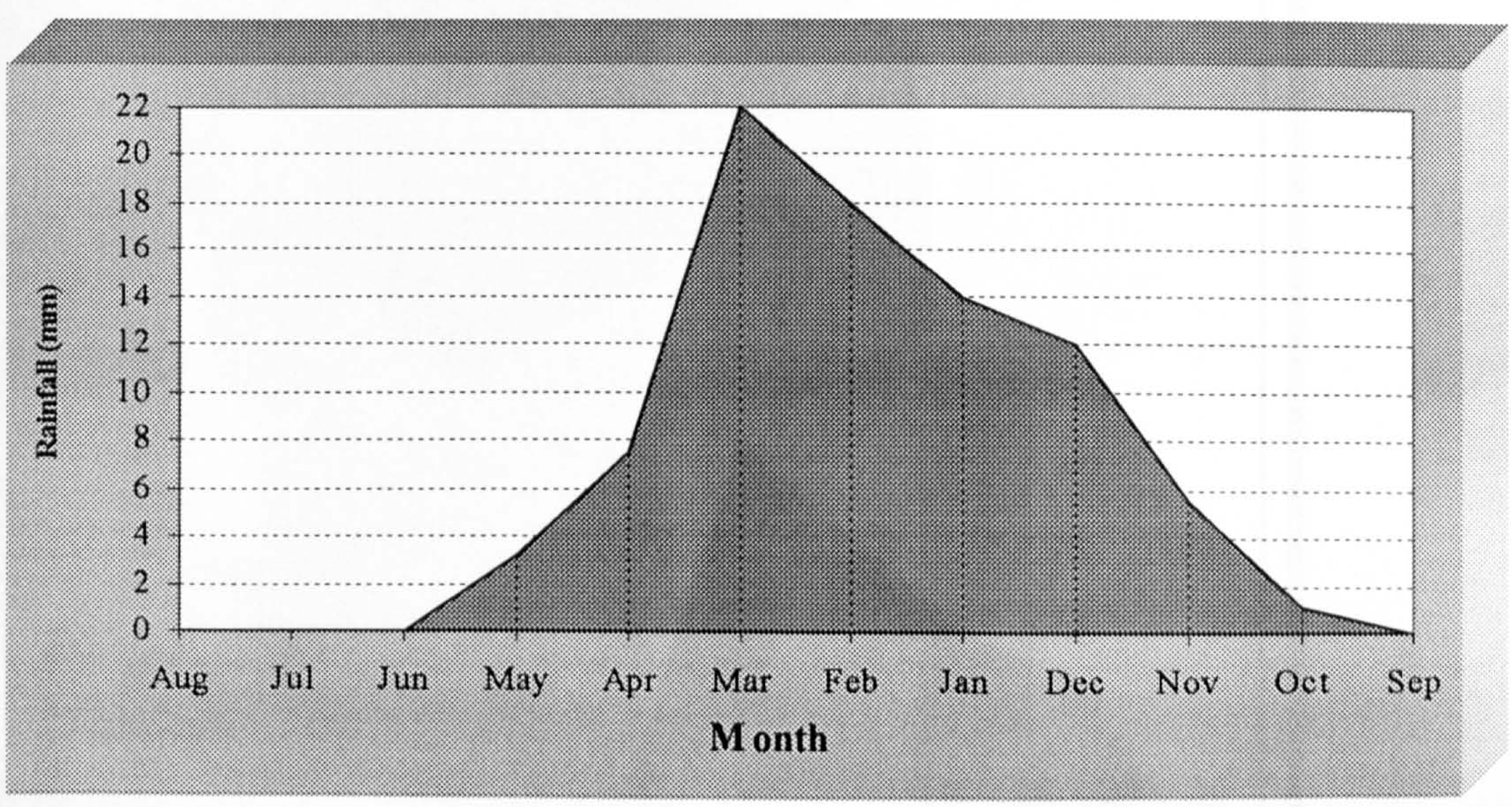

Figure 5.3. The Rainfall Data for Qatar (Record Period 1962-1999) (MCT, 1999; MCT, 2000).

The rain falling in the north tends to be greater than in the south, with the north receiving 30% more than the south (Figure 5.4). Rainfall is vital to groundwater recharge but it is not adequate to cover irrigation requirements (al-Nasr, 1988). Qatar in winter is influenced by easterly moving air streams and intense thunderstorms during the early and late winter. Although rainfall tends to be higher in northern and central areas in winter, during spring thunderstorms build up over the east coast (al-Kouleeb, 1990; FAO, 1981; Harhash and Yousif, 1985; Modawi, 1997, MCT, 1997; MCT, 2000).

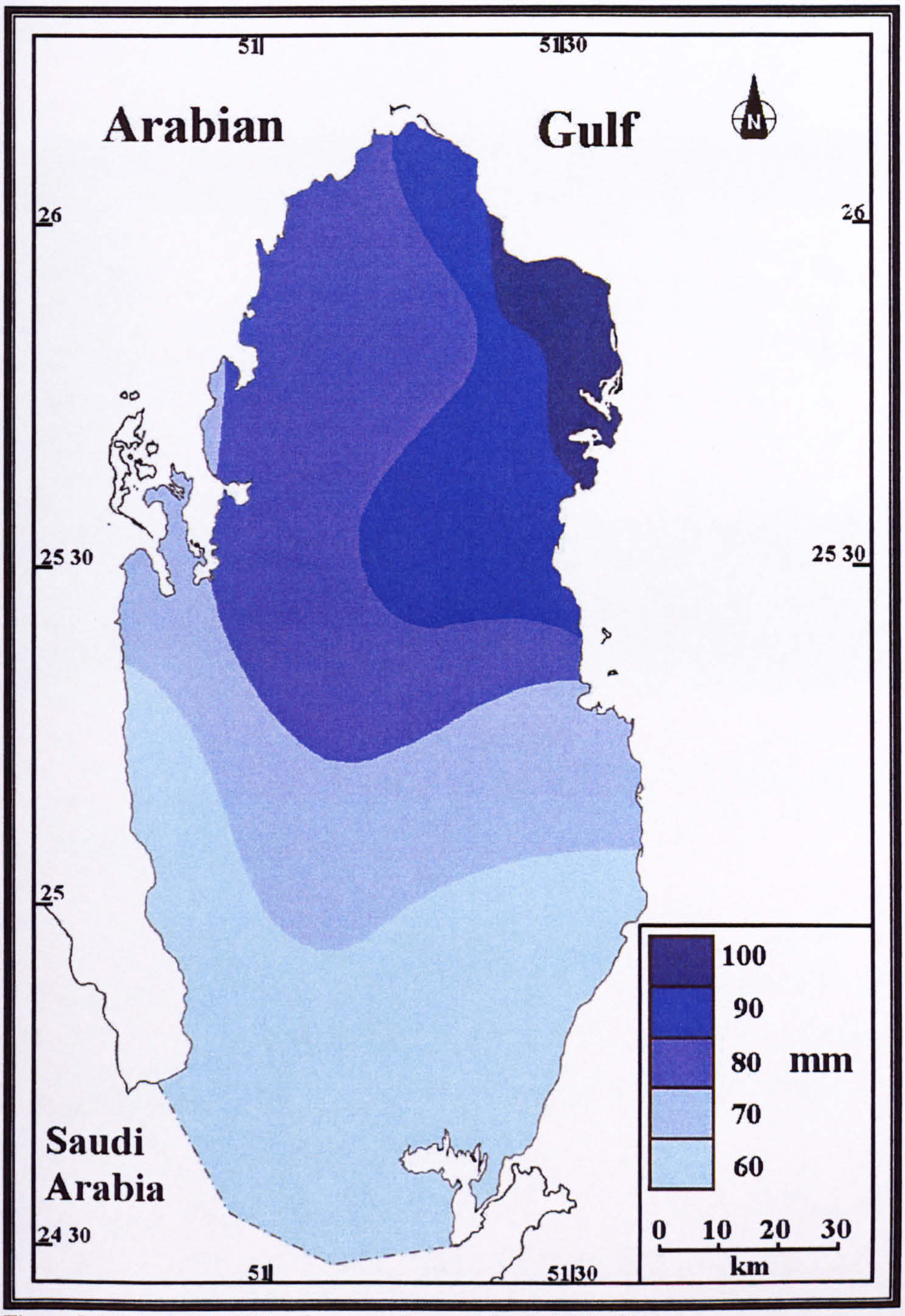

Figure 5.4. The Rainfall Distribution in Qatar (After Babikir, 1998a).

5.3.3. Air Temperature:

Qatar has a desert climate characterised by intense heat and atmospheric humidity and limited rainfall (al-Nasr and al-Sheeb, 1999). The mean of surface air temperature in Qatar varies between a minimum of 13° Celsius (C) and a maximum of 21.9° C in January, rising to a minimum of 29.5° C and a maximum of 41.6° C in July. There is also little difference in the mean annual average of temperatures between the coast and inland (Figure 5.5) (MMAA, 1995, al-Nasr, 1988; Bohairi and al-Fara, 1976; MCT, 1999; MCT, 2000).

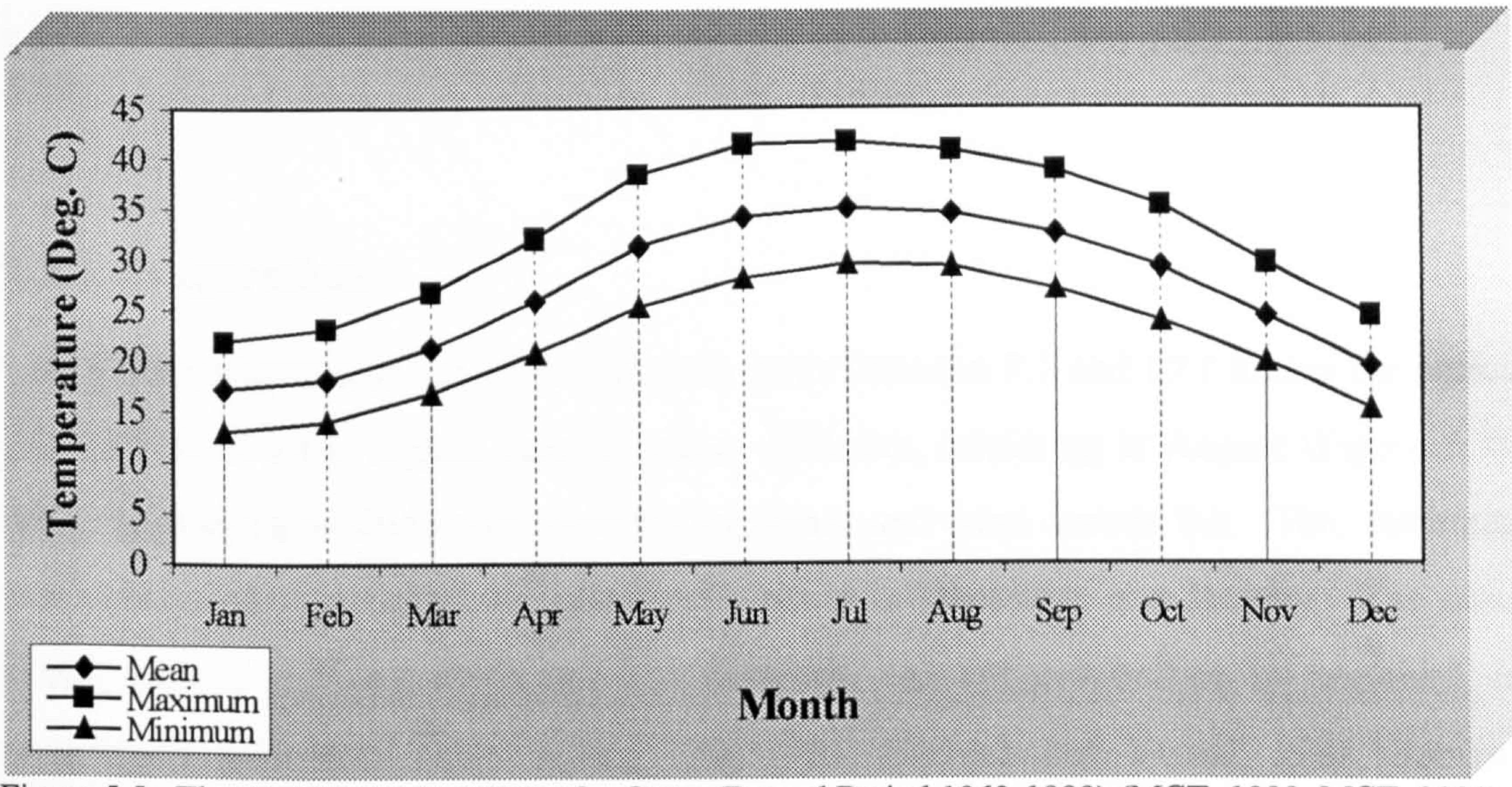

Figure 5.5. The Air Temperature Data for Qatar (Record Period 1962-1999) (MCT, 1999; MCT, 2000).

5.3.4. Relative Humidity:

The maximum value of humidity is 70% and it occurs in winter months (December, January and February). During may, June and July, the mean relative humidity is range of 40%-50% and 55%-65% from August to November (Figure 5.6). The closer the areas are to the sea the higher the humidity (FAO, 1981; Harhash and Yousif, 1985; MCT, 1999; MCT, 2000).

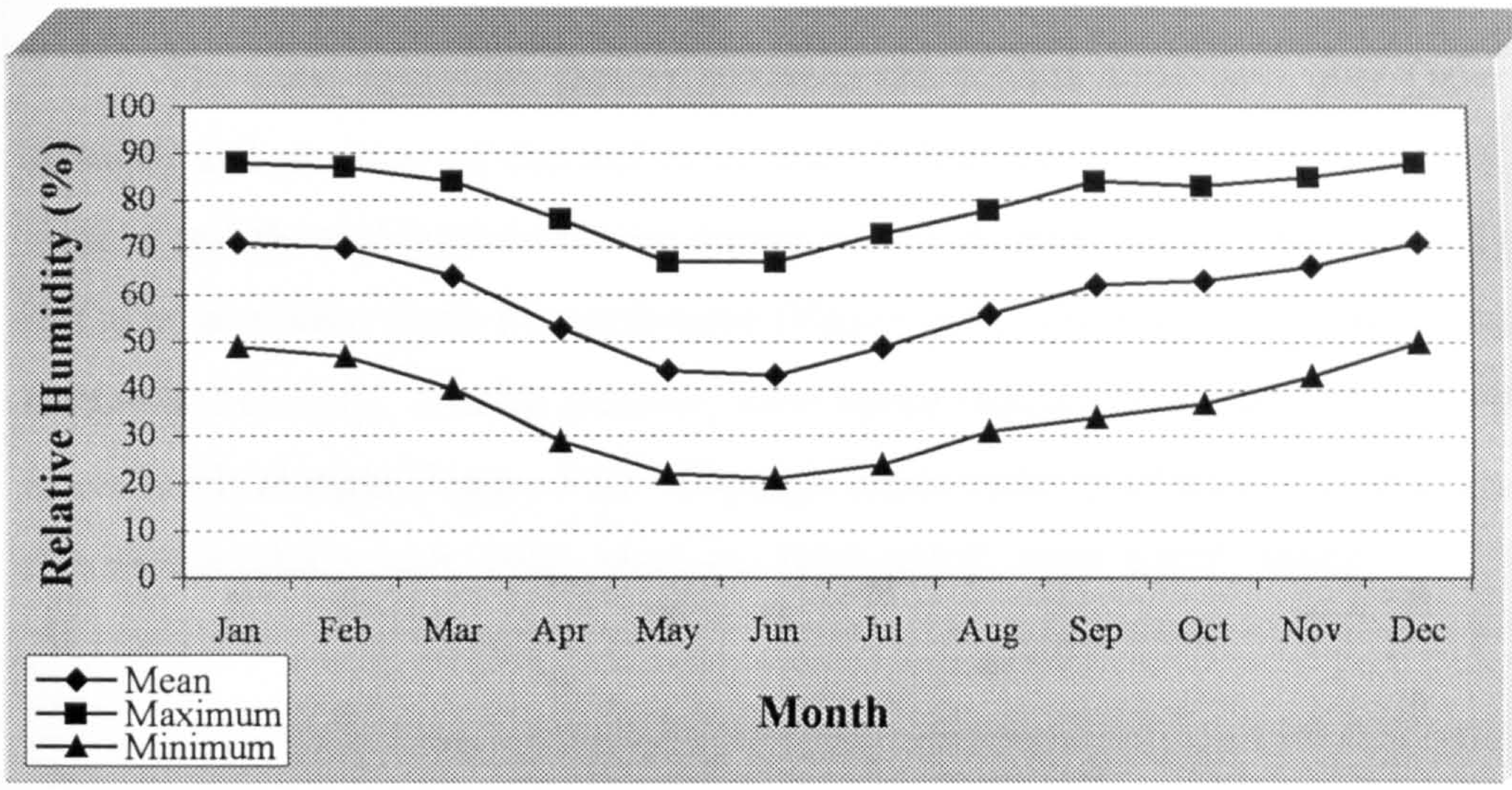

Figure 5.6. The Relative Humidity Data for Qatar (Record Period 1974-1999) (MCT, 1999; MCT, 2000).

5.3.5. Evaporation:

Pan evaporation has an annual daily mean between 7.7 and 10.1 mm in the period 1976-1999, with the highest rate recorded, 32.0 mm, occurring in August (Figure 5.7). After August, rates decline as humidity increases and wind speeds fall. The, minimum evaporation rates recorded, of 0.02 mmd^{-1}, occur in December and January. The oasis effect, with lower wind speed and high humidity, reduces evaporation by one-third, in comparison with open desert sites (FAO, 1981; Harhash and Yousif, 1985; Babikir, 1998a).

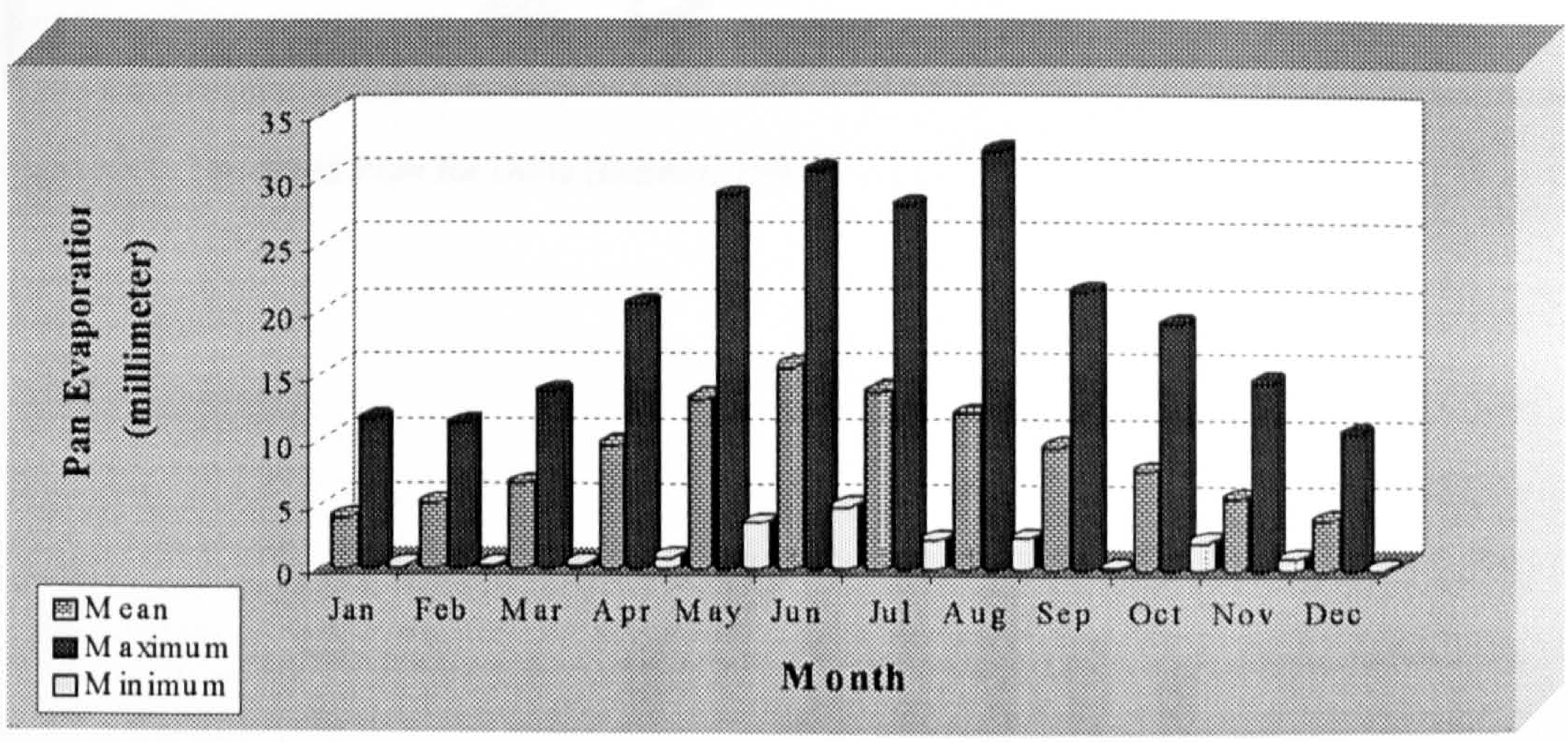

Figure 5.7. Mean Daily Pan Evaporation Data for Qatar (Record Period 1976-1999) (MCT, 1999; MCT, 2000).

5.3.6. Wind:

The most important factors influence the surface wind flow over Qatar are the strength and position of thermal lows over Indian sub-content and Sudan in summer months and the mid-latitude frontal during winter months (MCT, 1999). Wind direction in Qatar is mainly north by north-west (Figure 5.8), while south and south-east winds occrue in February. During summer, wind speed reaches 10 knots during the day, with lower levels at night (Figure 5.9). The high winds make troublesome sand storms during this season (al-Kouleeb, 1990; Modawi, 1997; MCT, 1997; MCT, 1999).

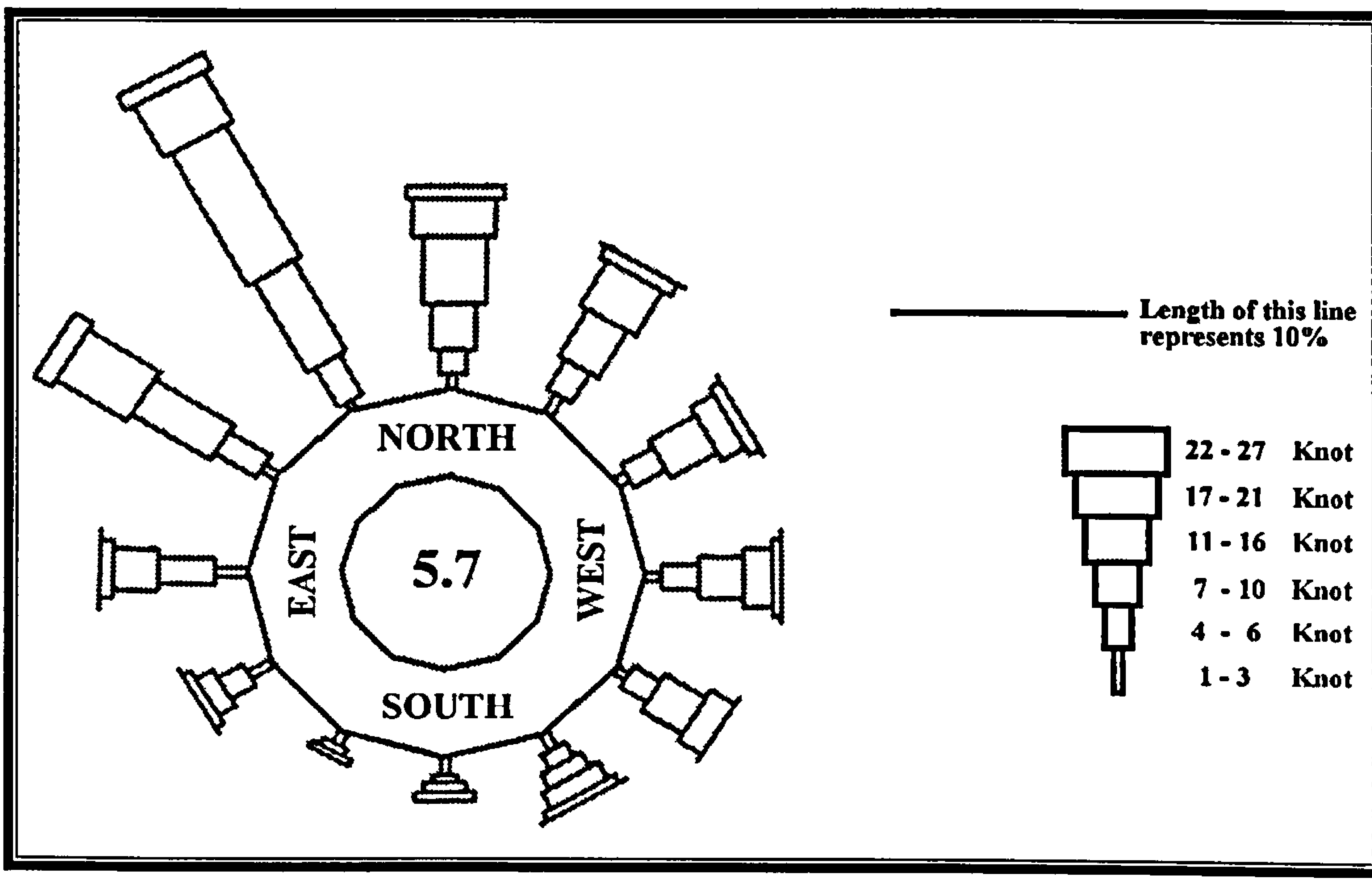

Figure 5.8. The Wind Rose for Doha (Babikir, 1998a).

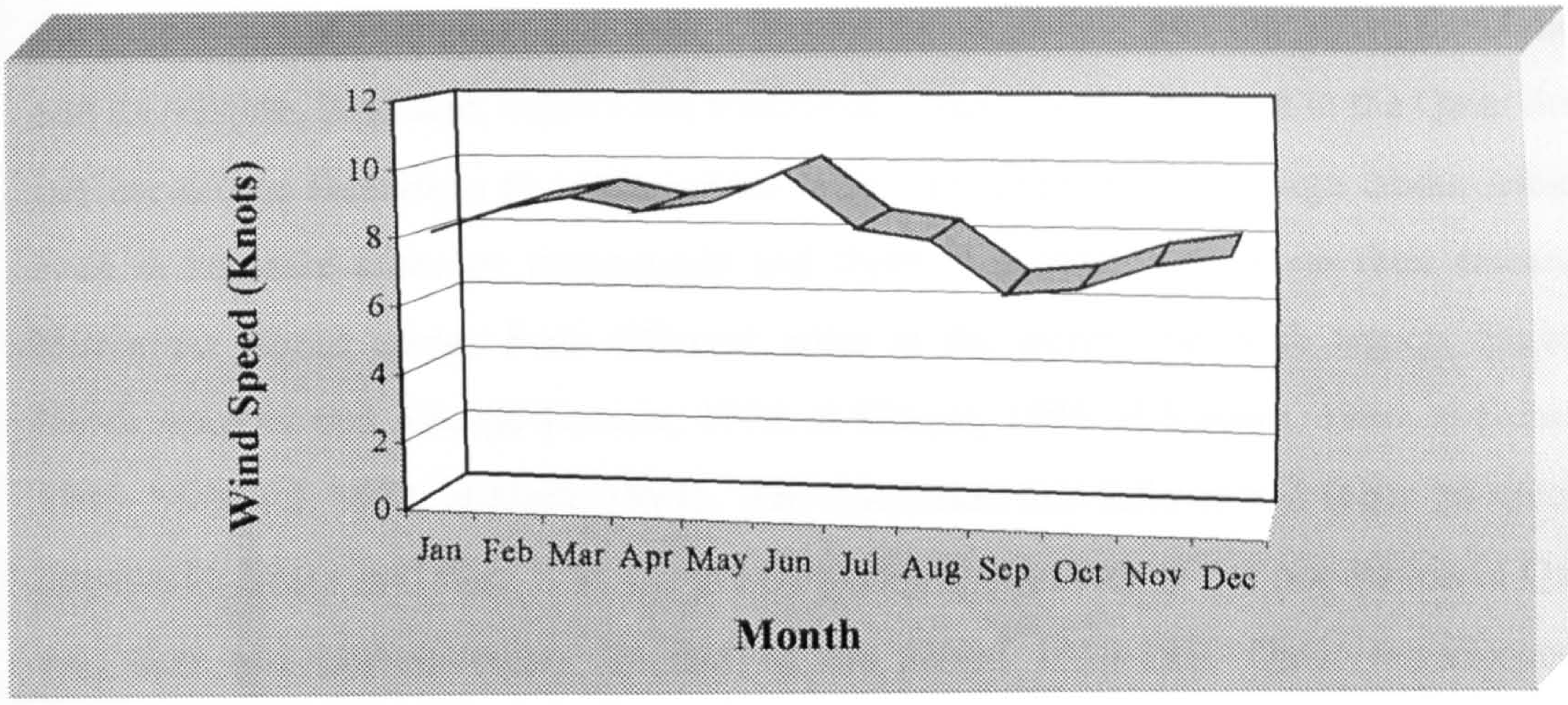

Figure 5.9. The Wind Speed Data for Qatar (Record Period 1974-1999) (MCT, 1999; MCT, 2000).

5.3.7. Summary of other Important Weather Elements Data:

Table 5.1. Other Weather Elements Data (MCT, 2000).

Monthly Mean	Thunder Storm (Day)	Lightning (Day)	Cb Cloud Reported (Day)	Fog (Day) (Visibility <1000m)	Dew Point Temperature (C)	Vapour Pressure (hPa)
January	0.6	1.1	1.7	3.5	11.4	13.9
February	1.2	1.6	2.6	2.7	11.9	14.4
March	2.0	2.3	4.4	1.1	13.2	15.7
April	1.5	2.1	3.0	0.3	14.6	17.3
May	0.5	0.6	0.8	0.4	16.2	19.3
June	0.0	0.0	0.0	0.6	17.6	21.4
July	0.0	0.2	0.4	0.7	20.7	25.9
August	0.0	0.1	0.2	0.6	23.1	29.5
September	0.1	0.0	1.2	1.6	23.3	29.4
October	0.5	0.6	3.1	2.2	20.6	24.9
November	0.6	1.2	2.4	1.4	17.1	19.9
December	0.6	1.0	1.5	3.1	13.9	16.3
Year	**7.6**	**10.8**	**21.3**	**18.2**	**17.0**	**20.7**

5.4. Population:

Qatar has similar demographic features to other Arabian Gulf states, there are a small native population and the presence of a large number of foreign workers, especially from Southeast Asia. The skills and expertise of these foreign workers were essential in the modernisation and development of this state. Yet, Qatar needs to balance between the proportion of foreigners and their influence on the society and the native population and its religion, language, culture and traditions. Thus, the government in the Qatar does not encourage foreigners to settle permanently. In addition, the foreign labour usually lives in separate areas or compounds and there is a strict control on their entrance. Immigrant labour comes from different areas in the world: the Arab region, Europe, North America and Asia (al-Kuwari, 1978; al-Khayat, 1988; al-Kuwari, 1986; al-Kubaisi, 1986; Melamid, 1972; al-Hajri, 1997). The discussion that follows will focus on specific population issues in Qatar. In the pre-oil period the growth of the population in Qatar was slow and unpredictable. In fact, in the period 1930-1950 Qatar experienced a population decline from 30,000 to 20,000 inhabitants (Table 5.2). This was due to the depression in its traditional economic activities, especially pearl trading, as well as the halt in oil exploration in the wake of World War II. These led Qatari citizens to emigrate to surrounding countries (al-Mohannadi, 1997a; Pereira *et al.*, 1977; el-Mallakh, 1985; al-Kubaisi, 1986; Melamid, 1972; al-Mansour, 1979).

Table 5.2. Qatar's Population during the Pre-oil Period (Fakro, 1998[a]; al-Kubaisi, 1986[b]).

Year	Total Population	Citizen	Citizen (%)
1872[a] (estimate)	10,000	---	---
1908[b] (estimate)	27,000	21,000	77.7
1930[b] (estimate)	30,000	19,000	63.3
1940[b] (estimate)	25,000	---	---
1945[a] (estimate)	25,000	---	---
1950[b] (estimate)	20,000	---	---

(--- Unavailable Data).

The commencement of oil production from the Dukhan oil field after 1949 had the effect of increasing the country's population. Many Arabian tribes immigrated to Qatar from the Arabian Peninsula and other Arabian countries to work in new economic activities, along with oil workers from the UK and India (Bohairi and al-Fara, 1976; al-Kuwari, 1978; al-Khayat, 1988). Qatar continued to attract foreign labourers, especially during the 1970s and early 1980s, with its increased oil-wealth and the expansion in its development programmes. Thus, in addition to indigenous Qataris, there are many Arab immigrants, including Palestinians, Omanis, Yemenis as well as a smaller numbers of non-Arabs, including Iranians, Indians, Pakistanis, and East Africans. There is also a small community of Europeans, especially British, and Americans (Key, 1976; al-Mohannadi, 1997a; al-Kubaisi, 1986; al-Kuwari, 1996).

The population of Qatar grew from approximately 40,000 in late 1955 to 369,000 at the time of the 1986 second census and to 522,023 at the time of 1997 third census (Table 5.3) (CSO, 1996; CSO, 1998; Kubaisi, 1986; al-Kuwari, 1996; Fakro, 1998; Ahmad and al-Faqeh, 1999). The indigenous Qatari population was recorded at about 21.5% of the total population and this small ratio is decline by 1% every year. Qatar's population remains the smallest in the Arab world (EIU, 1999; al-Kuwari, 1996; al-Hajri, 1997). Most of the population is urbanised, about 83% of them living in the capital Doha and its suburbs (PC, 1999a; Fakro, 1998).

Table 5.3. Qatar Population (al-Kubaisi[a], 1986; al-Kuwari[b], 1996; Fakro[c], 1998; PC[d], 1999a; EIU[e], 1999).

Year	Total Population	Citizen		Non-citizen	
		Total	%	Total	%
1955 (estimate)	40,000[a]	---	---	---	---
1960 (estimate)	60,000[a]	---	---	---	---
1965 (estimate)	70,000[a]	---	---	---	---
1970 (1st census)	111,133[b]	45,039[b]	40.5[b]	66,094[c]	59.5[c]
1975 (estimate)	180,000[c]	65,000[c]	36.1[c]	115,000[c]	63.9[c]
1980 (estimate)	233,000[c]	85,000[c]	32.7[c]	175,000[c]	67.3[c]
1986 (2nd census)	369,079[d]	98,000[b]	26.4[b]	---	---
1990 (estimate)	487,000[c]	125,000[c]	25.7[c]	362,000[c]	74.3[c]
1997 (3rd census)	522,023[d]	112,000[b]	21.5[b]	---	---
1998 (estimate)	560,000[e]	---	---	---	---

(--- Unavailable Data).

5.5. Agriculture:

The harsh climate, the scarcity of land suitable for agriculture and the scarcity of water resources restricts the development of agriculture in Qatar. Although historically agriculture was the main economic activity of a very small proportion of the population, this proportion had been falling as the country modernised and became more urban and production concentrated in the oil industry and related sectors of the economy (Bohairi and al-Fara, 1976; Pereira *et al.*, 1977; al-Kuwari, 1996; al-Biati, 1998a). Yet, it is this high dependence on the oil economy that has been pushing Qatar to diversity its economic base in order to achieve a more balanced development, and to have a variety of sources of income. Part of this effort aims at developing and improving the agriculture sector and achieving food security (FAO, 1981; al-Rufaai, 1989; el-Mallakh, 1985; IDTC, 1979; al-Nasr, 1998). The following is a discussion of the specificity of this sector in Qatar. The major agricultural objective in Qatar was to reach self-sufficiency by the end of 2000. This aim is considered by many as too optimistic if not unattainable (al-Kuwari, 1996; al-Mohannadi, 1997a; Ahmad and al-Faqeh, 1999). Limited cultivable land, unsuitable climate, shortage and expense of irrigation water and shortages of skilled farm labour are among the many problems facing the government in its efforts to develop and increase the productivity of the sector (Hashim, 1995; MMAA, 1997c; AOAD, 1994; al-Nasr, 1998; al-Sumori, 2001b).

In spite of these difficulties, the government, through the adoption of several measures to stimulate the sector, has succeeded in achieving some improvements. These measures include maximum utilisation of the available agricultural resources, improvement of soil quality, establishment of model farms for agricultural guidance (e.g. al-Mashabiya Palm Tree Project), provision of technical assistance, setting up of groundwater pumps, provision of equipment for ploughing the land and free-of-charge veterinary services (Nafi, 1984; GCC, 1996b; MMAA, 1997a; MMAA, 1997b; al-Nasr, 1998).

In 1956, the number of farms was 119 (el-Arifi, 1998) with a land area of 85.4 hectare (ha) (el-Mallakh, 1985). By 1980, this had expanded to reach a total of 603 farms and a land area of 2,385.8 ha (CSO, 1981; Shalan, 1981; al-Kuwari, 1996). This increase continued steadily until 1997, when a sharp rise in the number of active farms to occurred, reaching a total of 926 and a total land area of 11,509.6 ha (Figure 5.10 and Table 5.4) (CSO, 1998; PC, 1999a; Ahmad and al-Faqeh, 1999). Yet, this expansion in agriculture caused massive pressures on the groundwater resources of the country (Judah, 1994; al-Nasr and al-Sheeb, 1999; al-Sumori, 2001b).

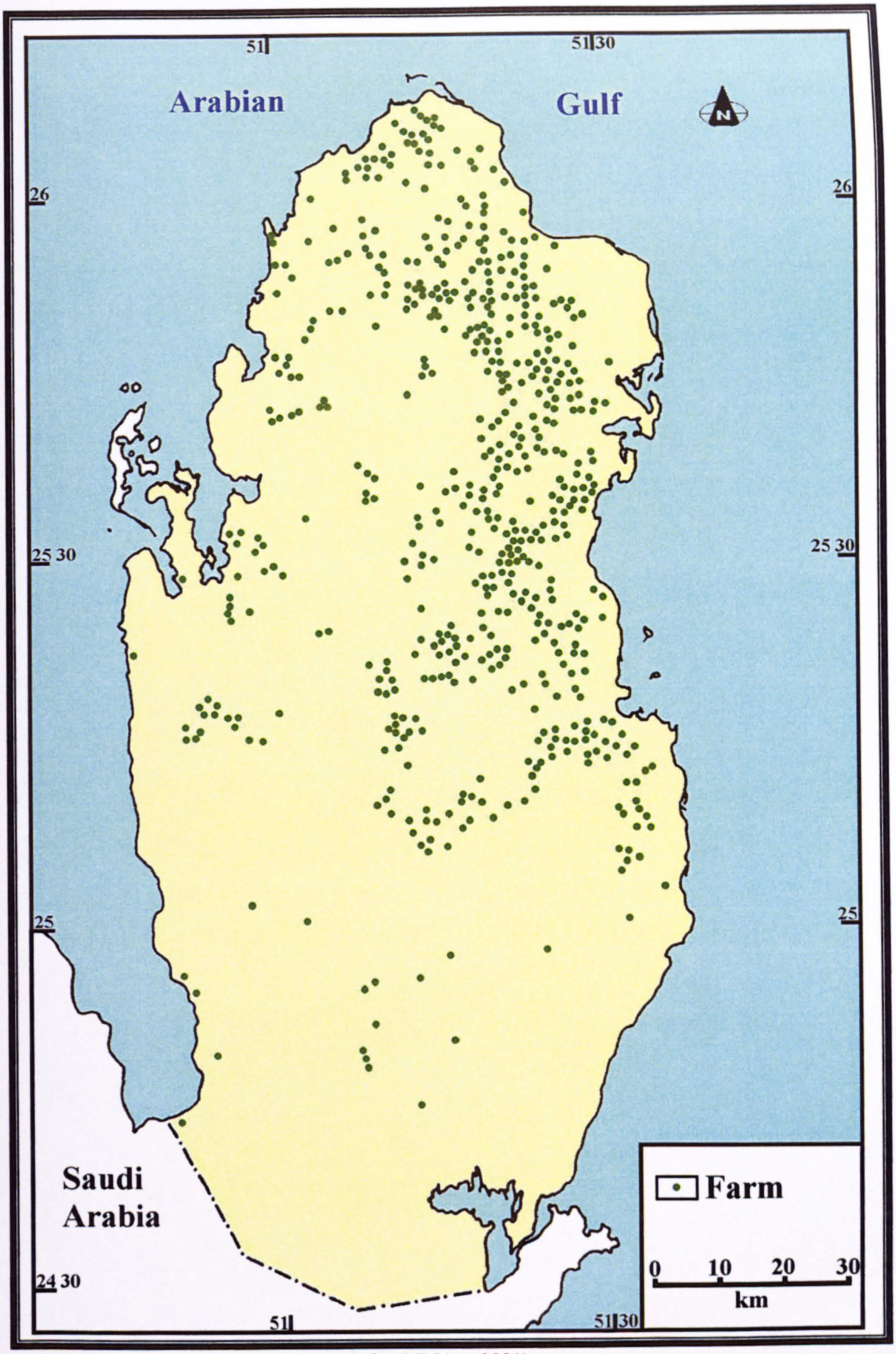

Figure 5.10. Farm Distribution in Qatar (After MMAA, 2001).

Table 5.4. Agricultural Land Utilisation (Hectare) (CSO, 1981[a]; CSO[b], 1983; CSO[c], 1987; CSO[d], 1988, CSO[e], 1991; CSO[f], 1998; PC[g], 1999a).

Year	Cultivable Lands						
	Cultivated Lands						Un-cultivated Lands
	Cereals	Vegetables	Fruits	Dates	Green Fodder	Total	
1973[a]	76.2	941.3	140.0	---	310.0	1,467.5	31,532.5
1974[a]	93.5	970.3	143.2	---	319.0	1,526.0	31,474.0
1975[a]	105.0	981.2	146.1	---	321.5	1,553.8	31,446.2
1976[a]	156.9	1,076.7	147.5	---	322.5	1,703.6	31,296.4
1977[a]	170.8	1,316.7	158.5	---	334.7	1,980.7	31,019.3
1978[a]	181.5	1,384.0	160.0	---	340.0	2,065.5	30,934.5
1979[b]	220.0	1,732.0	207.7	775.0	275.0	3,209.7	29,790.3
1980[b]	244.0	1,550.8	241.0	805.0	350.0	3,190.8	29,809.2
1981[b]	259.3	1,627.2	270.9	829.1	361.5	3,348.0	29,652.0
1982[c]	363.8	1,325.8	640.4	676.7	384.5	3,391.2	29,608.8
1983[c]	272.6	1,088.3	667.8	705.6	396.7	3,131.2	29,868.8
1984[c]	347.8	1,615.1	750.1	731.2	432.8	3,877.0	29,123.0
1985[c]	477.1	1,412.8	656.5	804.3	482.3	3,833.0	29,167.0
1986[c]	606.5	1,557.8	646.7	877.5	531.8	4,220.3	60,779.7
1987[d]	927.6	1,547.3	672.0	896.0	792.1	4,835.0	60,165.0
1988[e]	998.6	1,767.9	707.9	898.5	841.5	5,214.4	59,785.6
1989[e]	1,074.1	2,067.9	490.4	966.7	1,099.3	5,698.4	59,301.6
1990[e]	1,082.3	2,151.5	443.3	996.7	1,032.1	5,705.9	59,294.1
1991[f]	1,348.2	2,290.1	457.8	1,297.9	1,498.4	6,862.4	58,107.6
1992[f]	12,308	2,563.0	505.3	1,537.3	1,751.0	7,587.4	57,412.6
1993[f]	1,761.5	2,344.6	531.2	1,627.7	1,860.0	8,125.0	56,875.0
1994[f]	1,243.1	2,425.1	547.7	1,700.4	2,080.7	7,997.0	57,003.0
1995[f]	1,334.9	3,023.9	596.5	1,823.7	2,045.6	8,824.6	56,175.4
1996[f]	1,538.3	3,056.4	707.7	1,897.4	2,355.0	9,554.8	55,445.2
1997[g]	1,708.5	3,717.1	705.4	2,566.8	2,811.8	11,509.6	5 3,490.4

(--- Unavailable Data).

The pattern of land use for different crops for the year 1997 was as in Figure 5.11.

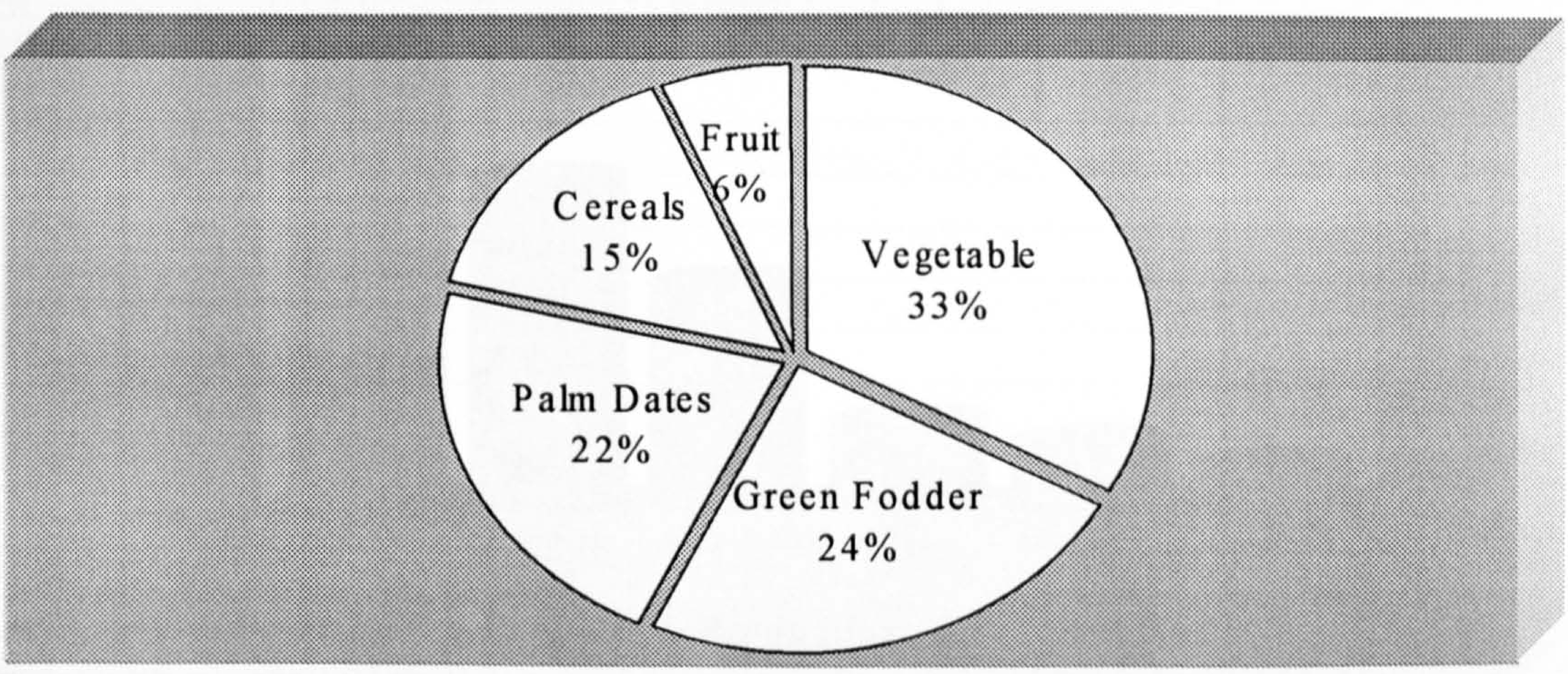

Figure 5.11. Land Use for Different Crops (PC, 1999a).

Table 5.5 indicates the food production, area and yield for major groups in Qatar in 1997.

Table 5.5. The Food Production for Major Groups in Qatar (PC, 1999a).

Crop/Kind	Area (Hectare)	Yield (Ton/Hectare)	Production (Ton)
Cereals	1,708.5	0.034	5,765
Vegetables	3,717.1	0.155	57,515
Fruits	474.0	0.0361	1,712
Date Palm	1,909.6	0.12	22,915
Green Fodder	2,811.8	0.835	234,802
Red Meat			3,557
Poultry Meat			3,259
Fish			5,032
Eggs			4,024
Milk & Dairy Products			35,323

The most important progress made by the government so far has been in vegetable production. Qatar meets 70% of the demand for vegetables in summer and more than 40% in winter. Dairy products grew significantly, increasing more than five times from only 6,208 tons in 1982 to 35,323 tons in 1997. Cereal products, which represent 50% of the Qatari diet, have increased but are still minimal. Egg production has risen to over 1.5 million per year, while the stock of chickens totals one million. Despite this, Qatar is still highly dependent on imports to meet the demand for all foodstuffs (Figure 5.12) (MMAA, 1997a; EIU, 1999). Imports of foodstuffs and live animals represented 8.9% of total imports in 1997 and the export was only 0.20% (76.6% live animals) of total exports in the same year (PC, 1999a).

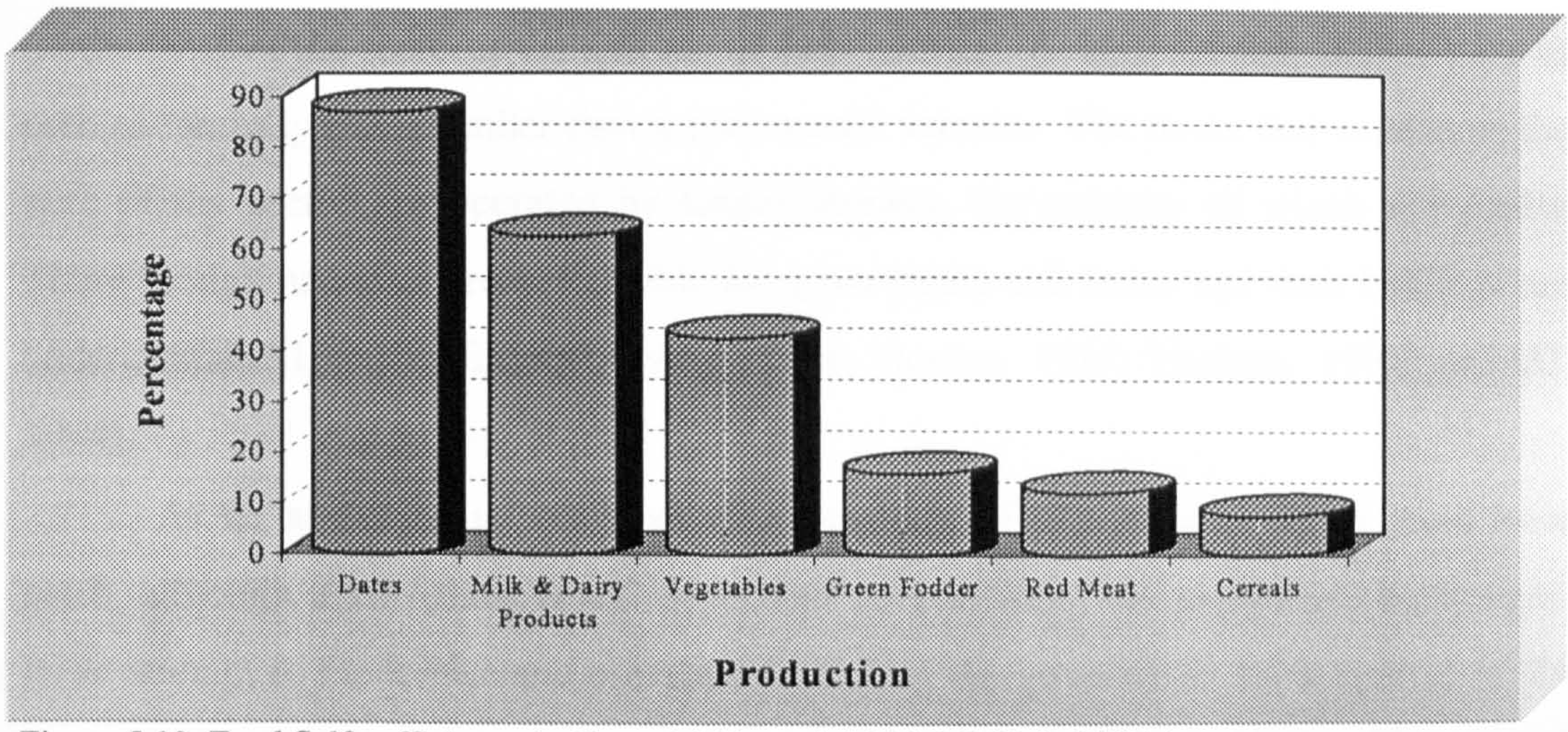

Figure 5.12. Food Self-sufficiency in Qatar (al-Kuwari, 1996; MMAA, 1997a).

In 1998, the agriculture and fishing sector comprised only 0.78% ($82.1 million) of gross domestic product (Figure 5.13) (PC, 1999a).

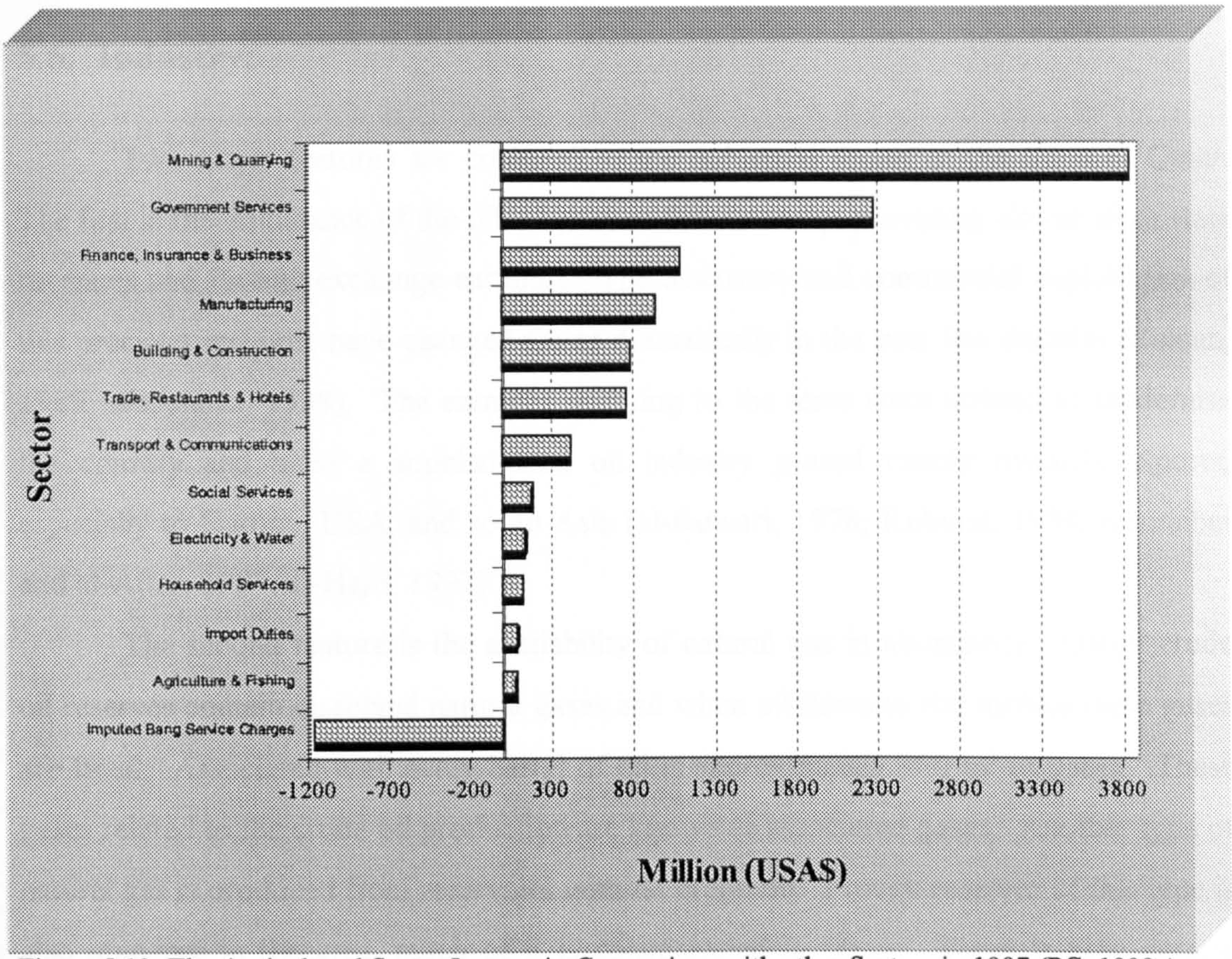

Figure 5.13. The Agricultural Sector Income in Comparison with other Sectors in 1997 (PC, 1999a).

Another major problem facing the government in its attempt to increase the productivity of the sector is the attitude of farm owners. A large number of farms are as seen as "amenity farms" rather than a commercial venture. The farms that constitute the core of the sector are operated by tenant farmers, the majority of which are Arabs. These foreign nationals are not eligible for government soft loans and their holdings are undercapitalised and inefficient (Nyrop, 1984; Besesu, 1987; Hashim, 1995; AOAD, 1994).

As far as fishing is concerned, 80% to 90% of the demand is met from local catch, although most fishing is still dependent on traditional techniques and equipment. In an attempt to modernise and prevent over-fishing the government took control of the Qatar National Fishing Company in 1980 (Nyrop, 1984; al-Kuwari, 1996). That helped to reduce the fish catch slightly. Some experimental fish farms have been started (MMAA, 1997c).

5.6. Industry:

Two major features are common to the industrial sector in the State of Qatar. The first is the dominance of the oil industry in the economy, providing almost all of state revenues and foreign exchange earnings. The discovery and commercial exploitation of this precious resource have changed Qatar dramatically in the past few decades (Zahlan, 1989; Abdulaziz, 1998). The earnings accruing to the state were utilised to modernise the country and build a sophisticated oil industry geared mainly towards exports, especially to Europe, USA, and south Asia (al-Kuwari, 1978; Kubursi, 1984; Khuraibet and al-Attar, 1997; al-Hajri, 1997).

The second feature is the availability of natural gas in abundance. Qatari crude oil reserves contain dissolved natural gases and when oil flows to the surface these gases are freed. Associated with every barrel of oil is approximately 500 m^3 of gases. These gases related to the crude oil production are known as associated gases. Another type of natural gas is produced from reservoirs with no crude oil. Proven reserves of this type is also immense in the area, much of it is concentrated in Qatar. There is now greater effort on the part of the government to develop the potential of natural gases as part of the policy of industrial diversification. Qatar, like the other Gulf states is aware of the need to diversity, since oil revenues can not last for ever and finding alternative sources of income is essential (al-Kuwari, 1996; Besesu, 1987; Aolund, 1998; al-Hajri, 1997).

Oil was discovered in Qatar in January 1940 but due to Second World War, commercial production did not start until December 1949 from onshore fields and 1960 from offshore fields. Since then, oil production has become the backbone of the economy and had profoundly changed the lifestyle and rate of development in Qatar (Melamid, 1972; Beaumont *et al.*, 1976; al-Kuwari, 1978; Metualy, 1981b; al-Kuwari, 1999b). In 1999, 40.2% of gross domestic product was derived from the export of crude oil, the bulk of which goes to Japan and other Far Eastern countries (Figure 5.14) (Shmisani, 2000).

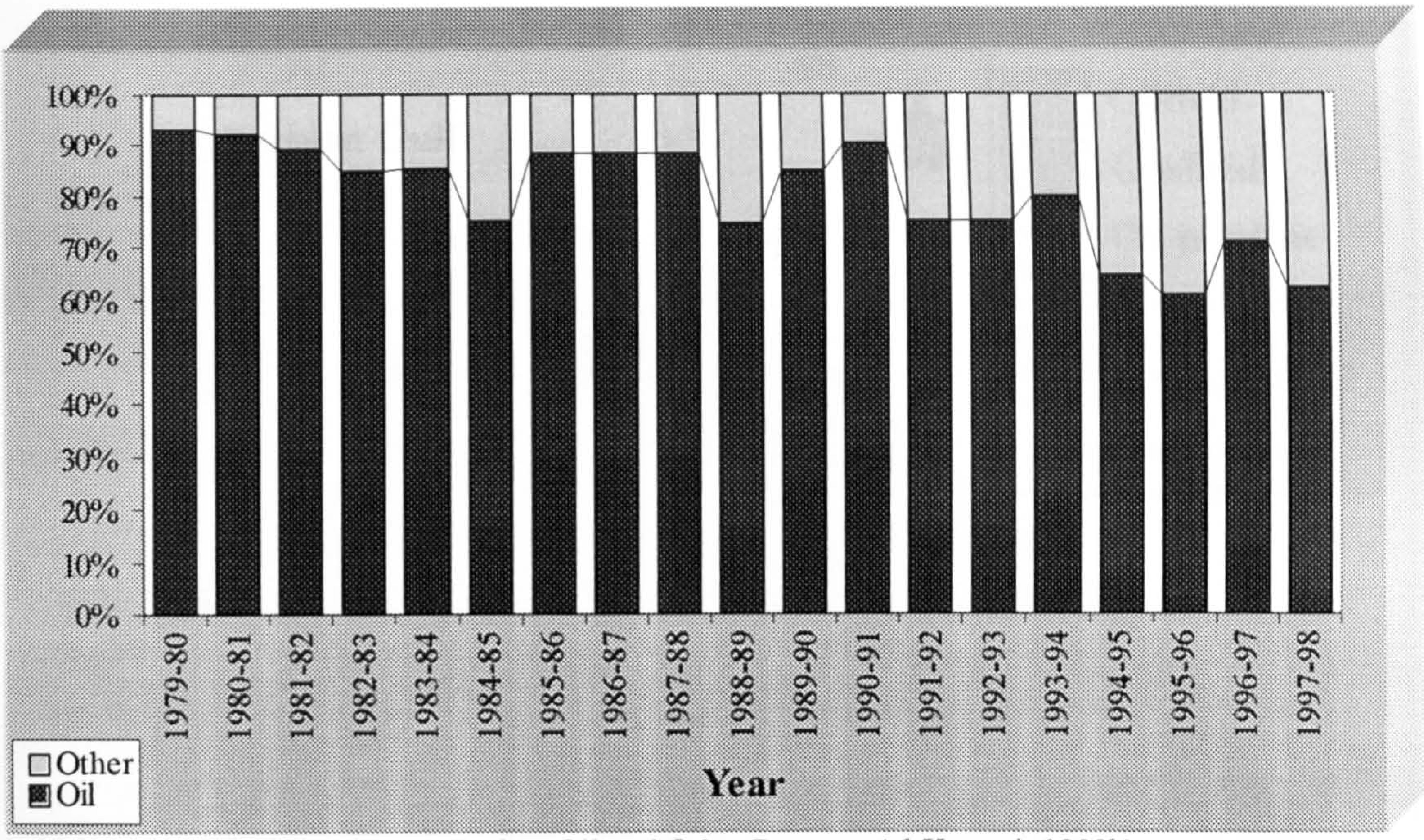

Figure 5.14. Qatar Government Budget Oil and Other Revenue (al-Kuwari, 1999b).

Onshore production comes from the Dukhan field (1940) (specific density is 40.9° with a sulphur content of 1.1%) on the western side of the peninsula. Offshore production (specific density is 34° with a sulphur content of 1.54%) comes from several fields to the east. The first offshore oil field was discovered at Id al-Shargi in 1960. Maydan Mahzam was found in 1963, Al-Bunduq in 1964 (this field is shared equally with the Emirate of Abu Dhabi), Abu Hanine in 1965, Al-Shaheen in 1992, Al-Khalij in 1996 and Al-Rayyan in 1996 (Figure 5.15) (Kubaisi, 1986; QGPC, 1997a; Beaumont *et al.*, 1976; MEI, 1996; EIU, 1999). Moreover, other new fields such as Al-Karkara and Najwat Najem have been discovered but require more studies and development (al-Shafai, 1998a). In 1998, Qatar oil reserves were estimated in excess of 4.5 billion barrels (al-Kuwari, 1999b).

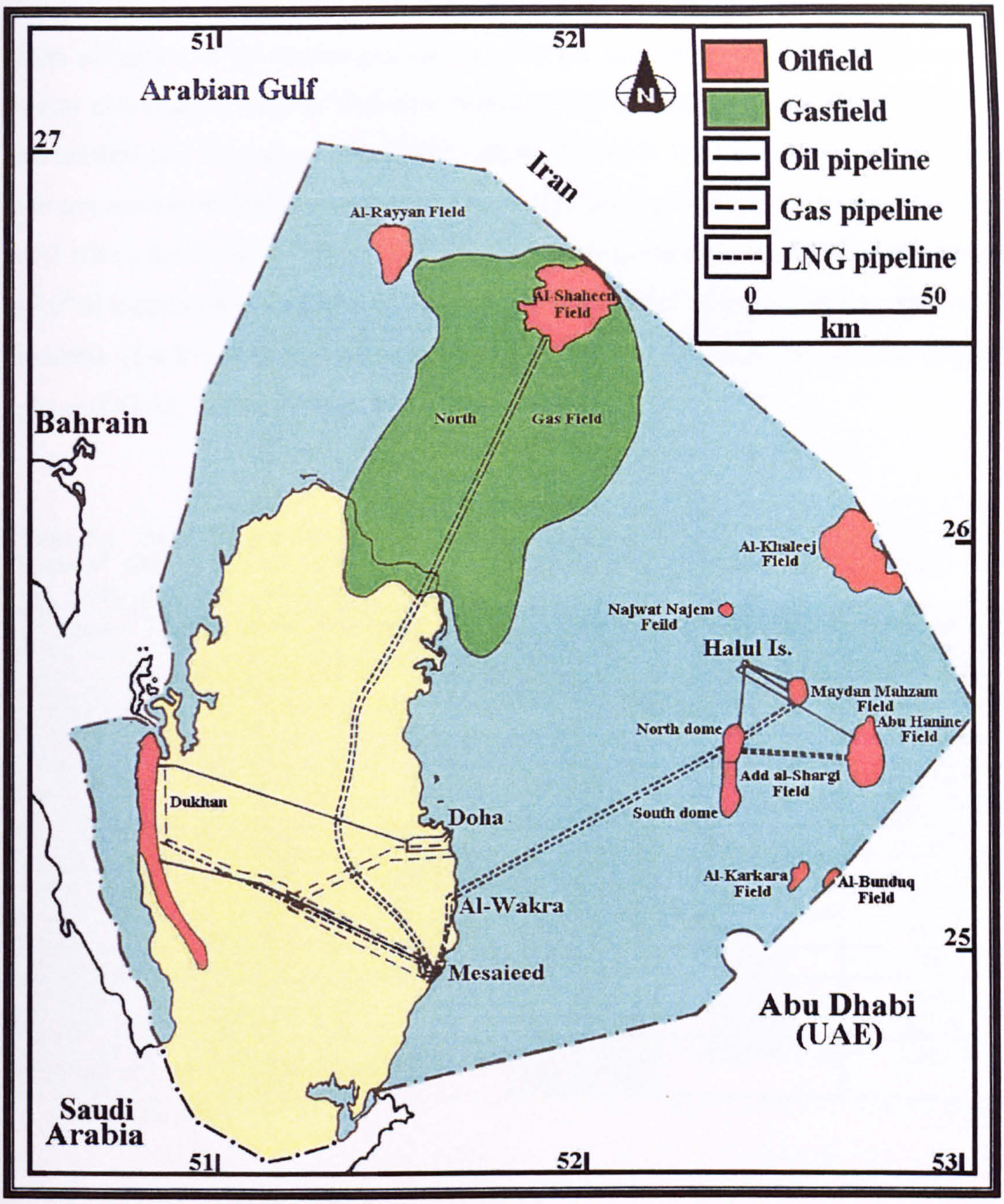

Figure 5.15. Oil and Gas Fields in Qatar (After al-Shafai, 1998a).

By 1949 Qatar's oil production was estimated at 1,000 barrels/day (bd^{-1}) (Table 5.6) (al-Otaiba, 1975). Average production in 1999 was some 630,000 bd^{-1} (al-Kuwari, 1999b) and this is expected to reach about 1 million bd^{-1} by the years 2000 (EIU, 1999). Much of the increase in output has come from offshore fields, where foreign companies are active (EIU, 1999; al-Shafai, 1998a). In addition, some 1,333.3 bf^3 of associated natural gas are produced 1999 by onshore and offshore oil and gas fields (PC, 2000). Up until the 1963, most of Qatar's associated gas was destroyed by an explosion and fire. First utilisation of associated gas was in 1963 for gas driven electricity generation and water desalination plant at Ras Abu Abboud (RAA). To overcome this waste, Qatar established two natural gas liquefaction plants (NGL) in 1975 and 1980, one to process the gas associated with the onshore oil field of Dukhan (reserves are estimated in excess of 2 billion barrels with 7 tf^3 and the second to process gas associated with offshore fields (5 tf^3 of associated gas without North Field). The amount of natural gas production will increase to 4.8 million tons per day by 2002 when the complete the third development phase (QGPC, 1997a; Aolund, 1998; EIU, 2000).

Table 5.6. Crude Oil and Natural Gas Production in Qatar, Selected Years (al-Otaiba[a], 1975; el-Mallakh[b], 1985; al-Kuwari[c], 1978; EIU[d], 1993; EIU[e], 1995; EIU[f], 1999; EIU[g], 2000; al-Shafai[h], 1998a; PC[i], 1999a; al-Kuwari[j], 1999b; PC[k], 2000).

Year	Crude Oil (bd^{-1})	Natural Gas (bf^3a^{-1})	Year	Crude Oil (bd^{-1})	Natural Gas (bf^3a^{-1})
1949	1,000[a]	---	1987	291,000[e]	---
1950	33,600[b]	---	1988	319,000[e]	---
1955	115,000[b]	---	1989	320,000[e]	---
1960	177,200[a]	---	1990	406,000[e]	242.0[c]
1965	232,600[a]	---	1991	391,000[e]	295.1[h]
1970	362,400[a]	131.0[h]	1992	423,000[f]	426.2[h]
1975	437,000[a]	146.0[h]	1993	412,000[f]	401.7[i]
1980	471,400[j]	224.0[b]	1994	412,000[f]	380.0[I]
1981	391,000[j]	222.0[b]	1995	422,000[f]	412.3[i]
1982	328,000[j]	212.0[b]	1996	490,000[f]	458.6[i]
1983	294,000[j]	---	1997	620,000[f]	468.3[i]
1984	402,000[j]	---	1998	680,000[f]	928.8[i]
1985	290,000[j]	214.5[h]	1999	630,000[g]	1,333.3[k]
1986	314,000[d]	---			

(---Unavailable Data).

More significant reserves of natural gas are located in the North Field. This field discovered in 1971 but the exploration was in 1987 and production delayed until 1991 due to technical problem and the Second Gulf War. The first shipment was to Japan in 1996. Its proven reserves are estimated at 500 trillion f^3, one of the largest reserves of non-associated in the world, equivalent to 6.4% of the world's proven natural gas reserves. The development of this resource has been hindered by several factors. Most important among them is the uncertainty of markets, since many large scale projects for using natural gas have been taken place in Australia, Canada and Indonesia. Despite that Qatar looks at its natural gas as the key for its future (QGPC, 1994; Nyrop, 1984; Aolund, 1998). The first phase completed in 1992, produced 22.6 Mm^3 of liquefied natural gas (LNG) and approximately 50,000 bd^{-1} of condensates. The second phase aimed to produce 22 Mm^3 and there is third phase to produce 22.6 Mm^3 (EIU, 1999).

There are other less important natural resources which provide opportunities for development, such as extremely salty water (sodium chloride, manganese, magnesia and barium), gypsum, limestone, clay, shale and sand (al-Shafai, 1998a; MEI, 1996).

The Qatari government has actively involved in diversification of the economic base in order to reduce its dependence on oil as the single most important source of income. In 1973 it set up the Industrial Development Technical Centre with the aims of identifying, co-ordinating, and monitoring the development of non-oil based industries. The government also provides a variety of incentives to investors such as credit at concessionary interest rates, services at cost, equity participation in large projects, exemptions from income tax and import duties and preferential purchasing by the government from Qatari industries (QGPC, 1997a; al-Kubaisi, 1986; IDTC, 1979). In addition the government has been involved in setting up the Mesieed industrial zone, the oil terminal south of Doha where oil and gas from Dukhan is available as sources of industrial energy. This area accommodates oil refinery, petrochemical plant, fertiliser complex, natural gas plant, steel mill, salt plant and terminal's oil reception and export facilities. The second industrial area is Ras Laffan north of Doha to accommodate gas based industries. The third is Doha industrial area set up for light and medium industries. In addition to these three areas, several other areas have been selected to specific industries. Among the most important of these industries are Cement Plant in Umm Bab, Sand Washing Plant in Al-Karaanah, Quarries Plant in Umm al-Afai, Compost Fertiliser Plant in Neijah (Figure 5.16) (MEI, 1996; al-Shafai, 1996; EIU, 1998b).

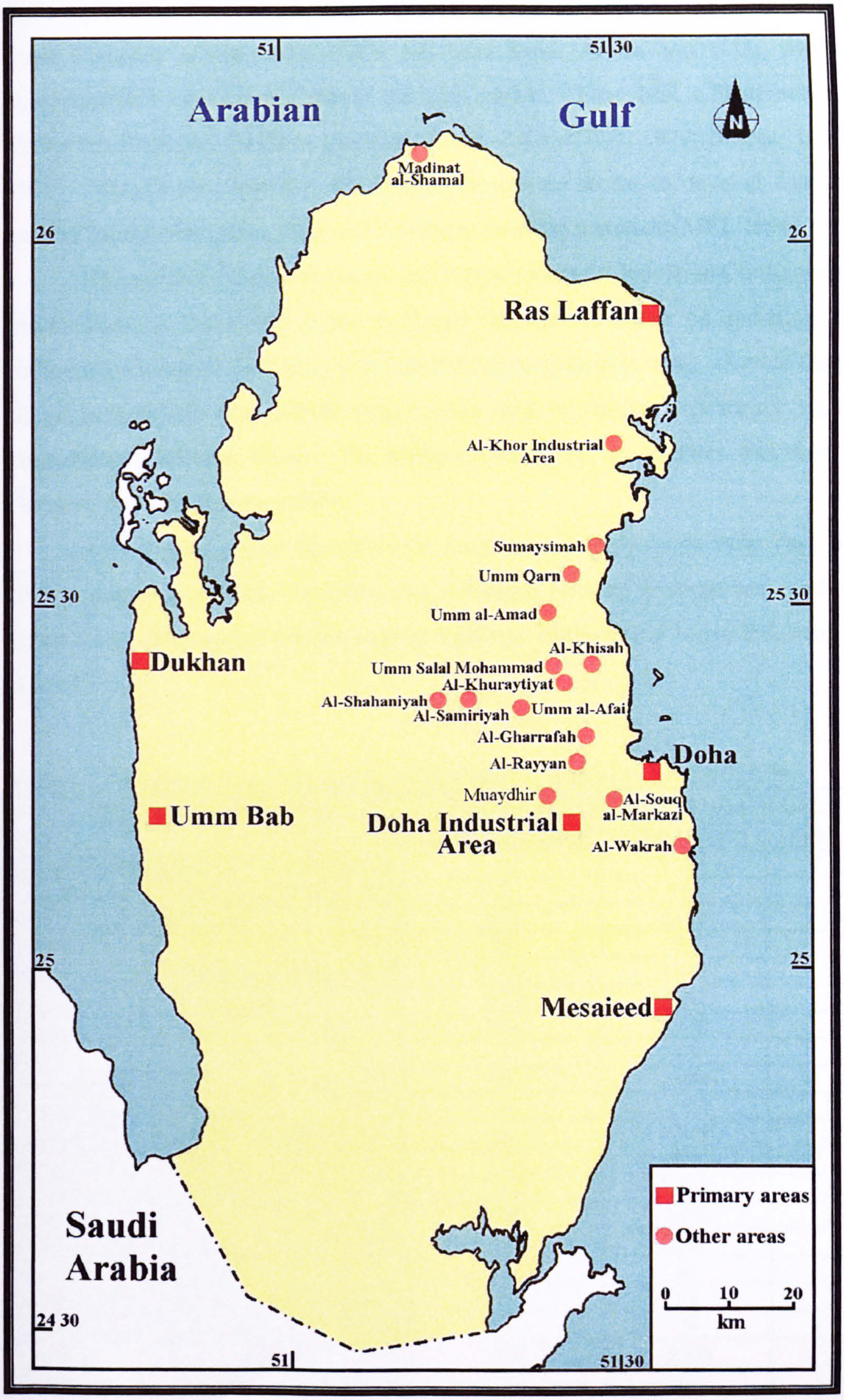

Figure 5.16. The Industrial Areas in Qatar (After al-Shafai, 1998b).

Consequently, there has been an expansion in industrial production, especially since the 1970s. Some of the most important economic ventures include Qatar Iron and Steel Company whose main market has been Saudi Arabia and UAE, two cement companies that meet the demands of the local market, a Flour Mill, a Pharmaceutical and Cosmetics Plant and Fertiliser Company (MEI, 1996; IDTC, 1979; Besesu, 1987; Key, 1976). The Government also encouraged the private sector to develop light industry such as paints, detergents, food and beverages, building materials (MEI, 1996).

The establishment of the Arab Gulf Organisation for Industrial Constancy with its headquarters in Doha was meant to herald the start of better co-operation and co-ordination among the Gulf states for industrial development in order to avoid duplication of projects which was already taking place and to reduce dependence on foreign consultants (al-Shafai, 1996). The effectiveness of this organisation has been limited (Besesu, 1987; al-Kuwari, 1996).

In summary, Qatar has moved a long way away from its early days of pearl diving, fishing and simple manufacturing industries catering to consumer need such as metal ware, clothing and kitchenware to high-tech medium and heavy industries (Table 5.7).

Table 5.7. Establishments and Persons Engaged by Economic Activity for 1997 (PC, 1999a).

Economic Activity	No. Establishments	No. Persons Engaged	Gross Output (000 USA $)
Extraction of Crude Oil & Natural Gas	33	8,787	5,421,887
Other Mining & Quarrying Activities	11	650	20,717
Food Product & Beverages	273	2,870	140,326
Textiles	81	203	3,273
Wearing Apparel, Dressing & Dying of Fur	1,198	9,482	131,727
Tanning & Dressing of Leather	1,198	9,482	2,817
Wood & Cork Products	431	2,175	23,343
Paper	5	45	1,135
Publishing & Printing	21	1,083	40,004
Refined Petroleum Products	3	1,404	559,812
Chemicals & Chemical Products	26	1,534	286,592
Rubber & Plastic Products	8	210	6,227
Other Non-metallic Mineral	101	4,130	207,524
Basic Metal Industries	34	1,408	198,903
Fabricated Metal Products	308	2,747	72,822
Machinery & Equipment	3	85	5,452
Motor Vehicles, Trailers & Semi-trailers	2	41	592
Other Transport Equipment	3	14	174
Furniture	215	2,108	49,985
Recycling	1	58	459

5.7. Conclusion:

Fast development in Qatar after oil production has meant that exceptional growth took place in a variety of economic activities. After the first commercial production of oil in 1949, Qatar experienced rapid socio-economic development and a massive increase in population with some natural increase and enormous labour migration to satisfy an ever-expanding labour market. Today, foreign labour constitutes more than three quarters of the population of Qatar. The increase in per capita income, especially after the boom in oil prices during 1970s and early 1980s, in addition to industrialisation, led to heavy consumption in water and conspicuous consumerism in general. Furthermore, the Government policy of food self-sufficiency caused a massive drain on groundwater, without actually being able to achieve its aims.

CHAPTER SIX:

WATER RESOURCES, PRODUCTION AND DEMAND IN QATAR

Chapter Six:

Water Resources, Production and Demand in Qatar

6.1. Introduction:

In this chapter the focus is on water resources, production and demand in the State of Qatar. The first section will present water resources (groundwater, desalination and recycling) focusing on production levels. The second section discusses water demands and the various uses of water (agricultural, residential, governmental, commercial and industrial) (Figure 6.1).

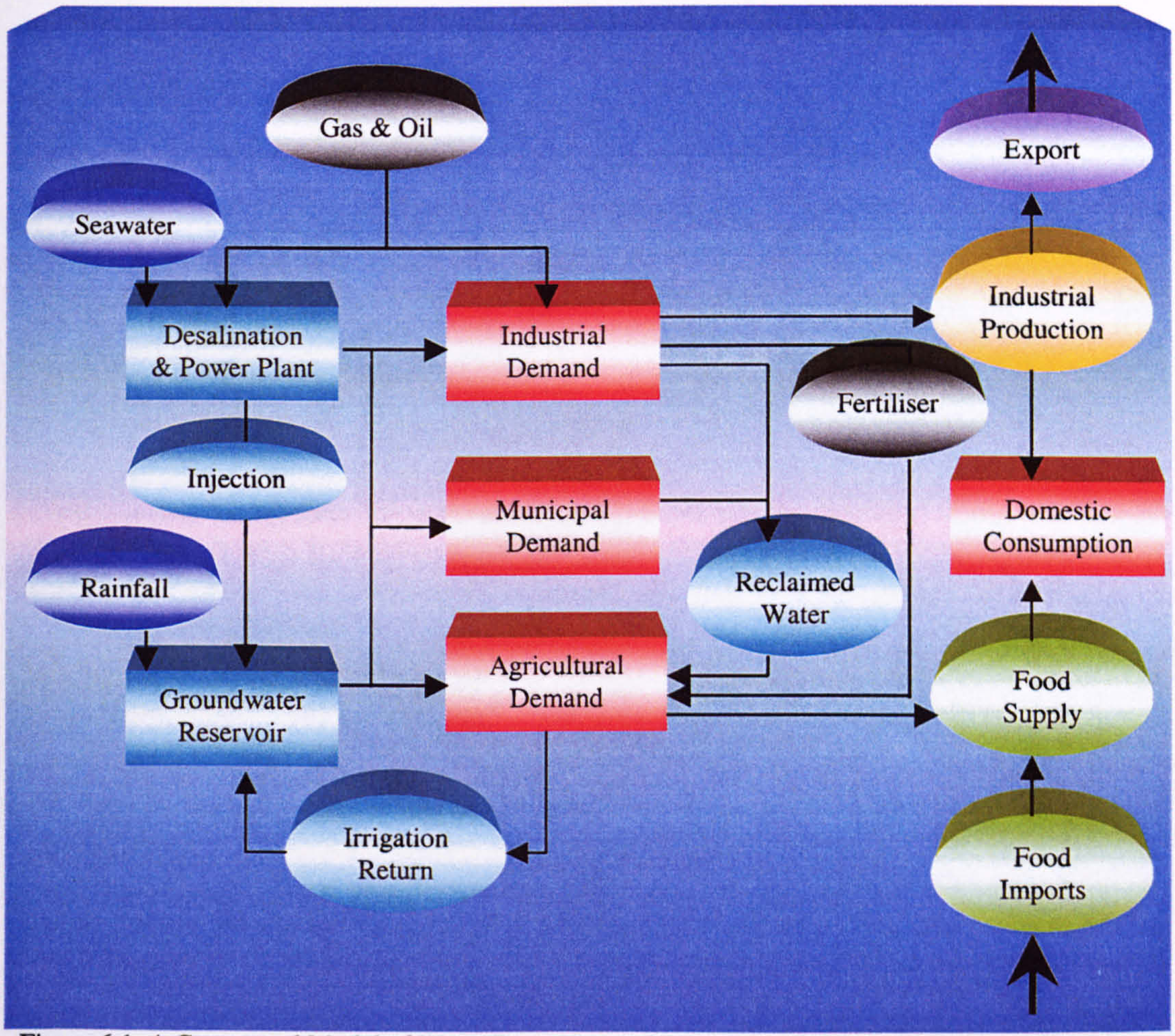

Figure 6.1. A Conceptual Model of Water Resources and Demand in Qatar (After FAO, 1977).

6.2. Water Resources:

6.2.1. Introduction:

Generally, Qatar suffers from lack of natural water resources, a common feature shared by most arid and semi arid areas (al-Biati, 1998a; Harhash and Yousif, 1985; al-Alawi and Abdurazzak, 1994). To meet the needs of its population and development the responsible ministries (Figure 6.2) come to depend on three major sources; firstly, shallow groundwater which is recharged primarily by percolating rainfall and deep fossil groundwater (Abdurazzak, 1995; Kotoub and Abdulrab, 1995), 25,000 to 30,000 years old (Jones and Dutton, 1983), secondly, on the desalination of seawater from the surrounding Arabian Gulf and brackish groundwater, accounting for the major part of domestic water supply, and thirdly on recycling. This third water source is used for irrigation of certain agricultural products, such as livestock feed vegetation and landscape irrigation (Figure 6.3) (al-Mugran, 1992; Kotoub and al-Mahmoud, 1997; al-Mohannadi, 1997a).

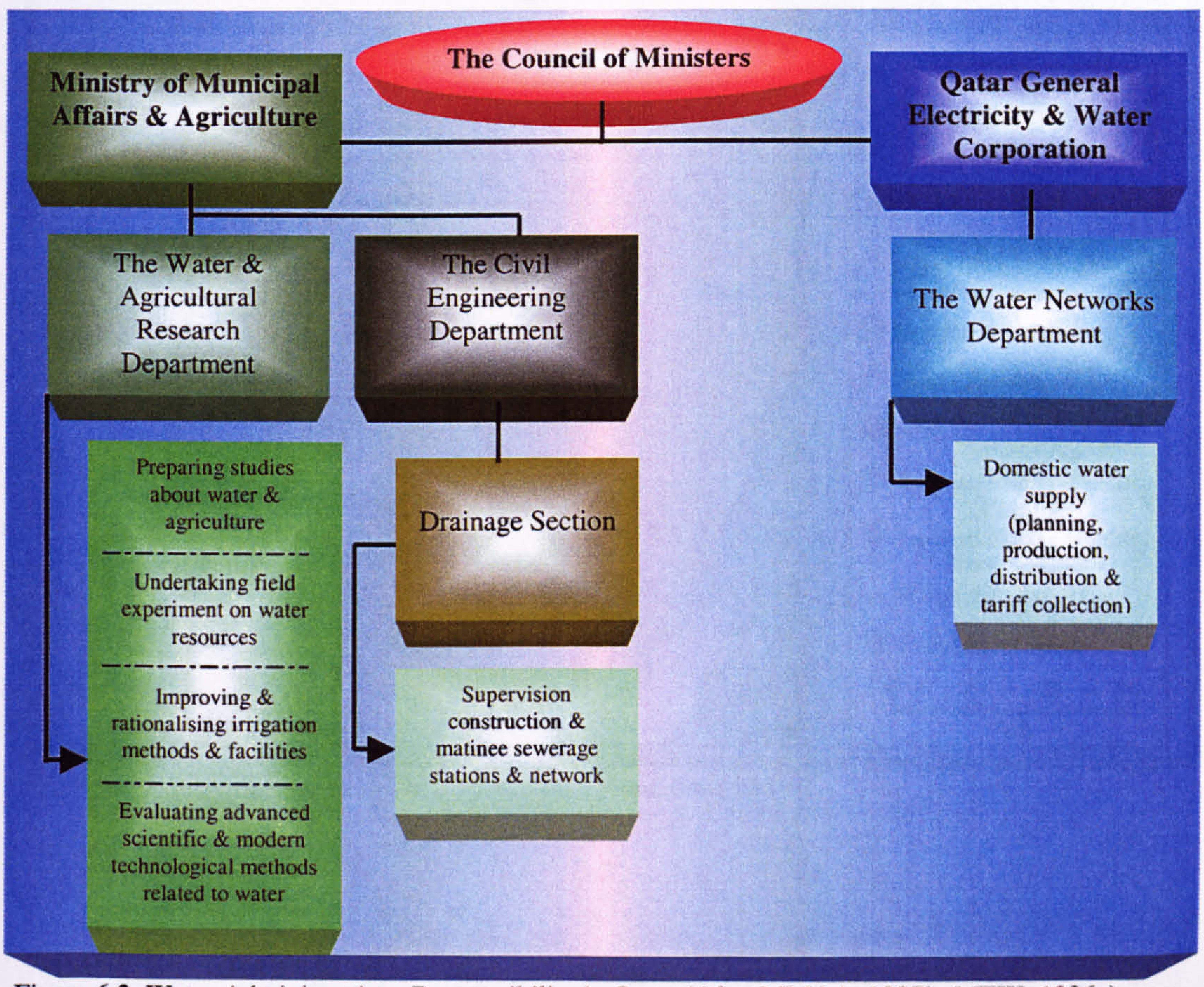

Figure 6.2. Water Administrations Responsibility in Qatar (After MMAA, 1997b; MEW, 1996a).

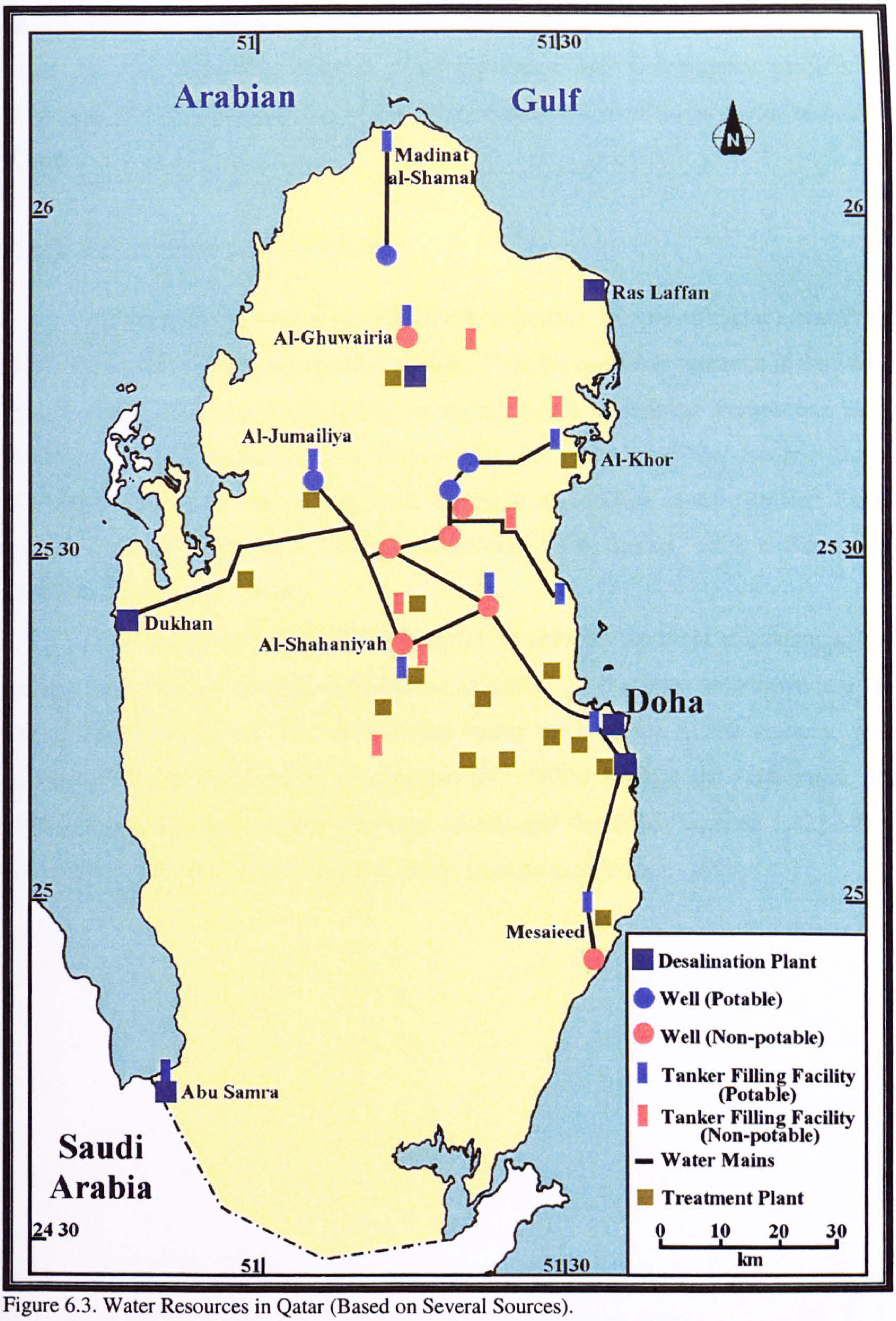

Figure 6.3. Water Resources in Qatar (Based on Several Sources).

Taking account of this difficult situation, the State of Qatar will be obliged to rely in the future on technologically extracted freshwater through desalination, in order to meet the ever increasing demand of its population and development projects. The following is detailed discussion of the above mentioned three major water resources for Qatar.

6.2.2. Groundwater Resources:

Groundwater constituted, until 1954, the major source of Qatar's water supply for both domestic and agricultural purposes. This groundwater resource is derived from three primary aquifers (from lower to upper) in the underlying Palaeocene Umm er Radhma (UER) Formation, the Eocene Rus Formation and the Eocene Dummam Formation; these are an extension of the regional aquifers in the Arabian Peninsula (Section A2.2) (FAO, 1981; Streetly and Kotoub, 1998; Shahin, 1989; al-Bassam *et al.*, 1997; al-Mohannadi, 1997b).

The freshwater of the northern reservoir remains the most important source of water, especially for meeting the needs of irrigation. It has been withdrawn at a rate of 291.5 Mm^2a^{-1} or about 74% of the total water consumption in the country, with an estimated cost at \$0.06 per m^3 (Figure 6.4) (PC, 1999a; Hashim and Abdulmalik, 1999). The groundwater table is dropping very quickly and the deficit reached 1,121.323 Mm^3 in 1996/97 (MMAA, 1997c; al-Diab, 1994; Hashim and Ibrahim, 1999).

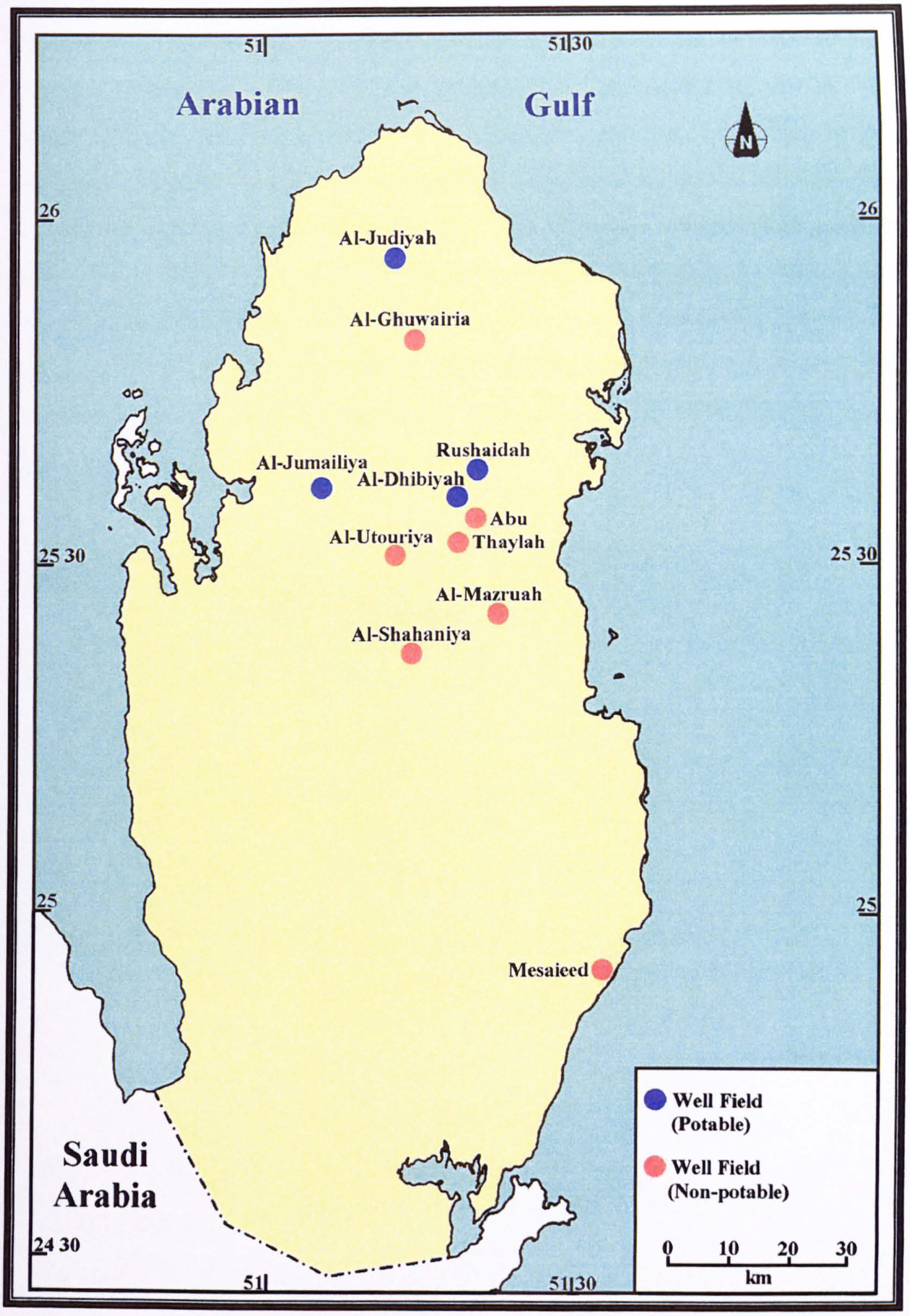

Figure 6.4. The Location of the Main Groundwater Fields (After MEW, 1996a).

Up until the middle of this century groundwater was the only source of freshwater in Qatar. This source was enough to meet the minimum needs of people. Despite finding other sources, dependency on groundwater has increased substantially (Table 6.1) (Babikir, 1998b). In 1960 groundwater pumping did not exceed 4 Mm^3, of which 25% was used for domestic and the rest for agriculture. Production in 1970 was 38 Mm^3, of which only 5% went to municipal uses. By 1980 production was 65.4 Mm^3 of which about 2% was for municipal uses. By 1998 groundwater production reached 294.28 Mm^3 which only about 0.94% was for municipal uses (Judah, 1994; Hashim and Abdulmalik, 1999; CSO, 1998). In other words, production over a span of 38 years increased 74 times. It is estimated that groundwater supply will be depleted in 20 to 30 years if the present rates of groundwater withdrawal continue (Jones and Dutton, 1983; Marcoux, 1996).

Table 6.1. Groundwater Withdrawal for Domestic and Agricultural Sectors (Judah[a]; 1994; Hashim and Abdulmalik[b], 1999; PC[c], 1999a).

Year	Domestic (Include OR Desalination)	Agriculture	Total
1960	1,000,000[a]	3,000,000[a]	4,000,000
1965	1,200,000[a]	22,000,000[a]	23,200,000
1970	2,000,000[a]	36,000,000[a]	38,000,000
1975	5,400,000[a]	48,000,000[a]	53,400,000
1980	1,500,000[a]	66,964,000[b]	68,464,000
1985	1,900,000[a]	96,902,000[b]	98,802,000
1990	2,400,000[a]	137,709,000[b]	140,109,000
1995	2,970,000[c]	220,736,000[b]	223,706,000
1996	2,730,000[c]	234,437,000[b]	237,167,000
1997	2,720,000[c]	267,850,000[b]	270,570,000
1997-1998	2,790,000[c]	291,408,000[b]	294,198,000

For the Qatari government, halting the depletion of groundwater is a top priority. Already the Government is using alternative sources of water for irrigation, in particular water from recycling (Agnew and Anderson, 1992; Babikir, 1998b). Also other measures are being taken to use water more efficiently, especially in agriculture. Because rainfall is scarce, and there are no streams in Qatar, the pressure on groundwater will continue especially with the expansion of agricultural development, population, urbanisation and the general development needs of the country (Hashim, 1995; al-Rufaai, 1989; Kotoub and al-Mahmoud, 1997).

6.2.3. Desalination:

The process of desalination involves the production of potable water from saline sources. The range of saline sources extends from seawater to merely brackish water, which is slightly salty for human consumption. The method used for the extraction of freshwater depends on three elements. The first is the type of the saline water resource that is available. The second depends on the quantity required while the third depends on the energy sources available to provide the power for the extraction plants (Mukemer and Hijazi, 1996; Gass *et al.*, 1974; Deming, 1975).

To meet the increase in the demand for water, especially in the domestic sector, the Government in December 1954 constructed its first desalination plant in central Doha. The plant used submerged coil technology and had a production facility of 680 m^3d^{-1}. The number and size of plants have increased in order to meet the demands of a growing population and economy and also to reduce the pressure on its groundwater reservoirs. Another plant was constructed in 1959 using MSF long tube acid dosed single purpose technology, and had production capacity of 1,360 m^3d^{-1}. It was closed down in 1965 (MEW, 1987; MEW, 1994; MEW, 1998).

A new plant was constructed in 1963 in RAA at a cost $4.1 million, which is considered the second most important desalination plant in Qatar in recent days. It was constructed in four stages. The first stage was in 1963 using MSF cross tube polyphosphate dosed single purpose technology with a production capacity of 6,800 m^3d^1. In the second stage (1968) MSF single purpose technology was used, with a production capacity of 9,100 m^3d^{-1}. These two plants were abandoned in 1981 and 1989 respectively (FAO, 1981; el-Mallakh, 1985; MEW, 1985; MEW, 1994; al-Mohannadi, 1998). The two operating plants at present are the ones constructed in phases three and four. Phase three commenced operation in 1973 and phase four in 1977, using MSF single purpose technology, with a capacity of 8 million imperial gallons per day ($mgald^1$) (36,364 m^3d^{-1}) by 4 MSF distillers (MEW, 1994; MEW, 1998). RAA Plant will close by 2003 due to end of its life (al-Attiyah, 2000).

The most important desalination plant in Qatar recently is at Ras Abu Funtas (RAF) (A), which developed over four stages. The first was in 1977-78 at a cost of $199 million. The total undertaking schedule for completion in 1979-1980 was cost $493.3 million. The third was in 1982-1983 at a $118 million and the last in 1995 at a cost of $265.7 million, using MSF dual purpose technology and a total capacity of 70 mgald^{-1} (318,182 m^{3}d^{-1}) by 14 MSF distillers. RAF (B) which constructed in 1994 at a cost of $1,614 million and started production 1997, using MSF dual purpose technology and a total capacity of 33 mgald^{-1} (150,000 m^{3}d^{-1}) by 5 MSF distillers (el-Mallakh, 1985; MEW, 1994; al-Diab, 1994; MEW, 1998). This plant is operating by Qatar Electricity and Water Company (Anon, 2000a; al-Mohannadi, 2000). These two plants are in east and south Doha (Figure 6.5).

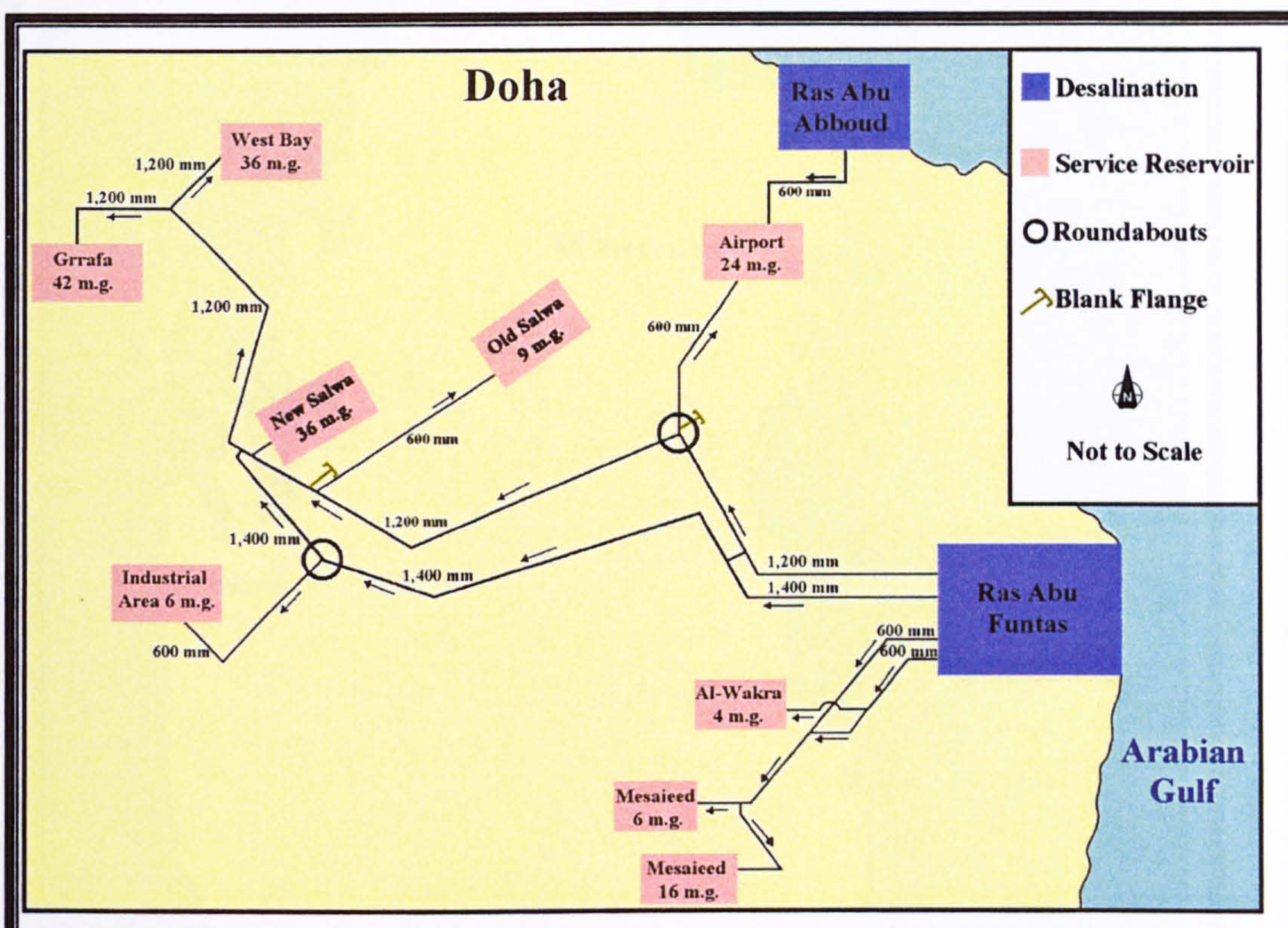

Figure 6.5. Schematic Diagram Showing Distillate Mains, Two Desalination Plants, and Nine Service Reservoirs in the Capital Doha (After MEW, 1996a).

Two other analogous but smaller desalination plants were constructed in the oil area at Dukhan in the middle of the east coast (9,090 m^{3}d^{-1}) and anther one for the new industrial area at Ras Laffan in north coast of country (9,000 m^{3}d^{-1}) (Figure 6.6). In addition, two plants were using (RO) to desalinate brackish groundwater were constructed in distant areas. The first of these plants was constructed in Abu Samra in the southern western part of the country in 1982 with a production capacity of 680 m^{3}d^{-1}

for the border centre and surrounding rural area. Another plant was constructed in al-Shamal Camp in 1993 with a production capacity of 1,100 m^3d^{-1} for the army camp and surrounding rural area (al-Diab, 1994; CSO, 1998; MEW, 1994; al-Mohannadi, 1998).

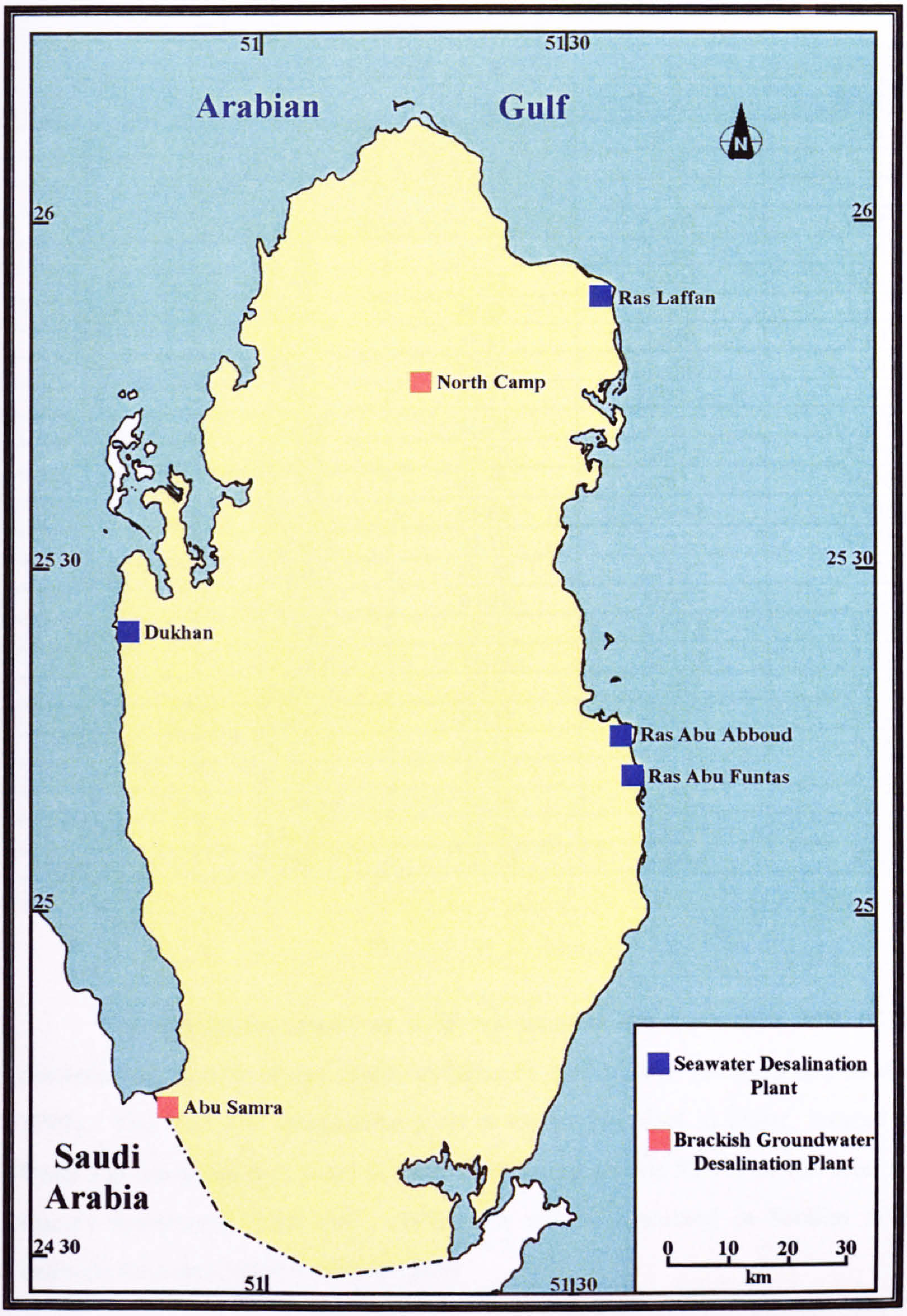

Figure 6.6. The Location of the Desalination Plants (After MEW, 1994).

As shown in Table 6.2, Qatar's production of desalinated water from the main two desalination plants in Doha jumped from 2.48 Mm^3 in 1963 to 131.33 Mm^3 in 1998. In other words, production increased 53 times in 35 years (CSO, 1983; PC, 1999a).

Table 6.2. Desalination Water Production from Two Main Plants (CSO, 1983[a]; Judah[b], 1994; CSO[c], 1988; CSO[d], 1991; CSO[e], 1992; CSO[f], 1997; PC[g], 1999a).

Year	Ras Abu Funtas (A & B)		Ras Abu Aboud	
	MIG	Mm^3	MIG	Mm^3
1963[a]			547.5	2.48
1965[b]			550	2.5
1968[a]			730	3.31
1973[a]			1,460	6.63
1977[a]	2,920	13.27	1,460	6.63
1978[a]	2,920	13.27	1,460	6.63
1979[a]	8,760	39.81	1,460	6.63
1980[a]	8,760	39.81	1,460	6.63
1981[a]	8,760	39.81	1,460	6.63
1982[a]	9,771	44.41	2,591.5	11.77
1983[c]	11,680	53.09	2,920	13.27
1984[c]	11,826	53.75	3,467.5	15.76
1985[c]	13,724	62.38	3,467.5	15.76
1986[c]	15,111	65.68	2,203.8	10.01
1987[c]	14,340.1	65.18	2,365.7	10.75
1988[c]	14,340.1	65.18	2,365.7	10.75
1989[d]	14,789.3	67.22	2,026.7	9.21
1990[d]	15,347.9	69.76	1,779.9	8.09
1991[e]	16,365.6	74.38	1,144.8	5.20
1992[f]	16,941.4	77.0	1,303	5.92
1993[f]	17,667.9	80.30	1,765.3	8.02
1994[f]	18,372.7	83.51	2,148.3	9.76
1995[f]	19,233.7	87.42	2,031.3	8.23
1996[f]	20,326.2	92.39	1,834.5	8.33
1997[g]	21,442	97.46	2,565.9	11.66
1998[g]	27,090.4	123.13	1,804.2	8.20

The desalination plants at RAF will account for more than 96% of the total domestic and potable water supply in Qatar by end of 2000 (Kotoub and al-Mahmoud, 1997). The RAF (A) desalination plant is the largest plant in Qatar, located south of Doha and along the east coast of Qatar, producing almost 93.7% of the total supply of Qatar's desalinated water (PC, 1999a). It will be discussed in Section A3.2 as an example for a desalination plant in Qatar.

Qatar opted to depend on desalination as a major source of water because of the availability of cheap energy, despite the fact that Qatar, compared with other Gulf countries, such as Saudi Arabia, has small oil reserves. Qatar has one of the largest gas fields in the world (North Field) and it is gradually shifting to it as its major source of energy (QGPC, 1997a; Aolund, 1998; el-Mallakh, 1985).

Importantly, the main desalination plants are using for power generation beside water production (MEW, 1998). The total electricity generation in 1999 was about 6,396.7 million kwh^{-1} (PC, 2000). Moreover, Qatar Salt Company established to use seawater and the (more concentrated) outfall water from desalination plants to produce some 2.1 million tons of salt per year (QGPC, 1997b).

6.2.4. Recycling:

The basic process of treatment begins with the flow of wastewater from connection pipeline through a network of gravity sewers to a pumping station. Treatment is initiated after the untreated water is pumped to a sewage treatment plant. Recycled water is directed to the water tower (Helmer and Hespanhol, 1997; Abdulmaqsud, 1981; Pescod, 1992; Ahmad, 1991b).

Qatar has used recycled water from 1971 in order to augment the water supply and at the same time to protect the environment from pollution. If this water is pumped into the sea, it will cause damage. If it is emptied into the desert it might seep into the groundwater and pollute it. In its efforts to conserve its groundwater and at the same time to meet the needs of an expanding agricultural sector, the Qatari government resorted to make huge investments in recycling (Ahmad, 1989; al-Diab, 1994; al-Saeig, Undated). The responsibility of managing these plants is given to the Drainage Division in the Ministry of Municipal Affairs and Agriculture (MMAA). This responsibility involves collecting, treating, and disposing of sewage and surface and groundwater (MMAA, 1994).

Qatar has two main sewage treatment plants which use advanced treatment technology (activated sludge and sand filters). One is at Naijah, south of Doha and the other one is at Saliyah west of Doha (Babikir, 1998b). These modern plants cover an estimated population of over 350,000 persons (al-Sharafi, 1998). Recycled water flows through 160 km of pipeline along the main roads of Doha and al-Khor on the Northeast coast. Two medium sized sewage treatment plants serve the population of al-Khor (1,500 m^3d^{-1}) and Mesaieed (4,000 m^3d^{-1}) on the Southeast coast. There are also another eleven package treatment plants (about 4,000 m^3d^{-1}) that serve many smaller villages (Figure 6.7) (MMAA, 1997c; al-Mohannadi, 1997a; al-Hajri, 1995; Mahmoud and Sadeqi, 1997).

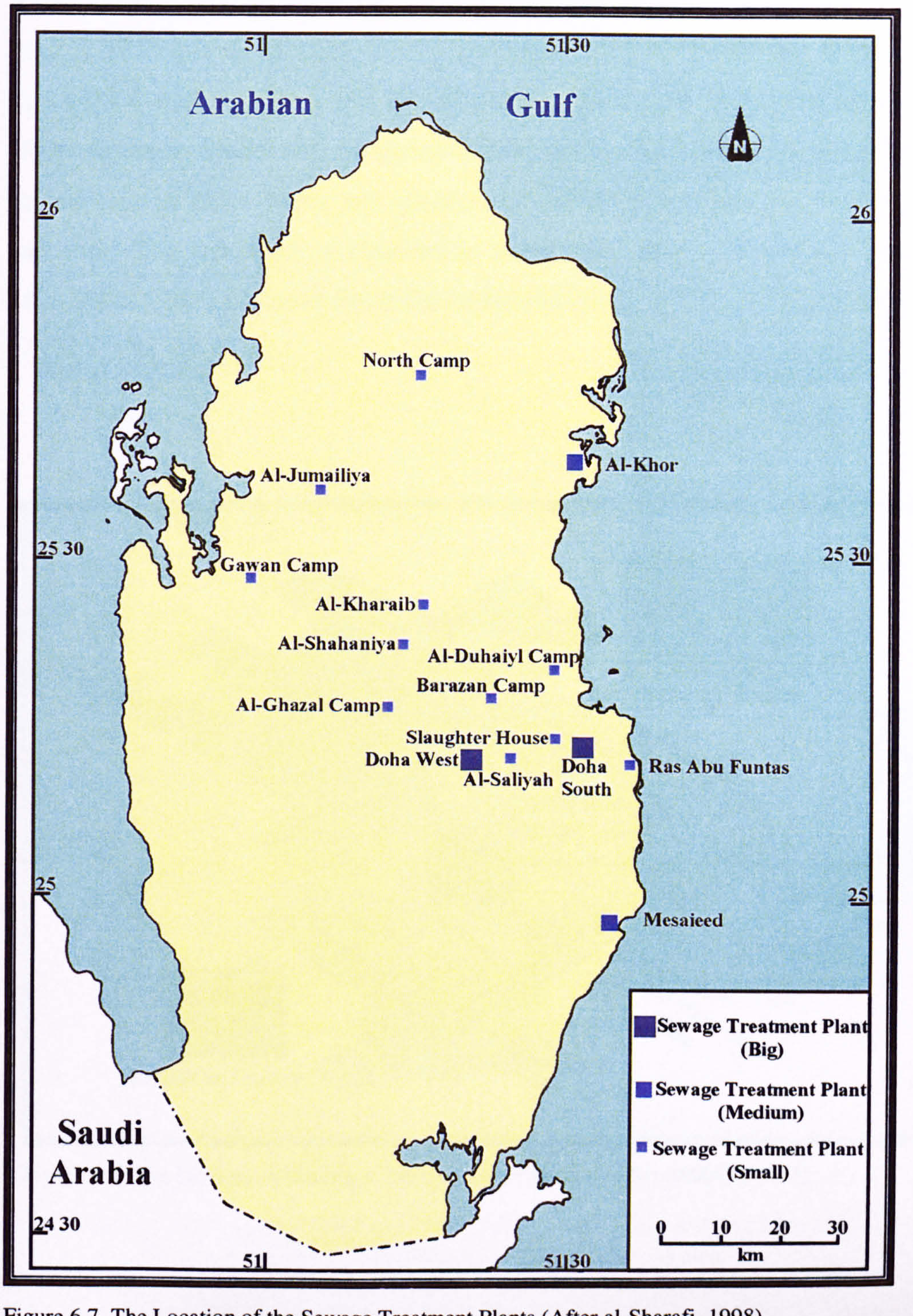

Figure 6.7. The Location of the Sewage Treatment Plants (After al-Sharafi, 1998).

The present sewage system and sewage treatment plants were designed on an overall figure of 270 l/cap/day, including a 15% allowance for infiltration. Estimates of availability of recycled water is based almost always on population growth and the same breakdown (by households) in order to determine future water demands (MMAA, 1994; al-Sharafi, 1998).

The flow of effluent from the two major treatment plants of Doha South and Doha West is around about 100,000-120,000 m^3d^{-1} (Hussin, 2001) with an estimated cost at $0.34 per m^3 (al-Diab, 1994). Of that, 20,000-30,000 m^3 are directed to water towers for park irrigation and 55,000 m^3 are distributed to a Government farm in Rakhiya and for fodder and maintenance of livestock (Figure 6.8). 15,000 m^3 is directed by tankers to other farms and gardens for irrigation of areas not on the recycling network. The remainder is disposed in emergency lakes. In addition, the MMAA distributes treated sludge to farms for fertiliser (MMAA, 1994; al- Sharafi, 1998).

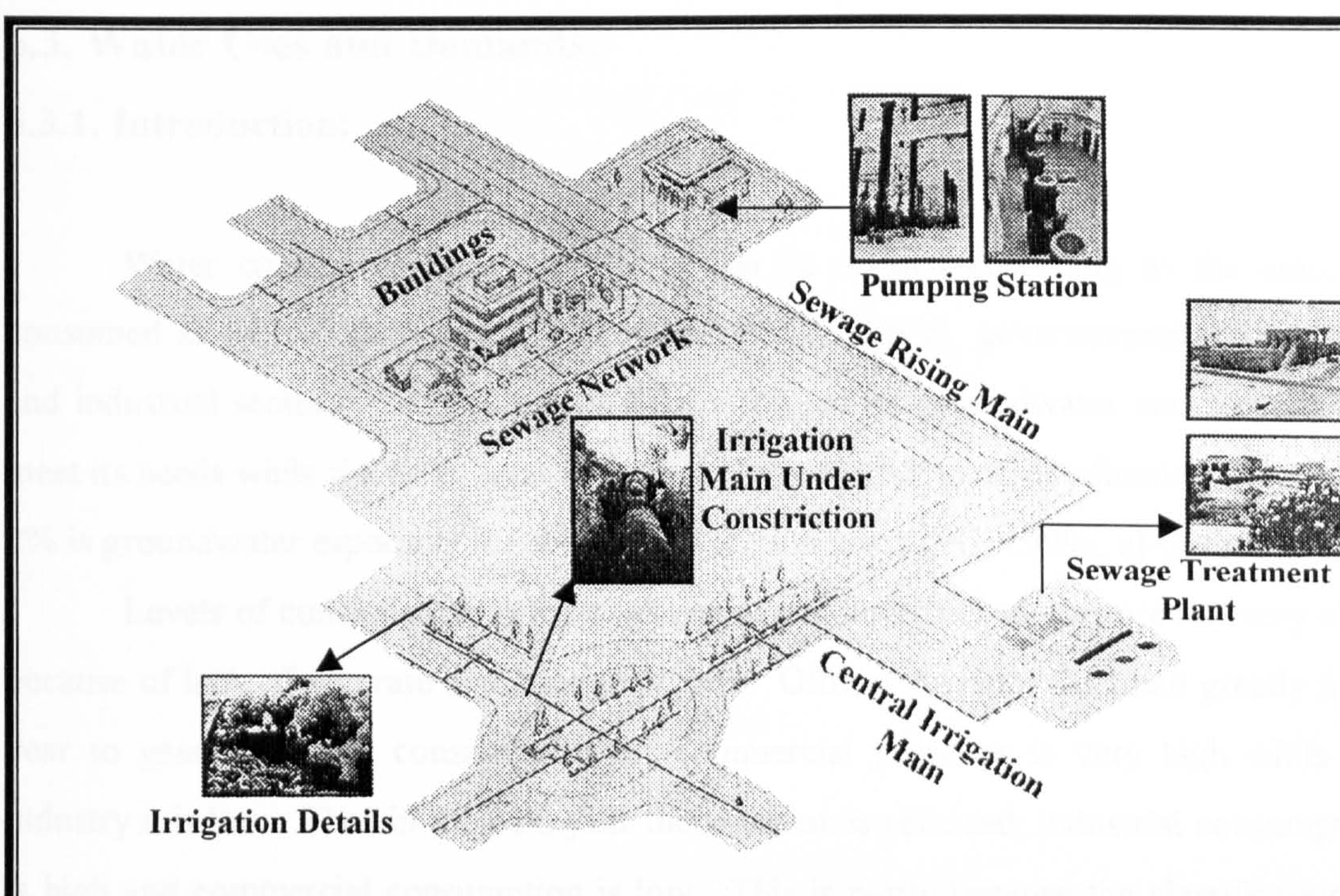

Figure 6.8. The Network of Drainage Division and Irrigation (After MMAA, 1994).

Recycling is increasingly becoming more important for meeting irrigation demand and it is considered the second source of water available for agriculture in Qatar. By the year 2000 the Government aimed to have an estimated 35 Mm^3 of recycled water available annually for agricultural usage, which was achieved as production but not consumption. This policy is in line with the suggestion from the FAO to increase the percentage of water used in irrigation from recycling (Cowan and Johnson, 1985; FAO, 1981; el-Mallakh, 1985; Hashim, 1995).

At present the use of this water is exclusively for irrigating public gardens and the greenery along roads, and for animal feed or produce that is not eaten raw. The Government aims to expand the use of this source to reduce the pressure on groundwater and to lessen dependency on desalination, especially for industrial demand and garden irrigation. Desalination water is expensive especially in comparison with recycling which does not exceed \$0.34 per m^3 (al-Mohannadi, 1997a; al-Diab, 1994; al-Hajri, 1995; Ahmad, 1991b).

6.3. Water Uses and Demands:

6.3.1. Introduction:

Water consuming sectors in Qatar can be divided according to the amounts consumed as follows: agriculture and municipal (residential, governmental, commercial and industrial sectors). Agriculture is totally depend on groundwater and recycling to meet its needs while the other sectors depend primarily (98%) on desalination. The other 2% is groundwater especially for settlements in rural areas (PC, 1999a; al-Diab, 1994).

Levels of consumption in the commercial and industrial sectors are not very clear because of lack of accurate and consistent data. Official statistics fluctuate greatly from year to year; one year consumption for commercial purposes is very high while for industry it is low. Then in the next year the situation is reversed, industrial consumption is high and commercial consumption is low. This is partly because the classification of what is commercial and industrial is blurred. Fortunately, what these two sectors consume is very small, especially when compared with the agricultural sector, hence making the fluctuations in data not that important.

6.3.2. Agricultural Demand:

In the pre-oil period, Qataris were aware of the limited resources in their country and concentrated their activities almost completely towards the sea; hence agricultural development was extremely limited (Zahlan, 1989; al-Mohannadi, 1997a; al-Kuwari, 1978; al-Nasr and al-Sheeb, 1999; Appendix 8). But with the accumulation of huge oil revenues, the Government focused on expanding the sector by using the latest technology to cultivate desert areas, drilling more wells to achieve the policy of food self-sufficiency and food security (al-Kuwari, 1996; Riad, 1992; el-Mallakh, 1985; Arthur, 1997). This was intensified when some fruit and vegetable imports from Lebanon stopped temporarily in 1970 when Syria closed its border. Further, when the cholera appeared in the Middle East, the Government feared to import fresh fruit and vegetable from countries considered as staple exporters (Metualy, 1981b). The Government encouraged the people to engage in agricultural activities and provided them with equipment, seeds, pumps, fuel etc. (MIC, 1996; Ahmad and al-Faqeh, 1999; al-Nasr, 1998). Many who were enriched by the oil boom adopted the Government policy, not because they wanted to contribute to food security, but as a way of showing their wealth and social status. Their farms became week-end rest homes (Besesu, 1987; Hashim, 1995; Nyrop, 1984; al-Akry, 1994).

That led to a massive increase in the number of farms. In the late 1950s the number was 250, but by 1997 it increased to 906 active farms. In the same period the agricultural land area increased from 150.0 ha to 9,554.8 ha (CSO, 1998; al-Kuwari, 1996; MIC, 1996; Ahmad and al-Faqeh, 1999). In other words, the agricultural area increased 64 times in about forty years. Naturally this expansion in agriculture was accompanied by a huge increase in groundwater consumption (Table 6.3). In 1960 groundwater pumping extracted 3 Mm^3 but by 1997-1998 it was 291.408 Mm^3, a 97 times increase (Judah, 1994; Hashim and Abdulmalik, 1999; Kotoub and al-Mahmoud, 1997).

Table 6.3. Agricultural Water Demand (Judah[a], 1994; Hashim and Abdulmalik[b], 1999).

Year	Agricultural Demand (1,000 m³)		
	Groundwater	Recycled	Total
1960[a]	3,000		3,000
1965[a]	22,000		22,000
1970[a]	36,000		36,000
1975[a]	48,000		48,000
1980[b]	66,964		66,964
1985[b]	96,902		96,902
1990[b]	137,709		137,709
1991[b]	145,000	14,965	159,965
1992[b]	158,460	14,965	173,425
1993[b]	171,920	14,965	186,885
1994[b]	185,380	14,965	198,345
1995[b]	220,736	14,965	235,701
1996[b]	234,432	14,965	249,397
1997[b]	267,850	18,100	285,950
1997-1998[b]	291,408	18,100	309,508

Moreover, the number of wells increased from 660 in 1975 to 3,388 wells in 1997-1998 (Hashim and Abdulmalik, 1999). This resulted in massive pressure on groundwater reserves and water quality began to change (Hashim, 1995; Babikir, 1998b; al-Kubaisi, 1999; al-Sumori, 2001b). The farms was concentrated in the middle and northern parts of the country where the water reserves have satisfactory quality, in contrast to the south, where the water is more saline. This is reflected by the distribution of wells: 42% of wells are in the north, 51% in the centre and 7% in the south (Hashim, 1995; MIA, 1984).

Table 6.4. Areas Covered and Annual Water Consumption (m³) per Hectare (FAO[a], 1981; CSO[b], 1998).

Crop	Area Covered (%)[b]	Water Consumption per Hectare[a]	
		Winter	Summer
Vegetables	33	11,000	16,000
Green Fodder	24	44,000	
Palms	22	24,000	
Cereals	15	9,000	
Fruit	6	11,000	16,000

6.3.3. Municipal Demand:

The total water demand for Municipal (residential, governmental, industrial and commercial) rose from 52.8 Mm^3 in 1988 to 102.16 Mm^3 in 1998 (official data about water consumption per sector started in 1988). Residential water consumption for 1998 was 65.39 Mm^3 or 64% of the total consumption in the municipal sector. The governmental sector consumption was 14.30 Mm^3 (14%). The industrial sector consumption was 9.19 Mm^3 (9%). The commercial sector water consumption was 13.28 Mm^3 (13%) (CSO, 1991; PC, 1999a). In the following sections, some of these issues are explored in depth.

6.3.3.1. Residential Demand:

Residential consumption is the second highest consuming sector after agriculture reaching 16.6% of the total amount consumed in the country in 1998 (Figure 6.9). It is the major consumer of desalinated water. Residential consumption increased gradually. Official statistics indicate that demand has increased from 38.6 Mm^3 in 1988 to 65.39 Mm^3 in 1998, an increase of 26.79 Mm^3 in ten years (CSO, 1992; CSO 1996; PC, 1999a). In addition, Qatar imported 22,397.6 m^3 of bottled drinking water in 1999 (PC, 2000). This is a per capita consumption of 42.9 litres of bottled water per year.

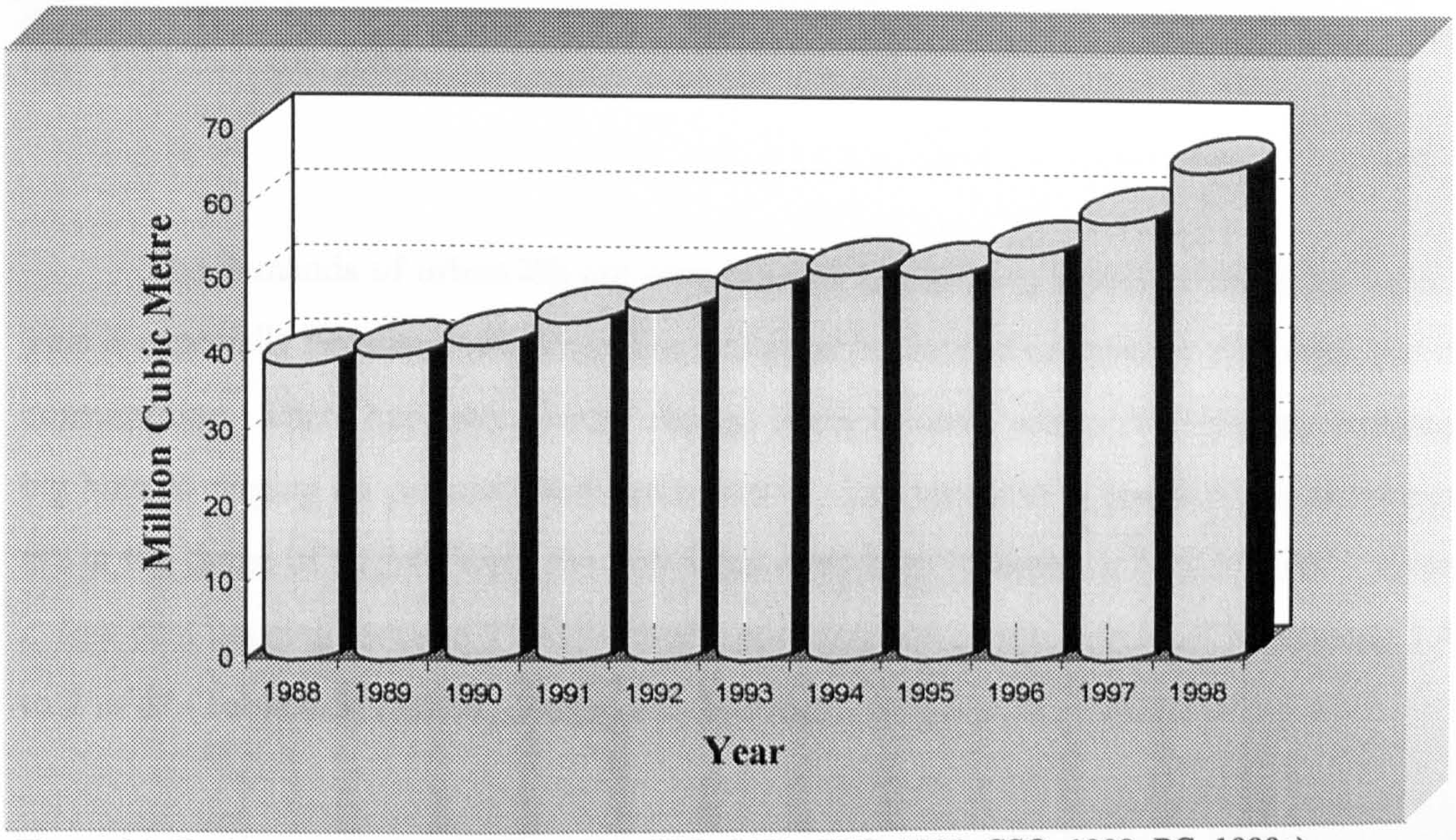

Figure 6.9. Residential Demand (CSO, 1991; CSO, 1992; CSO, 1996; CSO, 1998; PC, 1999a).

This increase is due to two main factors: the first is the population increase due to migration. Natural population increase in Qatar is 22.72 per thousand while migration is 98.25 per thousand (al-Khayat, 1988; al-Mohannadi, 1997a). The total population of Qatar in 1955 was 40,000 (al-Kubaisi, 1986; Fakro, 1998) and by the 1997 third census was 522,023 inhabitants (CSO, 1998). That is a thirteen fold increase in forty years and the trend is still on the increase. The second is the improvement in standards of living (Abdulrazzak, 1995; al-Akry, 1994; Marhon, 1994). Qatar at present is considered to have high national income and high per capita income (Figure 6.10) (CSO, 1998; Hayes, 2000).

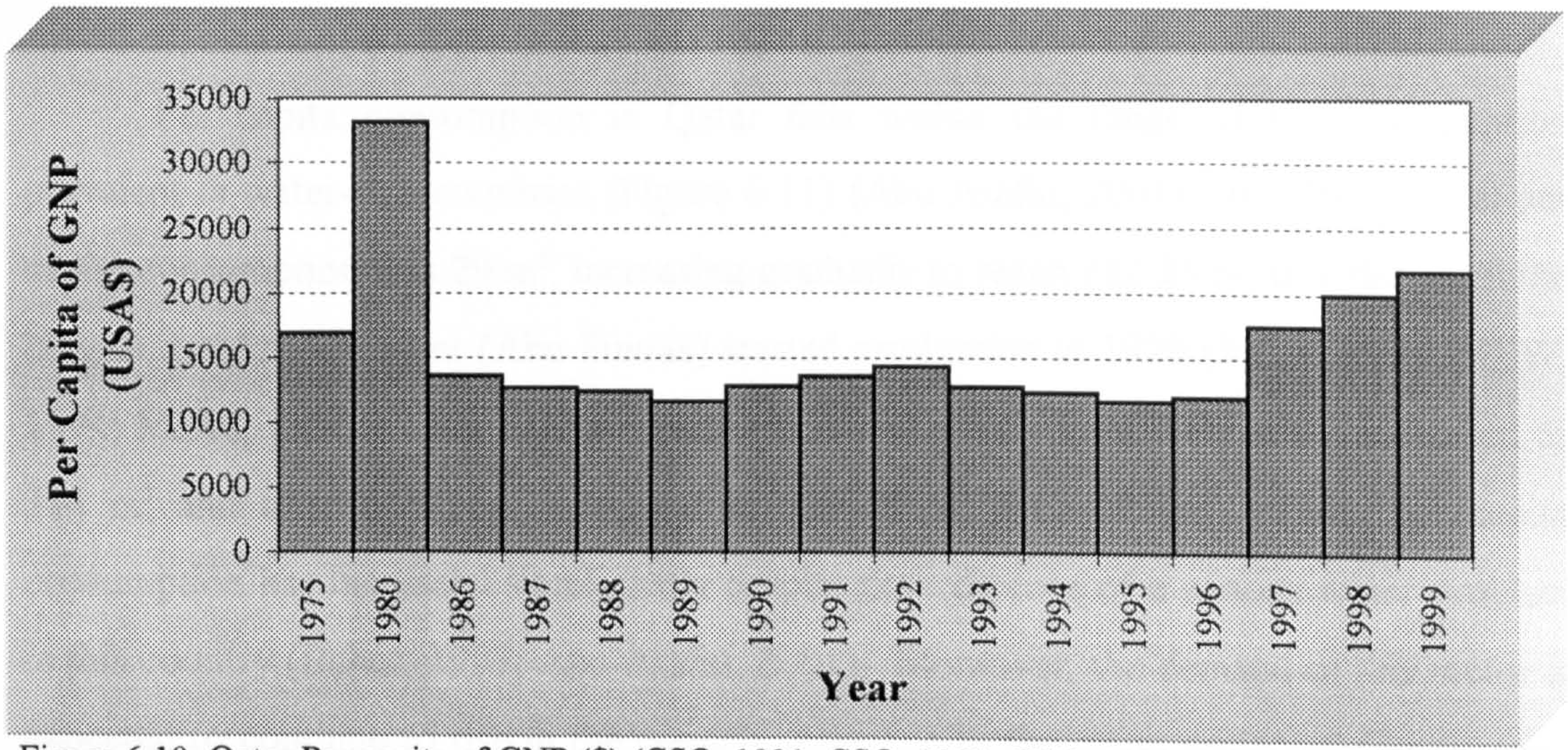

Figure 6.10. Qatar Per capita of GNP ($) (CSO, 1981; CSO, 1988; CSO, 1992; GOIC, 1997; MIC, 1996; CSO, 1998; Shmisani, 2000).

The demands of urban life are now beyond just gaining access to drinking water. This is especially because technology has provided household equipment with high water consumption. There has been a major change in the housing sector, with people building big houses verging on palaces (Abdulaziz, 1998). The numbers of major types of houses are in the range of 21,540 were the individual consumes between 1.7 to 35 m^3d^{-1}. Even in low cost housing (around 27,439 houses) consumption of the individual is between 1.4 to 2 m^3d^{-1} (Table 6.5) (MEW, 1996a; PC, 1999b).

Table 6.5. Estimates of Buildings by Type and their Estimated Water Demand (MEW[1], 1996a; PC[2], 1999b).

Type of Building	Number of Dwellings[2]	Estimated Water Demand (m^3d^{-1})[1]	Average Number of Occupants per Dwelling[1]
Arabic House	14,307		
Without Garden		1.4 - 1.7	8
With Garden		1.7 - 2.0	8
Public Houses	13,132	1.4 - 1.7	8
Villas	20,901		
Villa 400 m^2		1.7	5
Villa 1000 m^2		3.5	6
Palaces	639		
Palace 5000 m^2		20	12
Palace > 5000 m^2		35	15

Per capita consumption in Qatar falls within the range of the consumption prevalent in water-rich countries (Figure 6.11) (Abu Arafat, 2001). In 1960, annual per capita consumption was 29 m^3, increasing gradually to reach 181.25 m^3 in 1980 when the biggest desalination plant (Abu Funtas) started production in 1979 (Judah, 1994; MEW, 1994; MEW, 1996a). Per capita consumption was steady until 1997 when increased to 214 m^3 and after one year increased to 239.48 m^3 (PC, 1999a). Thus, per capita consumption has increased significantly despite the existence of a serious water problem in this country (Bahar, 1997; Abu Arafat, 2001). Moreover, the demand of this sector is expected to continue to rise in the coming years due to the many projected Government schemes, such as the new huge industrial area at Ras Laffan (al-Shafai, 1996). That will increase the demand for migrant labour and in view of the continued high per capita income, water consumption in this sector will no doubt increase.

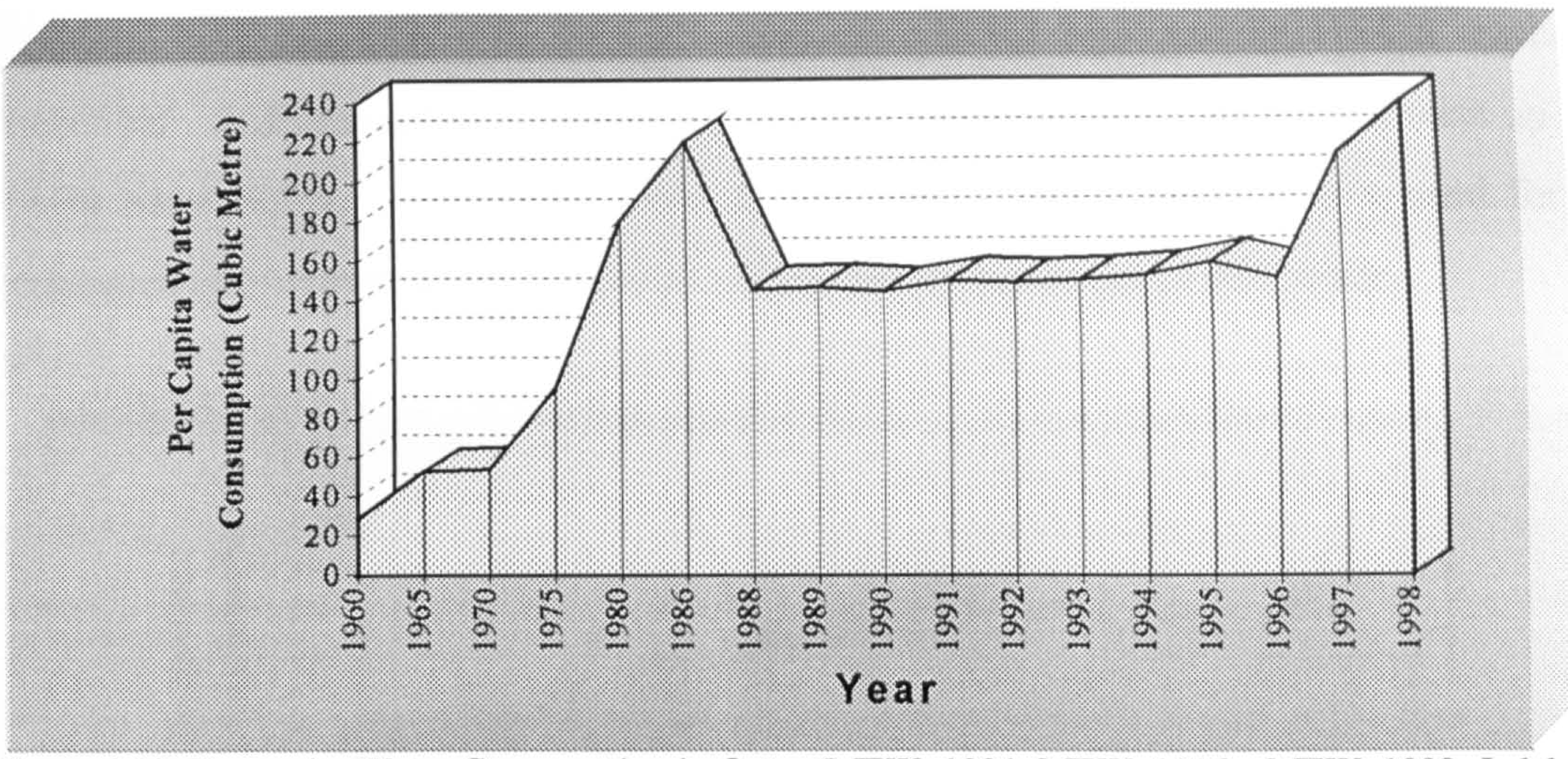

Figure 6.11. Per capita Water Consumption in Qatar (MEW, 1994; MEW, 1996a; MEW, 1998; Judah, 1994; PC, 1999a).

6.3.3.2. Governmental Demand:

This sector includes the various governmental agencies such as ministries, schools, mosques, hospitals, sports clubs, parks, and others that are managed directly or indirectly by the Government (Table 6.6). This sector is large, due to the Government policy of supervising large sections of social activities, especially those that are service oriented, in addition to the policy of providing employment to the citizens of Qatar, regardless of need, in the various governmental administrations (al-Mohannadi, 1997a; Khuraibet and al-Attar, 1997).

Table 6.6. Estimates of Some Governmental Buildings by Type and their Estimated Water Demand (MEW[1], 1996. PC[2], 1999b).

Type of Building	Number of Dwellings[2]	Estimated Water Demand (ld^{-1})[1]
Mosque	1,072	2,000 - 5,000
School	282	9,693
Governmental Offices	338	4,847
Gardens/Parks/ Nurseries	---	21,205
Sports Stadiums	8	109,712

(--- Unavailable).

Consequently, the governmental sector rates third in terms of water consumption, around 3.6% of total water consumed in 1998, despite all efforts by the Government to control demand in the sector (Figure 6.12). To some extent there was slight reduction between 1988 and 1997. In 1988 consumption was 9.3 Mm^3 and by 1994 it reached 14.0 Mm^3. It decreased to 11.2 Mm^3 in 1995 but the following three years it went up to 14.30 Mm^3 (CSO, 1992; CSO, 1996; CSO, 1998). There appears to a need for a consistent and clear strategy of how to reduce the consumption of this sector.

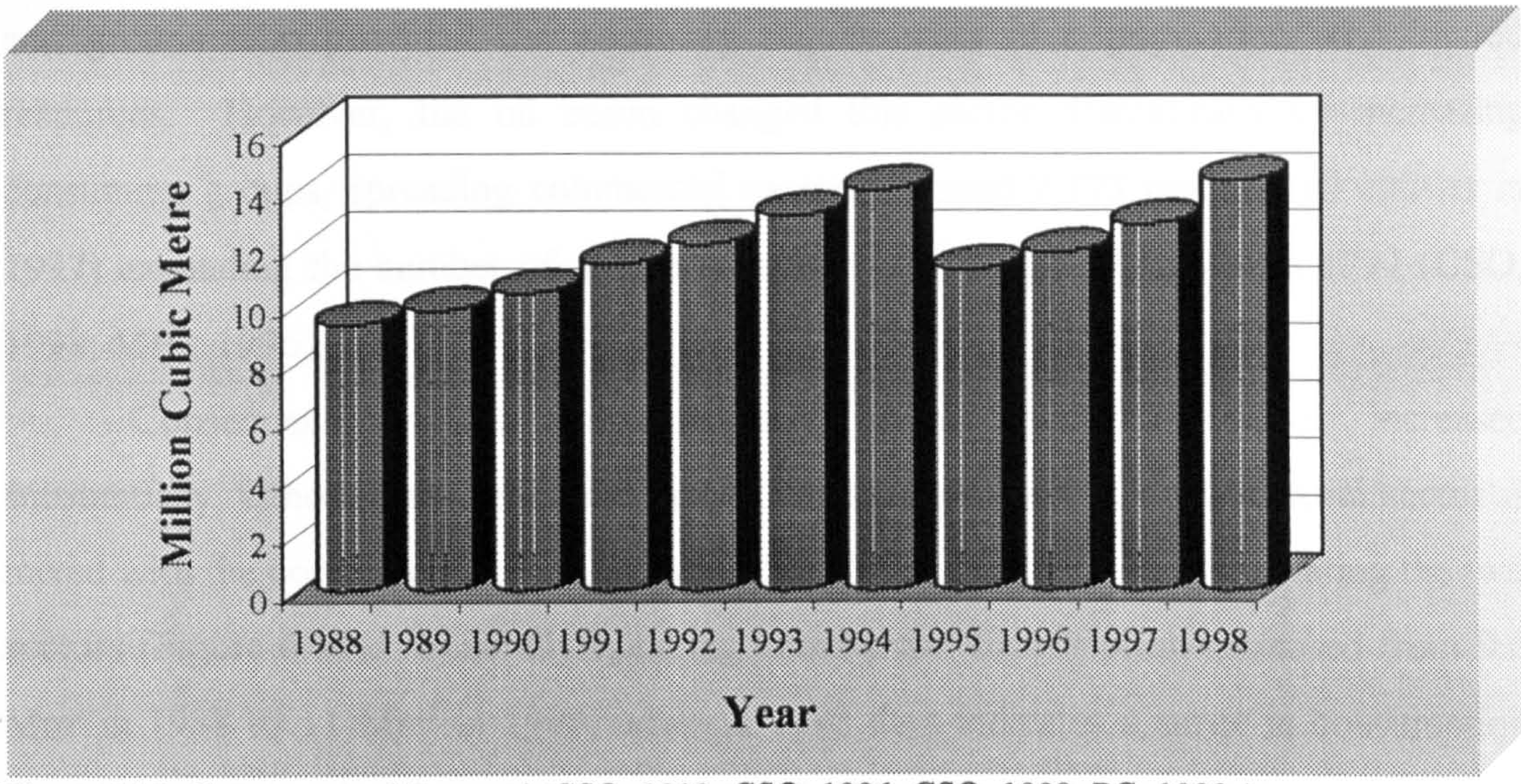

Figure 6.12. Governmental Demand (CSO, 1992; CSO, 1996; CSO, 1998; PC, 1999a).

A large percent of Government employment is concentrated in the service sector, followed by the education sector. The water consumed by this sector is of high quality because it is primarily meant for drinking. Another large part of it is used to irrigate public parks, gardens, sports centres etc., causing a waste of the water that costs so much to produce. Another important feature of the sector is the short period of consumption per day, which is concentrated between six or seven in the morning and one or two o'clock in the afternoon, the official work hours of Government agencies. Such short hours should translate into lower levels of water consumption, especially in comparison with other sectors, where consumption hours can extend over the full day.

The indications in this sector is that demand will continue to rise, especially due to the large number of graduates that will be absorbed by the sector, according to the present Government policy of providing employment regardless of the need of the various administration units, as well as the expansion in Government services and the gradual inflation of the sector (al-Kuwari, 1996; al-Kubaisi, 1986).

6.3.3.3. Commercial Demand:

The growth of the commercial sector was a natural consequence of the growth of the population, increase in income and the appearance of new social strata linked to oil revenues. Commerce, prior to the discovery of oil, was exclusive to a few individuals and groups who provided the necessary requirements of a population with limited resources. However, the oil boom changed this sector dramatically by increasing consuming groups, spreading commercial centres (around 7,773 commercial entities in 1997) expanding the number of people engaged in the sector to 36,970 in 1997 (CSO, 1998; MIC, 1996).

Consequently, water consumption of the commercial sector increased substantially, although as mentioned before, the consumption of the industrial sector is mixed with the commercial sector because of the lack of accurate data separating the two sectors (Figure 6.13). Generally speaking commercial consumption increased from 9.6 Mm^3 in 1988 to 11 Mm^3 in 1996, while in 1995 data indicates a surge in consumption reaching 16.5 Mm^3 and a decrease to 13.28 Mm^3 by 1998. This change in water consumption is, however, offset by massive decreases and increases shown for the industrial sector, indicating the blurring in the classification of commercial and industrial enterprises (CSO, 1992; CSO, 1996; CSO, 1998; PC, 1999a).

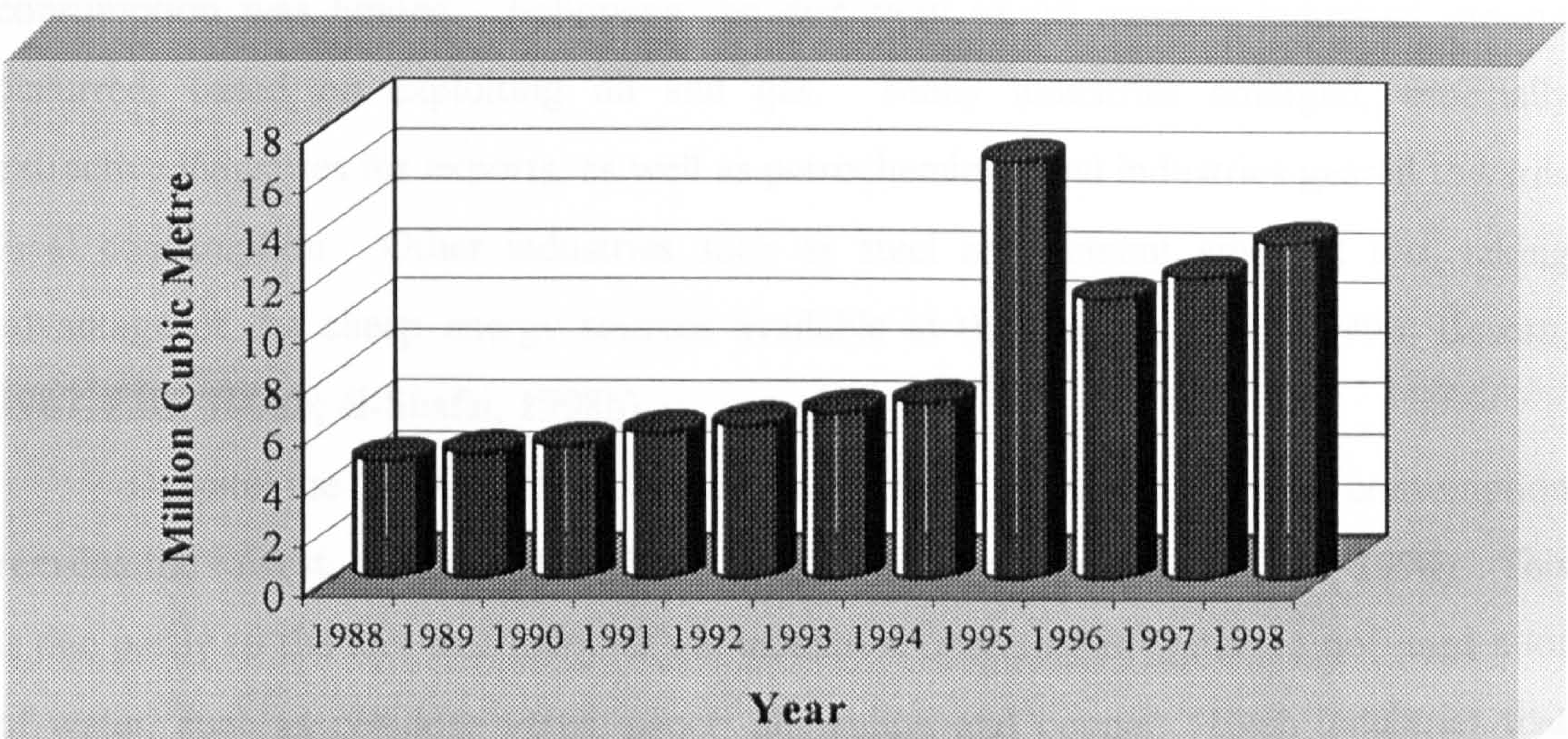

Figure 6.13. Commercial Demand (CSO, 1992; CSO, 1996; CSO, 1998; PC, 1999a).

The volume of commercial activity in Qatar and the number of enterprises, as well as the number of those employed by the sector are large, especially in comparison with the size of the country and the population. The biggest consuming sub-sector is hotels and restaurants. In 1996, there were 1,196 restaurants employing 4,531 persons and 14 hotels employing 1,614 persons (CSO, 1998). Most of these hotels and restaurants are concentrated in the capital. The number of those employed by the sector is 35,510, most of whom are foreigners with usually low levels of education and coming from water-rich countries, hence they do not have the awareness needed to treat water with caution and appreciate its scarcity.

This sector will witness a gradual increase in its overall demand, especially because of the completion of the third industrial area, which will require increased number of migrant workers to operate it. Also, present indicators show that high incomes will be maintained in the future, and that will support the increase in consumption of luxury commodities as well as essential ones (EIU, 1998a; EIU, 1998b).

6.3.3.4. Industrial Demand:

Prior to the discovery of oil, industrial activities were geared towards providing the things that are essential to help people earn a living such as local craft used in the pearling, sailing ships, fishing nets (Melamid, 1972; al-Kuwari, 1978; Zahlan, 1989; al-Othman, 1981; Lormer, 1978; Pereira *et al.*, 1977; Appendix 8). Consequently, water consumption was limited. Following the discovery of oil massive industrial growth occurred, based on exploiting oil and gas. Many industries emerged, especially extractive industries for exports, as well as petrochemicals and industries geared towards local consumption. Other industries such as steel and cement emerged too, taking advantage of the cheap energy sources available in the country (MEI, 1996; Besesu, 1987; EIU, 1998b; al-Shafai, 1998b).

Despite the growth of the industrial sector, its apparent water consumption remains the lowest, not exceeding 2.3% of total water consumption (CSO, 1998). This is due partly to the fact that many of the industries operating in Qatar do not need a lot of water, such as cellulose yarns, paper, aluminium and copper. Even industries that have high water consumption, such oil refineries, steel and food industries, do not consume a lot due to their small size. Consumption is, however, concealed because many of Qatar's industries (e.g. the biggest oil area at Dukhan and new industrial area at Ras Laffan) own independent sources of water that are not part of the official statistics of the Government (al-Mohannadi, 1997a).

The water consumption of the industrial sector in 1988 was 6 Mm^3 and increased gradually to reach 9 Mm^3 in 1994 (Figure 6.14). It showed a massive reduction in 1995 to 1,7 Mm^3 (around 16% decrease). In 1998, the consumption was 9.19 Mm^3 (CSO, 1992; CSO, 1996; CSO, 1998; PC, 1999a). As mentioned before, this can only be explained by the confusion that exists between commercial and industrial activities, since within three years industrial consumption was back to 9.19 Mm^3, while commercial consumption for that year decreased.

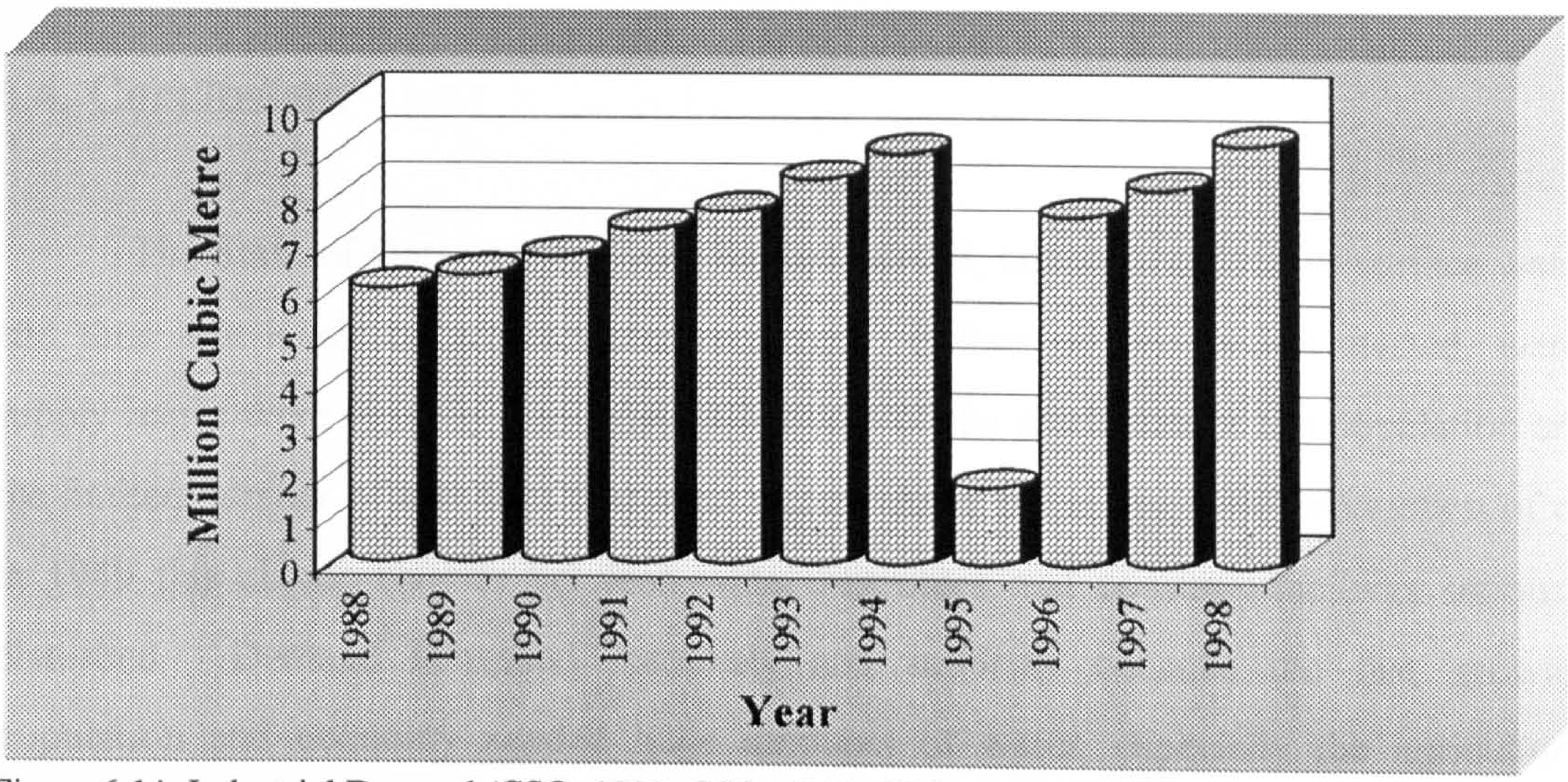

Figure 6.14. Industrial Demand (CSO, 1992; CSO, 1996; CSO, 1998; PC, 1999a).

Qatar at present has three industrial areas, one near the capital Doha specialising in light industries, and the other is in the south east at Mesaieed, where the port for exporting oil is located specialising in heavy industries. A new industrial city in Ras Laffan on the north east coast of the country will exploit the huge natural gas field of the area. Other industries are located in the western part of the country in cities such as Dukhan and Umm Bab (al-Kubaisi, 1986; QGPC, 1997a; EIU, 1998b; al-Shafai, 1998b). The number of industrial enterprises is 4,889 with a level of employment reaching 48,728 workers. 96% of the total workers are foreigners with sometimes high technical skills (CSO, 1998).

Qatar possesses industries that are high water consumers, such as paper and petrochemicals, but because of their limited size, water consumption is relatively small. Among the highest water consuming industries are the bottled mineral water industry, where one of the plants consumed 624,000 m^3a^{-1} and the steel industry which consumed 514,203 m^3a^{-1} in 1993, followed by the cement factory (290,639 m^3) and the petrochemical factory (195,000 m^3) for the same year (Personal Interviews, Ministry of Energy and Industry, 1998). The consumption of this sector will undoubtedly increase due to the completion, as mentioned before, of the third industrial city of Ras Laffan (EIU, 1998b).

6.4. Conclusion:

The State of Qatar suffers from limited rainfall, consequent lack of surface water and thus low levels of groundwater recharge. Before oil production started, water supply issues were virtually non-existent because of the small size of the population and the limited number of activities that need water. After the commercial production of oil in 1949 this classic balance between water resources and consumption was seriously disturbed. Demand increased massively and suddenly because the fast growing population and economy needed huge amounts of water, especially the agricultural sector.

According to the secondary sources, desalinisation remains, despite its high cost and long term unsustainability in the light of eventual energy depletion, the best alternative the Government has for municipal use. Groundwater is still the best option for agricultural use, although this has proved very costly and unsustainable with the depletion of groundwater reserves. Limited rainfall and continuous pumping meant that water levels have been declining over the years. Some studies (e.g. Kotoub and al-Mahmoud, 1997; Hashim, 1995) estimate that if present consumption levels are maintained, groundwater will be totally depleted within the next twenty years.

On the other hand it is not thought possible at present to invest more in recycling for health, social and technological reasons. This situation is forcing the Government to look at other alternatives, such as importing water from water-rich countries. An example from Turkey is through the Peace Pipeline project (e.g. Berkoff, 1994; Khalil, 1998; Mukemer and Hijazi, 1996), although as mentioned in Chapter Two there are many political and economical obstacles confronting this project which actually put a halt on its execution. Other possible sources include Japan and Malaysia, but among the options that are being seriously discussed is importing water from Iran through a pipeline named the Green Pipeline. The line, around 700 km, will carry water from the Karun River to northern Qatar (e.g. Marhon, 1994; MMAA, 1998d; al-Hussini, 2000). Even this option is faced with political and economic difficulties, hence the inability of the Government to make a decision.

Water use in Qatar is therefore unsustainable and this is already leading to severe management problems. Chapter 7 discusses water management problems in Qatar.

CHAPTER SEVEN:

WATER MANAGEMENT PROBLEMS IN QATAR

Chapter Seven:

Water Management Problems in Qatar

7.1. Introduction:

In this chapter the focus is on water resources management problems in Qatar. The first section will present a historical profile of water management prior to the production of oil, before 1950. In the second section the discussion focuses on water management in all its aspects: environmental, legislation, technological, economic, social, decision-making and the institutions responsible for water management in Qatar.

7.2. Historical Profile:

The oral history of water in Qatar is described in this section. The interviews with old people on the historical development of water resource in Qatar are described and integrated with other historical sources. Full details can be found in Section A8.2.

Qatar is one of the most arid countries in the world. Rainfall is scarce - about 73 mm - and fluctuates from place to place and year to year (al-Nasr and al-Sheeb, 1999). The country lacks any surface water (al-Nasr, 1988; al-Biati, 1998a; Metualy, 1981a; IDTC, 1979). Hence, historically not many people chose to live there, except a small group of Arabs. They depended mainly on the sea for food and trade. They dug wells to gain access to water in the shallow subsurface using very simple means such as the pickaxe and the hammer (Brice, 1966; al-Othman, 1981; Lormer, 1978; Section A8.2).

These wells were the basis of human settlement. When Lormer visited Qatar in the early 20th century he found many of these wells and classified them. In 1904 the Qataris had dug 219 wells, of which 166 had freshwater, 18 had brackish water and 35 had salty water. He linked freshness of water and depth of wells. For instance, wells of freshwater reached a depth of around 10 m while salty waters were found at depths not exceeding 2 m. He noticed that people maintained these wells and described them as "solid", since stones were used in their construction. That is a specificity to Qatar, not found in other areas in the Gulf (Lormer, 1987).

At that time some, wells were dug in the household, but most did not have freshwater because most settlements in that time were on the coast. Therefore, household well-water was used for purposes other than drinking (e.g. bathing and washing). Special wells were dug far from human settlements in the hinterland for drinking water. It was brought on the backs of camels and donkeys to be distributed for a fee. In some communities, women were responsible for bringing water and a significant part of their time was used for that purpose alone. According to a contemporary of that period they used to bring water to Doha, from two wells near the city. Usually water was stored in a special room that took up to about 5 to 40 gallons depending on the family situation. In some houses it was kept in pots made of clay in order to keep it cool, especially during the hot summer (al-Othman, 1981; Sections A8.2).

During rainy seasons, people tried to gather and store water as much as possible, despite the presence of some contaminants, such as worms. That did not stop people from using the water since purchasing it would have been more expensive. They did try to separate the contaminants from water (Section A8.2.2.4). Generally speaking, there was a balance between the supply and demand for water. The limited water resources corresponded with a limited number of people and activities, as seen in Figure 7.1. Water, which was pumped in reasonable quantities, was replaced by natural recharge through rainfall (al-Kuwari, 1996; Melamid, 1972).

Figure 7.1. A Conceptual Model of Man and Water Resources in Qatar Pre and Post Oil Economics (After Riad, 1992).

The imbalance began to appear in the years first following the discovery of oil in 1937. In the late 1930s there was a pressing need for water in the western part of the country where oil was found in areas uninhabited except for scattered nomads. Thus, it was necessary to find water for the oil sector and for the foreign workers who were used to higher standards of living. Qatar therefore turned to the State of Bahrain for water. Ships started carrying water to Zekreet, near the oil fields, with around 40 to 50 trips a week. The water was distributed, approximately one gallon a day per two workers (al-Othman, 1981; Section 8.2.2.5).

During this time, oil companies began to drill deep wells using sophisticated equipment to get freshwater. In 1948 the Qatari Oil Company made deep wells and pumped using pipelines to distribute the water to production areas. Soon the Government made deep wells to supply Doha. The imbalance between supply and demand started to appear slowly, despite resorting to technologically advanced methods to develop existing water resources and alternatives to traditional sources of water (al-Mohannadi, 1997a; Arthur, 1997; al-Kuwari, 1996; Harhash and Yousif, 1985).

7.3. Water Management Problems:

7.3.1. Introduction:

During the 1950s central Government began augmenting its control and expanding its sphere of influence to include controlling most of the state sector, including the water sector. The responsibility of developing, producing and distributing to all domestic consuming sectors fell totally on the Government (el-Mallakh, 1985; al-Kuwari, 1978; al-Kuwari, 1996).

The next section will focus on discussing all aspects related to water management in Qatar, starting with the environment and the mutual influences between it and the development of water. Secondly the legislation, thirdly the technological methods used at present, fourthly the economic factors and their relation to production and consumption of water, fifthly the social role and the extent of popular participation in water management and lastly the role of decision-makers and the various administrations in the protection and management of water. Discussing all these factors will show the positives and negatives associated with the management of water in Qatar.

7.3.2. Environment:

7.3.2.1. Introduction:

Oil wealth made Qataris, both officials and the public, convinced that everything was possible now, even making the extreme desert green. They consumed huge amounts of water which has depleted groundwater reserves (al-Mohannadi, 1997a; al-Kuwari, 1996; Rukin *et al.*, 1995; Arthur, 1997), since abstraction now exceeded recharge (al-Nasr, 1988; MCT, 1997; Harhash and Yousif, 1985; al-Akry, 1994).

7.3.2.2. Water Resources Problems:

Continuous and ever increasing levels of pumping caused a huge imbalance between water withdrawal and water recharge (Judah, 1994; Harhash and Yousif, 1985; Babikir, 1998b). In 1971-72 the water reserves were in deficit around 19.58 Mm^3 (Figure 7.2) (Kotoub and Abdulrab, 1995; MMAA, 1997c). This deficit increased to 264.26 Mm^3 by 1980-81 and by 1996/97 it reached 1,121.323 Mm^3 or about 47% of total groundwater reservoirs capacities (Hashim and Ibrahim, 1999).

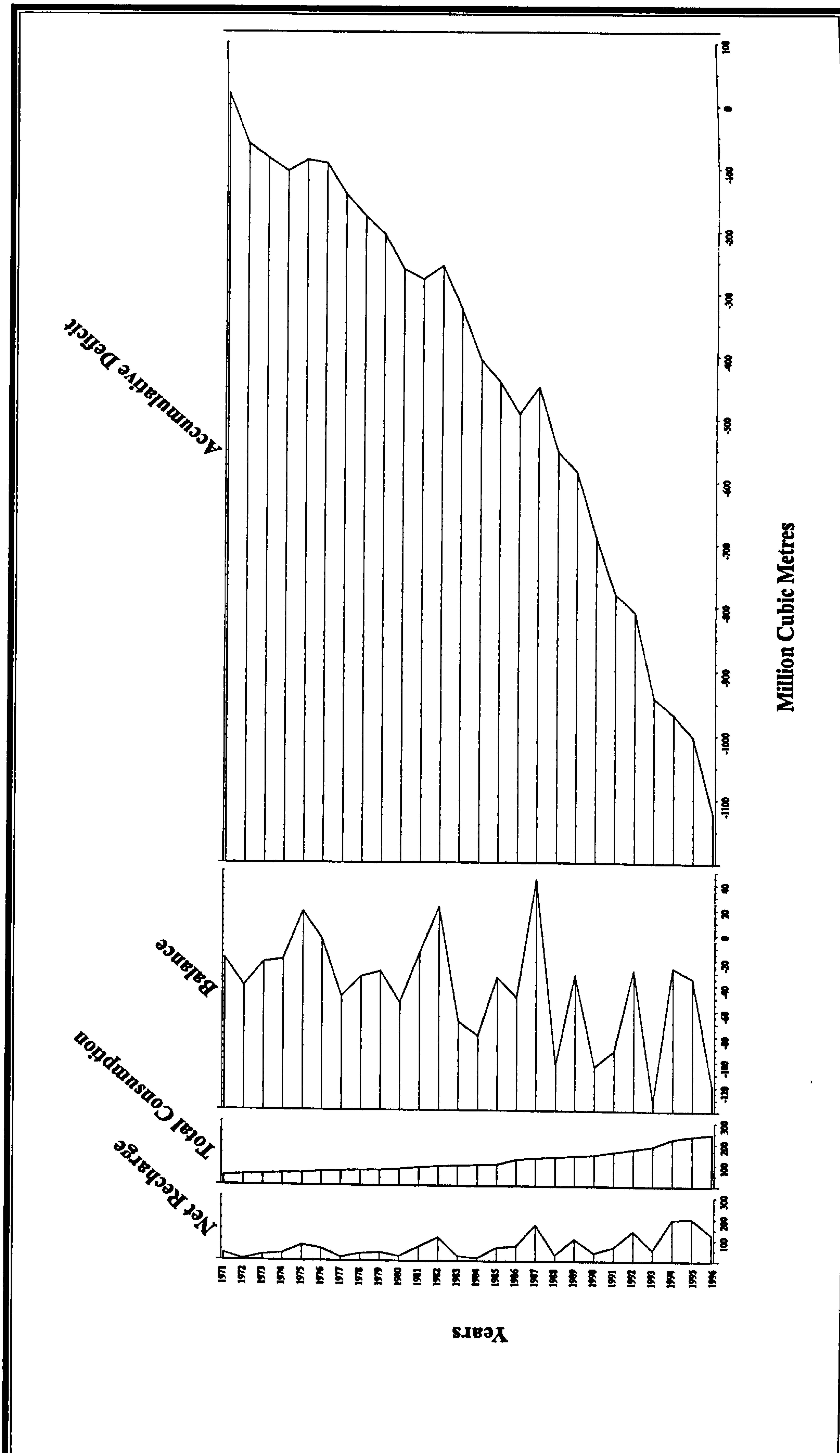

Figure 7.2. Groundwater Balance in Qatar (After Hashin and Ibrahim, 1999).

7.3.2.3. Groundwater Pollution and Depletion:

Some studies (e.g. Jones and Dutton, 1983; Marcoux, 1996) indicate that groundwater in Qatar will be totally depleted within the coming decades if controls are not put into place immediately. Also, water salinity has been increasing in the nine main water fields in the country due to natural reasons (e.g. salty rocks and high evaporation), depletion of groundwater and incursion of seawater, which advanced 1,000 ma^{-1} (Table 7.1). For instance, salinity for the Mazzrooa Water Field increased from a level of 3,700 micro-siemen/centimetres (μS/cm) in 1955 to 8,300 μS/cm in 1976 (Judah, 1994). The lowest increase occurred in the Rashaidah and Dhibyah fields, from 400 μS/cm in 1958 to 750 μS/cm in 1997 (al-Mohannadi, 1997b). Generally, the salinity of these important water fields has increased gradually and reached averages between 320 μS/cm and 4,600 μS/cm (MMAA, 1997c; al-Mohannadi, 1997b).

Table 7.1. Salinity Change in the Main Water Fields (Micro-siemen/centimetre) (Judah[a], 1994; al-Mohannadi[b], 1997b).

Water Field	Oldest Recording		Newest Recording		Production
	Year	(μS/cm)	Year	(μS/cm)	(m^3/Year)
Ghuwairia[a]	1959	1,600	1993	2,490	Non-potable
Rushaidah[b]	1958	400	1997	720	969,598
Utouriya[a]	1971	762	1992	1,300	Non-potable
Mazruah[a]	1955	3,700	1976	8,300	Non-potable
Judiyah[b]	1986	500	1997	1,000	606,136
Shahaniya[a]	1976	875	1993	2,465	Non-potable
Jumailiya[b]	1958	450	1997	1,140	181,279
Dhibiyah[b]	1958	400	1997	720	775,355
Abu Thaylah[a]	1970	1,200	1991	2,170	Non-potable

According to World Health Organization, the salinity that is acceptable to consider water suitable for drinking is between 500 μS/cm to 1,500 μS/cm (Section 8.2.4). In recent years, only four water fields in the country have potable water after treatment and some times mixing with desalination water (Section 6.2.2) (Judah, 1994; MEW, 1994; al-Mohannadi, 1997b).

Yet from among 2,769 wells used in agriculture sector in Qatar, only 49 wells have a salinity between 500 to 1,000 μS/cm. That is no more than 1.77% of the total number of wells. 21.34% of wells have a salinity of 1,000 to 3000 μS/cm. Around 42.16% of wells have salinity of 3,000 to 6,000 μS/cm. Another 34.73% has salinity over 6,000 μS/cm (Table 7.2) (Judah, 1994; MIA, 1984; al-Rufaai, 1989; Hashim and Ibrahim, 1999).

Table 7.2. The Conductivity Distribution in Farms Wells (MIA[a], 1984; Hashim and Ibrahim[b], 1999).

Conductivity (μS/cm)	**Number of Wells**			**Percentage (%)**		
	1982/83[a]	**1993/94[b]**	**1995/96[b]**	**1982/83[a]**	**1993/94[b]**	**1995/96[b]**
500-1,000	19	75	49	1.99	2.85	1.77
1,000-2,000	11	266	250	11.55	10.09	9.03
2,000-3,000	188	387	424	19.74	14.69	15.31
3,000-4,000	167	375	494	17.54	14.23	17.85
4,000-5,000	117	317	408	12.28	12.03	14.74
5,000-6,000	77	247	265	8.08	9.37	9.57
6,000-8,000	82	328	375	8.61	12.45	13.54
8,000-10,000	55	291	207	5.77	11.04	7.47
10,000-12,000	34	133	139	3.57	5.05	5.02
12,000-16,000	65	144	129	6.82	5.47	4.66
Over 16,000	37	72	29	3.88	2.73	1.04
Total	**952**	**2,635**	**2,769**	**100**	**100**	**100**

It is worth mentioning that most of these wells are located in the centre and northern parts of the country where water has historically been less saline than in the southern part, where groundwater salinity is higher (Table 7.3).

Table 7.3. Conductivity Increase for Different Years in Selected Farms (μS/cm) (al-Nasr and al-Sheeb, 1999).

No. Farm	**Location**	**1983**	**1984**	**1986**	**1987**
42	North	2,000	1,900	2,200	3,100
45	North	5,100	5,700	5,600	5,800
83	North	5,200	5,400	5,000	5,700
100	North	2,800	3,900	3,800	3,200
112	North	1,900	1,700	2,500	2,800
127	North	3,600	4,000	3,900	4,500
178	North	1,400	1,500	1,500	1,700
585	North	6,000	5,900	5,300	6,700
602	North	3,200	4,000	4,200	4,400
679	North	4,500	4,100	3,500	6,500
260	Centre	2,700	3,000	2,600	3,900
266	Centre	5,500	5,600	5,400	5,700
248	Centre	3,300	3,500	3,900	3,800
302	Centre	3,700	3,800	3,600	3,900
305	Centre	5,700	6,200	4,000	6,400
351	Centre	1,800	1,600	1,800	2,500
690	Centre	1,500	1,900	1,900	1,800
2,491	Centre	2,900	3,500	3,100	4,300
513	South	4,200	4,400	4,700	4,700
516	South	4,000	4,000	4,000	4,300
561	South	4,600	4,600	3,800	4,800
670	South	4,200	4,400	4,300	4,300
746	South	3,500	3,500	3,600	3,600

The poor-water quality impacts on the agricultural land because it makes soil less suitable for cultivation and plant growth, which affects crop production (Figure 7.3) (Harhash and Yousif, 1985; Hashim, 1995; al-Nasr and al-Sheeb, 1999; Ahmad and al-Faqeh, 1999).

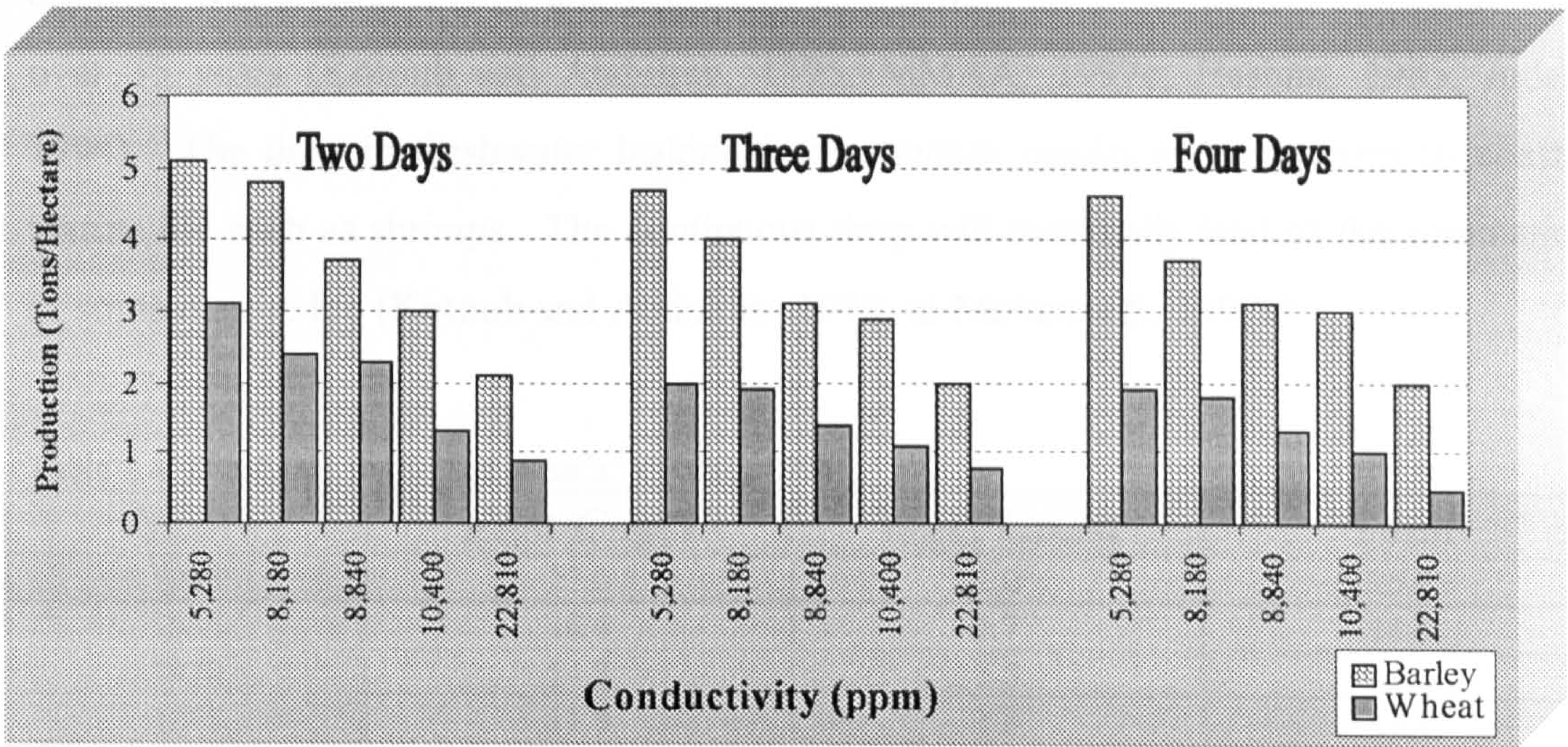

Figure 7.3. The Effect of Saline Water Irrigation for Different Days on Production of Selected Crops in Qatar (MMAA, 1989).

The most important evidence for impacts of water quality change is abandoned farms, which increased from 21 farms (5.1% of total farms) in 1971-72 (Shalan, 1981) to 288 farms (23.9% of total farms) in 1997-1998 (Figure 7.4) (Hashim and Abdulmalik, 1999; Hashim and Ibrahim, 1999).

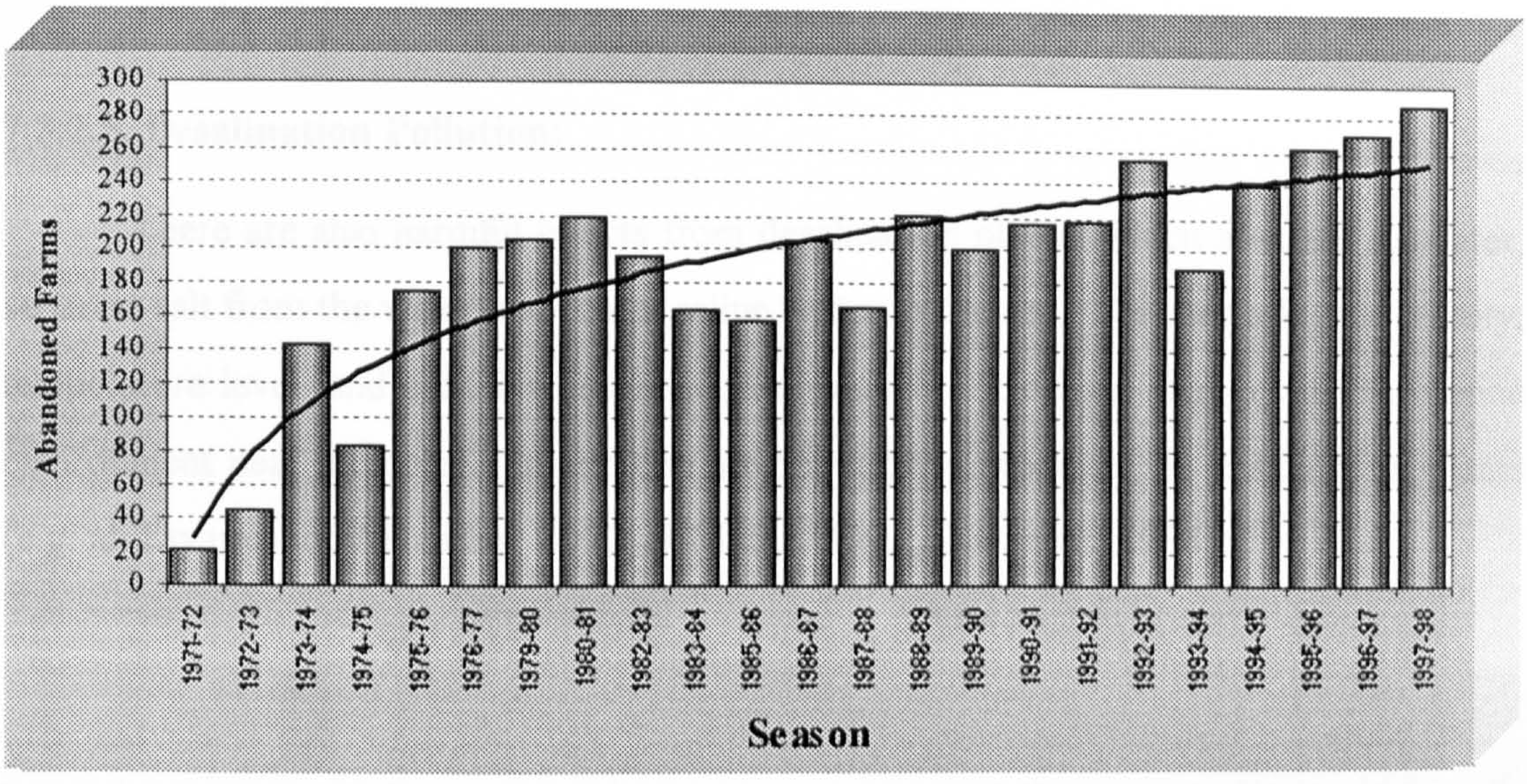

Figure 7.4. Number of Abandoned Farms in Qatar for Selected Years (Shalan, 1981; Hashim and Abdulmalik, 1999).

7.3.2.4. Groundwater Flow Problems:

Environmental damage results from a decrease in groundwater drainage into seawater (Table 7.4). This drainage in the Eastern Coast was 23 Mm^3 in 1960 and dropped to 4.1 Mm^3 in 1995, a decrease of around 82.2%. In the Western Coast this drainage was around 2 Mm^3 and decreased to 0.6 Mm^3 in 1995, that is a drop of 70% over 35 years (Kotoub and Abdulrab, 1995; MMAA, 1997c; Hashim, 1985; Judah, 1994). The drop in freshwater leaking into seawater results in great harm to coastal marine life such as shrimps. The continuous drop will eventually lead to the elimination of some marine life (Kotoub and Abdulrab, 1995; al-Mohannadi, 1997a).

Table 7.4. Discharge to the Sea (Mm^3a^{-1})(Judah, 1994).

Year	East Coast	West Coast	Total
1960	23.0	2.0	25.0
1965	16.9	1.7	18.6
1970	14.3	1.5	15.8
1975	11.9	1.3	13.1
1980	9.6	1.1	10.7
1985	7.6	0.9	8.5
1990	5.7	0.7	6.5
1995	4.1	0.6	4.6
2000	2.5	0.5	3.0
2005	1.2	0.4	1.5
2010	0.0	0.3	0.3
2015	0.0	0.2	0.2
2020	0.0	0.1	0.1
2025	0.0	0.1	0.1
2030	0.0	0.0	0.0

7.3.2.5. Desalination Pollution:

There are also harmful effects from desalination plants, which abstract seawater, separate salt from the water and return saline water to the sea. This has a higher salinity, temperature level, and contains desalination chemicals. It causes changes in the marine environment near the coast. In addition air pollution is produced by desalination plants (e.g. al-Tayaran and Manadny, 1992; al-Mutaz, 1991; al-Khayat, 1988).

7.3.2.6. Increased Groundwater Levels under Cities:

Another environmental change resulting from the development of water is the increase in the level of groundwater in the capital from 1 m above sea level in 1950 to 9 m in 1982, with the annual increase being about 0.82 m (MMAA, 1987; Hashim and Ibrahim, 1999). This is due to rainfall, the water used for irrigating public parks and gardens and leakage from water and sewage networks (Judah, 1994). Leakage from water networks may reach more than 40% (al-Attiyah, 2000; al-Emadi, 2000a). This also caused the appearance of a belt of salty water on the western side of the capital. This might cause serious health and economic problems in the city that contains the majority of the population and economic activity of Qatar (JICA, 1987). The most important of these problems is the erosion of the foundations of buildings and carriageways, which has become obvious to the naked eye in the past few years. Some building are threatened with collapse (Mohammad, 1990; Rushdi, 2001b). The construction of an underground network in 1991 to discharge this water into the sea was limited to some badly affected areas (al-Hajri *et al.*, 1992). The discharge of water to the sea reached 20,000 m^3d^{-1} with a salinity mean of 7,000 μS/cm, therefore it could be exploiting for some irrigation of species less sensitive toward poor water quality such as barley and palms (Hashim and Ibrahim, 1999).

7.3.2.7. Conclusion:

In summary, the management and development of water in Qatar did not take account of the delicate environmental circumstances of the area, which meant any change might have huge adverse consequences. The accelerated development of groundwater has caused serious damage that might lead to its depletion in the next few years. Many of the water fields are not suitable for drinking water anymore. Non-traditional sources of water such as desalination have adverse influences on the marine environment. The environment must be taken into account when managing and developing water sources.

7.3.3. Legislation:

Consequently, a number of regulations have been enacted and most of them are antiquated due to the fact that most of these regulations were enacted during 1960s (al-Harmi, 2000b). Most important among them is law no.1/1988, which tackles particularly the problem of increased well digging by private farmers. Most of these farms (about 98% of the total farms) are not of economic or commercial significance (al-Barghouti, 2000) but more of recreational value for the owners who usually have high situations in the country. The law attempted to regulate and control the drilling of wells on environmental, economic and technical grounds. For instance, article one stipulates the need to have a permit to drill a well and the necessity to control the amounts pumped by putting special meters to show the amounts of water being drawn. Any changes in the levels of pumping would need prior approval. Article 18 stipulated clearly that groundwater is ultimately owned by the State (al-Mahmoud, 1992; MMAA, 1998c, al-Rufaai, 1989).

7.3.3.1. Disadvantages of Water Laws:

Thus, the Government wanted, through this law, to organise production of groundwater and to conserve the amounts consumed. It seems that enacting the law by itself is not enough, however. What is essential is its application is equity and justice among all those concerned. In a small country like Qatar, particular social groups have the power to impair the execution of the law by using their influence in the absence of real surveillance (Figure 7.5) (al-Kuwari, 1996; Safar, 1998b; Bahar, 1997; al-Rufaai, 1989). Thus, when one person is able to attain permits to drill several wells while others are not able to attain a permit for one borehole, the law has little significance. A strong mechanism is needed to put the law into force equally and justly among all concerned.

Figure 7.5. Caricature Showing the Suffering of Laws from Exceptions (After al-Malik, 1999b).

7.3.3.2. Conclusion:

The slow pace of enacting the necessary laws to regulate well drilling has had some negative influences. Even when the law eventually was enacted it lacked the necessary means for proper enforcement and equity. Existing laws emphasise control over production. Very few effective laws presently regulate consumption.

7.3.4. Technology:

7.3.4.1. Groundwater and Desalination Technology:

The Government used the same method to provide water to the inhabitants of the capital. The phenomenon took off and it reached the people themselves. They started to drill wells in their farms and use pumps to draw water. 1997-1998 there were 3,388 wells utilising groundwater in the country (Judah, 1994; MMAA, 1997c; Hashim and Abdulmalik, 1999). For lifting groundwater, most of farmers used a diesel pump without a meter which led to water loss (MIA, 1984). Despite this expansion in drilling deep wells, water shortages persisted. The Government changed to a very expensive non-traditional method of producing water by establishing the first water desalination plants in Doha in 1954. These used the submerged coil technology. Later, in 1959, it switched to using MSF long tube acid dosed single purpose technology (MEW, 1994; MIC, 1996).

The addition of units to desalination plants continued in order to keep up with the ever increasing demand for water. In recent times, Qatar has had six desalination plants (Section 6.2.3). The largest and most important one is at RAF and uses the MSF dual purpose technology and the second is RAA and uses the MSF single purpose technology. The last plant became old and will close in 2003 (al-Attiyah, 2000). Two small but comparable plants are at Dukhan and Ras Laffan for oil companies and industrial consumption. The other two are smaller and are used to desalinate brackish groundwater in areas far from the capital, at Abu Samra and North Camp. These use RO technology which is the cheapest desalination method, especially when used for brackish groundwater (al-Diab, 1994; Kotoub and al-Mahmoud, 1997; al-Mohannadi, 1998).

7.3.4.2. Water Network Technology:

The method of water distribution also started to change to distribution through water networks (83%), which at present are limited to some parts of the country specially the capital and surrounding areas (Table 7.5). These distribution networks have developed significantly and covered 76,310 consumers (3,000 km) in 1997 (PC, 1999b) as compared to 8,000 (390 km) in 1971 and 28,000 in 1981 (MEW, 1998). The rest of the consumers in the capital suburbs and rural areas (17%) have water distributed by water tankers (al-Qahtani, 2000; MEW, 1998). In 1997 there were about 1,158 water tankers, compared with 50 in 1971 and 550 in 1976. There are tanker - filling facilities at 12 locations around the country, especially in the centre and north (MEW, 1981; MEW, 1994; MEW, 1998; al-Diab, 1994). It is worth mentioning that water loss through networks is estimated at around 40% of the amount of water distributed (which cost about \$165-\$192 million) (al-Attiyah, 2000; al-Emadi, 2000a). In developed countries leakage of 15% is usual (ESCWA, 1993).

Table 7.5. Water Distribution Methods in Different Municipals (PC, 1999b).

Municipal	Population		Pipeline Network		Tankers	
	No.	%	No. Building	%	No. Building	%
Doha	264,009	50.6	32,300	96.3	1,232	3.7
Al-Rayyan	169,774	32.5	14,456	77.1	4,291	22.9
Al-Wakra	24,283	4.7	3,043	88.3	403	11.7
Umm Salal	18,392	3.5	1,497	59.5	1,018	40.5
Al-Khor	17,793	3.4	298	16.8	1,478	83.2
Al-Shamal	4,059	0.8	0	0	847	100
Al-Ghuwairiya	1,716	0.3	0	0	142	100
Al-Jemailiya	9,836	1.9	912	44.1	1,154	55.9
Jeryan al-Batna	4,521	0.9	30	7	399	93
Mesaieed	7,640	1.5	887	98.5	13	1.5
Total	**522,023**	**100**	**53,423**	**83**	**10,977**	**17**

The water network in Qatar is designed in the shape of a tree with closed branches, which is an easy and less costly design. But it tends to collect residues because of the stagnancy of water in the closed ends. Also, when repairs or improvements in the networks are undertaken, water supply is cut (Judah, 1994). The continued dependence on water tankers to distribute water leads sometimes to water pollution or its unavailability when needed (Plate 7.1) (al-Jeadah, 2000; al-Qahtani, 2000; al-Qudeemi, 2000; Lutfi, 2000; Saleh, 2000; Rushdi, 2001a).

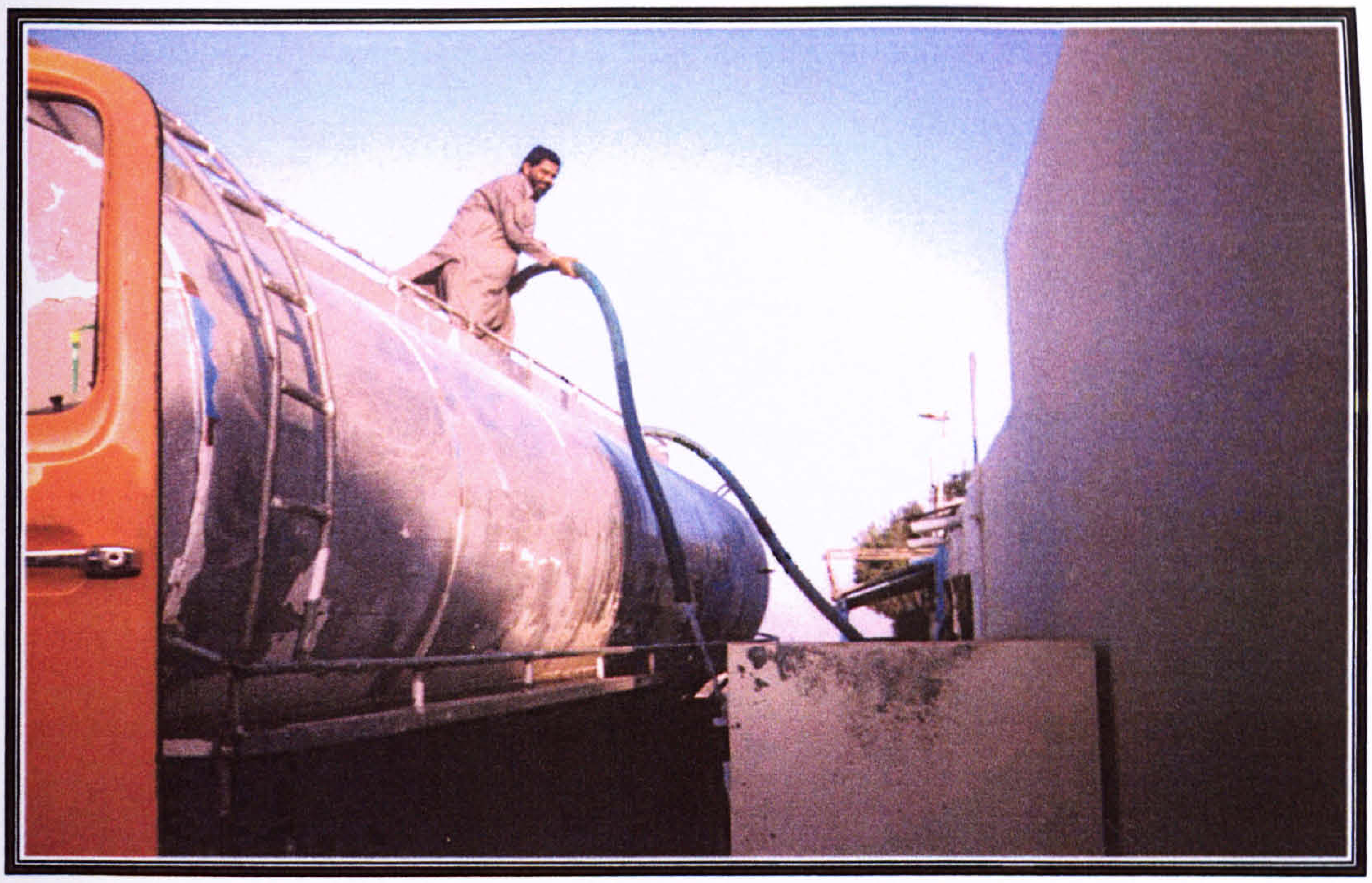

Plate 7.1. Water Distributed by Tankers in Al-Thakirah City (The Researcher, 2000).

As for storage, water reservoirs capacity increased to 251.8 MIG (1,144,545 m^3) in 1998 from 10 MIG in 1971 (27,272 m^3) and 60 MIG (45,454 m^3) in 1982 (Table 7.6) (MEW, 1998; al-Kuwari, 1999a). In spite of that, the total storage is enough for less than four days only (Kotoub, 1998; Babikir, 1998b).

Table 7.6. Reservoirs Capacity in Qatar in Million Imperial Gallons (MEW, 1998).

Reservoirs	Capacity (MIG)	Reservoirs	Capacity (MIG)
Ras Abu Funtas (A)	38	Gharafa	42
Ras Abu Funtas (B)	19.3	West Bay	36
Airport	24	Wakrah	4
Old Salwa	9	Mesaieed Town	6
New Salwa	36	Al-Shimal	4
Mesaieed Industrial	16	Mazrouah	1
Al-Khor	4	Industrial Area	6
Abu Samrah	0.5	Bni Hajr	6

7.3.4.3. Domestic Water Supply Technology:

The discussion will move now to detailing some of the technological methods in water production and development in the domestic and agricultural sectors. In the domestic sector, and because of the improvement in the standard of living, modern equipment is used in houses and governmental and non-governmental offices. Thus, consumption was once restricted by scooping from pots, but now Qataris are used to tapped water, washing machines, dish washers etc., which consume huge amounts of water (Riad, 1992; al-Mohannadi, 1997a). Despite the fact that the Qatari society is a Muslim one, where performing prayer requires the population to wash five times a day (ablutions), consumption technology, such as using water pressurised by air has not been used.

7.3.4.4. Irrigation Technology:

In the agricultural sector, modern irrigation methods such as sprinkle and drip are used only on 18.91% of cultivated land, around 2,177 ha, while the rest, around 9,333 ha, still depends on traditional methods which cause massive loss of water through evaporation and leakage and led to soil salinity (al-Mugran, 1992; Kotoub and Abdulrab, 1995; Hashim and Abdulmalik, 1999). It is worth mentioning that the use of modern irrigation techniques, especially drip irrigation, is very successful in Qatar in the cultivation of vegetables. It reduced the amounts of water used significantly. Using modern irrigation techniques was, however, restricted to experimental farms run by the Government because of its high cost and the need for high scale labour. Most of the private farms in Qatar are not for commercial purposes, hence there is no incentive on the part of the owners to invest in expensive modern techniques of irrigation (MMAA, 1998b; Hashim, 1995; AOAD, 1994).

The type of worker engaged in agriculture has also had a direct impact on the choice of irrigation methods. In general, agricultural workers are migrants from East Asia or Arab countries such as Egypt, where traditional method are prevalent due to being water-rich and technologically poor (Hashim, 1995; al-Nasr, 1998; al-Kubaisi, 1999; al-Kuwari, 2001). It is difficult for these workers to change and accommodate to the totally different desert environment in Qatar. Moreover, most of the farms in Qatar use diesel pumps, which pump large amounts of water without any control, although electric units are considered more efficient (MIA, 1984). It is, of course, the cost of the technology that determines the method. But these cheaper methods cause massive losses of water.

7.3.4.5. Recycling Technology:

Another major development in developing water resources during the oil boom has been recycling. The first sewage network was established in Qatar in 1969 to service some areas in the capital. Two years after that, a sewage treatment plant was established. At present, Qatar has at four main plants and several small plants around the country (Section 6.2.4) (al-Sharafi, 1998; al-Diab, 1994; al-Mohannadi, 1997a). The capital has two main plants, one in the south and the second in the west that can treat the sewage of 350,000 persons. The other important plants are smaller and are located in al-Khor in north east and Mesaieed in south east. These plants produce around 100,000-120,000 m^3 daily which is used to irrigate parks and some agricultural produce that is consumed by animals or not eaten directly (MMAA, 1994; Cowan and Johnson, 1985; al-Sharafi, 1998; al-Saeig, Undated). That has reduced the pressure on groundwater to some extent.

At present, there are no plans to use this water for industrial or domestic purposes. That will depend on the purity of the water since ideologically Islam stresses the fact that Muslims must use clean and pure water (Abu Hggag, 1981; Helmer and Hespanhol, 1997; Abdelhaleem, 1989). Moreover, even farmers and some sport clubs, including golf refused to use recycled water for psychological reasons. Therefore, in 2001 consumption was reduced to 25,000 m^3d^{-1}. This led to disposal of about 21 Mm^3a^{-1} of recycled water into the emergency lakes, especially at Abu Nahklah (Hussin, 2001).

7.3.4.6. Conclusion:

In summary, the use of technology in water management is strongly tied to Government plans and development projects while the improvement in the standards of living of the population played a secondary role, restricted to the use of modern equipment and machines in households.

7.3.5. The Economy:

7.3.5.1. Introduction:

The management of water has been a purely governmental matter from the moment that political rule in Qatar became concentrated in a central Government. The

Government undertakes all studies, construction and administration of water facilities in the country (Metualy, 1981b; al-Kuwari, 1996; al-Mugran, 1992; MIC, 1996).

7.3.5.2. Water Production Costs:

Groundwater Production Costs:

The Government utilises four main potable water fields. These produce 2.78 Mm^3 in 1998, in addition to investing in another 12 brackish groundwater fields for irrigation (MEW, 1994; PC, 1999a). The FAO, in one of its studies, in 1980, estimated the cost of production of one m^3 of groundwater at $0.05 (FAO, 1981). In recent years, one m^3 of ground water costs around $0.06 (al-Diab, 1994). This means the Government spends around $166,800 annually to produce fresh groundwater for rural areas. The estimate does not take into account the rest of the costs involved regarding construction, operation, maintenance, brackish groundwater production, and distribution.

Seawater and Brackish Groundwater Desalination Production Costs:

The Government invested heavily in studying groundwater in the country and when it became clear that it is not possible to depend entirely on groundwater it started investing in non-traditional sources of water (FAO, 1981; al-Mohannadi, 1997a). It promoted, the construction of desalination plants that are highly costly and technologically advanced (only RAF "B" MSF plants costs about $1,614 million in 1994 and Abu Samra RO plant costs $550,000 in 1982) (al-Diab, 1994; MEW, 1998). Qatar has six different desalination plants, as mentioned before, the most important two in Qatar use the MSF technology which costs $1.16 to produce one m^3 of water, assuming the cost of energy at zero, but the cost increases to $1.64 when the price of energy on the international market is taken into account (Table 7.7) (al-Diab, 1994; ESCWA, 1987; al-Sofi, 1994).

Table 7.7. Desalination Water Production Cost in Qatar (ESCWA, 1987; al-Diab, 1994).

Desalination Unit	Cost ($ per m^3)	Remarks
MSF Dual Purpose	1.16	Energy at Zero Cost
MSF Dual Purpose	1.64	Energy at Market Cost
Reverse Osmosis	1.06	---

In 1998, the production of two important plants reached 131,33 Mm^3 at a cost of \$152,353,345.45, at zero energy cost and \$215,396,109.09 at international market energy cost (\$80 a ton), calculating the cost of importing the technology and its operation as well as the skilled labour required to operate the plants. Besides, there is the cost of maintenance, especially after the recurrence of pollution in Gulf waters as a result of leakage from oil rigs or oil tankers. The maintenance costs of these plants is very high, especially during the Iran-Iraq war from 1980 to 1988 and during the Iraqi invasion of Kuwait during 1990 to 1991 (al-Alawi and Abdulrazzak, 1994; al-Tayaran, 1992; al-Tayaran and Mandany, 1992). The other two plants operate on RO technology, which is relatively cheaper than the MSF method when used for brackish groundwater (\$1.06 per m^3) (el-Mallakh, 1985; Uqba, 1991; Dabbagh *et al.*, 1994; Abduljauad and Ibrahim, 1994). The cost of production of these two plants was \$226,342 a^{-1} in 1997.

Recycling Costs:

Treatment plants have been established by the Government to utilise recycling and for that purpose four main plants have been constructed with a network of 680 km covering the east areas of the country (el-Mallakh, 1985; al-Sharafi, 1998; Ahmad, 1989; MMAA, 1994). The cost of recycling has been \$0.34 per m^3 (al-Diab, 1994; al-Mohannadi, 1997a). By 2000, these plants have treated about 36-43 Mm^3 of sewage effluent with a cost of \$12-14.5 million a^{-1}. Adding to this cost is the cost of construction and maintenance of both plants and networks.

Water Distribution Costs:

The Government is also heavily involved in the distribution of water. In the capital, a distribution network of 3,000 km has been established and in the rest of the country water tankers distribute the water (MEW, 1994; al-Diab, 1994) which costs about \$7,000,000 a^{-1} (al-Attiyah, 2001).

7.3.5.3. Water Tariff:

The heavy investment that the Government undertakes has virtually no return, since Qatar is the only Gulf state whose citizens and some non-citizen do not pay for water (al-Alawi and Abdulrazzak, 1994; el-Mallakh, 1985; Abu Arafat, 2001). In the early 1950s, the Government tried to collect fees on governmental services including water in the capital, while people in the rural areas were paying a fee for water, which was distributed by private companies. Water rates were set at 4 Niabeeze (the local currency of the time equal to about $0.084) per gallon, but the citizens resisted and refused to pay, partly because they believed that water is a gift from Allah and it is owned by everyone and partly because of their limited economic situation in that time. The fees were also perceived as unjust, since those who were most able to pay were exempted (Figure 7.6). In the end, water rates were paid only by foreign companies and agencies. The Government in 1963 made an attempt to encourage citizens to pay by reducing the rate to 1 Niabeeze ($0.021) per gallon, but to no avail (al-Kuwari, 1996; Section A8.2.7). The oil boom of the 1970s and the accumulated wealth in the hands of the Government when the oil price increased from $1.8 in 1953 to $38 per barrel in 1980 put an end to the matter. For non-citizens the Government collects $1.20 per m^3 which is about 67% lower than the cost of producing and distribution the water (al-Alawi and Abdulrazzak, 1994; al-Attiyah, 2000; al-Sumori, 2001a).

Figure 7.6. Caricature Showed the Public Objection about Exception in Tariff Enforcement (After al-Malik, 1999a).

7.3.5.4. Governmental Economic Policy:

In the agriculture sector, the owners of land have the right to decide on drilling wells on their land. Yet, the Government provides immense assistance, such as drilling equipment and fuel. That led to high levels of pumping as well as quite an increase in the number of wells (Kotoub and Abdulrab, 1995). In general, Government policy has been slowly changing. Most of the water policies of Qatar were adopted when the price of the barrel of oil was increased to more than \$38 b^{-1} in late 1970s (Metualy, 1981b; al-Kuwari, 1996), hence money was no object and the Government provided free water and encouraged a water costly agricultural policy. With the oscillation in the price of oil from \$10 to \$28 b^{-1} (al-Deewan, 2000), the Government is rethinking its policies, as is happening in other Gulf states (Figure 7.7) (al-Suleti, 1998; Safar, 1998a; Abu Heleeqa, 1998; Bakar, 1999).

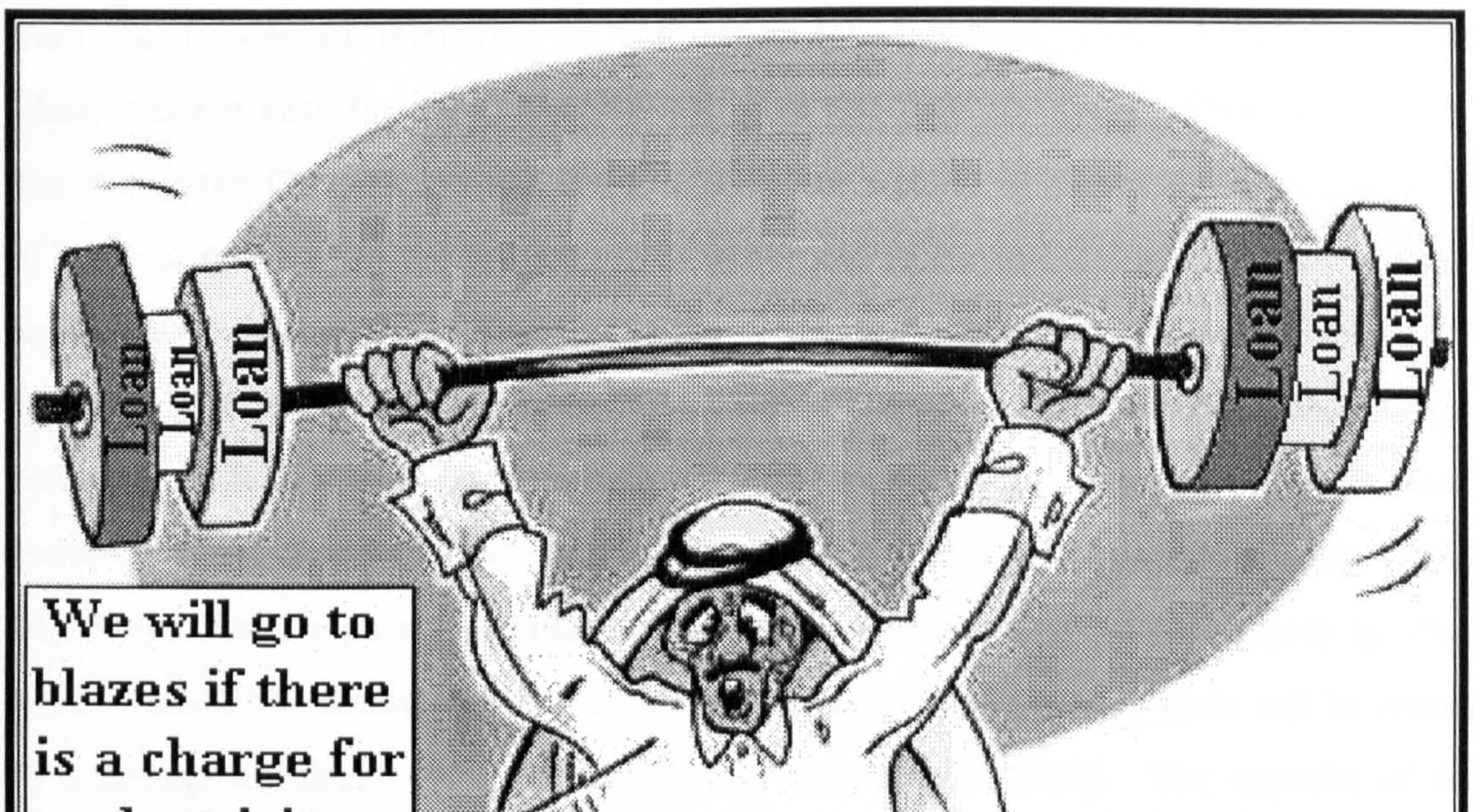

Figure 7.7. Caricature Showing Citizens Apprehension about the Possible Future Water and Electricity Tariffs (After al-Malik, 2001).

7.3.5.5. Water Sector Privatisation:

Recently privatisation of water has been a very important issue in Qatar, especially after MEW was transformed into a corporation in mid 2000 (al-Attiyah, 2000; EIU, 2000; MJ, 2000). Many believed this is the first step towards partial or total privatisation (e.g. Abu Arafat, 2001), as happened with the Qatar Public Telecommunications Corporation (Q-Tel) which became partly private (55% Government and 45% citizens and foreigners) in late 1998 (Kamal, 1998; EIU, 1998c). Q-Tel is facing imputations of carelessness in its service and monopoly (al-Noaimy, 2000; Obaydan, 2000; al-Harmi, 2000a; al-Emadi, 2000b; Safar, 2000).

The Government in Qatar, like other Arabian Gulf countries, are thinking about privatising the service sector, including water. Such a step might prove too difficult to implement, since the citizens of these countries have got used to not paying for services (Anon, 1998d; Anon, 1998a). Accepting the concept of privatised services might take a long time. One of the important water laws enacted in Qatar in 1988 stipulated that water resources are owned by the state and no one can invest in them without permission from the concerned ministries or authorities (al-Mahmoud, 1992; MMAA, 1998c). Thus, it is not easy for the Government to give this right to others. There is no doubt that the Qatari Government will have to carry out a series of measures to recover some of the cost involved in the production of water and to control the ever increasing water consumption (Abu Arafat, 2001). On the other hand, the Qatar Electricity and Water Company (QEWC) is partly private (57% citizens and 43% Government). This company manages the RAF Plant (B) from early 1998 which product 113,637 m^3d^{-1} but it works under QGEWC directions and policies (EIU, 1998c; Anon, 2000a; al-Mohannadi, 2000). Moreover, there is plan to establish an independent water and power project by 2003 which costs $700 million (al-Attiyah, 2001; Saleh, 2001). The new plant will be owned by a foreign developer (60%), QGPC (20%) and QEWC (20%). The capacity of this project is 27 $mgald^{-1}$ (0.12 Mm^3d^{-1}) and will rise to about 60 $mgald^{-1}$ (0.27 Mm^3d^{-1}) in 2007 (Anon, 2000b; EIU, 2000; Saleh, 2001).

7.3.6. Society:

7.3.6.1. Introduction:

At the beginning of the twentieth century, the Qatari population was estimated at 27,000, of which 27% were foreigners (al-Kubaisi, 1986; Fakro, 1998). Those lived in absolute poverty and depended on fishing and pearl-diving and were well accommodated to the severe conditions of the country (Pereira *et al.*, 1977; al-Kuwari, 1978; al-Mansour, 1979; Melamid, 1972; Zahlan, 1989; Metualy, 1981b; al-Shafai, 1996). Freshwater was highly valued and hence salty and brackish water were used for all purposes except drinking (Section A8.2.2.2). Freshwater was conserved and protected (Section A8.2.2.1). Qataris were able subsequently to live in harsh desert conditions as individuals or as members of a self-sufficient tribe. Co-operation in digging wells to depths not exceeding 10 m, as well as storing water was prevalent among the population (Lormer, 1978; Melamid, 1972; Section A8.2.6).

7.3.6.2. Increase in Living Standard of the Society:

The production of oil in the late 1940s influenced the lives of a small group of Qataris but standard of living of the majority were not affected. They deserted the sea and started working on oil fields, but their wages were low: around \$6 to \$40 per month, barely enough to cover the basic costs of a large family. Extended families were still the norm at that time. The small influential minority were able to transform their ways of living and adopt new consumption patterns. The situation continued like this until the oil boom of the 1970s (Riad, 1992; Section A8.2.6).

This time the boom influenced the livelihood of most of the people in Qatar, which reached to 5,220,23 inhabitants (1997 Census). Per capita income increased to \$21,841 in 1999 (Shmisani, 2000). Qatar is considered among the high income countries and the prices of consumer goods in Qatar is much lower in comparison to most countries of similar per capita income (al-Farah, 2001). Also, citizens do not pay income tax or pay for services such as water and electricity (el-Mallakh, 1985; Abu Arafat, 2001). Although Qatari society is still very conservative and retains most of the traditional values and customs, its consumption patterns have changed drastically. Water resources are one of the victims of this drastic change (al-Mohannadi, 1997a; al-Kuwari, 1996; al-Khayat, 1988; Riad, 1992; ESCWA, 1993).

7.3.6.3. Change in the Society:

Citizens, as mentioned before, resisted any attempt by the Government to impose fees on their water consumption. Family structure has changed and the prevalent form is the nuclear family which puts further pressure on water resources by the multiplication of the number of houses, machinery and equipment, gardens, cars etc. (Table 7.8) (al-Khayat, 1988; Riad, 1992). Therefor, citizens consume about 40% of total water production (al-Attiyah, 2000; PC, 2000; al-Sumori, 2001a). Sand storms are common and it is necessary to wash cars and floors after such storms. Also, the presence of a large number of foreign labourers servicing domestic homes (al-Barghouti, 2001), who come from water-rich countries, increases the waste in water. Campaigns for the conservation of water by the Government do not reach this vital group because of language problems. Thus, per capita water consumption in Qatar is among the highest in the world (MEW, 1994; MEW, 1996a; al-Sumori, 2001a).

Table 7.8. Statistic about Machinery and Equipment in Qatari Houses in 1997 (PC, 1999b).

No. Equipment		No. Families	No. Household
Toilet	Zero	1,553	2,321
	One	22,509	74,421
	Two	23,109	118,805
	Three	12,238	75,323
	Four & more	13,775	128,084
	Not Stated	158	1,614
Kitchen	Zero	1	1
	One	66,330	332,694
	Two	5,641	50,800
	Three & more	1,325	16,734
	Not Stated	45	339
Washing Machine	Zero	8,277	16,327
	One	51,140	280,458
	Two	12,134	79,292
	Three & more	1,701	23,756
	Not Stated	90	735
Dishwasher	Zero	67,953	365,407
	One	4,640	25,341
	Two	620	8,354
	Three & more	39	759
	Not Stated	90	707
Car	Zero	15,782	40,096
	One	33,224	171,972
	Two	16,928	105,779
	Three & more	7,310	81,906
	Not Stated	98	815

7.3.6.4. Change in the Agriculture Sector:

The change in the pattern of water consumption extended to the agriculture sector, too. Agricultural activities were restricted to a small group of people (Lormer, 1978; el-Mallakh, 1985; al-Nasr and al-Sheeb, 1999; Section A8.2.5.2), but the oil boom allowed large numbers of the emerging middle class to enter the sector, competing with the rich. The number of small farms increased across the country, despite the unfavourable land and weather conditions. These farms are more recreational than commercial. The Government, when supporting the sector, was targeting the development of commercial farms and not recreational ones as happened in reality (Hashim, 1995; Besesu, 1987; EIU, 1995; Marhon, 1994; Ahmad and al-Faqeh, 1999; al-Mahmoud, 1999).

7.3.6.5. Change in the Commercial Sector:

The improvement in living standards influenced also the development of the trade sector. Commercial centres spread across the country, carrying all kinds of consumption goods and durables. Water consumption of the commercial sector far exceeded that of the industrial sector. The nature of the labour involved in these two sector plays a major role in the high level of their consumption (al-Khayat, 1988; Riad, 1992; Marhon, 1994). Most of the foreign labour employed in these two sectors come from water-rich countries and usually they have a low educational background.

7.3.6.6. Society and Governmental Policies:

The increase in water consumption was not only due to drastic changes in the society in the wake of the oil boom. Government policies played a role, too. The Government, by giving up on imposing water rates, rooted in the society the idea that water consumption is a guaranteed right to the citizens, regardless of consequences. The agricultural policy of self-sufficiency promoted by the Government pushed many capable citizens to establish farms, but for status or recreational, rather than for commercial reasons (Nyrop, 1984; Riad, 1992; Ahmad and al-Faqeh, 1999). The consequences were dire, in terms of depletion of groundwater and total failure in achieving food self-sufficiency. This pushed the Government to enact a major law to curb this trend in the agricultural sector.

7.3.6.7. Public Participation:

The absence of popular participation in the management and development of water played a major role in making people unaware of the value of water and causing a lack of any sense of responsibility towards the water problem (Bahar, 1997; Filho, 1995; Ali, 1999; Khuraibet and al-Attar, 1997). Popular participation in Qatar is exclusive to the Advisory Council (*Majlis al-Shura*), whose members are chosen by the Amir from among prominent figures of the main tribes in the country and whose role is limited to a consultative one. In March 1999, there were the first municipal elections (29 seats) (Kreeshan, 1999; Gardner, 1999). There was hope to bring to the political arena people who would be more understanding of society's problems and who might be able to concentrate on finding solutions. Unfortunately, the limited democratic experiment found many obstacles, especially Government nonchalance toward the council (al-Emadi, 2001).

7.3.6.8. Water Awareness:

Qatar lacks the training and education needed concerning water management. Qatar's single University does not offer courses in water resources management. The curricula of the other education organisations do not mention the subject, and no training workshops are offered to the public. Also, most of the advertising campaigns to conserve water are of questionable effectiveness. They are spaced out and run for short periods of time, as if it were an administrative task that must be undertaken regardless of its effectiveness or rate of success. Moreover, these campaigns target the citizens in particular, as they mainly use the Arabic language, in a country where foreigners are about 78.5% of the total population. Most of the foreign community does not understand the Arabic language (Bahar, 1997; Hashim, 1995; Filho, 1995; Khuraibet and al-Attar, 1997).

It is very important to reach these foreigners since they run a large section of life in Qatar. There is at least one domestic servant in each Qatari home and they represent a majority of workers in agriculture, industry and commerce (al-Barghouti, 2001). Thus, Government agencies have a role to play in preventing waste and depletion of water in Qatar. The social solution remains one of the most difficult for water management. The Government was able to import the most advanced technology and invest huge sums of money in the service sector but had little success in influencing consumption behaviour, partly because of the difficulty involved in changing human behaviour and because the methods used were ineffective (al-Othman, 1996; Saleh, 1999; al-Khatib, 1999; Sideq, 1999; al-Bader, 2001).

7.3.7. The Decision-making and Water Administration:

7.3.7.1. Introduction:

Before the 1950s, all decisions concerning the running of the country were made by the Amir who inherited the position from the ruling family. Things started changing gradually and the Amir began to distribute the responsibility among various administrative units (al-Kuwari, 1978; al-Kuwari, 1996; Zahlan, 1989; Holden, 1971). The first water administration was founded in 1954 (ten employees) (Figure 7.8), but ultimate decisions remained in the hands of the Amir supported by a British adviser (the country was under British mandate then). In 1956, the constitution of a municipal council for the Doha City was promulgated, stipulating that two thirds of its members must be elected. This did not happen, however, and the Amir continued to supervise and make decisions on all important state matters (el-Mallakh, 1985; al-Kuwari, 1996).

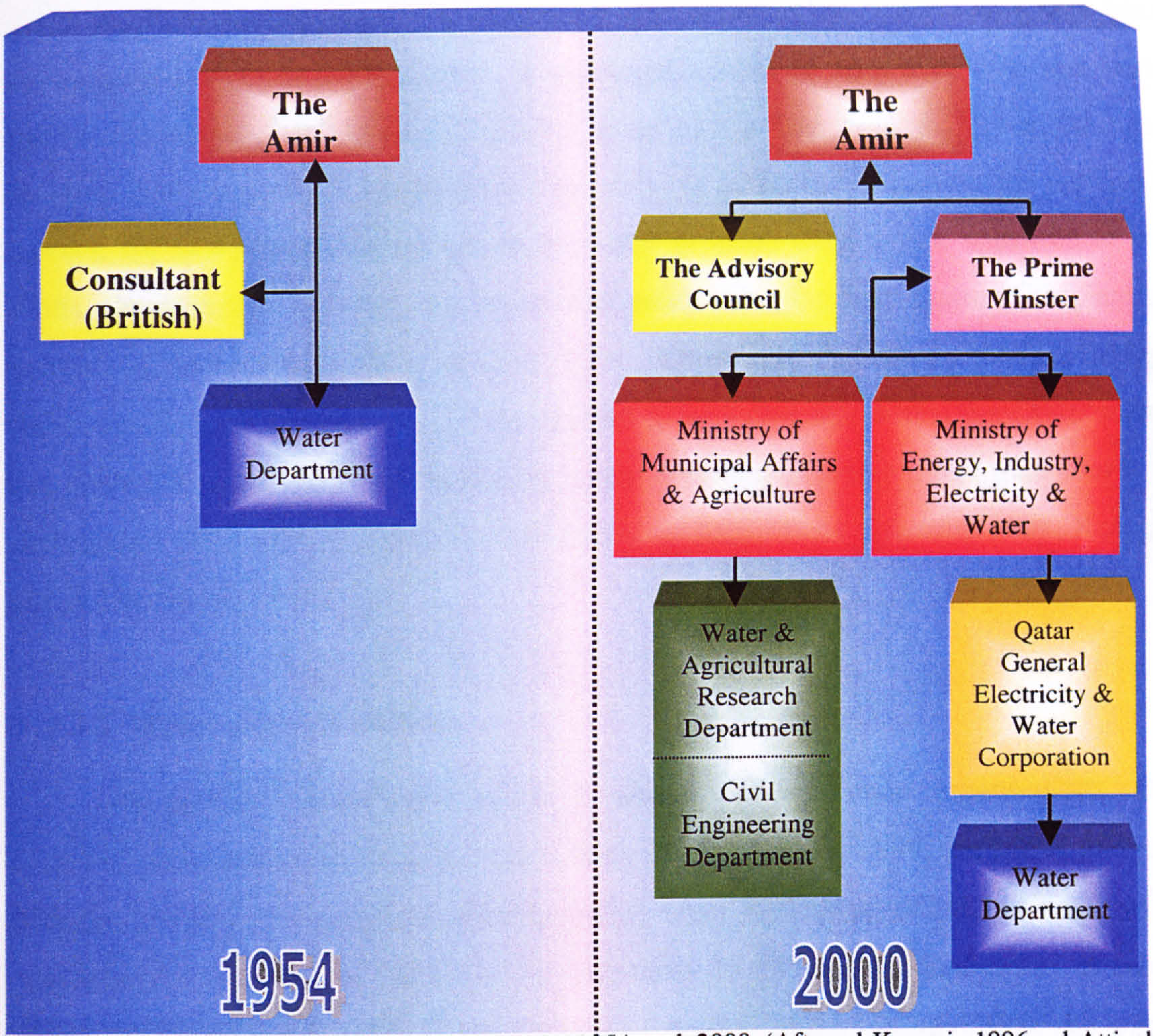

Figure 7.8. Decision-making Process in Qatar in 1954 and 2000 (After al-Kuwari, 1996; al-Attiyah, 2000).

7.3.7.2. The Decision-making Process:

In 1969, a Government consultant and a deputy were appointed to help the Amir in carrying out his responsibilities. By 1970 many ministries were created and a consultative council was founded whose members were appointed by the Amir. The duties of the council included proposing laws and regulations, and giving advice to the Government (al-Kuwari, 1996; el-Mallakh, 1985). At present, water management is divided between two organisations, the Qatar General Electricity and Water Corporation (QGEWC) and MMAA. Important decisions such as importing water, establishing desalination plants, promulgating water laws and appointing senior staff remain in the hands of the Amir and the prime minister (al-Kuwari, 1996; Khuraibet and al-Attar, 1997).

For instance, the discussion over the project aimed at importing water from Iran was carried out by the Government. It appointed a team of specialists who met with Iranian officials and presented a feasibility study to the Government. Thus, all vital decisions rest ultimately in the hands of the Amir. It is worth mentioning the increased concern the Government has shown to the water problem since it first appeared in the 1950s. It responded by taking the decision of establishing the first desalination plant in the area (al-Mohannadi, 1997a; al-Diab, 1994; Agnew and Anderson, 1992). Today, Qatar has six desalination plants. There appears to be a direction within the Government that prefers to spend on the economically costly desalination plants rather than resort to importation which can be politically very costly (al-Akry, 1994; Marhon, 1994; Kotoub and al-Mahmoud, 1997).

7.3.7.3. Water Administrations:

At present, water management is shared by two main organisations, the QGEWC, and MMAA (al-Mugran, 1992, MIC, 1996). In early 1999, the MEW merged with the Ministry of Energy and Industry (MEI) under the control of MEI Minister with responsibility reduction for financial (cutting costs by eliminating duplication of jobs) (Saleh, 1999; al-Khatib, 1999; Sideq, 1999; Abu Arafat, 2001). In July 2000, the water and electricity sector changed again to be QGEWC. The new corporation still work under the Ministry of Energy, Industry, Electricity and Water (MEIEW) direction (al-Attiyah, 2000; EIU, 2000; MJ, 2000). The water part of the new corporation is responsible for the planing, development, production, and distribution of water for the domestic sector.

7.3.7.4. Qatar General Electricity and Water Corporation (QGEWE):

The water part of the corporation is divided into five units (Figure 7.9). One specialises in water and the remaining three share the responsibility of both water and electricity. The water administration unit is divided into six sections, responsible for distribution, operation, maintenance, control, overseeing wells operating in villages and an emergency section. In general, the law specifies the duty of this corporation as responsible for providing suitable drinking water for direct consumption (Saleh, 1999; al-Khatib, 1999; Sideq, 1999; MJ, 2000).

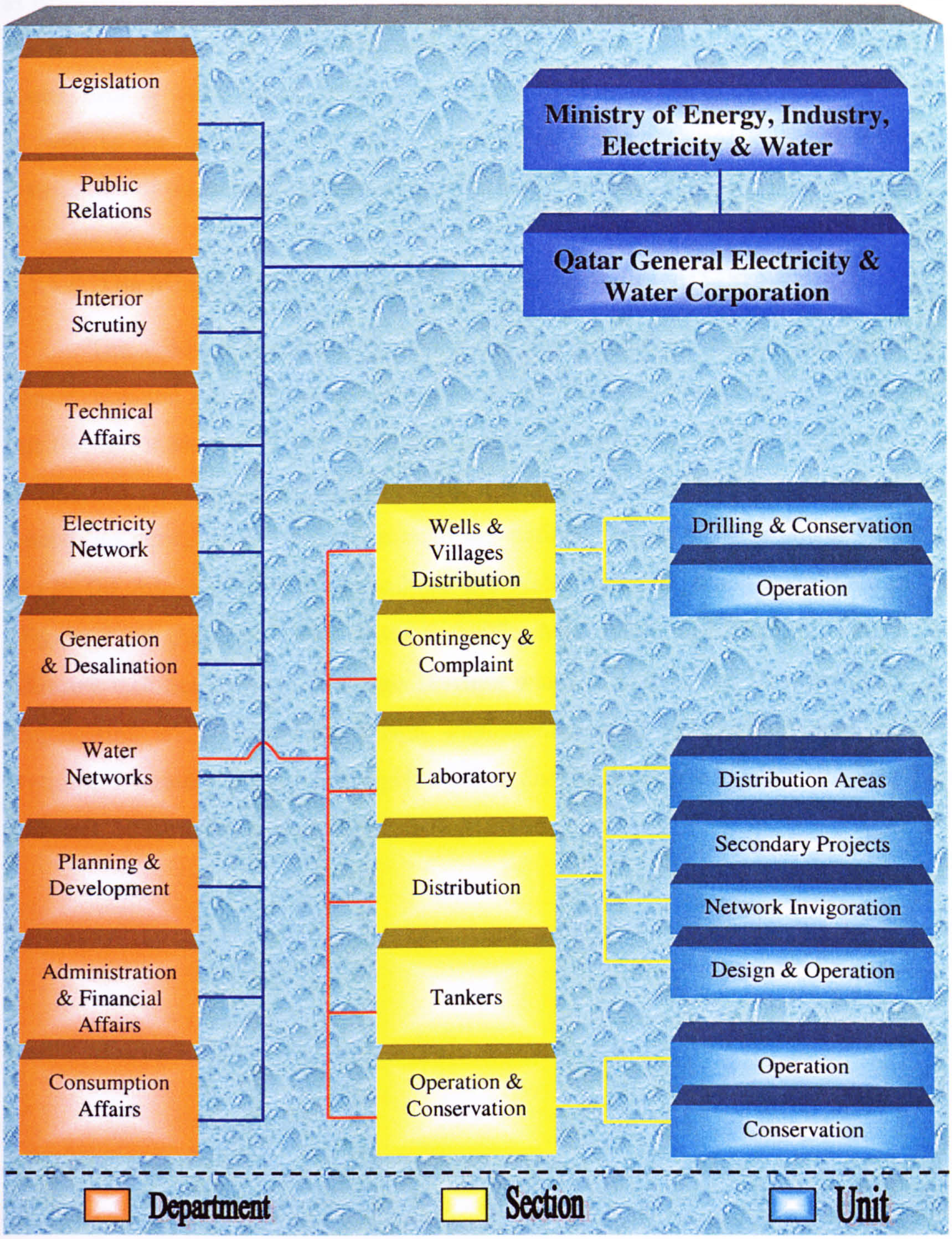

Figure 7.9. The Water Section Constitution in QGEWC (MEW, 1996a; al-Mahmoud *et al.*, 2000).

At present, the corporation produces water from four desalination plants as well as from four main water fields to villages and those areas that desalinated water does not reach. It oversees also the development of water sources, establishment of desalination plants, drilling wells, establishment of water distribution networks and pumping stations as well as the operation and maintenance of all these facilities. It guarantees the distribution of water to the consumer (MEW, 1987; MEW, 1994).

7.3.7.5. The Ministry of Municipal Affairs and Agriculture (MMAA):

The MMAA specialises in water for the agriculture sector and supervision constriction and maintenance of sewage network. This is not necessarily of high quality but the sector has the largest share of the total consumption. It gives permissions for drilling and supervises the drilling of wells, it also monitors the level of groundwater and establishes agricultural and water monitoring stations. Many of these duties are carried out by the Administration of Agriculture and Water Research which established in 1982 (Figure 7.10) (MMAA, 1994; MMAA, 1997a; MIC, 1996; al-Mahmoud, 1999). The Ministry includes also the Drainage Division which is part of the Department of Civil Engineering which supervises design, implementation of sewage networks, pumping stations, treatment plants, and pipelines that distribute recycled water to some farms (Ahmad, 1989; al-Mahmoud, 1992; al-Hajri, 1995).

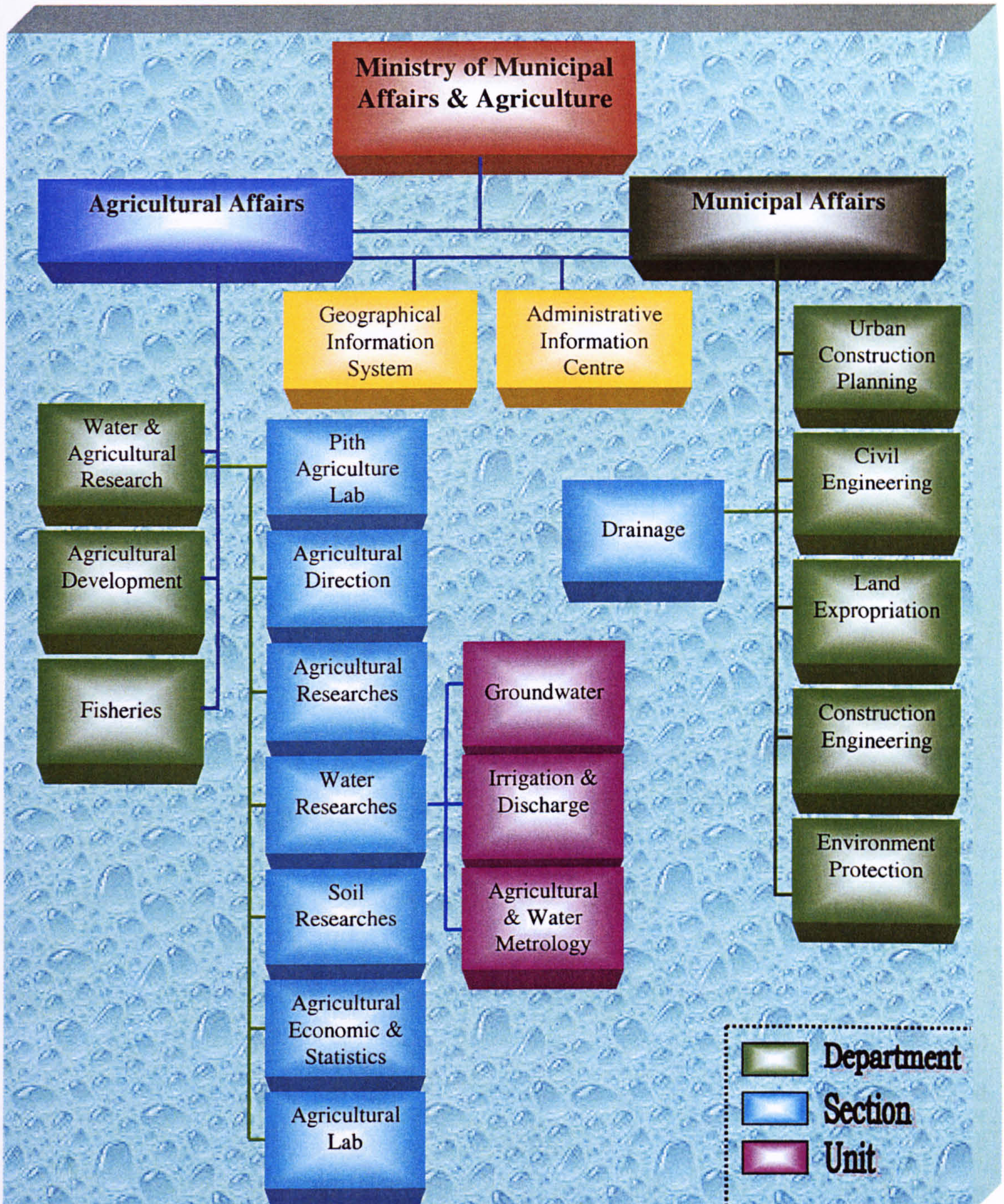

Figure 7.10. The Water Section Constitution in MMAA (After MMAA, 1997a).

7.3.7.6. Manpower of the Water Administrations:

These administrative units are staffed, at present, with a majority of Qataris, especially in upper levels of management. Foreign labour is concentrated in technical positions that require technical excellence and in unskilled jobs that require more physical strength (Table 7.9) (el-Mallakh, 1985; Judah, 1994; Hamdan, 1989; Filho, 1995;

Khuraibet and al-Attar, 1997). Many of the financial departments are concentrated in the capital and dispersed among many buildings across the city. Sometimes they are operating from old and run-down buildings that are not suitable for such important administrations (al-Harmi, 1998).

Table 7.9. The Water and Electricity Administration Staff (al-Attiyah, 2000).

Year	Top Brass		Other		Citizen	Skilled
	Citizen	Non-citizen	Citizen	Non-citizen	(%)	Workers (%)
1994-95	173	116	2,778	5,327	35	23
1995-96	196	109	2,625	4,777	37	27
1996-97	232	87	2,608	4,649	37	25
1997-98	272	79	2,647	4,585	38	30
1998-99	304	70	2,780	4,594	40	31
1999-00	347	64	2,946	4,510	42	35

7.3.7.7. Water Administrations Situation and their Efforts:

It is noticeable that these administrative units are not concerned with building good ties with the public, hence they lack sections specialised in public advertising campaigns. Most of the time such campaigns are carried out without the appropriate research that enables an effective advertising message to reach the public and influence their behaviour (al-Mugran, 1992; Abdulrazzak, 1995). These institutions also lack, especially in the departments responsible for the domestic sector, sections for research on consumption patterns, desalination and fresh groundwater. In comparison, in the Administration of Agricultural and Water Research, such a section exists. It carries out research, and is very active in organising seminars and conferences.

Another constraint concerning these administrative units is the lack of local researchers and experts. This domain is exclusive to foreigners who do not understand the local language and who do not understand the local environment, customs and traditions, hence all their studies focus on technical elements without any due concern for social factors that are as important (Abdulrazzak, 1995; Judah, 1994; Hamdan, 1989).

7.3.7.8. Water Administration Co-ordination:

The establishment of a higher co-ordinating administrative unit has become a necessity in most countries in order to have a clear national strategy and policy for water management that is capable of co-ordinating the various elements concerning water management on a national level. In most Gulf states such as Oman and Bahrain a higher council for water management exists (al-Mugran, 1992; Abdulrazzak, 1995) but it seems the idea has not been adopted in Qatar.

7.3.7.9. Public Participation:

A major issue concerning water management in Qatar is the lack of opportunity for popular participation in water management. Most of the policies in Qatar are taken in isolation of pubic opinion, which encourages people to feel less responsible towards the scare water resource, and consequently consume it as they wish without any social constraints. In some developed countries the opinion of the people living in the project area is often solicited and in many occasions their opinion is very important to the technicians working on the project since they have a better knowledge of their area (Willeke, 1976; Whitland and ReVelle, 1990; Hunter, 1998; House, 1996; O'Rourke, 1992; McDonald and Kay, 1988).

7.3.7.10. The Collaboration with Counterpart Organisations:

Contact between the water management in Qatar with its counterparts in other countries and co-operation with the relevant international institutions is well established (MMAA, 1997a; Harhash and Yousif, 1985; Besesu, 1987). Qatar is a member in the Gulf Co-operation Council (GCC), which was established in 1981 and incorporates six of the Arab Gulf countries (al-Zamat, 1998; Zahlan, 1989). One of the articles of the Rules of Procedures of the Council emphasises the importance of encouraging scientific advancements concerning water resources, the establishment of research centres and joint projects and encouraging the co-operation of the private sector in this field. The aims of the Committee for Agricultural and Water Co-operation (whose members are the ministers of agriculture of the Council countries) include enacting common water legislation, adopting the best methods to conserve water resources, carrying out research especially concerning the common groundwater aquifers and organising conferences and seminars in the field (al-Mugran, 1992; Abdulrazzak, 1995; GCC, 1996a; GCC, 1998a).

The Council has been successful in passing some polices, such as a common agricultural policy that depends mostly on efficient utilisation of the available water resources and a common system for water resources conservation. Most of these polices however, remain resolutions on paper and are rarely implemented. There are many reasons for this but mainly the inability of member states to see beyond their own interests. The Council's foremost priority is the security of the Gulf; other matters are only important in proving the existence of a common body for these Gulf States (al-Mugran, 1992; Abdulrazzak, 1995; GCC, 1998b; Khuraibet and al-Attar, 1997). Hence, most policies, including water policies, have not yet overcome obstacles to their implementation (al-Thani, 1993; al-Thani, 2000; al-Mahmoud, 2001).

Moreover, the Government resorted to international organisations and experts in its attempt to find the best practice for water management. In 1960, the Government contracted Ralph M. Parsons from the USA in order to carry out a study on groundwater sources in the country. The recommendations included carrying out a survey at very deep levels reaching the middle Cretaceous and the Palaeocene. The Government followed the advice of Parsons and contracted a Saudi Arabian company to drill three wells in 1963. That resulted in the discovery that these formations are salty and not suitable for direct consumption (Harhash and Yousif, 1985).

At the same time, the Government was awaiting the results of well explorations done by the Qatari Oil Company. Those results were disappointing too. In 1966 the Government contracted Sogreah Company to find ways to deal with the severe water problem in the capital. The company recommended investing in the brackish groundwater in the south-western part of the country, and extending pipelines to the capital and suggested either mixing the brackish groundwater with desalinated water or desalinating it. The recommendations was rejected by the Government and instead they opted to develop the groundwater in the centre and northern part of the country for rural areas and agriculture and to increase the capacity of the desalination plant that provides water to the capital and to Government activities (al-Kuwari, 1996; Harhash and Yousif, 1985).

These solutions were temporary and the problem of diminishing water reserves emerged. This forced the Government to contact UN agencies such as the UNDP and FAO in 1971 in order to carry a survey of water and agricultural sources in the county. A similar project was carried out in 1974 for the comprehensive use of land and water and a third one in 1980. The most important results of these studies indicated the volume of water resources and the cost of production. They delineated the safe level of annual groundwater withdrawal, which should to decrease to reach 33 Mm^3 for the next thirty years with artificial recharge wells. 36.5 Mm^3a^{-1} of recycled water should be produced to use in agriculture. A new desalination plant at Ras Laffan should be established to produce 21.8 Mm^3a^{-1} for domestic use and 35.2 Mm^3a^{-1} for agriculture. Recommendations for the agricultural sector included raising farmer awareness and supporting them by improving irrigation methods and growing the most suitable crops (e.g. dates and green fodder) for the Qatari environment. Finally, it was stated that food self-sufficiency is not suitable for Qatari water resources and agricultural land, which is able to produce only 20% of the country's food needs in 2000 (FAO, 1981; Harhash and Yousif, 1985; al-Kuwari, 1996). If the FAO policies and recommendations were taken as a whole, such a balance would have possible in Qatar, despite some mistakes in estimations, especially concerning the size of the population and safe groundwater yield. The FAO estimated the population will reach 437,000 by the year 2000, while in 1997 the population stood at 522,023 inhabitants. The safe groundwater yield was estimated for different wells. Presently, the production is less than the estimated safe yield but the problem still exists.

The co-operation with the UN agencies continued, through work with the Economic and Social Commission for Western Asia (ESCWA), especially with the unit of energy and natural resources. Many studies (e.g. ESCWA, 1987; ESCWA, 1993; Judah, 1994) were carried out on Qatar or the region to investigate groundwater as well as non-traditional sources of water such as desalination. These studies had some success in drawing an accurate picture of the dimension of the water problem and ways to invest in what is available as well as identifying the best ways for desalination and recycling.

7.3.7.11. Conclusion:

Decision-makers in Qatar during the oil boom looked for alternative ways of providing water by any means possible, to continue with the development process, especially in the agricultural sector, without paying much attention to the adverse consequences for groundwater or the economic costs of desalination. With the aggravation of the problem of groundwater pollution and depletion, concern is beginning to emerge about the damage to such a vital resource.

Adopting temporary solutions without looking at their long-term consequences has had negative impacts, too. For instance, choosing to expand the costly option of desalination of seawater and develop fresh groundwater in the centre and northern part of the country rather than desalinate brackish groundwater in the southern part of the country had adverse effects on the environment. It polluted some water fields and depleted and changed groundwater quality.

Water management in Qatar needs to further its co-operation with regional and international institutions while taken into consideration the suitability of the research to the environmental and social circumstances of Qatar. Most of the experts that participate in such studies do not have enough experience with local circumstances. Subsequently, these studies are lacking in important social factors and focus on technical or economical aspects. To overcome this, it is important to train local people to carry out such studies on their own or in co-operation with the foreign experts.

7.4. Overall Conclusion:

The problem of scarcity of water in the Qatar has been discussed in Chapter 6. Attempts to deal with this problem were limited, concentrating on importing technology to provide desalinated water, while neglecting other important aspects of the management of the situation. Social and economical aspects in particular were neglected and legal constraints applied incompletely for a number of reasons.

One-sided solutions such as depending on desalinated water did provide the much-needed water, but had adverse consequences. Sustainability requires a more comprehensive approach to water management, which considers water policy as part of the wider national policy of socio-economic development, is more suited to finding solutions and limiting adverse effects. This approach concentrates on management of the relationship between supply and demand taking into account environment, technology, economics, decision-making, legislation, administration, social and religious factors. It must be kept in mind that finding drastic and final solution is not possible in either water-deficit countries or water-surplus countries. Thus what can be achieved is coexistence with the problem and the reduction of its adverse effects so it will not become a constraint on human development and progress.

In the next chapters, the results of a number of surveys dealing with various dimensions of water issues in Qatar are presented. The first of these is a survey of major element water quality, since this is an important part of the whole problem. The following chapters discuss the results of discussions with stakeholders in the water industry, a survey of domestic hydrology and a survey of public attitudes and behaviour.

CHAPTER EIGHT:

WATER QUALITY

Chapter Eight:

Water Quality

8.1. Introduction:

This part of the study will concentrate on freshwater quality in Qatar and comparisons with standards set by the WHO and EC for domestic use, and by Zajic (1971) and Train (1979) for industrial and agricultural uses. Methods and sampling are described in Section 4.3.6. More details can be found in Appendix 10.

8.2. pH:

8.2.1. pH Level by Sources and Areas:

pH in all samples was inside recommended levels, except one desalination sample before treatment, which was still suitable because it is used for industrial purposes (Figure 8.1). Desalination water is more suitable than other sources especially desalinated brackish groundwater. These are no relationships between the geographical distribution of these samples and sources (Figure 8.2). In general, therefore, there is no water pH problem in Qatar.

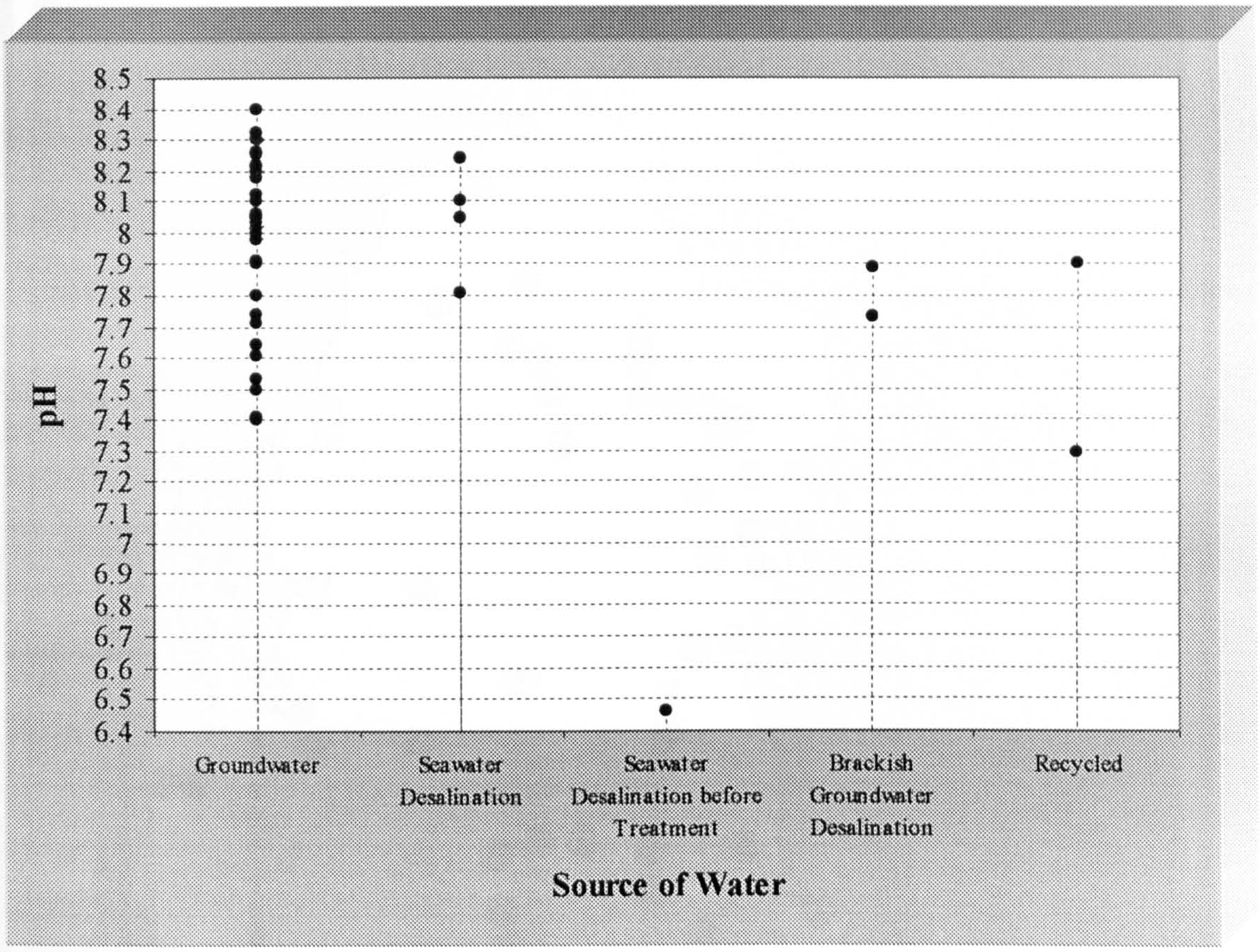

Figure 8.1. pH Tests for Different Water Sources.

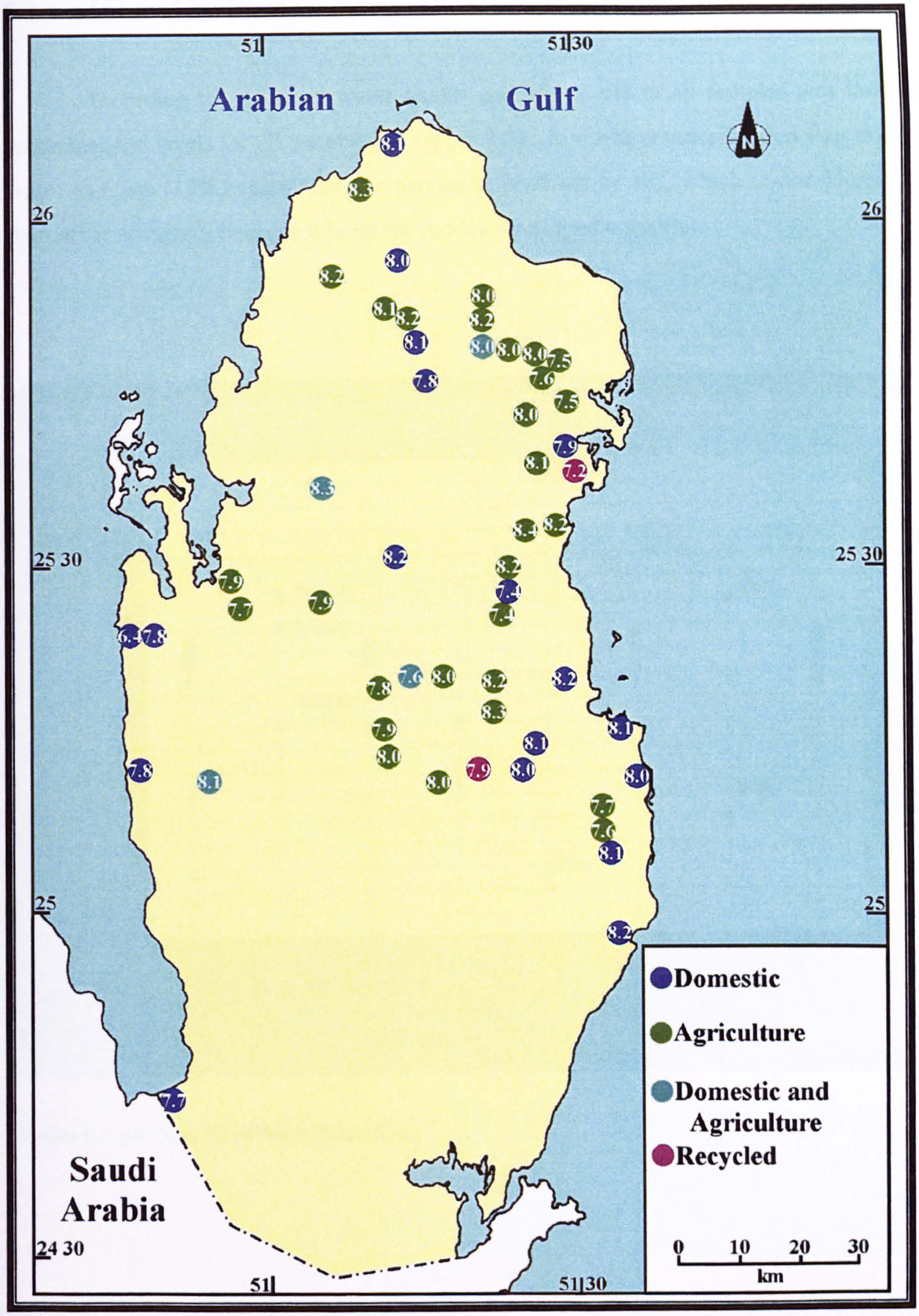

Figure 8.2. Geographical Distribution of pH Levels at Selected Points.

8.2.2. pH Level by Uses:

According to published water quality guidelines, pH in all samples was inside the recommended levels for all water uses (Figure 8.3). It worth mentioning that four domestic water samples (19%) came near the maximum level set by EC, which is considered strict than other standards because it is set for mostly developed countries.

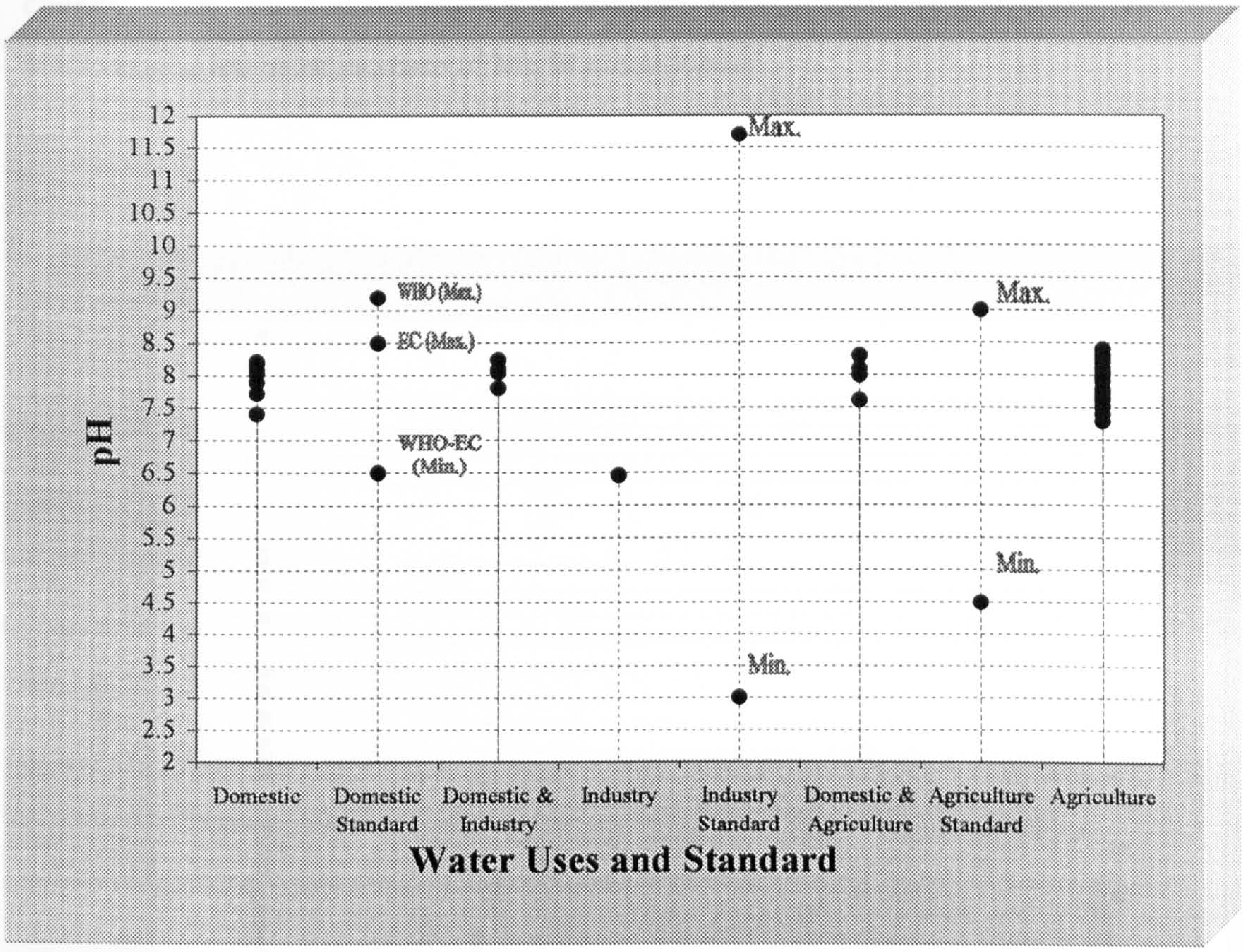

Figure 8.3. pH Tests for Different Water Uses.

8.3. Magnesium (Mg):

8.3.1. Magnesium Concentration by Sources and Areas:

Mg was found in low concentrations in all desalination samples and in a wide range of concentrations among groundwater samples (Figure 8.4). There were strong relationships between the high level of Mg in domestic water samples and geographical distribution (Figure 8.5). High levels were found in groundwater for domestic purposes in the north of Qatar, while for agricultural water, high levels of Mg were found all around the country. The common occurrence of dolomite rock in Qatar (e.g. Harhash and Hassan, 1982) maybe led to an increase of Mg in groundwater.

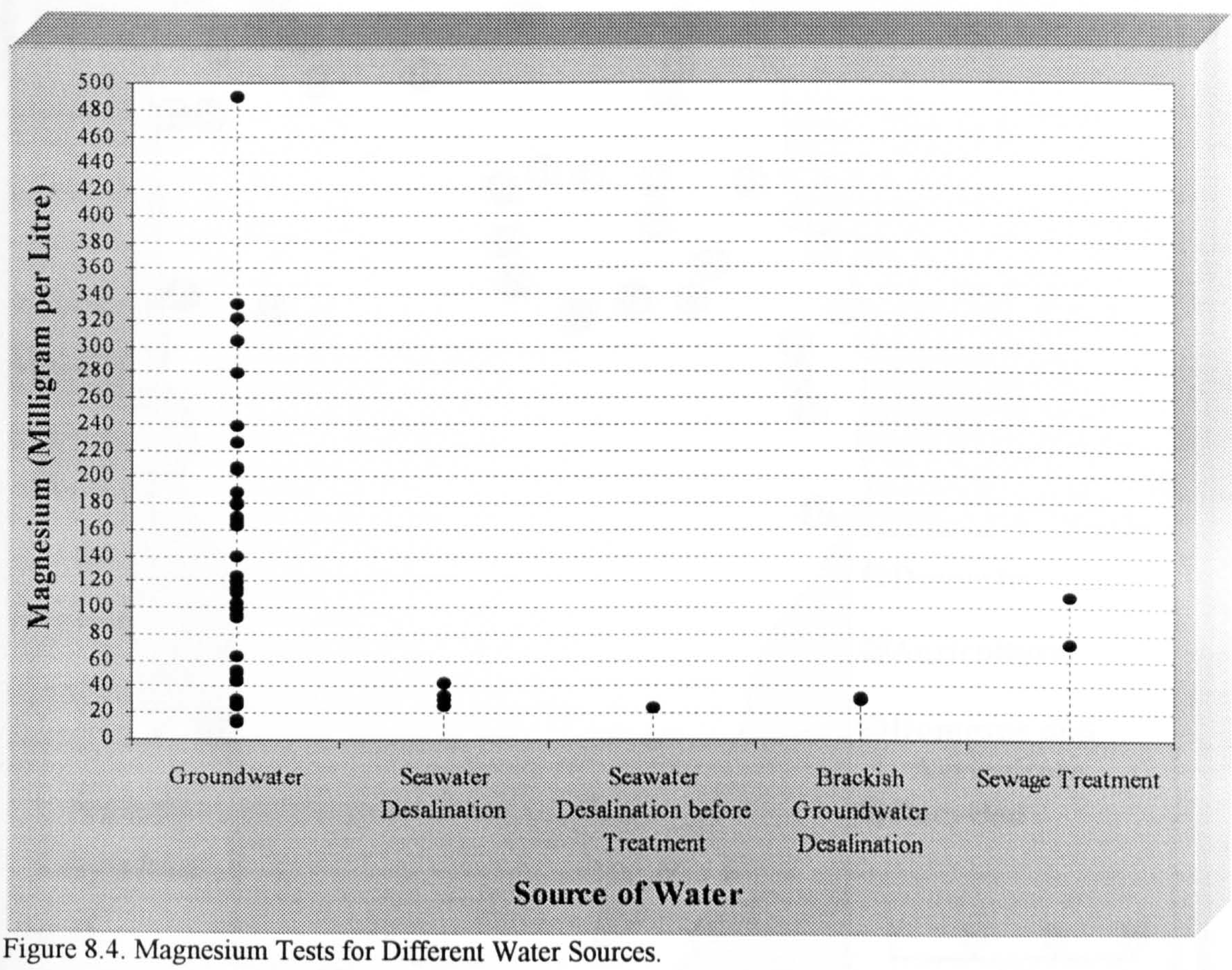

Figure 8.4. Magnesium Tests for Different Water Sources.

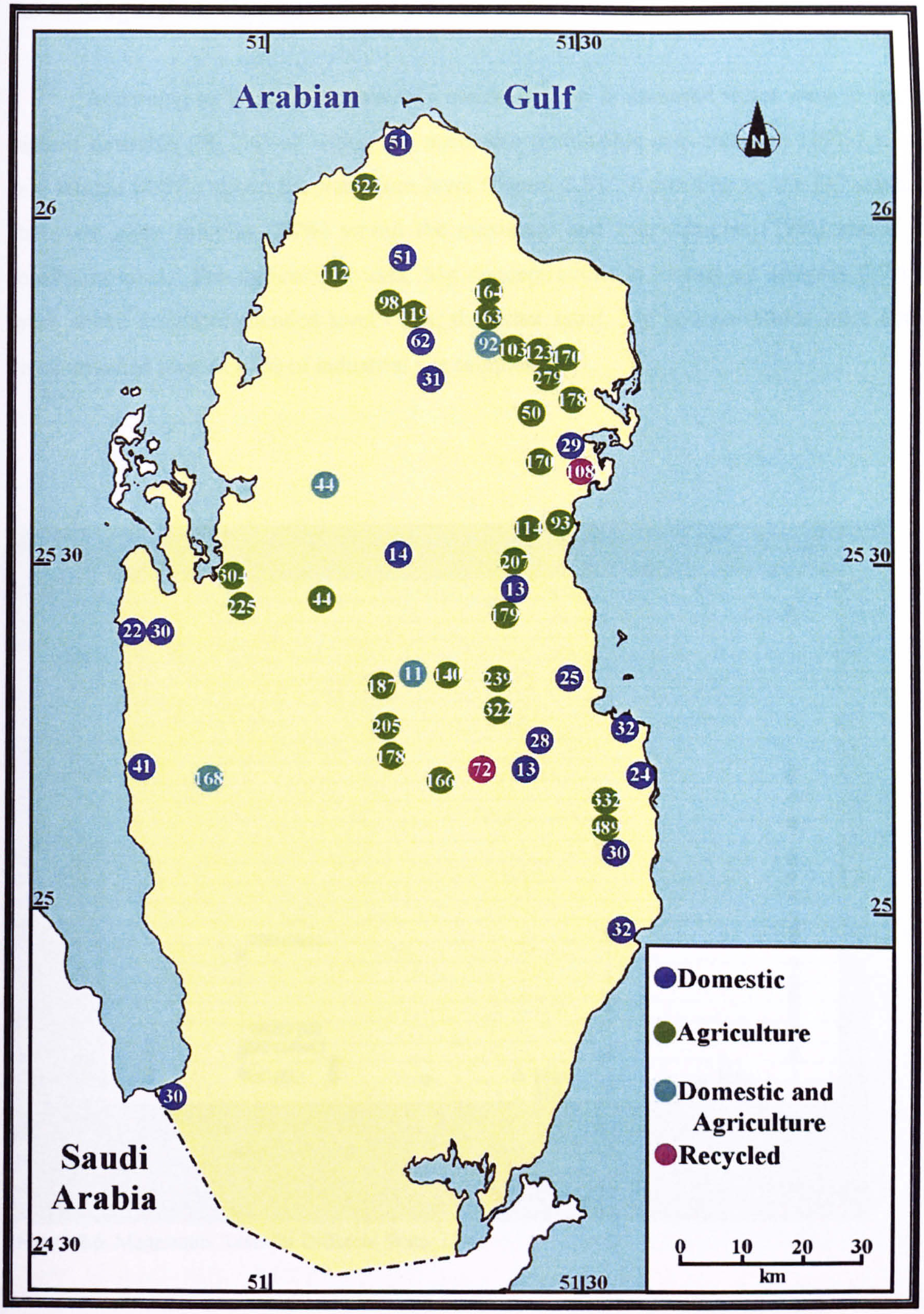

Figure 8.5. Geographical Distribution of Magnesium Levels (mgl^{-1}) at Selected Points.

8.3.2. Magnesium Concentration by Uses:

According to WHO guidelines, Mg concentrations in domestic water were under the highest desirable (76.2%) or within the maximum permissible concentration (19%) except one sample (4.8%) above the maximum level (Figure 8.6). According to the EC standard there are eight samples (38%) within the maximum and four samples (19%) above the maximum level. For agricultural uses, Mg concentrations in almost all samples (97.1%) were above the recommended level. On the other hand, Mg concentrations were above recommended level in 67% of industrial use samples.

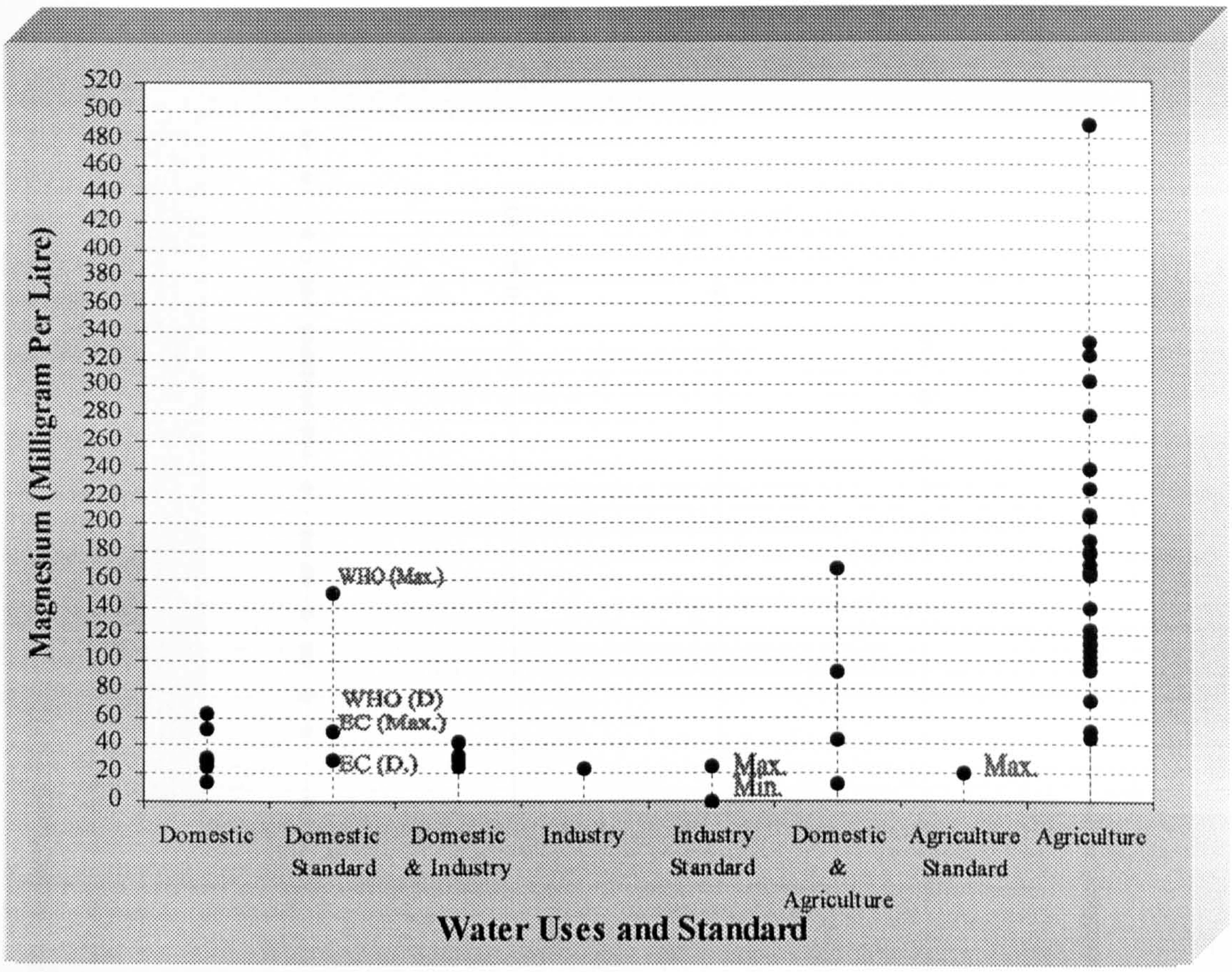

Figure 8.6. Magnesium Tests for Different Water Uses.

8.4. Iron (Fe):

8.4.1. Iron Concentration by Sources and Areas:

Fe concentration was above recommended levels for all water samples. Its concentration in the majority of groundwater and recycled water samples was less than other sources specially seawater desalination (Figure 8.7). There were no strong relationships between high concentration of Fe and geographical distribution because high levels were found in different areas (Figure 8.8). The most important source of Fe in water, beside natural sources, is iron materials such as pipelines and tanks, which are widely used in Qatar for water distribution and storage (e.g. Judah, 1994).

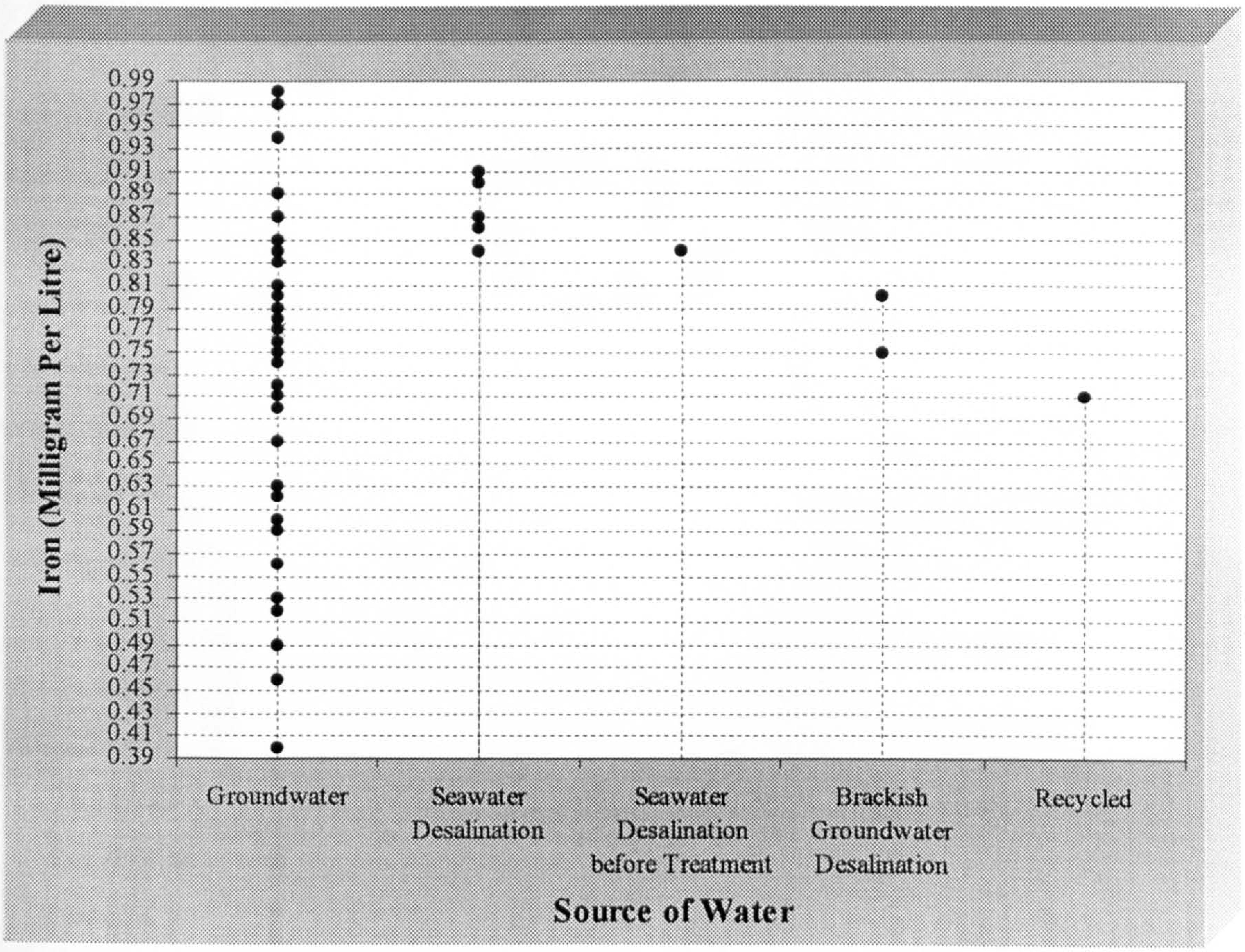

Figure 8.7. Iron Tests for Different Water Uses.

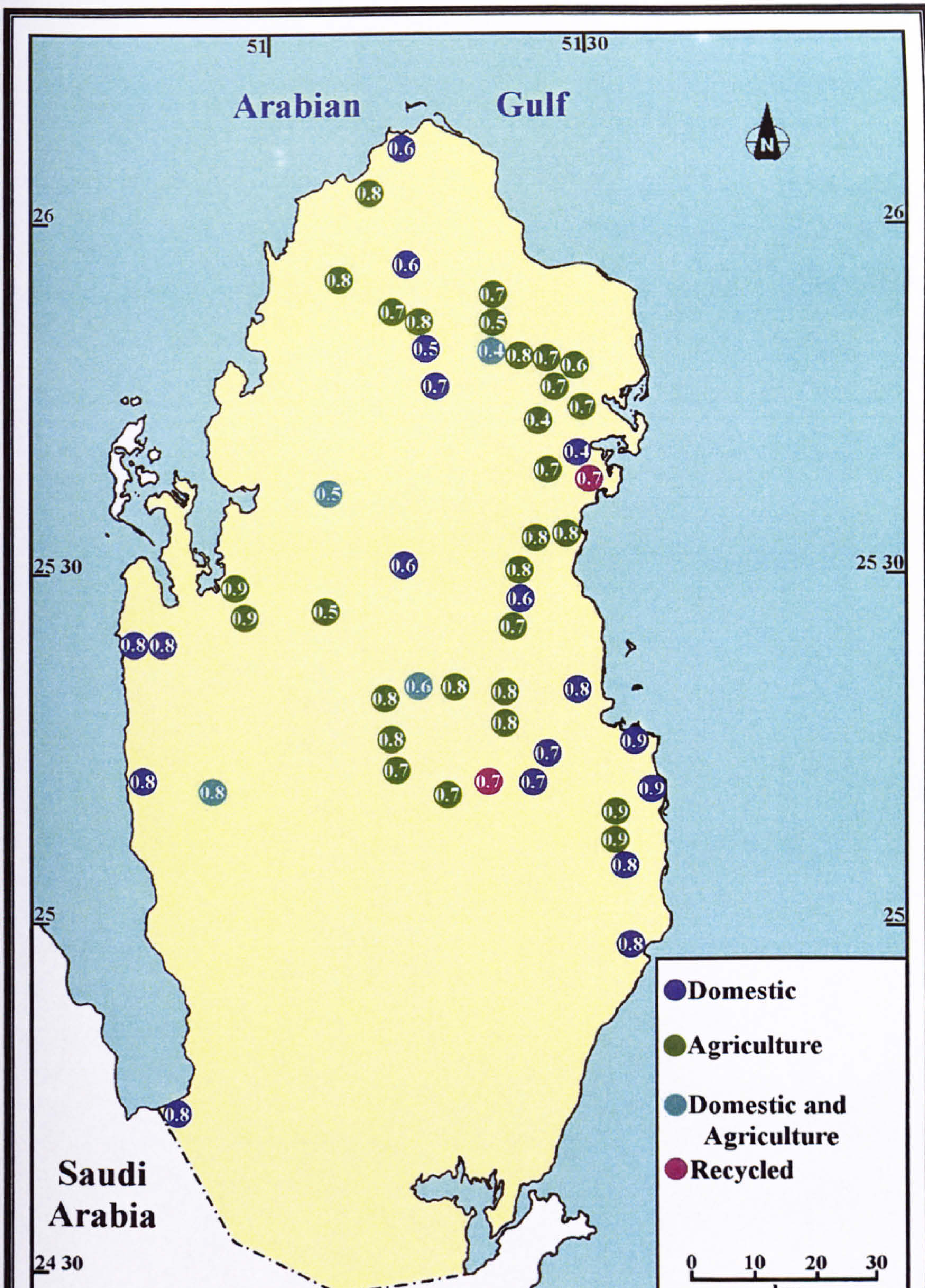

Figure 8.8.Geographical Distribution of Iron Levels (mgl^{-1}) at Selected Points.

8.4.2. Iron Concentration by Uses:

Iron concentration in all domestic water samples was inside the maximum concentration recommended by WHO guidelines (Figure 8.9), but when compared with the EC domestic guideline, all samples were above the recommended levels. For agricultural uses, Fe concentration in all samples was inside maximum level. There are no specific water quality criteria for agricultural uses. Fe concentrations were above the recommended level in all industrial water samples.

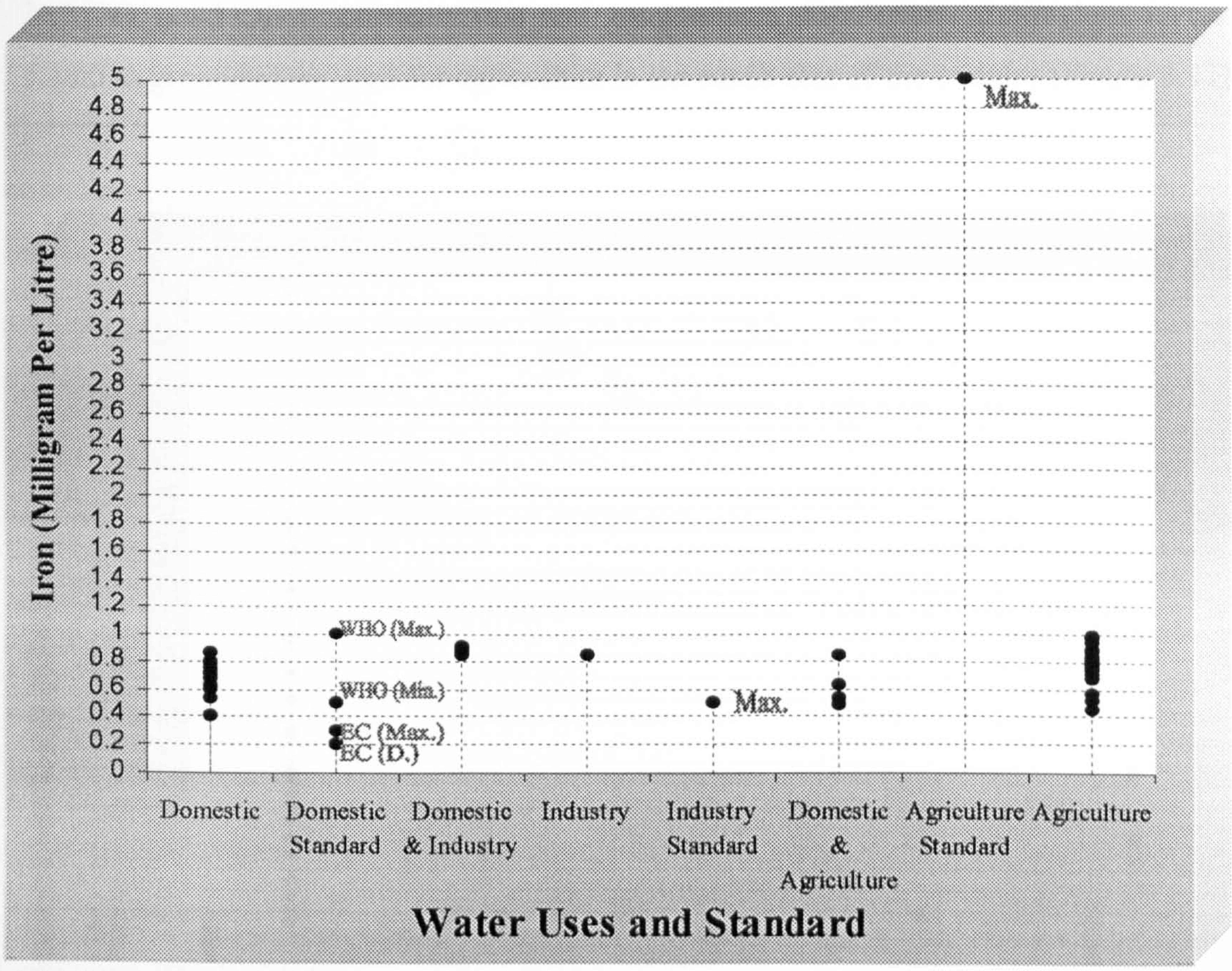

Figure 8.9. Iron Tests for Different Water Uses.

8.5. Conductivity:

8.5.1. Conductivity by Sources and Areas:

The concentration of soluble material in potable water is consider as one of the main water resources problems in Qatar due to natural reasons such as salty rocks, high evaporation and poor recharge and over pumping which led to mixing shallow groundwater with brackish fossil groundwater or with seawater (Section 7.3.2.3).

There were strong relationships between high levels of conductivity and source of water. The highest levels were found in groundwater (Figure 8.10). The lowest concentrations were found in seawater desalination followed by brackish groundwater desalination and recycled water. On the other hand, there was a moderate relationship between conductivity concentration and geographical distribution: the highest levels were found in groundwater used for agriculture in the south east of the country (Figure 8.11).

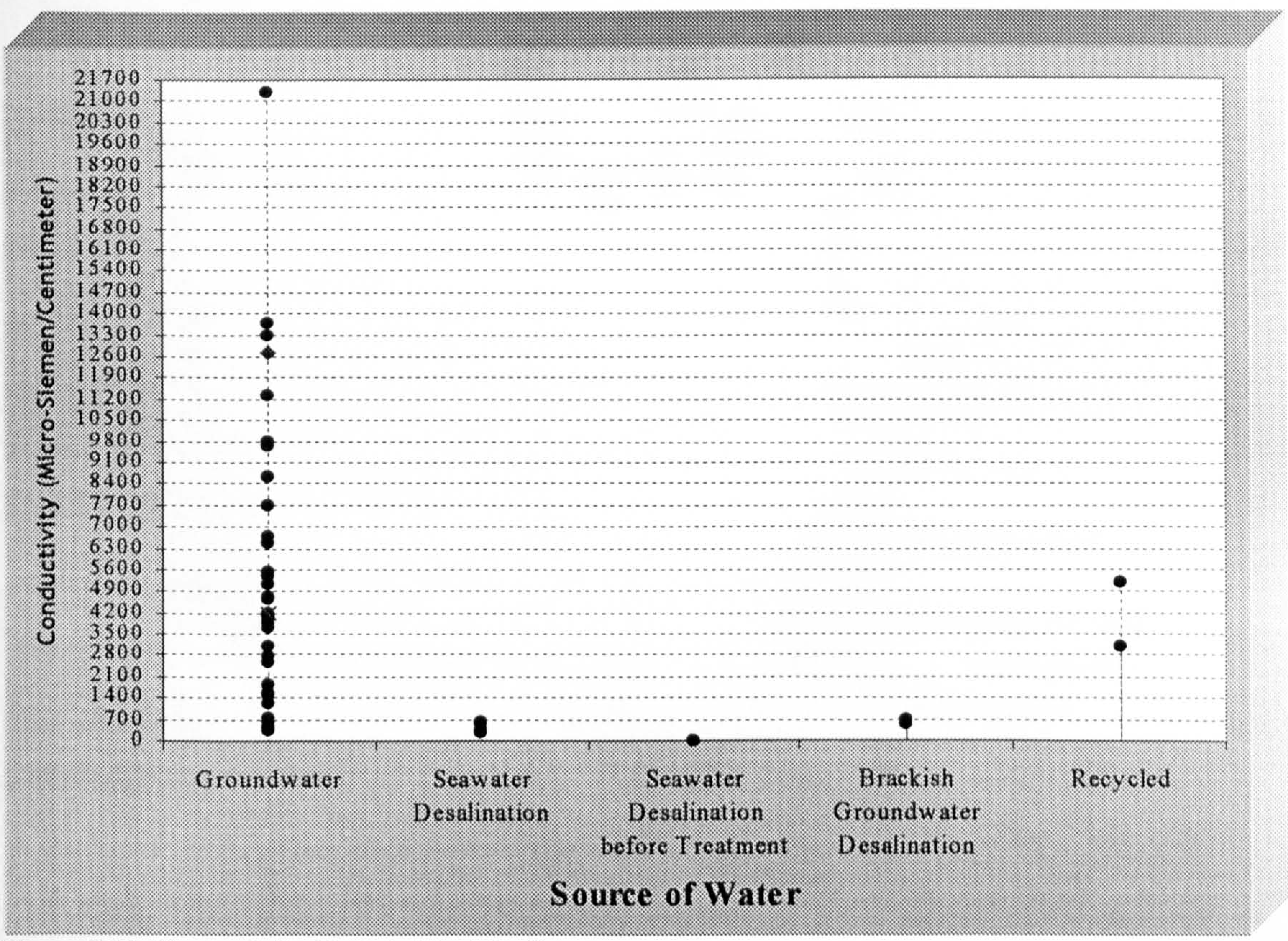

Figure 8.10. Conductivity Tests (μS/cm) for Sources.

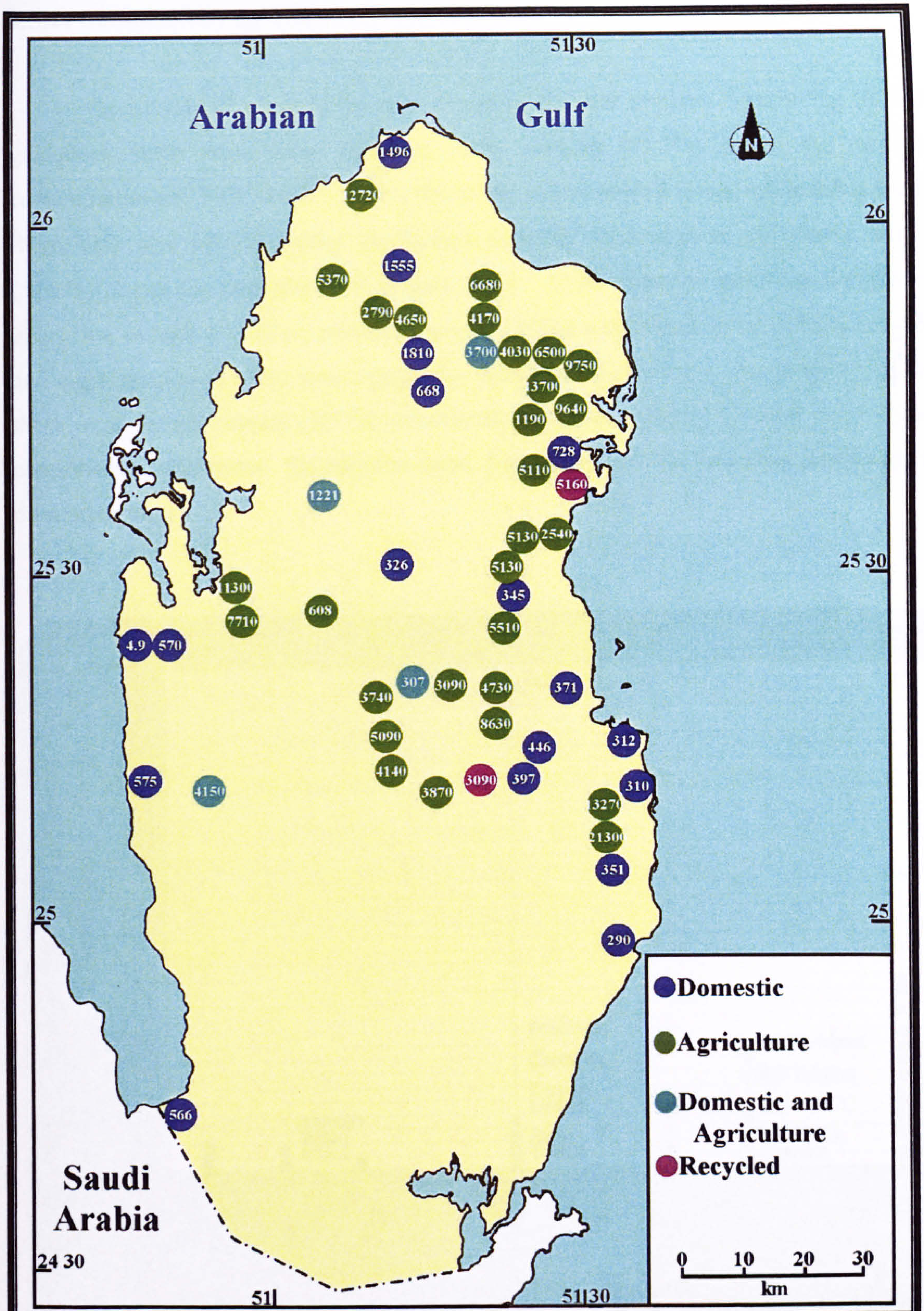

Figure 8.11. Geographical Distribution of Conductivity Levels (μS/cm) at Selected Points.

8.5.2. Conductivity by Uses:

High levels of conductivity were found in different samples. According to WHO guidelines, there were seven domestic water samples (33.3%) within the maximum concentration and four samples (19%) above the recommended levels, while using the EC there were nine (42.9%) under the highest desirable concentration and twelve samples (57.1%) above the desirable level (Figure 8.12). There were no problems for different industries, excepting textiles; only two samples (5.7%) were found to be suitable for crops and eight samples (22.8%) were completely unsuitable (Table 8.1). For domestic animals there were sixteen samples (30.7%) considered as excellent quality, because some animals consume domestic water. On the other hand, five samples (9.6%) may have posed risks for domestic animals.

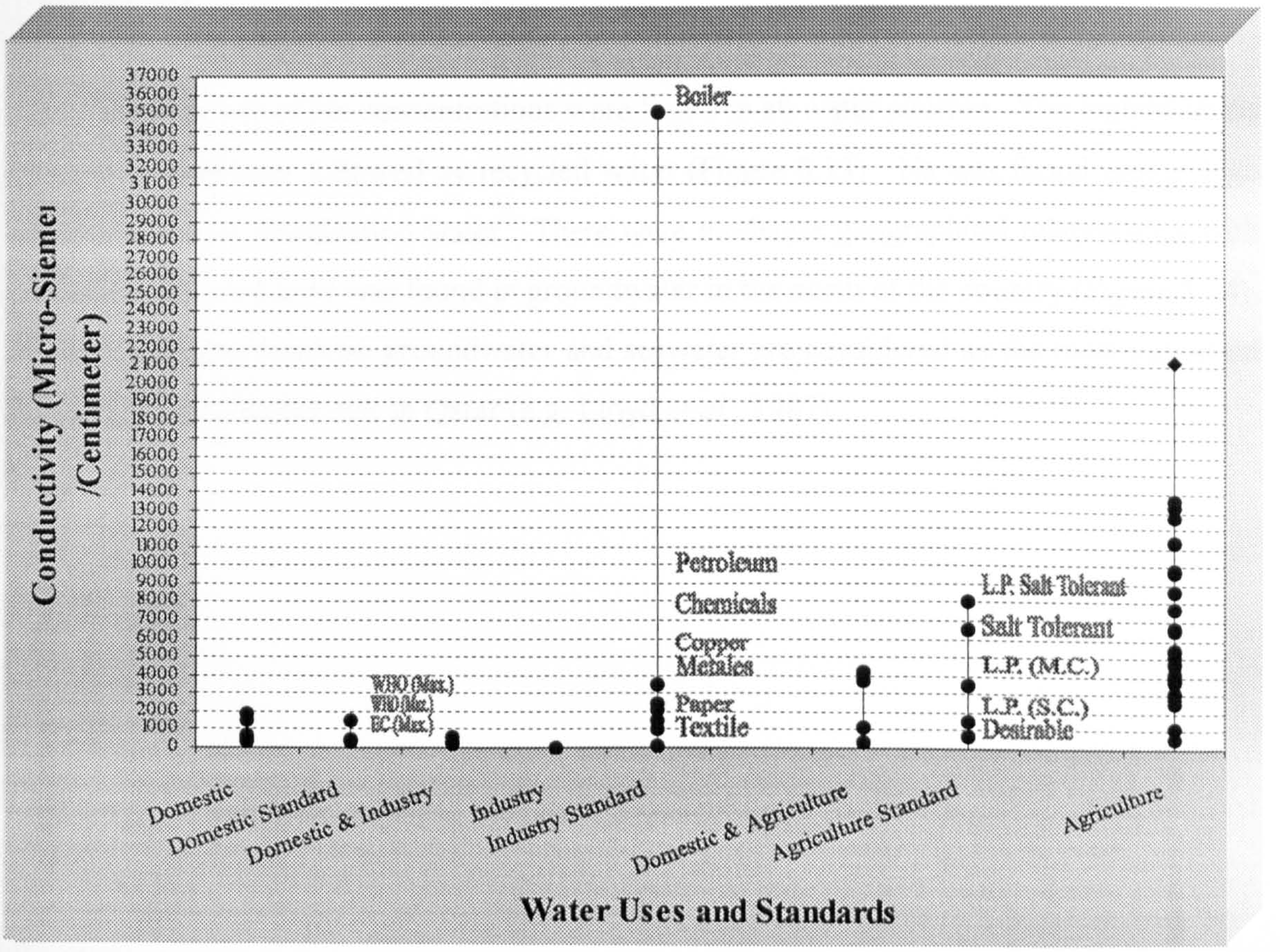

Figure 8.12. Conductivity Tests (μS/cm) for Different Water Uses.

Table 8.1. Above Maximum Recommended Level of Conductivity (Following Judy and Wilkinson, 1980; Train, 1979) Found in Water Samples Using by Industry, Agriculture and Animals.

Industry	>Recommended Levels		Agriculture	>Recommended Levels		Animals	>Recommended Levels	
	No.	%		No.	%		No.	%
Textile	6	100	No Problems	33	94.3	Excellent	36	69
Pulp & Paper	0	0	Limited Production (Sensitive Crops)	31	88.6	Very Satisfactory	29	55.8
Chemicals	0	0	Limited Production (Many Crops)	27	77.1	Satisfactory	18	34.6
Petroleum	0	0	Salt Tolerant Crops Only	10	28.5	Can be Used with Reasonable Safely	9	17
Primary Metals	0	0	Limited Production (Salt Tolerant Crops)	8	22.8	Unfit for poultry and probably for Swine	5	9.6
Copper Mining	0	0				Risks	5	9.6
Boiler Make-up	0	0						

8.6. Sodium (Na):

8.6.1. Sodium Concentration by Sources and Areas:

High levels of Na concentrations were found in all water sources. The highest levels were in groundwater followed by recycled water (Figure 8.13). Na was found also in high concentrations in desalination water. There were moderate geographical relationships with sodium, the lowest level was found in groundwater in the north of the country (Figure 8.14). Mixing with deep brackish groundwater and seawater are considered as the most important sources of Na in freshwater in Qatar (e.g. Lloyd *et al.*, 1987).

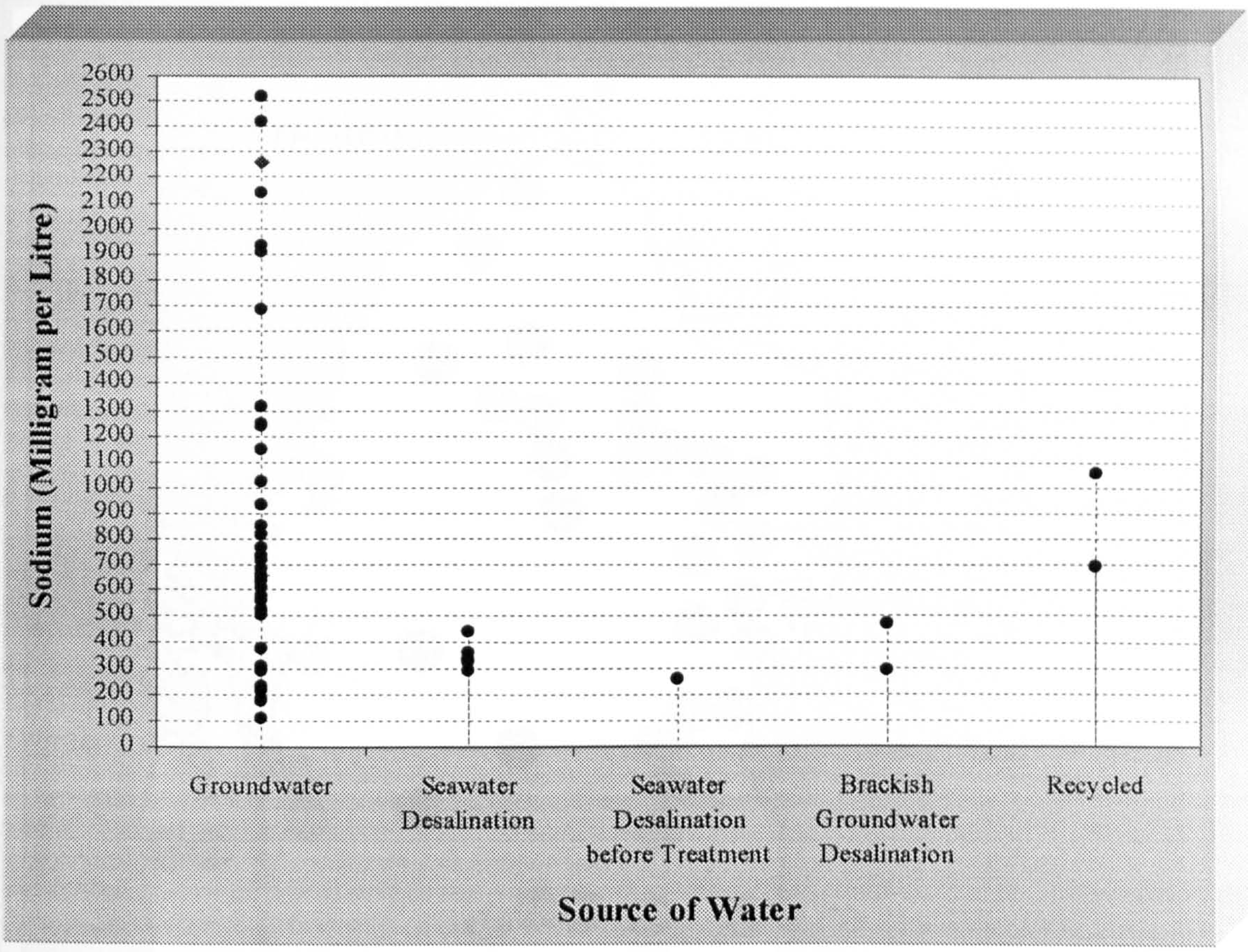

Figure 8.13. Sodium Tests for Different Water Uses.

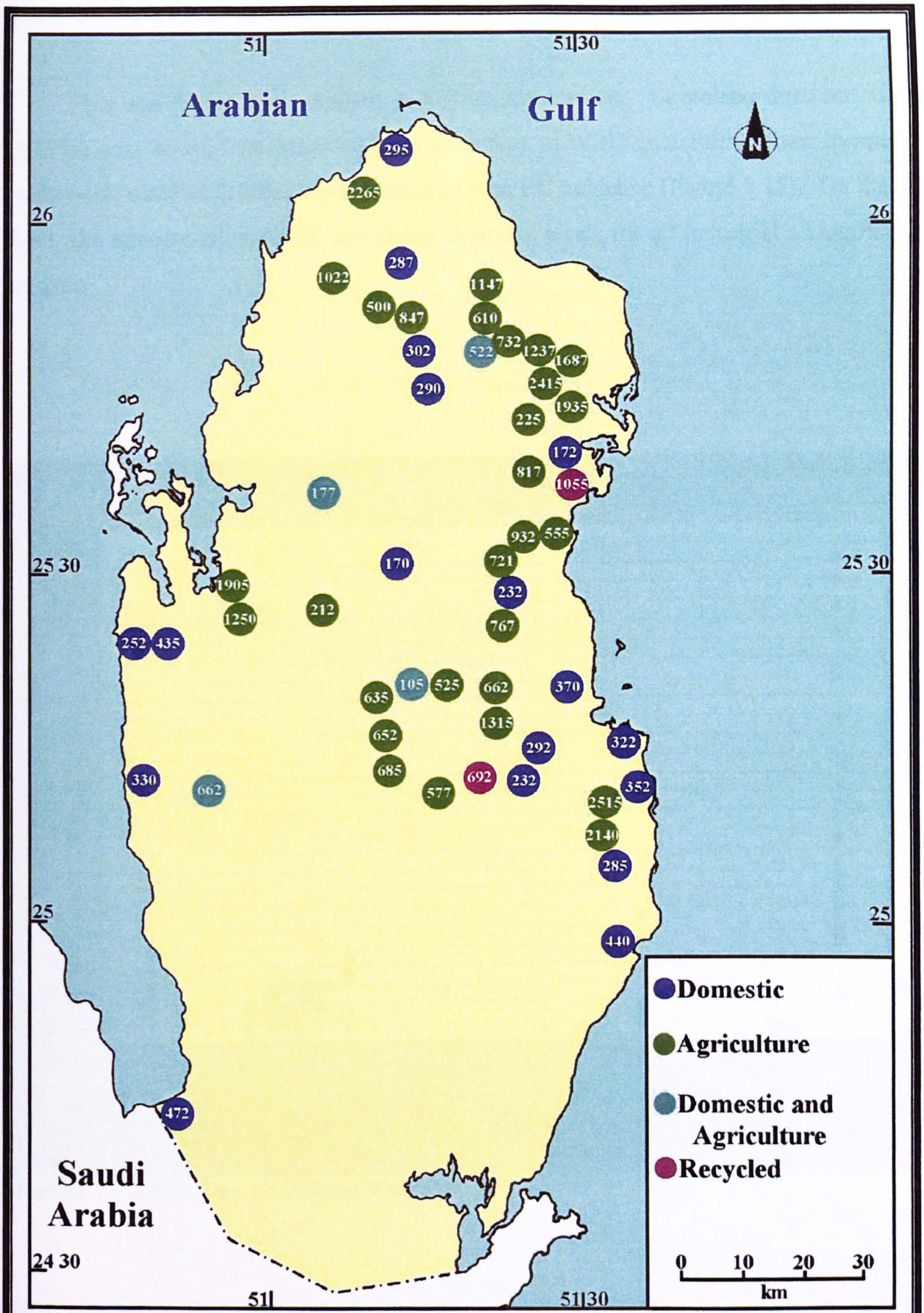

Figure 8.14. Geographical Distribution of Sodium Levels (mgl^{-1}) at Selected Points.

8.6.2. Sodium Concentration by Uses:

Na was found in all samples in high concentrations. Seventeen domestic samples (80.9%) were above recommended level, according to WHO guidelines. These increased to twenty-one samples (100%) when compared with EC guideline (Figure 8.15). On the other hand, the concentration of Na was above desirable levels for all industrial and agricultural samples.

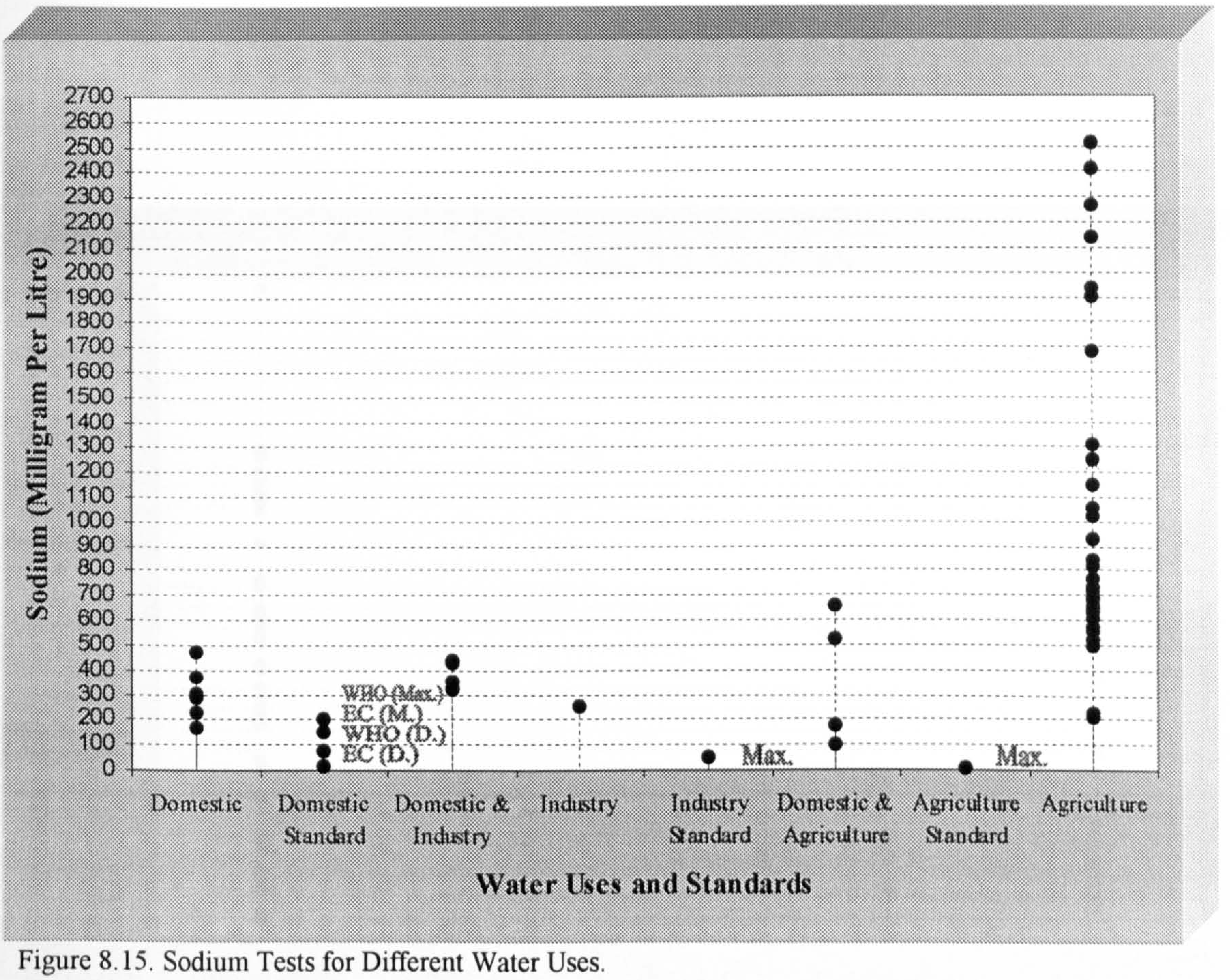

Figure 8.15. Sodium Tests for Different Water Uses.

8.7. Calcium (Ca):

8.7.1. Calcium Concentration by Sources and Areas

The concentration of Ca was less than sodium, in spite of wide distribution of limestone (e.g. Lloyd *et al*, 1987) and gypsum rocks (Harhash and Yousif, 1985) in Qatar, which are considered as the main source for this element (e.g. Twort *et al.*, 1985). The lowest and highest concentrations of Ca were found in groundwater samples (Figure 8.16). In general, brackish groundwater desalination comes near to recommended levels, followed by seawater desalination and some domestic groundwater samples. On the other hand, the highest level of Ca was found in groundwater in the south east of country (Figure 8.17).

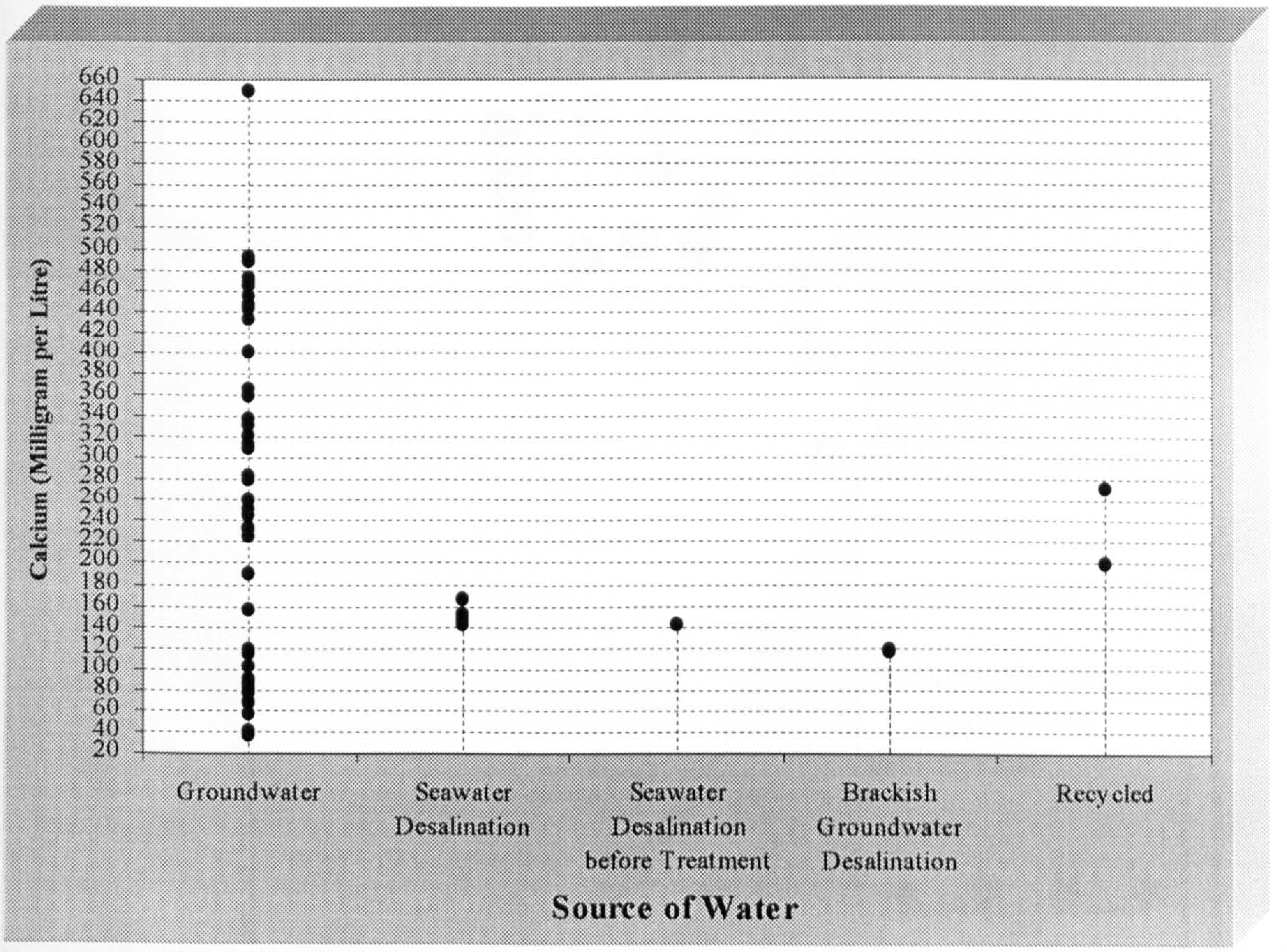

Figure 8.16. Calcium Tests for Different Water Sources.

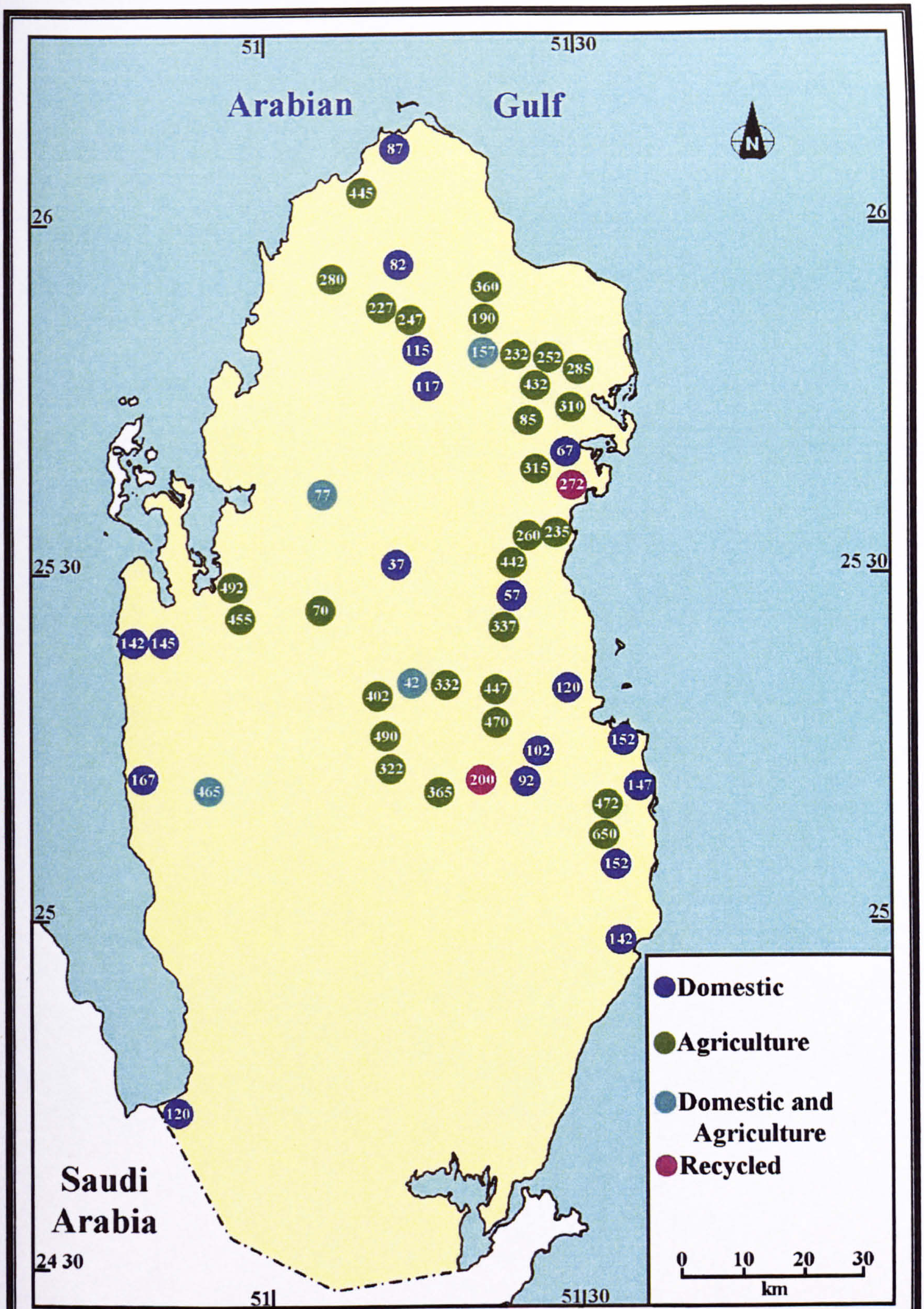

Figure 8.17. Geographical Distribution of Calcium Levels (mgl^{-1}) at Selected Points.

8.7.2. Calcium Concentration by Uses:

According to WHO guidelines, almost all domestic samples (85.7%) were within the maximum concentration, while there were thirteen samples (61.9%) above the EC desirable level (Figure 8.18). Ca concentration was found above recommended levels in almost all agriculture water samples (97.1%), while inside recommended levels in all industrial samples.

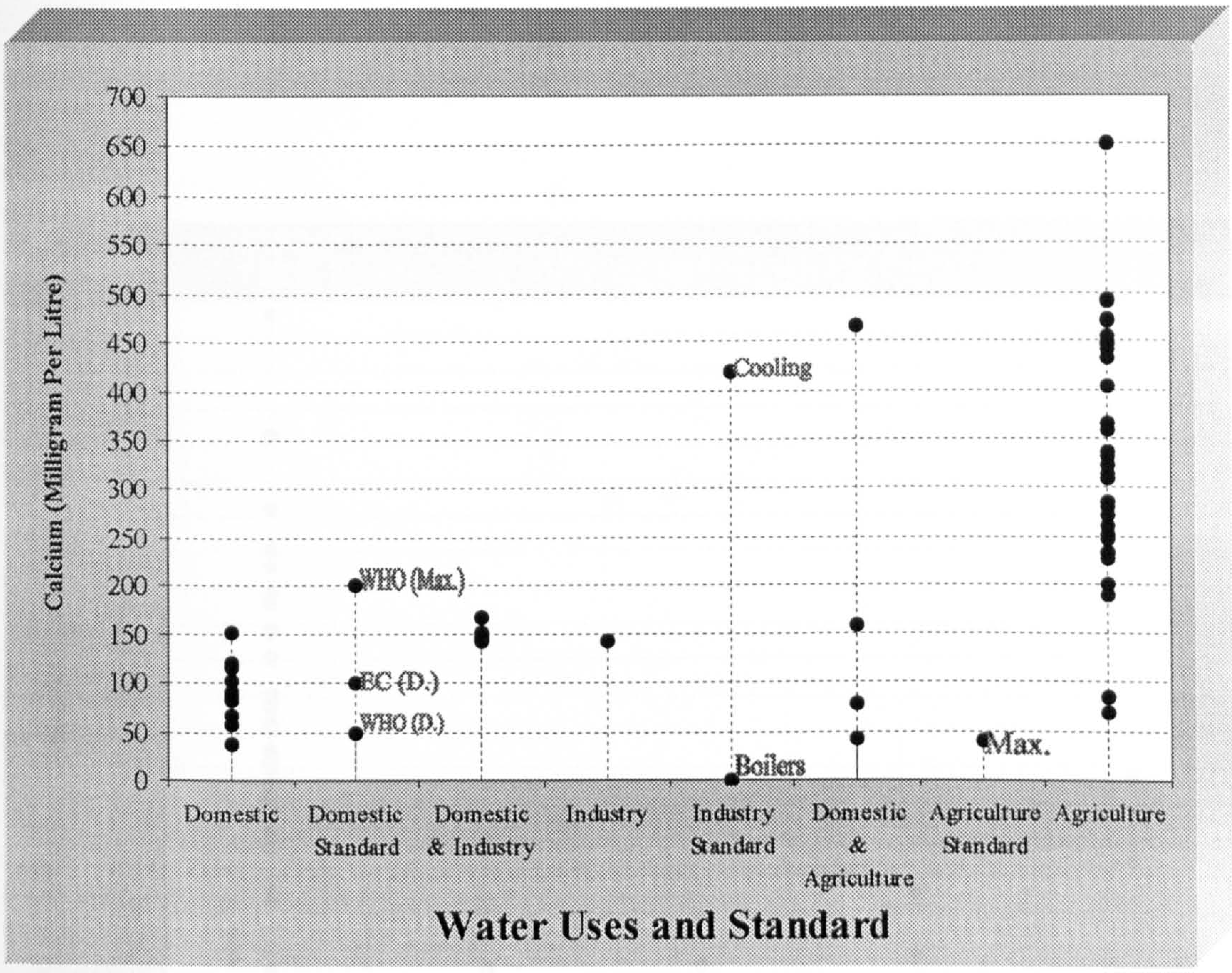

Figure 8.18. Calcium Tests for Different Water Uses.

8.8. Potassium (K):

8.8.1. Potassium Concentration by Sources and Areas:

The most suitable concentration of K was found in desalinated seawater, followed by desalinated brackish groundwater and some domestic groundwater samples (Figure 8.19). The highest concentration of K found in groundwater in the north-east and south-east of the country (Figure 8.20). The main sources of K in freshwater in Qatar are sedimentary rocks (e.g. Harhash and Hassan, 1982) and fertiliser which is widely use to enrich agricultural land (e.g. Sumori, 2001b; al-Kuwari, 2001).

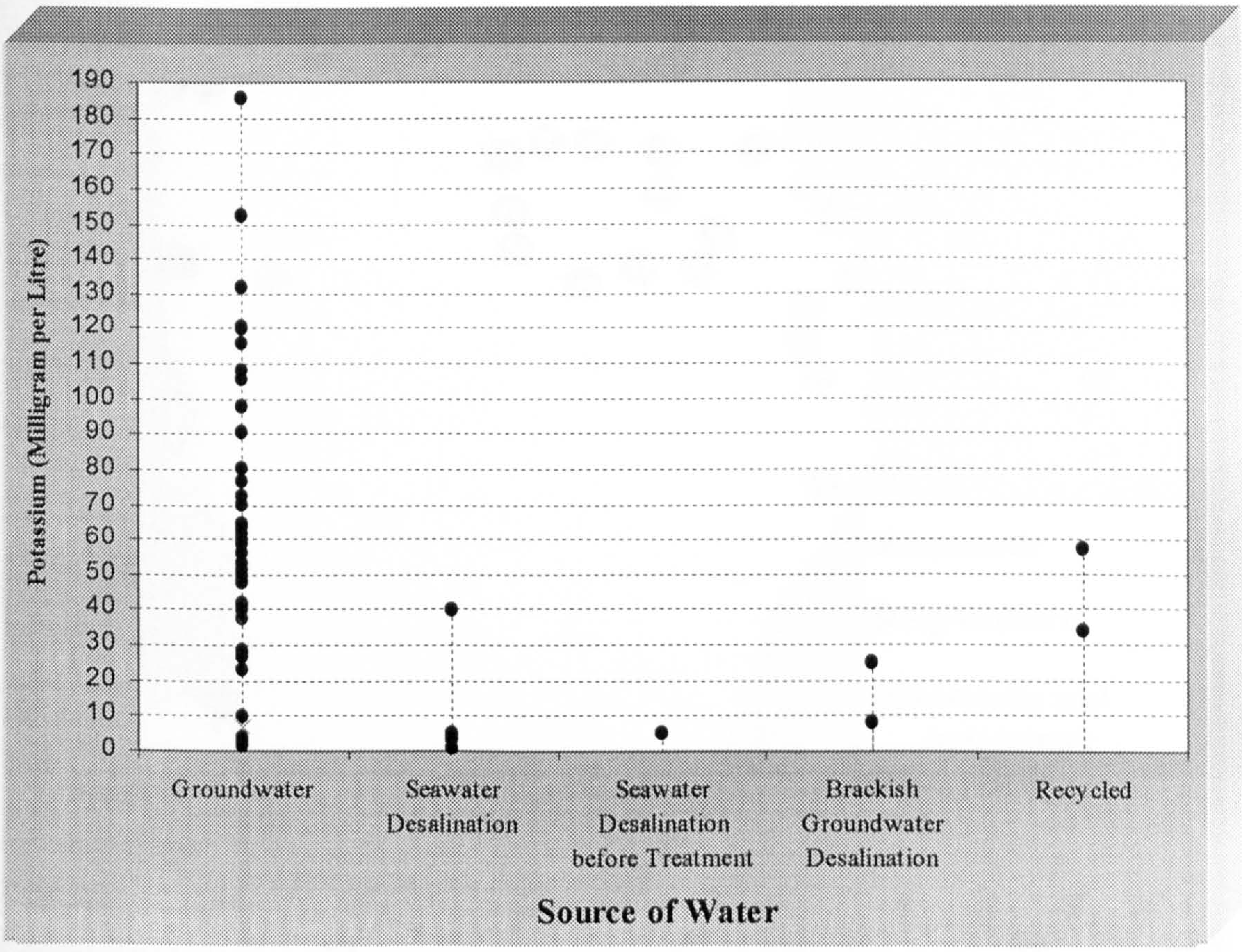

Figure 8.19. Potassium Tests for Different Water Sources.

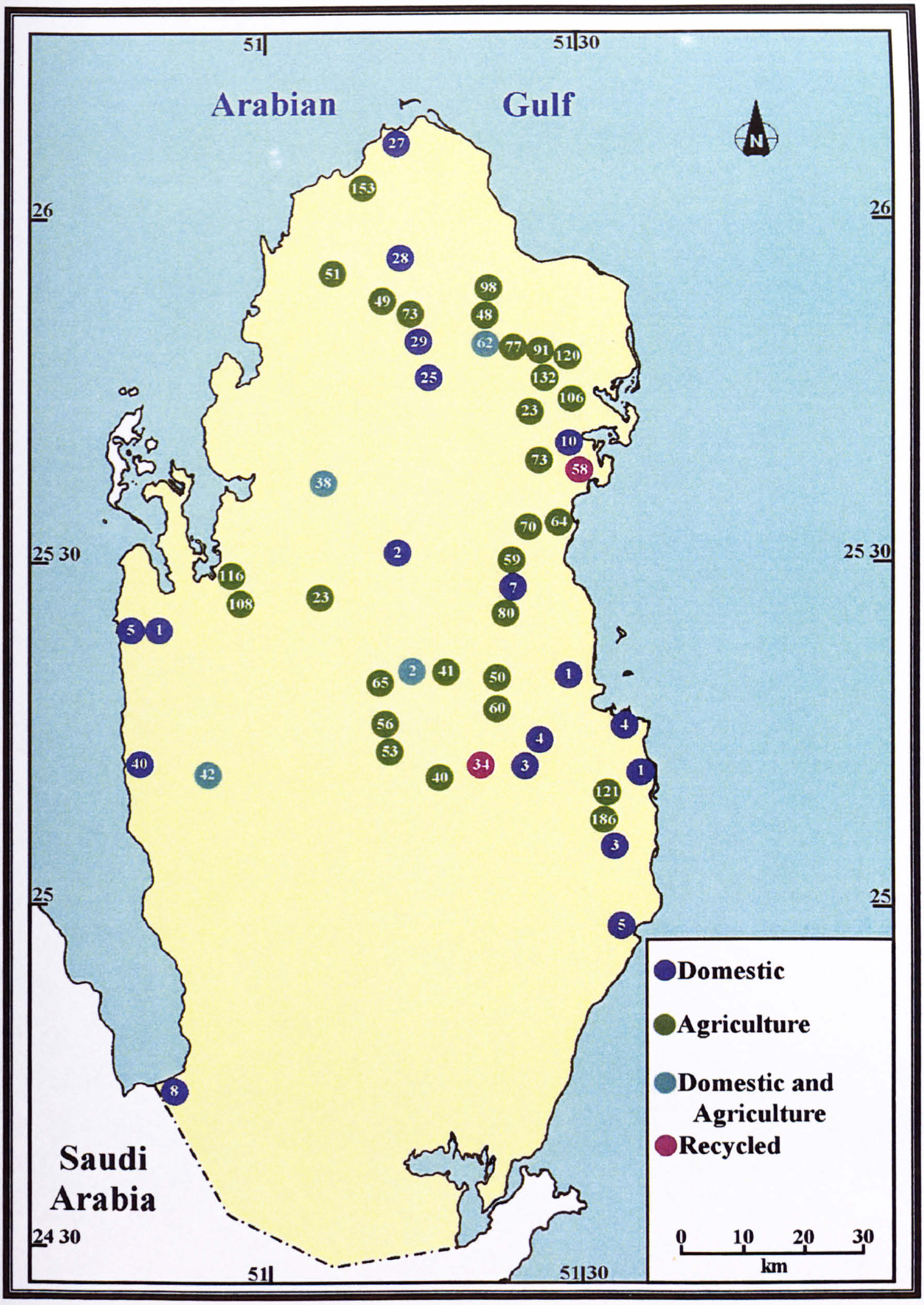

Figure 8.20. Geographical Distribution of Potassium Levels (mgl^{-1}) at Selected Points.

8.8.2. Potassium Concentration by Uses:

According to WHO and EC guidelines, eight (38%) domestic water samples were above maximum levels. There are no values given for industrial and agricultural uses (Figure 8.21).

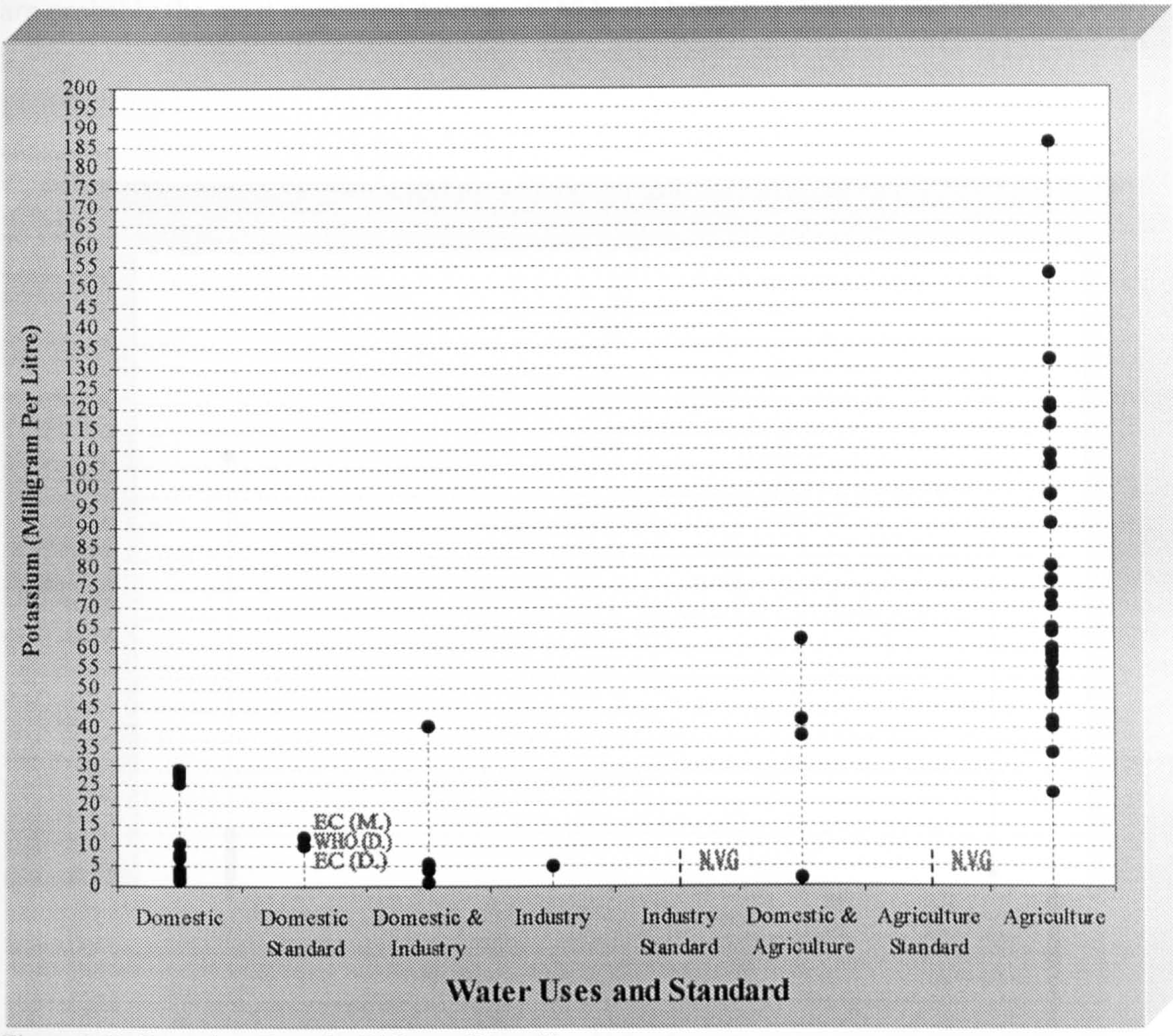

Figure 8.21. Potassium Tests for Different Water Uses.

8.9. Nitrate (NO_3):

8.9.1. Nitrate Concentration by Sources and Areas:

The NO_3 concentrations were at low levels in most samples (Figure 8.22). There were only two samples from recycled water and groundwater found with high concentrations of NO_3 and both of them were used for irrigation purposes. On the other hand, there were no geographical relationships because similar concentration of NO_3 was found around the country (Figure 8.23). Fertilisers, animal waste and domestic wastewater are probably the most important sources of NO_3 in Qatar (e.g. Hashim and Ibrahim, 1999).

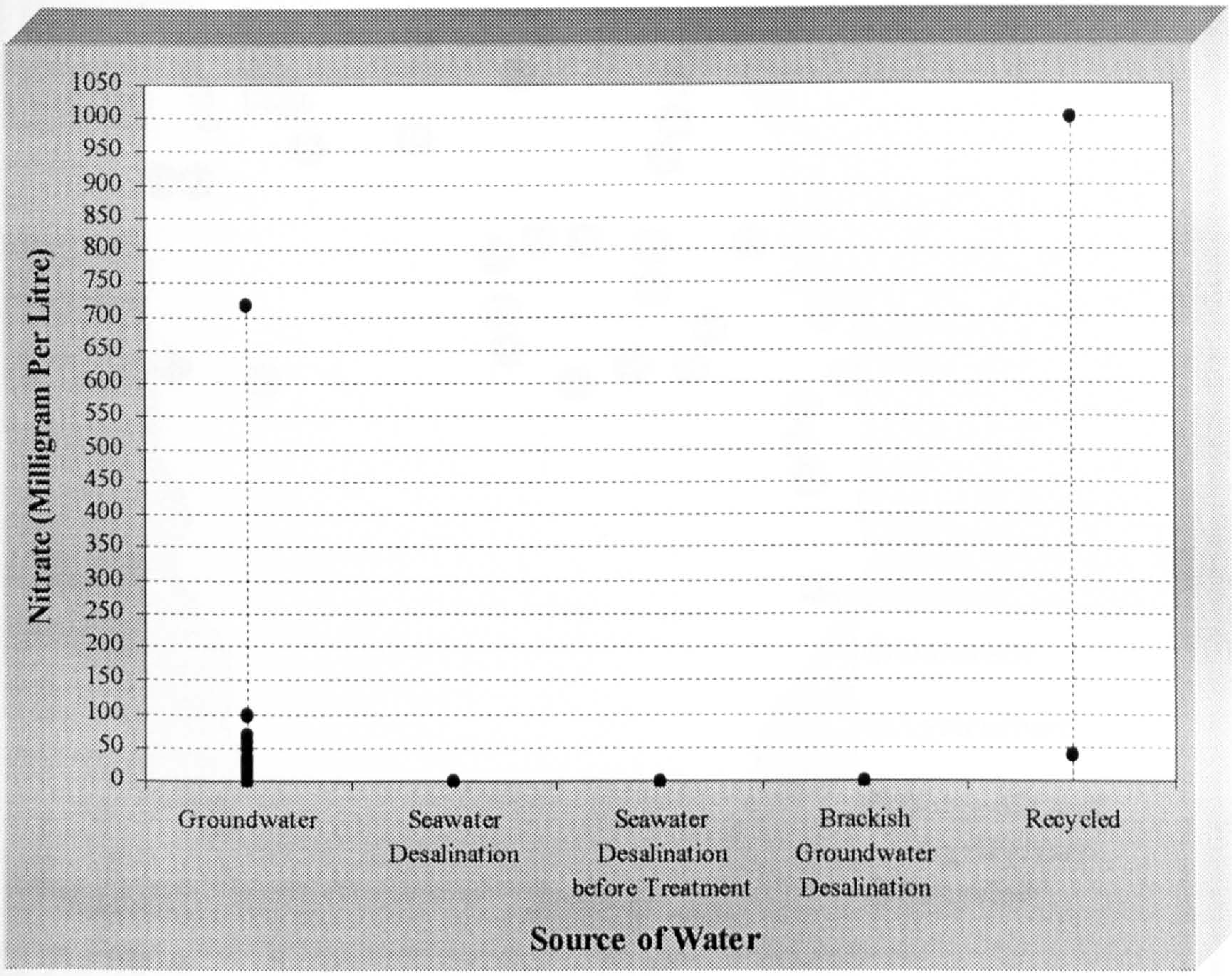

Figure 8.22. Nitrate Tests for Different Water Uses.

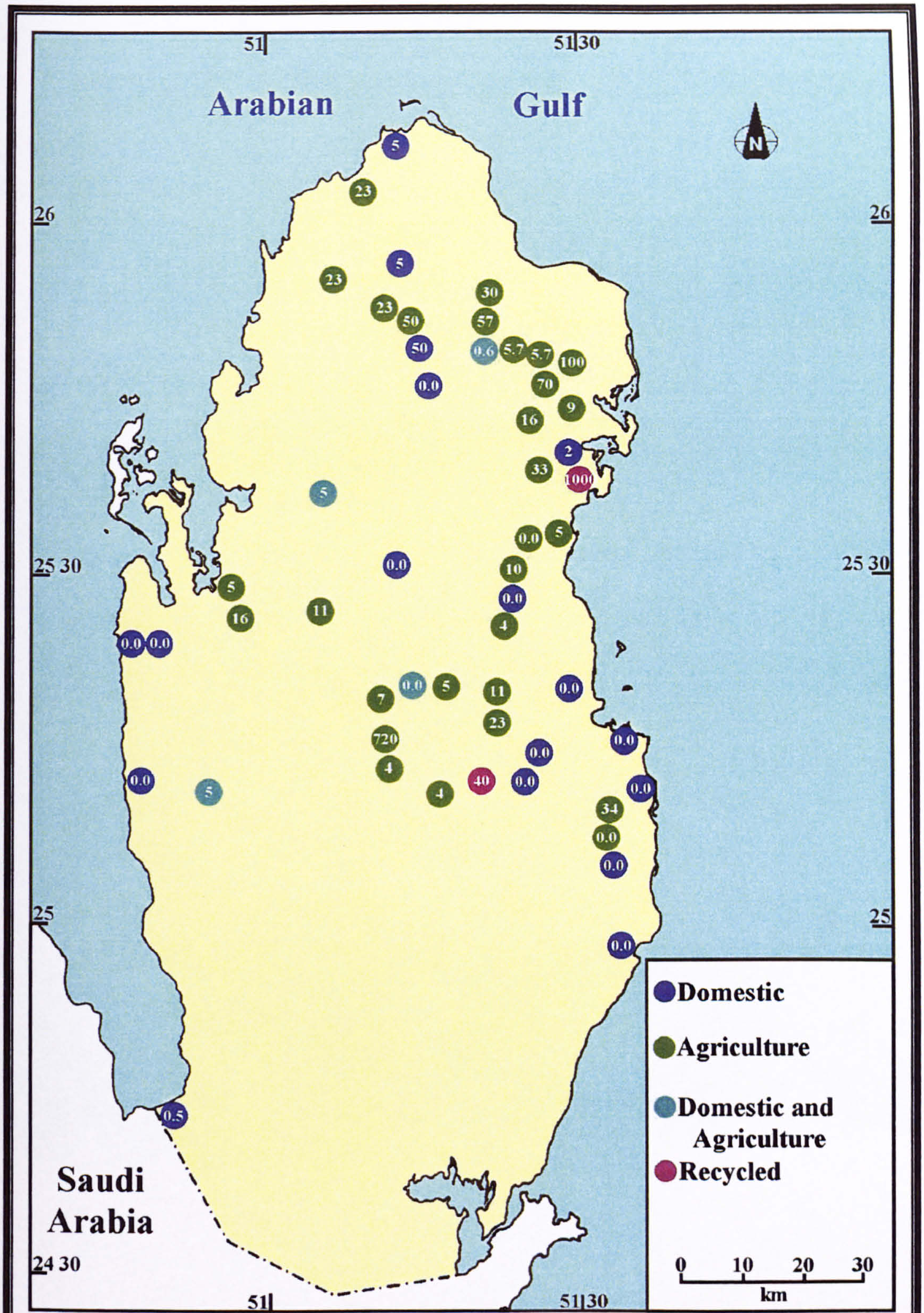

Figure 8.23. Geographical Distribution of Nitrate Levels (mgl^{-1}) at Selected Points.

8.9.2. Nitrate Concentration by Uses:

NO_3 concentrations found at desirable levels in almost all domestic samples (95.2%) according to EC and only one sample (4.8%) is above maximum level for the WHO guidelines. There are no values given for industry and agriculture (Figure 8.24).

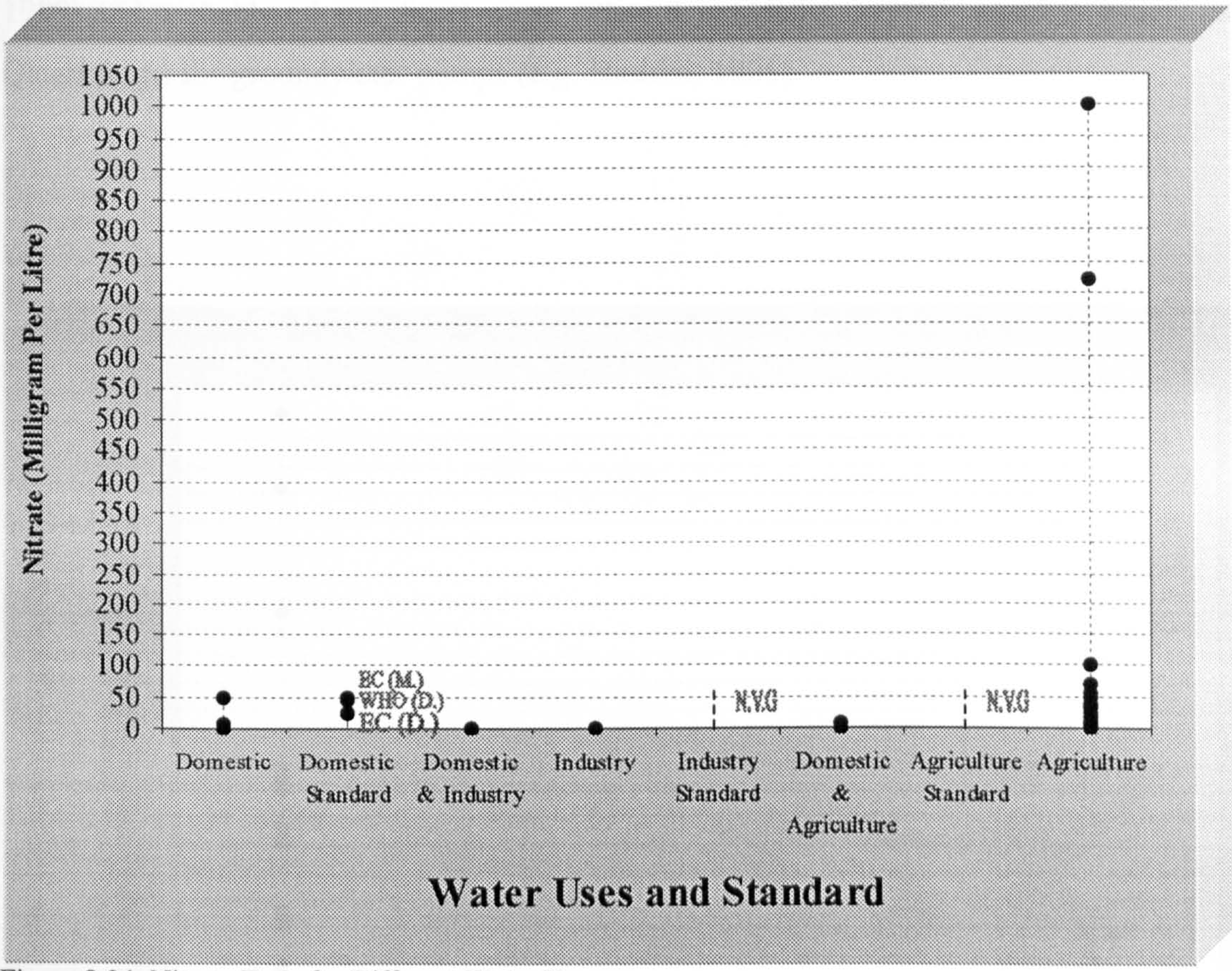

Figure 8.24. Nitrate Tests for Different Water Uses.

8.10. Chloride (Cl):

8.10.1. Chloride Concentration by Sources and Areas:

The most desirable levels of Cl were found in water production from two-seawater desalination plants in Doha followed by desalinated brackish groundwater (Figure 8.25). Cl concentration was found at a high level in the majority of groundwater samples from different areas around the country, but in slightly lower levels in the north (Figure 8.26). The increase of Cl concentration in groundwater in Qatar results from mixing of shallow fresh groundwater with fossil brackish groundwater and seawater (e.g. al-Nasr and al-Sheeb, 1999) and probably oil and diesel waste (Plate 8.1) (MEW, 1996b), which is widely use in Qatari farms for groundwater pumps (e.g. Hashim, 1995).

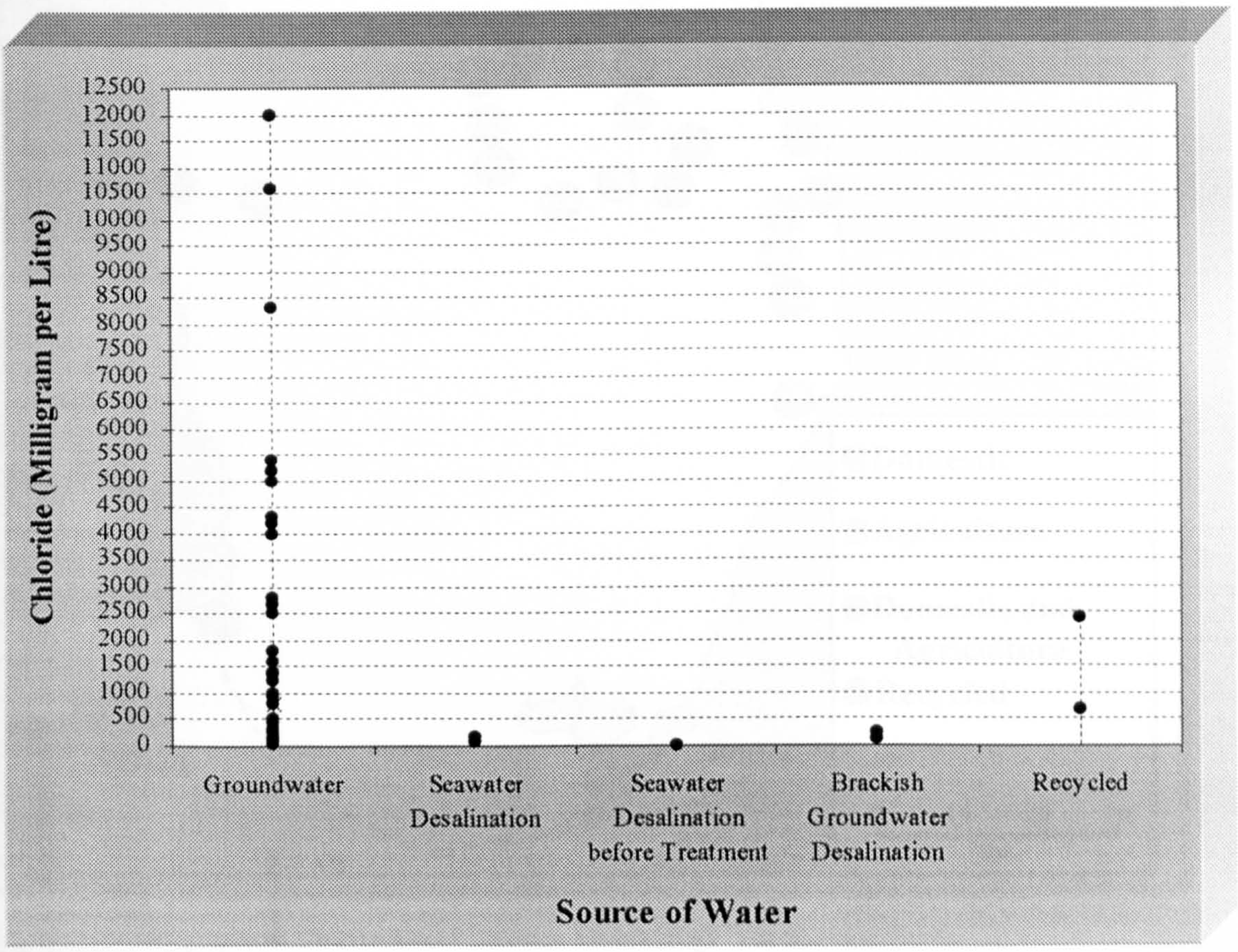

Figure 8.25. Chloride Tests for Different Water Sources.

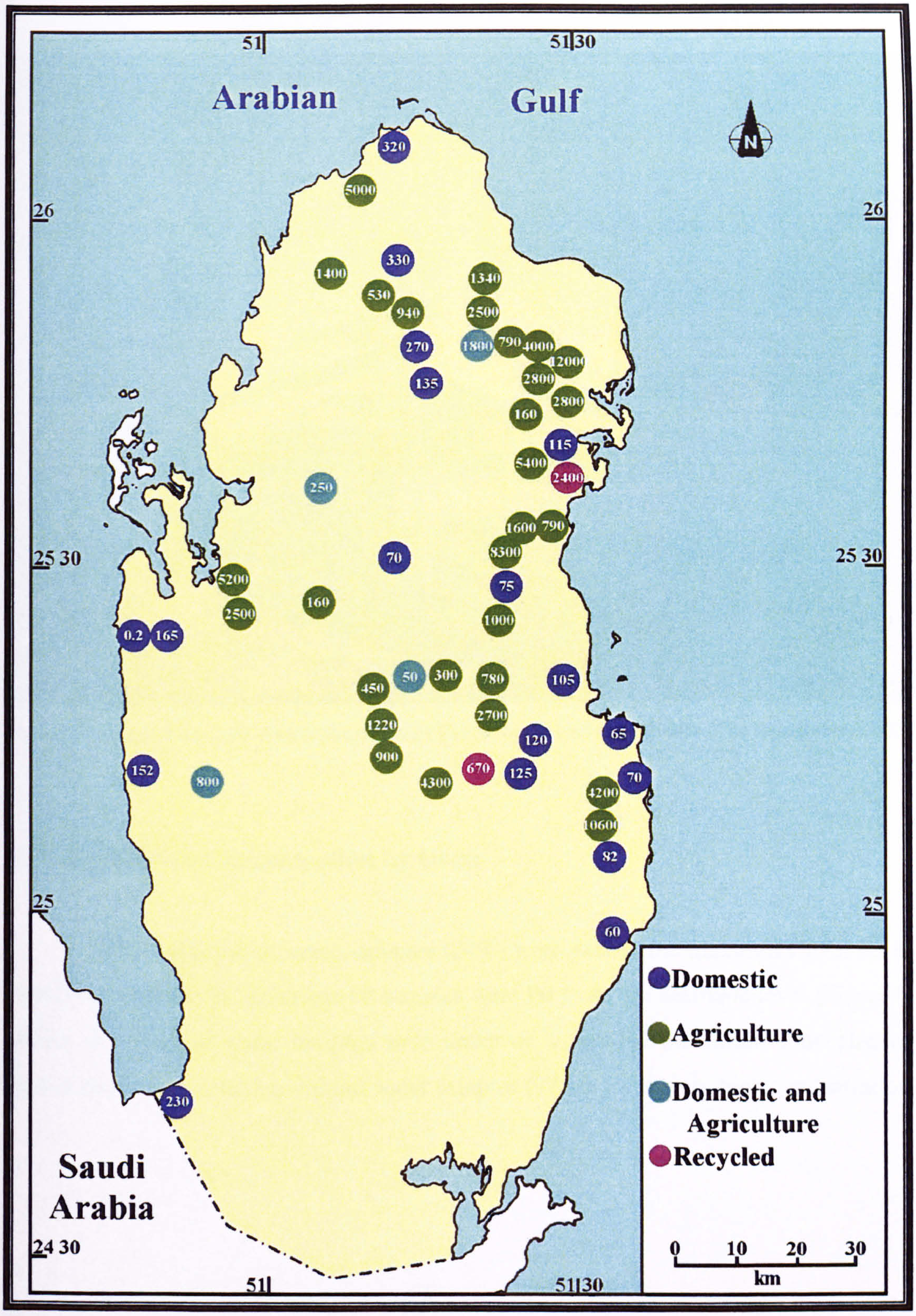

Figure 8.26. Geographical Distribution of Chloride Levels (mgl^{-1}) at Selected Points.

Plate 8.1. Oil and Diesel are Widely use in Qatari Farms for Groundwater Pumps (The Researcher, 2000).

8.10.2. Chloride Concentration by Uses:

Only two domestic water samples (24%) were exceed the maximum level set by the WHO but with the EC guideline all samples were far from the desirable level (Figure 8.27). While all industrial water samples were under or within the maximum concentration, Cl was found in almost all agriculture water samples (97.1%) with very high concentration.

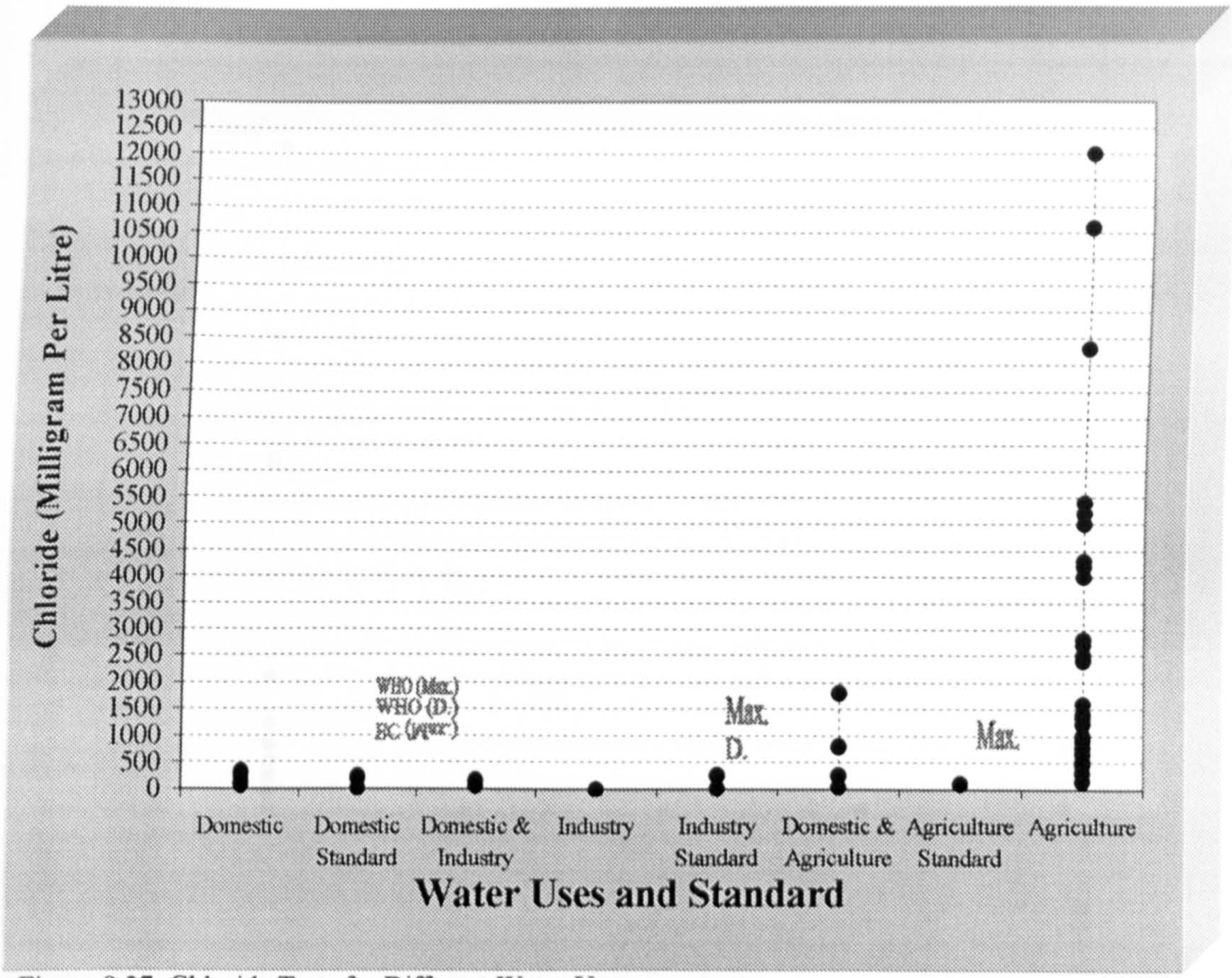

Figure 8.27. Chloride Tests for Different Water Uses.

8.11. Sulphate (SO_4):

8.11.1. Sulphate Concentration by Sources and Areas:

The lowest level of SO_4 was found in seawater desalination and desalinated brackish groundwater following by some groundwater samples (Figure 8.28). Geographically, SO_4 was found in the highest levels in the south and centre of the country (Figure 8.29). The widely spread of sedimentary rocks in Qatar (e.g. Bohairi and al-Fara, 1976), domestic wastewater and using recycled water for irrigation (e.g. Hashim and Ibrahim, 1999) maybe led to an increase SO_4 in freshwater, especially groundwater.

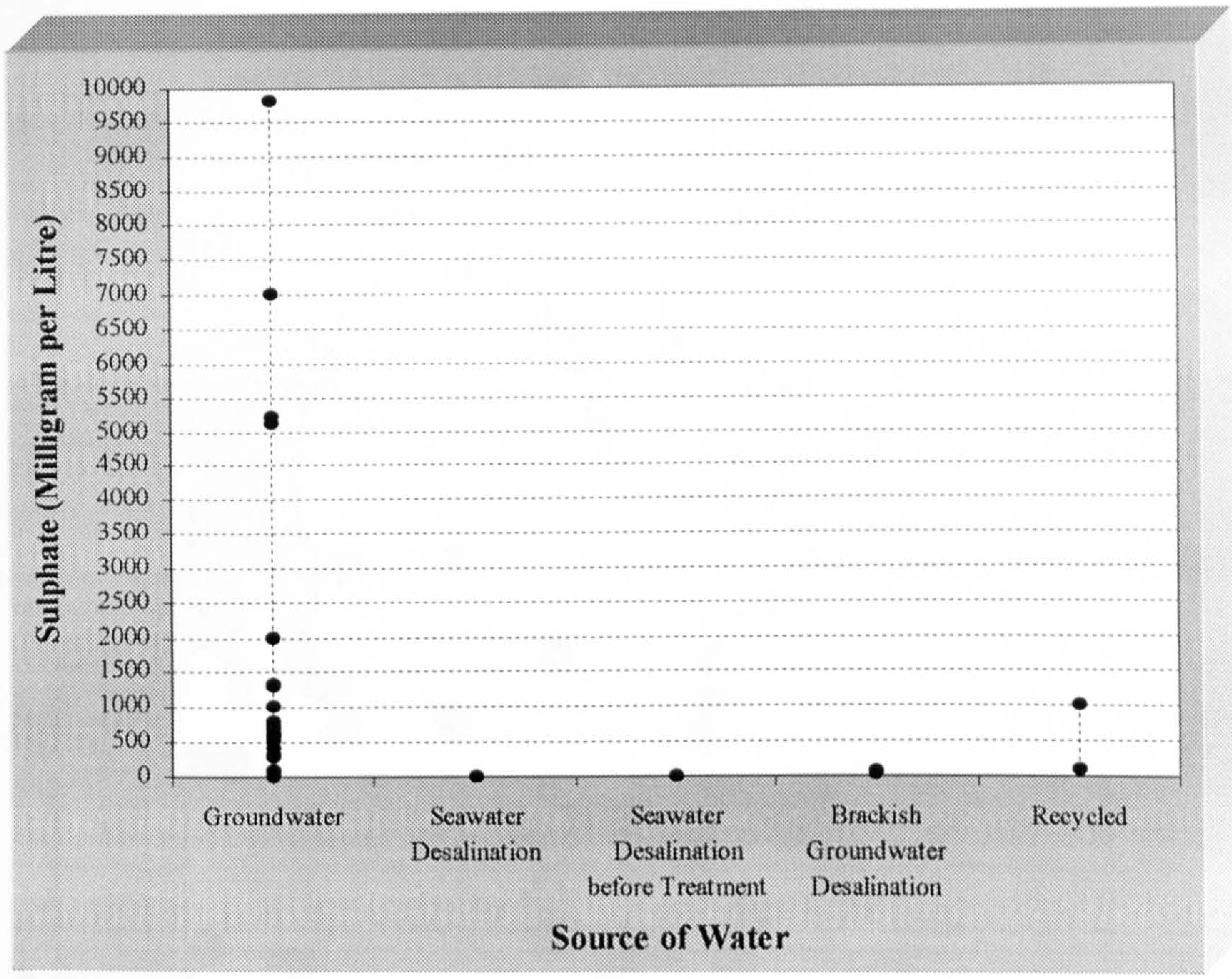

Figure 8.28. Sulphate Tests for Different Water Sources.

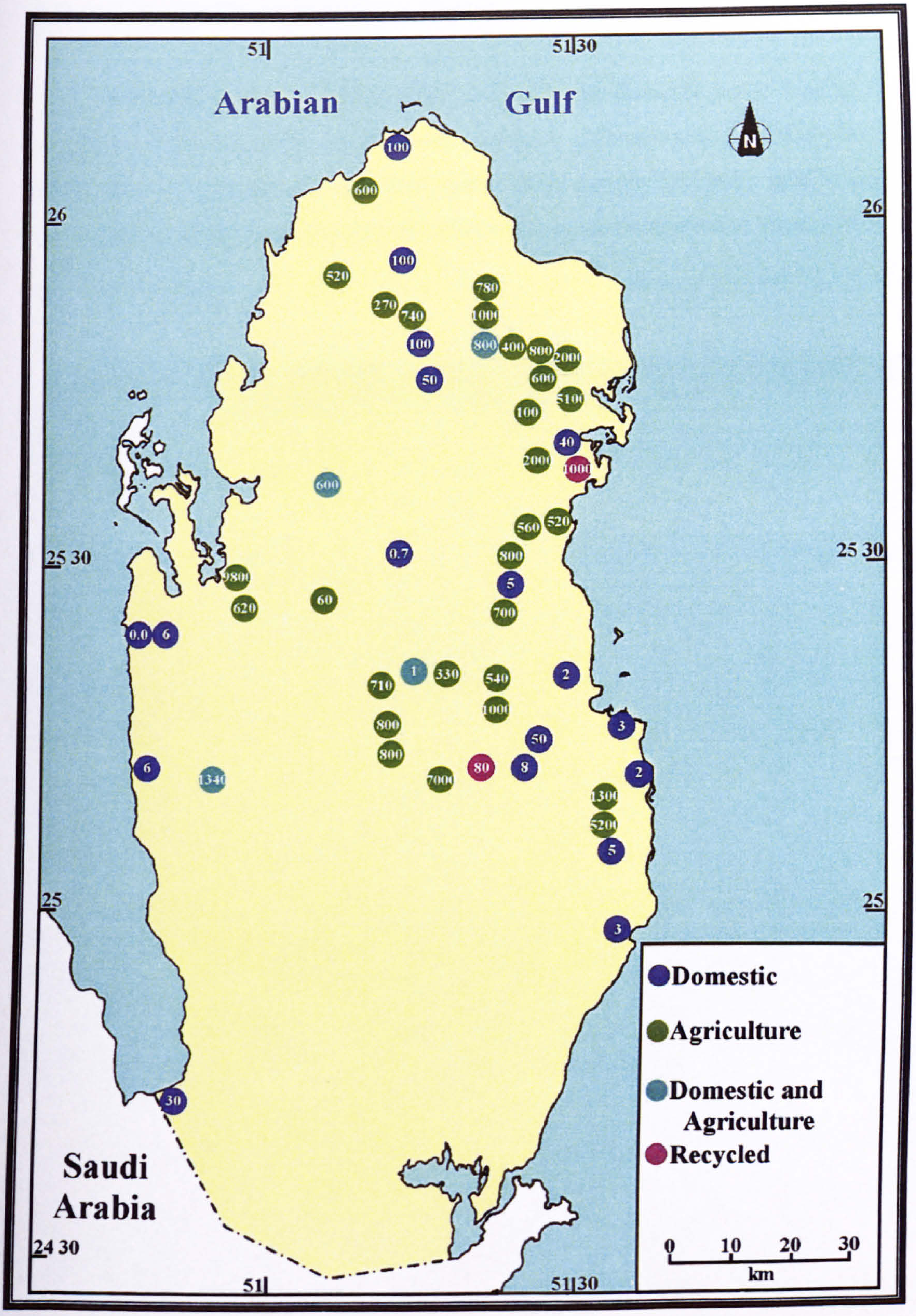

Figure 8.29. Geographical Distribution of Sulphate Levels (mgl^{-1}) at Selected Points.

8.11.2. Sulphate Concentration by Uses:

According to WHO and EC guidelines only three domestic water samples (14.3%) exceed the maximum levels and its concentration in other samples was very low (Figure 8.30). SO_4 Concentration in industrial water samples were extremely satisfactory, while thirty-one agricultural water samples (88.6%) were above recommended level.

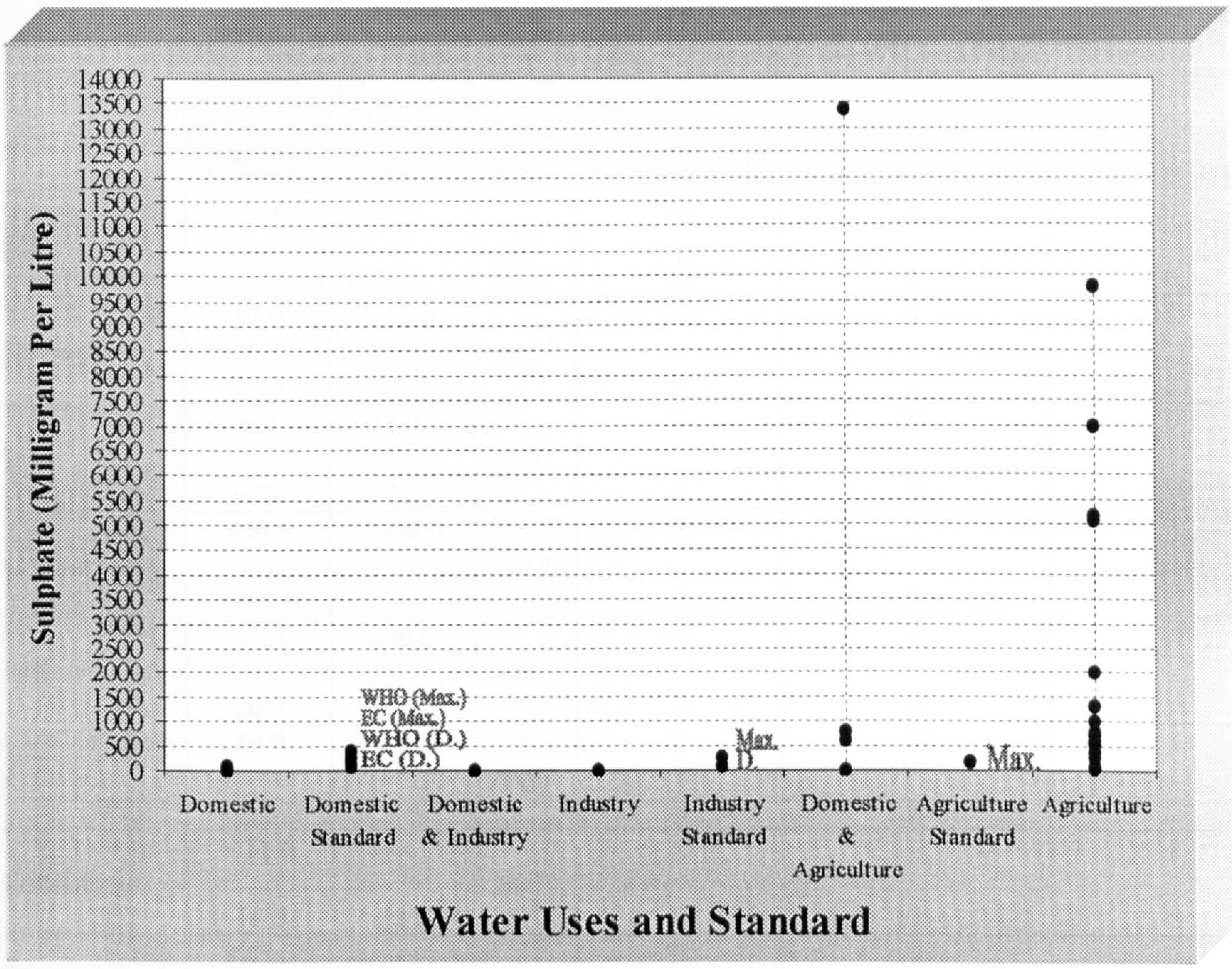

Figure 8.30. Sulphate Tests for Different Water Uses.

8.12. Phosphate (PO_4) by Sources, Areas and Uses:

No PO_4 was found in any samples from any sources (Table A10.10).

8.13. Discussion:

The tests undertaken on the samples gathered for the purpose of this research show that water used in the domestic sector comes near to common international specifications for acceptable water quality a the range of criteria, especially desalination water. It was above specification for chloride, sodium, iron, calcium and conductivity, especially when compared with the EC standard and for sodium when compared with the WHO standard (Table 8.2 and Figure 8.31). It can thus be seen that there is cause for concern on health grounds (Appendix 9).

Table 8.2. Domestic (Drinking) Water Quality in Qatar According to the WHO and the EC Standards.

Parameter		**Standard** Highest Desirable	Max.	**Unit**	**Desirable (No. Samples)**	**>Desirable <Maximum (No. Samples)**	**Above Maximum (No. Samples)**
pH	WHO	6.5 to 9.2		pH	21	0	0
	EC	6.5 to 8.5			17	4	0
Magnesium	WHO	50.0	150.0	mgl^{-1}	16	4	1
	EC	30.0	50.0		8	8	5
Iron	WHO	0.3	1.0	mgl^{-1}	0	21	0
	EC	0.05	0.2		0	0	21
Conductivity	WHO	500.0	1500.0	µS/cm	10	7	4
	EC	<400.0	---		9	0	12
Sodium	WHO	75.0	200.0	mgl^{-1}	0	4	17
	EC	20.0	150.0		0	0	21
Calcium	WHO	50.0	200.0	mgl^{-1}	2	18	1
	EC	<100.0	---		8	0	13
Potassium	WHO	<12.0	---	mgl^{-1}	13	0	8
	EC	10.0	12.0		12	1	8
Nitrate	WHO	<45.0	---	mgl^{-1}	20	0	1
	EC	25.0	50.0		20	1	0
Chloride	WHO	200.0	250.0	mgl^{-1}	14	2	5
	EC	<25.0	---		0	0	21
Sulphate	WHO	200.0	400.0	mgl^{-1}	18	0	3
	EC	100.0	250.0		18	0	3
Phosphate	WHO	No value given		mgl^{-1}	---	---	---
	EC	<2.0			21	0	0

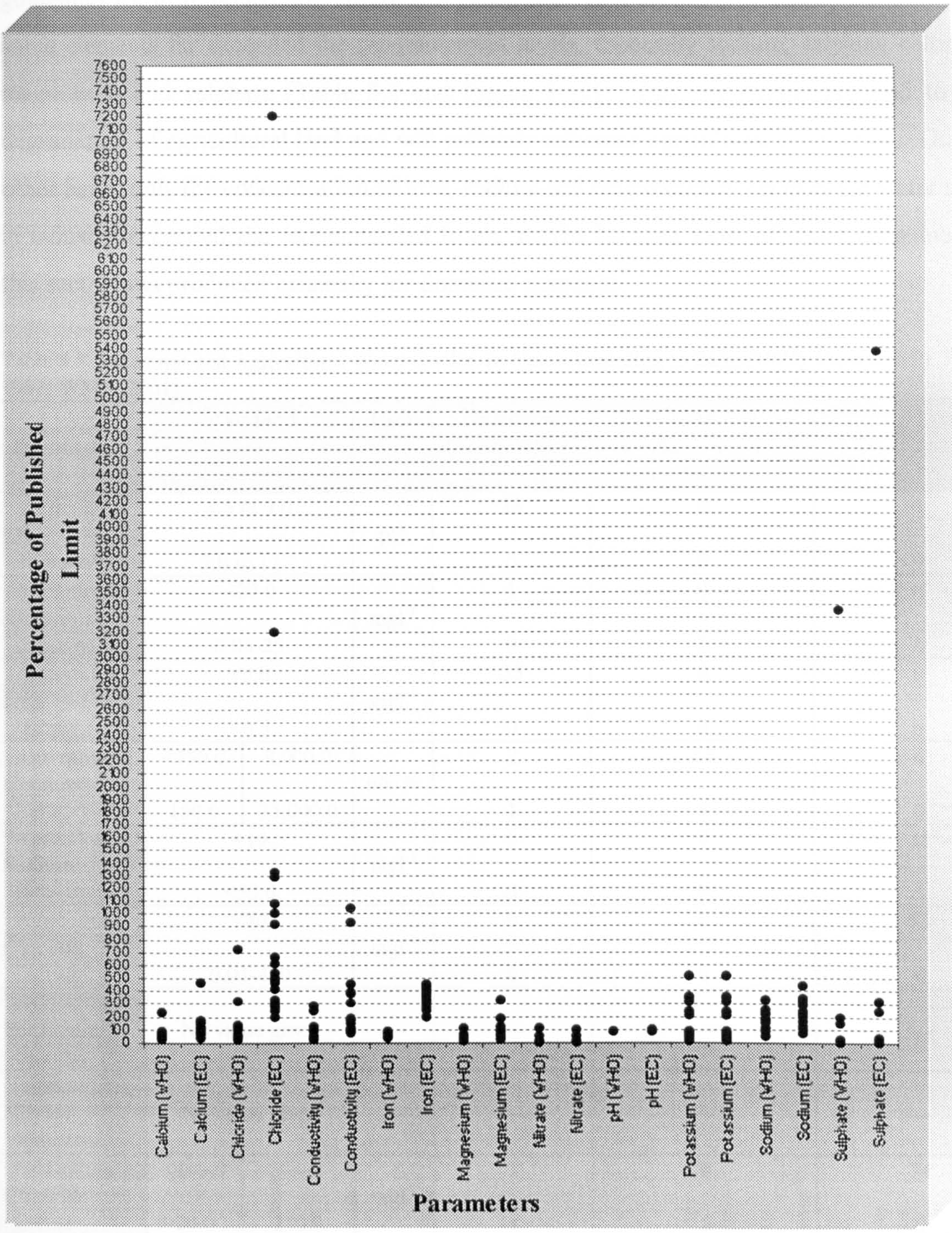

Figure 8.31 Domestic Water Quality Limit for Different Parameters.

The specification of the water used in irrigation did not coincide with published guidelines for iron, potassium, nitrate and phosphate. In most samples, the concentration of some elements far exceeded the recommended levels, especially sodium, calcium, chloride, magnesium and sulphate (Table 8.3 and Figure 8.32). This will potentially lead to the degradation of agricultural land and will certainly influence agricultural production. On the other hand, only the concentration of iron, sodium and magnesium in samples for water used in industry exceeded the recommended levels, maybe because most of water consumed in this sector was produced originally for domestic purposes.

Table 8.3. Industrial and Agricultural Water Quality in Qatar According to Zajic (1971) Train (1979); FAO, 1981; WMB, 2001).

Parameter		Standard: Highest Desirable	Standard: Max.	Unit	Desirable (No. Samples)	>Desirable <Maximum (No. Samples)	Above Maximum (No. Samples)
pH	Agriculture	4.5 to 9.0		pH	35	0	0
	Industry	3.0 to 11.7			6	0	0
Magnesium	Agriculture	<20.0		mgl^{-1}	1	0	34
	Industry	0.05-25			0	2	4
Iron	Agriculture	<5.0		mgl^{-1}	35	0	0
	Industry	<0.5			0	0	6
Conductivity	Agriculture	<750.0	8,000.0	µS/cm	2	25	8
	Industry	150.0	35,000.0		1	5	0
Sodium	Agriculture	<10		mgl^{-1}	0	0	35
	Industry	<50.0			0	0	6
Calcium	Agriculture	<40		mgl^{-1}	0	0	35
	Industry	0.01-420			0	6	0
Potassium	Agriculture / Industry	No value given		---	---	---	---
Nitrate	Agriculture / Industry	No value given		---	---	---	---
Chloride	Agriculture	<100.0	---	mgl^{-1}	1	0	34
	Industry	20.0	250.0		1	5	0
Sulphate	Agriculture	<190.0	---	mgl^{-1}	4	0	31
	Industry	100.0	250.0		6	0	0
Phosphate	Industry / Agriculture	No value given		---	---	---	---

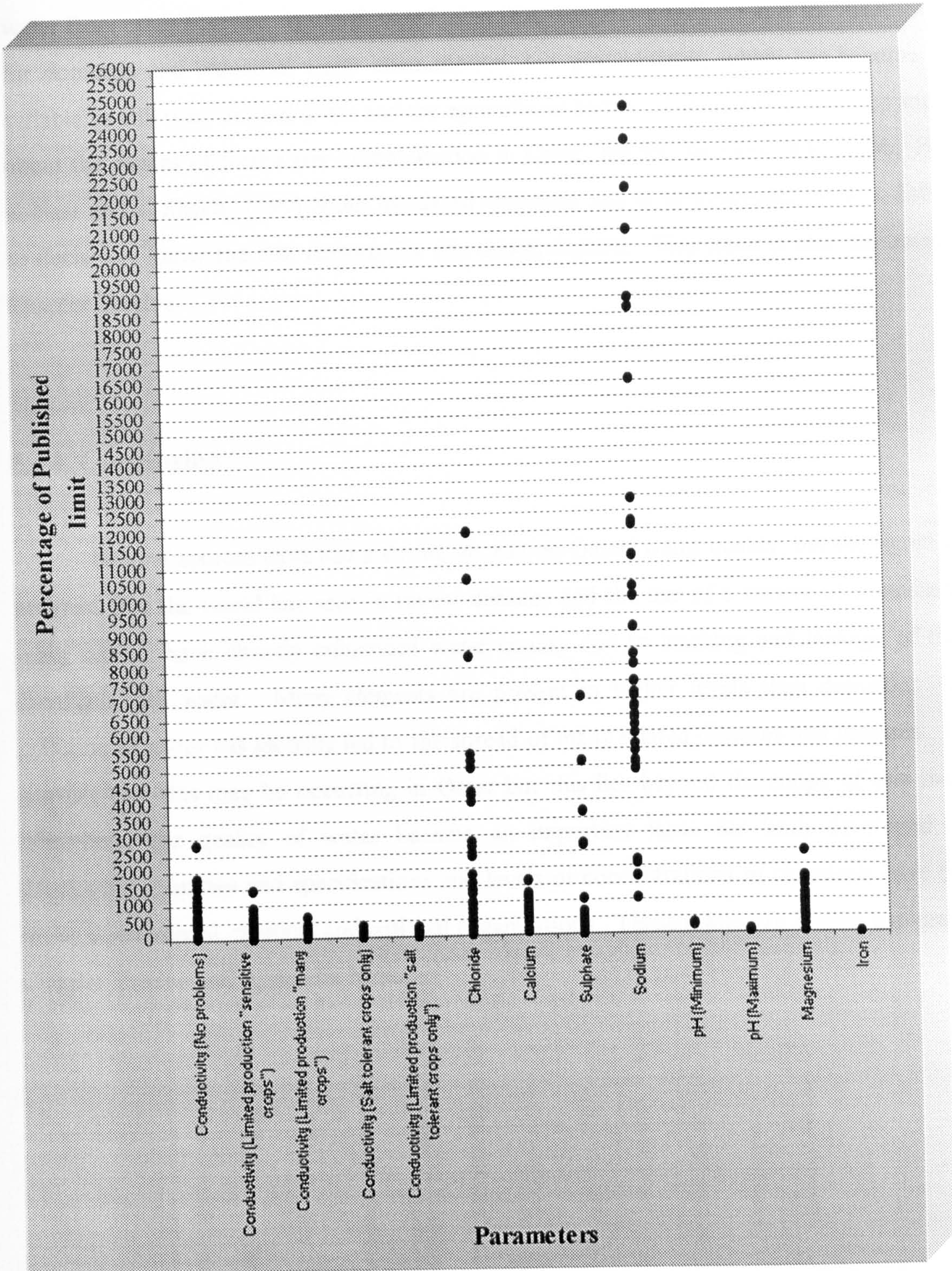

Figure 8.32. Irrigation Water Quality Limit for Different Parameters.

The quality of water produced by desalination was more suitable for all uses than water from other sources. It worth mentioning that seawater desalination is the main source for domestic and industrial water consumption, but groundwater, which has become less suitable, is still used in rural areas and the agricultural sector. There are no precious studies about the causes of freshwater contamination in Qatar, except the view (e.g. Judah, 1994; al-Nasr and al-Sheeb, 1999) about increased dissolved salt in groundwater, so it is difficult to decisively know the real reasons for this contamination. This issue is also discussed in Chapter Twelve.

8.14. Conclusion:

Natural sources have had a strong imprint on Qatari water quality, but the significant progress that the world has seen in recent decades and the use of a variety of chemicals in many sectors have directly influenced water quality due to leaching and leakage of these chemicals into water. Many elements are present in higher levels than desirable. The pollution of water has globally led to the spread of many related diseases and illnesses. It is possible that this may be occurring in Qatar but this lies beyond the scope of this thesis. Elsewhere, the quality of water became an important issue for both developed and developing countries and specifications and levels of concentrations of chemicals have been set by international, regional and national organisations. These issues are further explored in Chapter Twelve and Appendix Nine.

CHAPTER NINE:

STAKEHOLDERS DATA AND OPINION

Stakeholder Data and Opinion

9.1. Introduction:

In this chapter, information from the stakeholder interviews is set out and the range of opinion is assessed. The rationale behind the questions is set out in Section 4.3.3, but is revisited here to set the answers in contrast. Full details can be found in Appendix 12.

9.2. Responses to Question about Issues Concerning Water Supply in Qatar:

There was a unanimous agreement among the respondents that there is a water problem and it is worsening (Figure 9.1). Around **93%** emphasised its presence and highlighted that natural conditions, lack of rain and its fluctuation from year to year, along with the existing water policy (which is not appropriate to the human and natural resources of Qatar) are factors contributing directly to the problem. This had serious consequences: most significant among them is the depletion of groundwater. According to one respondent "the problem has reached a serious level, and there is urgent need for an appropriate water policy that aims to avoid the dangerous consequences".

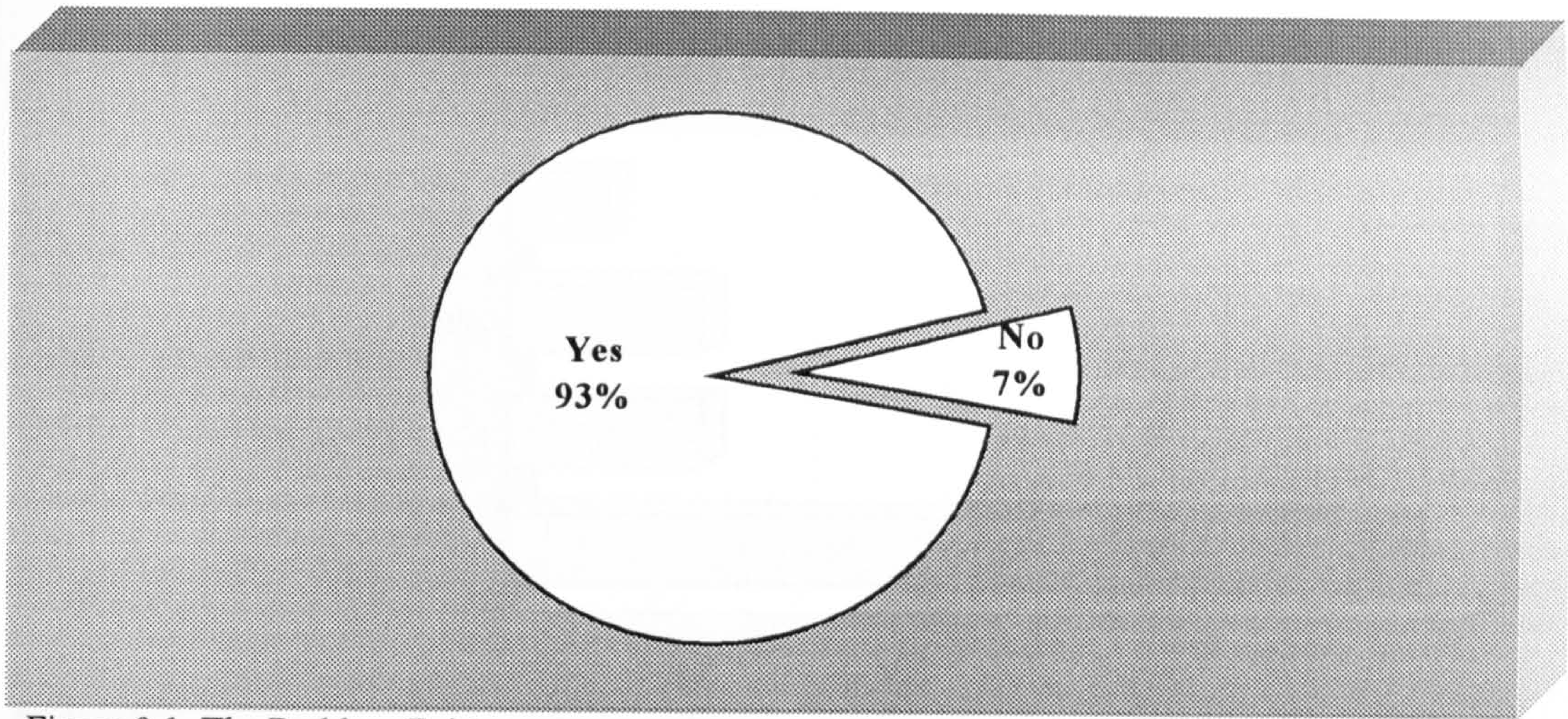

Figure 9.1. The Problem Exist.

9.3. Roots of the Problem:

As for the reasons behind the presence of a water problem, there is agreement that the commercial production of oil in the 1949 and the increase in its price during 1970s and early 1980s led to its emergence. Around **65%** of the respondents emphasise that the oil era raised living standards for most of the society, hence consumption levels of water increased massively over a short period of time (Figure 9.2).

Around **14%** of the sample emphasise that improved living standards, with the absence of water tariffs for the citizens and nominal tariffs for foreigners, led to lack of awareness of the importance of water, as well as its waste. The problem continues, therefore, to escalate with the absence of a water tariff that reflects the real cost of the production and provision of water. Another **14%** argue that this pattern is normal. Socio-economic development necessitates large quantities of water, and since these are not available a problem emerges. Also, water deficit was considered as a world problem and not exclusive to Qatar or its neighbours. Most of the countries that experienced rapid economic development, accompanied with a lack of natural water resources, suffered water deficits.

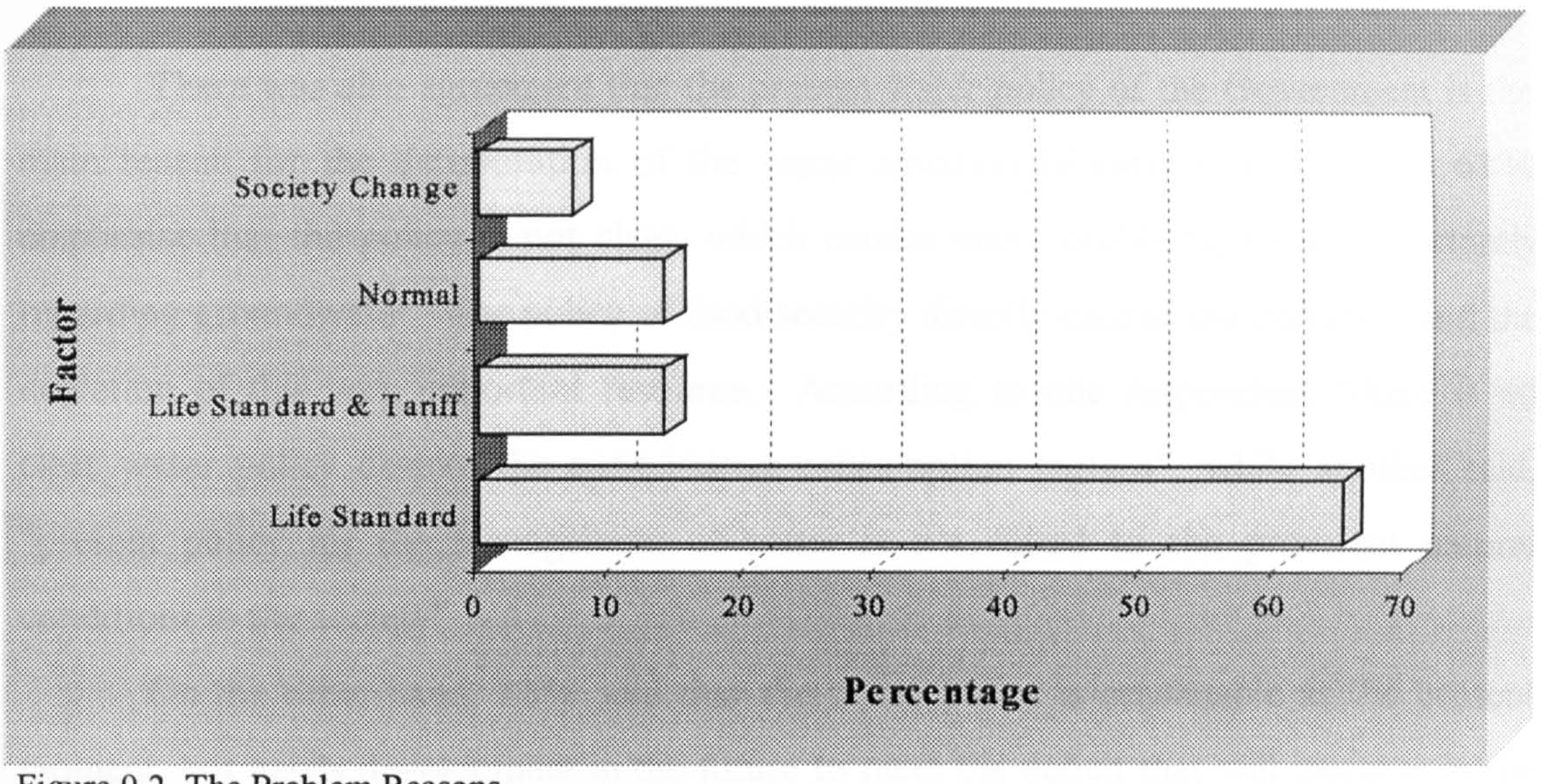

Figure 9.2. The Problem Reasons.

9.4. Religious Opinion about the Current Use of Water:

Qatari society is known to be conservative and religious, like the rest of the Arabian Peninsula and the Islamic world. Hence, the opinion of religious scholars was sought concerning the prevalent pattern of water consumption for the individual and for different economic sectors. They **all** emphasised that conspicuous patterns of consumption are prohibited, according to the Qur'an and the Prophet's sayings. According to one respondent "conspicuous consumption in such a vital resource is disallowed. All kinds of flagrant behaviour that leads to harm is forbidden in Islam. According to Qur'an (*...And eat and drink and not cross the limit. Undoubtedly, the persons crossing the limit are not liked by Him*) and the Prophet (peace be upon him) said (*Excess in the use of water is forbidden, even if you have the resources of a whole river*)".

9.5. Water Management Policy:

There was also agreement that the present water policy of the Government is the main reason for the deterioration of the water situation (Figure 9.3). Around **61%** emphasise that the policy is not clear, which causes many problems, most importantly regarding groundwater. The policy of food security directly caused the pollution and the depletion of this very important resource. According to one respondent "there is no clear water policy despite the conspicuous consumption pattern", while another said, "present policy for the management of water is not suited to the prevalent natural conditions in the society".

On the other hand, **22%** said that the water policy is reasonable at the present moment, but needs development in the future to meet the deficit that will increase in the future, as a result of population growth and economic development. One of the respondents indicated that the "water policy is good except for a lack of few things such as the absence of specialised committees for emergency situations and the absence of a strategic reserve of water". This is emphasised by another who indicated that "the present level of reserve is enough in emergency situations to cover not more than three days".

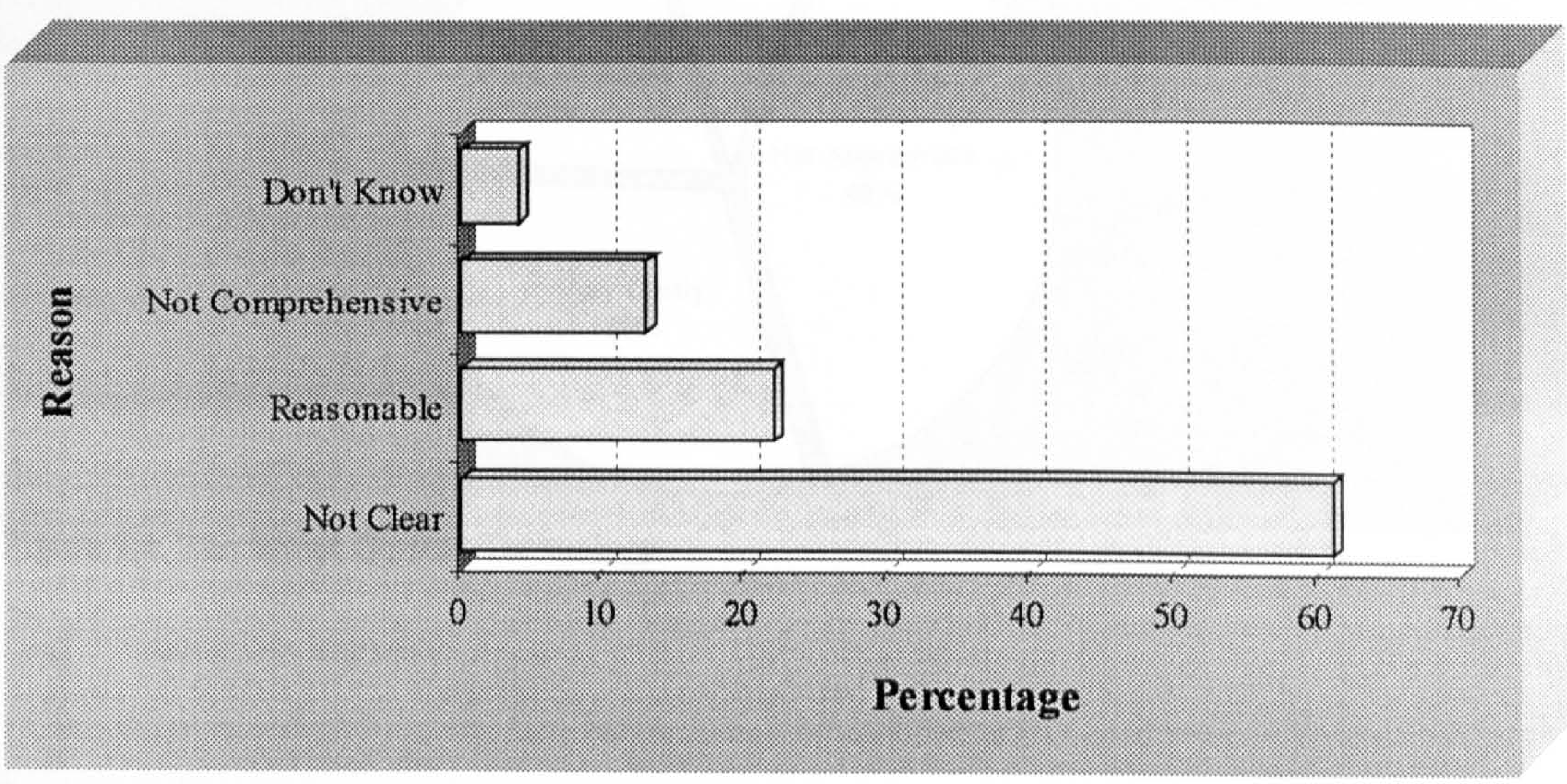

Figure 9.3. The Current Water Management Policy.

9.6. Suitability of Current Water Technology:

Concerning the question about the technological side of the management of water in Qatar and its appropriateness for local conditions (Figure 9.4), **40%** confirmed that it is not appropriate, but there is no alternative at present.

Around **30%** emphasised that desalination technology is very costly so there is a need to choose a technology that is cheaper, especially because oil is available now but might not be available in the near future. According to one respondent, "some of the technology used in water production such as desalination is very costly and not very economical. The cost of providing one m^3 of water is higher than the cost of the same quantity of oil". Another one said "studies must be undertaken for finding alternative sources of energy for the process of desalination in order to decrease cost and increase production". On the other hand, **20%** called for the use of more advanced technology in the desalination of seawater and recycling and emphasised the need to extract groundwater in safe quantities.

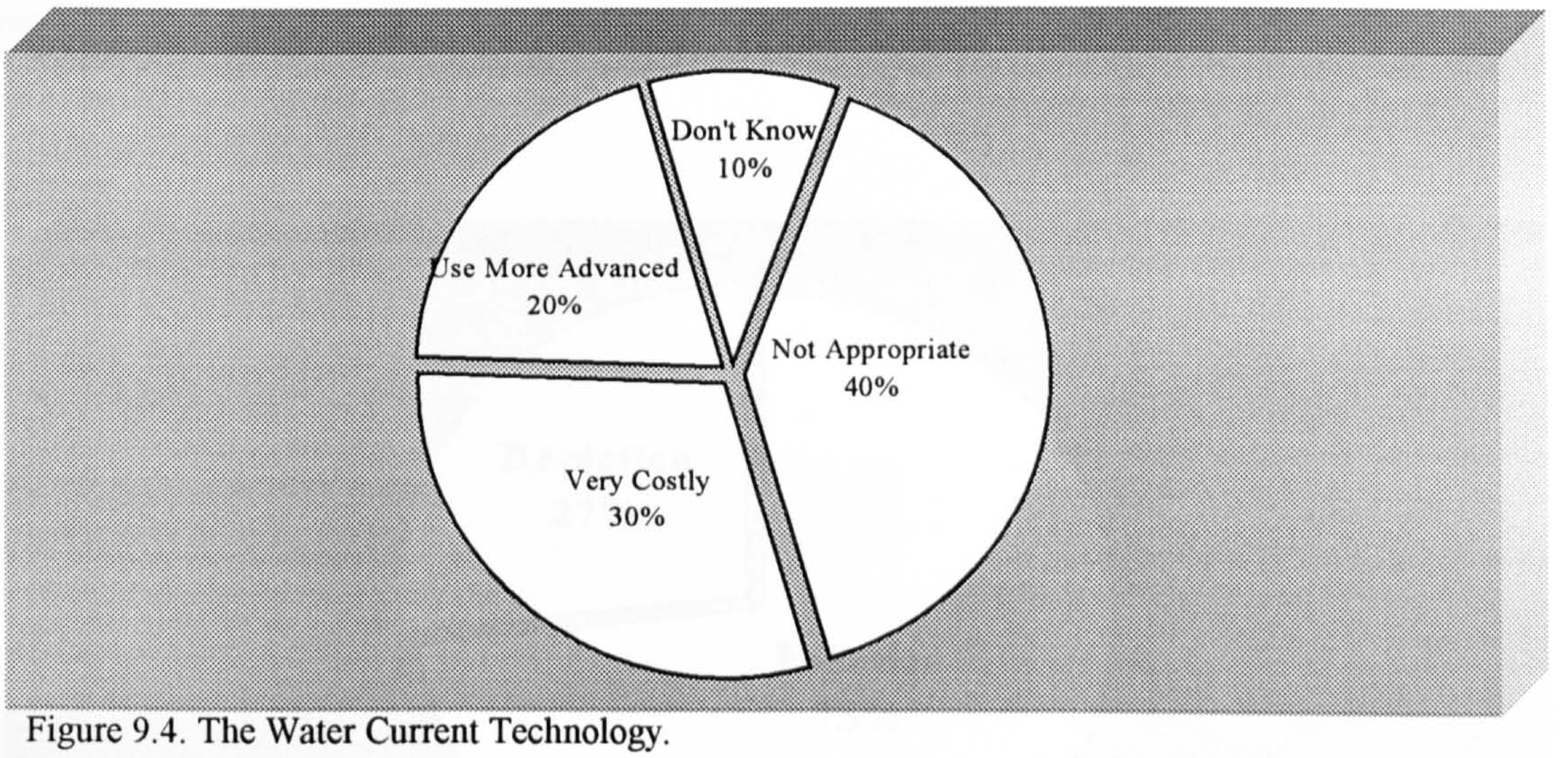

Figure 9.4. The Water Current Technology.

9.7. Groundwater Issues:

9.7.1. Groundwater Pollution and Deficit:

Concerning the situation of groundwater - the only natural resource of the country - **73%** of the survey pointed out that the present policy of exploiting groundwater has led to serious problems (Figure 9.5). The continual increase of extraction caused a decrease in groundwater reserves and seawater incursion and mixing, hence the increased salinity of this source and its decreased suitability for direct consumption. This problem also led to another: - soil salinity- caused by using brackish groundwater in irrigation. According to one respondent "continuous drawing of groundwater led to a decrease in its level, soil salinity, reduction of productivity of agricultural land, and in some cases desertification".

A similar view is shared by another **27%**, who added to it another problem, namely the depletion of groundwater, since continuous withdrawal is not replaced by recharge and the gap is increasing annually. That might lead to total depletion in the future. This is further emphasised by one respondent who said, "the increase in draw led to decrease in groundwater resources, which are considered the strategic reserve of the country".

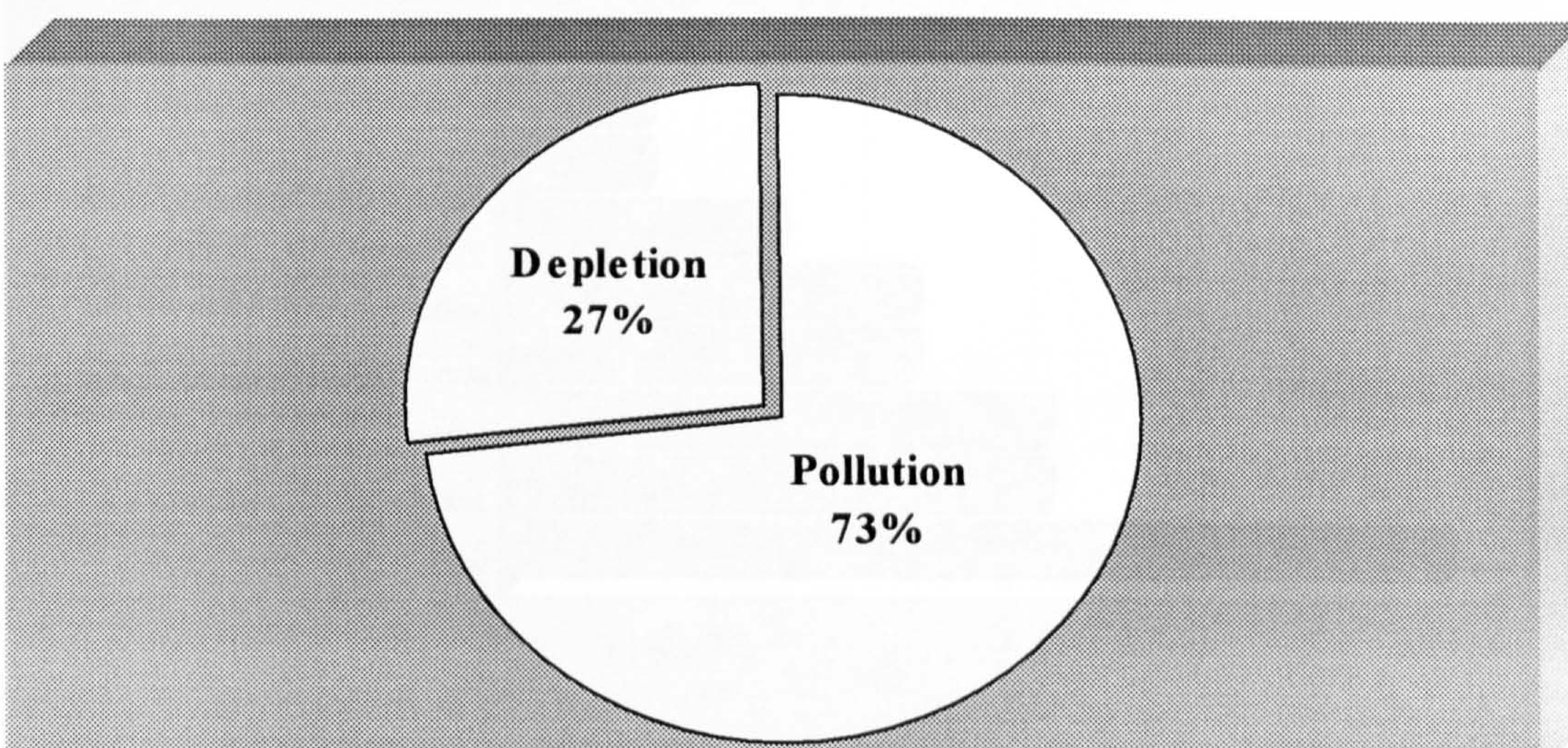

Figure 9.5. The Main Groundwater Issues.

9.7.2. Addressing Groundwater Issues:

Opinions differed as to the best ways to conserve groundwater, according to the significance of the suggestion and its priority at present (Figure 9.6). The need to legislate strict laws concerning drilling of underground wells and the amounts pumped was emphasised by **28%**. These laws must be strictly adhered to without giving allowances to anyone. The need for a comprehensive water management policy was emphasised by **16%**. For instance, before adopting an agricultural policy, water requirements must be considered first. These respondents felt it important not to depend on one source, such as seawater desalination, while neglecting groundwater. For the present **16%** believe priority lies in using advanced technology, such as drip or spray in irrigation, instead of the prevalent traditional ways which consume huge amounts of groundwater on the one hand, and expose water for evaporation due to the severe heat, on the other. According to one respondent "the present irrigation methods are the main reason behind depletion of groundwater, since it is used to irrigate more than 75% of cultivated land".

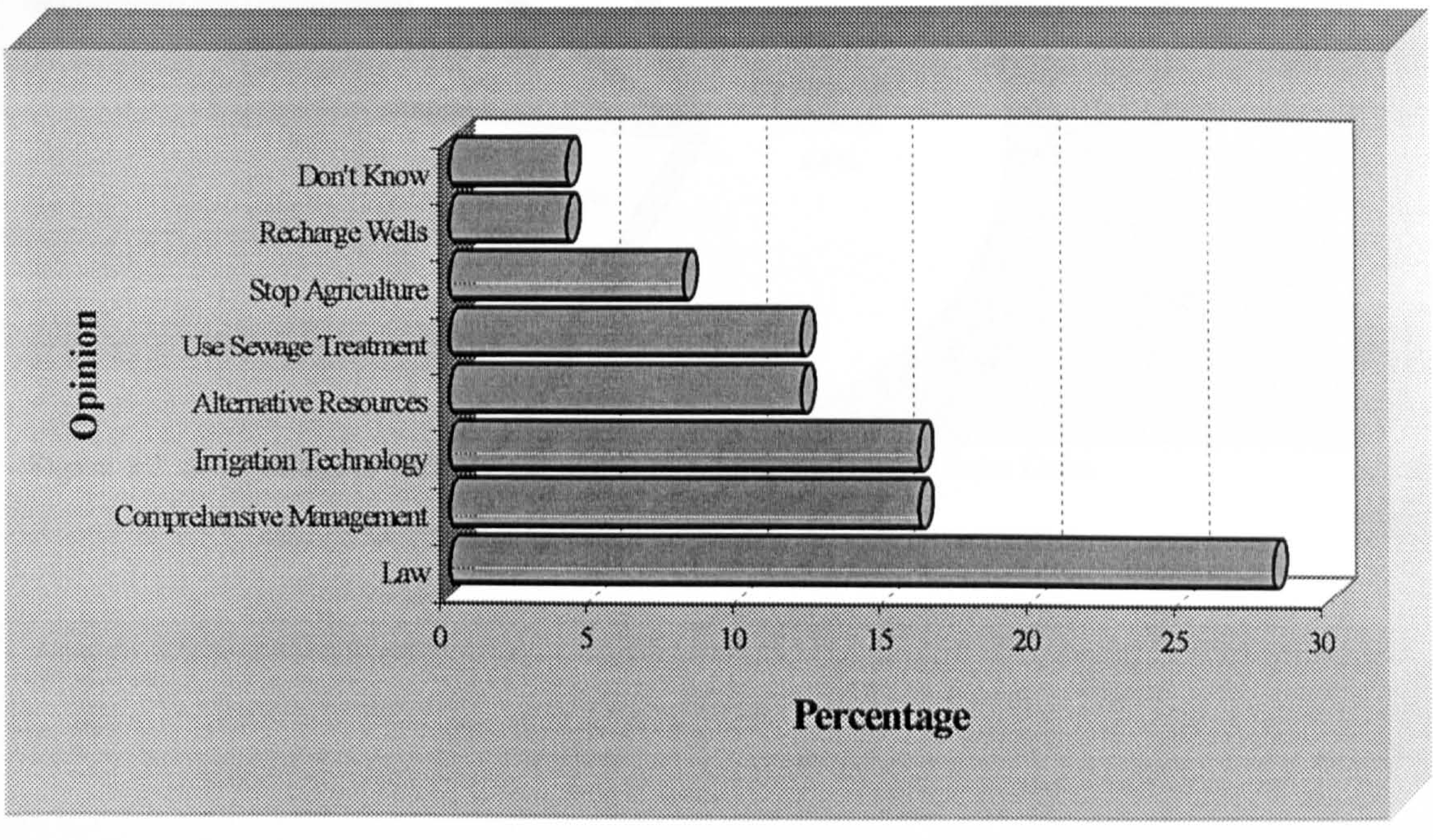

Figure 9.6. Addressing Groundwater Issues.

9.7.3. Changing Groundwater Levels under Doha:

Another problem related to groundwater first identified at Doha is the change in its level. This led to seawater incursion into the groundwater, thus raising its salinity and making it difficult to use. In the same time, leakage in distribution networks - more than 40% of the distributed water (e.g. al-Attiyah, 2000) - as well as water seeping from garden irrigation, led to the increase in the level of groundwater, which threatens the structure of buildings. There is a general agreement to withdrawal this water. The necessity to solve this problem urgently is emphasised by **64%** through constructing a network to drain this water (Figure 9.7). The absence of this network may lead to the aggravation of the problem in the near future.

In the same context, **18%** call for the drilling of wells that are of appropriate distance from each other to draw this water and drain it into the sea, or treat it and use it for irrigation.

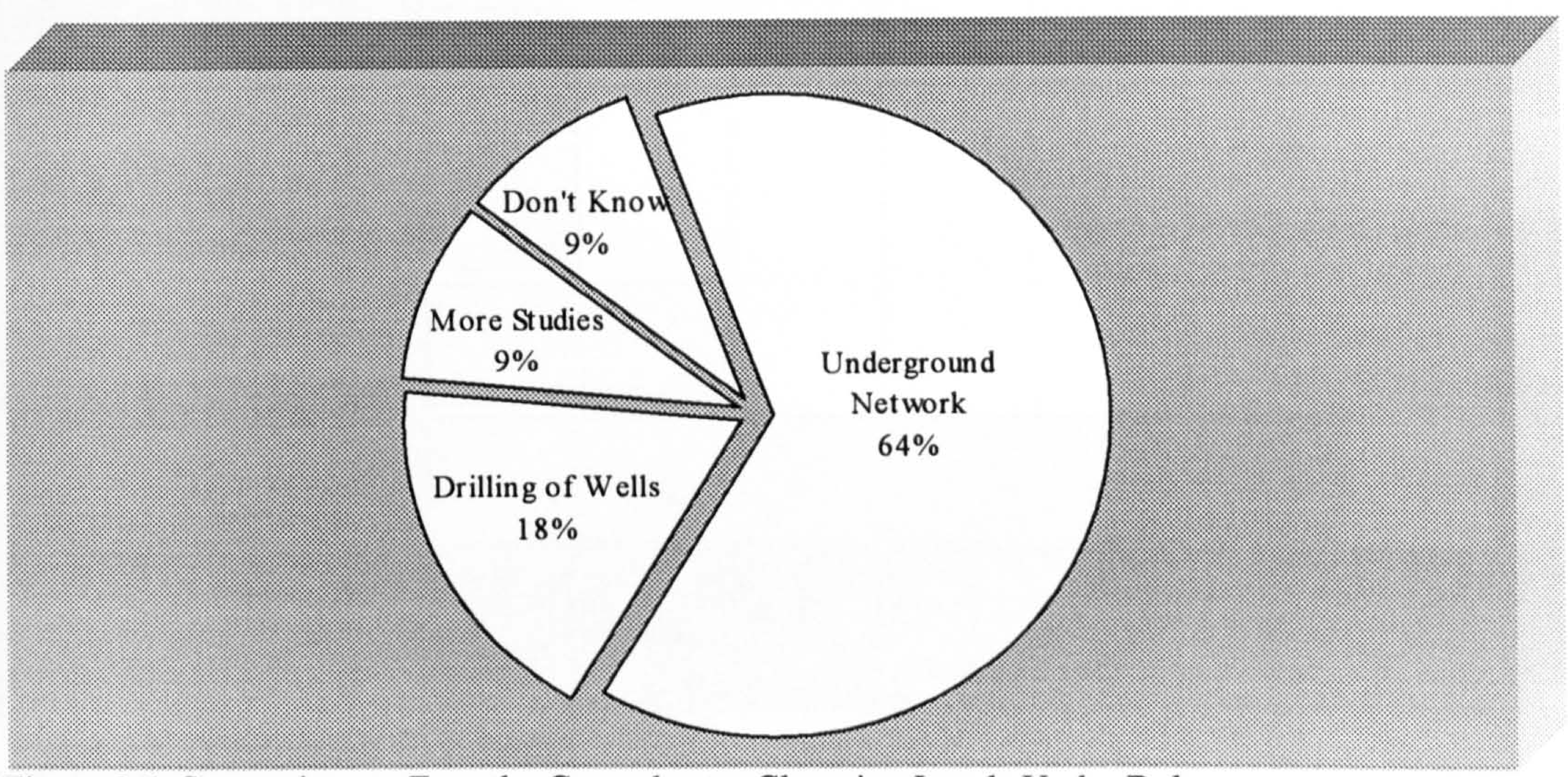

Figure 9.7. Suggestions to Face the Groundwater Changing Levels Under Doha.

9.8. Desalination:

9.8.1. Desalination Technology:

Due to the significance of desalination at present in Qatar, it was necessary to ask several questions concerning the effectiveness of this technology and its nature. The technology used for desalination of seawater is believed by **60%** to be good but is very costly, thus its usage is exclusive to the municipal sector (Figure 9.8). According to one respondent "with more effort and support for research on desalination, it is possible to provide desalinated water at lower cost, hence be able to expand its usage".

Around **20%** believe the technology is old and needs to catch up with global developments. This will allow for the production of less costly water which conforms to WHO specification. According to one respondent "at present gas turbine technology is used in most plants, neglecting steam turbine technology that has good specifications".

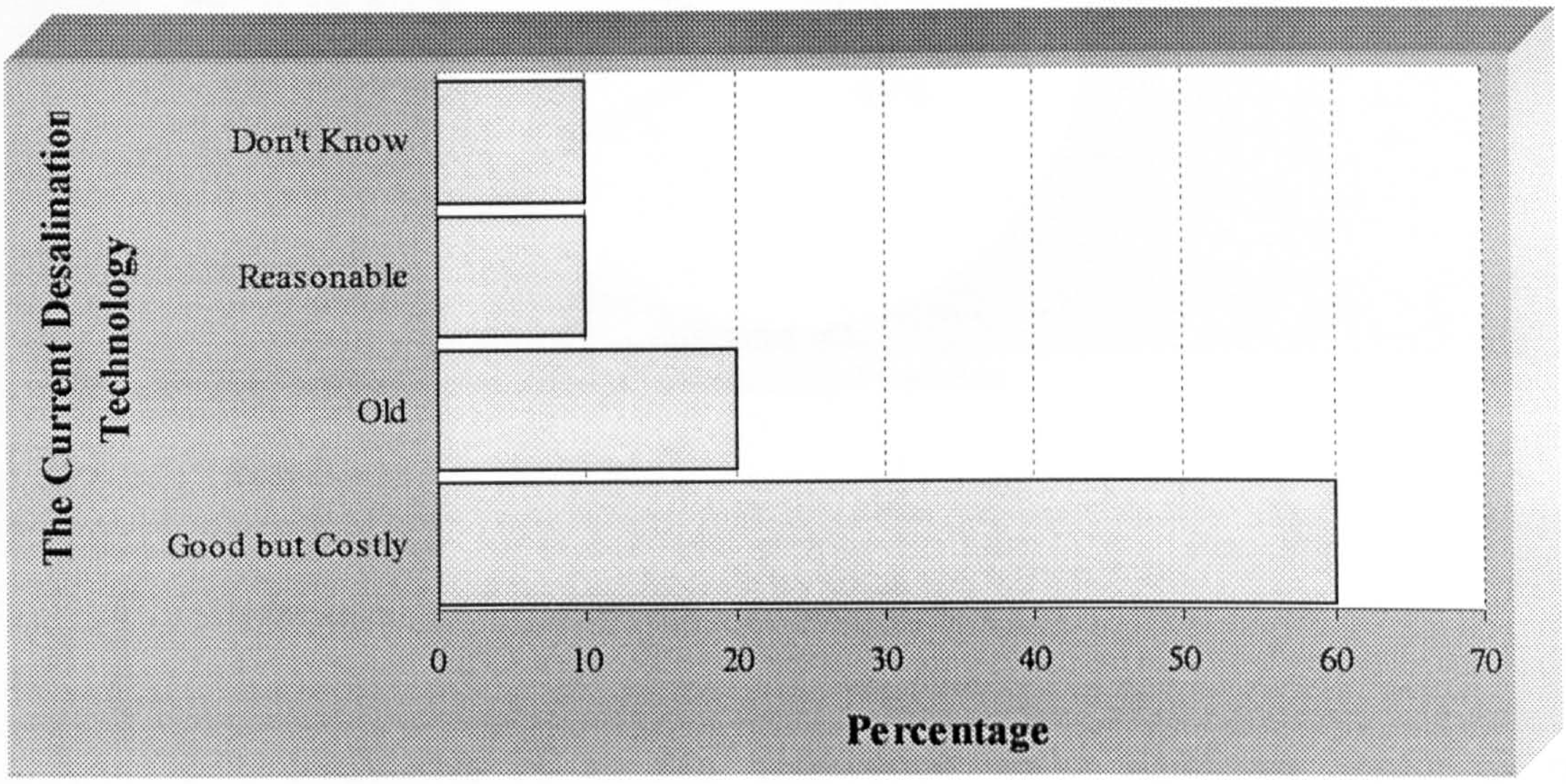

Figure 9.8. Desalination Technology.

9.8.2. Expansion of the Uses of Desalination:

When asked if it is possible to expand the construction of desalination plants, to provide water to the municipal sector, and irrigation to substitute for groundwater, the answers were all positive providing the expansion meets some conditions (Figure 9.9). The expansion according to **86%** must depend on the availability of technology with high specifications and lower cost than the present cost. According to one of the respondents "with the increased involvement of the private sector in the production of desalinated water, it is possible to reduce the cost of this method and have as many plants as possible since energy is available. We would be also in position to export water to neighbouring countries". According to **14%,** it is possible to expand desalination plants, especially in the light of the depletion of groundwater. There might not be another alternative and dependency on desalination will increase, especially as a source for irrigation.

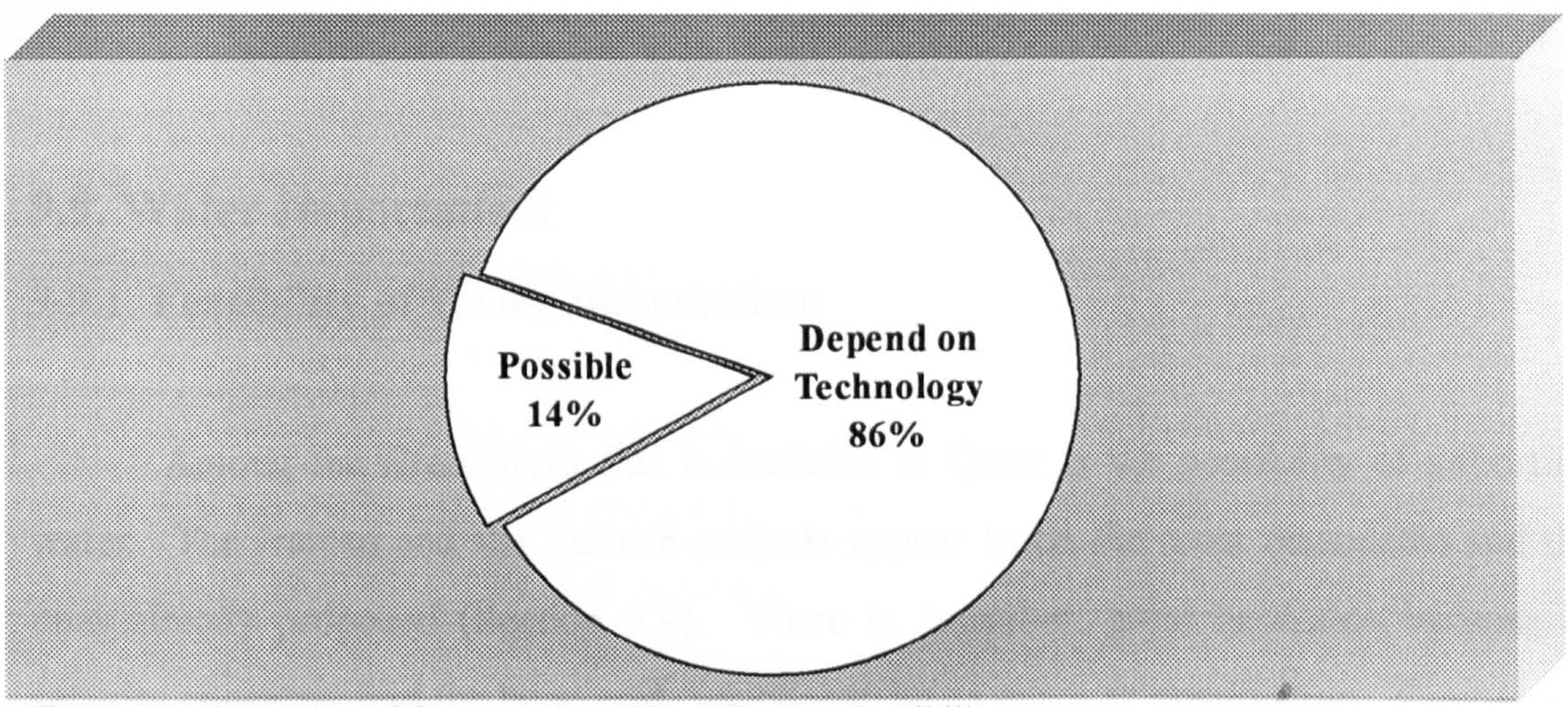

Figure 9.9. Expansion of Construction of Desalination Possibility.

9.8.3. Desalination and Environmental Pollution:

It is emphasised by all that desalination has a significant impact on the environment (Figure 9.10). Around **73%** are concerned with the water returned to the sea after desalination and they emphasise that the increase in the temperature of this water and the concentration of salt as well as its of chemical content causes immense damage to the marine environment. This leads to destitution or migration of sea life near desalination plants. As indicted by one of the respondents "the side effects are grave, but they can be avoided by extending very long pipes to the high seas to get rid of this water".

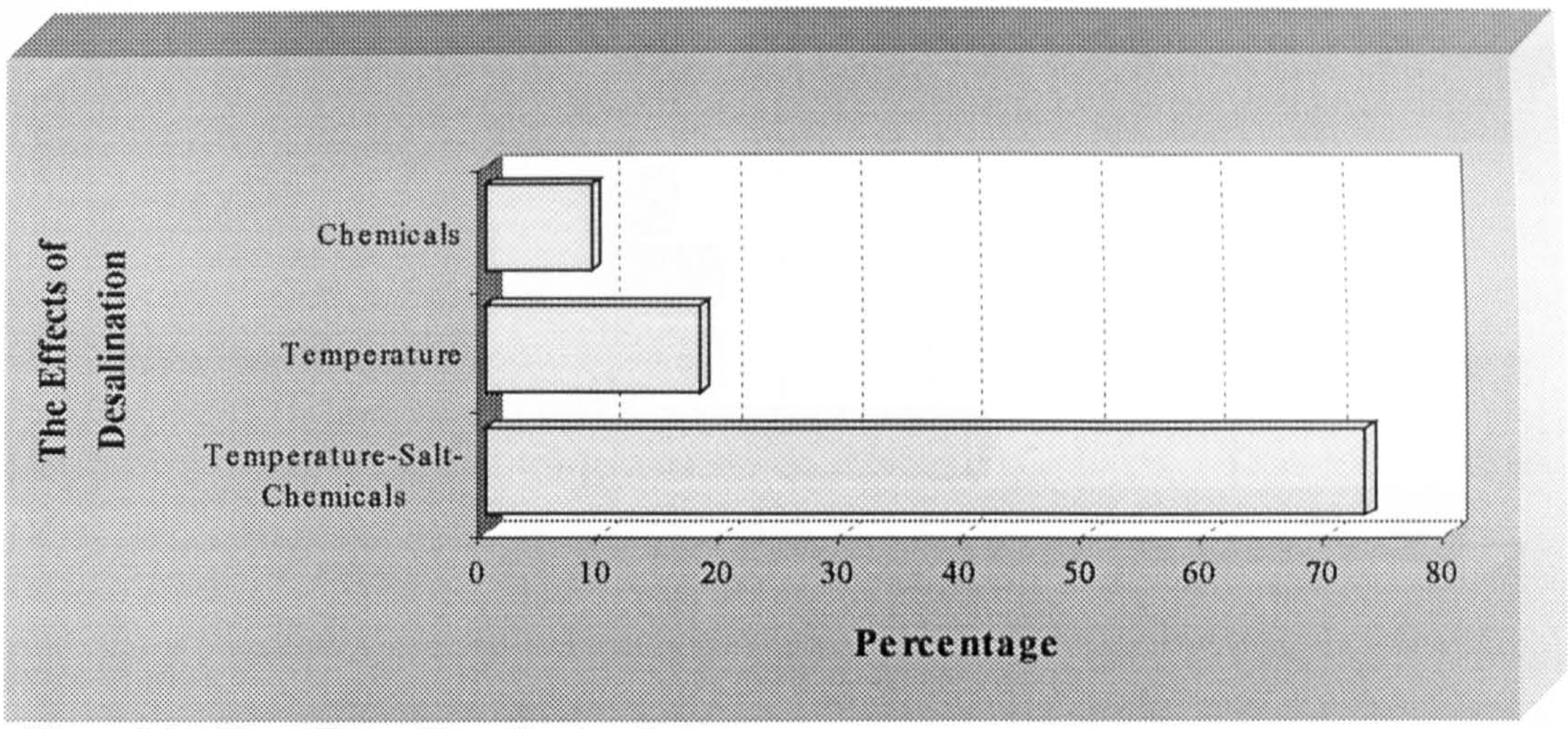

Figure 9.10. The Effects of Desalination Process.

9.9. Water Importation:

9.9.1. Feasibility of Water Importation:

Among the alternatives that is available to Qatar is the possibility of importing water. The Iranian and the Turkish projects appear to be the most reasonable and the ones already proposed (Section 6.4). There is, however, great hesitation because of security concerns, and the huge cost, which may be as much as desalination. Concerning this alternative (Figure 9.11), around **57%** thought it was a good idea, on condition that security and economic guarantees are available for such projects. The security guarantees must include international guarantees of the unhindered flow of water, while the economic guarantees must be based on an extensive study, since the project entails the construction of a massive water network. According to one respondent "it will all depend on the amount, quality and source of the water", while another indicates that "if guarantees are available this is an effective alternative, especially as some countries such as Turkey have excess of water, and it reduces the pressure on local sources".

A **quarter** do not support this alternative because of its high cost, which nears the cost of desalination. Besides, the necessity of security arrangements makes it a difficult alternative to pursue. As indicated by one of the respondents "as long as it is possible to utilise local sources at reasonable cost, there is no need for water import".

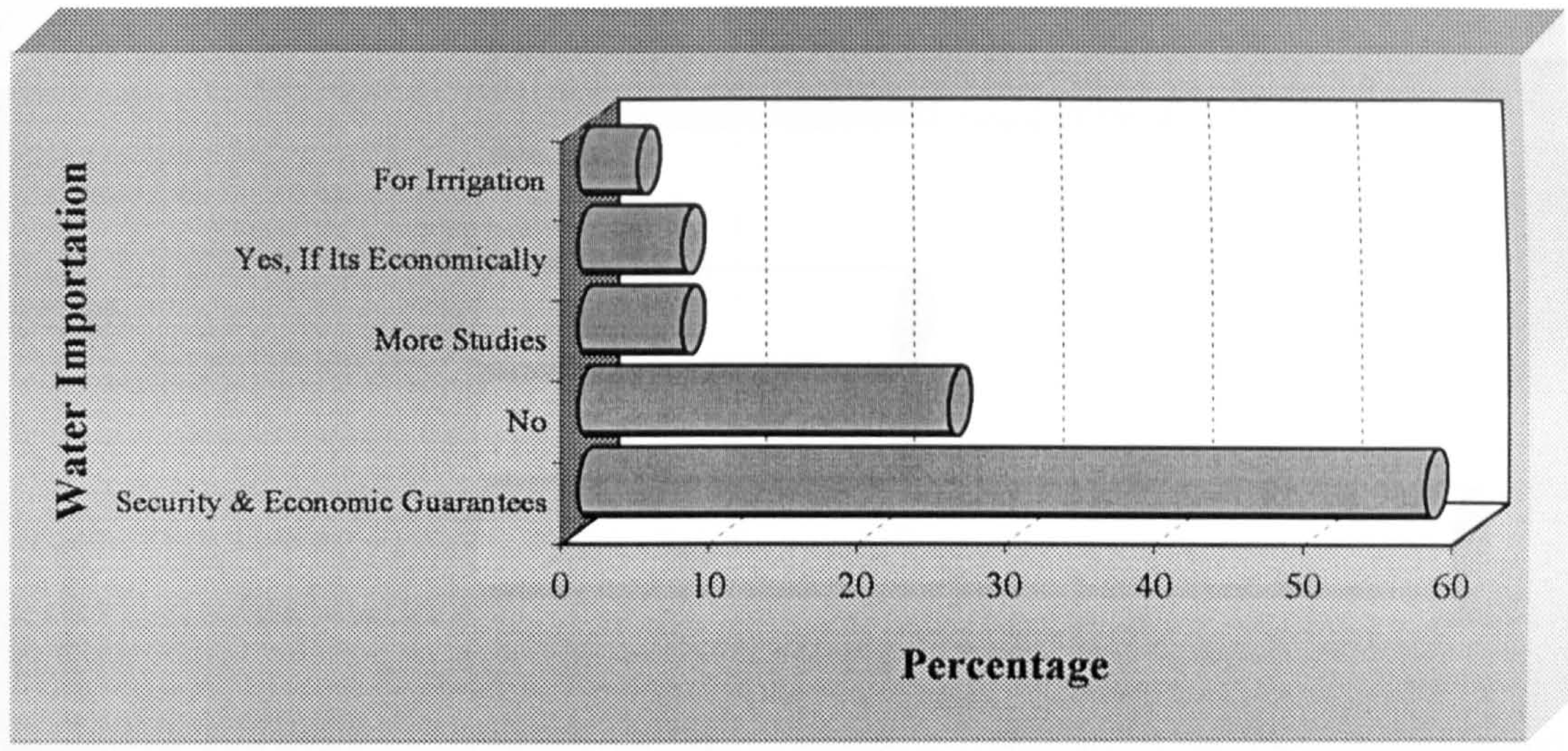

Figure 9.11. Feasibility of Water Importation.

9.9.2. Comparison between Desalination and Importation:

When asked about their preference for desalination or import of water, **half** of the sample survey thought that there is no reason why the country should not depend on both sources (Figure 9.12). The municipal sector can be supplied from desalination and irrigation from import of water. One respondent indicated that "using imported water instead of groundwater for irrigation purposes is crucial for maintaining ground reserves and having a strategic reserve of water". Around **21.5%** emphasised that desalination is the only solution for solving the problem of water deficit. One of the respondents indicated that "desalination of water is better than import it because of the dependency it creates". Around **21.5%** emphasised that preference of method should be decided based on the cost; if import of water is cheaper than desalination then it should be the dominant source especially if security guarantees are provided.

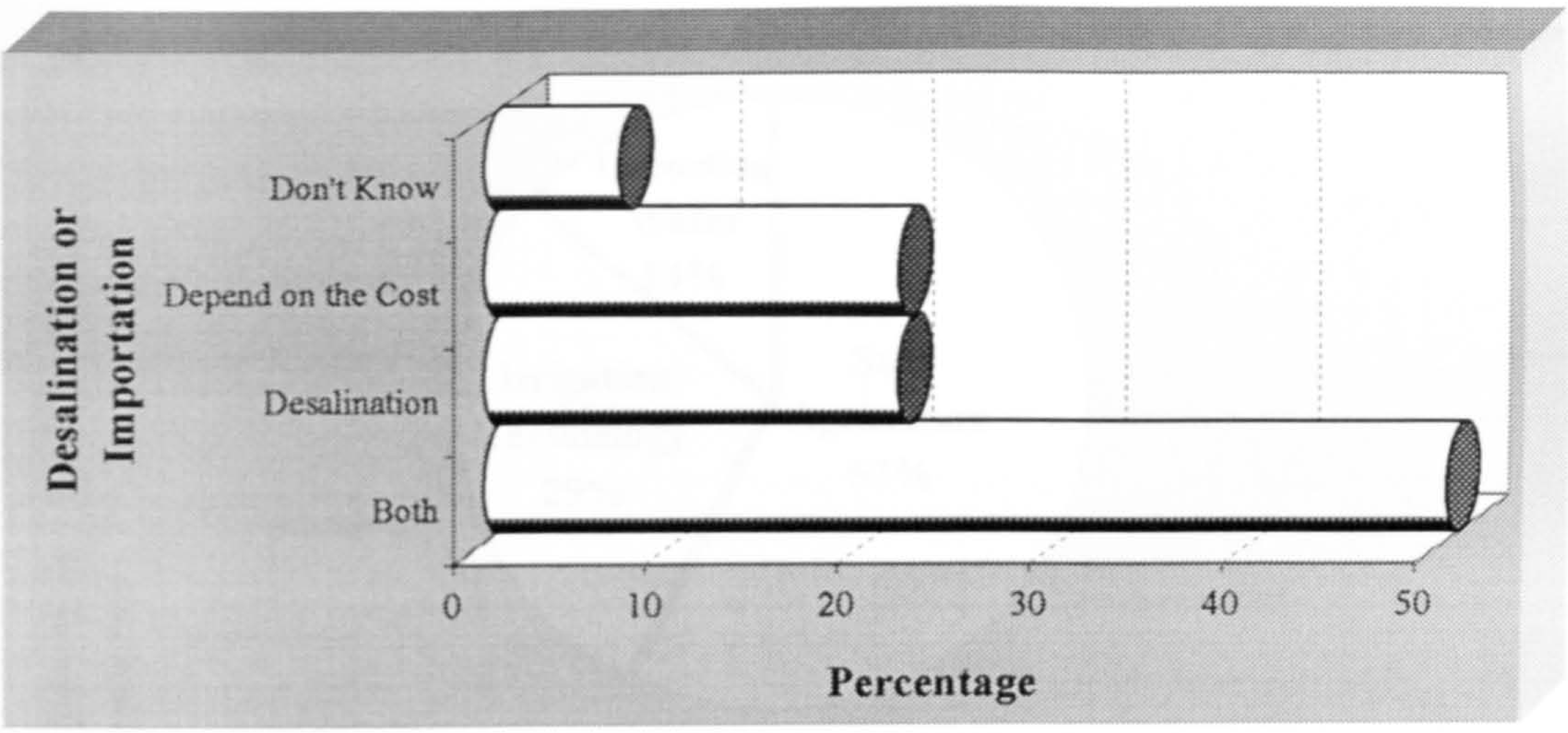

Figure 9.12. Comparison between Desalination and Importation.

9.9.3. Comparison between Water Importation and Agriculture Expansion:

When asked whether if is better to import water or to conserve groundwater by limiting the expansion in agriculture (Figure 9.13), **57.5%** supported the idea of limiting agricultural development rather than importing water from outside especially as the policy of food self-sufficiency has proved virtually impossible to achieve. According to one of the respondents "if one is dependent on the import of commodity from a particular country and that country stopped its export for some reason or another, then one can look for another source next day. But in the case of water, in the light of the huge costs involved in such a project, that possibility does not exist".

Around **28.5%** thought that neither the import of water, or the restriction of agriculture is a valid policy. They believe that the use of advanced technology in irrigation would help to reduce the amounts of groundwater extraction and maintain the achievements in the agricultural sector or even possibly expand it.

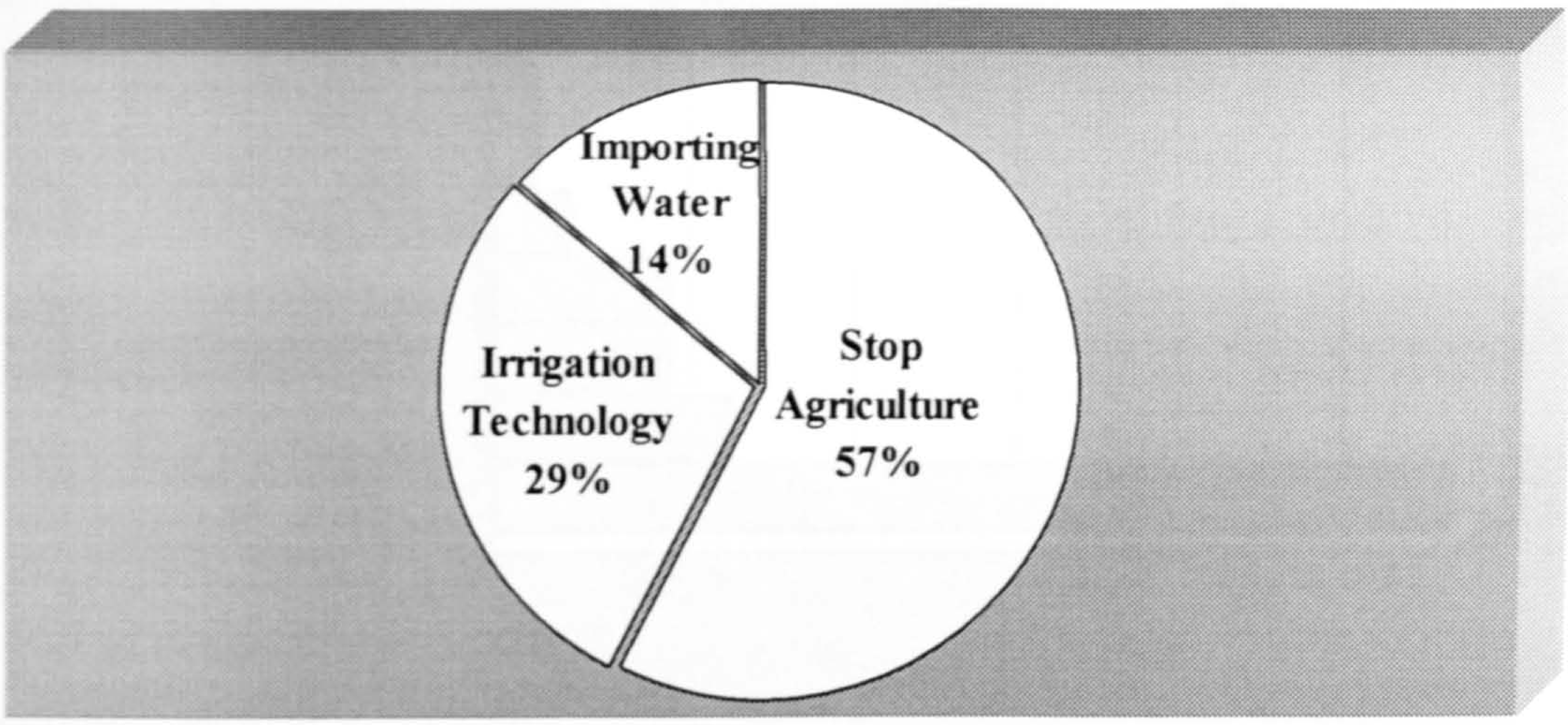

Figure 9.13. Comparison between Water Importation and Agriculture Expansion.

9.10. Water Reuse:

9.10.1. Feasibility of Use Recycled Water:

Recycling is another potentially important non-traditional source of water in Qatar. It has been utilised only to irrigate some plants used for animal feed, and for watering some gardens and parks (Section 6.2.4). Thus, when asked whether if is possible to expand the use of this source, **58%** believed that there is a major opportunity for more investment in this field (Figure 9.14), especially for agricultural purposes. According to one of the respondents "expansion in this source must take place as soon as possible, especially because most of the costly desalinated water ends up in the wastewater drainage network without it being used again". Another respondent stresses that "every drop of water must be properly invested".

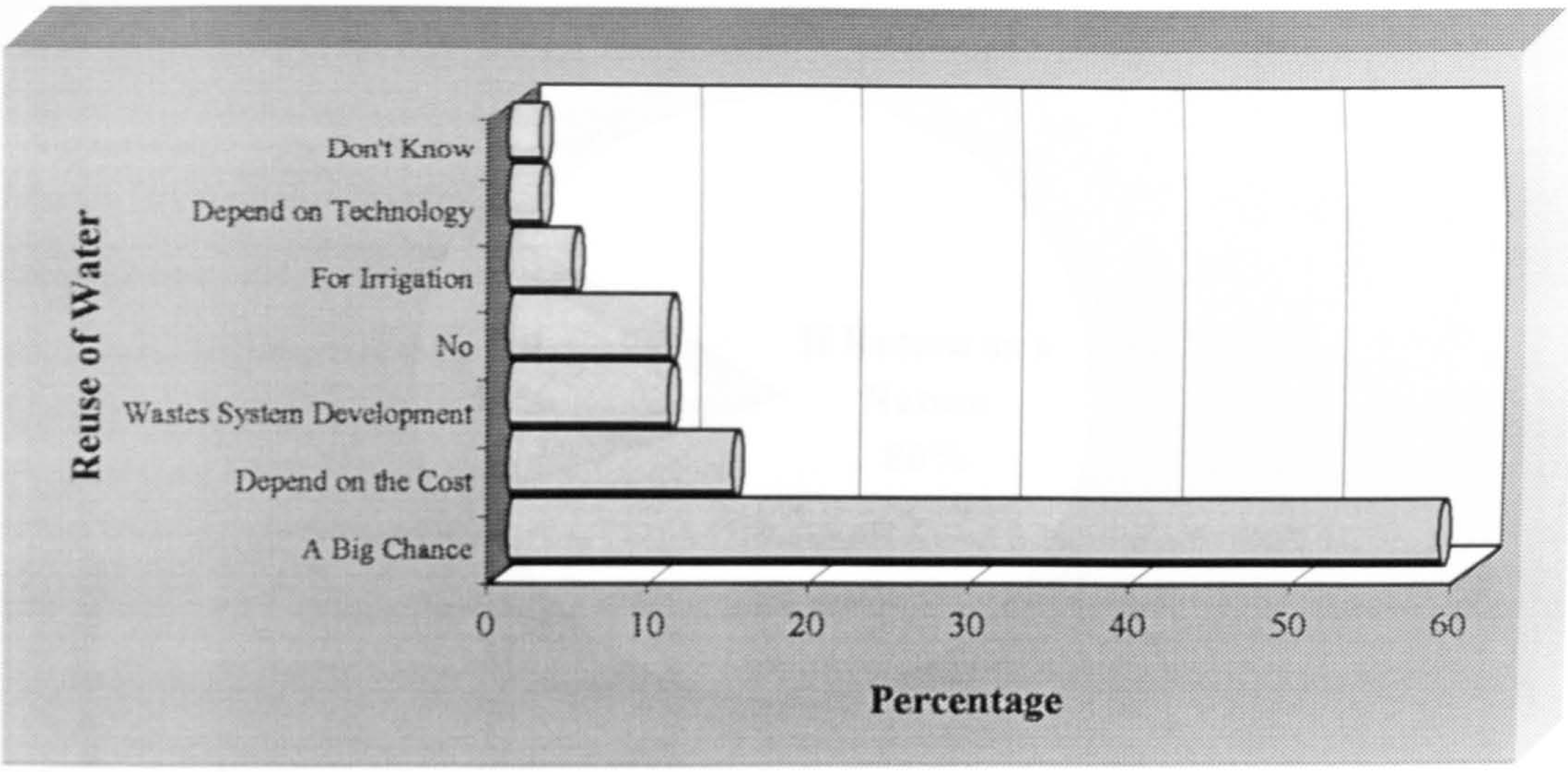

Figure 9.14. Feasibility of Use Recycled Water.

9.10.2. Religious Scholars Opinion of Water Reuse:

Most religious scholars **(6 of 7)** believe that this source can be used in all sectors if modern treatment gives it its natural attributes (Figure 9.15), while **1** objected to its use. It is significant that the use of this source has the support of religious people considering the stress that Islam puts on the issue of cleanliness in order to perform religious duties. According to the Holy Qur'an "*O you who believe, what rise to pray, wash your faces and your hands as far as the elbow, wipe your heads, and your feet to the ankle. If you are polluted, cleanse yourselves...*".

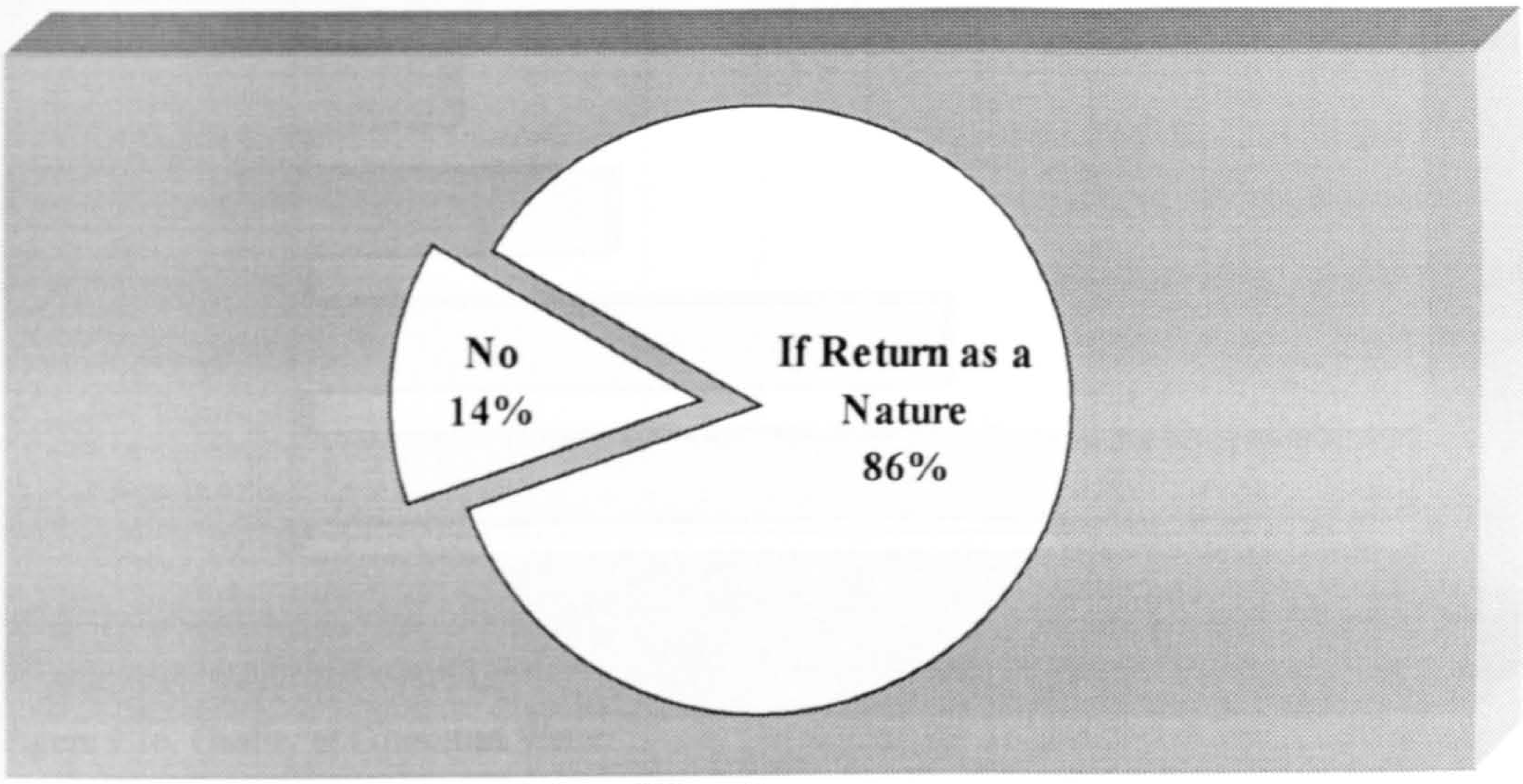

Figure 9.15. Religious Scholars Opinion of Water Reuse.

9.11. Water Quality:

9.11.1. Quality of Consumed Water:

Discussing the quality of the different sources of water and its suitability for consumption was among the most difficult questions because it requires expertise and knowledge of the topic. It is worth mentioning that many of the people living outside the capital complain regularly about the quality of water and its unsuitability for consumption, due to high salinity (e.g. al-Deecie, 1998). It must be noted that the majority of the sample survey comes from the capital, which reflects the concentration of economic activities and population in the capital.

Half of the respondents believe the quality of water is acceptable and can be consumed without any consequences for health (Figure 9.16), while **29%** think it is of high quality.

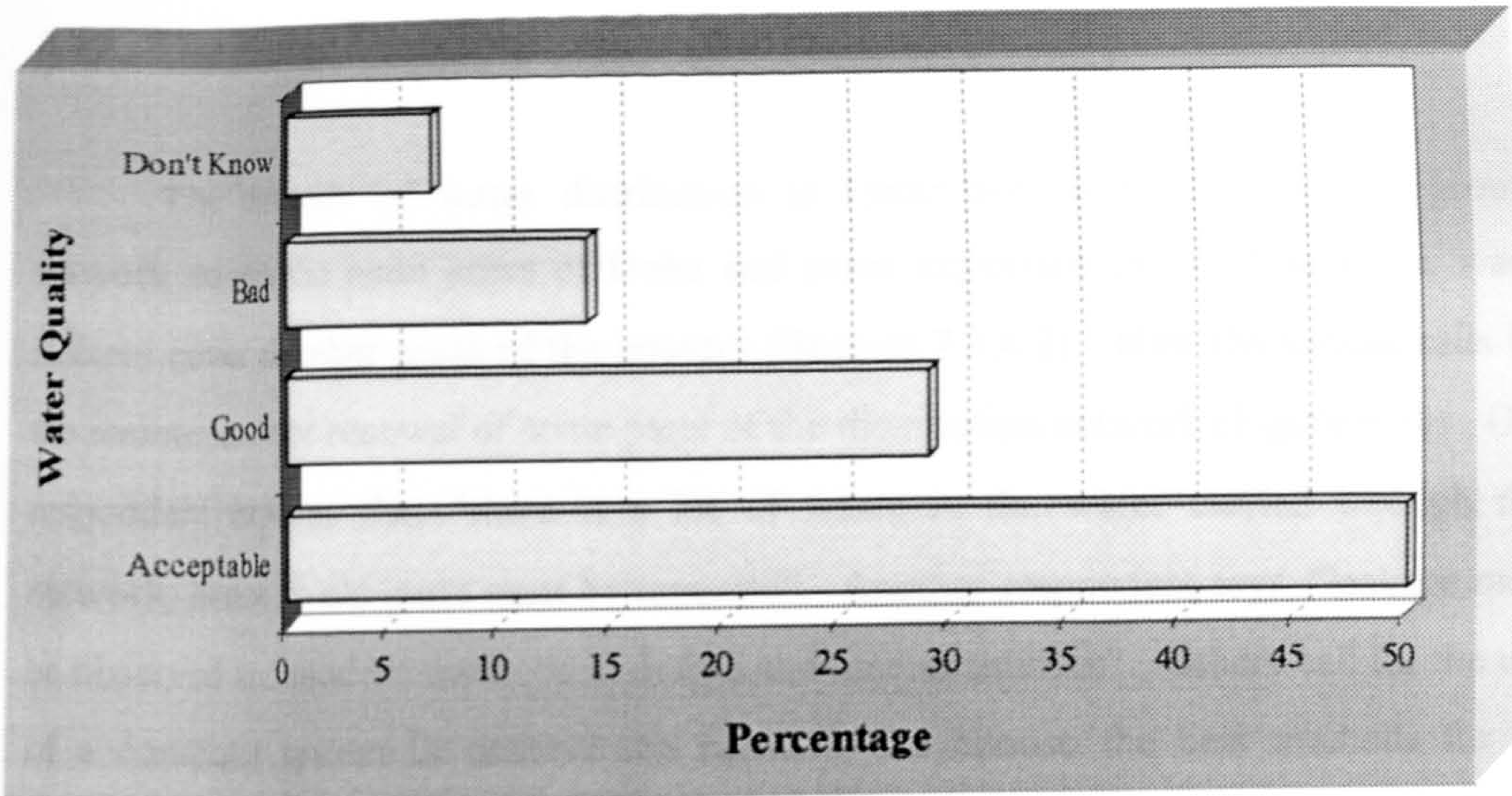

Figure 9.16. Quality of Consumed Water.

9.11.2. Sources of Water Pollution:

When asked about the quality of the groundwater, **64%** believe the most important pollutant sources for this source come from industrial waste, particularly from the oil industry and urban landfills, and from unplanned urban expansion where the type of soil is not take into account, leakage of wastewater from distribution networks and irrigation into the groundwater (Figure 9.17).

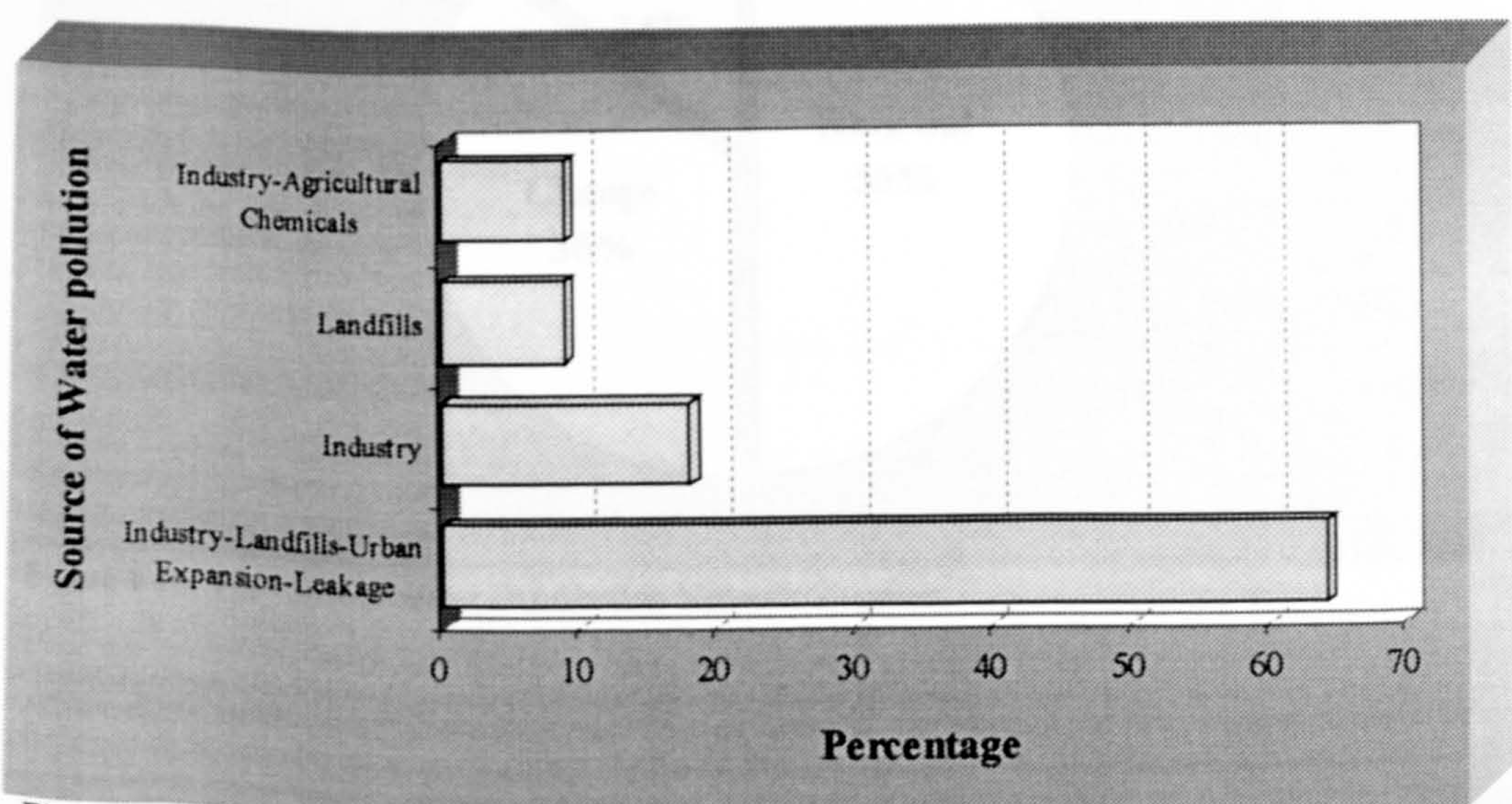

Figure 9.17. Sources of Water Pollution.

9.12. The Water Distribution Network:

The methods of water distribution in Qatar are twofold. An underground network covers the main areas of Doha and some important cities. Elsewhere, water tankers cover all other areas of the country (Section 7.3.4.2). **Half** the sample calls for the maintenance or renewal of some parts of the distribution network (Figure 9.18). One respondent explains that "there is a lot of waste in the water carried through this network, hence its old parts must be renewed". Another respondent says, "leakage must be observed and modern methods in design and implementation". Others call for the use of a computer system to observe the network and choose the best methods for its maintenance. Around **36%** call for the extension of a new network to cover all the country and end the use of water tankers because of water pollution. One respondent observes that "the use of steel in the water network leads to water pollution and subsequently diseases, while the transfer of water in tankers should not be happening when we are nearing the twenty first century".

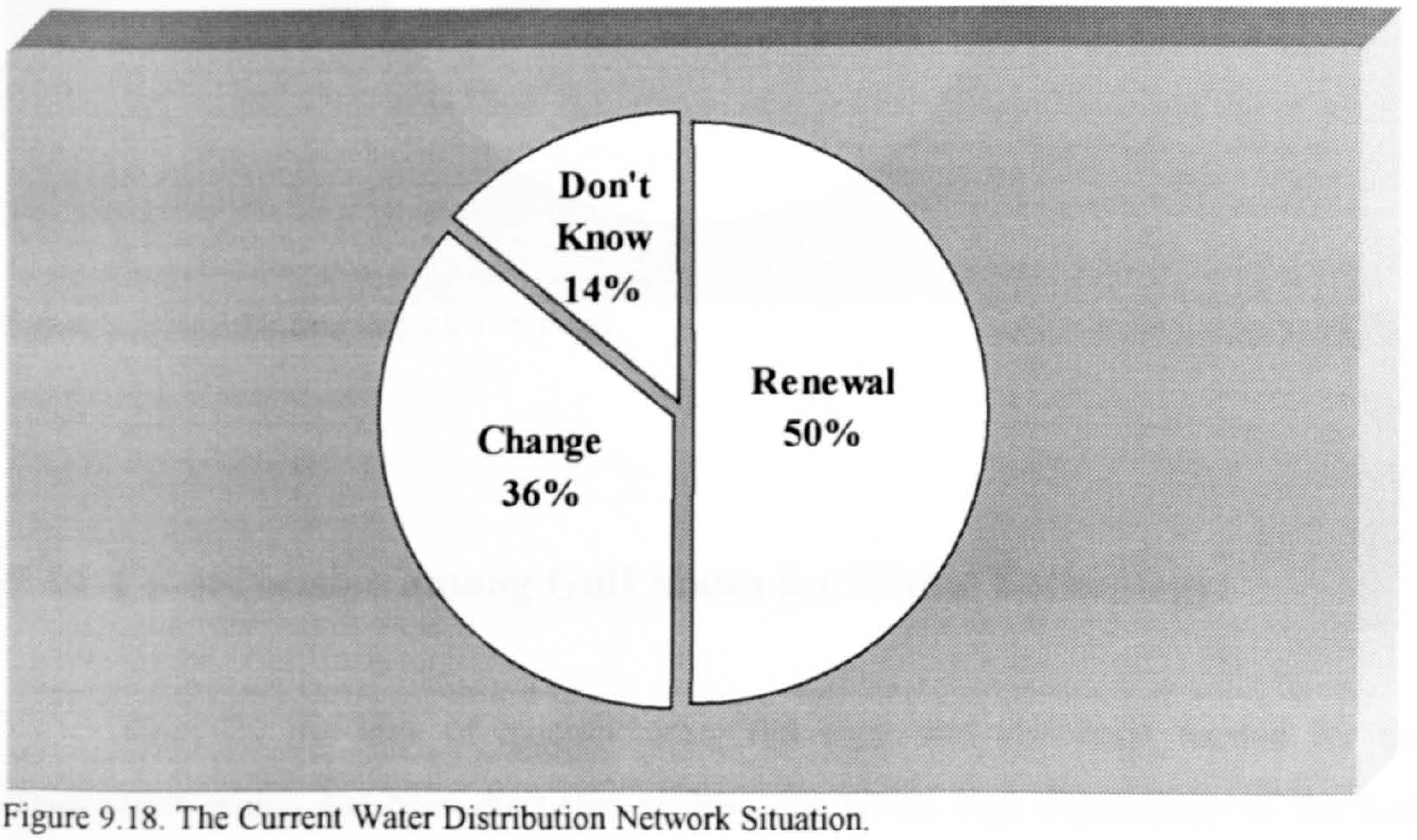

Figure 9.18. The Current Water Distribution Network Situation.

9.13. Irrigation Methods:

This question concerns the use of modern irrigation methods, which does not cover more than a quarter of the total cultivated land in the country (Section 7.3.4.4). Around **70%** emphasise the necessity of replacing old irrigation methods with more modern ones (Figure 9.19). The old methods are a source of a huge drain on groundwater. One respondent says, "it is necessary to expand the use of modern technology because of its high efficiency in saving water". While another respondent says, "modern methods of irrigation such as drip and spray had achieved excellent results in some state farms in conserving water".

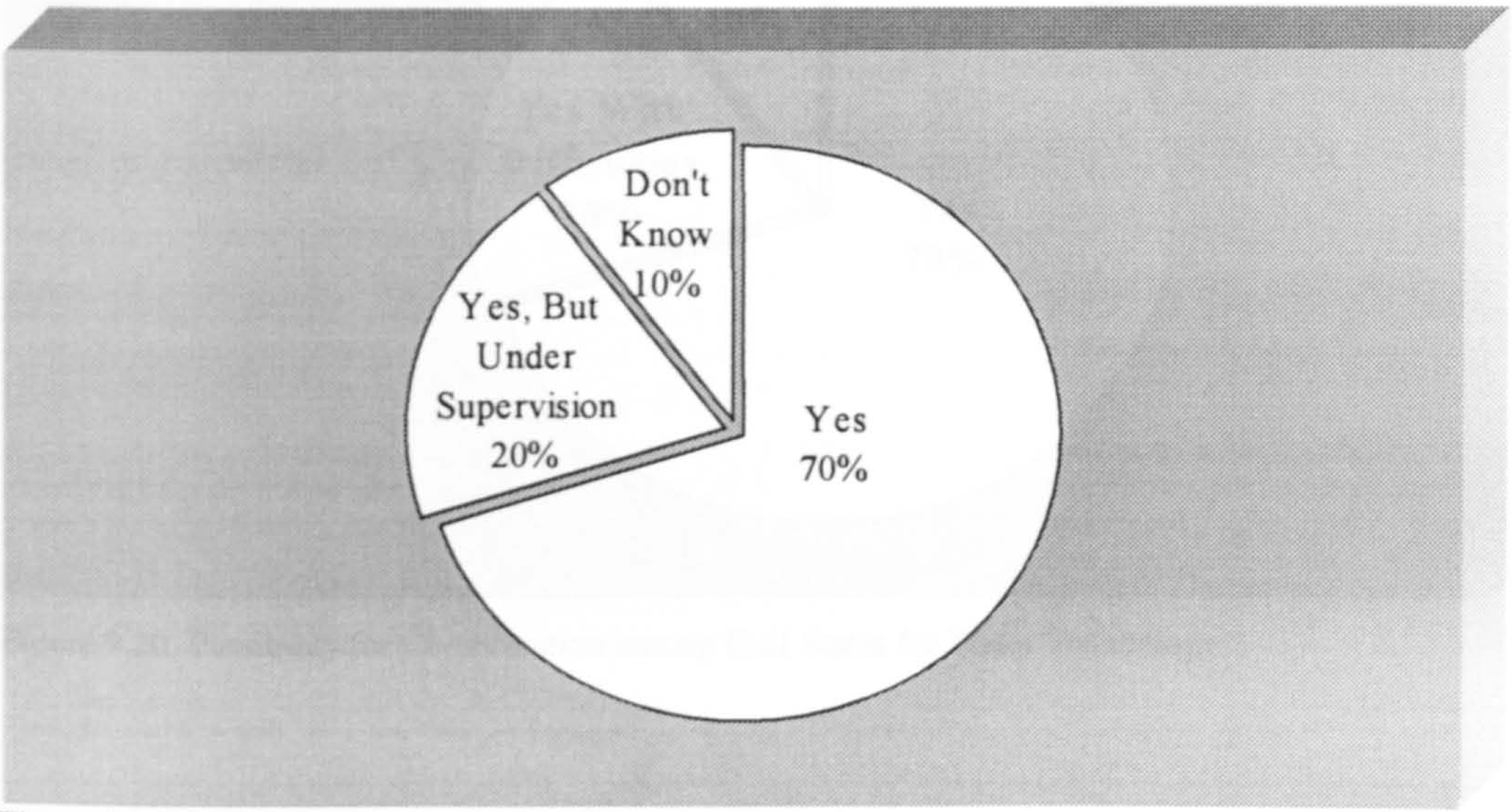

Figure 9.19. Use Modern Irrigation Methods.

9.14. Co-ordination among Gulf States for Water Technology:

Recently the idea of manufacturing the plant and chemicals needed for the desalination plants has been discussed widely, due to the high dependency of the Gulf area on this method for its water consumption, especially in the municipal sector. It appears to be most logical that Gulf states should co-operate in this field in order to find ways to reduce the high cost of this method and abate the pollution that results from the plants, especially as they possess the resources to undertake such a project (Section 7.3.7.8).

A high percentage **(70%)** supported this idea and called for co-operation among the Gulf states because of the strategic importance of water technology (Figure 9.20). One respondent emphasises "not only the need to manufacture the technology of desalination but also the technology of storing and pumping groundwater, in addition to the necessity to support scientific research at universities to develop this kind of technology".

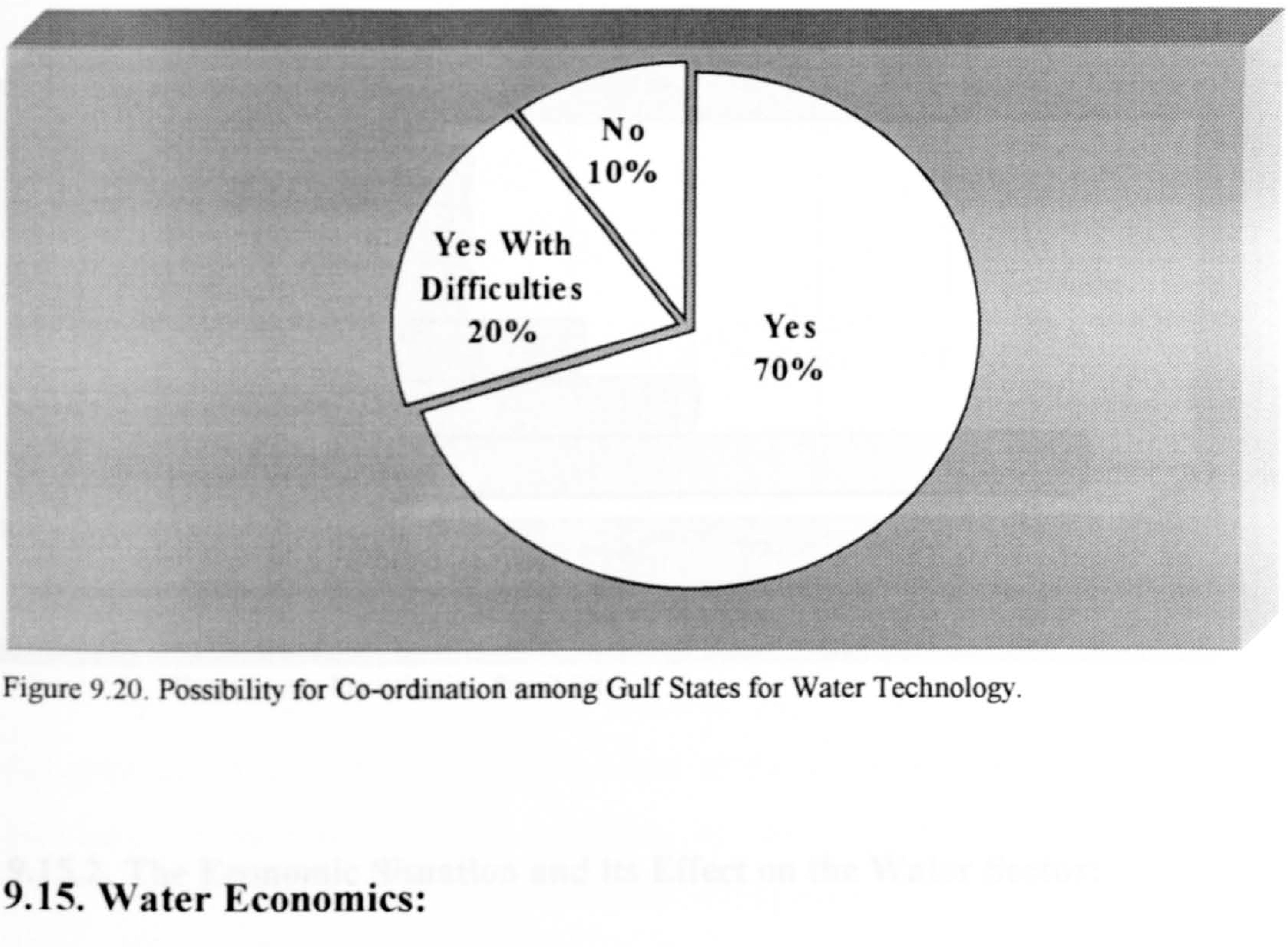

Figure 9.20. Possibility for Co-ordination among Gulf States for Water Technology.

9.15. Water Economics:

9.15.1. Water Sector Privatisation:

The decline in oil prices has caused a deficit in the budget of all the Gulf states, and consequently many voices are now calling for the privatisation of the public sector, including the water sector (Section 7.3.5.5). This idea was supported by a small percentage of the survey sample (Figure 9.21). Around **53%** supported partial privatisation, while the Government remains the ultimate controller of this vital sector. According to one respondent "privatising the water sector is not totally new. In the past, individuals owned and pumped wells. The problem today is that the shortages are so severe that the Government must remain the control of the sector to prevent any monopoly".

The idea of privatisation is rejected by **22%** and more than 70% of these are the religious scholars. According to the most renowned scholar on Islamic economy "the origin is that water is a public resource and hence must remain in the hands of the state and not the private sector due to the Holy Qur'an (*Tell them that water is to be divided between them*) and the Prophet (peace be upon him) said (*People are co-owners of three: water, fire and pastures*)".

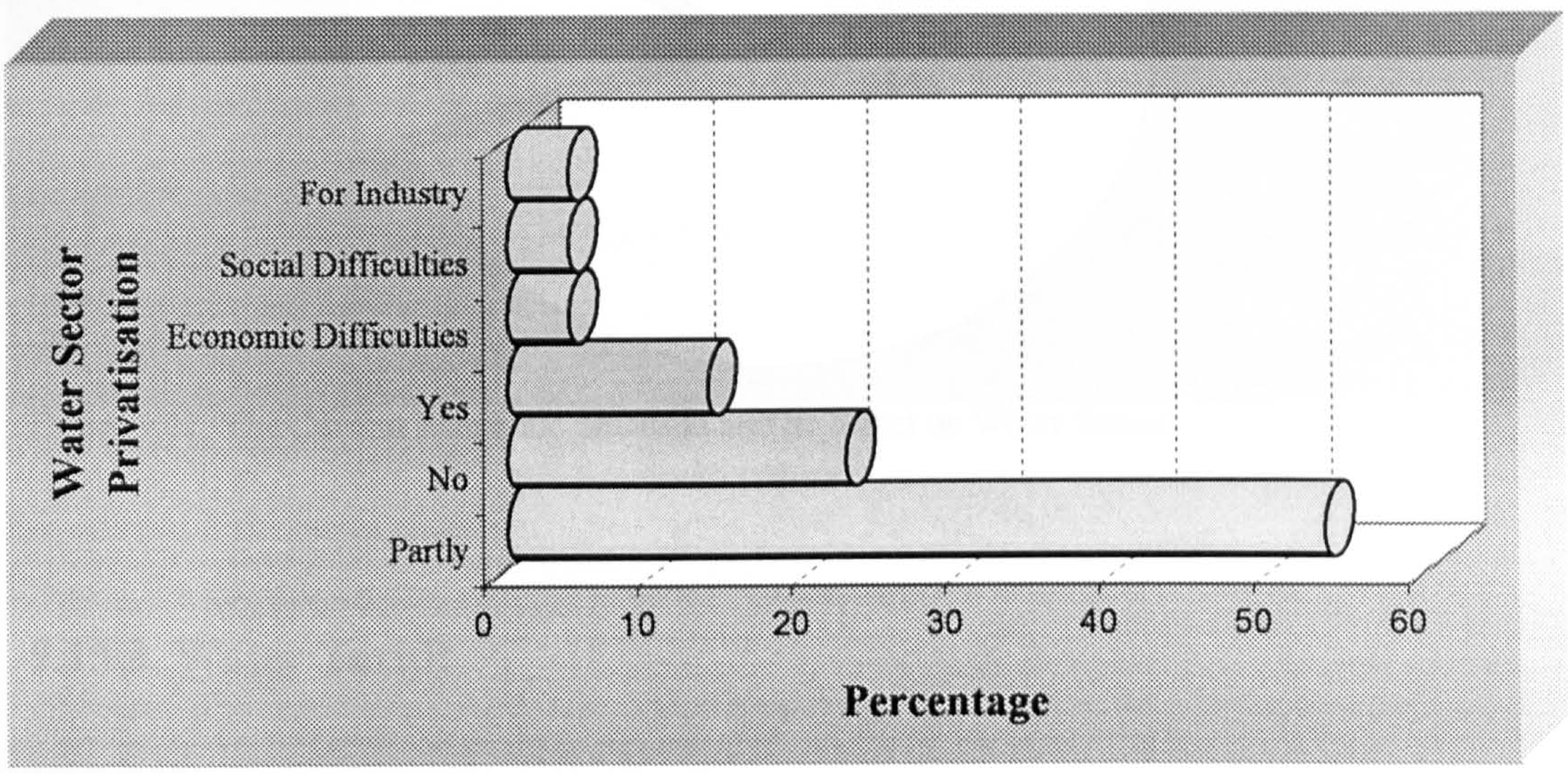

Figure 9.21. Water Sector Privatisation Possibility.

9.15.2. The Economic Situation and its Effect on the Water Sector:

Another issue relating to the Government's control of the sector is the effect of the decline of state revenues. The deficit in the Government's budget for the year 1999-2000 is \$986.8 million. The Ministry of Finance indicated that there would be a reduction of Government expenditure not only in the education, health and housing sectors but also other sectors including water (e.g. al-Ashqar, 1999). In spite of increased the oil prices in 1999, the deficit in the budget for the year 2000-2001 was \$762.5 million (e.g. Abu Arafat and Sadeq, 2000). Most of the respondents **(86%)** believe that such an effect is expected and that it will worsen over the years (Figure 9.22), especially in the light of the fact that oil prices are unlikely to ever reach the level witnessed during 1970s and early 1980s. This might increase the pressure on the Government to privatise the sector to relieve itself from its huge financial burden.

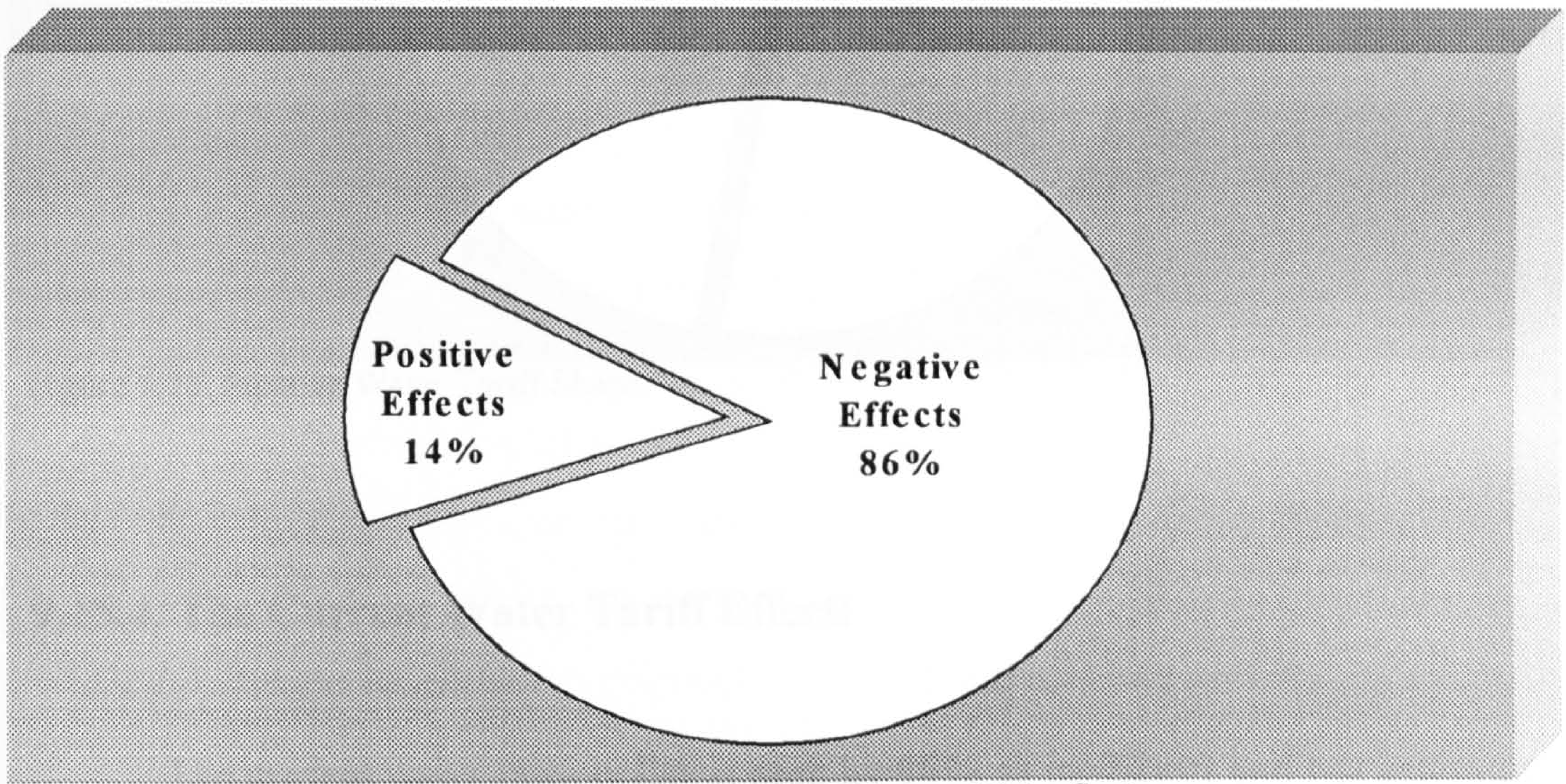

Figure 9.22. The Current Economic Situation and its Effect on Water Sector.

9.15.3. Water Tariff:

As mentioned before, water is provided free of charge for citizens and to foreigners at rates lower than the actual cost of the water (Section 7.3.5.3). Hence, respondents were asked whether this could be used to pressure people to reduce consumption. The majority of the respondents **(57%)** emphasised that fixing rates closer to the cost of the provision of the water will undoubtedly limit consumption (Figure 9.23). According to one respondent "everyone must pay for what they consume as they pay for other commodities". This is supported by **43%**, who called for further research on the matter, and indicated that water rates must be imposed on everyone equally so people would not refuse to pay when they see others, more able, exempted.

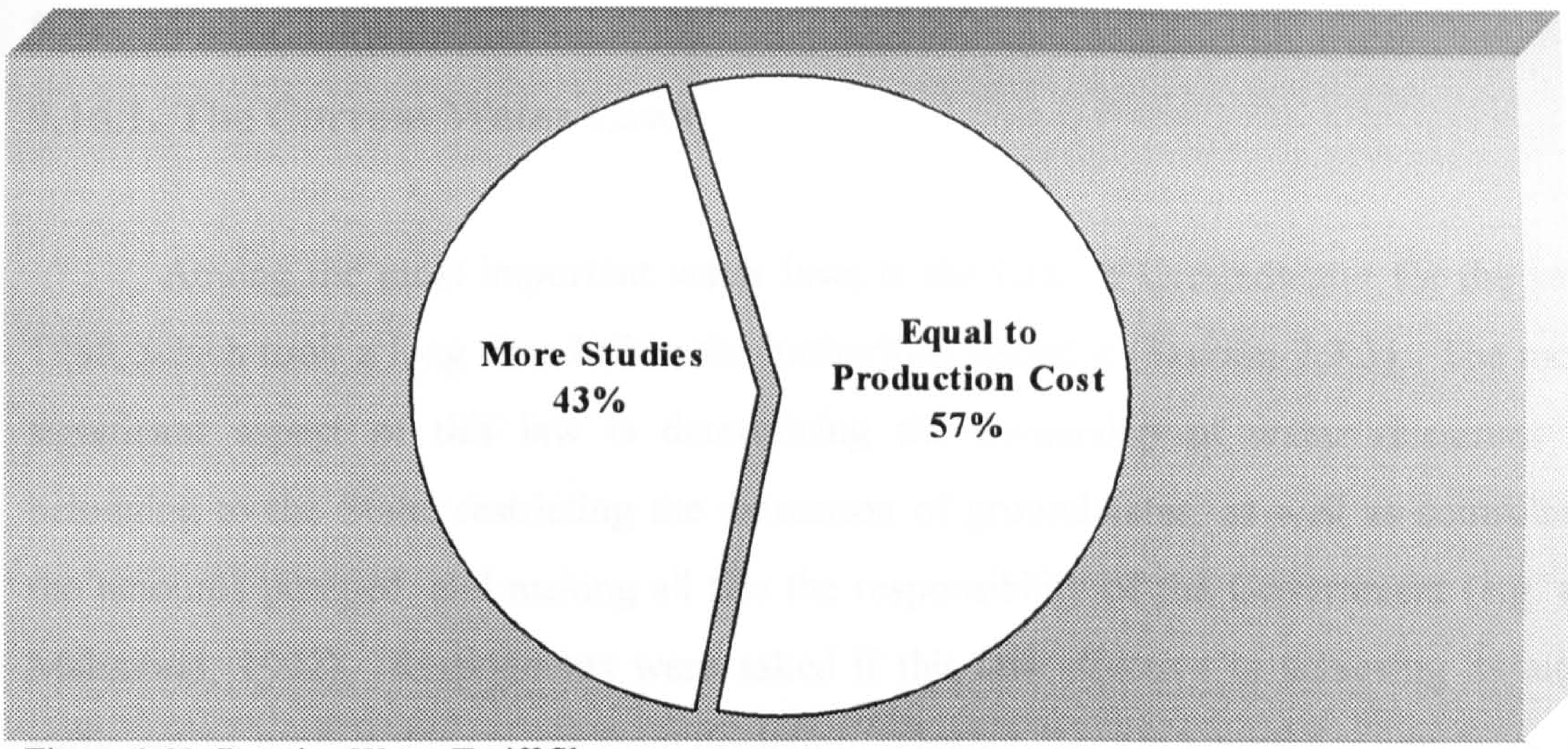

Figure 9.23. Putative Water Tariff Shape.

9.15.4. The Current Water Tariff Effect:

The present water rates policy is seen by **86%** as inefficient and not achieving its aims because it is not imposed on everyone, being more of a nominal fee when compared with the actual cost of the production and distribution of water (Figure 9.24). According to one respondent "the policy of water rates is not suitable for the social conditions, where most of the population have high incomes, and can afford to pay for their consumption of water".

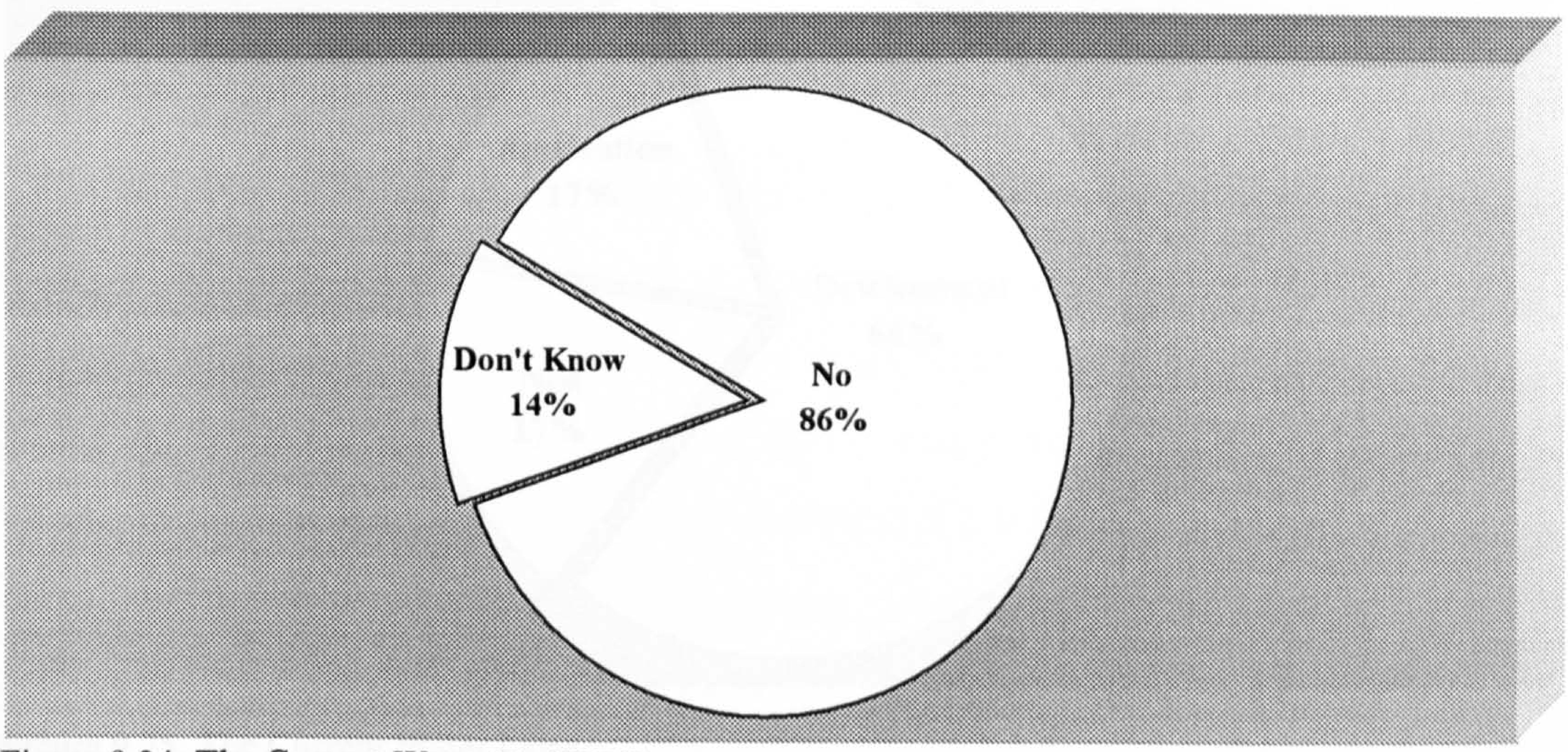

Figure 9.24. The Current Water Tariff Effect.

9.16. Water Laws:

9.16.1. The Current Water Laws:

Among the most important water laws is the Law of Groundwater for the year 1988, which took a long time before the authorities issued it (Section 7.3.3). The most significant aspect of this law is determining the ownership of water resources as belonging to the State, restricting the extraction of groundwater, as well as controlling the amounts pumped, and making all this the responsibility of the Government (e.g. al-Mahmoud, 1992). Respondents were asked if this law effective in achieving its aims sufficient to protect this source from depletion, whether there is a need for new laws, or the development of existing laws.

According to **66%** of the survey sample the law needs to be developed and modernised to keep up with what is new in the field and to stop breaches due the weakness of some of its articles (Figure 9.25). According to one respondent "water laws in general need continuous reviewing, as well as specificity in their articles due to the many uses of water resources". Another respondent indicates that "for the law to be effective it must be issued by experts and specialists in local environment and social matters, which requires officials to have contact with the citizens to understand their needs".

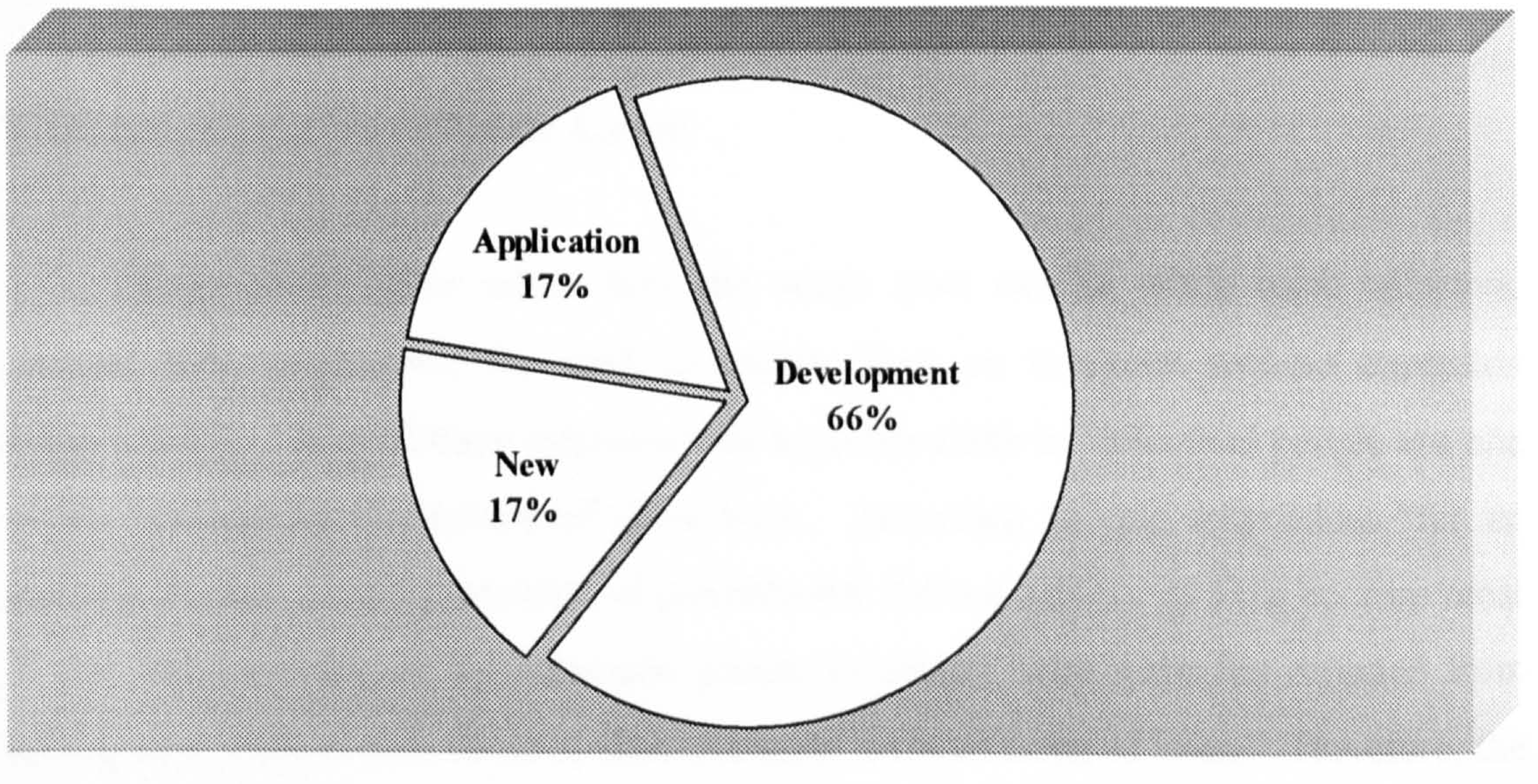

Figure 9.25. The Current Water Laws.

9.16.2. Need for New Water Laws:

When asked about the coverage of present laws of all aspects related to water (Figure 9.26), **33%** indicated that there are aspects not covered by the law. These include two most important issues: the volume of consumption and water rates. One **quarter** of the sample emphasised the need for laws to protect water sources in general and not just groundwater, and also issues such as protecting sea life from pollution by desalination plants.

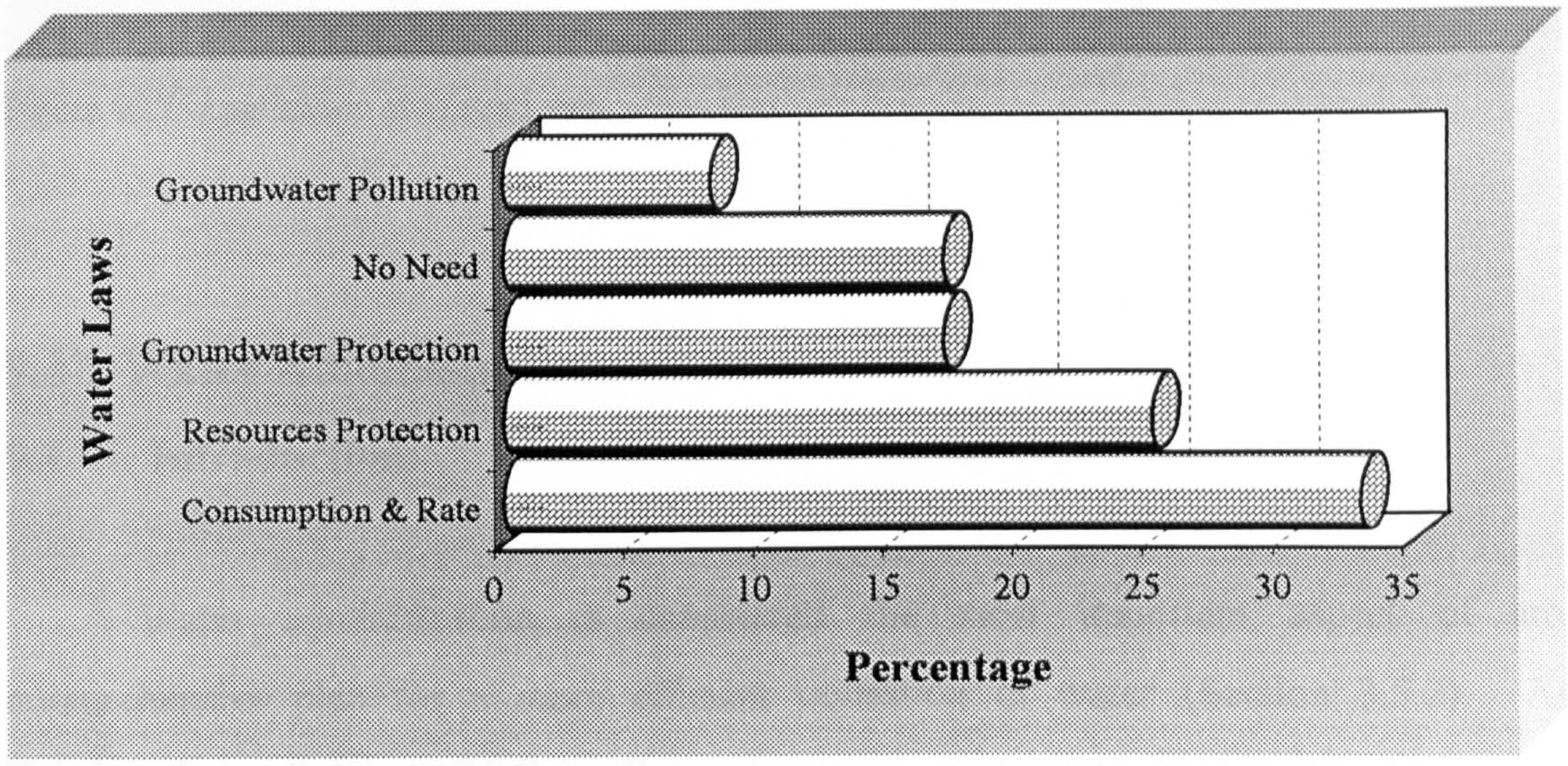

Figure 9.26. Need for New Water Laws.

9.16.3. Application of Water Laws:

Respondents were asked how the water laws can be made more effective. Around **50%** emphasised the need to impose laws on everyone without exception (Figure 9.27). Many of them indicated that breaches made by influential people are one of the reasons for the failure of these laws. According to one respondent "for an example the law for the protection of groundwater did not achieve its aims because most of the farms are owned by influential people in society who were not stopped from drilling new wells in their farms or from pumping extra amounts of water. Therefore, the law must be applied first to them so other citizens would not breach the law".

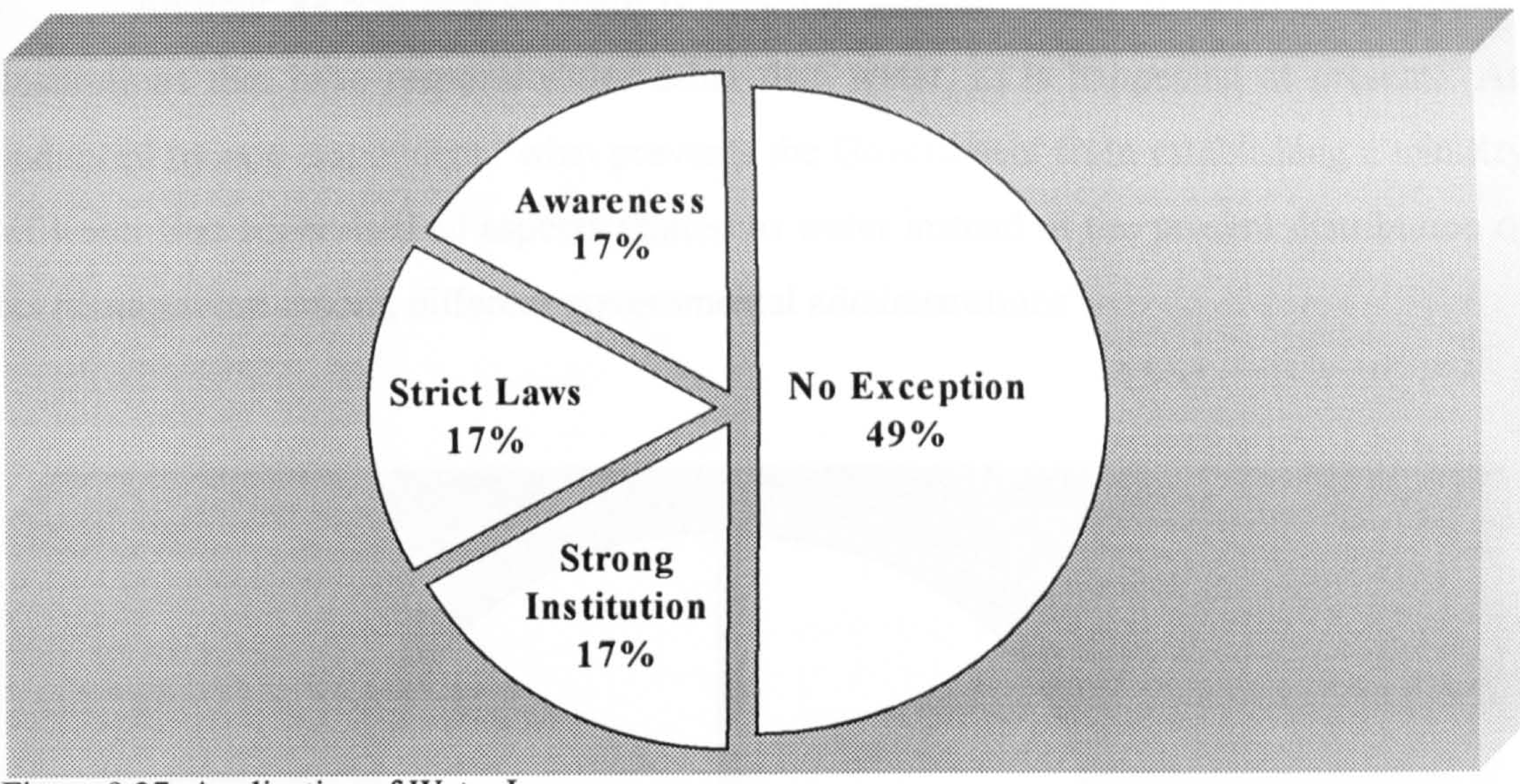

Figure 9.27. Application of Water Laws.

9.17. Water Administration:

9.17.1. Introduction:

Water administration is considered the most important aspect of any comprehensive plan for a more efficient utilisation of water (Section 3.5.2). As mentioned in Section 7.3.7.3, Qatar has two authorities responsible for water administration. Respondents were questioned concerning this aspect the efficiency of these institutions as well as the level of co-ordination among them and with international institutions.

9.17.2. Level of Water Administration:

The present management is seen by **55.5%** as sufficient if one takes into account the size of the country and the population (Figure 9.28). What is required is the activation of these institutions, until more powers to carry out their responsibilities. According to one respondent "we have what is sufficient to manage all aspects of water, but what we need is a restructuring and more support for these institutions so they will carry out their responsibilities more efficiently".

Another **44.5%** believe there is need for separate water authorities not tied to institutions that have responsibilities other than water, as is happening at present. As indicated by one respondent "what prevents the Government from establishing a ministry of water that supervises all aspects related to water instead of the present distribution of its management among different governmental administrations".

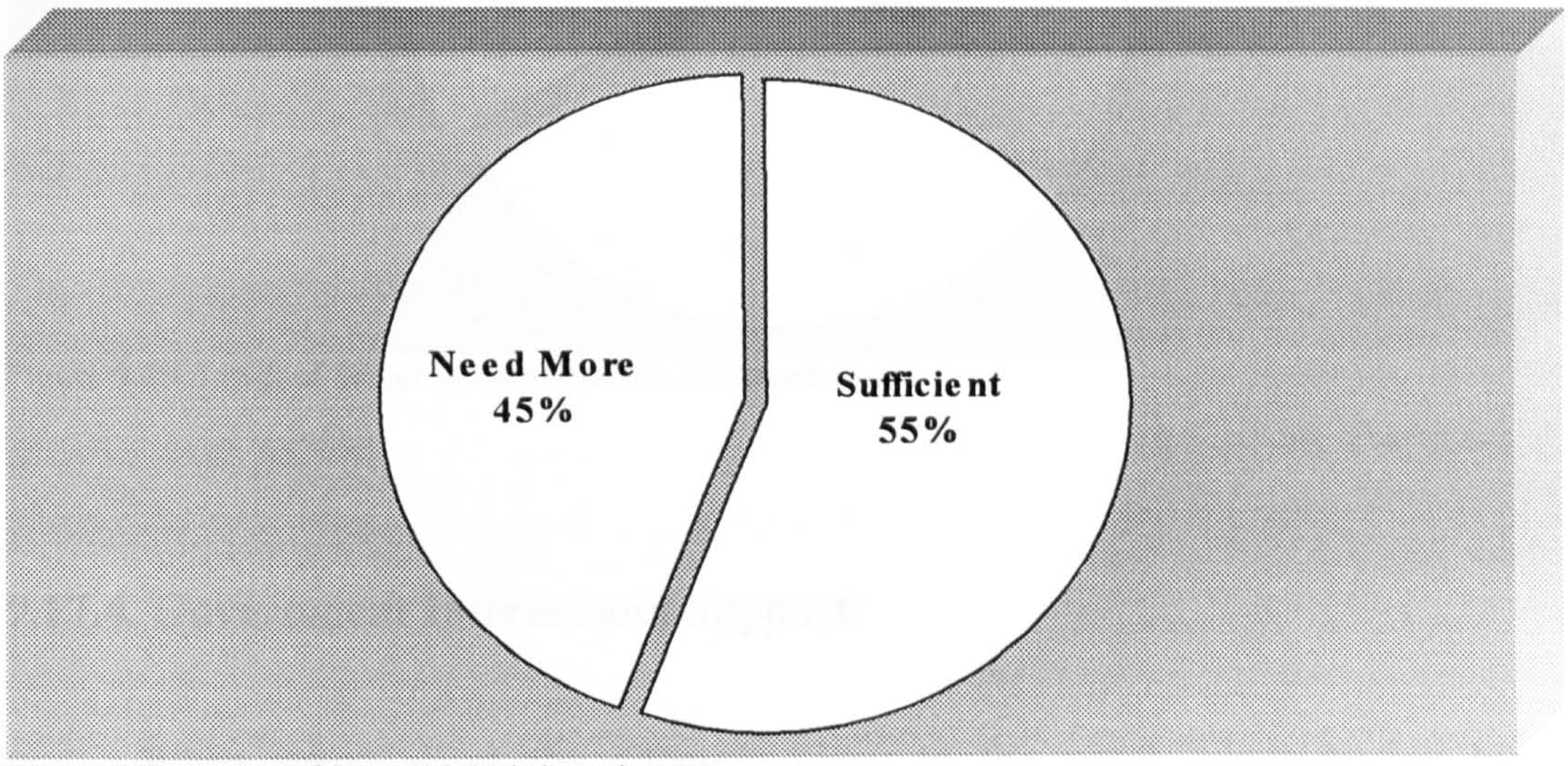

Figure 9.28. Level of Water Administration.

9.17.3. Level of Water Administration Independence:

Respondents were asked how independent water management is in its decision-making process and execution of its policies. Around **67%** believe its independence is limited (Figure 9.29). The important decisions are made from the top and the management implements these decisions, which leads often to the disruption of the plans and programmes of the water management. According to one respondent "water management is part of the structure of ministries hence its independence is limited". Another indicates that "the independence of the water management is limited especially in financial and employment issues". Around **22%** believe the independence that exists at present has a negative impact. According to one respondent "There is negative independence because it creates disputes as a result of the lack of one unified system for specialists". Another respondent says, "in fact their independence exists, but it has been a negative impact because of lack of co-ordination among water administrations".

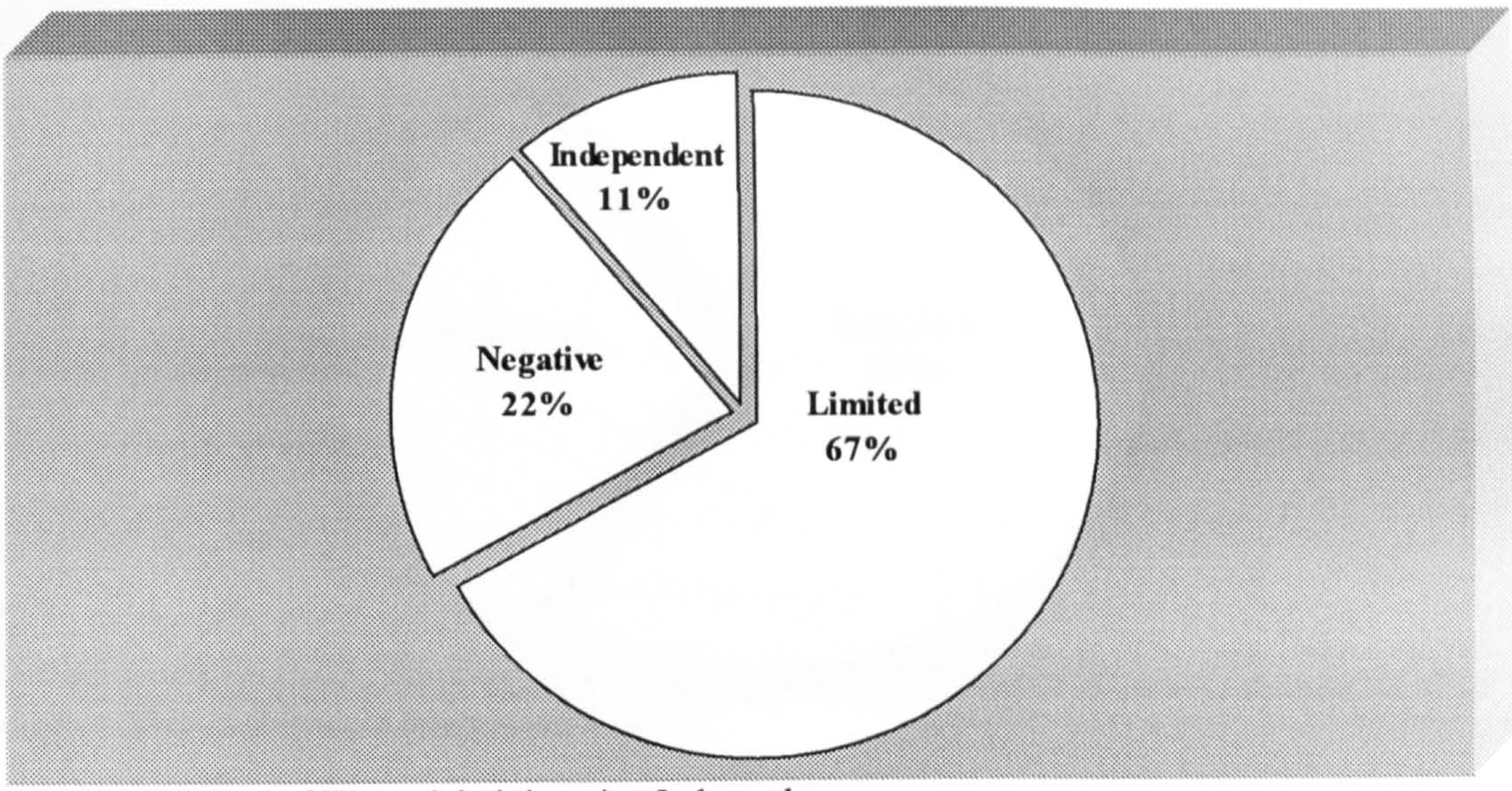

Figure 9.29. Level of Water Administration Independence.

9.17.4. Government Interest and Support:

When asked about the attention given to the water administration by the Government, especially with the decline in the economy and reduction of State revenues, **67%** believe the attention is not as it should be for a vital resource as water (Figure 9.30). All aspects of life depend on it, and other institutions that are less important attract more attention and support. According to one respondent "the attention and support that exist at present is not enough and hence I call upon the Government to give the water administration and its programs more attention". Around **33%** emphasised that attention and support from the Government might not be in accordance with the importance of this resource but it is sufficient in the light of the present economic developments. According to one respondent "the attention is enough, but there is a need for greater co-operation between those who make decisions and the water administration". Another says, "water administration is part of certain ministries, thus it gets the attention needed from the Government".

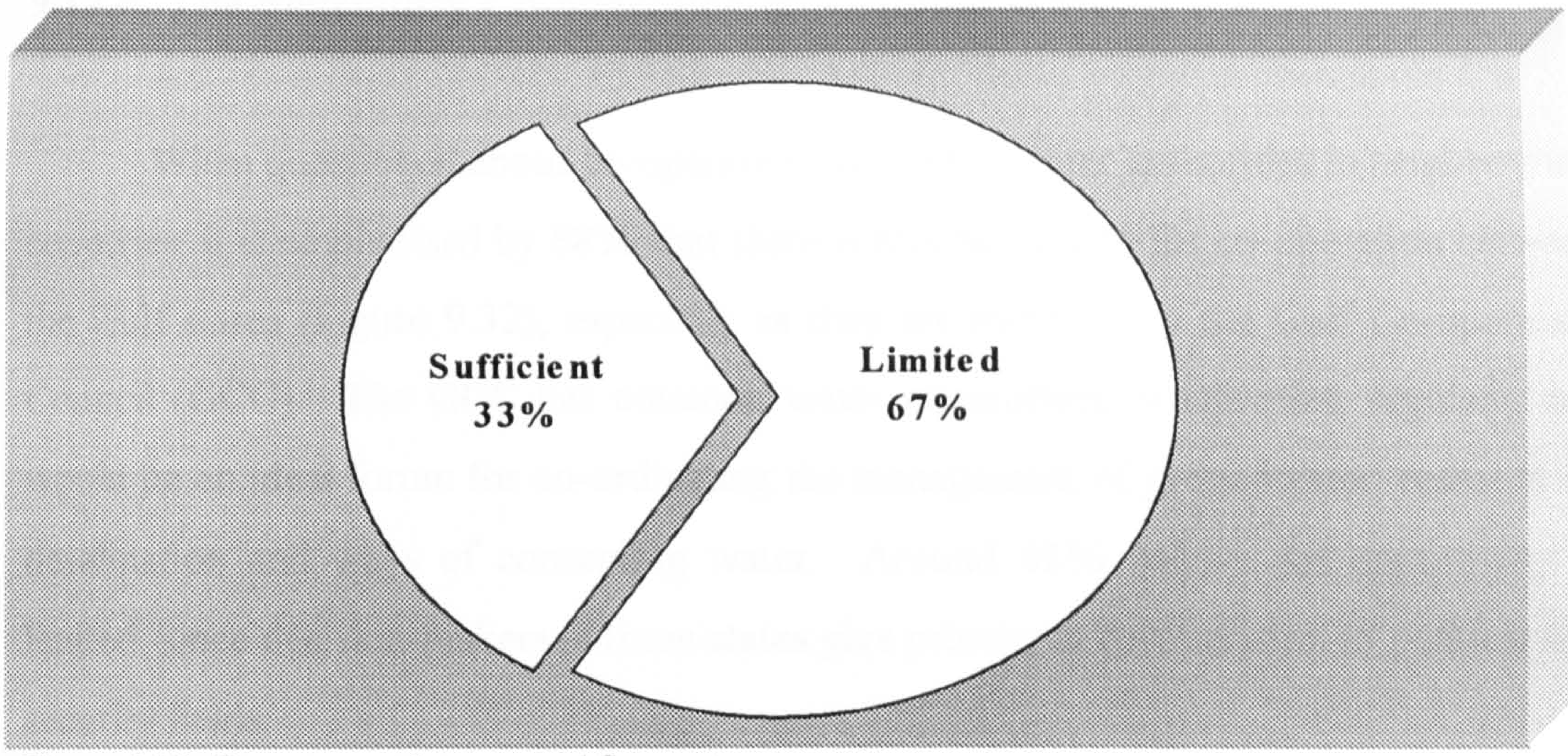

Figure 9.30. Government Interest and Support.

9.17.5. Co-operation between the Local Water Administrations:

When asked about co-operation between the various administrations, **78%** confirm that it is non-existent, despite the need for massive co-ordination in order to find appropriate solutions (Figure 9.31). One of the respondents indicates that "there is limited co-ordination which lead to duplications of decisions in many fields". Another **22%** believe that co-operation exists, especially concerning groundwater and water programmes in general, as well as in organising conferences concerning water issues, but this has not yet reached the needed level.

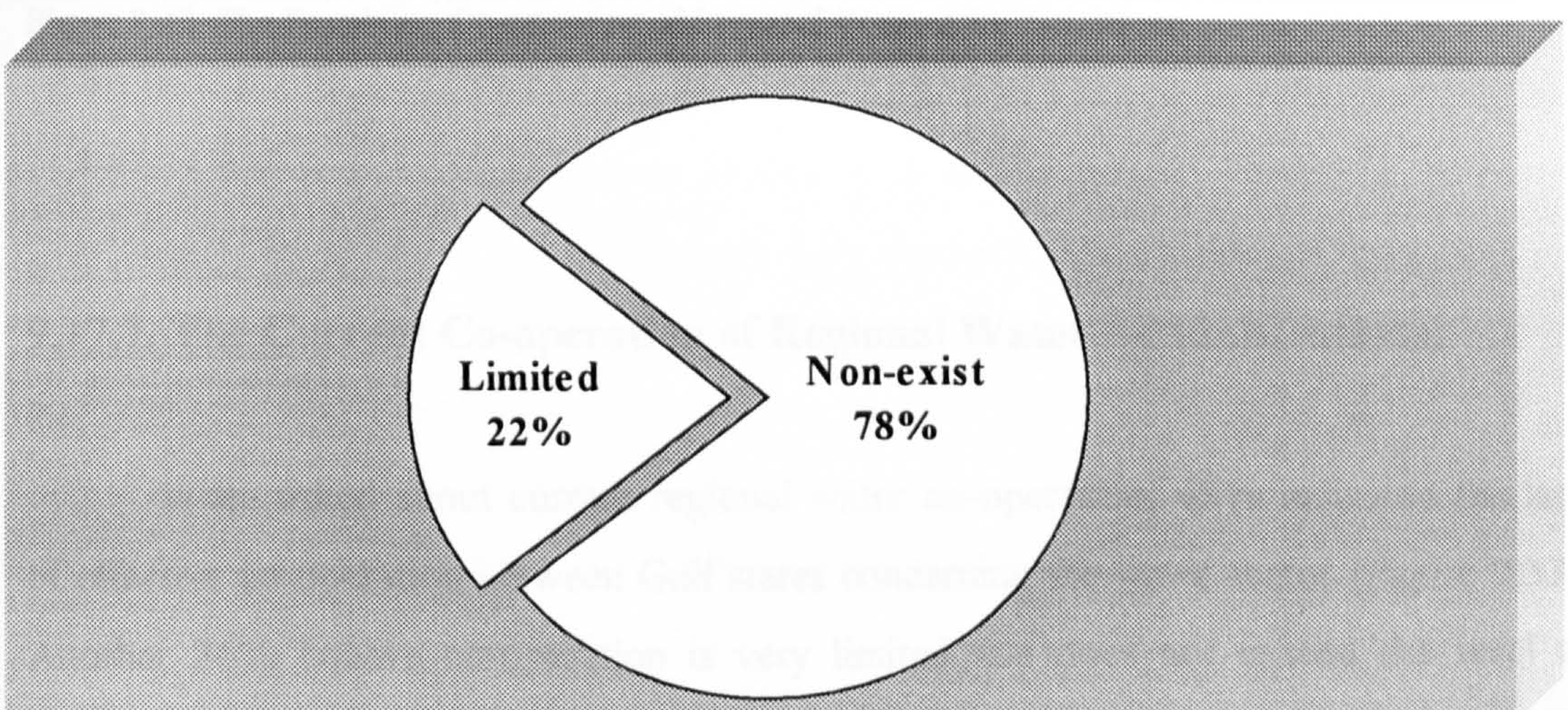

Figure 9.31. Co-operation between the Local Water Administrations.

9.17.6. The Feasibility Co-operation of Regional Water Administrations:

When questioned about co-operation with other water authorities in neighbouring countries, it is emphasised by **58%** that there is an opportunity for co-operation between the Gulf states (Figure 9.32), especially as they are members in the Gulf Co-operation Council (GCC). The GCC has common water committees, which meet regularly and would be an ideal forum for co-ordinating the management of groundwater, research on desalination and ways of conserving water. Around **42%** believe the opportunity is limited, since decision-makers in these states give priority in co-operation to political and security fields.

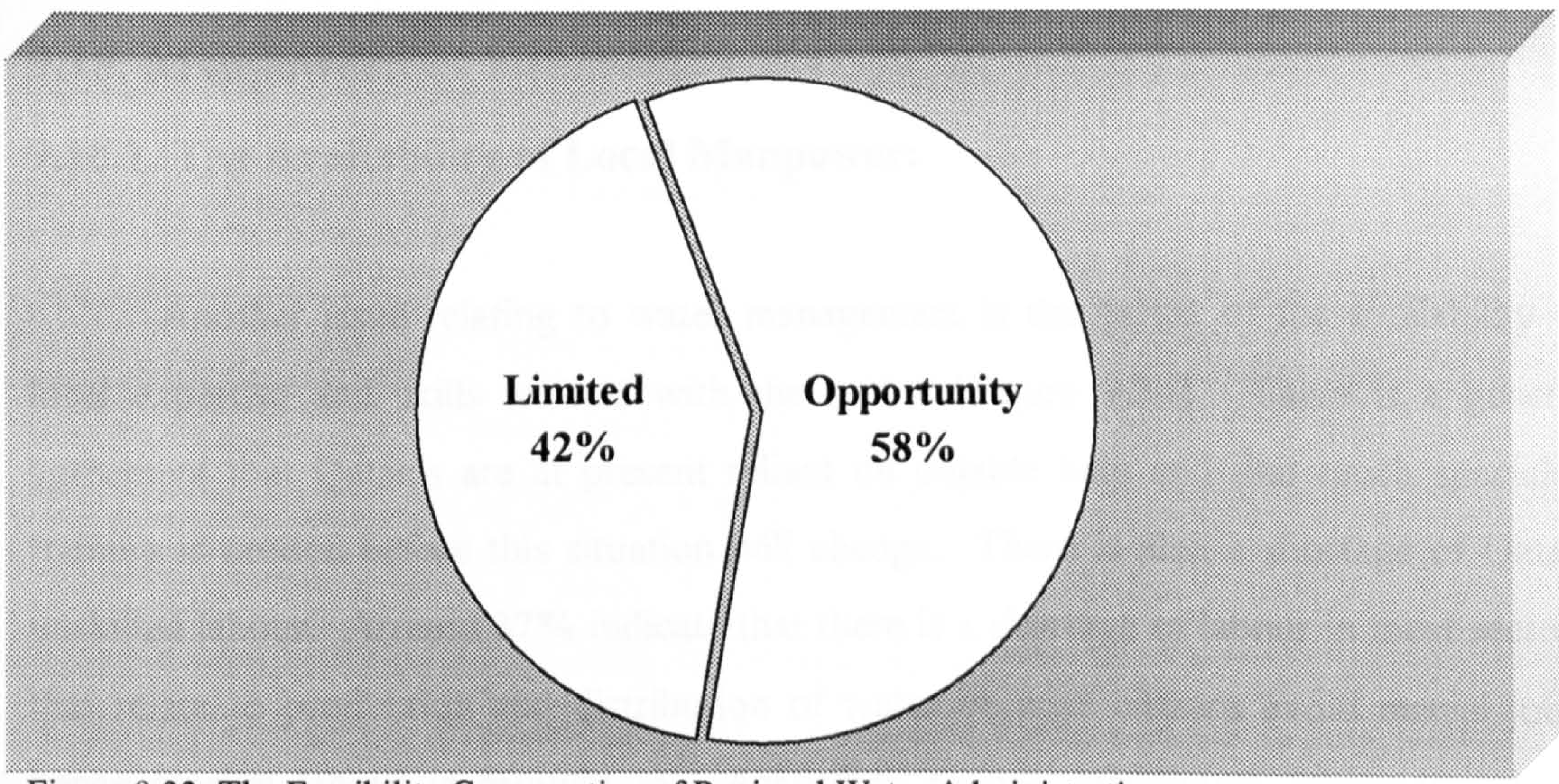

Figure 9.32. The Feasibility Co-operation of Regional Water Administrations.

9.17.7. The Current Co-operation of Regional Water Administrations:

When asked about current regional water co-operation, **43%** indicated the lack of effective co-operation between Gulf states concerning the water sector (Figure 9.33). Another **36%** believe co-operation is very limited and does not exceed the level of meetings and conferences.

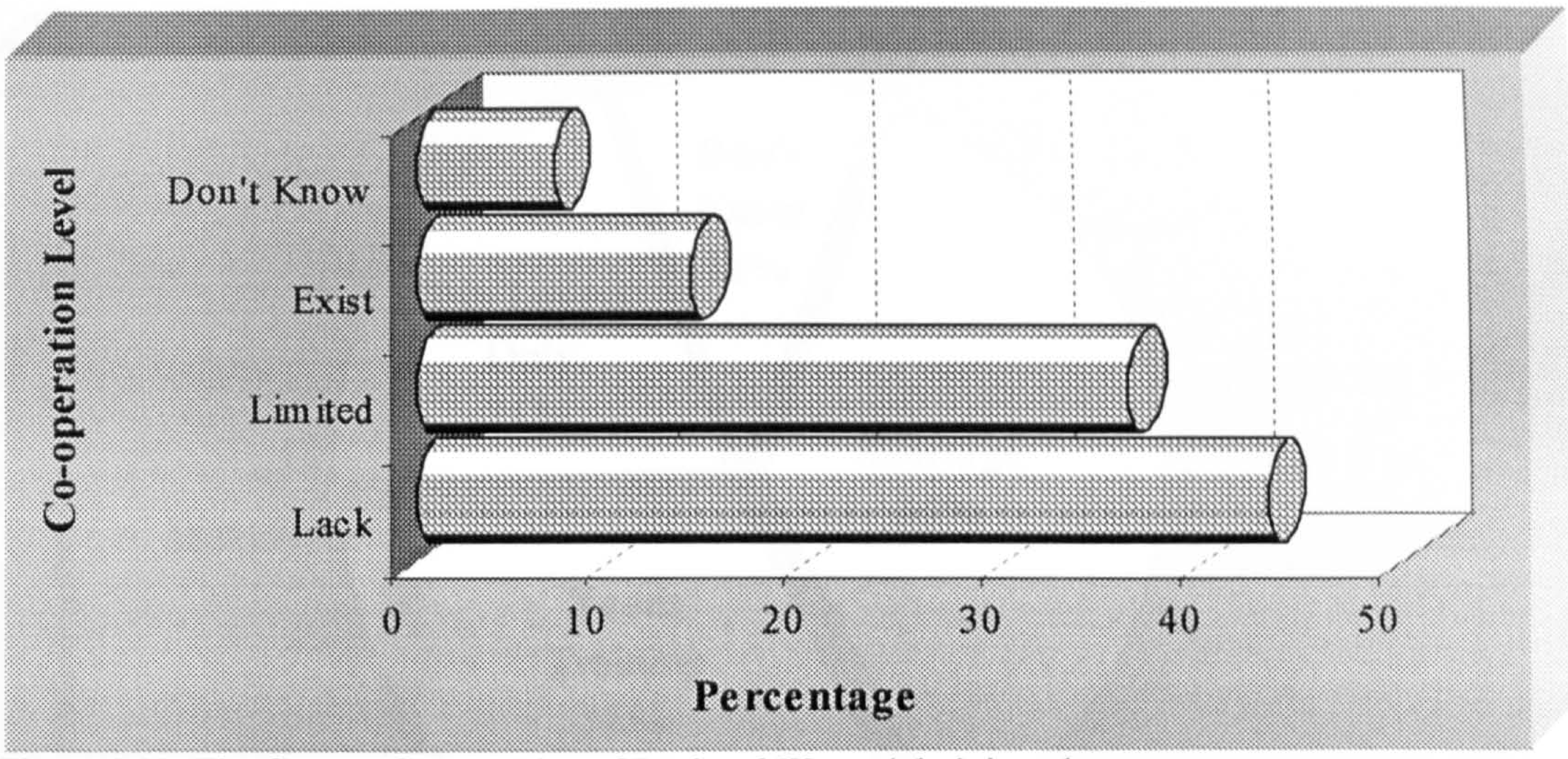

Figure 9.33. The Current Co-operation of Regional Water Administrations.

9.18. Manpower:

9.18.1. The Availability of Local Manpower:

Another issue relating to water management is the extent of the availability of local expertise and skills to deal with the sector (Figure 9.34). There is a general agreement that Qatar's are at present reliant on outside help and that much specialist training is needed before this situation will change. There is also a shortage of Qatari unskilled labour. Around **37%** indicate that there is a shortage of labour in most sectors that relate to production and distribution of water because citizens avoid menial jobs: hence foreign labour is brought in. According to one respondent "there is a huge shortage in the number of experts, which necessitates bringing in foreign companies in a variety of water projects". Another **31.5%** confirm that labour is available but needs training and development to be self-reliant in its management of the sector.

According to those holding this view there would be an increase in the participation of local labour in this sector as a result of population growth and lack of job opportunities in other areas in near future. **21%** indicate that labour is available but it is concentrated in the top layers of administration and not in technical specialities or unskilled jobs. Another one indicates that "local labour must be utilised but that depends on the readiness of domestic institutions such as the university to carry the burden of training them so they could carry out their jobs efficiently".

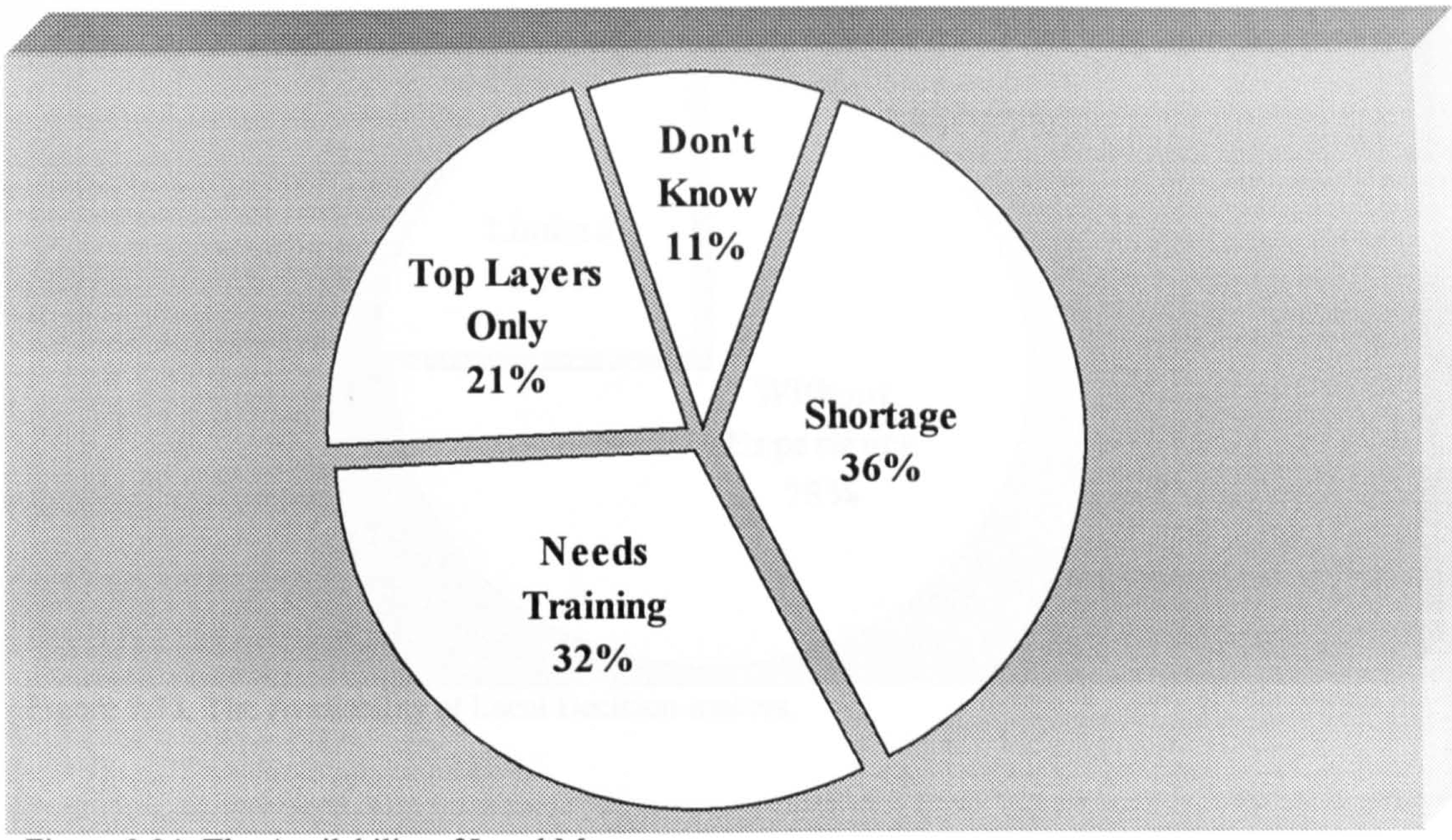

Figure 9.34. The Availability of Local Manpower.

9.18.2. The Availability of Local Decision-makers:

On the level of decision-makers (Figure 9.35), **75%** confirmed that labour is available in that layer of management. These jobs attract local skills but decision-makers lack experience because of their lack of practical training. Besides, many of them are placed inappropriately as a result of family contacts. Persons end up in a sensitive position without having the training or perhaps the ability to carry out his responsibilities. According to one respondent "the issue is not the number as much as in the credibility of decision-makers. In fact the expertise is available but unfortunately some of them are working for their own benefit". Local expertise is seen by **25%** as very limited non-existent in some specialities, especially the technical ones. Sometimes this leads to the wrong decision, which aggravates the problem further. According to one respondent "some local expertise is available at the level of decision-making, but it is badly distributed and concentrated in the upper levels of administration, while the technical side lacks such expertise".

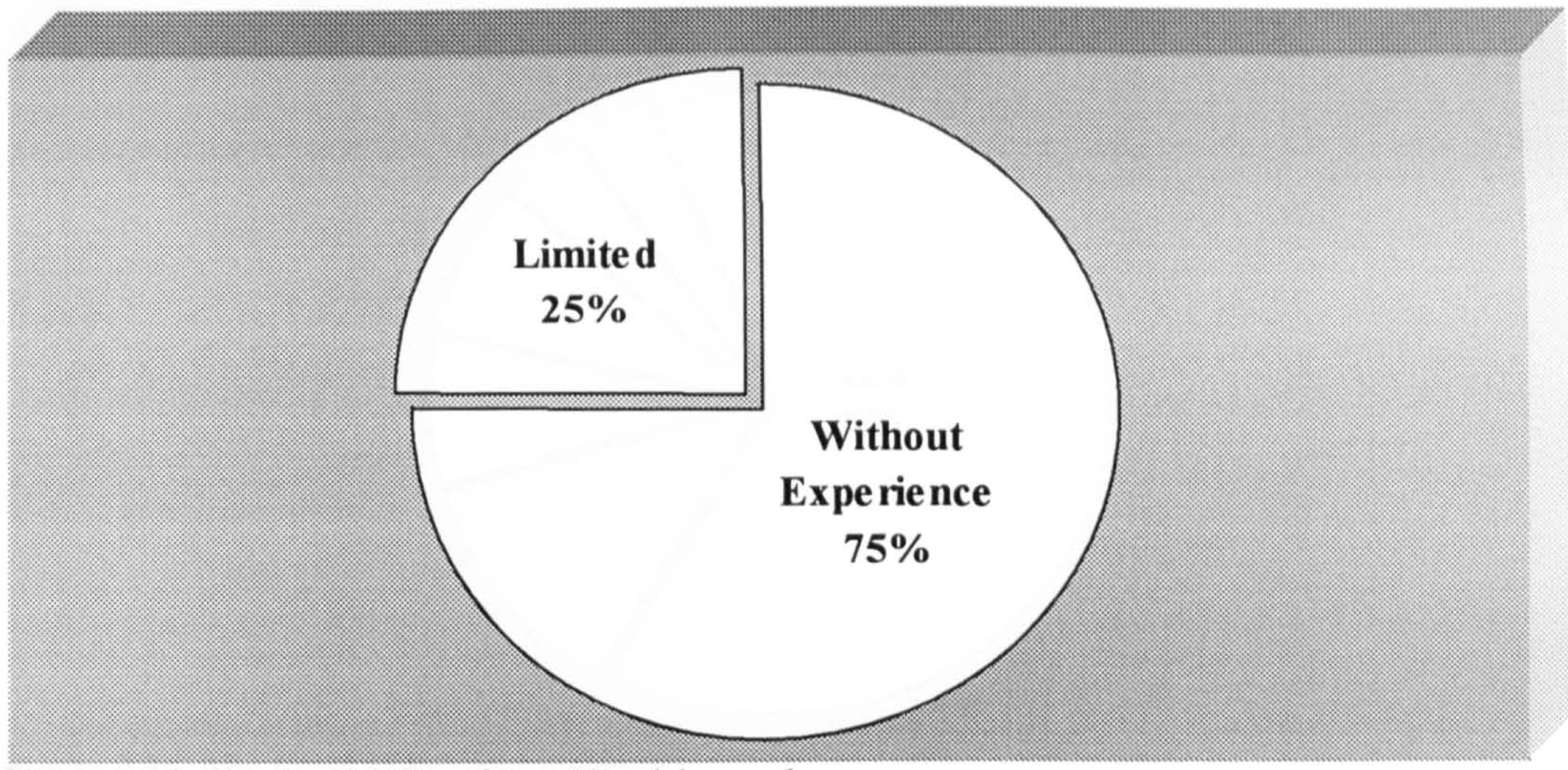

Figure 9.35. The Availability of Local Decision-makers.

9.19. Water Awareness:

9.19.1. Introduction:

The issue of public awareness of water issues occupied a large part of the discussion with all the experts and they all emphasised its utmost importance. Many indicate that lack of awareness is one of the main reasons for the present difficulties, not only in Qatar, but also in many other parts of the world.

9.19.2. The Level of Public Awareness:

Hence the respondents were asked about the extent of public awareness, how it can be raised and the possibility of encouraging popular participation, however if nominal (Figure 9.36). Most of the respondents **(64%)** believe that lack of awareness is prevalent among the population and even among officials. Hence, overcoming ignorance requires massive effort. As indicted by one respondent "public awareness is very low and a huge effort must be exerted by many authorities: religious, educational, media and social affairs in order to raise it". Another indicated that "creating public awareness needs to grew and intensify through increasing the number of programmes aimed at raising the level of people's awareness".

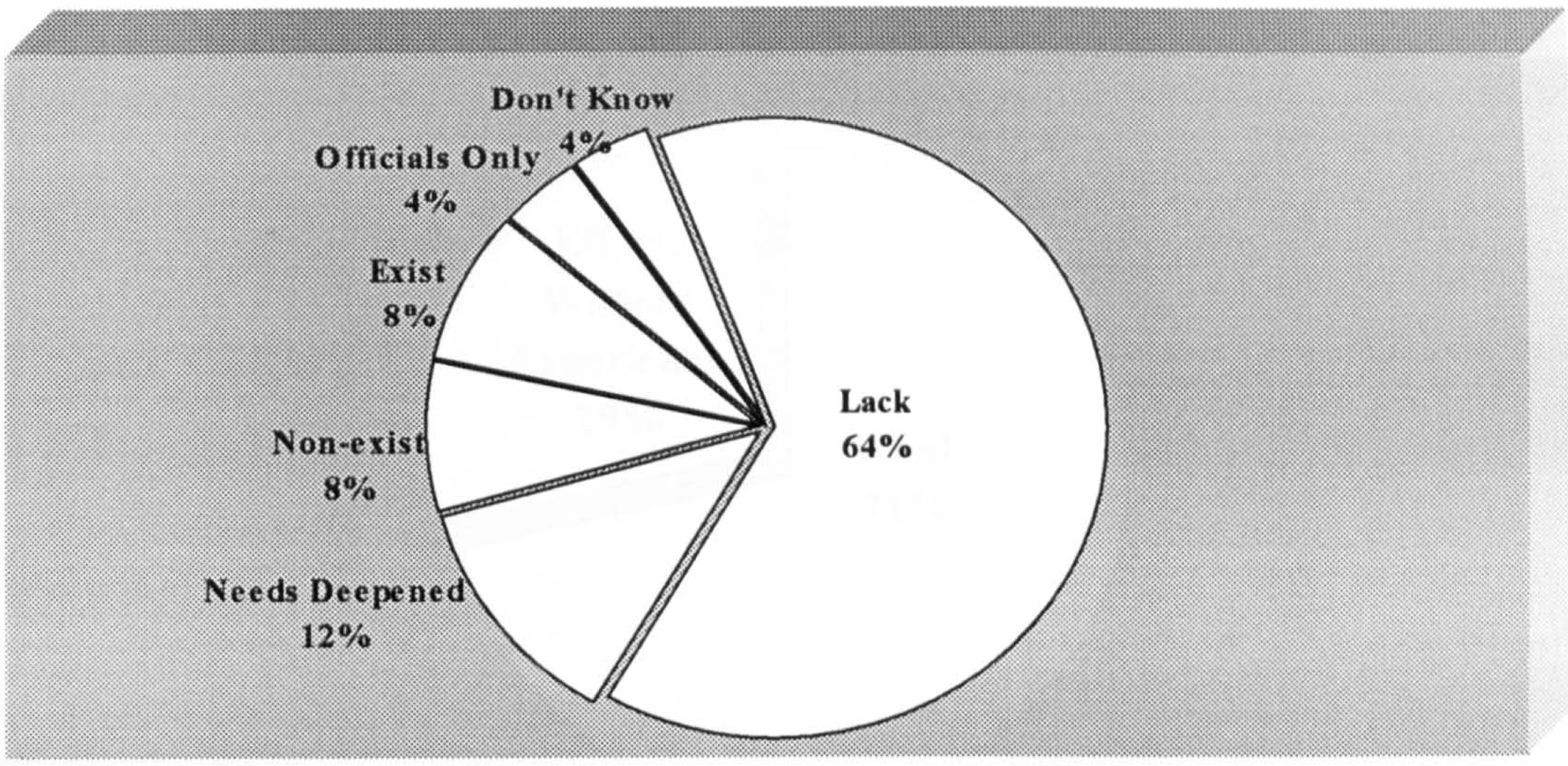

Figure 9.36. The Level of Public Awareness.

9.19.3. Current Methods to Create Public Awareness:

Respondents were asked about the efforts that the water administration is exerting to raise public awareness (Figure 9.37). According to **71.5%** of the sample survey, the efforts are weak; restricted to a limited number of uninteresting adverts on television or newspapers; and conferences are organised where the public does not have the opportunity to participate. One respondent indicates that "efforts are not enough, in fact it is less than the minimum necessary and advertising campaigns have no effect". According to more than a quarter **(28.5%)** the authorities possess the means to influence public awareness but they do not have the experience to do it. For instance, television advertising programs are of low quality and are not given the time and effort to make them effective and appealing. Advertising should not be done in a haphazard manner, which is a waste both of money and effort.

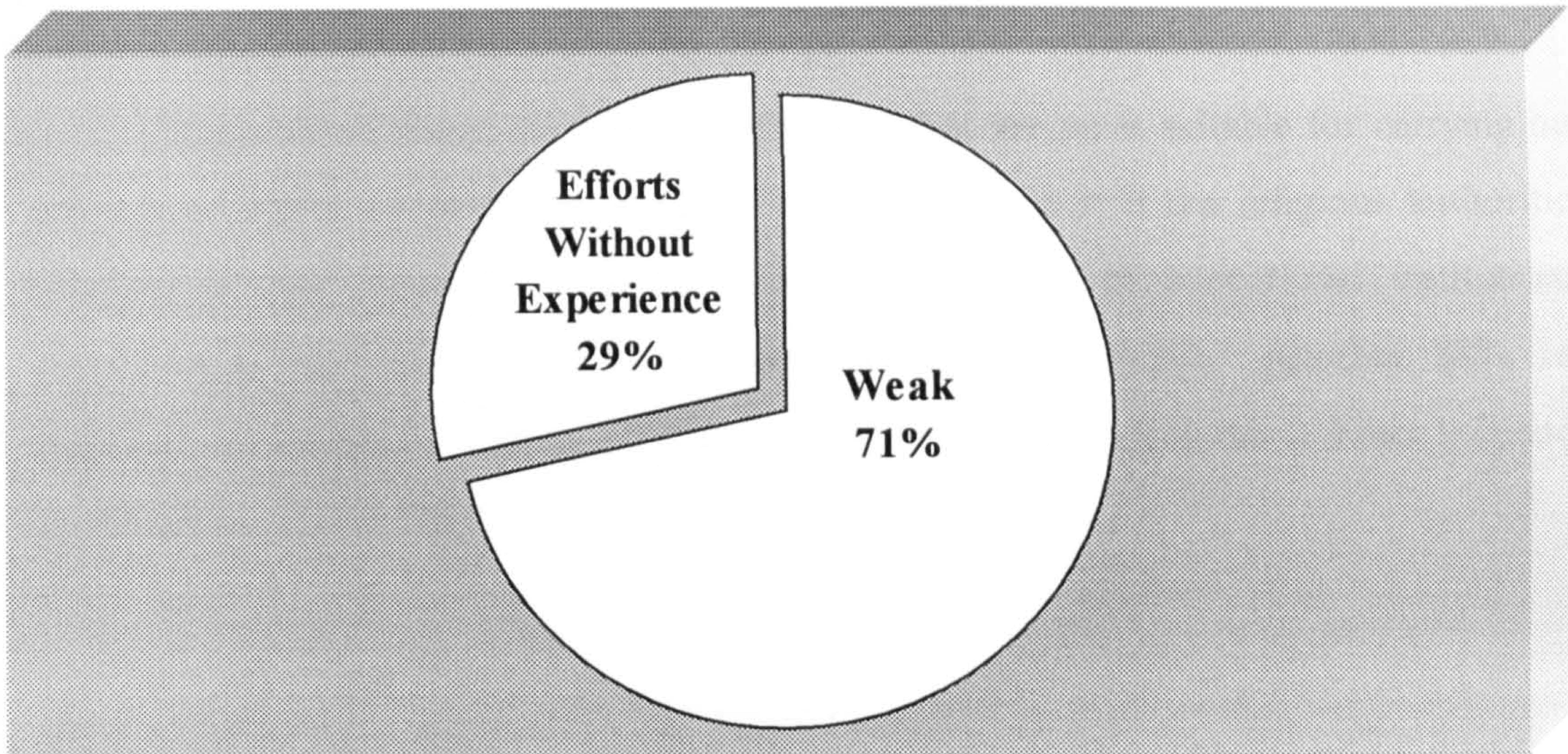

Figure 9.37. Current Methods to Create Public Awareness.

9.19.4. New Methods to Create Public Awareness:

Around **57.5%** emphasise the need to create awareness from a young age by initiating scientific programmes about water and its importance at different educational levels (Figure 9.38), as well as creating workshops to train young people in ways of conserving water. More than a quarter **(28.5%)** confirm that the matter requires the co-operation of various governmental administrations to develop scientific programmes with adverts to raise public awareness.

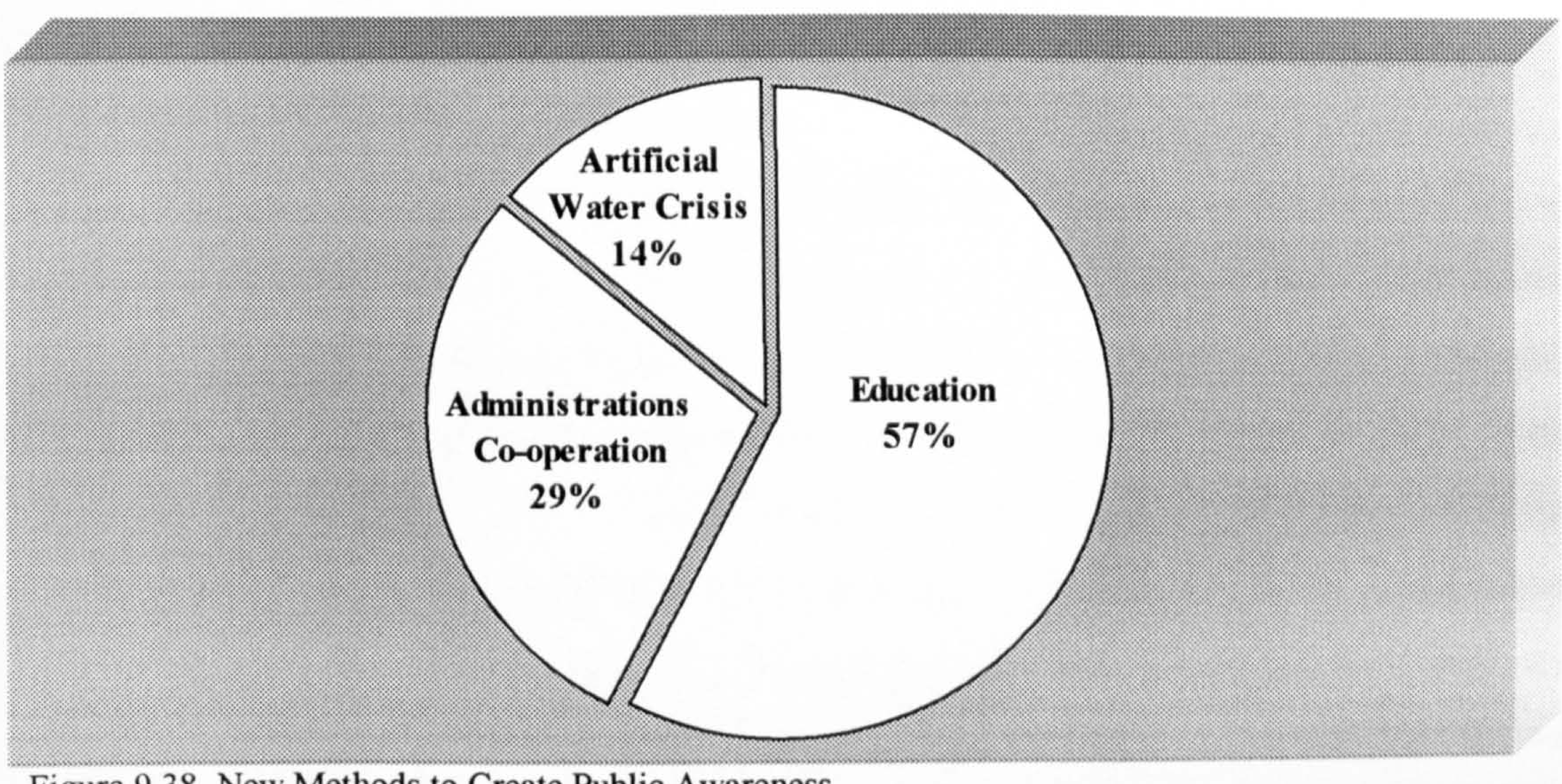

Figure 9.38. New Methods to Create Public Awareness.

9.19.5. Institutional Responsibility to Create Public Awareness:

When asked about the type of authorities that are most suitable for carrying out awareness raising programmes, around **72%** agreed that it is the religious authorities because of their immense influence in society, as well as educational institutions, especially as they can start with the very young (Figure 9.39). Another **28%** see religious institutions, women's organisation and the media, which has a direct influence on the public, as ideal for such a role.

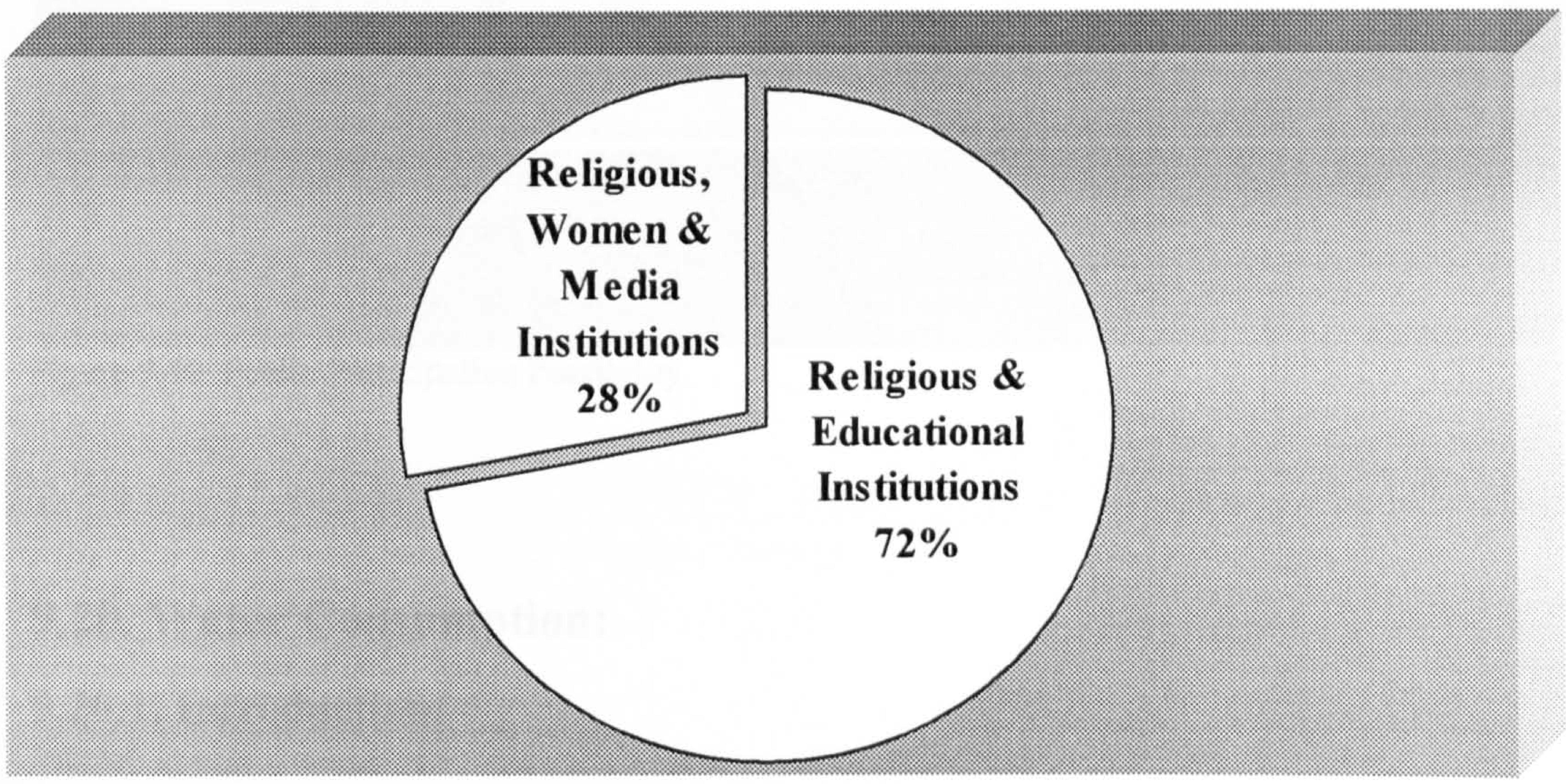

Figure 9.39. Institutional Responsibility to Create Public Awareness.

9.19.6. Public Participation:

When asked about the possibility of public participation in the management of water, most of the respondents **(78.5%)** supported the idea (Figure 9.40). They believe even a nominal participation will lead to increased awareness and knowledge of the scale of the issue, and hence may make the public more cautious about waste of water. Also, the public would feel that these projects belong to them and are for them and hence create a sense of protectiveness and care about them. That at present is non-existent. Another respondent indicates that "participation should not only be nominal but must include participation in planning and supervising the management of water and this will not happen unless the water sector is privatised". According to one a high official in one of the water administration "it is a good suggestion, but needs to be more studied before implementing it".

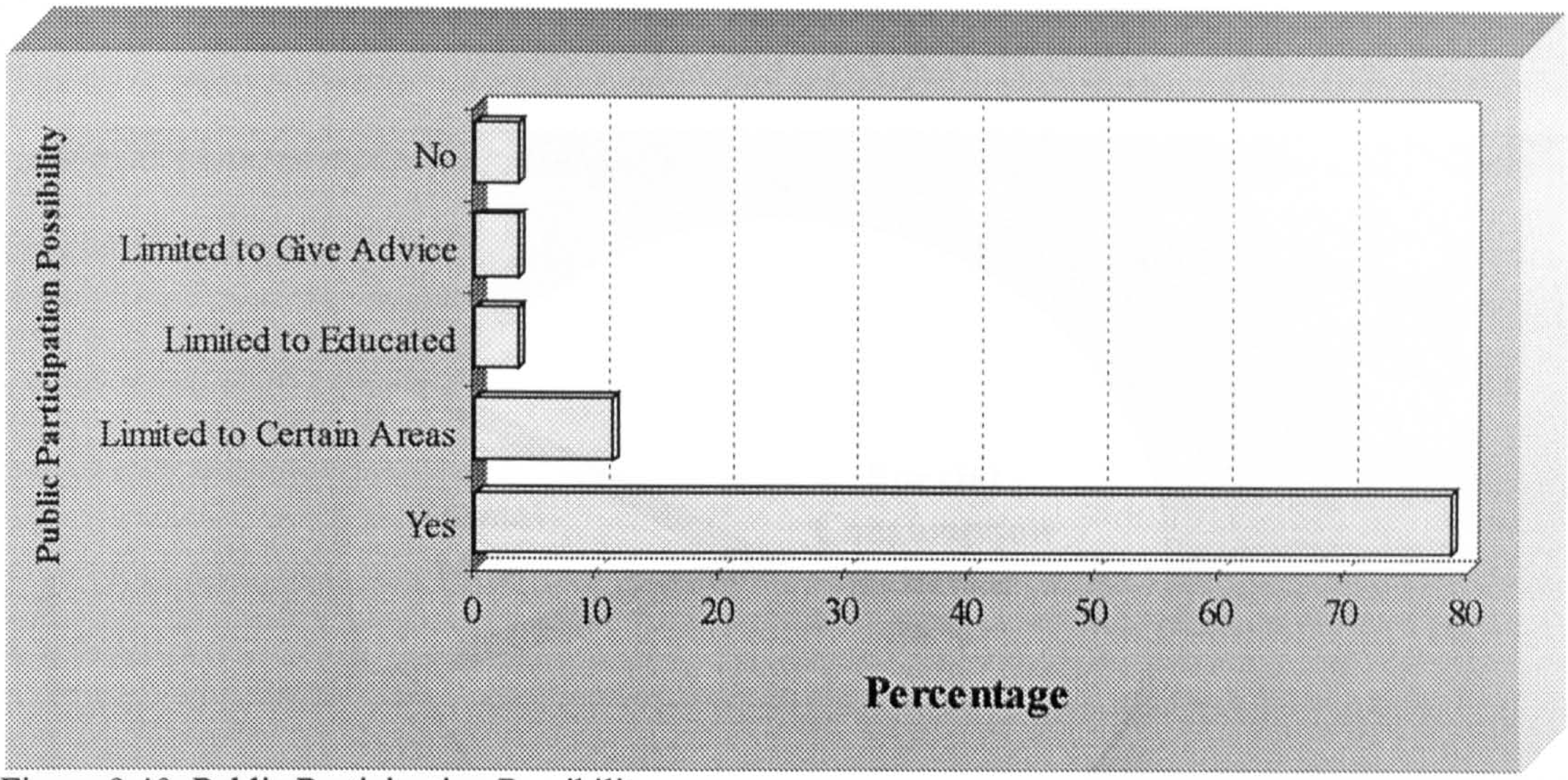

Figure 9.40. Public Participation Possibility.

9.20. Water Consumption:

9.20.1. Introduction:

Control of the level of consumption and the balance between production and consumption is a central concern of water management. Opinions and directions on how to limit and control this consumption varied.

9.20.2. Societal Consumption Behaviour Patterns:

First one should assess the behaviour of the society, especially to ascertain if it differs from other societies. Qatar, like other Arabian Gulf societies went through a rapid transformation over a very short period of time from extreme poverty to extreme riches (Section 7.3.6). The majority of the sample survey **(86%)** confirms that the Qatari society is like other societies in the Gulf area, characterised by special consumption behaviour due to the sudden wealth accruing to the society as a result of the discovery of oil (Figure 9.41). The native population became capable of getting everything easily, including all types of household equipment that consumes a lot of water. According to one sociologist "consumption behaviour is excessive and that was acceptable in the past few years, but now with the oil recession it is unacceptable and the authorities are being very lenient in addressing this matter".

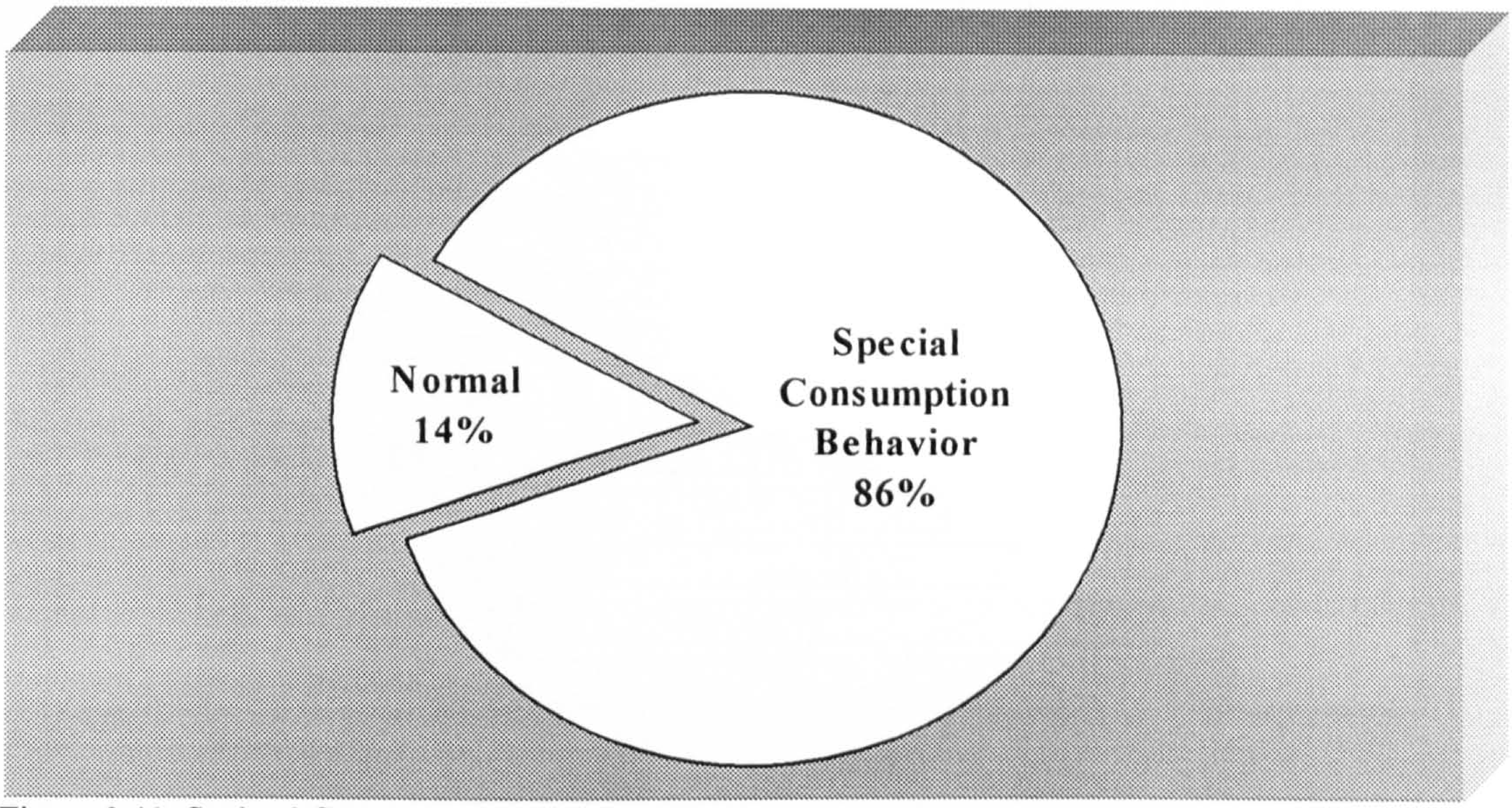

Figure 9.41. Societal Consumption Behaviour Patterns.

9.20.3. Methods for Water Consumption Control:

When asked their opinions concerning ways of control consumption, around **20%** emphasise that the matter needs to be addressed through a comprehensive water policy that takes into account all aspects of the problem and without concentrating, for instance, on one aspect, such as technology (Figure 9.42). The importance of awareness raising is emphasised by **18%**. **14%** call upon social institutions, especially the religious institutions, to encourage people to conserve their consumption. The importance of technology is emphasised by **12%.** Another **10%** concentrate on the need for education programmes and workshops. **6%** of the sample see a new water tariff policy as the best way to control water consumption. Around **4%** emphasise the need for creating public awareness of the importance of water, accompanied by a policy of levying fees on water. Another **4%** call for limiting the level of consumption by issuing strict laws. **4%** call for the creation of a strong authority with wide range of powers. Another **4%** call for raising the awareness about water, accompanied by a new policy for using recycled water.

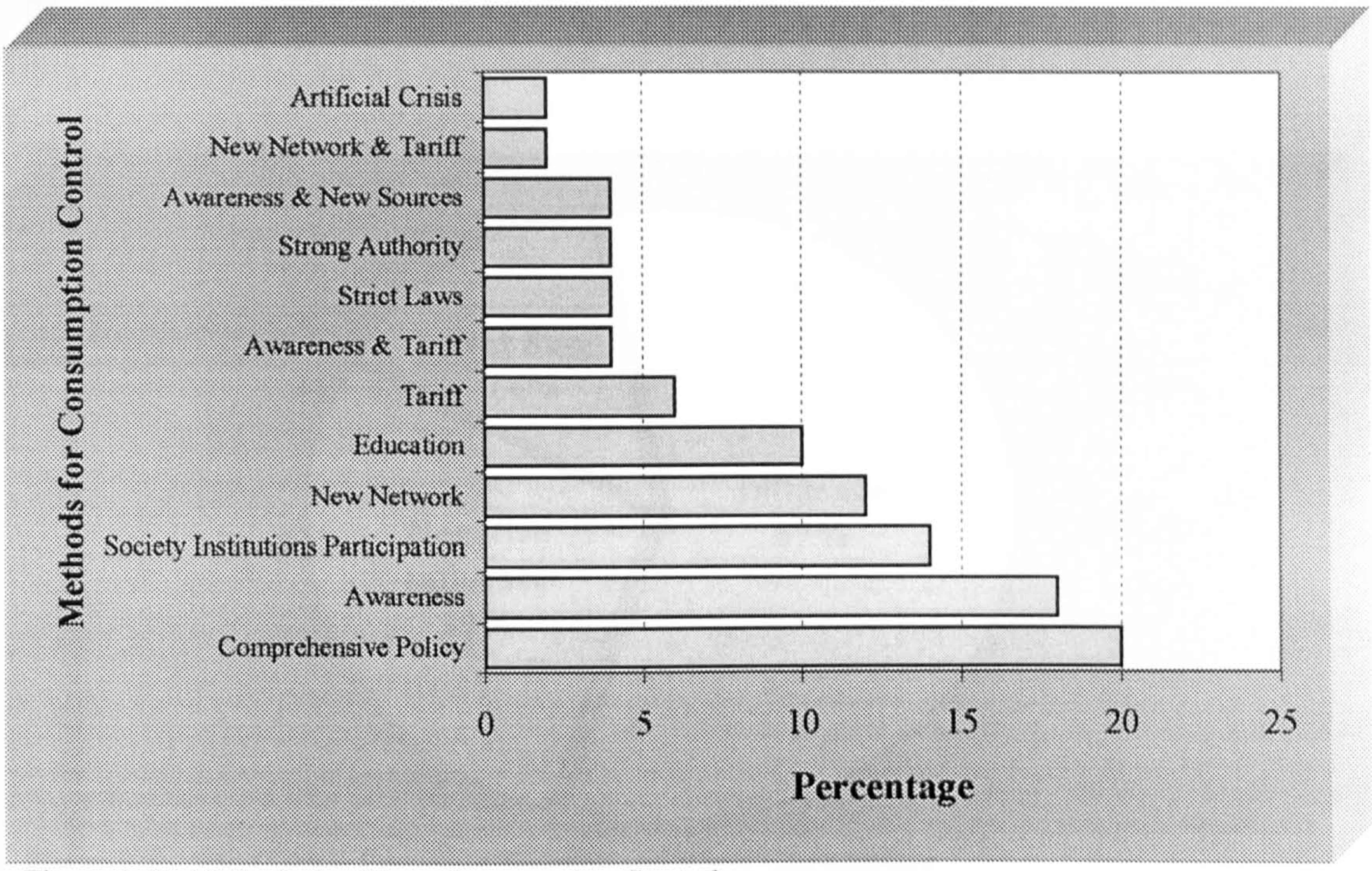

Figure 9.42. Methods for Water Consumption Control.

9.20.4. The Current Economic Situation and Water Consumption:

The economic situation at present is difficult and many individuals are becoming aware of the presence of a serious water problem that needs to be addressed. Hence the respondents were asked about the possibility of limiting consumption following the present economic decline and its after-effects on the Government and the individual (Figure 9.43). A majority of **57.5%** emphasise that the economic decline - due to lower oil prices - will necessarily influence consumption because the Government will reduce its responsibilities and transfer them gradually to the private sector. That will lead necessarily to restricted water consumption.

According to one respondent "the Government will pull out gradually from support of the water sector without totally abandoning its basic overall responsibility of supervising it". Another says "wealth has created a society that is insensitive in all its patterns of consumption, a reduction in the level of this wealth will undoubtedly influence consumption and reduce it". More than a quarter **(28.5%)** do not believe that the economic decline alone will help reduce consumption. The matter needs more effort on behalf of the concerned agencies, because people got used to their consumption patterns and pressure must be exerted to change it.

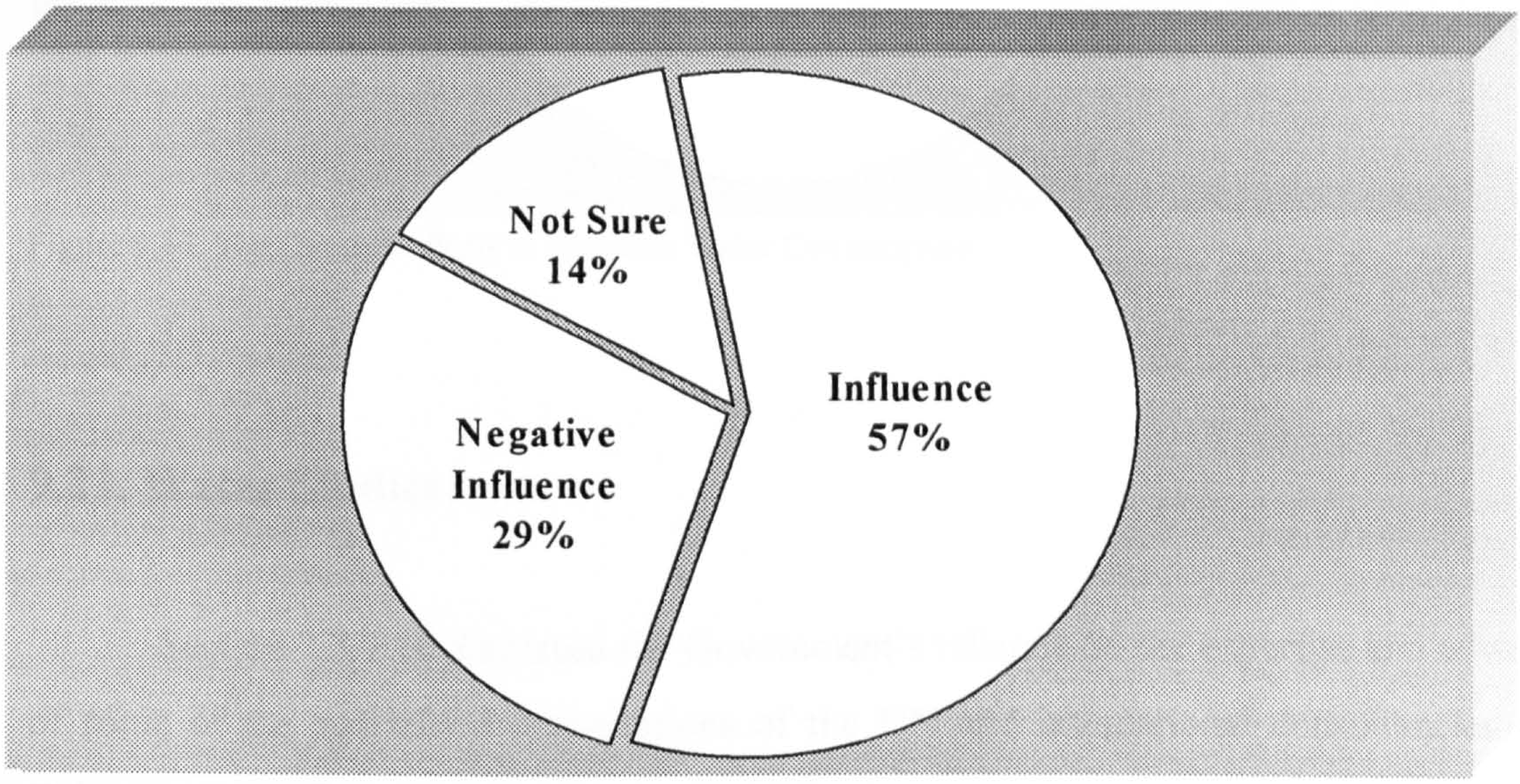

Figure 9.43. The Current Economic Situation and Water Consumption.

9.20.5. Current Efforts to Decrease Water Consumption:

When asked about the efforts exerted by the concerned administrations to reduce consumption (Figure 9.44), **86%** emphasise that there are some efforts but they need to be developed and followed-up in order to achieve success, since so far results are not so good, which caused a waste of money and effort. According to one respondent "there are some administrations of the water management that are exerting effort to reduce consumption but without any effective results yet". The failure of these efforts is justified by the respondents on the ground that these efforts do not take into account the prevalent socio-economic conditions of Qatari society. These conditions must be studied prior to any undertaking. Furthermore, the principle of reward and punishment, which is now absent from the campaigns to limit consumption, must be applied.

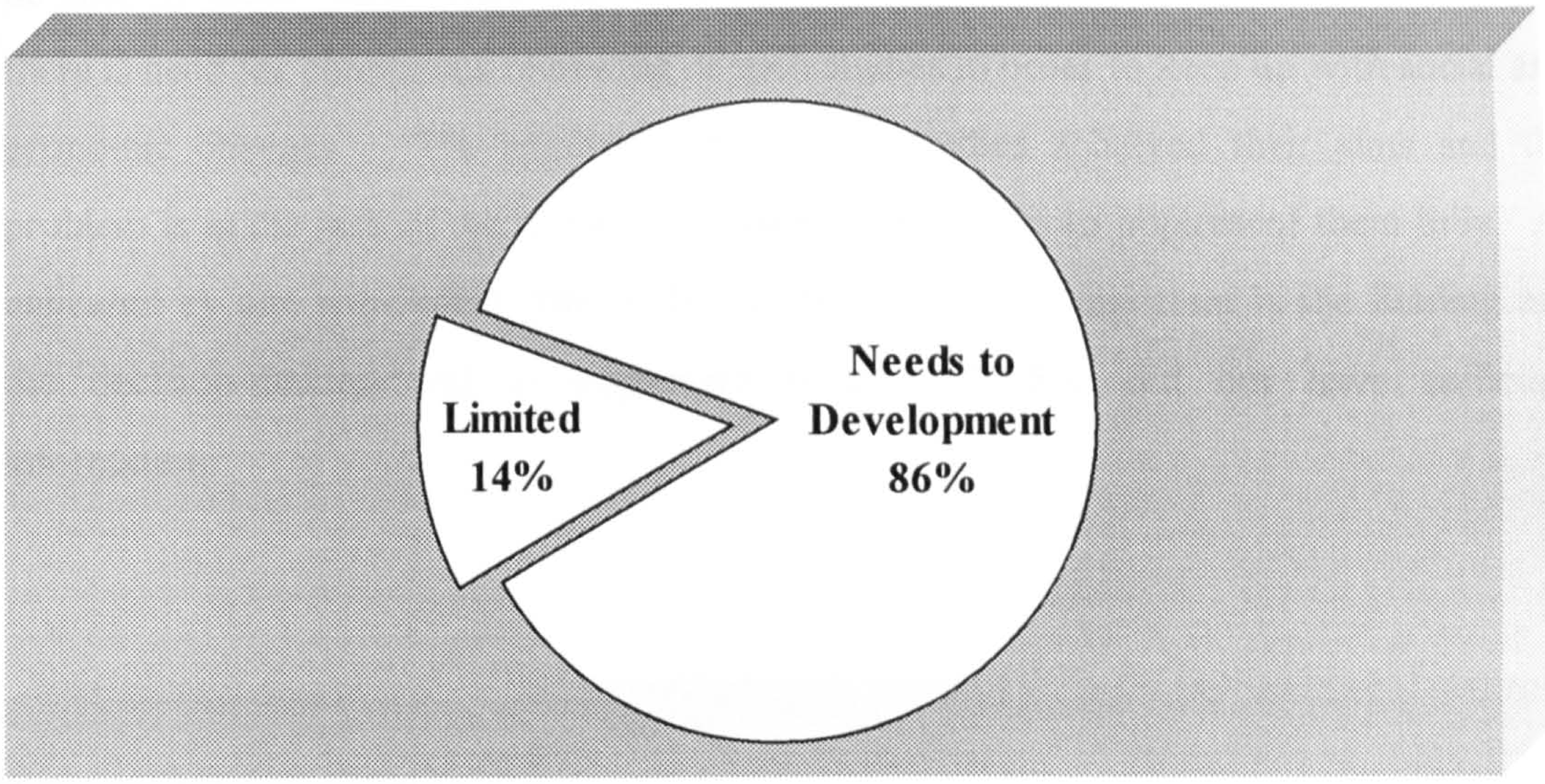

Figure 9.44. The Current Efforts to Decrease Water Consumption.

9.21. Water Studies:

Section 7.3.7.10 discussed the Government's reliance on the expertise and advice of some of the specialised organisations of the UN and international consultancies in order to study the water situation and put forth a comprehensive strategy to manage water resources. Hence, when respondents asked about the effectiveness of this assistance and the success achieved by these studies. **36%** believe that this co-operation was useless because these studies were carried out by foreign experts who are unaware of all local conditions and hence their recommendations are based on erroneous assumptions (Figure 9.45). According to one respondent "these studies are inadequate because they relied on inaccurate information due to the fact that these experts spend very short periods of time in the country, insufficient to give them a clear picture of the situation". Another respondent says that "these studies did not help in solving the problem but acted as temporary sedatives, without producing a long term strategy".

More than a quarter **(28.5%)** believes these studies could have been beneficial if they were implemented. Most of them are shelved in the offices of officials, for instance a comprehensive study that was carried out by a British company (Consultants DHV International Ltd.) in 1992 on the Iranian Green Pipeline (e.g. MMAA, 1998d). As indicated by one respondent "these studies need to be carefully implemented in order to be able to judge them. Also, one should not be satisfied with what has been studied, there is need for continuous reviewing of such studies in order to keep up with social and economic changes". **7%** emphasise that these studies achieved their aims and the problem is in the lack of the human and financial resources to implement them fully. As indicated by one respondent "the studies exist but what is important is the funding and the decision-making will to implement them". **28.5%** did not have sufficient information.

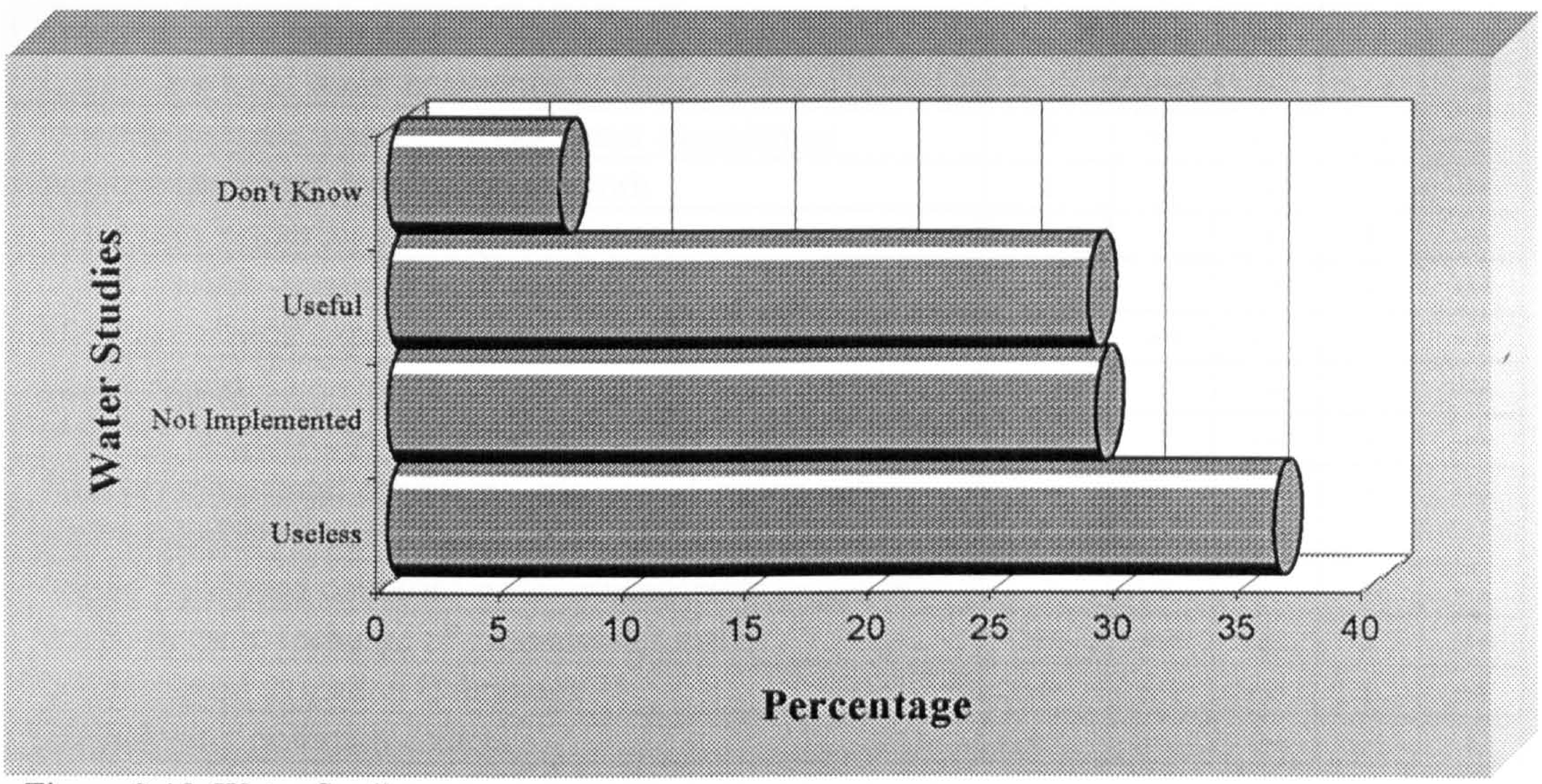

Figure 9.45. Water Studies.

9.22. The Stakeholders Recommendations:

Recommendations by the respondents were numerous and each group of respondents proposed what it sees as appropriate in its area. For instance, the economists concentrated on cost and tariffs, while the sociologist focused on raising the awareness of society. The diversity of specialities brought a broad range of beneficial suggestions and recommendations. As seen in Table 9.1, these recommendations are placed according to the importance and frequency of the recommendation. It is worth mentioning that some have suggested the need for a comprehensive water policy without identifying its components, while others enumerated the priorities needed to arrive at a comprehensive water policy.

Table 9.1. The Stakeholders Recommendations.

Recommendation	The Importance of Recommendation				
	I	II	III	IV	V
Raise public awareness	16	9	9	1	---
Enactment and application of water laws	12	10	3	---	---
Establish new a comprehensive water management policy	10	6	3	---	---
Depend on new advance desalination technology	11	---	---	---	---
Use more advanced and economical technology	10	1	2	---	---
Improve the technique of the administrative officials	8	2	3	---	---
Establish a High Water Council	6	2	1	1	---
An expansion in uses of recycled water	4	1	5	---	---
Encourage scientific studies of water	2	4	---	3	---
Give water administrators more authority	2	5	---	---	---
Establish water bank data	2	---	---	---	---
Establish a local water committee	2	---	---	---	---
Arrange periodic meetings about water experiences	2	---	---	---	---
Improve the water distribution network	1	3	1	---	---
New water resources developments	1	1	1	1	---
Use of modern administrative methods	1	1	---	---	---
Stop agricultural expansion	1	---	---	---	---
Water import	---	1	---	---	---
Brackish groundwater desalination	---	1	---	---	---
Take environmental conditions into consideration before establishing any water project	---	1	---	---	---
Follow developed countries water management experience	---	1	---	---	---
Establish more recharge of groundwater wells	---	---	1	2	---
Use advanced irrigation technology	---	---	---	1	---
Groundwater pollution control	---	---	---	---	1

9.23. Overall Conclusion:

In Chapter Four (methodology) it was mentioned that numerous lists of questions had been addressed to the expert stakeholders in the different fields because finding one list that take into account the diversity of the issues and the backgrounds of the respondents was difficult. For instance, the questions addressed to experts in administration differ on those addressed to sociologists etc. In this chapter similar questions were merged, such as the questions related to the possible ways for reducing consumption that were asked of more than one group. Other questions could not be merged, such as the questions relating to the appropriateness of technology used in the production and distribution of water. Such questions could not be asked to a religious scholar or a sociologist.

The issues relating to water management are many, such as the size of the problem, types of water sources, methods of distribution, type of technology used to produce and conserve water, legal and economic aspects, efficiency of management, consumption behaviour of the population etc. It helps to take all these aspects into account in order to find a comprehensive strategy for water management.

CHAPTER TEN:

DOMESTIC HYDROLOGICAL MEASUREMENTS

Chapter Ten:

Domestic Hydrological Measurements

10.1. Introduction:

The aim of this study is to establish the daily per capita consumption of water and its distribution among the various domestic uses in Qatar (Appendix 13). In addition, it aims to establish the peak times of water consumption during the day. This knowledge can help in many aspects, such as putting forward appropriate control measures and laws. It may also help in the design of advertising campaigns that aim to limit water consumption. Furthermore, the study will suggest some technological means to limit the amount of water consumption.

10.2. Survey Process:

The survey methodology is described in Section 4.3.5. There are many difficulties involved in carrying out such a survey. Obstacles include an almost complete lack of public interest in such surveys and embarrassment in answering some questions (e.g. water use in toilet), considering the conservatism of the society. Respondents needed time to answer such the questionnaire (which may need more than one day), strong memory, patience and cooperation. Consequently, the sample survey is small, and not necessary a good reflection of the population and its various social strata and groups. It represents only 0.0038% of the population, according to the 1997 census (CSO, 1998).

Considering the nationality of the respondents, this has been divided equally between nationals and the immigrant community, despite the fact that nationals represent only 21.5% of the population (Table 10.1) (e.g. al-Kuwari, 1996). The majority of immigrants are temporarily in the country (e.g. PC, 1999b), however, and the nationals are the ones who reside permanently. The decision making should take this fact into account when establishing any water policy. Therefore, the sample was skewed towards nationals. The respondents from the immigrant community were chosen on the basis that they have been in the country for no less than three years and are from different nationalities - Westerners, Arabs and Asians.

The gender of the sample survey is skewed towards more male respondents (60%). Males, however, represent 66% of the population of Qatar (CSO, 1998). The level of education of the respondents represented a serious problem, since the less educated of the population (around 43.2%) did not respond to the survey (most of those people are non-citizens because citizens classified as very little educated in 1999 did not exceed 13%) (e.g. Kafood, 2000). They represent only 15% of the sample. On the other hand, people with higher education (15.2% of the population) represented 60% of the sample. This is natural because members of this group were ready and able to participate in such a survey.

When age breakdown is examined, those under 20 years of age (around 32% of the population) were not interested or unable to respond to this survey. Most of the support for the survey came from the age group 30-39. They are 28.4% of the population but represented 40% of the sample. It is not possible to provide comparative income levels and employers for the sample because there are no official statistics concerning these two indicators.

Table 10.1. Census and Survey Population Data (CSO[1], 1998; Survey Data[2], 1999).

Group		Census[1] (1997) (%)	Survey[2] (%)
Nationality	Citizen	21.5*	50
	Non-citizen	78.5*	50
Gender	Male	66	60
	Female	34	40
Education	Very Little	43.2	15
	Elementary	13.2	5
	High School	28.4	20
	Higher Education	15.2	60
Age	Less than 20	32	5
	20-29	17	25
	30-39	26	40
	40-59	17	15
	50 and over	8	15
Income	<5,000	Unavailable	25
	5,000-9,999	Unavailable	40
	10,000-14,999	Unavailable	20
	>15,000	Unavailable	15
Occupation	Government	18.7	60
	Private	81.3	40

(* Informal data - see Section 5.4).

10.3. Water Diary:

The respondents were requested to keep a water diary and water consumption was calculated from the figures they provided, as shown in Section 4.2.5. Per capita use of water for the sample was found to be 445.62 litres per day (ld^{-1}). This is a very high level of consumption, exceeding the level of consumption in developed countries, rich with water. However, this quantity is close to the official record of water consumption which was 414 ld^{-1} in the last report (MEW, 1996a) and in some studies reach 500 (al-Khater, 2000) to 640 ld^{-1} (al-Sumori, 2001c). This consumption is spread over different uses, including shower, personal washing, dish washing, toilet, garden irrigation, car washing, clothes washing, floor washing, drinking and cooking (Table 10.2 and Figure 10.1). The following is a discussion of each use separately:

Table 10.2. Daily Per Capita Water Consumption for Different Purposes.

No.	Drinking	Shower	Personal washing	Toilet	Cooking	Dish washing	Clothes washing	Floor washing	Car washing	Watering gardens	Other	Total
1	0.3	88	24	33	10.6	45.7	28.3	28.5	3.3	150	0	411.7
2	0.9	165	22	33	6.4	48	17	5.7	14.2	8.5	0	320.7
3	3	110	24	82.5	0.28	53.3	9.4	7.1	6.3	16	0	311.88
4	1.2	275	192	66	4	30	10.6	8	5.3	21.4	0	613.5
5	1.5	188.5	128	33	4.5	34.2	21.1	6.1	6.1	6.1	0	429.1
6	1.5	165	168	85.5	5.3	80	14.1	7.1	7.1	11.9	0	545.5
7	0.6	275	160	82.5	4.5	22.8	12.1	8.1	8.1	24.4	0	598.1
8	0.9	110	120	16.5	4	40	6	3.2	1.7	0	6.2	308.5
9	1.8	220	126	49.5	6	40	4.5	35.7	7.1	8.9	0	499.5
10	1.5	440	166	33	3.2	32	9.7	30	2.8	4.2	0	724.4
11	1.5	47.1	24	49.5	6.4	32	2.4	2.8	0	0	0	165.7
12	1.5	110	16	82.5	16	26.6	56.6	4.7	4.7	33.3	0	351.9
13	1.2	110	166	33	8	60	21.2	7.1	10.7	14.2	0	431.4
14	1.2	110	112	49.5	3.2	16	2.4	5.7	2.8	4.2	0	307
15	3	165	32	82.5	16	80	12.1	28.5	9.5	100	0	528.6
16	2.1	110	48	66	10.6	53.3	4	28.5	14.2	0	0	336.7
17	2.1	47.1	24	33	32	80	12.1	7.1	0	0	0	237.4
18	2.7	330	128	49.5	4.5	45.7	12.1	3	16.3	3	0	594.8
19	3	275	112	33	4	40	3	5.3	42.8	25	0	543.1
20	1.5	440	64	16.5	8	60	6	32.1	3.5	21.4	0	653
Total	**33**	**3,780.7**	**1,856**	**1,009.5**	**157.48**	**919.6**	**264.7**	**264.3**	**166.5**	**452.5**	**6.2**	**8,912.5**
Av.	**1.65**	**189.04**	**92.8**	**50.47**	**7.87**	**45.98**	**13.23**	**13.2**	**8.3**	**22.6**	**0.3**	**445.62**
%	**0.37**	**42.42**	**20.82**	**11.32**	**1.76**	**10.31**	**3**	**3**	**2**	**5**	**0.07**	**100**

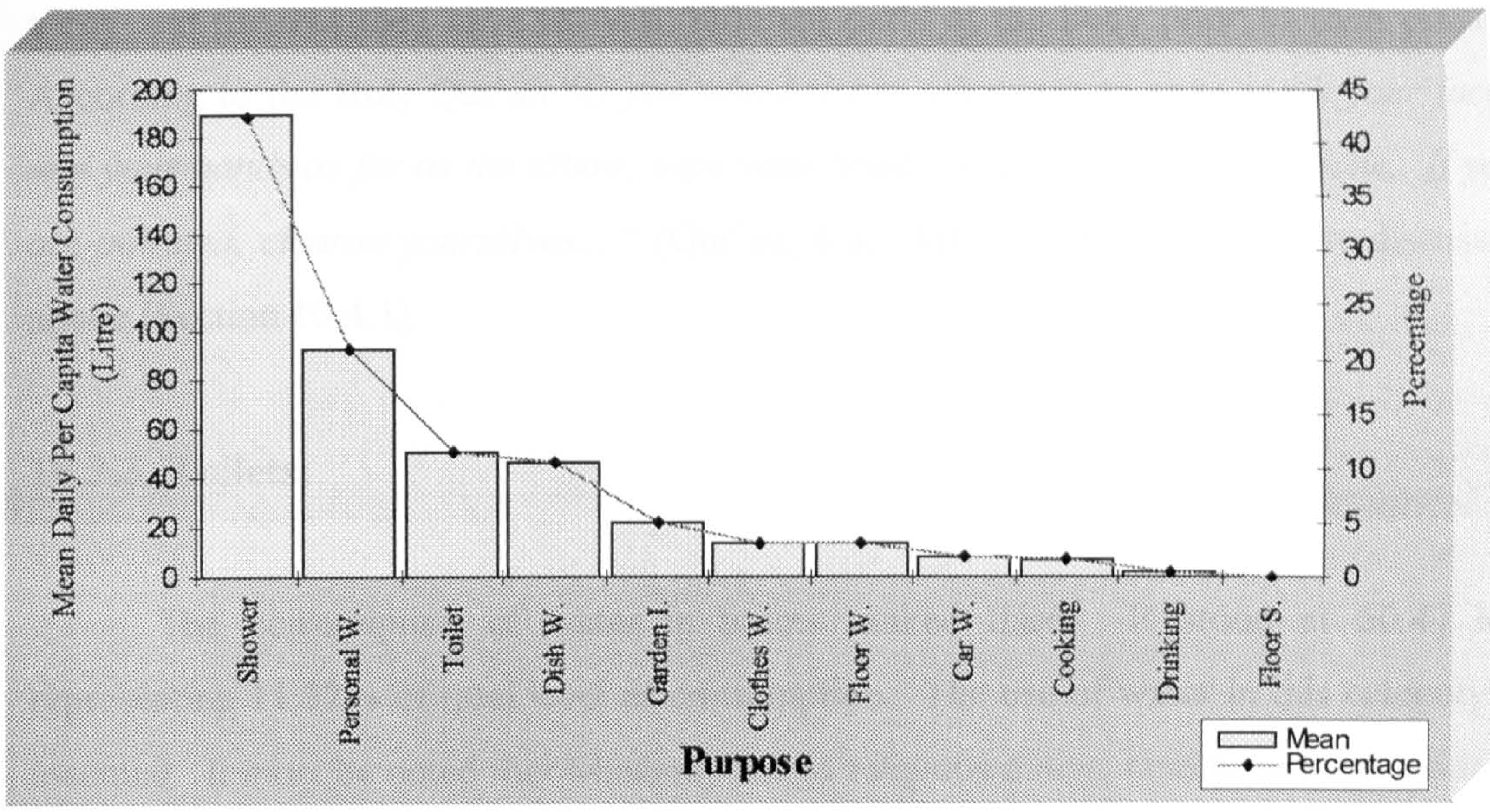

Figure 10.1. The Mean Daily Water Consumption for Different Purposes.

10.3.1. Shower:

The use of water for showers constituted the highest amount among all other uses, amounting to 184 ld^{-1}. This amount is 42.42% of the water used in the sample survey. Big differences appeared, however, among the sample survey. For an example, one person was using no more than 47.1 ld^{-1} while another was using 440 ld^{-1}. There are reasons for such a high level of consumption. Firstly, religious, since Islam encourages cleanliness; in fact personal hygiene is a duty required by each Muslim. According to the Holy Qur'an "*He loves those who purify themselves*" (Qur'an, 2:222). A second reason is the weather. The high temperature and humidity makes people want to shower more than once a day. In addition, the sandstorms encourage people to shower more than once per day. A third reason is health awareness, in addition to the high standards of living.

10.3.2. Personal Washing:

Personal washing is ranked second among the sample survey, using around 20.82% of the water used by the sample (92.8 ld^{-1}). Differences were found among the respondents, also. For instance, one would use 16 ld^{-1} while another 192 ld^{-1}. As mentioned before, personal hygiene in Islam is a religious duty. Muslims pray five times a day and for that they have to wash different parts of the body prior to each prayer. According to the Holy Qur'an "*O you who believe, what rise to pray, wash your faces and your hands as far as the elbow, wipe your heads, and your feet to the ankle. If you are polluted, cleanse yourselves...* " (Qur'an, 4:6). Other reasons for this are discussed above (Section 10.4.1).

10.3.3. Toilets:

The consumption of water in toilets ranked third. It stood at 50.47 ld^{-1} representing 11.32% of total level of consumption. The use of water in this category is essential. It must be noted that Muslims, due to religious duties, tend to use more water. Differences among individuals were found ranging between a high of 85.5 ld^{-1} to a low of 33 ld^{-1}.

10.3.4. Dish Washing:

Dish washing uses up to 45.98 ld^{-1}. That is around 10.31% of the total consumption by the sample group. This is average for a society that takes two main meals at home and considering the high standards of living. Moreover, the size of Qatari families is often large (al-Khayat, 1988; Fakro, 1998). The extended family is a norm and even the size of the nuclear family is relatively big especially in comparison with developed countries. Another important factor that accounts for this high consumption, is the presence of maids in most homes. From anecdotal evidence, they do not economise on water used for dish washing.

10.3.5. Watering Gardens:

Consumption by watering gardens ranked fifth with an average of 22.6 ld^{-1}. That represents 5% of total water consumption. The reason for this low percentage can be attributed to the fact that the amount was divided by the size of the family. In addition, 20% of the sample did not have gardens. Consumption ranges between 0-100 ld^{-1}. Limited rainfall, high temperature, poor soil and lack of experience with gardening in general limits the size and number of gardens.

10.3.6. Clothes Washing:

Clothes washing ranks sixth, averaging 13.23 ld^{-1}. This represents 3% of total consumption. This percentage might seem modest but this consumption is not daily and it has been divided by the size of the household. Consumption ranges from 2.4 ld^{-1} to 56.6 ld^{-1}. The high living standards and natural conditions of heat and humidity require large amounts of water to wash clothes. Additionally, there is the religious factor "*And purify your garments*" (Qur'an, 74:4). Finally, the country has few public launderettes.

10.3.7. Floor Washing:

Floor washing ranks seventh and averages 13.2 ld^{-1}. This represents 3% of total consumption. Consumption ranges between 2.8-35.7 ld^{-1}. Natural conditions (sandstorms and lack of rainfall) and hygiene helps create this level of consumption. In addition, the widespread use of servants (e.g. al-Barghouti, 2001) makes cleaning more frequent and increases this type of consumption. On the other hand, the consumption has been divided by the size of households and it is not a daily occurrence, which might contribute to its modest level.

10.3.8. Car Washing:

Car washing ranks eighth with an average of 8.3 ld^{-1} and a share of 2% of total consumption. Consumption ranges from 0-42.8 ld^{-1}. Car ownership is wide spread due to the oil boom and most households have more than one (e.g. PC, 1999b). Yet, the consumption of water for car washing seems to be modest, especially in comparison with other uses. The reason is that this activity is either weekly or monthly, despite the weather conditions and sandstorms. Second, some people prefer to wash their car away from their houses. Another reason that consumption appears modest is that car washing has been divided by the size of family, although 10% of the sample do not own cars.

10.3.9. Cooking:

Consumption of water for cooking ranks ninth. It averages 7.87 ld^{-1} and represents 1.7% of total consumption. The elements that constitute this have been mentioned before; washing food, washing the cooking utensils, preparation of food etc. Consumption ranges between 0.28 to 32 ld^{-1}. This large difference is due to differences in the size and nature of household.

10.3.10. Drinking:

Consumption of drinking water ranks tenth. It averages 1.65 ld^{-1} and represents 0.36% of total consumption. This modest percent is due to lack of extravagance in this type of consumption. Those that work outside drink larger amounts of water due to heat and humidity, hence there is a huge difference among the respondents. Some drink only 0.3 ld^{-1} while others drink 3 ld^{-1}.

10.3.11. Other:

One respondent mentioned a type of water consumption that the questionnaire did not include, namely spraying the ground with water in order to reduce the heat. It was common in the past before air conditioning became widely used. This represents only 0.07% of total consumption.

10.4. Use of Water by Groups:

One of the aims of the study is to identify the differences in consumption pattern in accordance to influences such as nationally, gender, education, age, occupation, income and number in household. It proved difficult to have a balanced representation in all these influences. Yet, the sample gives some indication of the differences in consumption patterns.

10.4.1. Nationality:

The study showed that the average per capita consumption for a Qataris is 550.9 ld^{-1} (Table 10.3 and Figure 10.2). In comparison immigrants consume 340.2 ld^{-1}, thus Qataris consume 210.7 ld^{-1} more. Moreover, not all immigrants can be put in one category. Those coming from Western countries - who often occupy high positions - consume 407.2 ld^{-1}, while those coming from Arab countries with a medium living standard consume 353 ld^{-1}. Those coming from Asia, who represent the majority of the immigrant community with a low living standard, have a consumption of 238.3 ld^{-1}.

Table 10.3. The Mean Water Consumption for Different Nationality Groups (Litre per Day).

Nationality Group	Consumption (Mean)	Divergence From General Mean	Standard Error
Qataris	550.95	105.2	37.25
Non-citizen	340.29	-105.4	32.03
Westerners	407.22	-38.4	43.57
Arabs	353.03	-92.6	39.38
Asians	238.32	-207.3	42.20

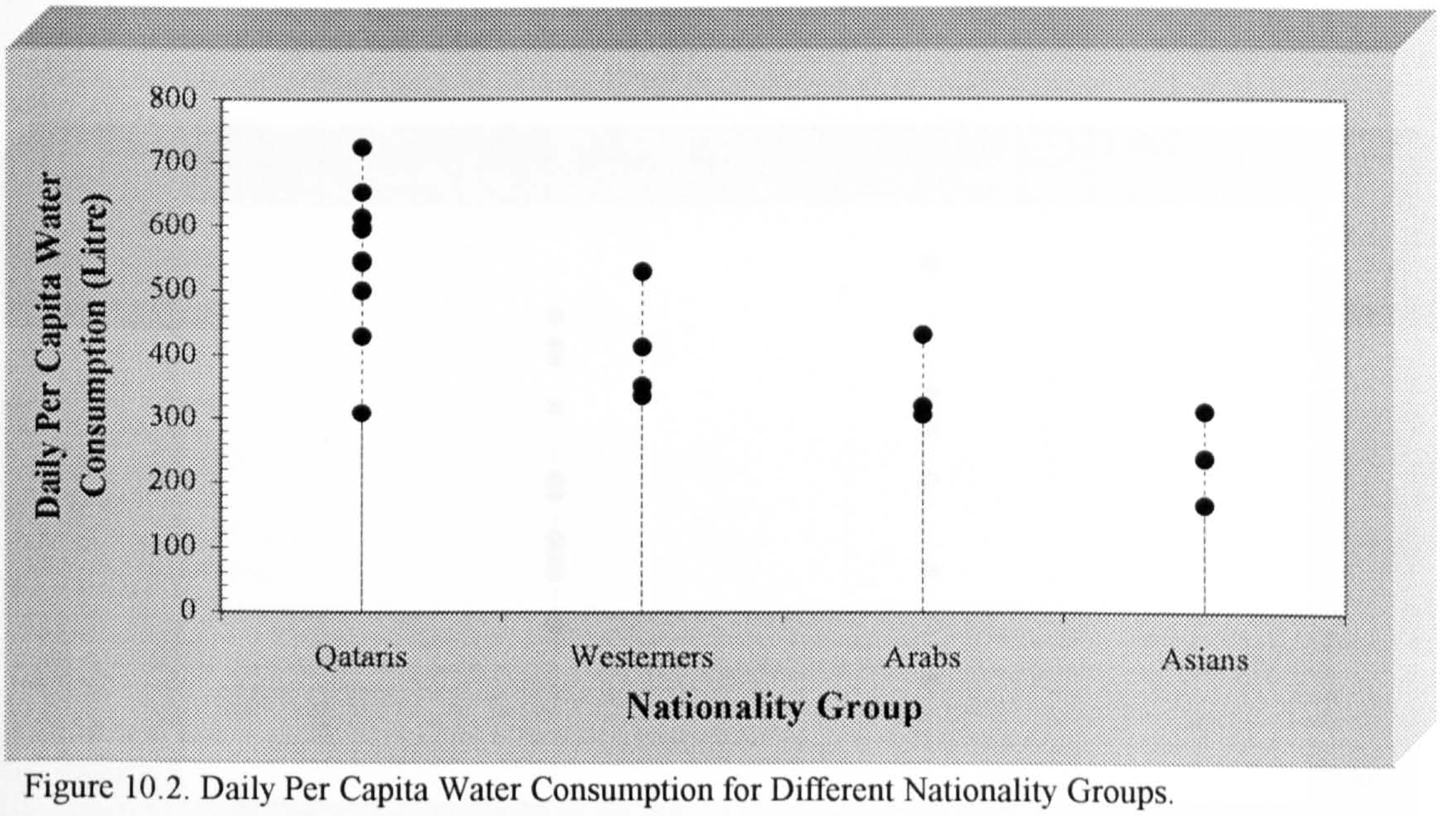

Figure 10.2. Daily Per Capita Water Consumption for Different Nationality Groups.

This reflects the influence of living standards on the level of water consumption. Those coming from developed rich countries consume more than those coming from developing low-income countries. A reason for the high consumption among the nationals is due to the fact that water is provided free while the immigrant community pays for its consumption (Section 7.3.5.4). In addition, Qataris have servants in their large homes, which usually leads to increases in consumption.

10.4.2. Gender:

The consumption for women is usually higher than men (Bulajich, 1992; Jordan and Wagner, 1993; al-Shinshori, 1999). In this study, however, men consume more than women, although by a small amount (around 8 ld^{-1}: Table 10.4 and Figure 10.3). This is due to the presence of large percentage of Asian women whose consumption of water is modest. The range of consumption figures for women is actually larger than the range for men. Therefore, there is no certain difference between man and women in water consumption behaviour.

Table 10.4. The Mean Water Consumption for Different Gender Groups (Litre per Day).

Gender Group	Consumption (Mean)	Divergence From General Mean	Standard Error
Males	448.76	3	41.17
Females	440.96	-4.7	61.99

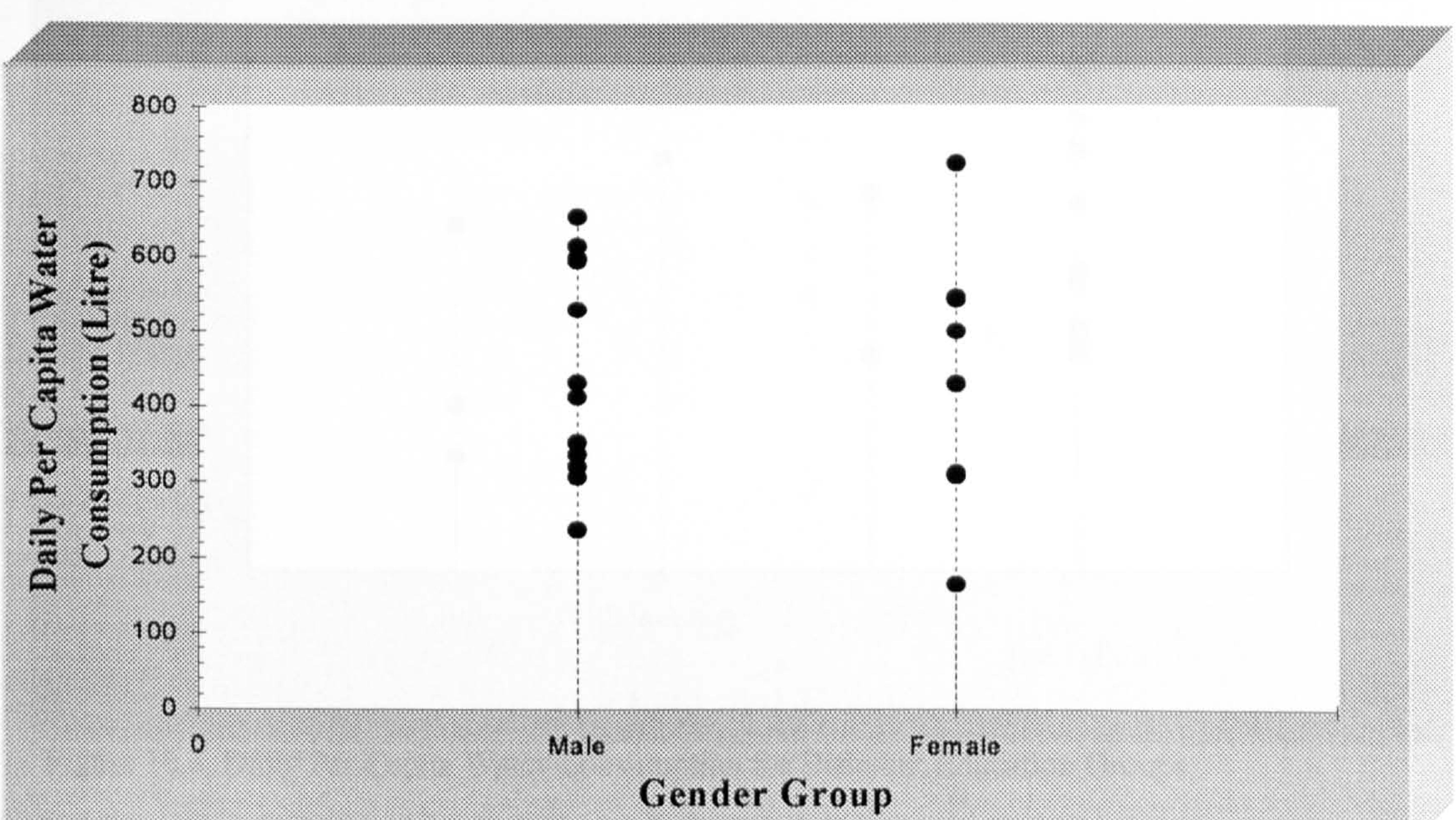

Figure 10.3. Daily Per Capita Water Consumption for Different Gender Groups.

10.4.3. Education:

Those with little, primary and high school education have relatively low consumption (Table 10.5 and Figure 10.4). Consumption of water for those in with higher education is 475.5 ld^{-1}. Most of the nationals and Western immigrants fall within this category. As mentioned before, these people have the highest consumption. Their education, reflected in social status and income, contributes to their high consumption pattern.

Table 10.5. The Mean Water Consumption for Different Education Groups (Litre per Day).

Education Group	Consumption (Mean)	Divergence From General Mean	Standard Error
Little to High School	400.79	-44.83	57.78
Higher Education	485.1	39.48	50.47

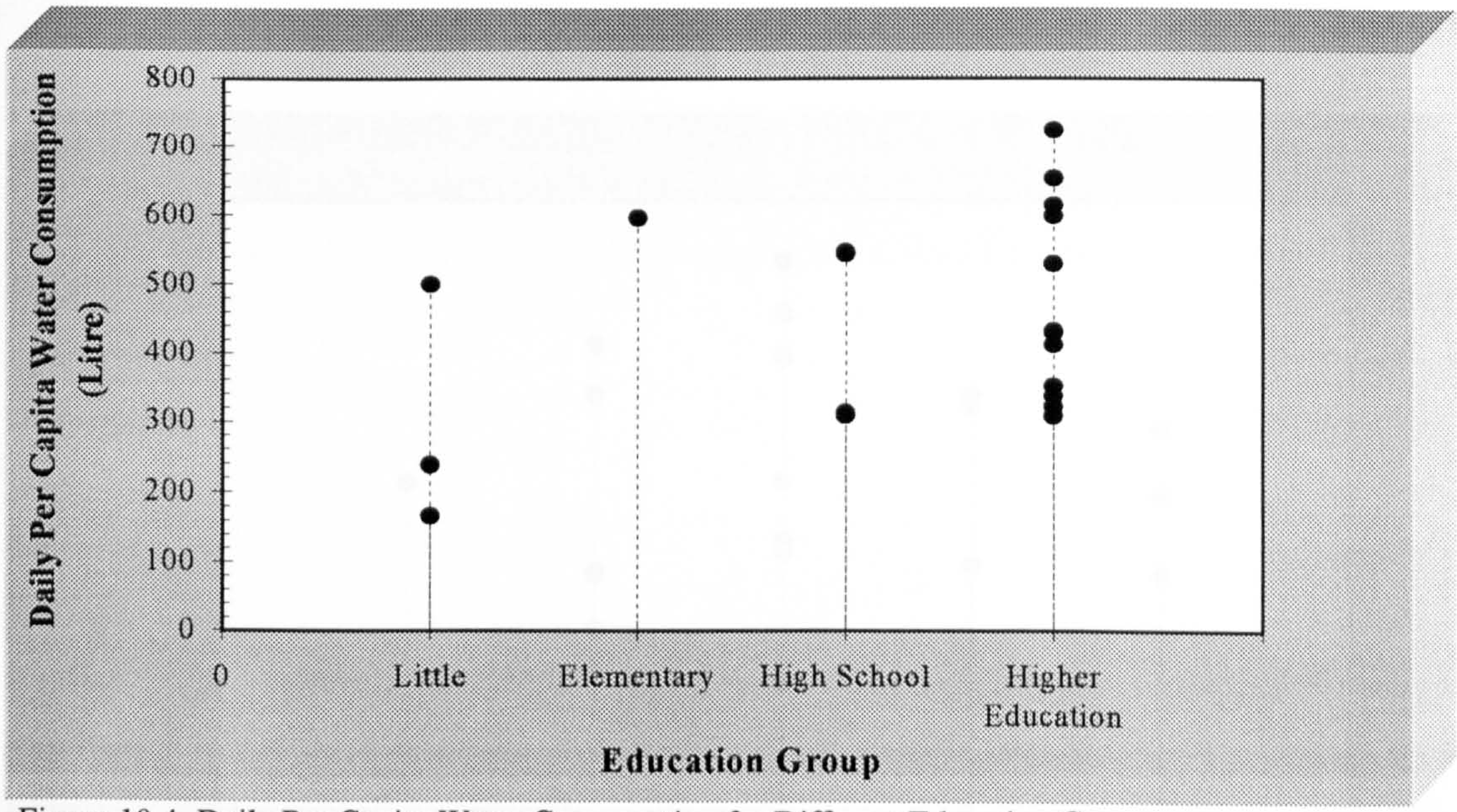

Figure 10.4. Daily Per Capita Water Consumption for Different Education Groups.

10.4.4. Age:

It does not appear that there is a strong relation between age and levels of water consumption. However, there is a noticeable increase for the middle age group. This might be attributed to the fact that the majority in this age group are immigrants hence of high-income and life standard, especially in the age group 30-39 (Table 10.6 and Figure 10.5). Their consumption reaches 482.25 ld^{-1}. That is approximately 36 ld^{-1} more than the average consumption. This, the most numerous group in the sample, also has the widest range.

Table 10.6. The Mean Water Consumption for Different Age Groups (Litre per Day).

Age Group	Consumption (Mean)	Divergence From General Mean	Standard Error
<20	429.1	-16.5	---
20-29	402.87	-42.8	73.68
30-39	481.75	36.1	67.33
40-49	464.93	19.2	72.28
>50	409.06	-36.6	55.64

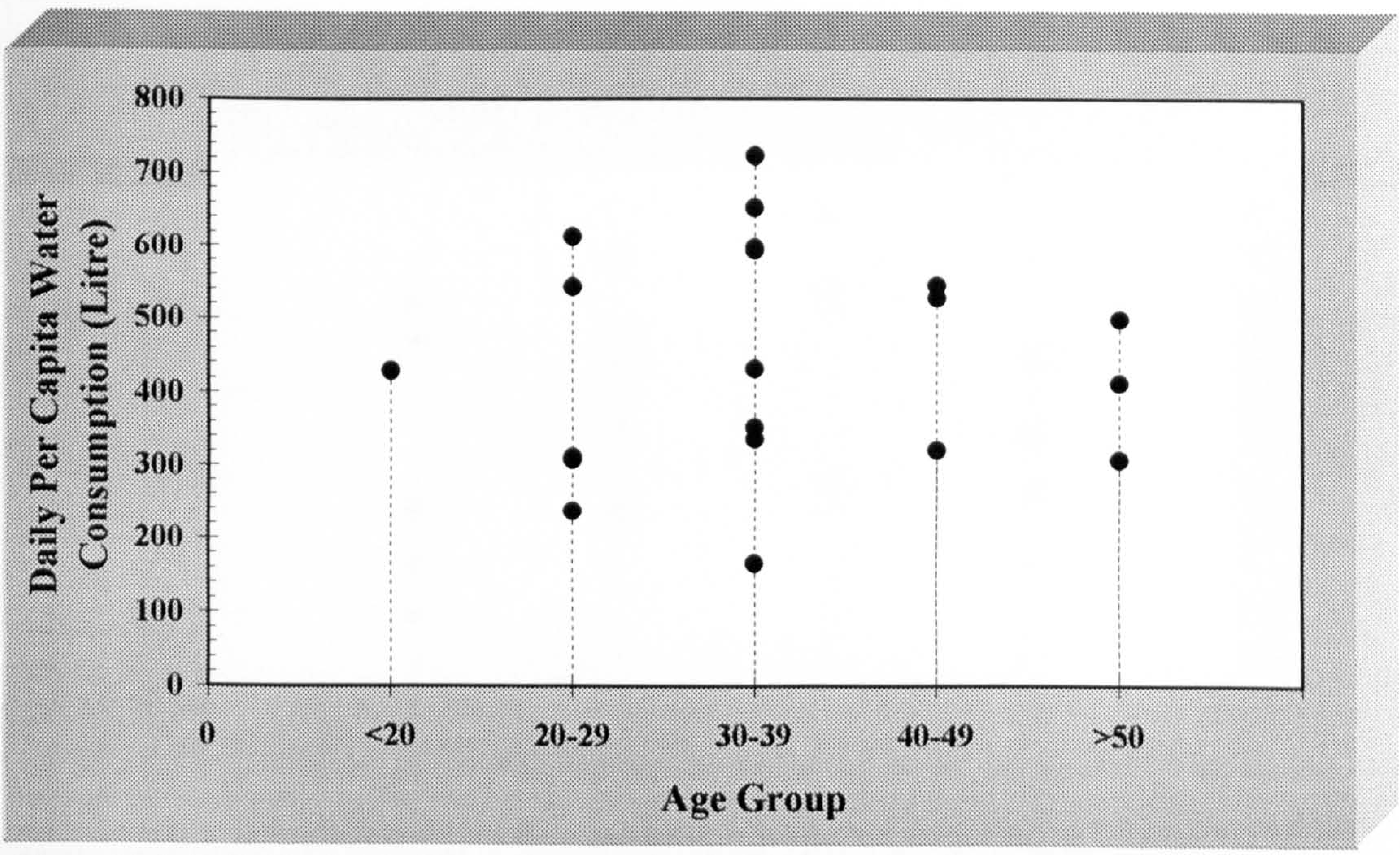

Figure 10.5. Daily Per Capita Water Consumption for Different Age Groups.

10.4.5. Income:

The average consumption of the middle income range of QR 10,000-14,999, is much higher than average per capita consumption (Table 10.7 and Figure 10.6). It is around 137.8 ld^{-1} higher. Near highest is the consumption of those whose income ranges between QR 5,000-9,999. In fact, it is difficult to relate income to consumption but the fact that those in middle income range are nationals and immigrants from Arab countries might explain the in higher levels of consumption. They are Muslims and tend to use more water for religious reasons and their living standards are usually high. They may have less interest in water issues.

Table 10.7. The Mean Water Consumption for Different Income Groups (Litre per Day).

Income Group	Consumption (Mean)	Divergence From General Mean	Standard Error
<5,000	371.05	-74.6	84.86
5,000-9,999	436.53	-9.1	44.08
10,000-14,999	571.97	126.2	78.56
>15,000	425.66	-20	55.83

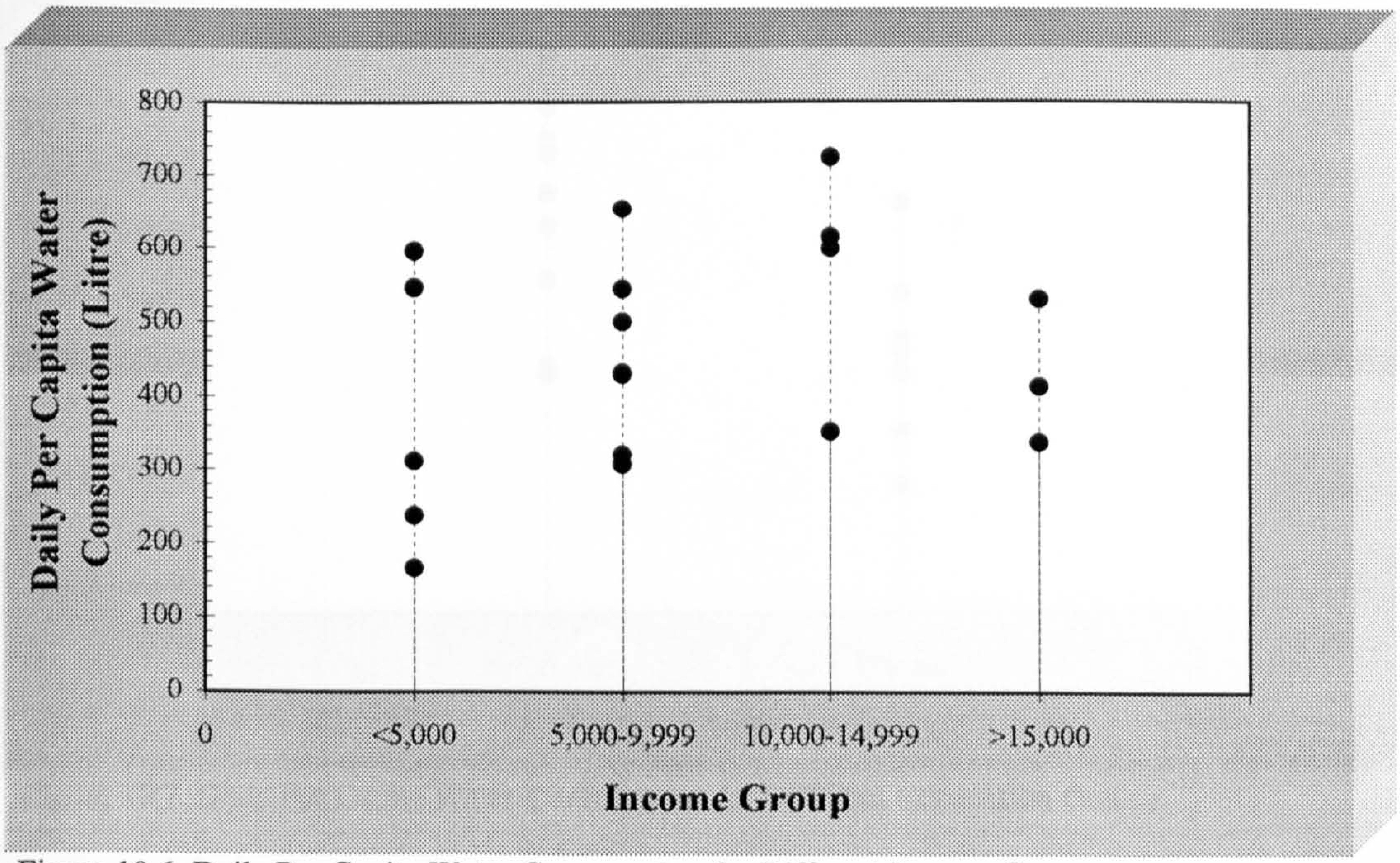

Figure 10.6. Daily Per Capita Water Consumption for Different Income Groups.

10.4.6. Occupation:

There is a clear relation between employment and level of consumption. Those working in the government sector, namely nationals and most of the Arabs, have a much higher consumption than those working in the private sector, despite the fact many in the private sector are from Western countries. Those in the government sector consume 521.8 ld^{-1} in comparison to 331.3 ld^{-1} for those in the private sector (Table 10.8 and Figure 10.7). This difference is attributed to nationality, religious and social factors. In addition, those working in the government sector work fewer hours than those in the private sector. Hence, they have more time at home to consume more water.

Table 10.8. The Mean Per Capita Water Consumption for Different Occupation Groups (Litre per Day).

Occupation Group	Consumption (Mean)	Divergence From General Mean	Standard Error
Government Sector	521.8	76.1	37.13
Private Sector	331.36	-114.3	38.51

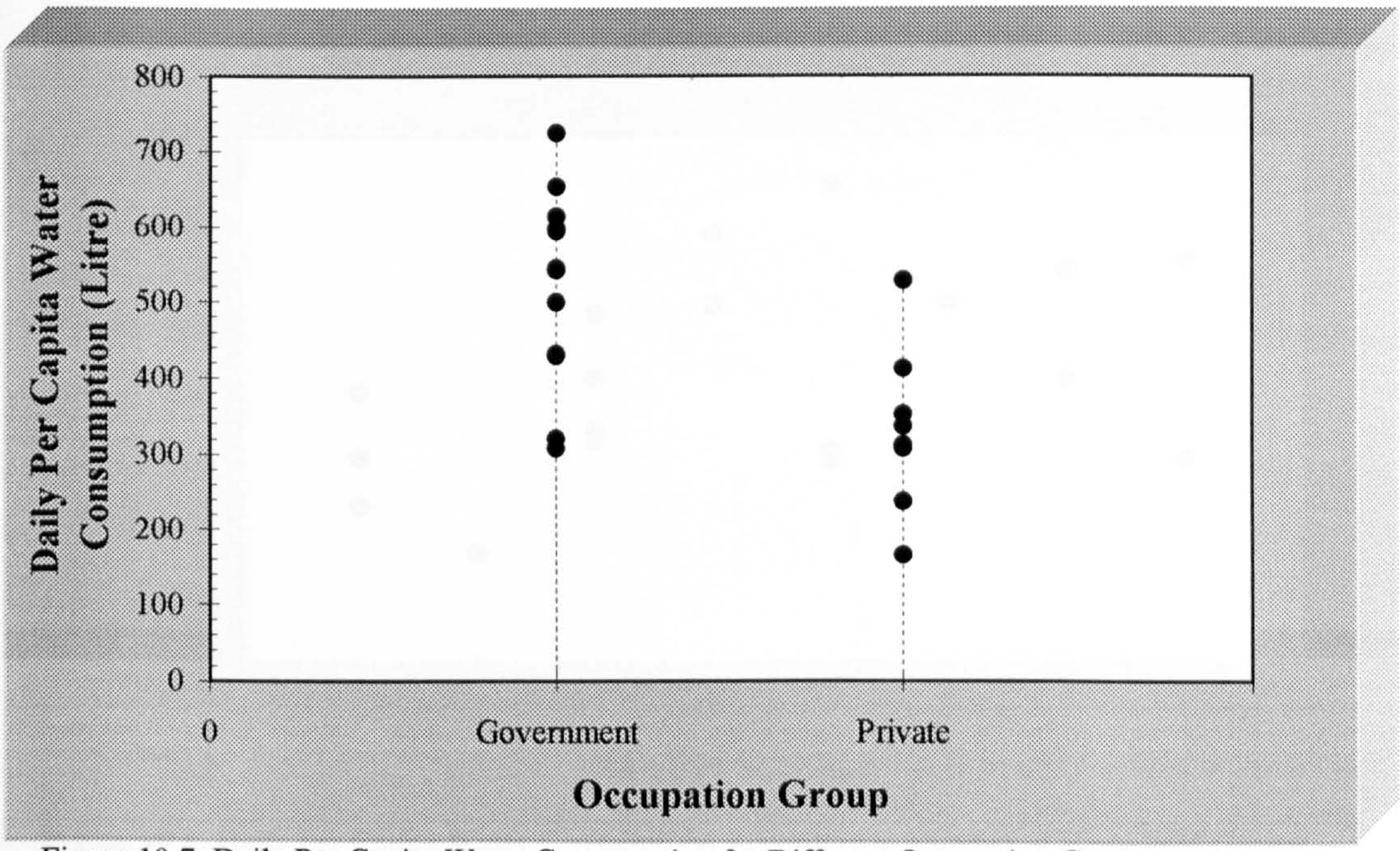

Figure 10.7. Daily Per Capita Water Consumption for Different Occupation Groups.

10.4.7. Number in the Household:

Consumption tends to increase in middle size families. The average is around 598 ld^{-1} for a family of four members, while it is 165.7 for a family of two (Table 10.9 and Figure 10.8). The middle-sized family consumes more for common uses of water such as washing clothes, floors and cars. For large sized families, the average is lower because consumption for common uses is divided by the number of family members.

Table 10.9. The Mean Per Capita Water Consumption for Different Number of Household (Litre per Day).

No. Household	Consumption (Mean)	Divergence From General Mean	Standard Error
1	320.32	-125.3	50.49
2	165.7	-279.9	---
3	412.15	-33.4	44.02
4	598.05	152.3	54.95
5	450.7	5	136.90
6	545.5	99.8	---
7	540.66	94.9	55.79
8	473.83	28.1	88.97

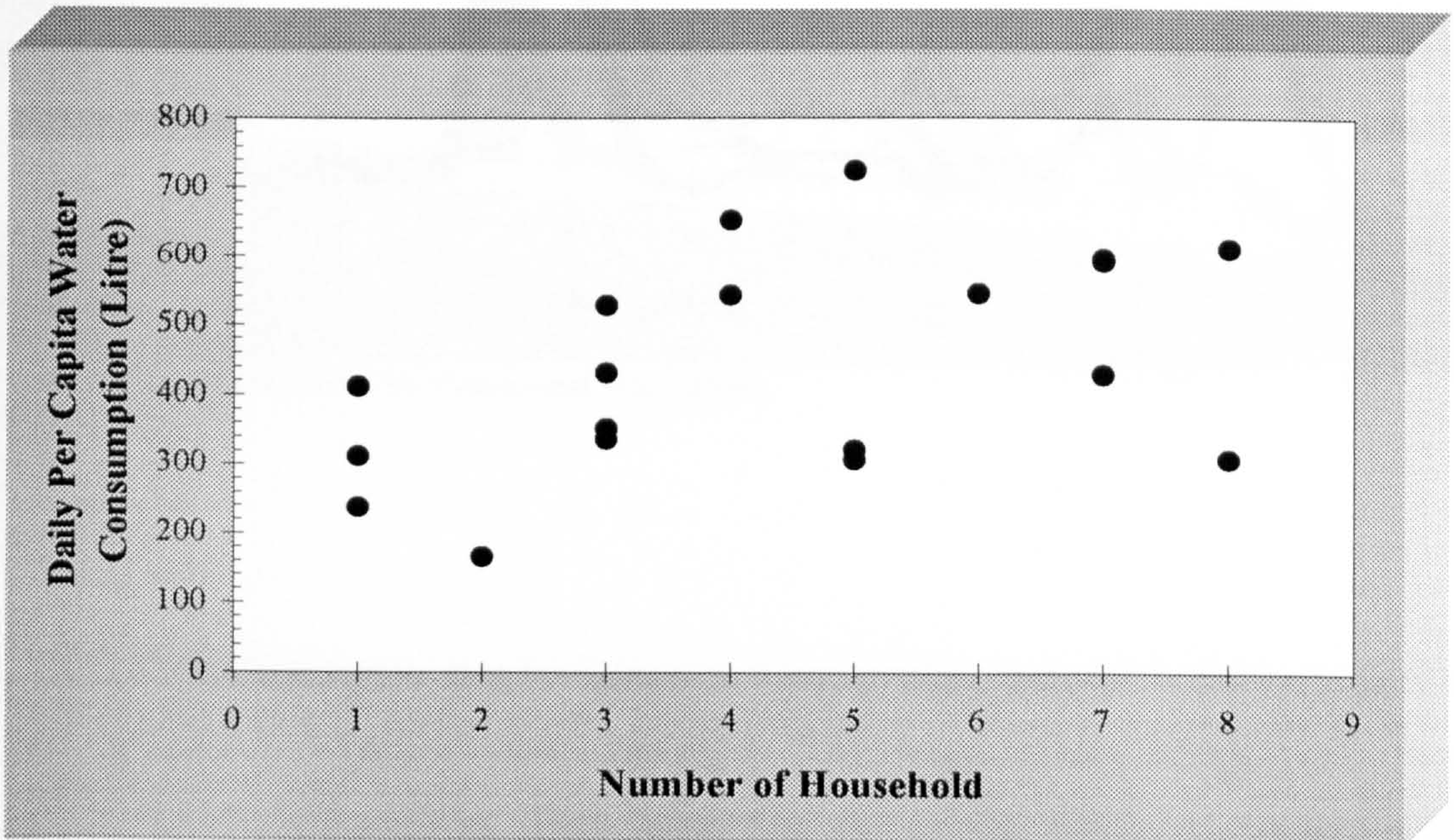

Figure 10.8. Daily Per Capita Water Consumption According to Number of Household Groups.

10.5. Daily Consumption:

Finding out the pattern of hourly consumption is useful to identify peak times and hence be able to make the necessary amounts of water available to the public. The study revealed a strong correlation between working hours and levels of consumption. For Qataris, who mostly work in the government sector, peak hours start from five in the morning reaching their highest at six and starting to decline afterwards as work starts between six and seven (Figure 10.9). For foreigners, the highest consumption is between five and six, since most of them work in the private sector. Work in the private sector usually starts between six and eight (MFA, Undated).

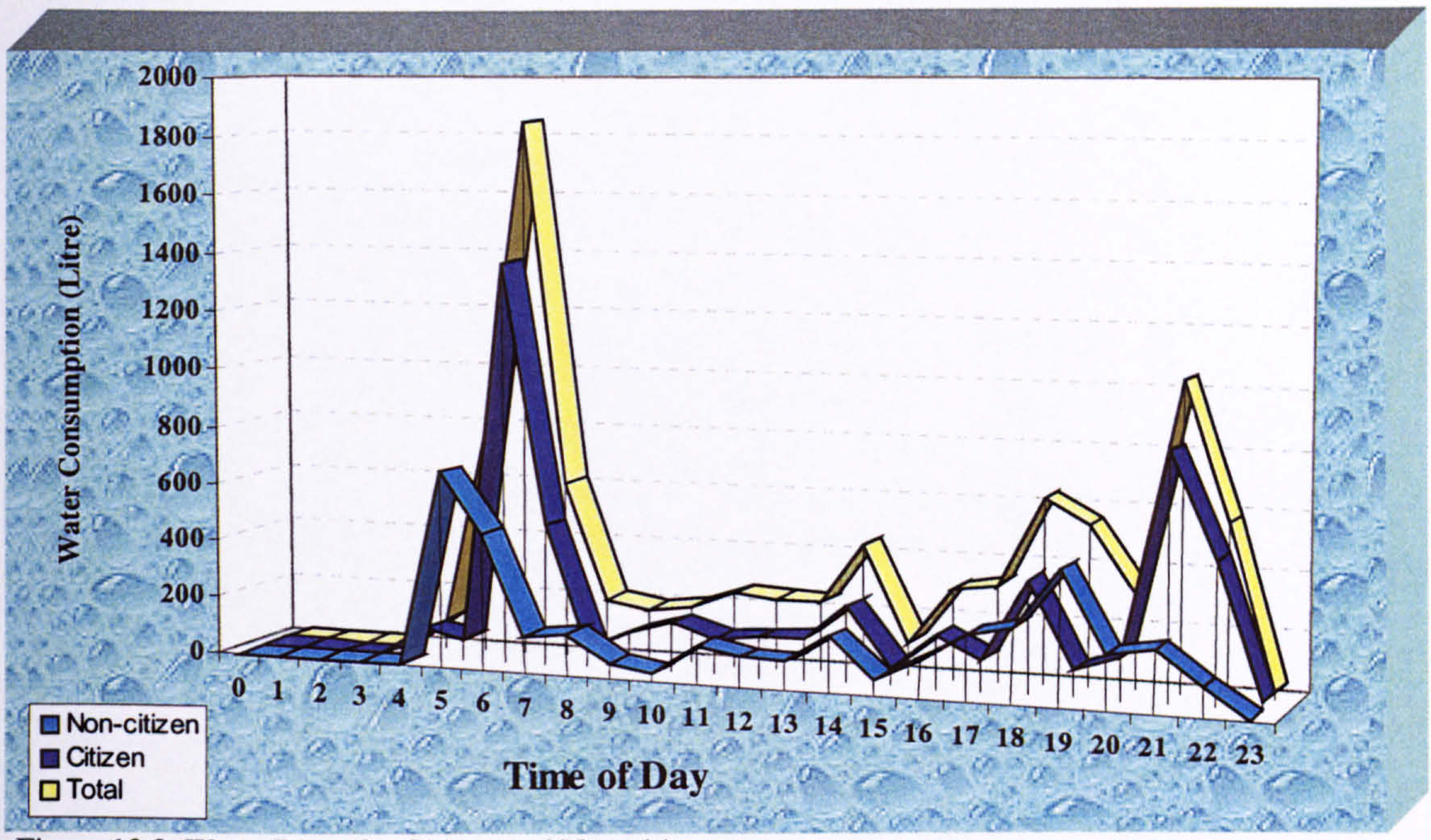

Figure 10.9. Water Diary for Citizen and Non-citizen.

The second peak time for Qataris is between eight and nine in the evening, while for foreigners it is between seven and eight. The reason for this second peak is to the use of showers and washing. There are another two periods where consumption is high too. The first is in the evening, around six, when consumption increases due to specific activities such as watering gardens or car washing. The second is around two in the afternoon when it is time for cooking and eating at the end of work. Consumption is lowest between twelve at night and four in the morning and between two and four in the afternoon. The latter is rest time for those working in the government sector since workday ends usually at two in the afternoon and the first rest time for those working in the private sector.

10.6. Conclusion:

The study was able to identify the consumption patterns of a variety of water uses, in addition to identifying influences of factors such as education, age and income on levels of water consumption. Personal hygiene - showers and personal washing - ranks first in water consumption, representing about 63% of total consumption. Thus, it is essential to curtail this type of consumption and find ways to economise. For instance, new types of taps and showers could be used that are designed to reduce the amount of water consumed. New technology can be adopted for toilets too. For example, in the American city of Tucson a law was enacted that limits the amount of water used in showers to 9 litres a minute and for toilet to 6 litres a minute (e.g. Othman, 1999). The law similarly limited the amount of water flowing from taps.

Another method for reducing consumption is through awareness raising public campaigns. The lack of tariffs for Qataris and some immigrants on the consumption of water is a major contributing factor to the high levels of consumption. This policy must be reconsidered. The study indicated that there is no strong functional relationship between education and increased awareness of the importance of water. The absence of water issues in the school curriculum contributes to high levels of consumption.

Finally, this survey has shown peak of times of consumption. This data is important because it may suggest ways to reduce consumption, possibly, for instance, by imposing penalties when exceeding a set limit during peak hours.

CHAPTER ELEVEN:

PUBLIC QUESTIONNAIRE

Public Questionnaire

11.1. Public Data and Opinion:

11.1.1. Introduction:

The objective of this survey is to assess the patterns of behaviour, perceptions and attitudes of the public towards water issues in Qatar (Sections 4.3.4 and A14.1). In addition, it aims to examine the reasons underlying behaviour and attitude patterns for different groups. This knowledge can help in many aspects of the formulation of a comprehensive water management policy.

11.1.2. Survey Process:

Water touches the lives of all members of society, hence the questionnaire included all the strata of society (Table 11.1). This posed the difficulty of obtaining a representative sample when compared with Census data and Government statistics (Section 4.5). A relatively large sample was taken of Qataris since they will represent the majority of the politically active population in the long term and any future water policy must take that into account. The respondents from the immigrant community were chosen on the basis that they have been in the country for no less than three years and are from different nationalities - Western, Arab and Asian. Gender shares reflected the real proportion in Qatari society.

It was more difficult to achieve respondents for education and age because of the lack of response from the very little educated and the younger age groups. When age breakdown is examined, those under 20 years of age (around 32% of the population) were not interested or unable to respond to this survey. Most of the support for the survey came from the higher-educated and middle-aged groups.

There are no official statistics for income and some types of employment. It is expected, however, that the majority of Qataris are in the middle income bracket and work in the governmental sector, while foreign workers are generally in the lower income bracket and work usually in the private sector.

Table 11.1. Comparison of Census and Survey Population Data (CSO[a], 1998; Survey Data[b], 1999).

Group		Census[a] (1997) (%)	Survey[b] (%)
Nationality	Citizen	21.5*	60.5
	Western	Unavailable	2
	Arab	Unavailable	22
	Asian	Unavailable	15.2
	African	Unavailable	0.3
	Non-citizen (Total)	78.5*	39.5
Gender	Male	66	67.5
	Female	34	32.5
Education	Very Little	43.2	11.7
	Elementary	13.2	12.4
	High School	28.4	31.1
	Higher Education	15.2	44.8
Age	< 20	32	11.9
	20-29	17	29.3
	30-39	26	38.8
	40-49	17	13.5
	50-59	5.5	3.9
	> 60	2.5	2.6
Monthly Income (QR)			
	<5,000	Unavailable	36.7
	5,000-9,999	Unavailable	46.3
	10,000-14,999	Unavailable	12.7
	>15,000	Unavailable	4.3
Occupation	Official	12.1	28.7
	Labour	29.5	15.5
	Engineer	Unavailable	2.3
	Teacher	5	14.4
	Student	9.9	11.6
	Housewife	13.2	2.9
	Policeman	Unavailable	3.2
	Retired	0.3	2.1
	Technical	4.8	2.2
	Clerk	12.2	11.7
	Domestic	16.2	0.4
	Driver	Unavailable	1.9
	Businessman	1.3	1.9
	Farmer	1.9	1.1

*Informal.

11.1.3. The Service:

11.1.3.1. Source of Water:

There are two sources of water; desalination and groundwater (Section 6.2). Desalination accounts for 63.5% of the water consumed by the survey sample while ground water is consumed by 26% of the sample (Figure 11.1). Around 10.5% of the sample indicated that they do not know the source of the water they consume. Knowing the source of water consumed is important, as we shall see later when discussing the opinion of the respondents about the quantity and quality of water.

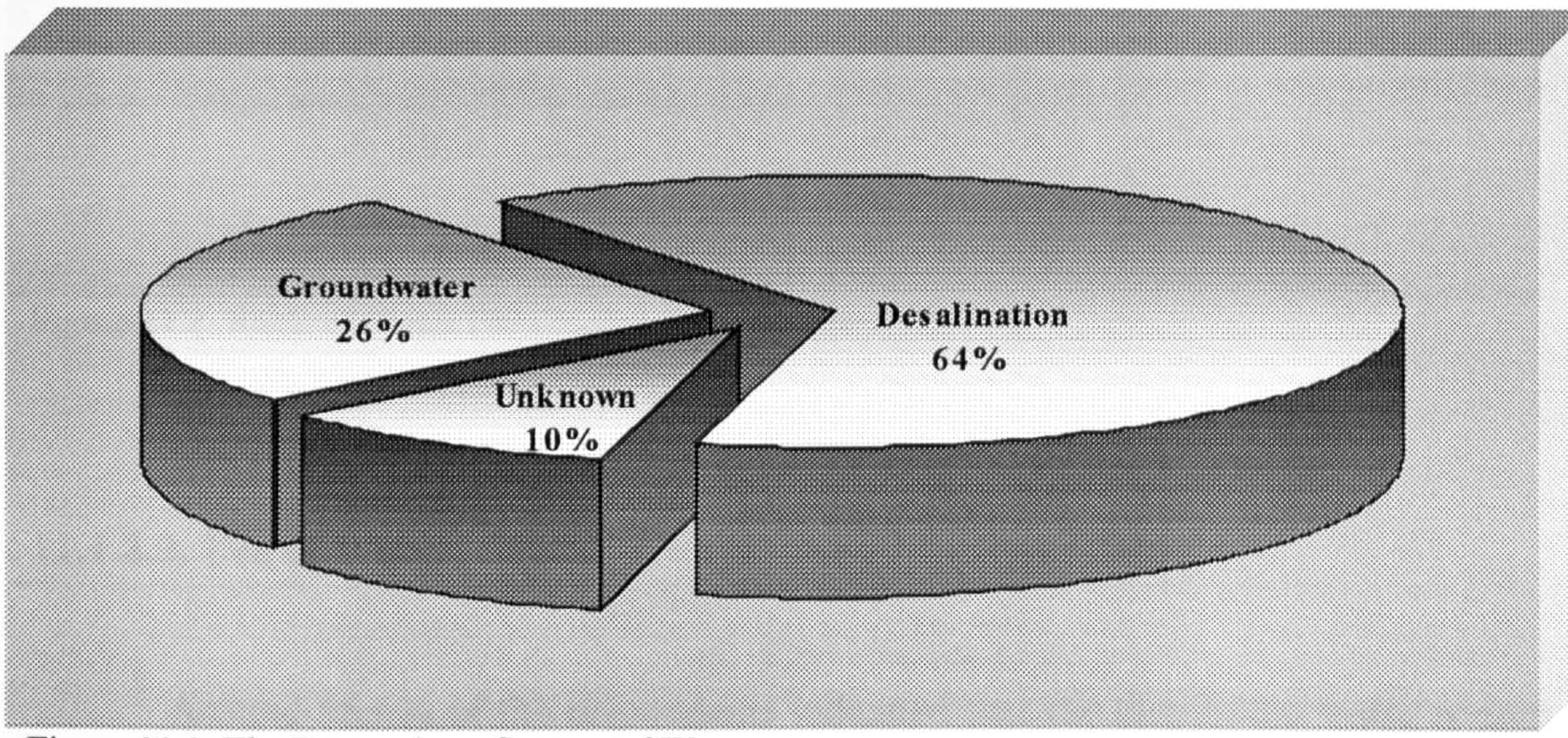

Figure 11.1. The Respondents Sources of Water.

11.1.3.2. Route of Water Distribution:

There are two ways of distributing water in Qatar (Section 7.3.4.2). Around 61.6% of the respondents get their water though the pipeline network, with the rest (38.4%) by water tankers (Figure 11.2). The water network serves the capital and some suburban areas while the rest of the country and some areas of the capital get water through water tankers (Section 7.3.4.2). The method of distributing water also influences people's opinion of the quantity and quality of water.

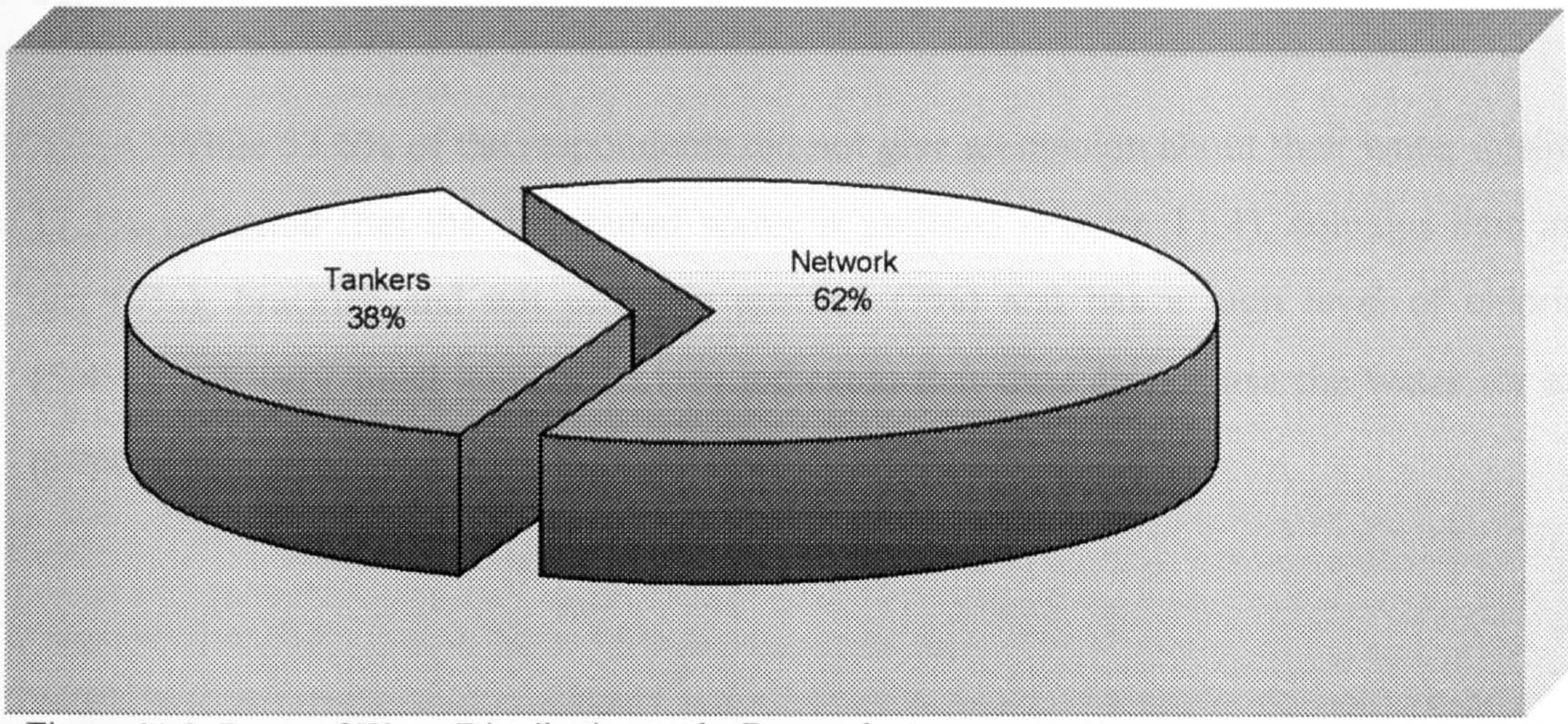

Figure 11.2. Route of Water Distribution to the Respondents.

11.1.3.3. Use of Water:

Around 56.6% of the respondents indicated that the distributed water is used for drinking, while 43.3% indicated that they used it for purposes other than drinking because it is contaminated (Figure 11.3). Therefore, they use bottled water for drinking. This accounts for the proliferation of bottled water companies in the Qatari market - there are more than thirty kinds from different countries (Table A11.1) and imports in 1999 were 22,397,602 litres (PC, 2000).

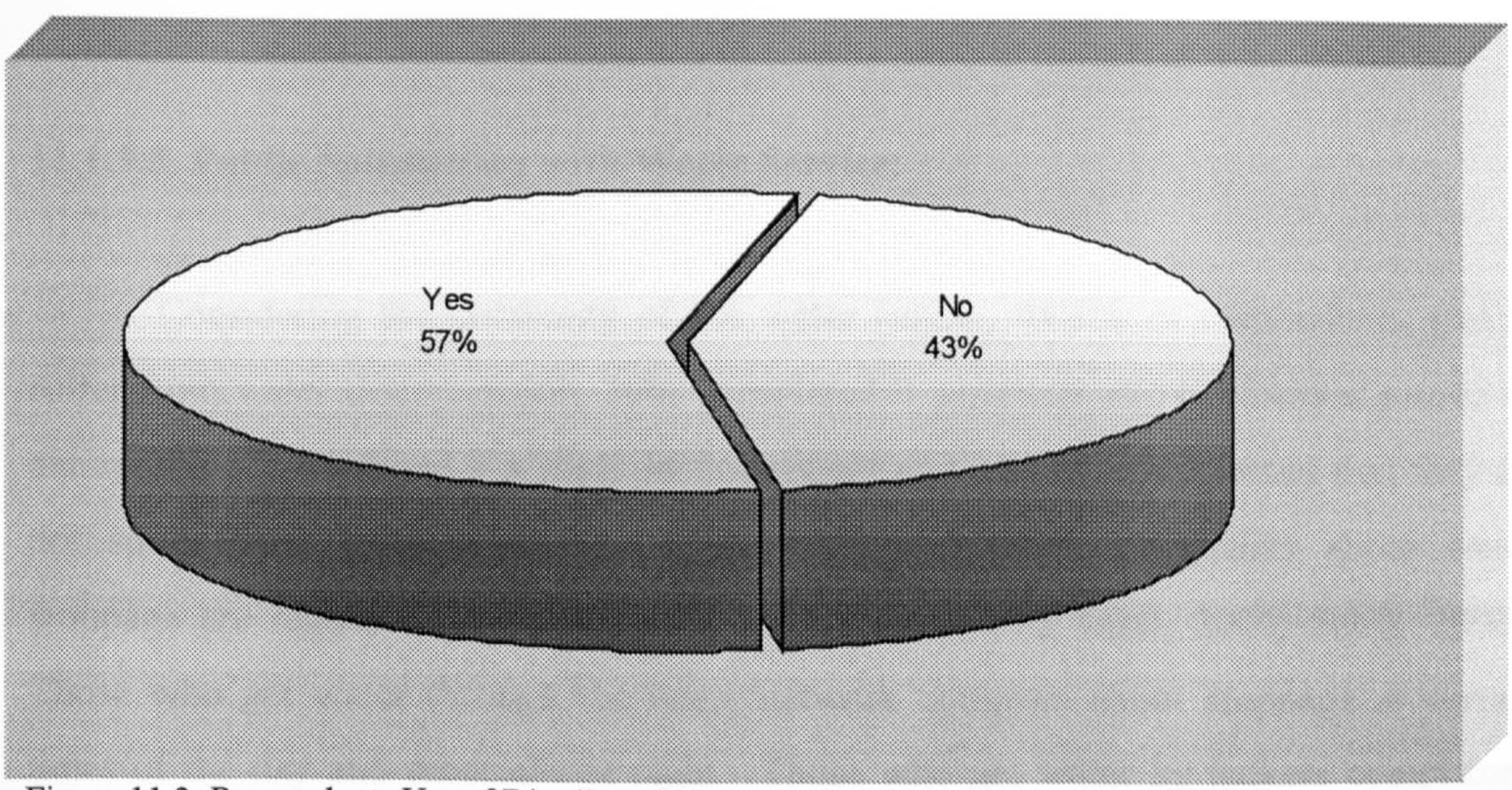

Figure 11.3. Respondents Use of Distributed Water for Drinking.

11.1.3.4. Public Satisfaction with Water Quality:

While 53.6% of the respondents did not give an opinion about their water quality, 17.3% indicated that the distributed water is polluted (Figure 11.4), contains lime and dirt (9%), brackish and not properly purified (7%) and has a high level of chlorine (5.4%). A very small number (0.1%) indicated that they do not use the water for any purposes.

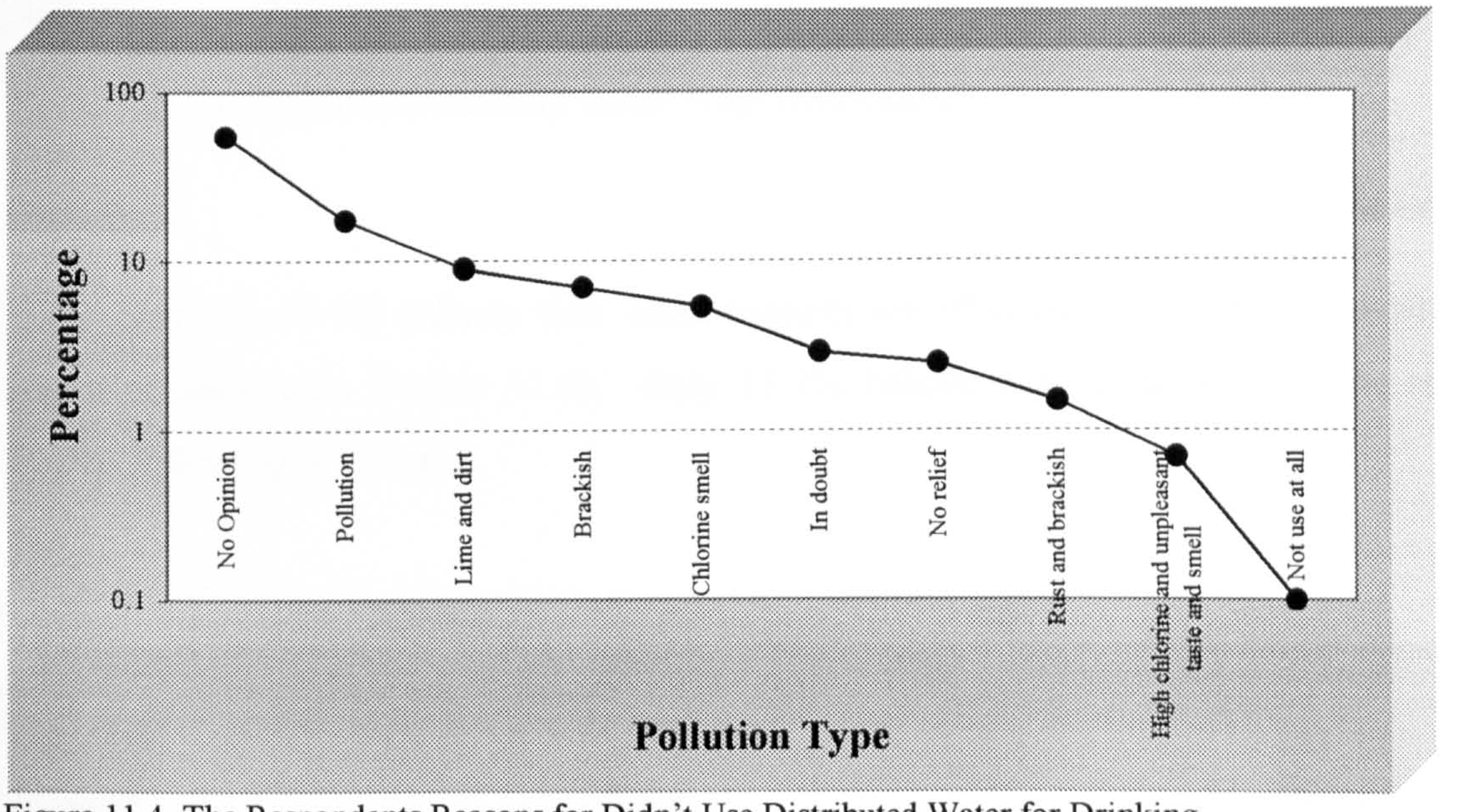

Figure 11.4. The Respondents Reasons for Didn't Use Distributed Water for Drinking.

11.1.3.5. Public Satisfaction with Water Service:

Considering the continuity of the water supply, 44.6% of respondents greatly suffer from water disconnection, 30% considered it a serious and continuous source of annoyance, 17.3% found it a slight inconvenience and only 9.2% indicated that they do not suffer from water stoppage (Figure 11.5). Actually, complaints about water stoppage are regular (al-Qahtani, 2000; al-Qudeemi, 2000; Lutfi, 2000; Saleh, 2000). Those who get water through the water network complain about stoppage at certain times of the day and especially at night. Those who get water by tankers complained about its irregularity.

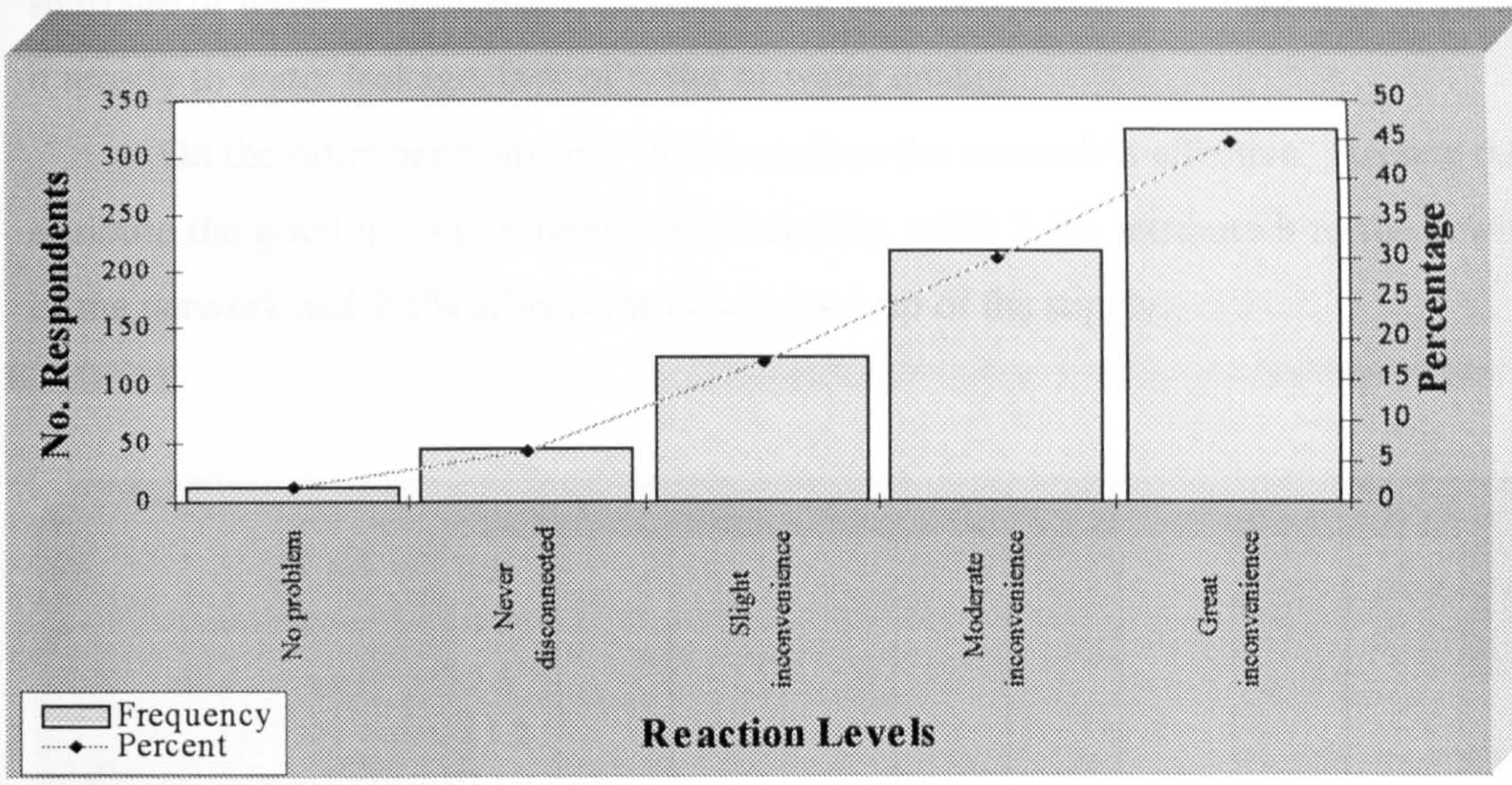

Figure 11.5. The Respondents Reactions toward Water Disconnection.

Around 45.4% indicate that water supplies are efficient, while 34.8% indicated that it is reasonable (Figure 11.6). Only 15.7% believe it is inefficient and the rest (4.1%) did not give opinions.

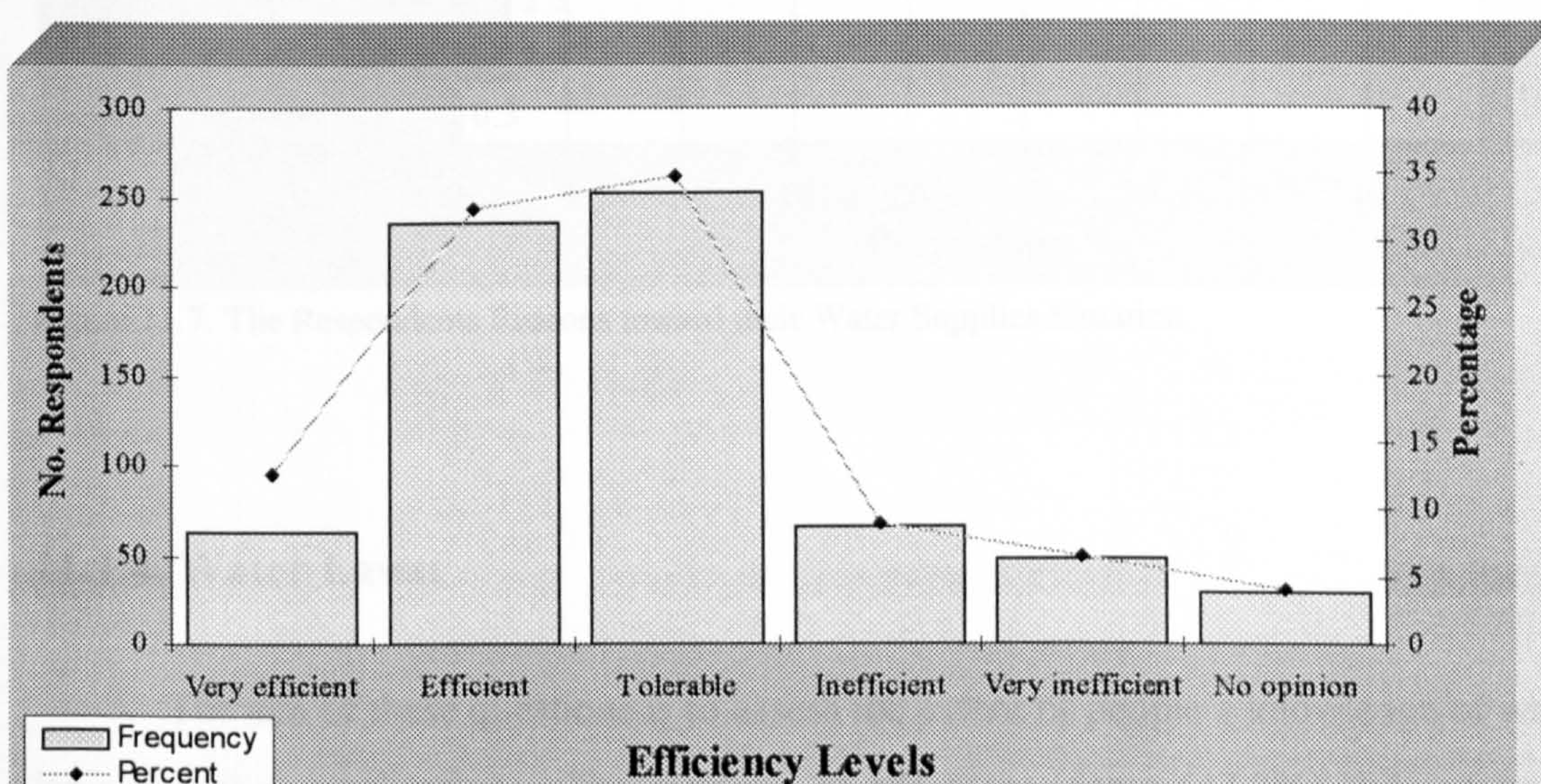

Figure 11.6. The Respondents Water Supply Efficiency.

When asked about the reasons for their water supply situation, 9.5% of the respondents attribute this to continued leakage (Figure 11.7). Another 8.1% suffer from shortage of water. Those that indicated a lack of effectiveness of the network attributed it mostly to water leakage, lack of water or water quality.

On the other hand, around 15.9% confirm the network is effective. Around 6.2% attribute the good quality to regular maintenance, while 2.5% attribute it to the newness of the network and 2.5% affirms the efficient set-up of the supply.

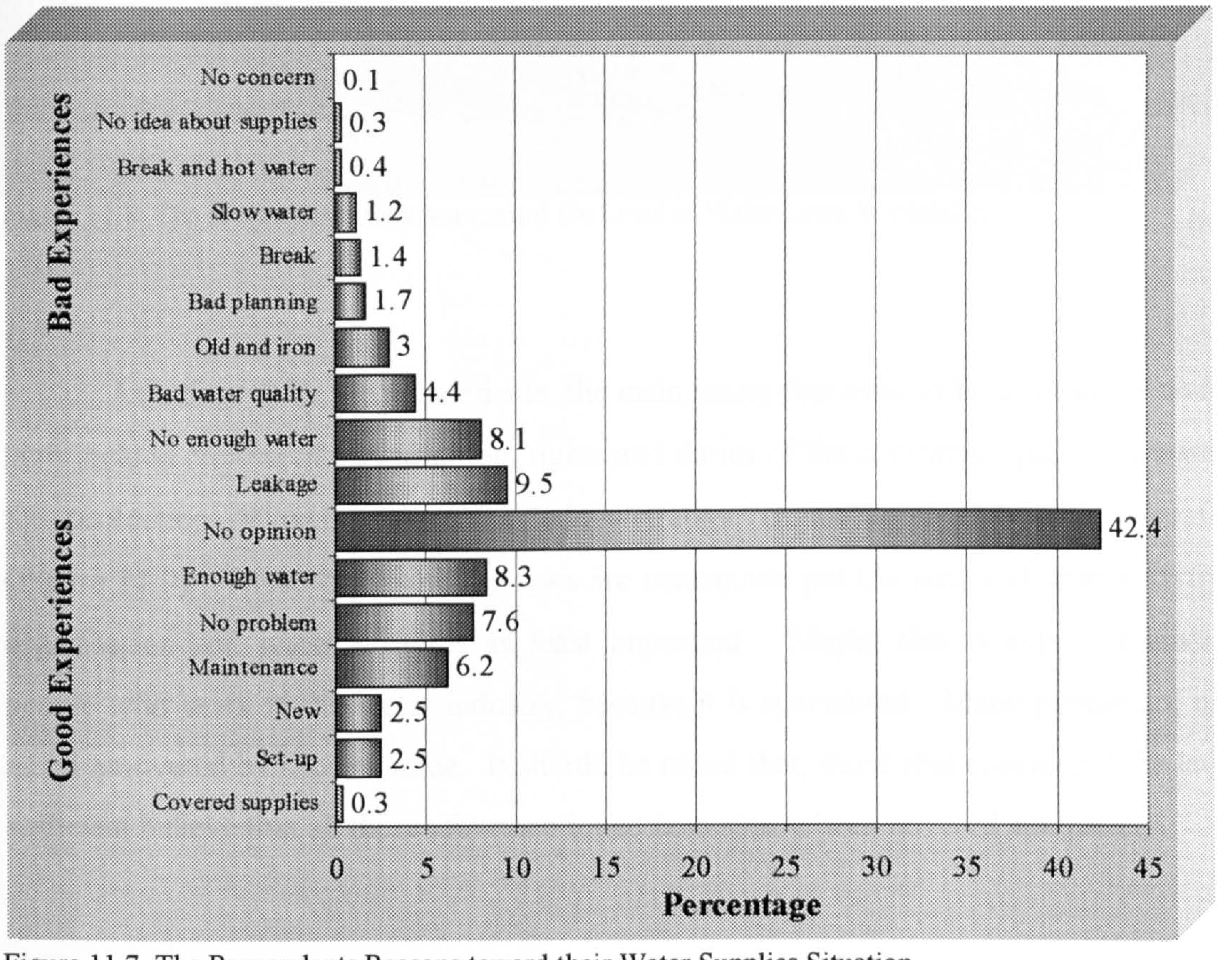

Figure 11.7. The Respondents Reasons toward their Water Supplies Situation.

11.1.4. Water Laws:

The aim of these questions is to assess the extent of people's knowledge of water laws and their application. The majority of the respondents (47.2%) did not know whether these laws existed, while a similar percentage (46.4%) believed that the current existing laws are not sufficient (Figure 11.8). A small percent (6.4%) confirmed that the existing laws are sufficient.

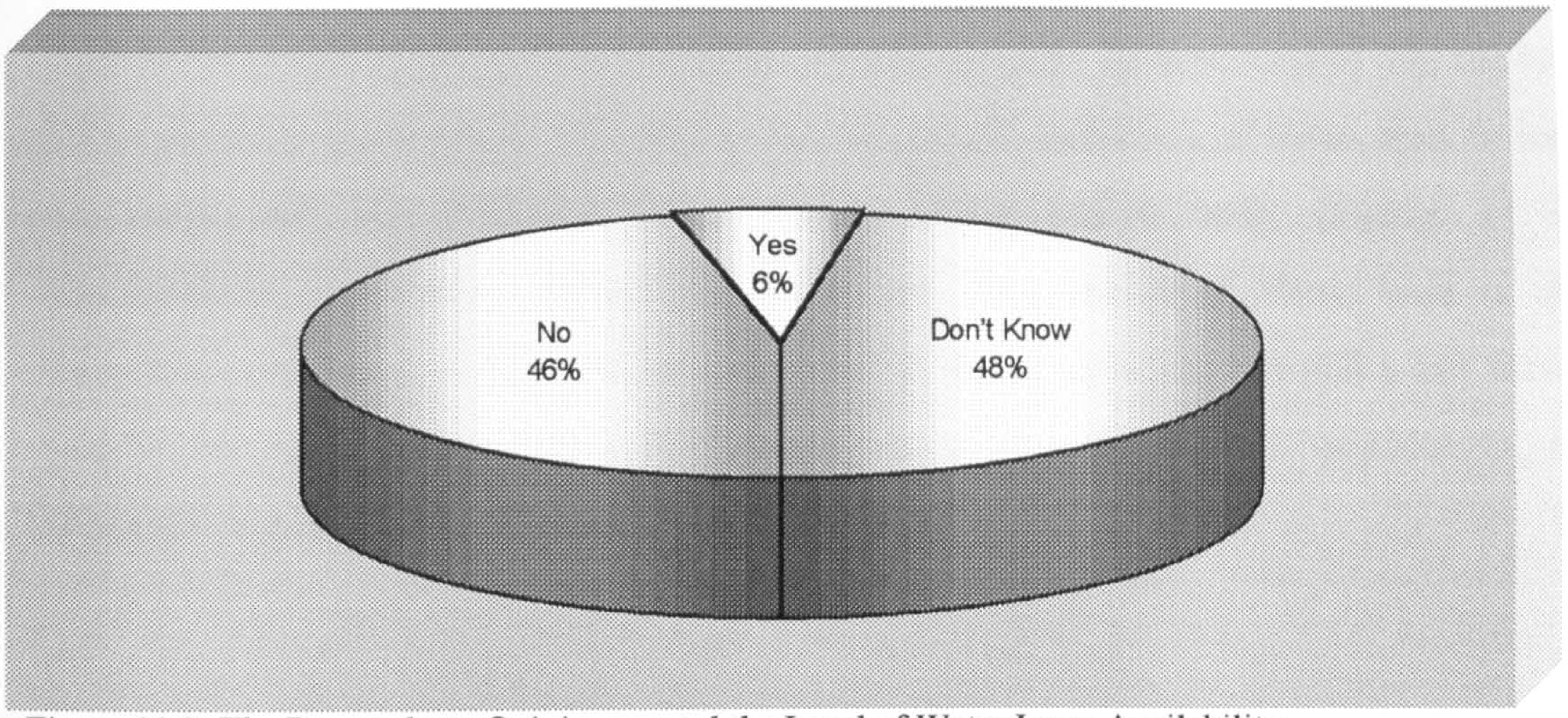

Figure 11.8. The Respondents Opinion toward the Level of Water Laws Availability.

As indicated by the respondents, the main issues that need to be covered by water laws include control of consumption, rights and duties of the consumer, quality of water, the protection of water resources, administrative, organisation and water disputes (Figure 11.9). Those that think the laws are inadequate put the issues of administrative organisation and water disputes as least important. Maybe this is expected among people who work in the water industry, because it is specialised. Many people are not much motivated by such an issue. It should be noted that, those that considered the laws sufficient believe that all these aforementioned issues have been covered adequately.

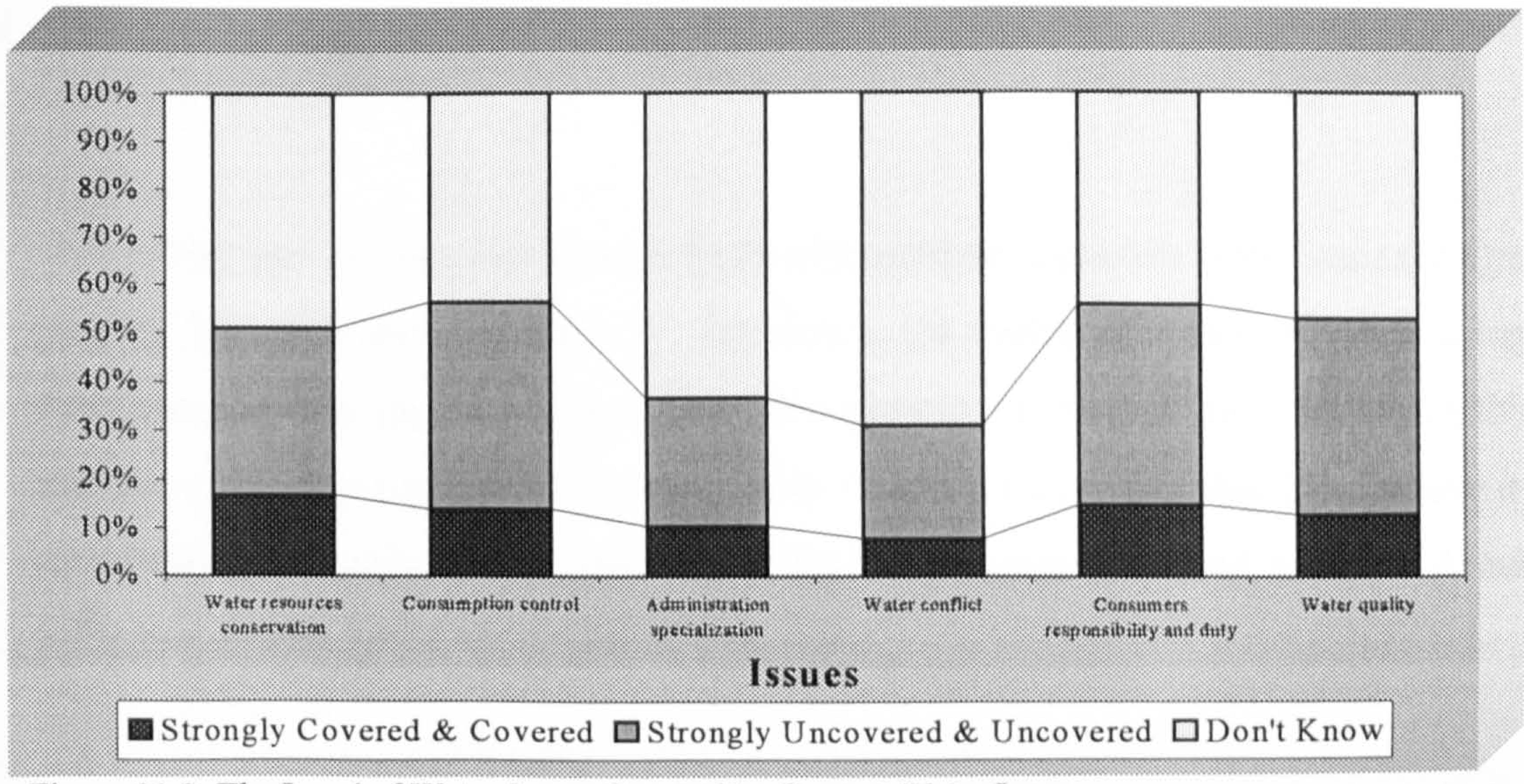

Figure 11.9. The Level of Water Issues Covered by Current Water Laws.

It was clear that the most important influence on people's behaviour and attitudes towards obeying the law is the sense of justice and equality, in other words that the laws apply equitably to everyone. Additional factors are the suitability of these laws to local conditions and the existence of a strong administrative body (Figure 11.10). Disseminating information about the nature and the content of these laws is also important. The issue of punishment came least in importance but it is still a key factor. Among the other factors suggested by the respondents is financial punishment, the utilisation of religion maxims and law enforcement.

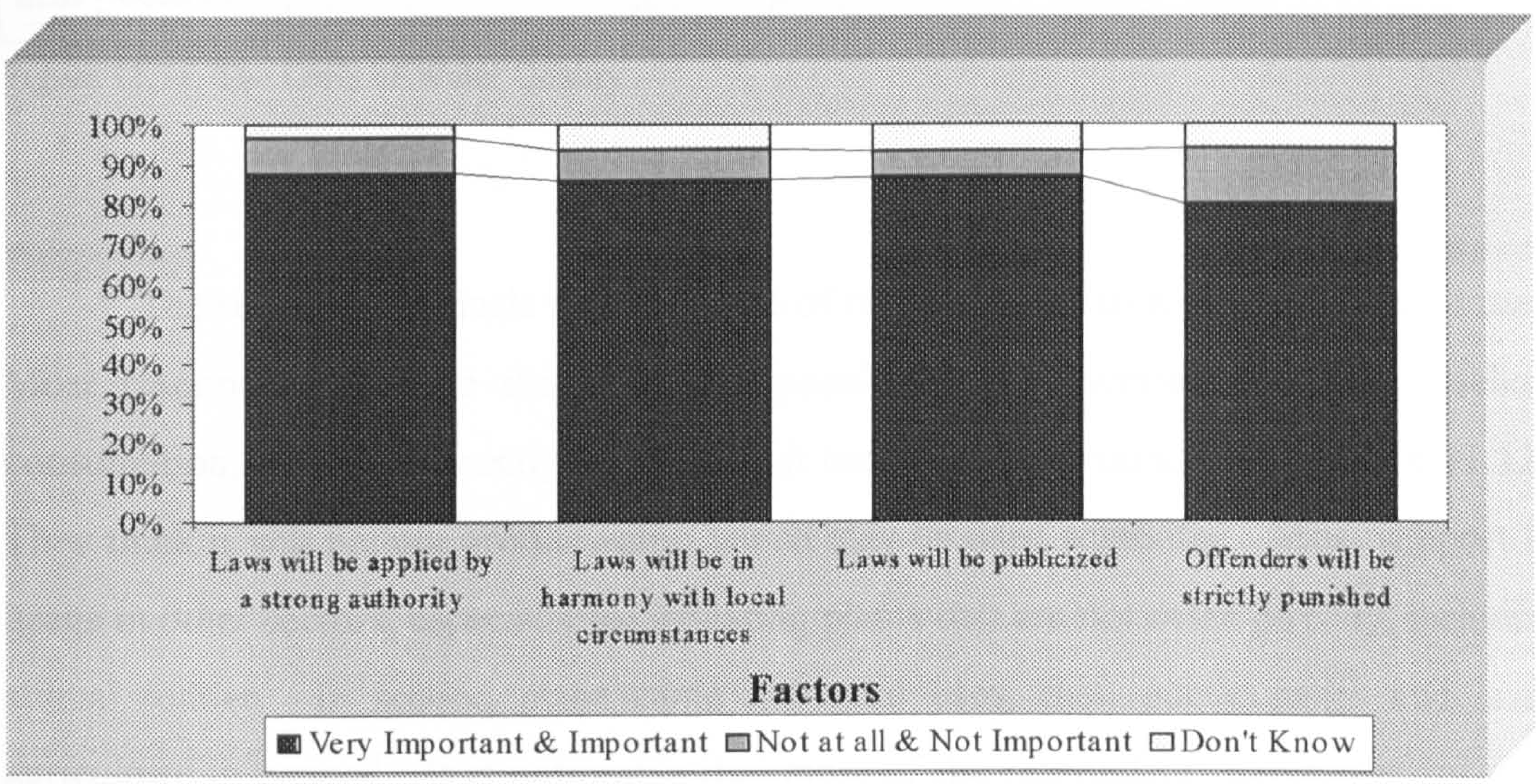

Figure 11.10. The Level of Important of Factors Influencing Obedience to Water Laws.

11.1.5. Water Issues:

This part of the questionnaire deals with multiple important water issues in Qatar (quality, recycling and importation). The first is the quality of water, which is a topic that concerns many people (Section 8.1). The majority (53.9%) of the respondents think that the water they consume is of poor quality (Figure 11.11). Another 26% believe it is reasonably good while a small percent (14.5%) believe it is good and healthy. Around 5.7% had no idea about the quality of their water.

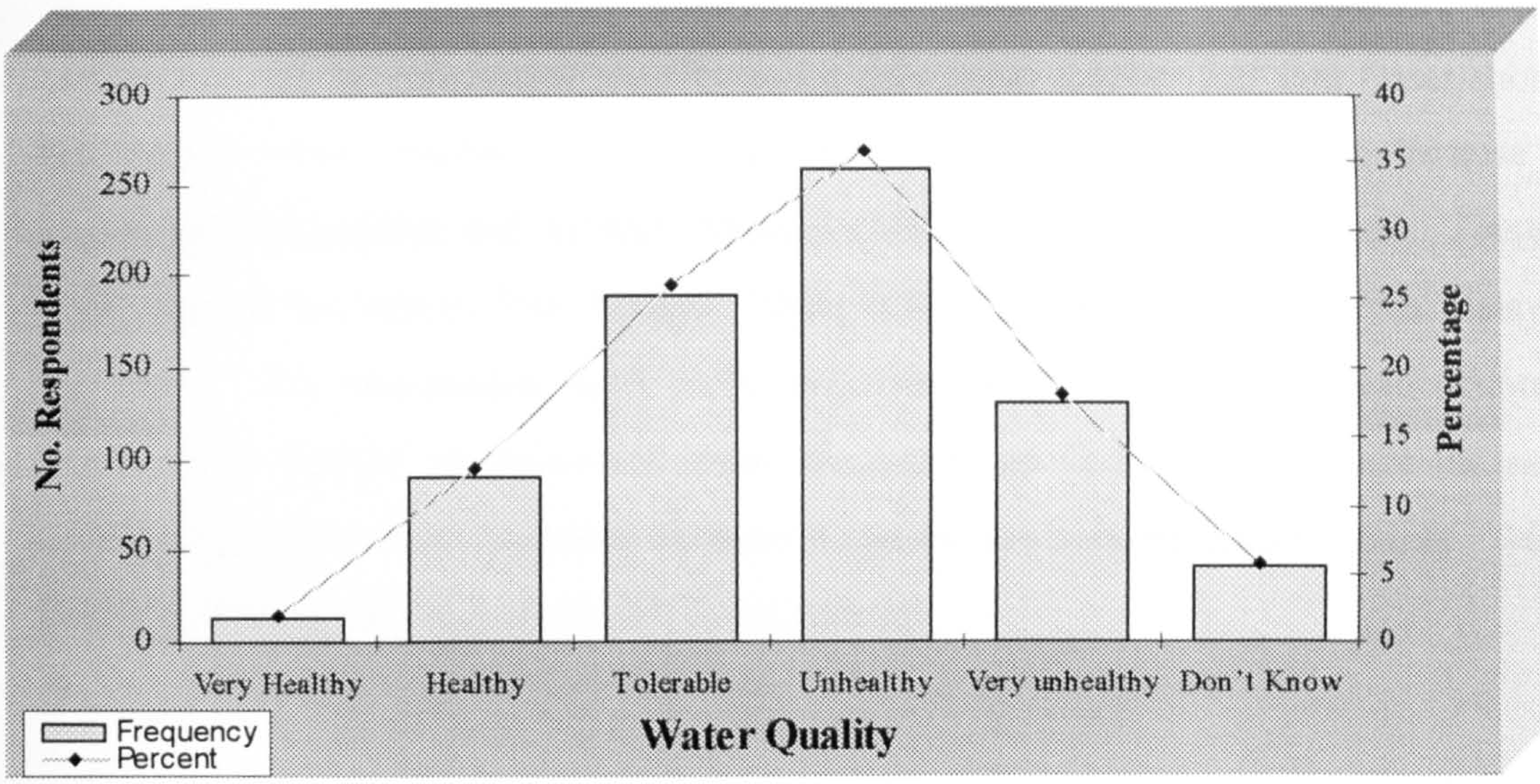

Figure 11.11. The Level of Water Quality.

The second issue deals with the issue of re-using of wastewater for different uses. Most respondents believe that it is not possible to use wastewater for household consumption, or even indirectly by injecting it back into the groundwater (Figure 11.12). They think it will pollute groundwater, which may be used some day. Most support its usage in other sectors, especially for irrigating plants that are not eaten directly; including animal fodder. In second place came industrial uses, then public parks and lastly agriculture in general. It is noticeable that most of the respondents agree that recycled water must be used in some way.

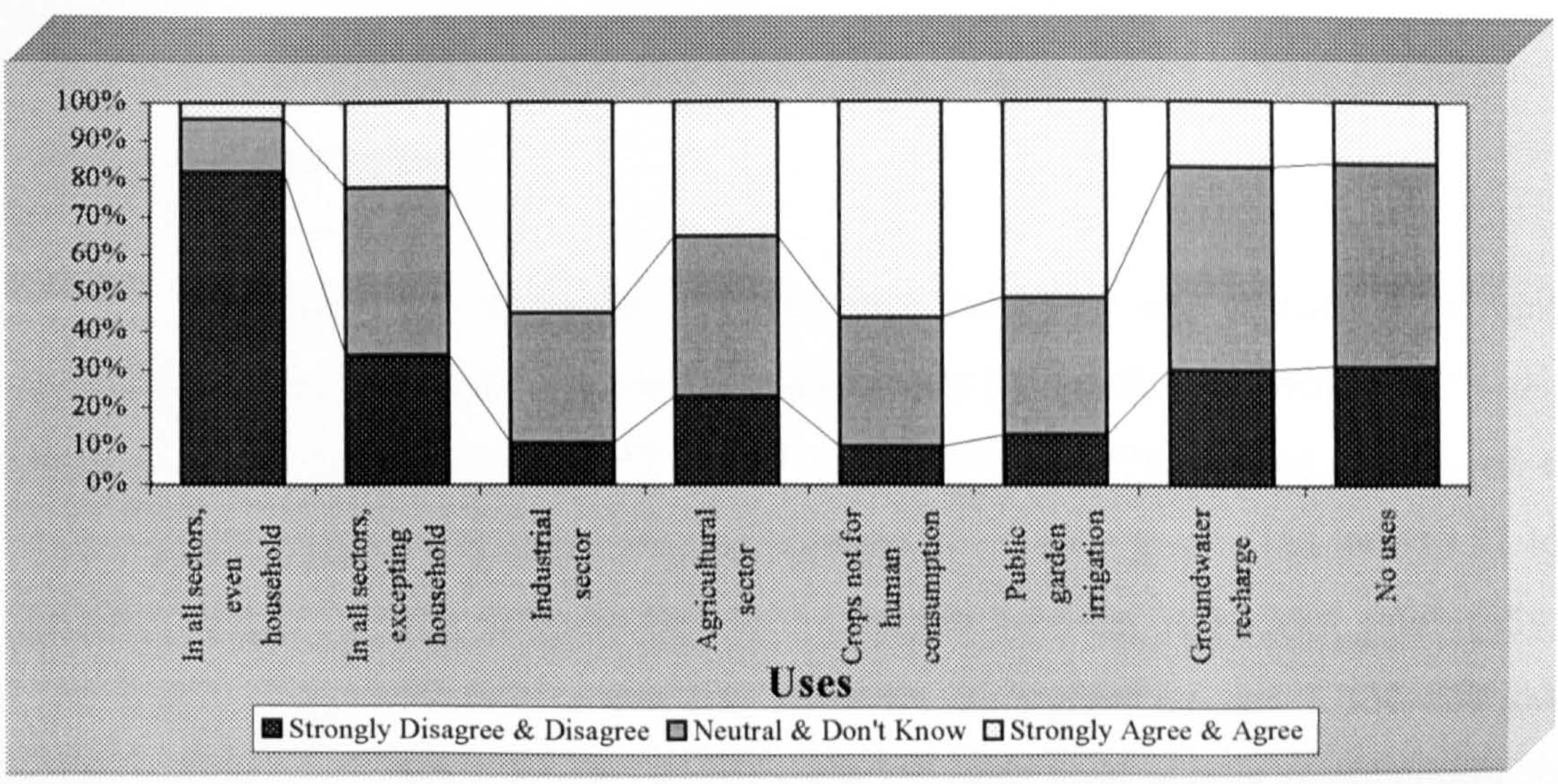

Figure 11.12. The Respondents Opinion toward Using Recycled Water.

The third issue concerns importing water (Section 6.4). The majority of the respondents are hesitant about the idea and a substantial number feel that Qatar should not import water (Figure 11.13). Import from Iran or even Pakistan because of geographical proximity and friendly relations (Muslim countries) is favoured. There is some support for import from Turkey. There is little support for import from Malaysia and Japan. The respondents most prefer importing water from Arabian Gulf countries (maybe they thought about bottled water because other Gulf countries have the same problem) or other Arab countries because it causes less concern about security. Most prefer to depend on desalination as a local resource.

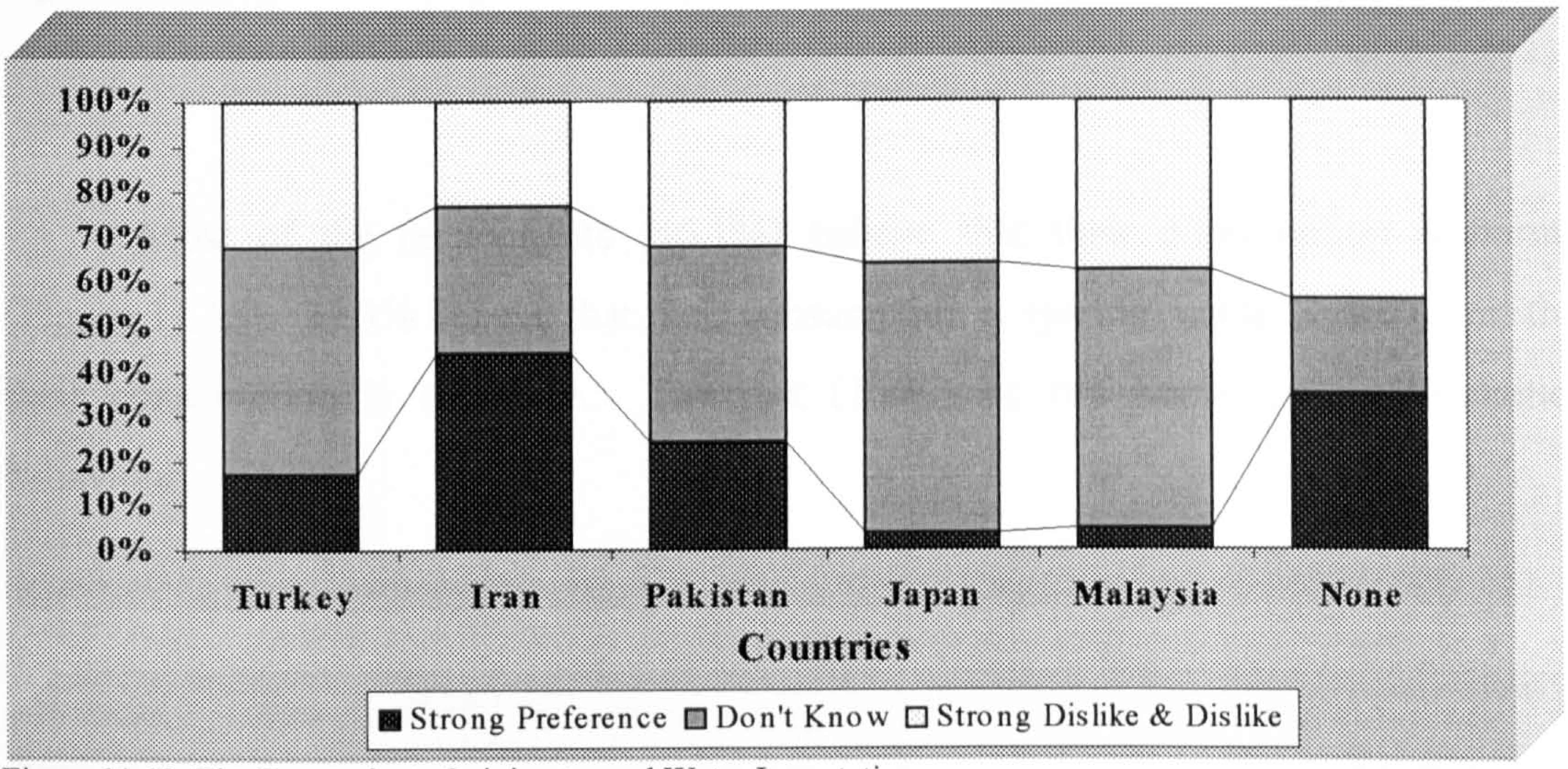

Figure 11.13. The Respondents Opinion toward Water Importation.

11.1.6. Consumption:

The knowledge of society's consumption behaviour and attitude is extremely useful for formulating policy to control consumption (Appendix 7). While 13.3% think they consume between 10 to 39.9 $gald^{-1}$ (45.4-181.84 ld^{-1}), around 16.9% of the respondents estimate that they consume between 40 to 69.9 $gald^{-1}$ (181.84-318.22 ld^{-1}) (Figure 11.14). 13.3% estimate that they consume between 100-129.9 $gald^{-1}$ (454.6-590.9 ld^{-1}). Only 5.1% believe that they consume the highest amount – 130-160 $gald^{-1}$ (590.9-727.3 ld^{-1}). Many (39.2%) do not know the exact level of their consumption.

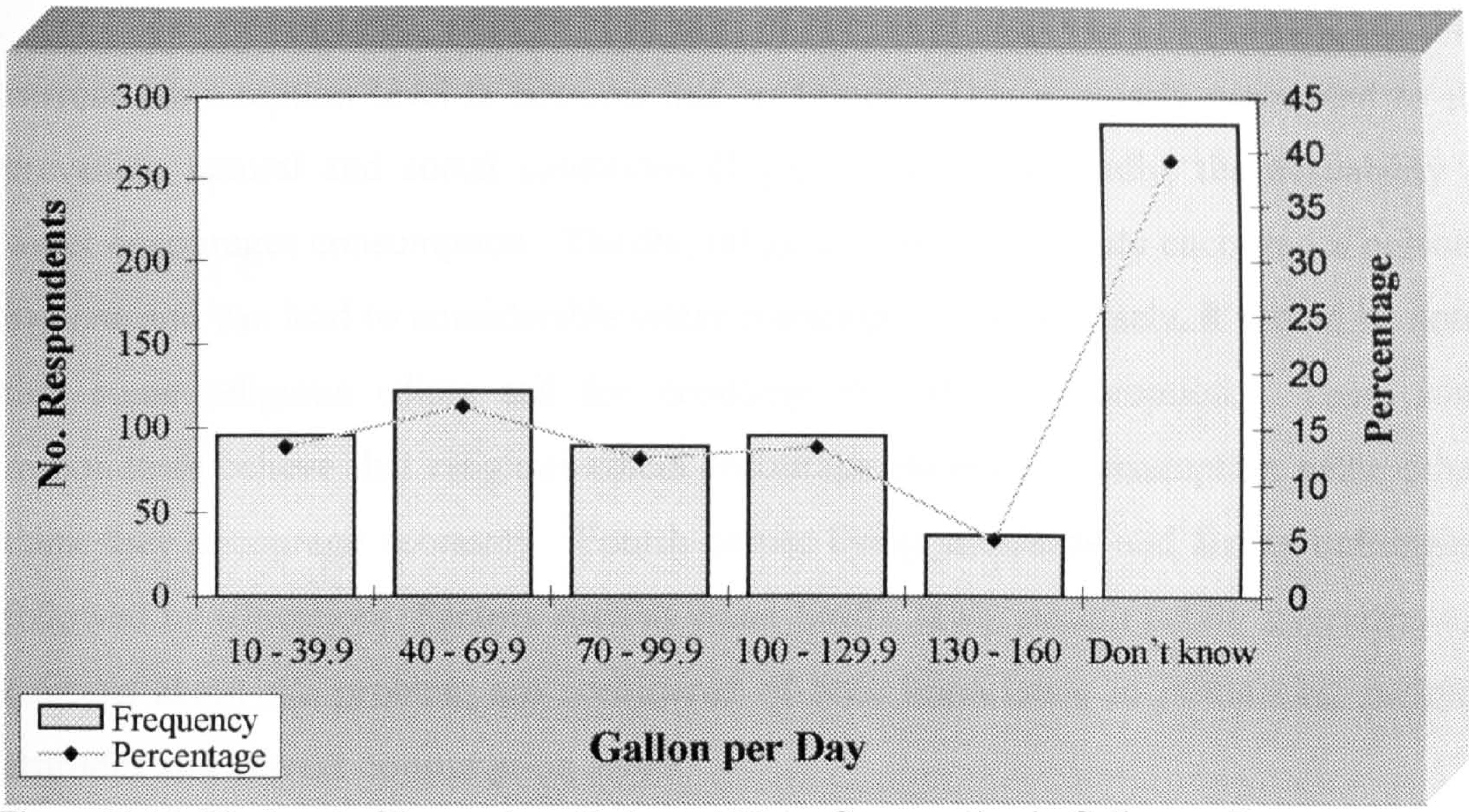

Figure 11.14. The Level of Respondents Estimated Water Consumption in Gallon per Day.

Most of the respondents (46.1%) believe that their consumption is normal (Figure 11.15). 29.3% believe that their consumption is sparing, while 22.8% admit that their consumption is excessive. The rest (1.8%) do not know their consumption behaviour.

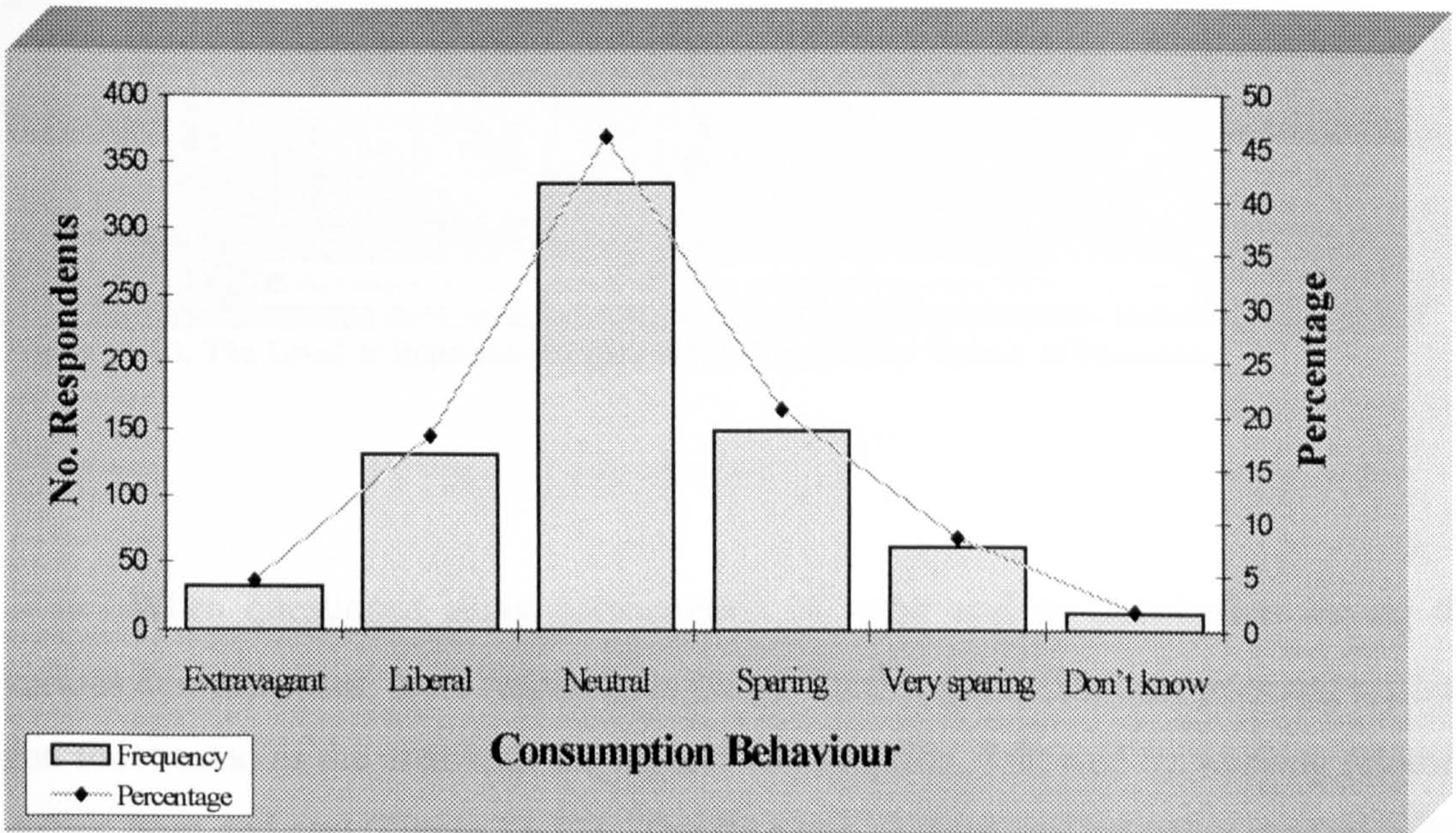

Figure 11.15. The Respondents Opinion in themselves as Water Consumers.

The respondents indicate that one of the most important influences on their current consumption level is customs and traditions. This is closely connected to the prevailing natural and social conditions (Figure 11.16). Secondly, the availability of water encourages consumption. Thirdly, religious maxims and duty encourages personal hygiene and can lead to considerable water consumption. Conversely, it should be noted that some religious edicts call for economy in water consumption. Thus, some respondents believe that religious edicts encourage excessive consumption while others think they encourage economy. Fourth comes living standards and family upbringing, followed by education. Factors such as water tariffs, laws, raising public awareness and concern about the problem are considered of little importance in influencing people's attitudes and current consumption levels.

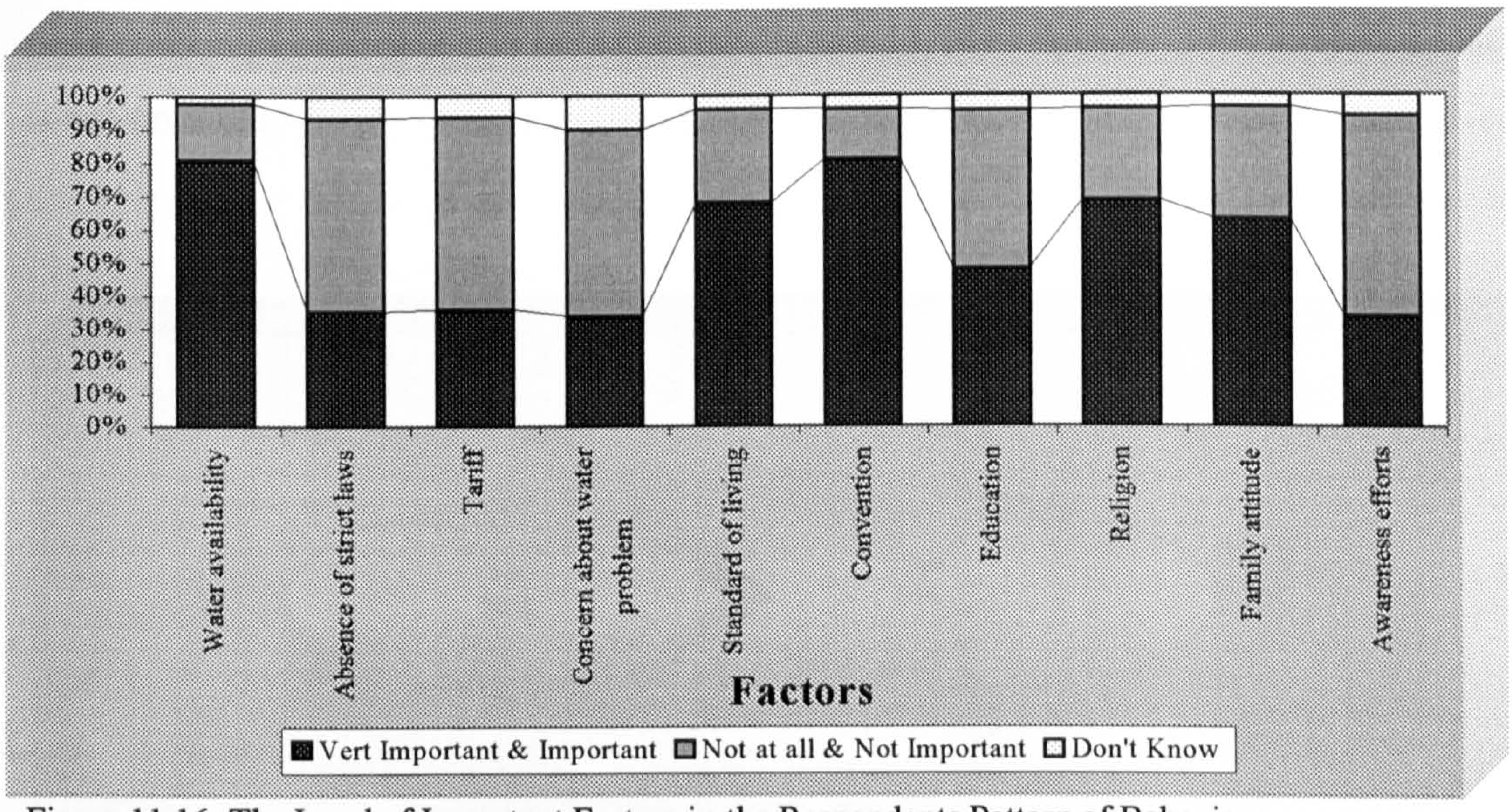

Figure 11.16. The Level of Important Factors in the Respondents Pattern of Behaviour.

When questioned about consumption of water and its distribution among the various domestic uses, most respondents see personal hygiene (shower, personal washing and toilet uses) as the area with the highest consumption, followed by washing (clothes, dishes, floor and car) (Figure 11.17). Thirdly come cooking and irrigating gardens, while drinking came last.

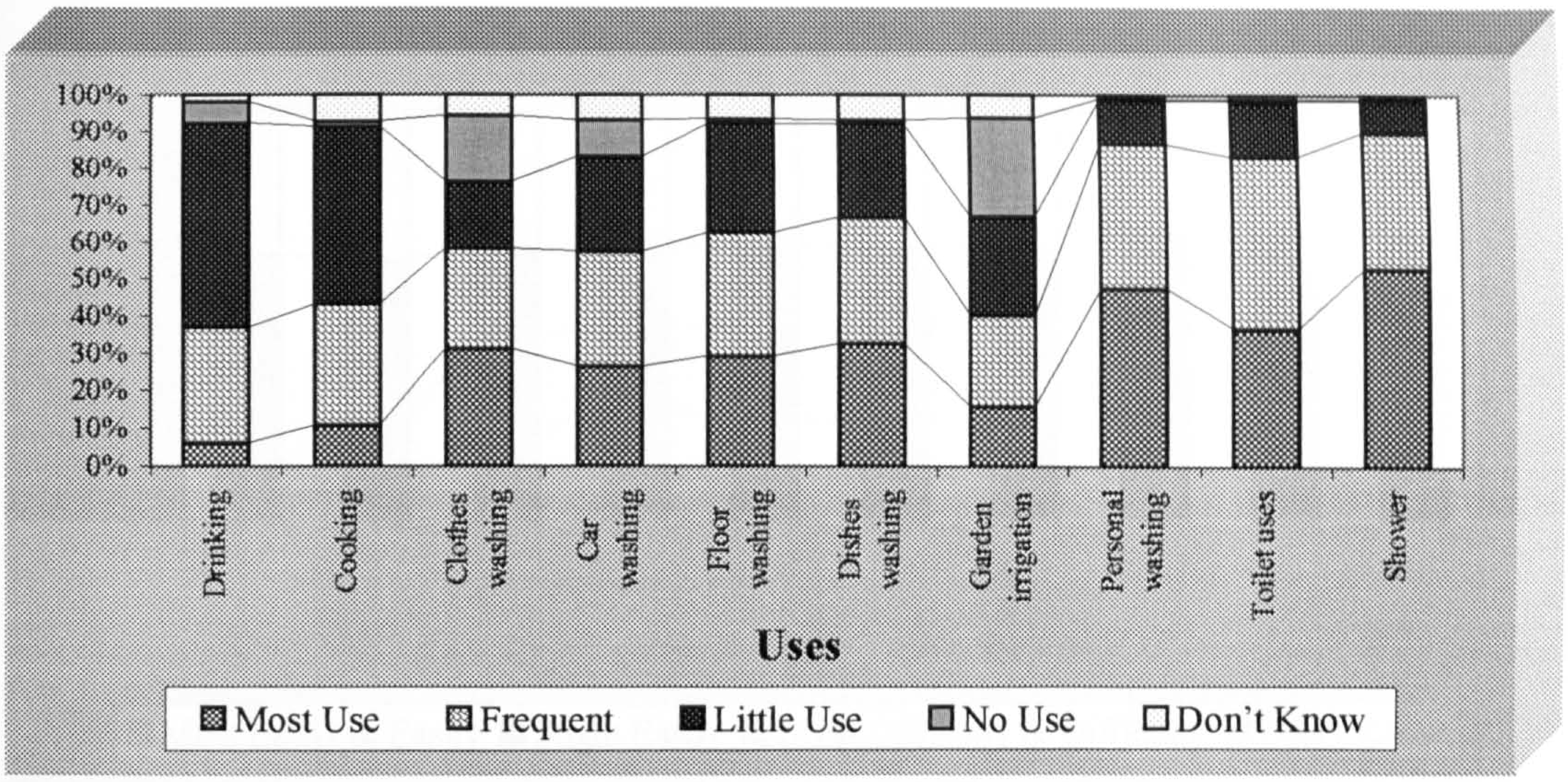

Figure 11.17. The Domestic Water Consumption Levels for Different Purposes.

Most respondents (61%) indicated, when asked about the possibility of reducing their consumption that it can be achieved (Figure 11.18). Around 39% indicated that it is not possible.

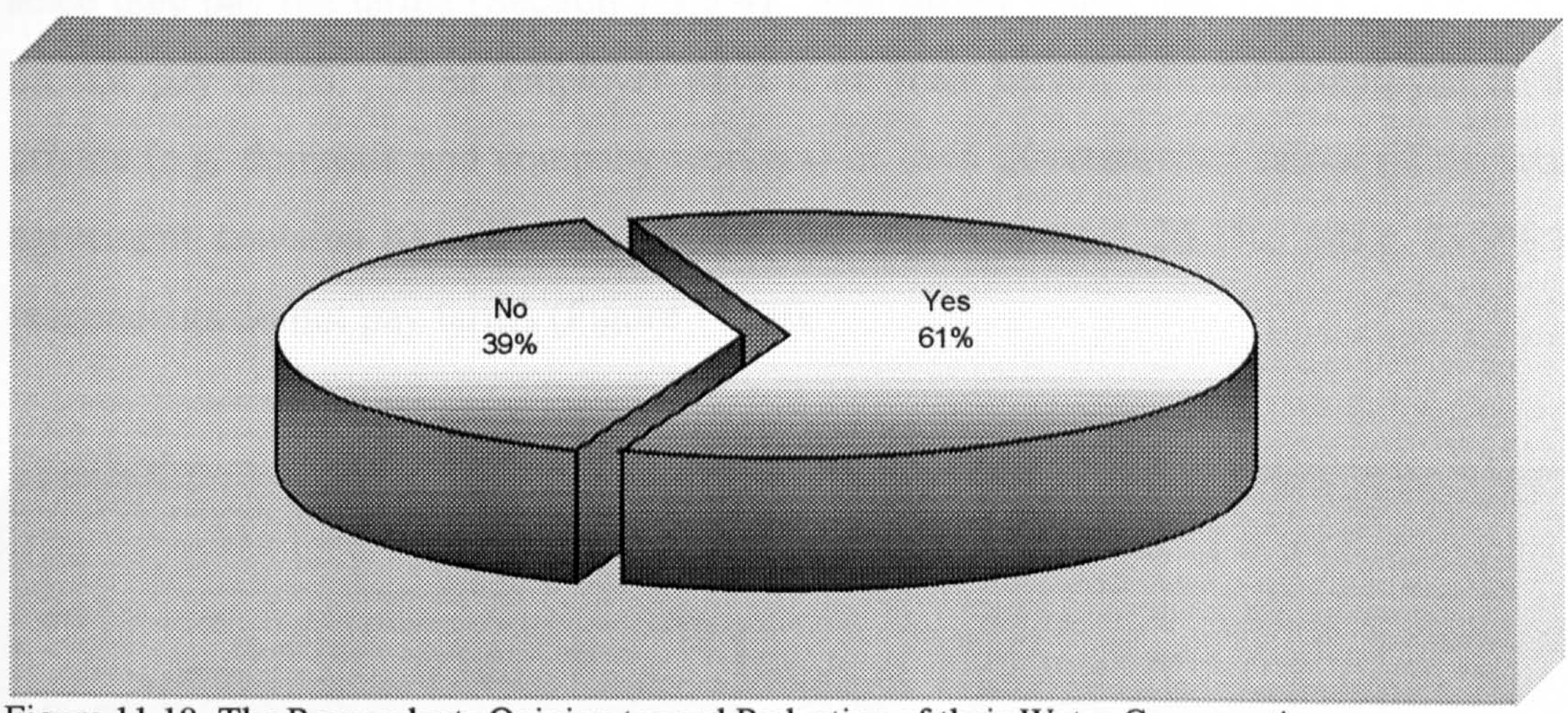

Figure 11.18. The Respondents Opinion toward Reduction of their Water Consumption.

The area that respondents thought most feasible for reduction is irrigating gardens (maybe because some have no gardens) (Figure 11.19). Secondly is personal hygiene and washing, as they believe these purposes have the highest consumption, while it was not considered easy to reduce consumption for cooking and drinking.

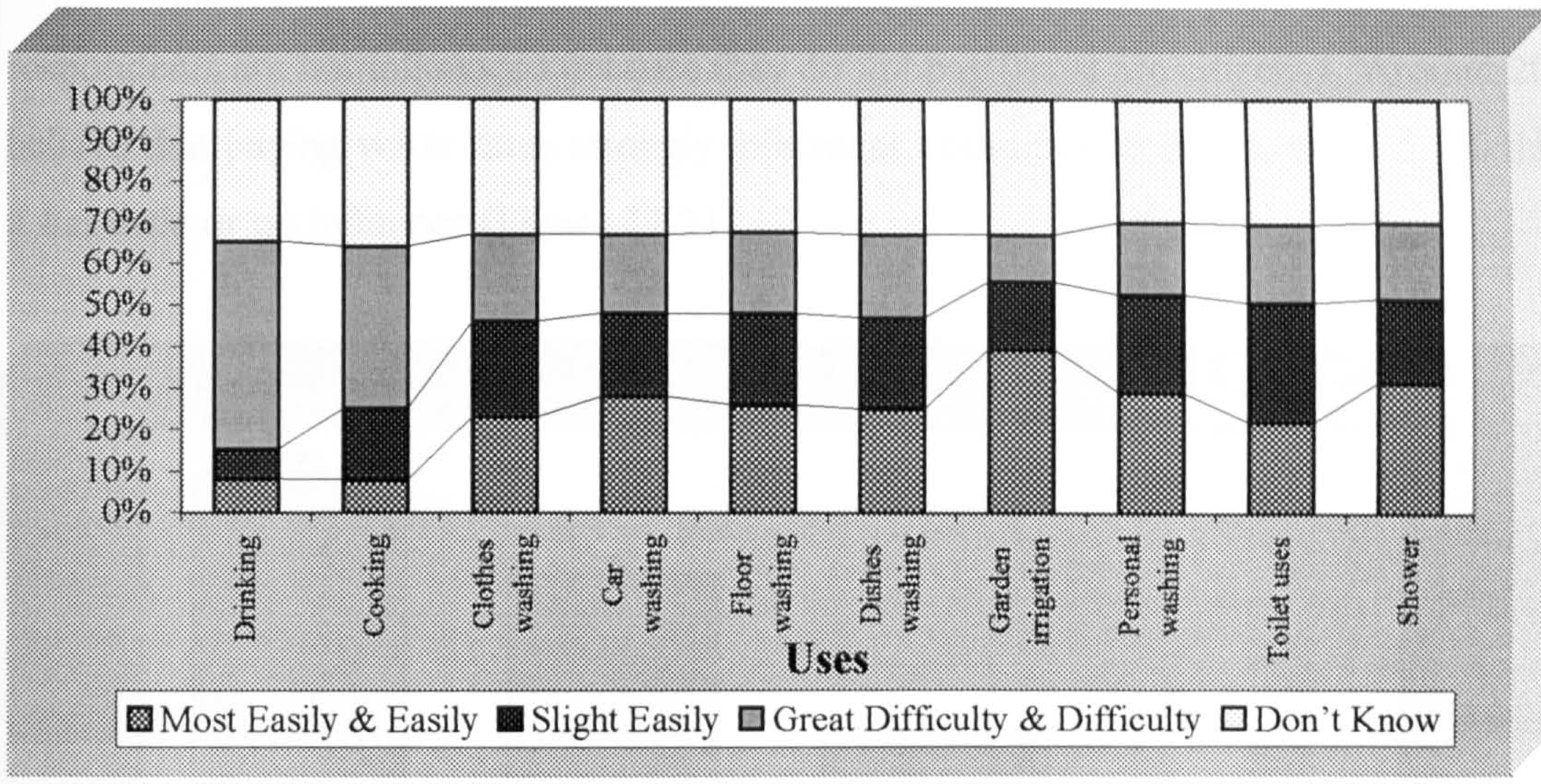

Figure 11.19. The Possibility of Reducing Levels of Water Consumption.

11.1.7. Water Tariff:

This section deals with establishing people's opinion about policy concerning water tariffs. This today concerns foreigners, and the commercial and industrial sectors, since they pay the tariffs (Section 7.3.5.4). The survey found that 13.4% of foreigners do not pay tariffs. Their employer pays it on their behalf, whether employed in the private (e.g. domestic and company workers) or even governmental sector (if the work agreement contains it). The percentage that pay is around 26.1%, while 73.9% of respondents do not pay tariffs (Figure 11.20).

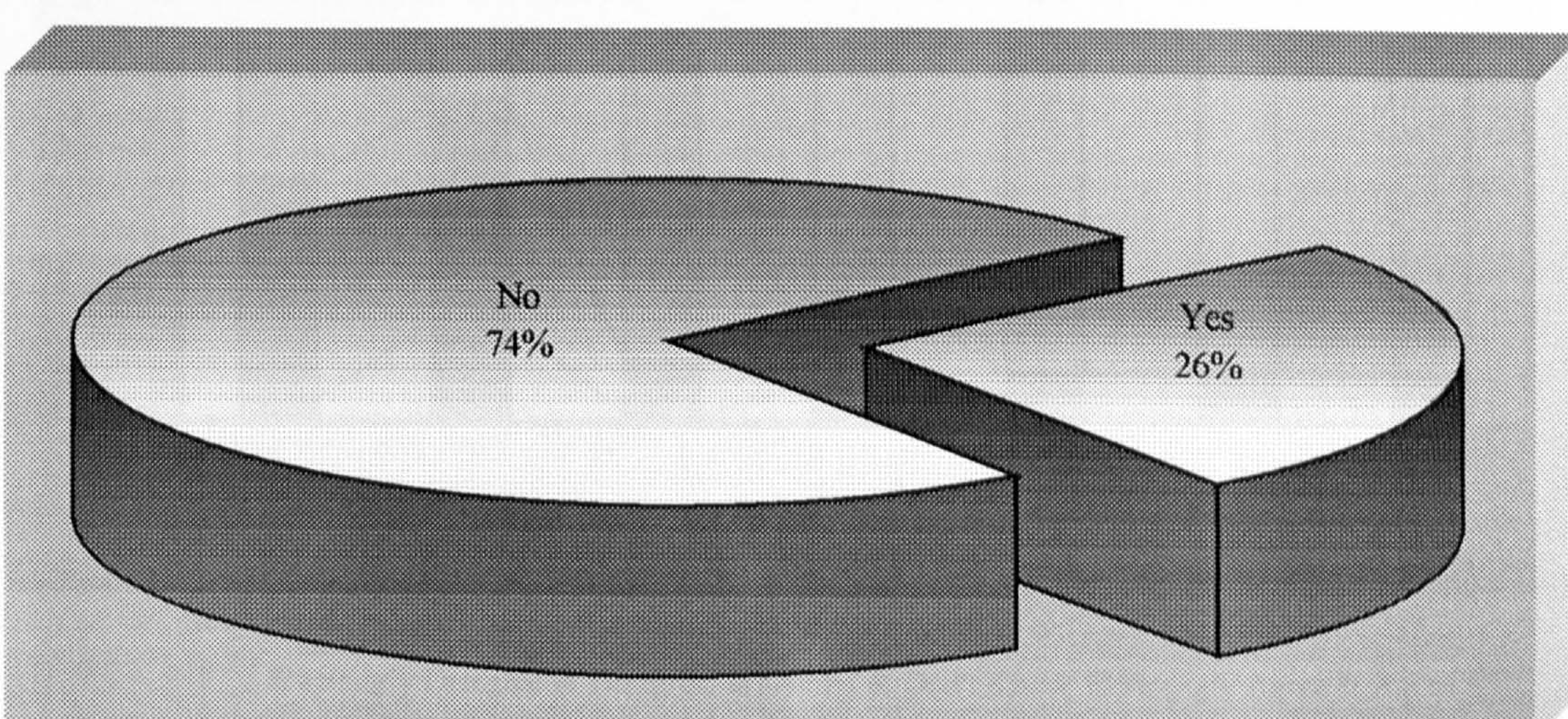

Figure 11.20. Respondents Paying the Water Tariff.

When questioned about the influence of the current water tariff, 74.3% of the respondents are not influenced because they do not pay (most are citizens). Around 20% believe that paying water rates strongly influences consumption levels, while 5.7% think it has little or no influence (Figure 11.21).

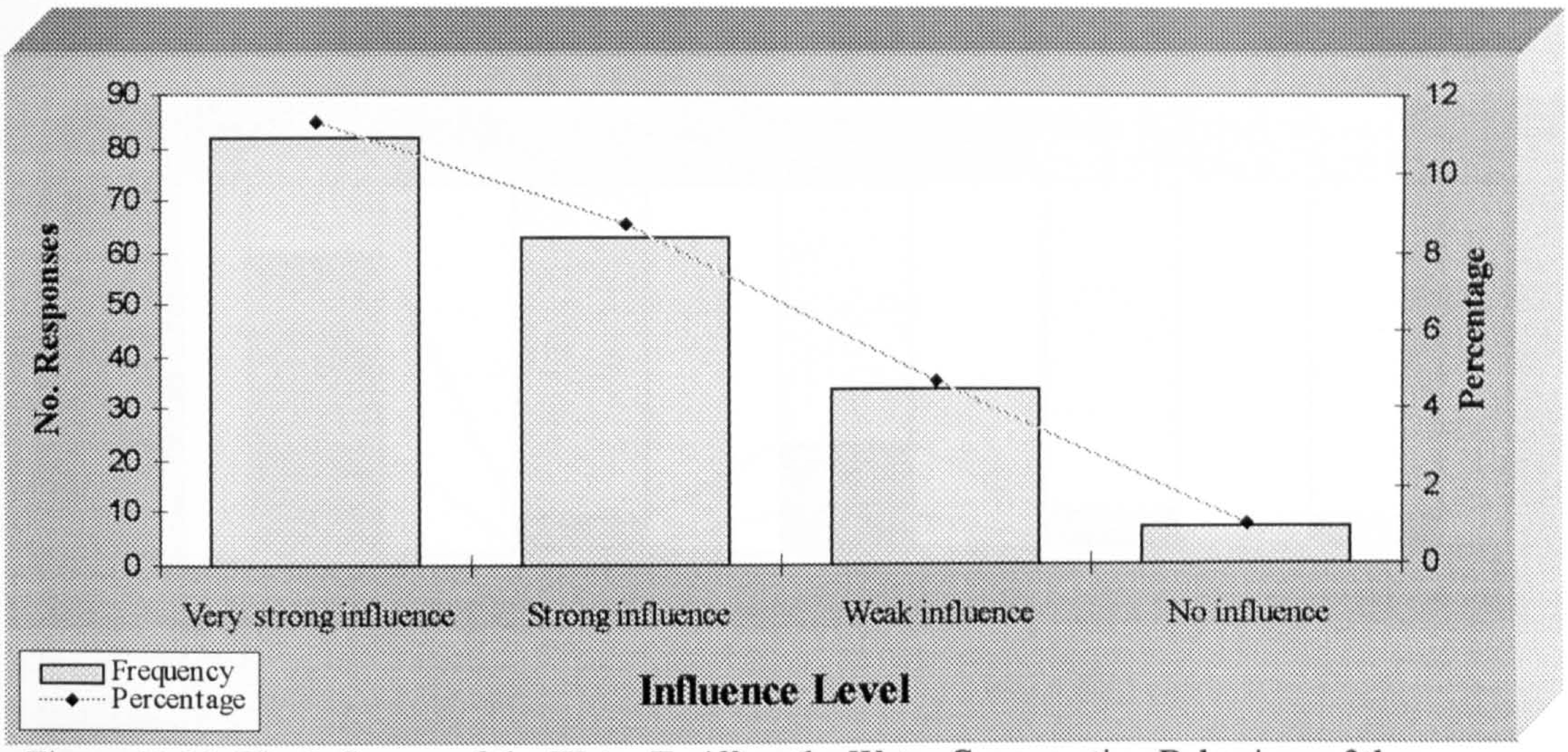

Figure 11.21. The Influence of the Water Tariff on the Water Consumption Behaviour of those Respondents who Pay the Tariff.

When questioned about their expectation in return for paying tariffs, improvement of water quality, taking into account family conditions and level of consumption came top (Figure 11.22). The majority objected to the making the tariff cover the cost of providing the water, even among those that had no idea of how much this might be.

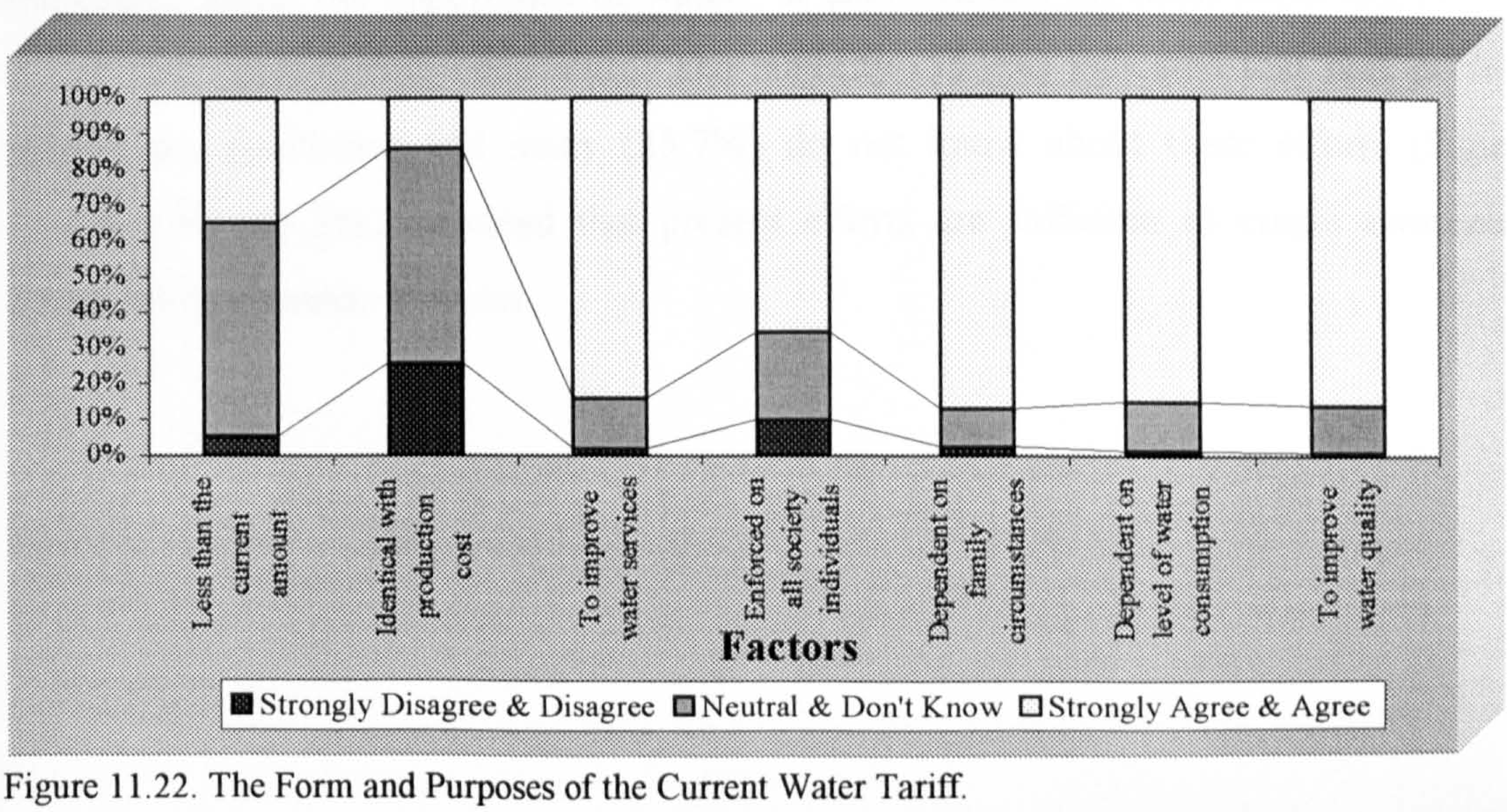

Figure 11.22. The Form and Purposes of the Current Water Tariff.

It was clear, when those that do not pay tariffs were asked the same question, that their expectation was similar to those who do (Figure 11.23). Most respondents objected to the idea of making the tariff equal to the water production and distribution cost. Others suggested that water should be provided free or at nominal charges.

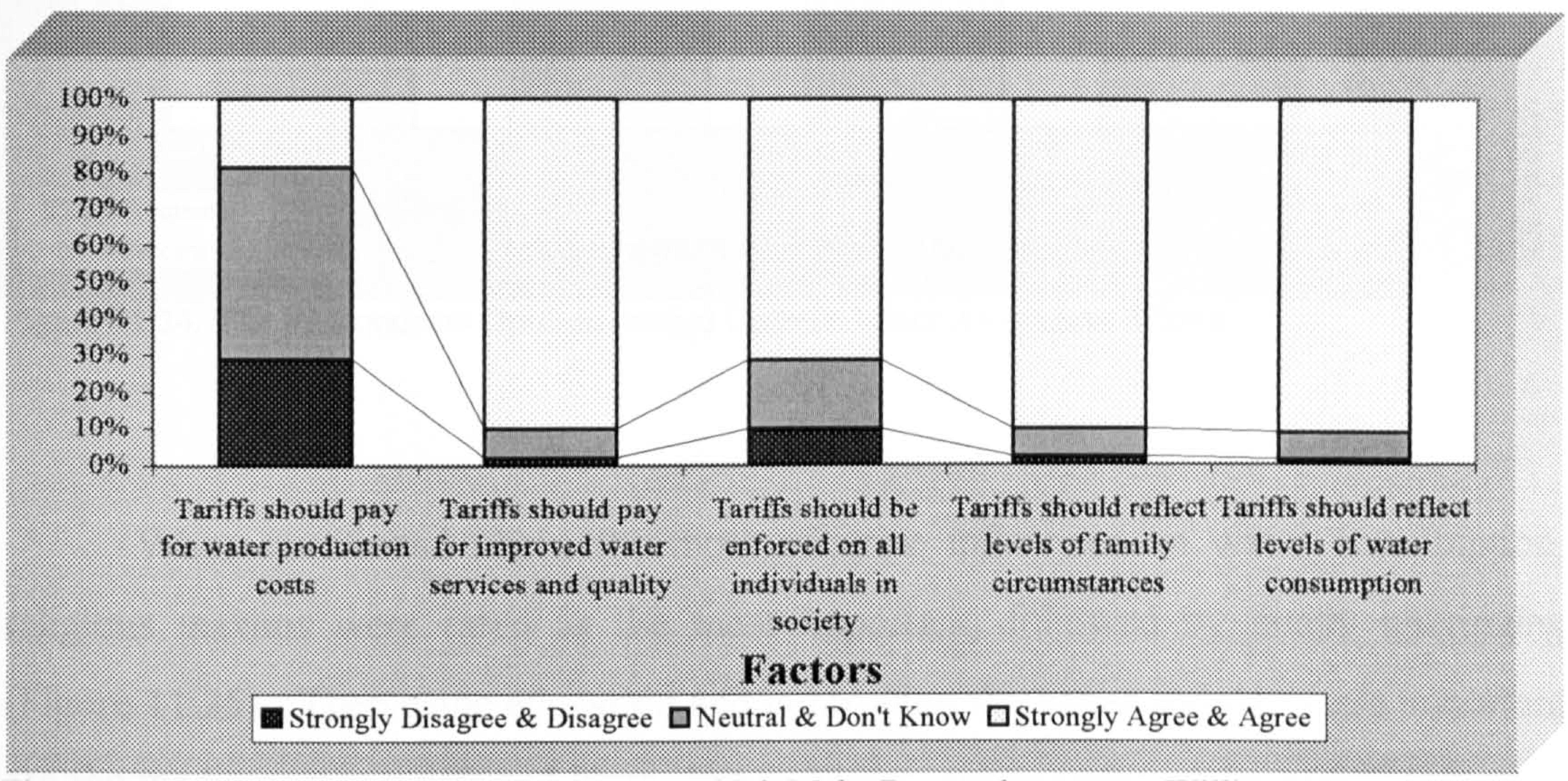

Figure 11.23. The Level of Important Factors which Make Respondents more Willing to Pay the Water Tariff.

11.1.8. Public Relations:

This part of the questionnaire assesses the influence of public awareness campaigns about the importance of water. It also assesses the most important factors influencing consumption behaviour. The majority (55.9%) indicated that that present efforts are insufficient and many (35.7%) do not know about these efforts (Figure 11.24). Few (8.3%) indicated that present efforts are sufficient to create awarenes about the importance of water.

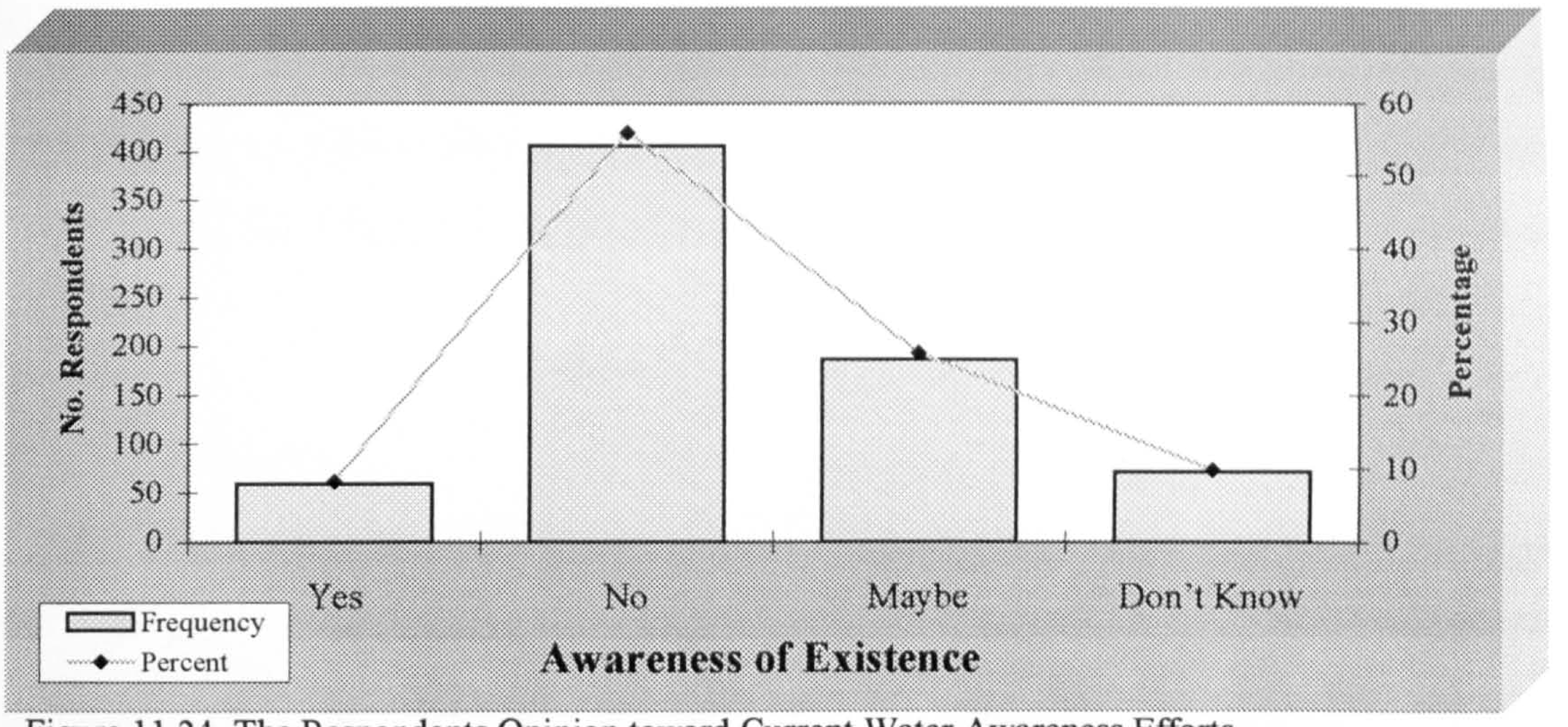

Figure 11.24. The Respondents Opinion toward Current Water Awareness Efforts.

When questioned about the most effective influences on water consumption, religious maxims were rated as the most important, followed by family upbringing (Figure 11.25). Then came education and controlling the water supply. Less important are the media, water tariffs and laws. Prospectuses, conferences, clubs and friends were rated as least important influences.

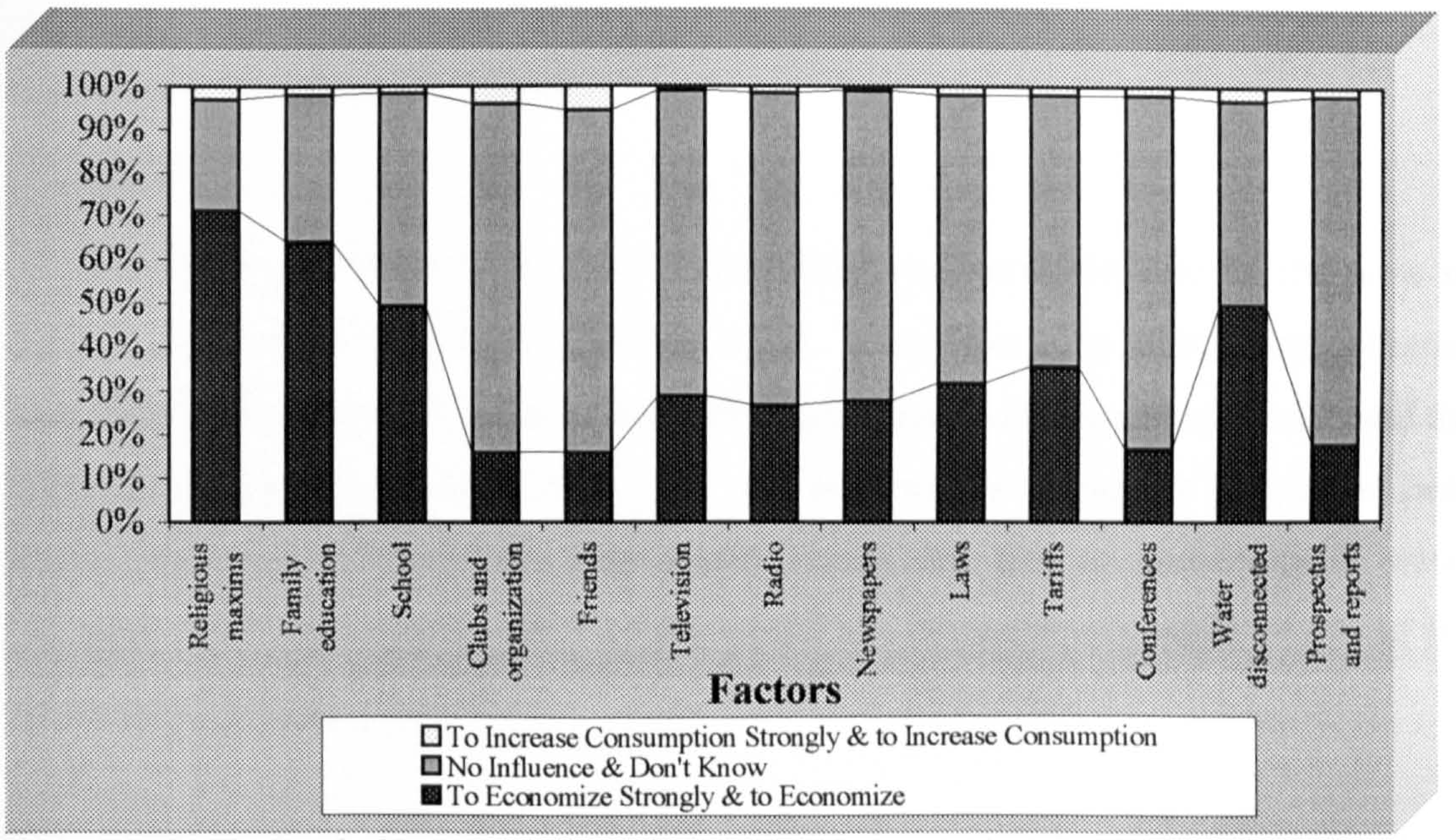

Figure 11.25. The Level of Important Factors Influencing the Respondents Water Consumption Behaviour.

For creation of awareness, the first group of influences are school, family upbringing and religious organisations, following by media then water controls, law and public participation in making decisions (Figure 11.26). Prospectuses, reports and water tariffs were rated next. Least important were conferences and clubs, and lastly influences of friends.

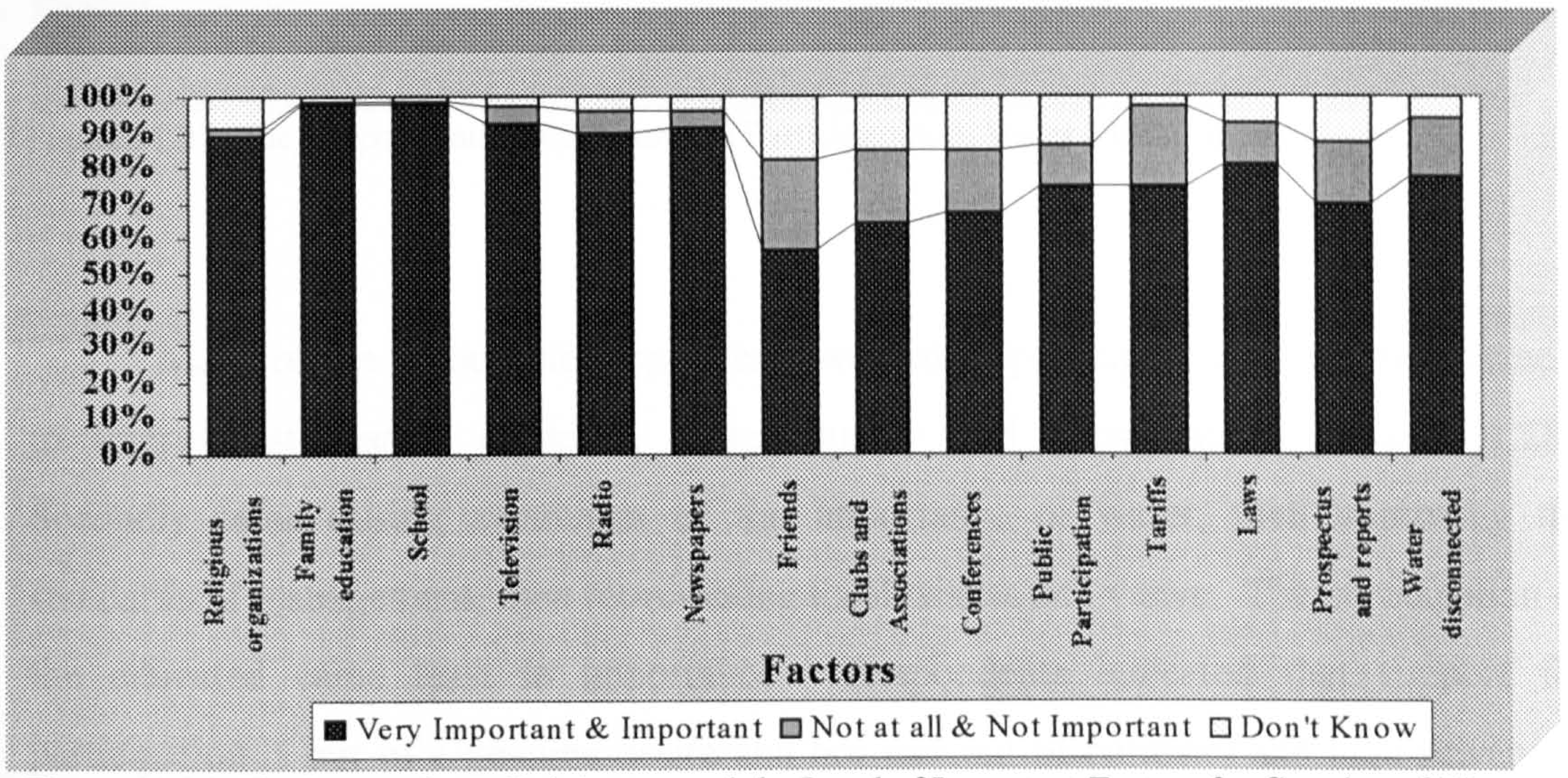

Figure 11.26. The Respondents Opinion toward the Level of Important Factors for Creation of Water Awareness.

11.1.9. Water Administration:

Public participation in water management is considered one of the aims of modern successful administration (Section 3.2.2). It has been adopted by many countries (e.g. USA and Holland) in order to solve problems, raise public awareness and instil the spirit of responsibility in the public. This part assesses the opinion of people in Qatar about this issue. 47% of the respondents would not like to participate in water management (Figure 11.27). Only 37.8% would like to participate, while 14.9% of the respondents have no opinion.

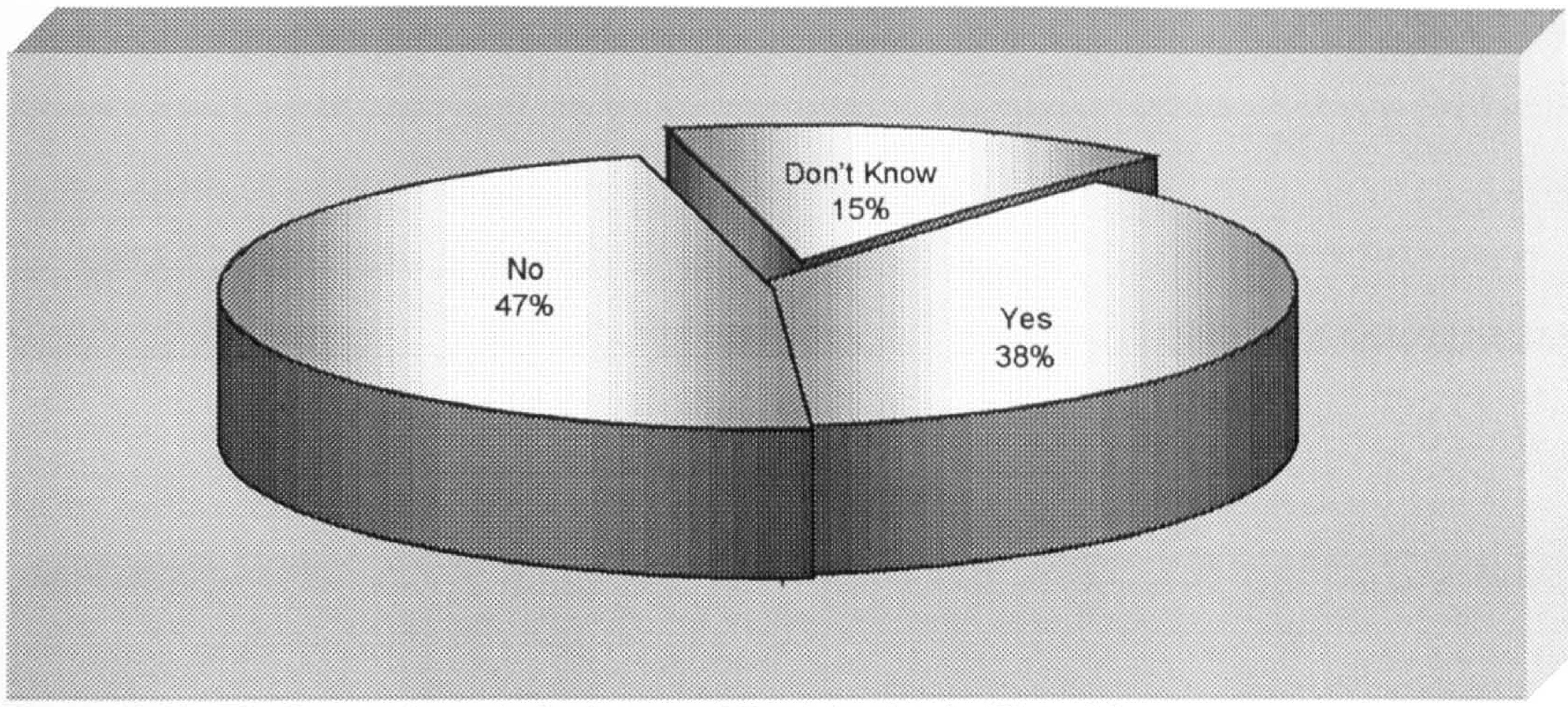

Figure 11.27. The Respondents Attitude toward Participation in Water Management.

Many of the favourable respondents wanted to participate in water management to improve standards, especially water quality and conservation (Figure 11.28). Secondly came raising awareness of the importance of water, then improving the standards of management, then representing local wishes and views. The participation of the educated came least in importance. Respondents indicated that support for participation is out of a genuine desire and not just out of curiosity and inquisitiveness. Others supported the idea of raising awareness in children. There was support for implementing the law on all members of society without exceptions.

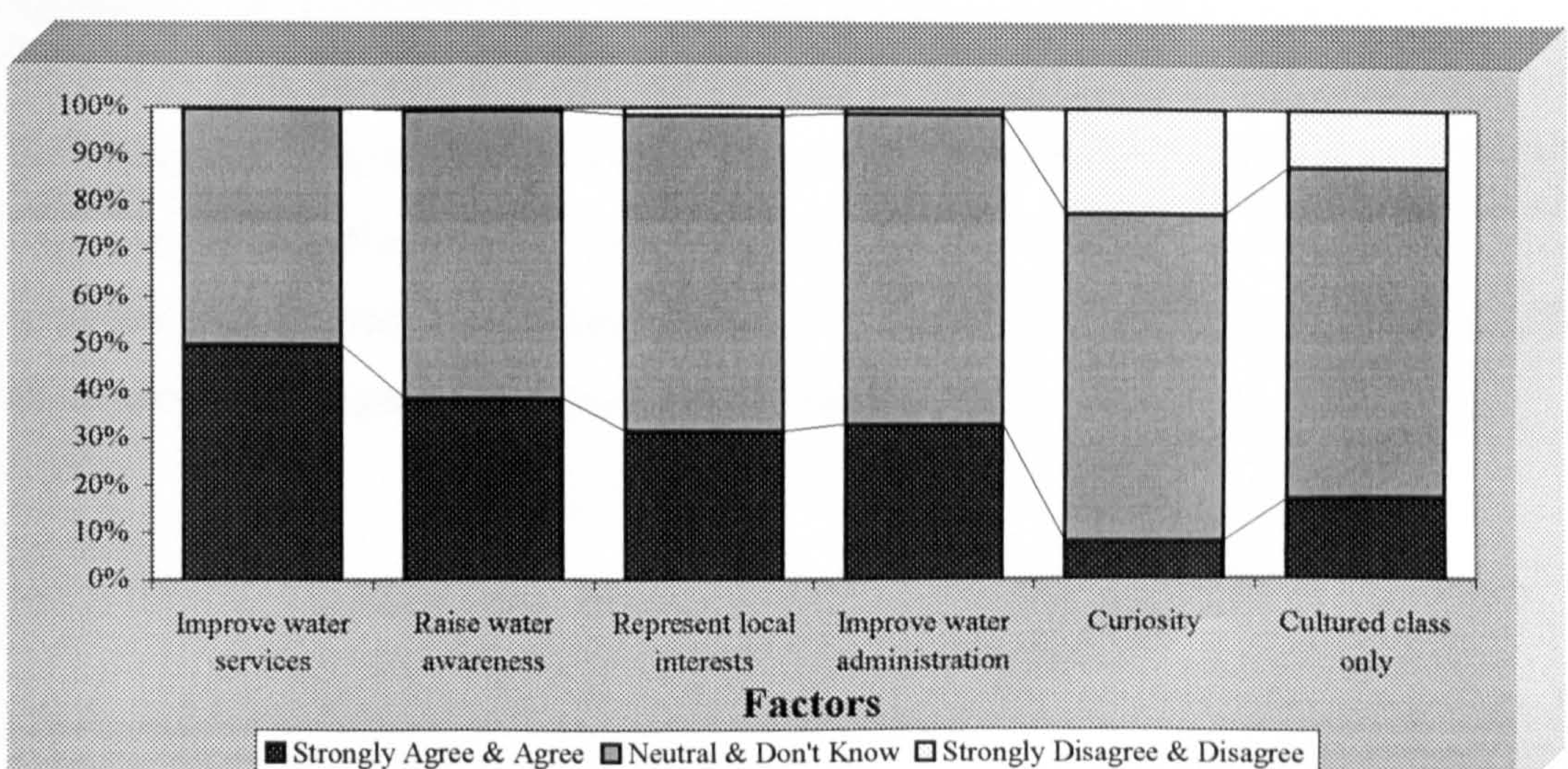

Figure 11.28. The Respondents Attitude toward Acceptance of Participation in Water Management.

When questioned about the forms of participation, participation for the purpose of knowing programs and plans came first followed by participation through advice and consultation (Figure 11.29). Direct participation in making decisions and policy design or indirect participation through a parliament followed.

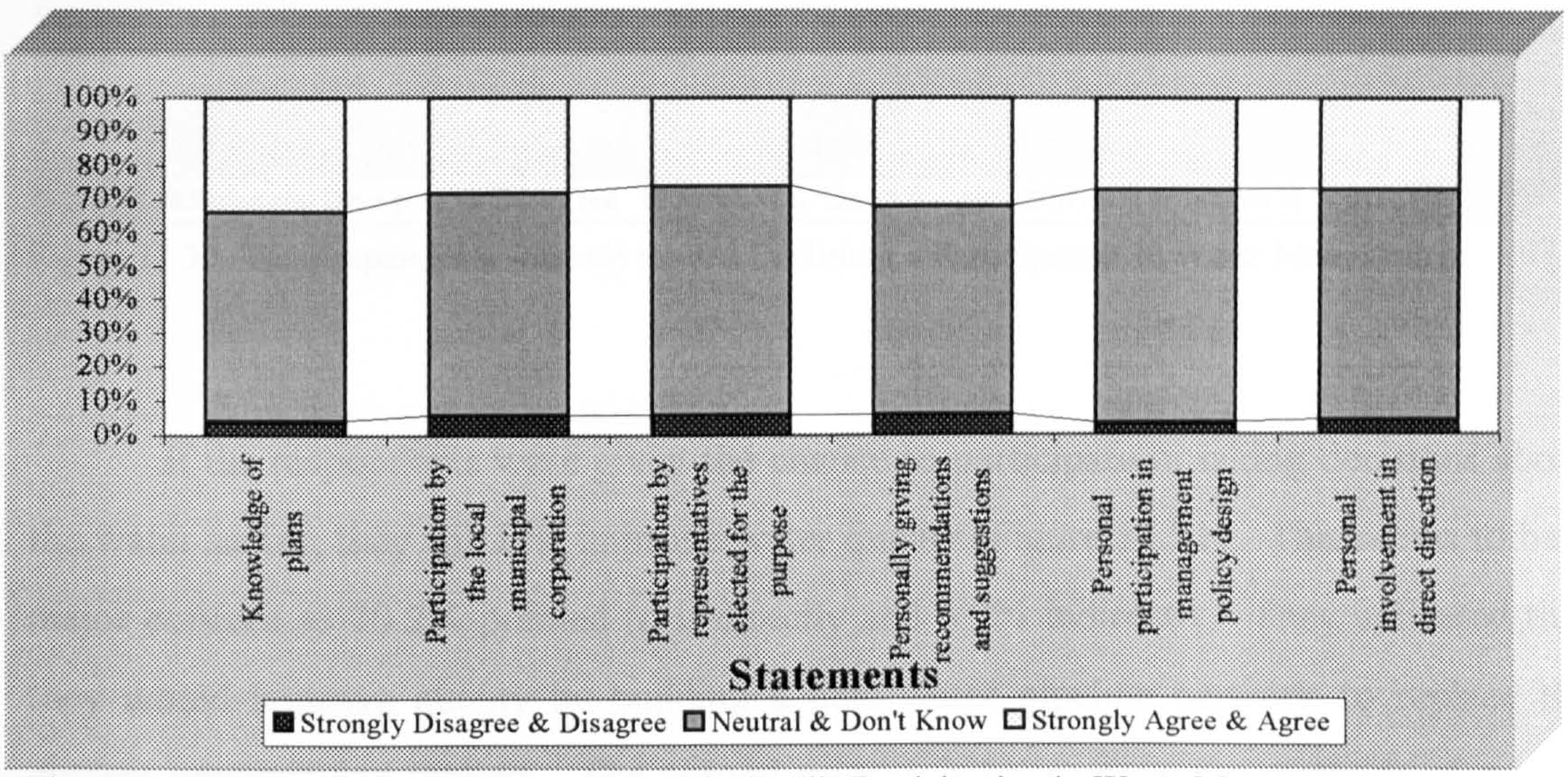

Figure 11.29. The Level of Important Forms for Public Participation in Water Management.

For those opposing participation, the most important reason was their lack of experience of participating in water management, followed by a feeling that the possibility of it happening is very slim (Figure 11.30). Thirdly came the absence of a personal interest to encourage them to participate. Importantly, most of the respondents opposing participation feel that public participation will not harm the water sector. They indicated that this was not because of lack of concern with water issues or because they think present management and policy is successful.

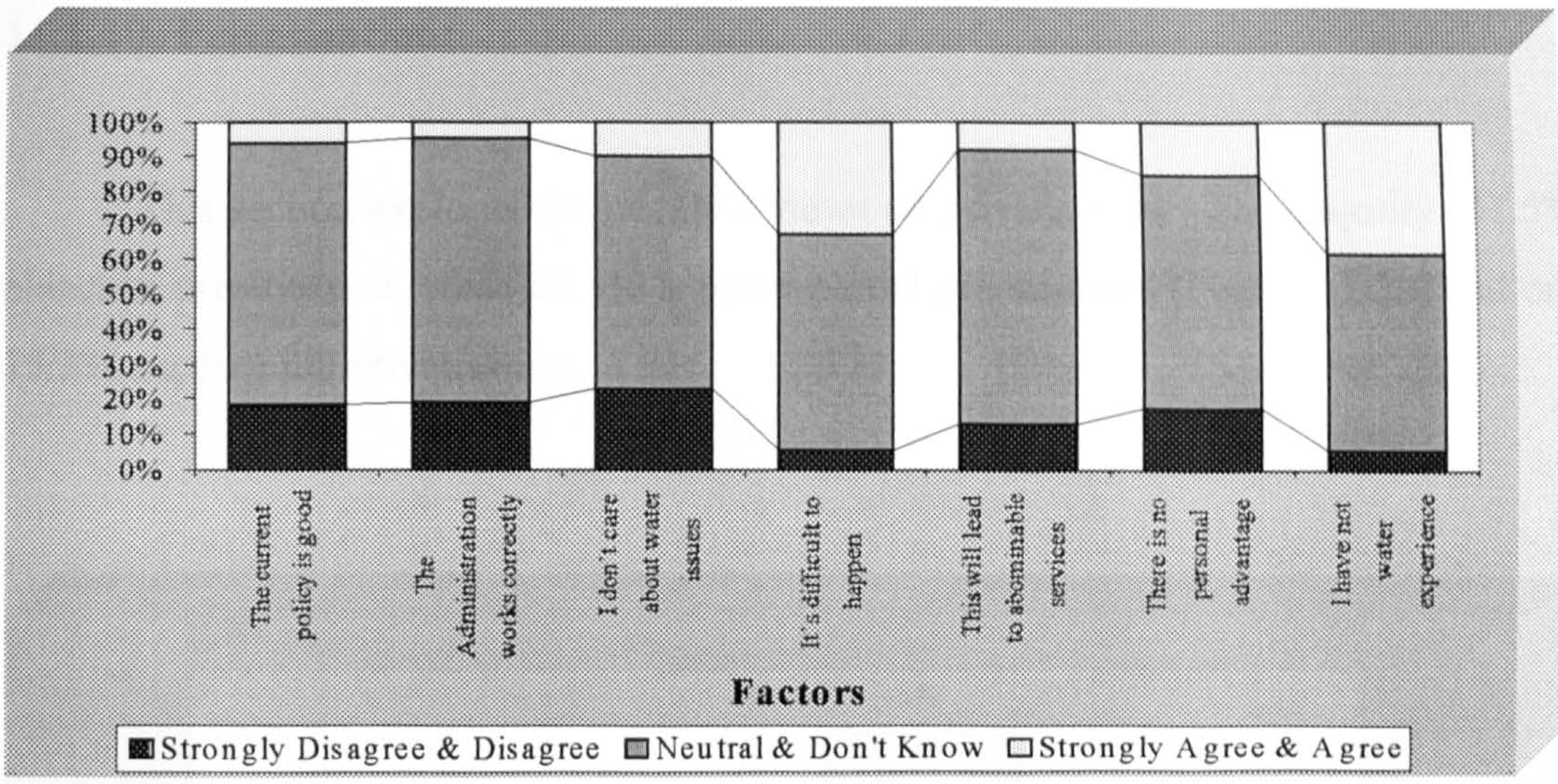

Figure 11.30. The Respondents Attitude toward Declining a Participation in Water Management.

If the respondents were given the chance to participate in taking decisions about the water sector, they will first improve water quality (Figure 11.31). This seems to be a major concern as 10.2% pointed to it directly and 6.2% indirectly. They indicated that they would improve quality by building a new water pipeline network to replace the current network and tankers. The second priority is to improve the methods of raising public awareness about water issues (9.3%).

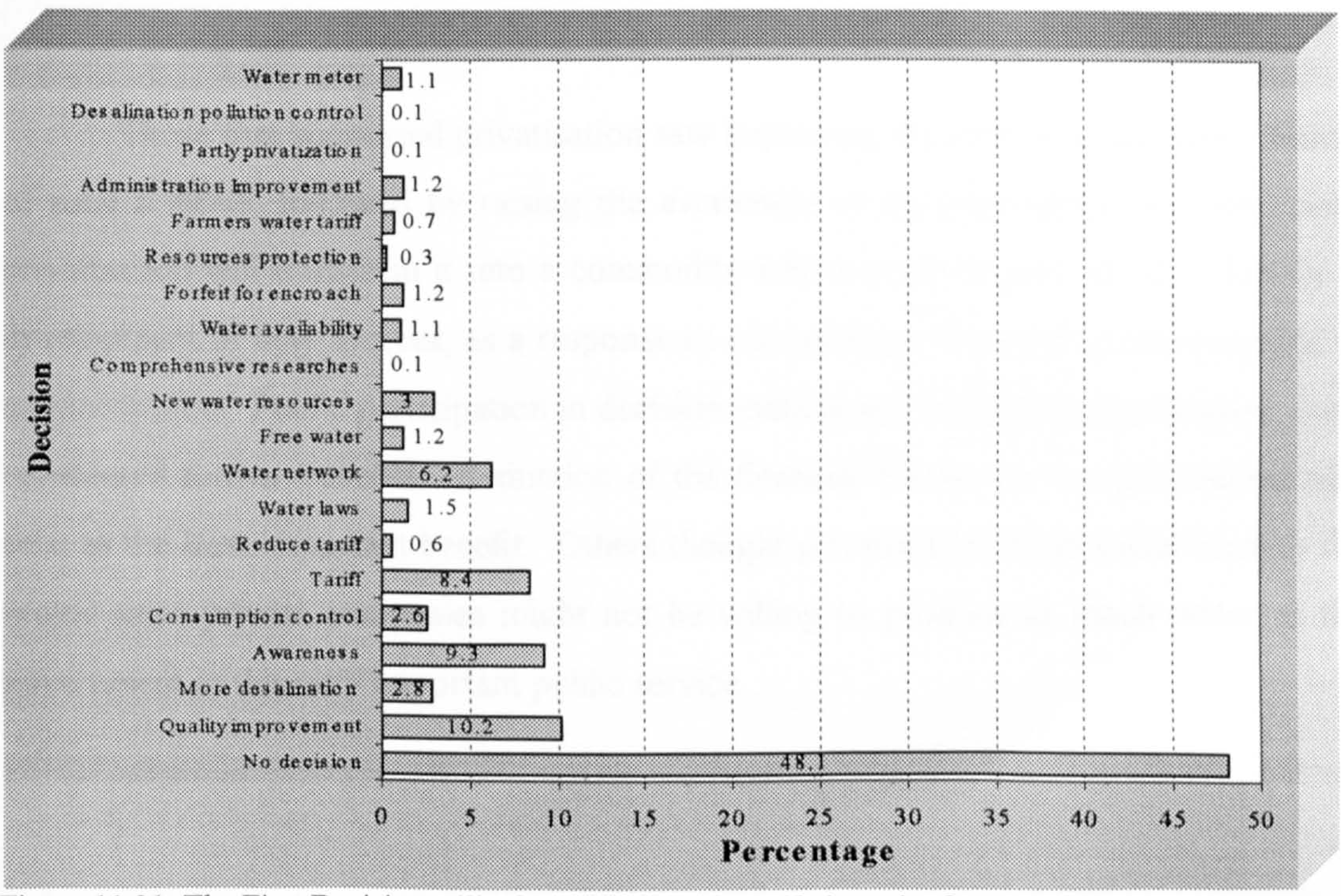

Figure 11.31. The First Decision will taken by Respondents if given the Opportunity.

11.1.10. Privatisation:

This section explores the people's views on privatisation. The majority (47.5%) object to privatisation, while 21.4% support partial privatisation (Figure 11.32) and only 15.3% support full privatisation.

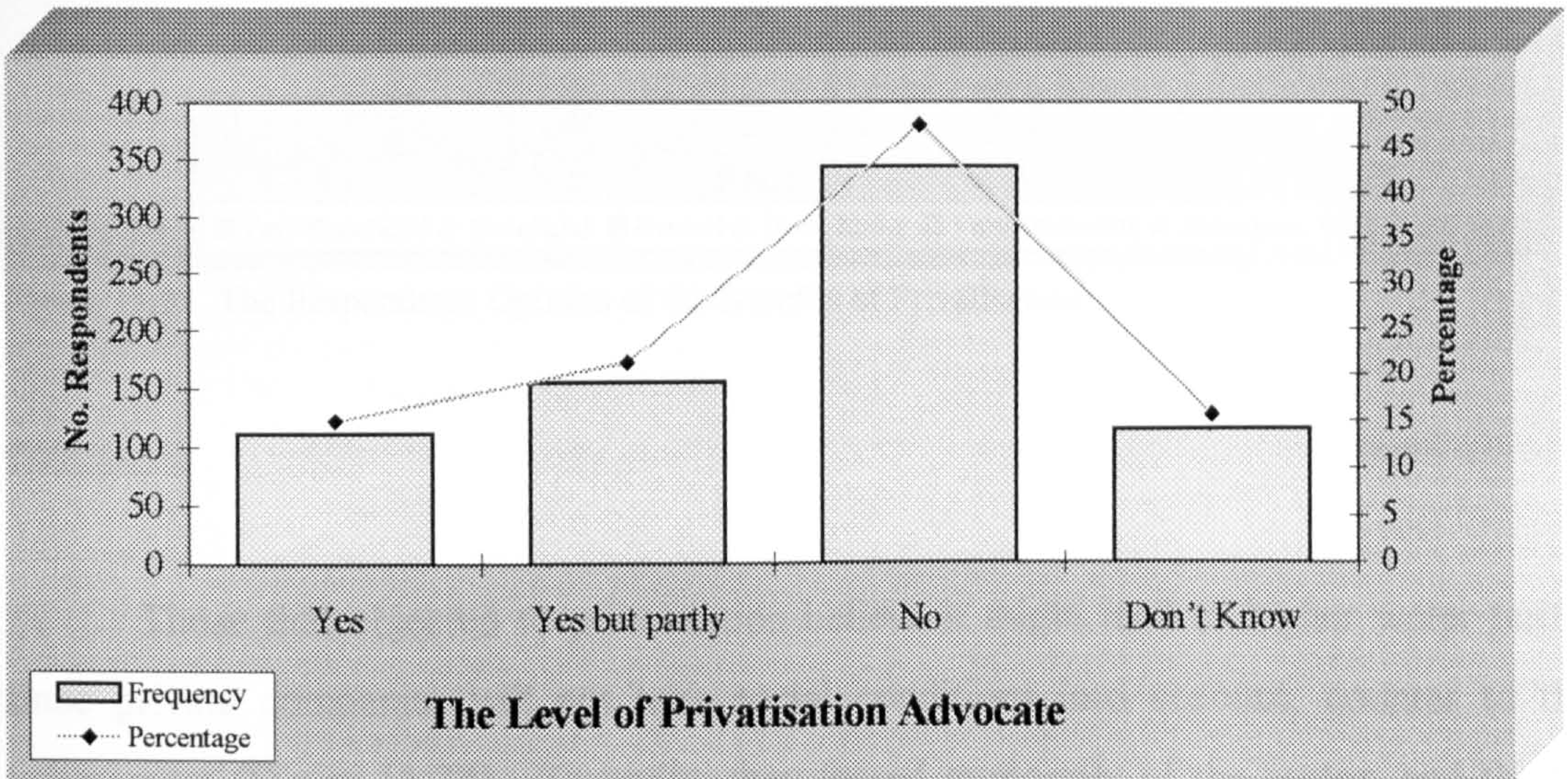

Figure 11.32. The Respondents Attitude toward Water Sector Privatisation.

Those that supported privatisation saw improving the service as the major benefit of such a move, followed by raising the awareness of the importance of water, since privatisation will transform it into a commodity with a price (Figure 11.33). Thirdly is development of new sources, as a response to competition. Fourthly is improvement of administration. Public participation in decision-making and control of consumption were considered further benefits. Reduction of the financial burden on the government was seen as the least important benefit. Others thought privatisation might cause harm to the sector since private companies might not be willing to produce as much water as the government in this very important public service.

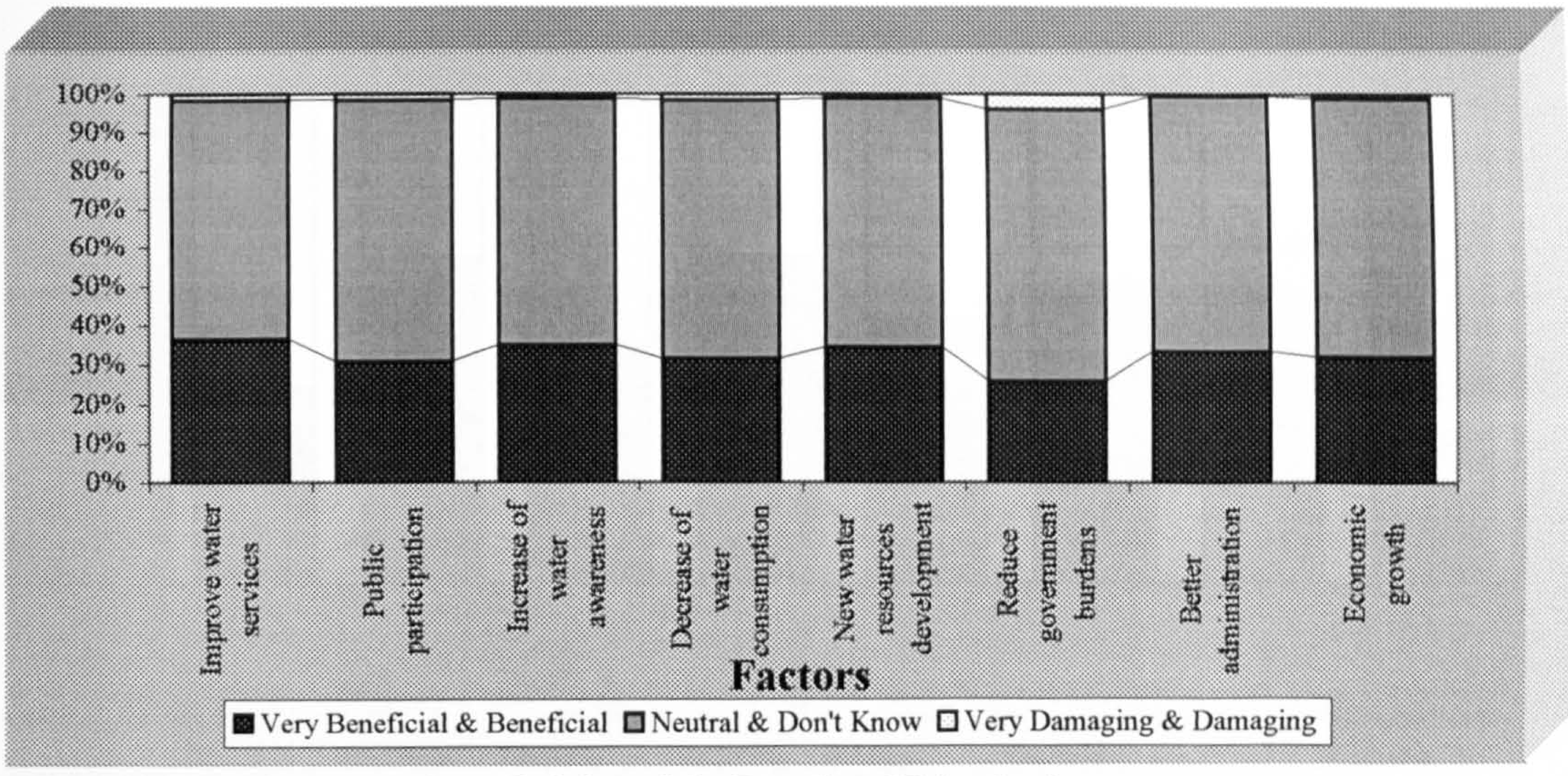

Figure 11.33. The Respondents Opinion of the Benefits of Privatisation.

Those that objected to privatisation believe it might lead to higher water tariffs since private companies will not take social conditions into account, counter to the government (Figure 11.34). Secondly, they feared monopoly of the sector, and thirdly the possibility of job losses. In fact job losses (65.6% of the total employees) have been happening since the ministry was transformed into a corporation (al-Attiyah, 2000). Many respondents feared water resource depletion. Also they feared the possibility of over-utilisation, which is against religious edicts which consider water resources as a public good. Another concern was the possibility of a reduction in the quality of the service. The least of their concerns were disputes as threats to national security and water conflicts. Among the most important ideas advocated by the respondents is that water is a gift from Allah with a public utility and hence must be publicly owned.

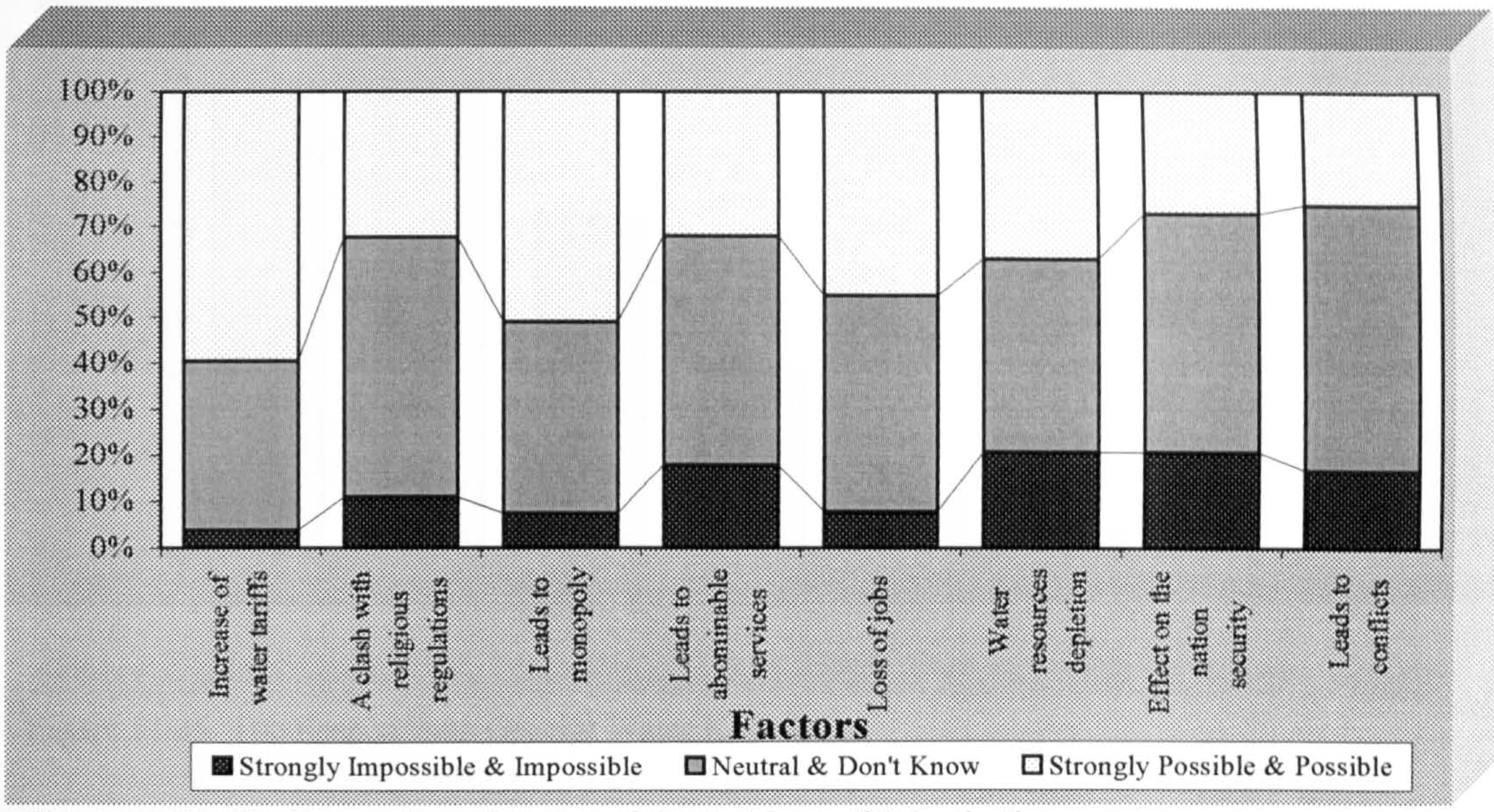

Figure 11.34. The Respondents Opinion of the Problems of Privatisation.

11.1.11. Knowledge of Water Issues:

This section assesses public knowledge about water issues in Qatar, hence the questions dealt with resources, production, costs, law, awareness and administration responsibility. It was clear from eleven questions that, 30.8% could not answer any question, another 30.1% could answer only one, while 22.2% could answer two questions (Figure 11.35). Only two respondents (0.3%) were able to answer six.

A good number of the respondent knew of a *hadith* of the Prophet (peace be upon him) about economising on water "*Excess in the use of water is forbidden, even if you have the resources of a whole river*". Fewer knew the water administrations responsibility and sources of water, though some believe there are surface waters in Qatar. The least knowledge was on levels of water production and costs.

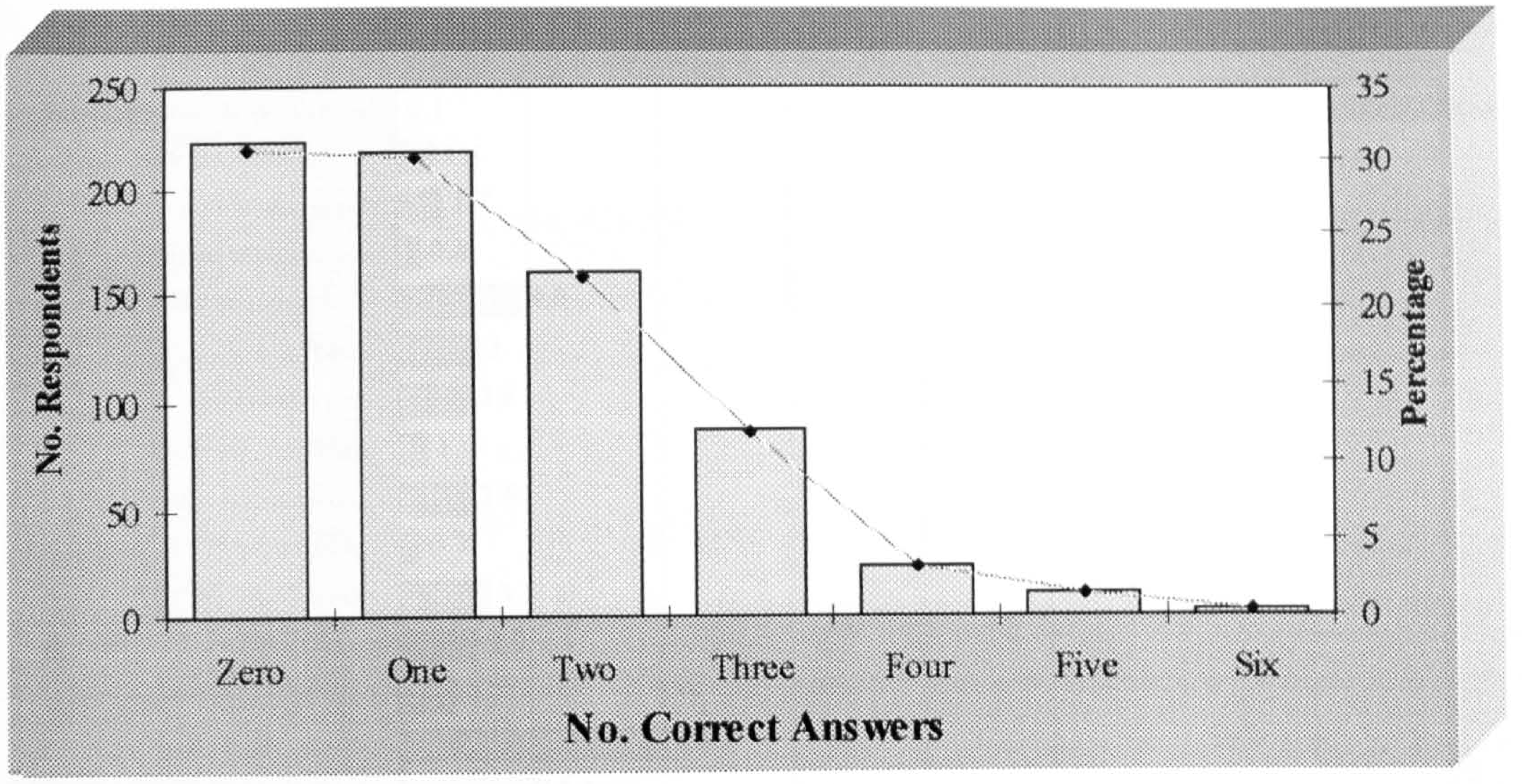

Figure 11.35. The Respondents General Water Knowledge.

11.1.12. Comments:

There were many suggestions about things that water management should undertake and most were similar to the replies given to the question dealing with respondents first decision in water management (Section 11.1.9). 39.4% of the respondents did not give any comments. The most important issues were the improvement of water quality (10.1%) the related issue about building a new network (5.5%) to replace the current network and tankers (Figure 11.36). Also important were finding new ways to raise public awareness (9.5%), the protection of water resources (5.5%) and the reduction of the current water tariffs (4.6%). That was the favourite suggestion by foreigners and some nationals who own companies and hence pay for their employees.

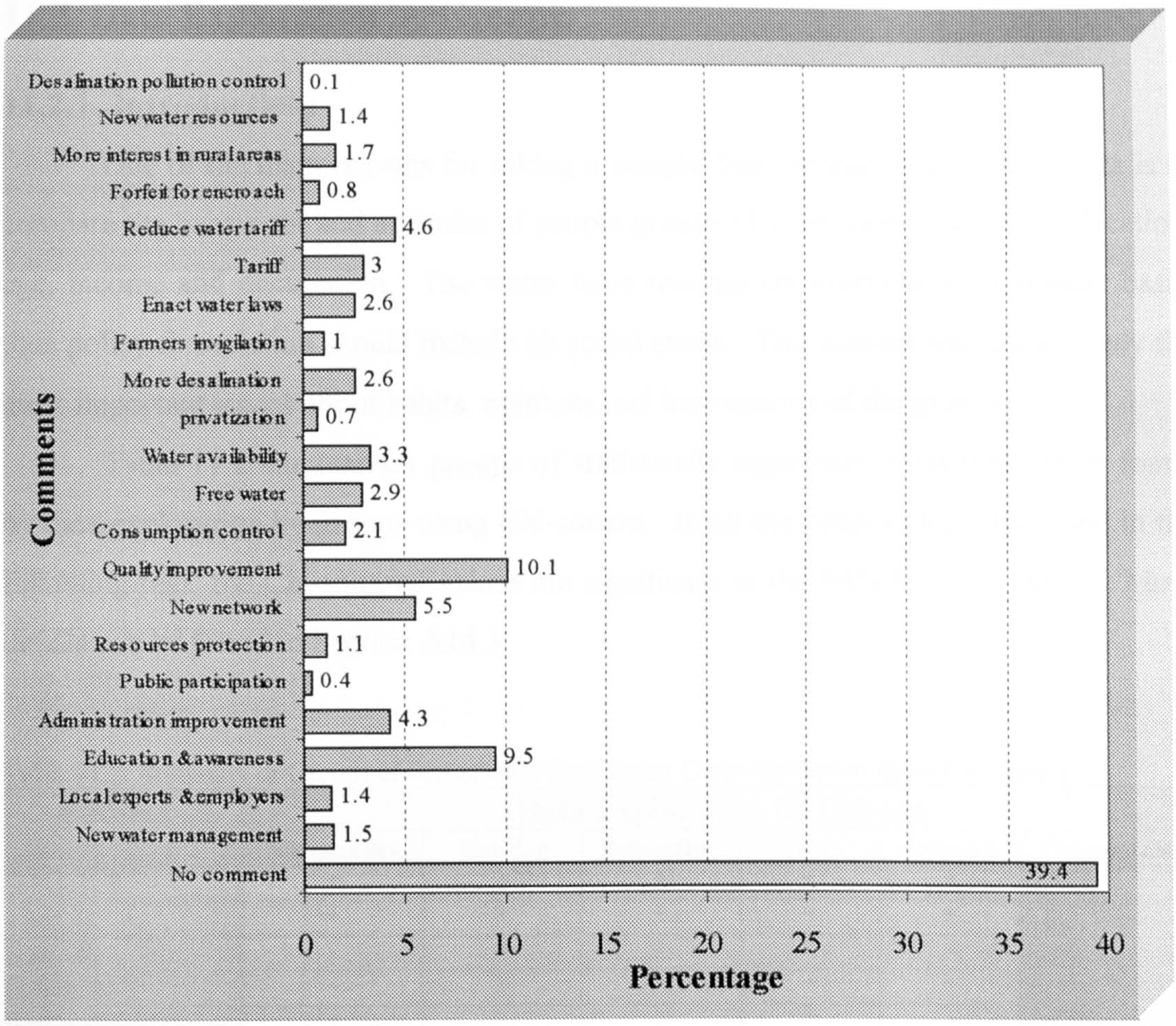

Figure 11.36. The Respondents Comments.

11.1.13. Conclusion:

The most important initial conclusions relate to the worry that most people have about the quality of water. This came directly from the question about the quality of water and indirectly through suggestions linking water tariffs to improving water quality, participation or changing the present water network. The positive conclusions include the readiness to pay a tariff with service improvement and the ability to reduce consumption, despite the fact that many indicated that their consumption is normal or tends to be economical. The lack of information on water, the reluctance to expand use of recycled water, water importation, the neglect of important factors such as law and raising public awareness and the lack of interest in participation in the management of water are considered among the negative conclusions. Some of the reasons behind such attitudes will become clearer when we discuss the respondents as groups and the reasons for behaviour patterns in the following sections.

11.2. Data Exploration by Groups:

11.2.1. Introduction:

One of the main reasons for taking a sample that represents all social strata is to compare the behaviour and attitudes of people grouped by nationality, gender, education, age, income and occupation. The water issue touches on everyone on a regular basis: thus policy formulation should include all social strata. This section will discuss only the most important issues about habits, opinions and impressions of the groups.

Table 11.2 summarises groups of statistically significant cross-tabulations found by data exploration by groups using Chi-square. In all the relationships discussed in the following text, the Chi-squared values are significant at the 95% level or higher. More details can be found in Section A14.3.

Table 11.2. Summary of Groups of Statistically Significant Cross-tabulation using Chi-square.

Subject	Data Exploration by Groups					
	Nationality	Gender	Education	Age	Income	Occupation
Service. 3	+	+	+	+	+	
Law. 1	+	+	+	+	+	
Law. 3	-	-	-	-	-	
Issues. 1	+	+	+	+	+	
Issues. 2	+	-	+	+	+	
Issues. 3	+	-	+	+	+	
Consumption. 1	+	+	+	+	+	
Consumption. 2	+	+	+	+	+	
Consumption. 3	+	-	+	-	+	
Consumption. 4	+	+	+	-	+	
Consumption. 5	+	+	+	+	+	
Consumption. 6	+	-	+	-	-	
Tariff. 2	+	+	+	+	+	
Tariff. 3	+	-	-	-	-	
Tariff. 4	+	-	-	-	-	
Public Relation. 1	+	+	+	+	+	
Public Relation. 2	-	-	-	-	-	
Public Relation. 3	-	-	-	-	-	
Administration. 1	+	-	+	+	+	+
Administration. 2	+	-	+	-	+	
Administration. 3	+	-	+	+	+	
Administration. 4	+	+	-	-	-	
Administration. 5	+	-	+	-	+	
Privatisation. 1	+	+	+	+	+	
Privatisation. 2	+	-	+	-	+	
Privatisation. 3	+	-	+	+	+	
Knowledge	+	+	+	+	+	
Comments	+	+	+	+	+	

(+ All statistically significant relationships at 95% level or greater).
(- Most tests statistically significant at more than 95% level).

It worth mentioning to that, chi-squared analysis will not work with cells with expected counts less than 5. Consequently, for analysis of nationality data, the two Africans were recorded as Asians, since their responses seemed essentially similar in most ways to Asian respondents. In the following discussion, this mixed group is referred to as 'Asians'.

11.2.2. The Service:

The majority of Qataris (59.8%) and Westerners (53.3%) tend not to drink the distributed water while most Asians (97.3%) and some Arabs (74.8%) do (Figure 11.37). This is because of the high incomes of most Qataris and Westerners, who hence can buy mineral water. The Asians and Arabs do not have the means, since mineral water in Qatar is very expensive (in 1999, one litre of bottled water in Qatar costs about $0.34 while same amount of oil costs about $0.23) (PC, 2000).

With gender, many females (57%) do not like to drink the water distributed by the QGEWC while many males (63.2%) will drink it. This can be attributed to most females being Qataris or Arabs. Many males are Asian or Arabs. Males also tend not to care about health as much as females (Gray, 1994; Bulajich, 1992; Jordan and Wagner, 1993; al-Shinshori, 1999).

There appears to be a strong relationship with education. The more educated people are, the less likely that they would drink the distributed water, since they are more aware of the health hazards and opt to drink mineral water (which is also a fashion statement). The big population of non-Qatari workers who have little education, also affected the figures.

For age and income, there seems to be a strong relationship, which is strongly linked to nationality. Members of the young and old age groups who are also in the middle income bracket tend not to drink the distributed water. The majority of these are Qataris. The middle age group, the majority of whom are Asians and Arabs in the lower income bracket, tend to drink the distributed water.

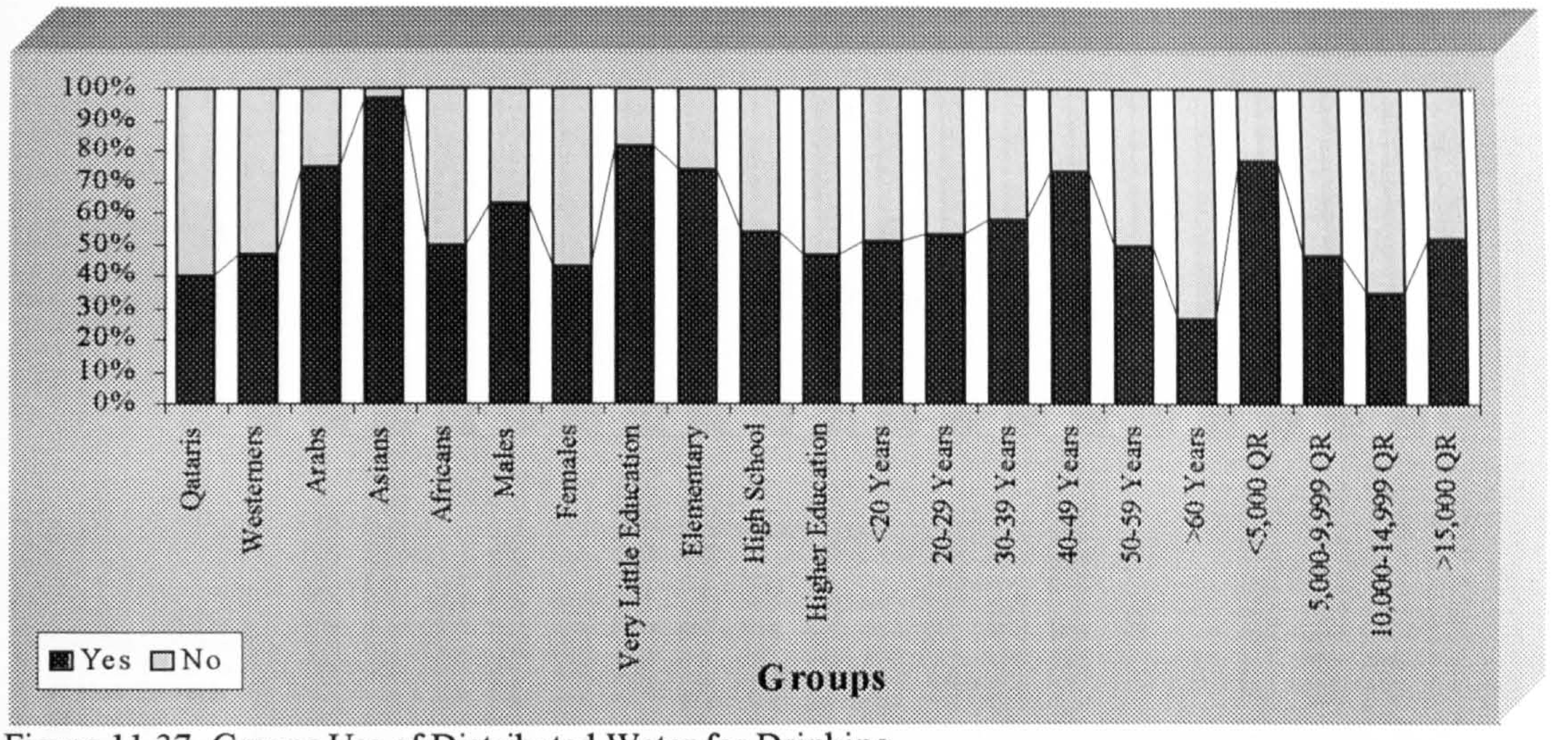

Figure 11.37. Groups Use of Distributed Water for Drinking.

11.2.3. Water Laws

11.2.3.1. The Current Water Laws:

A large member of Qataris (62.6%) believe there is a need for more laws while Asians (90%) and Westerners (80%) and to some extent the Arabs (53.5%) tend not to know about this issue (Figure 11.38). This is attributed to language barriers and lack of involvement in society's issues and problems. Asians and Westerners are more concerned about their work and have no incentive to learn Arabic or get involved in local concerns, so they are not interested in this matter.

Gender was an influence on attitude: there appears to be more ignorance among males (50.4%) than females (40.4%), and this too can be linked to a preponderance of male foreign labour. Ignorance about laws is very high among the little educated (81.2%) although many of the educated also deny the presence of water laws. This too can be linked to the issue of citizenship. On the other hand, education usually increases one's knowledge and concern about society's issues and problems.

There is a strong relationship with age. Ignorance about the issues increases with age. Younger people seemed to care more about water issues, have better interaction with society and have firm opinions. Income has an influence on knowledge, since most of the middle income bracket are Qataris.

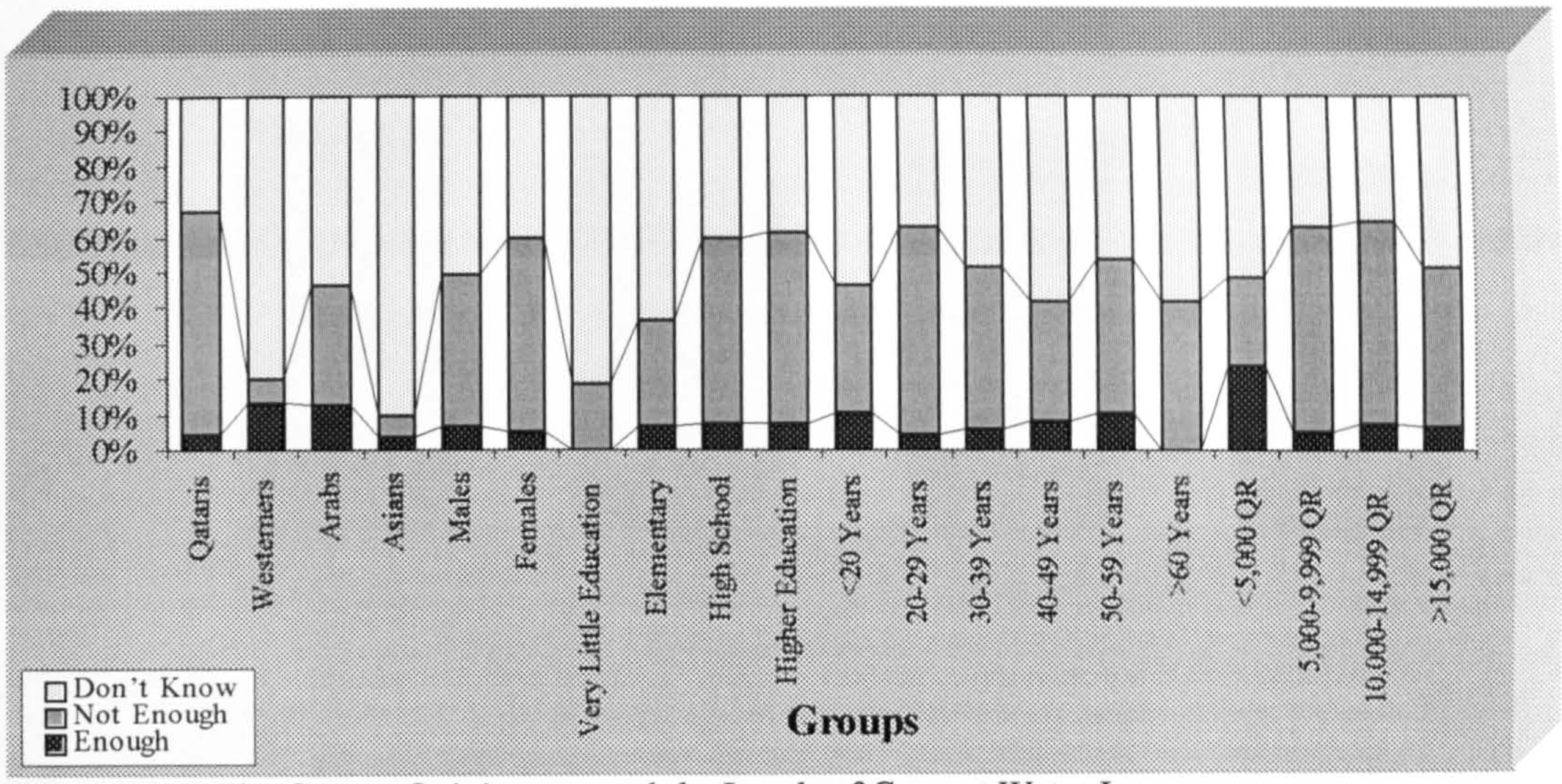

Figure 11.38. The Groups Opinions toward the Levels of Current Water Laws.

11.2.3.2. Obedience to Water Laws:

When the most important influences encouraging obedience to the law were explored, Qataris, Westerners and some Arabs highlight the nature of the law, its suitability to local conditions and its uniform application to all (Figures 11.39, 11.40 and 11.41). Asians and some Arabs, however, tend to emphasise financial penalties and the strength of the authority. This is because Asians and Arabs have low incomes while Qataris and Westerners have usually higher incomes, so financial penalties will not affect their budgets severely.

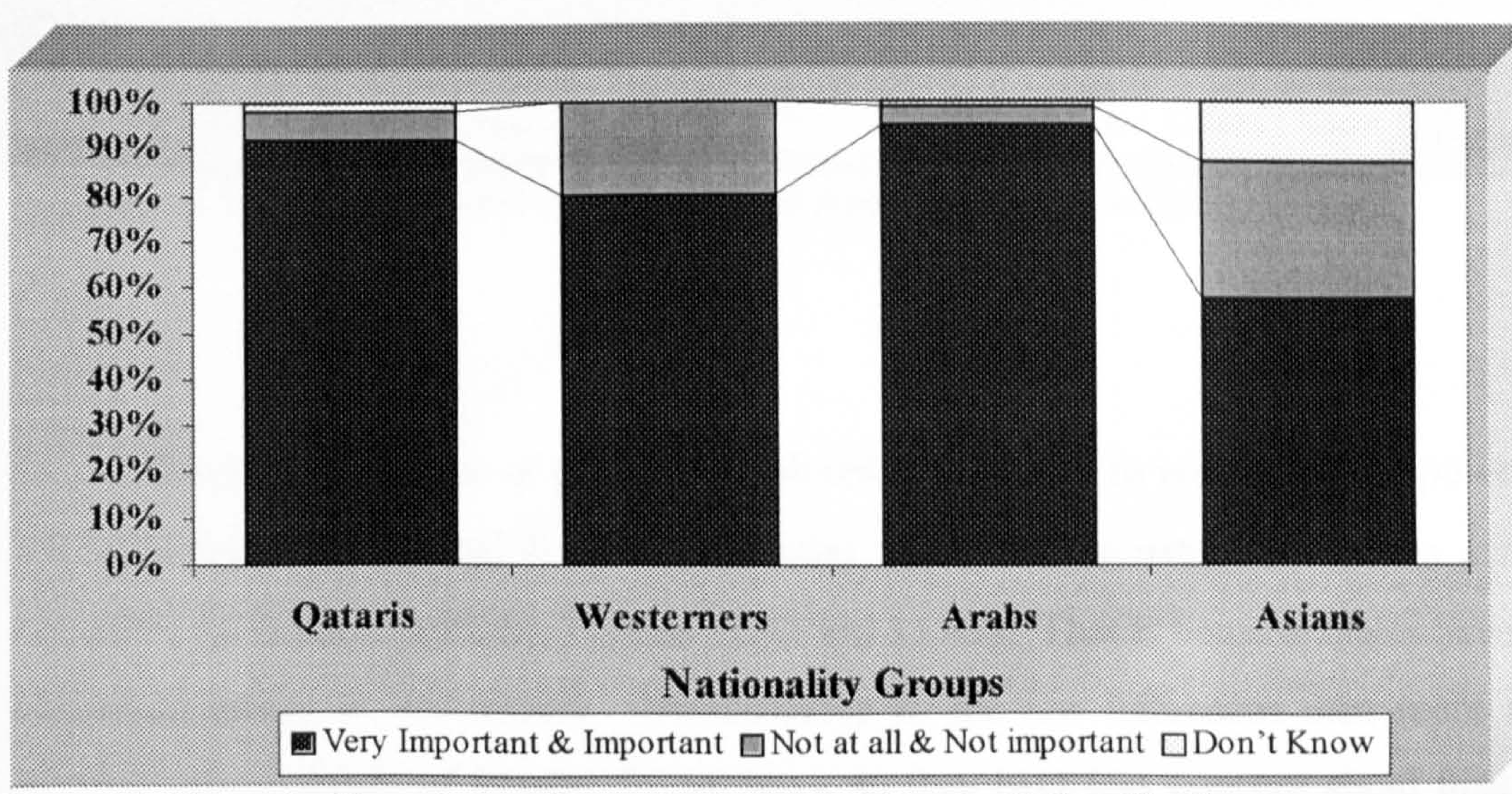

Figure 11.39. Level of Importance of Laws Applying to all People: Nationality Groups.

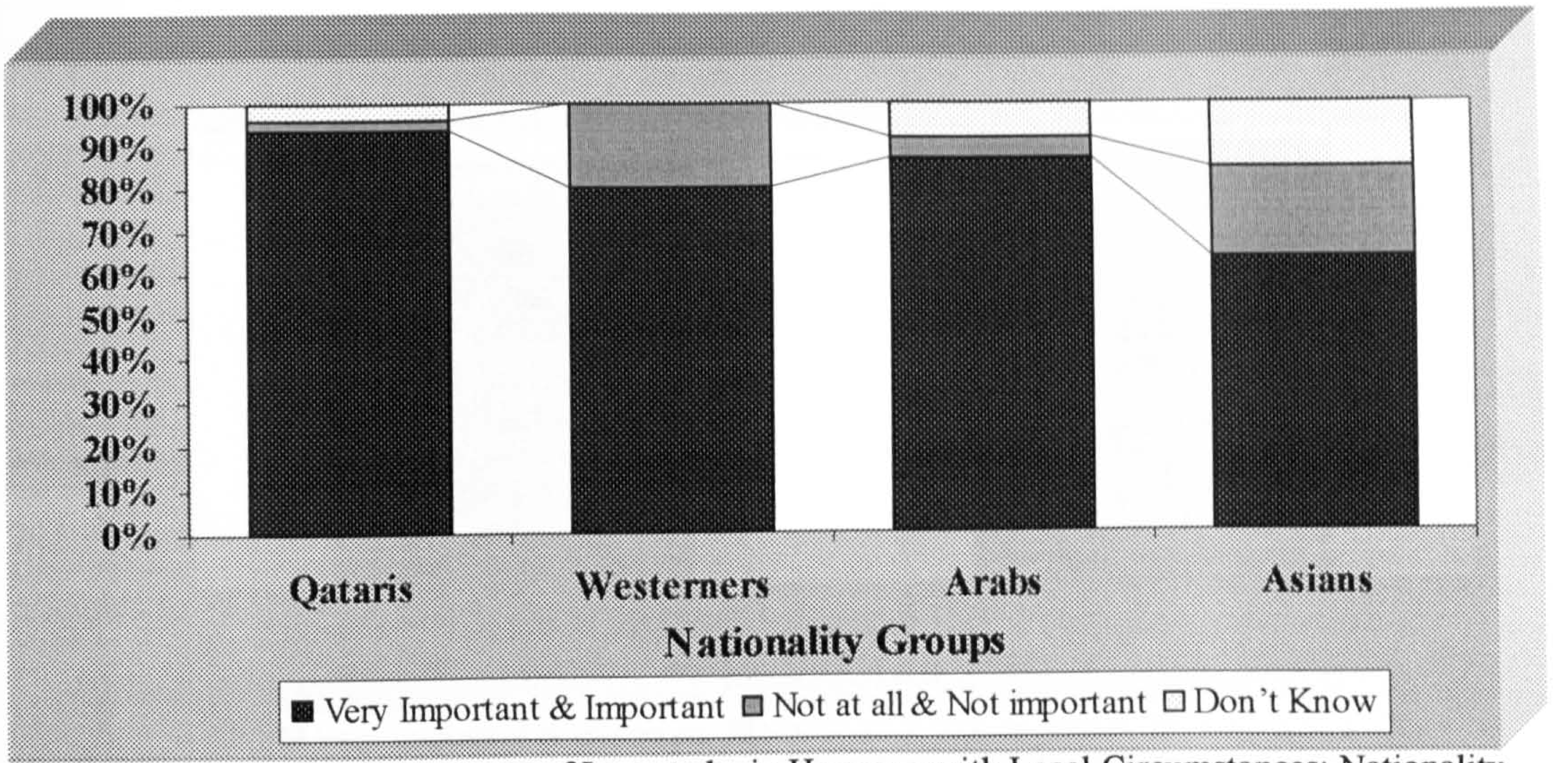

Figure 11.40. Level of Importance of Laws to be in Harmony with Local Circumstances: Nationality Groups.

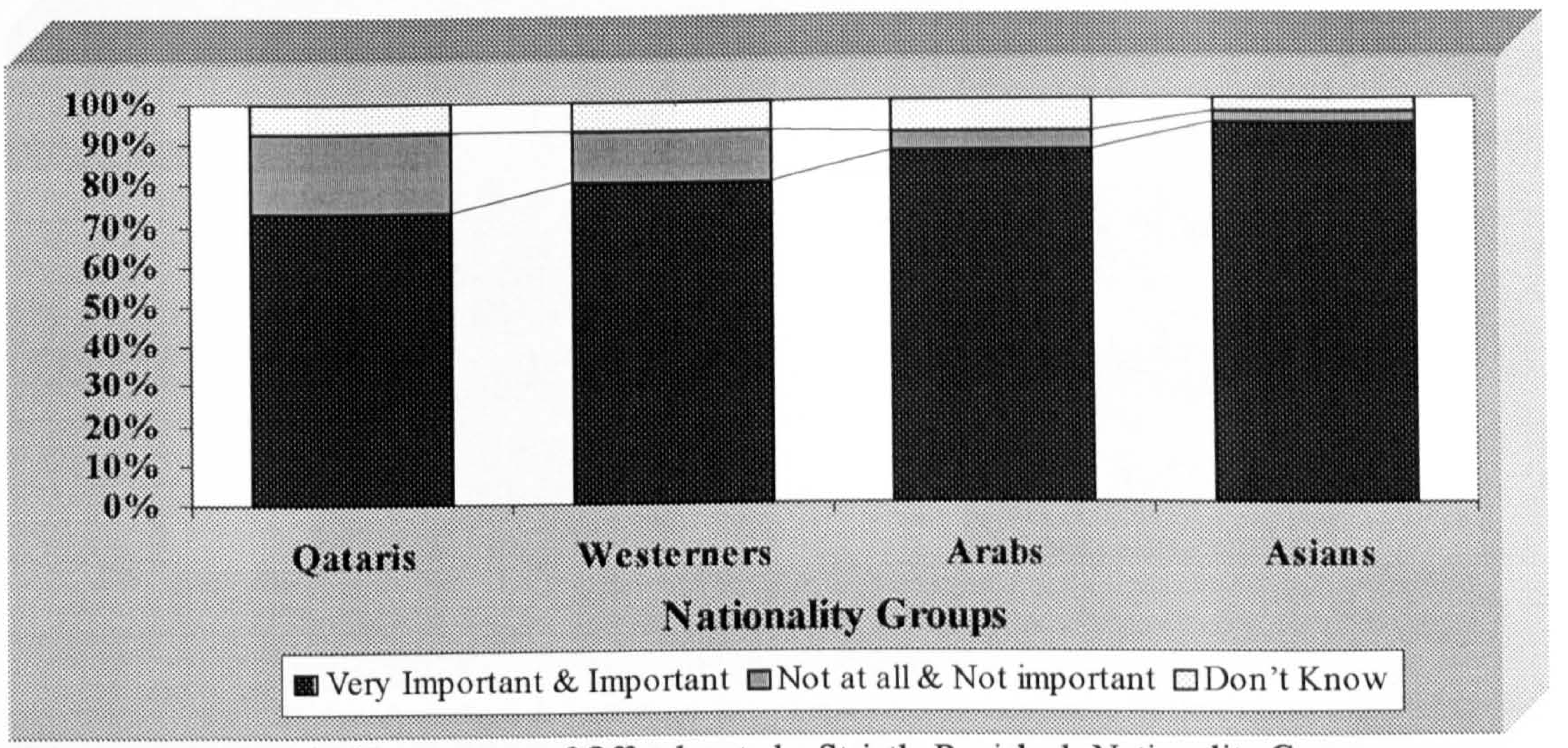

Figure 11.41. Level of Importance of Offenders to be Strictly Punished: Nationality Groups.

When the influence of gender is explored, males tend to emphasise the power of the executing authority and fines while females emphasise the nature of the law and its suitability for local conditions (Figures 11.42 and 11.43). That is because males have the economic power in the society. Disobedience to the law influences men more than women - the majority of females do not work so they have less concern about financial matters.

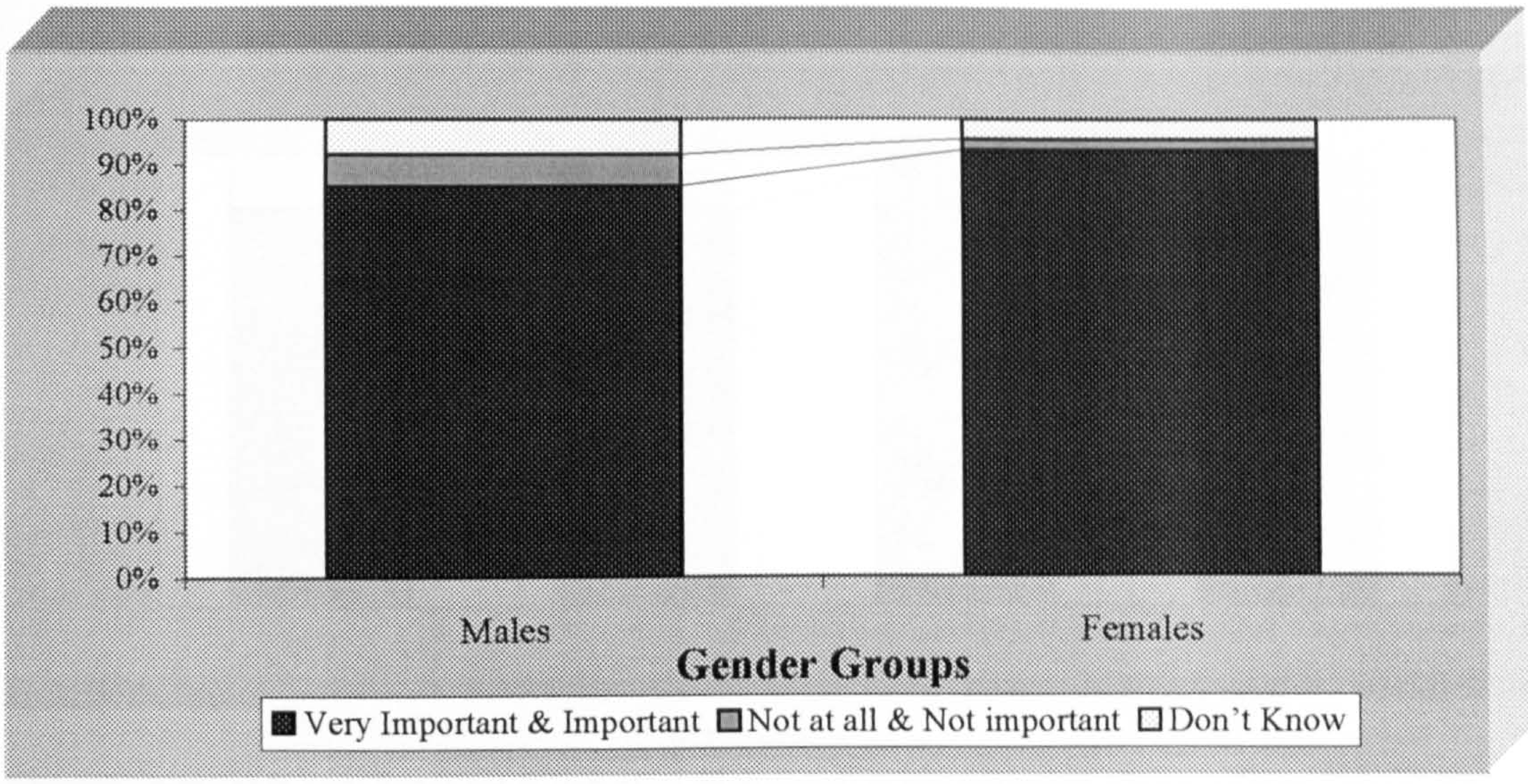

Figure 11.42. Level of Importance of Laws to be in Harmony with Local Circumstances: Gender Groups.

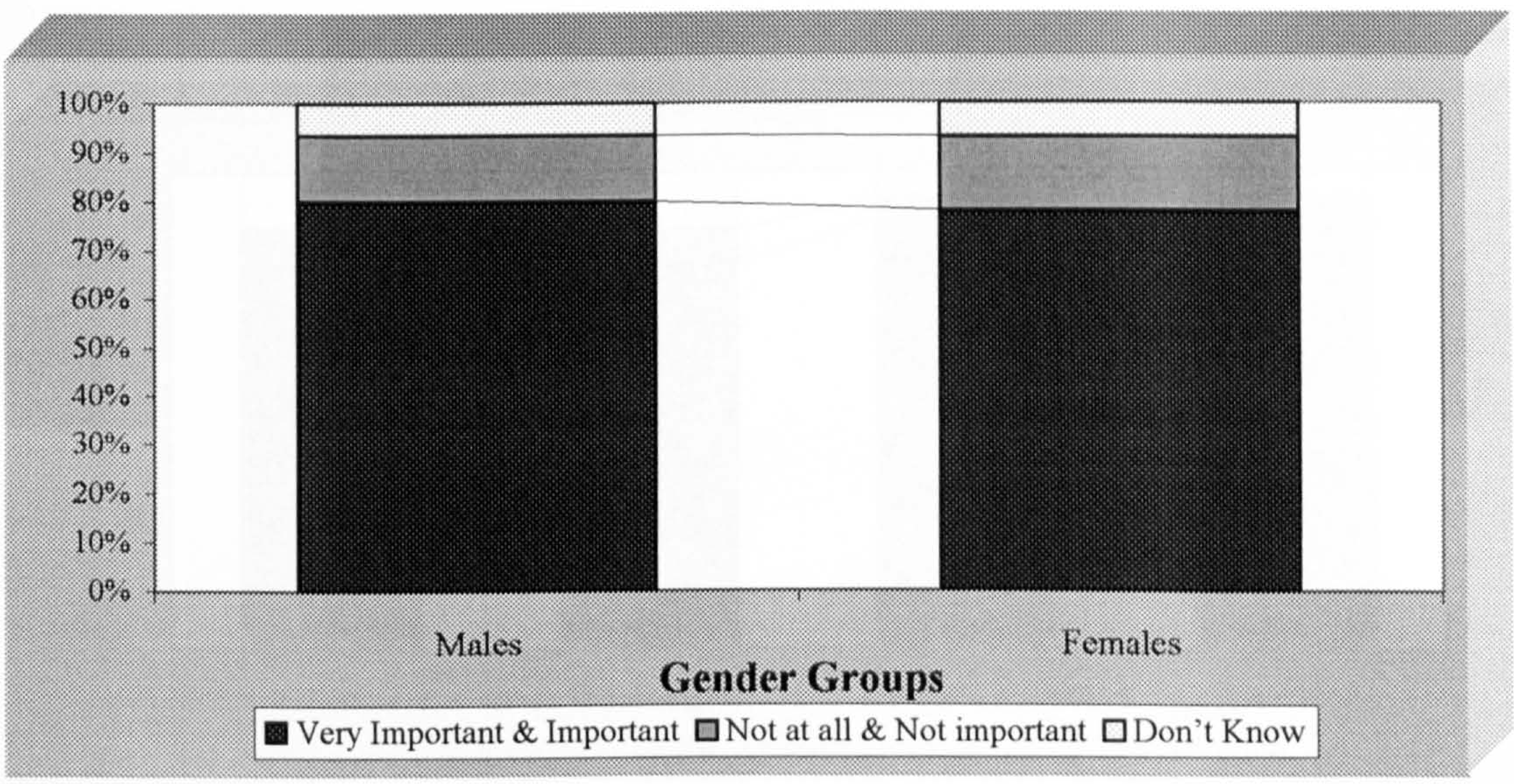

Figure 11.43. Level of Importance of Offenders to be Strictly Punished: Gender Groups.

On the other hand, water laws, concern over fines and the executing authority is most pronounced among the very little educated, while highly educated people are concerned with the nature of the law and equity (Figures 11.44, 11.45 and 11.46).

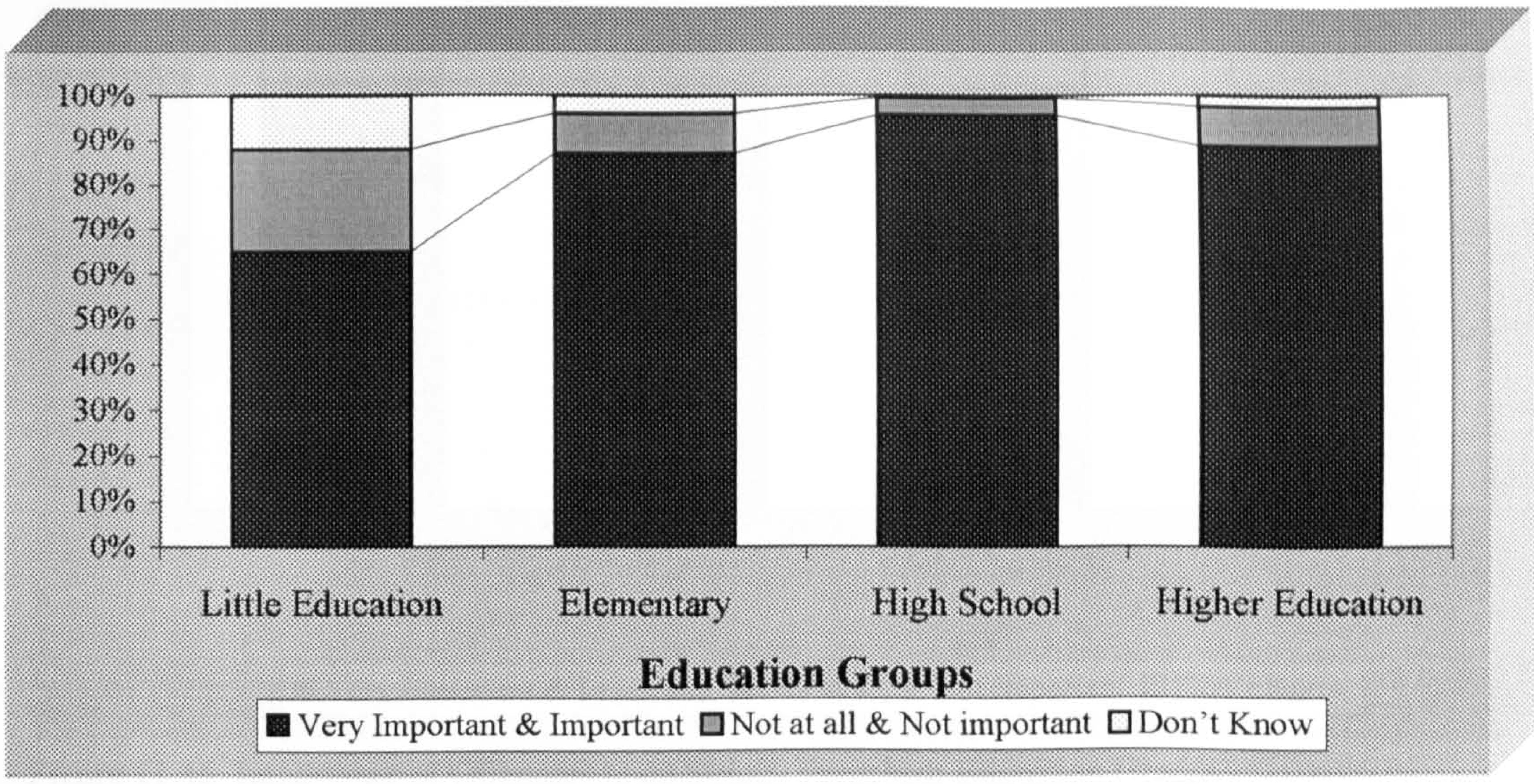

Figure 11.44. Level of Importance of Laws to Applying to all People: Education Groups.

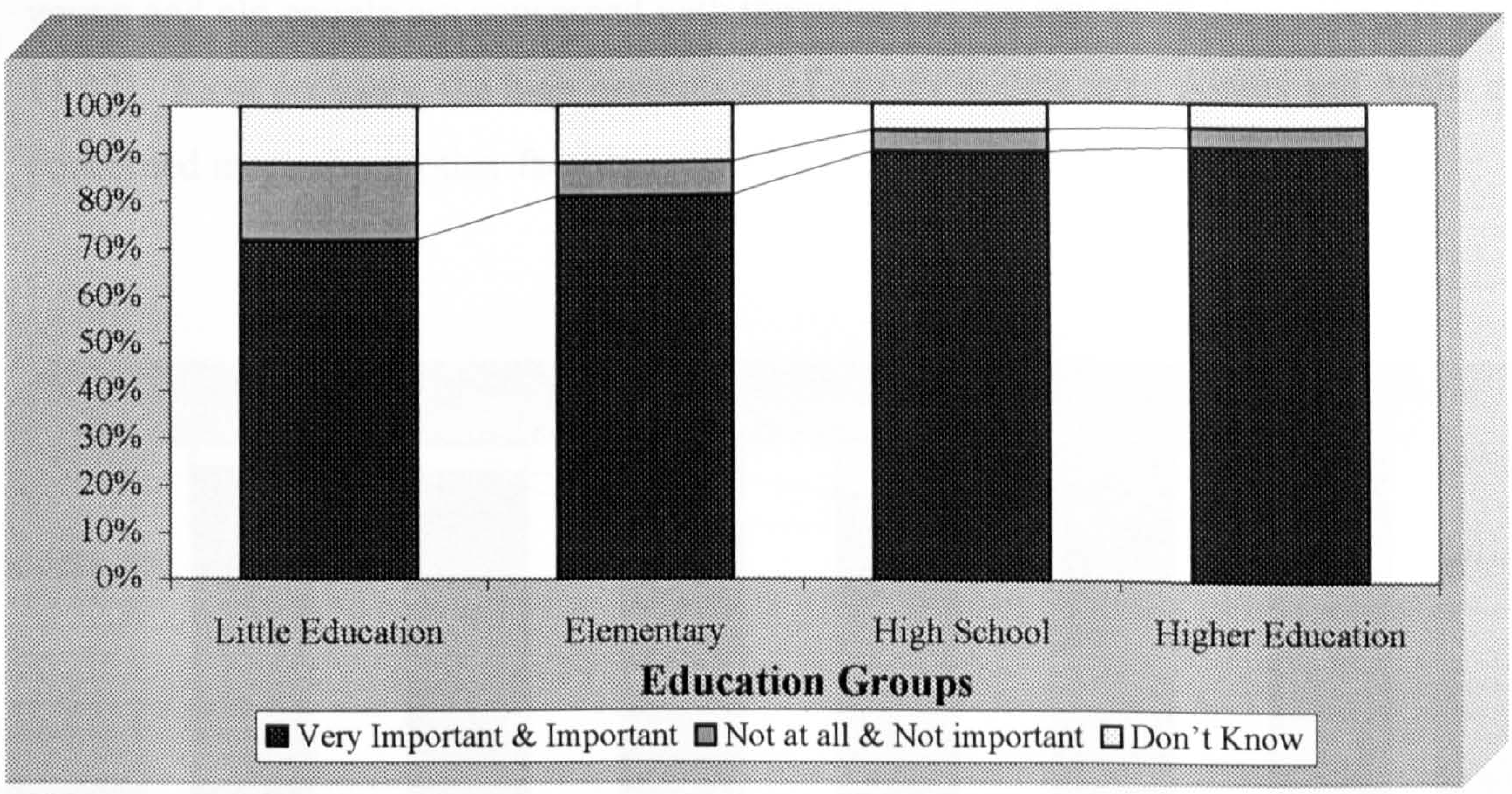

Figure 11.45. Level of Importance of Laws to be in Harmony with Local Circumstances: Education Groups.

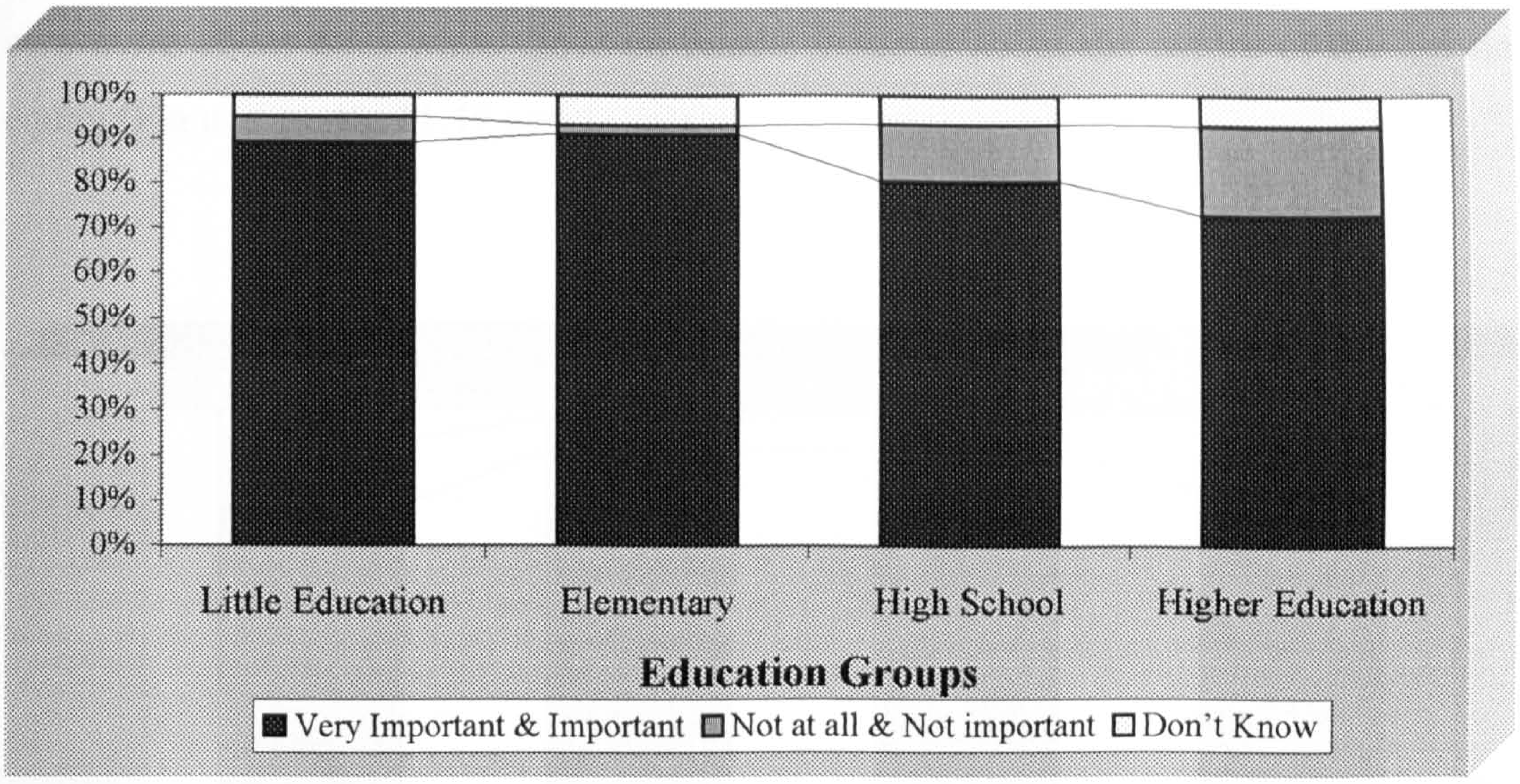

Figure 11.46. Importance of Offenders to be Strictly Punished: Education Groups.

Attitudes to the laws are not clearly influenced by age group. All the same, very young and old people are concerned with the nature of the law more than others (Figure 11.47). Most probably, the high percentage of usually middle aged Asians and Arabs are concerned more about other factors.

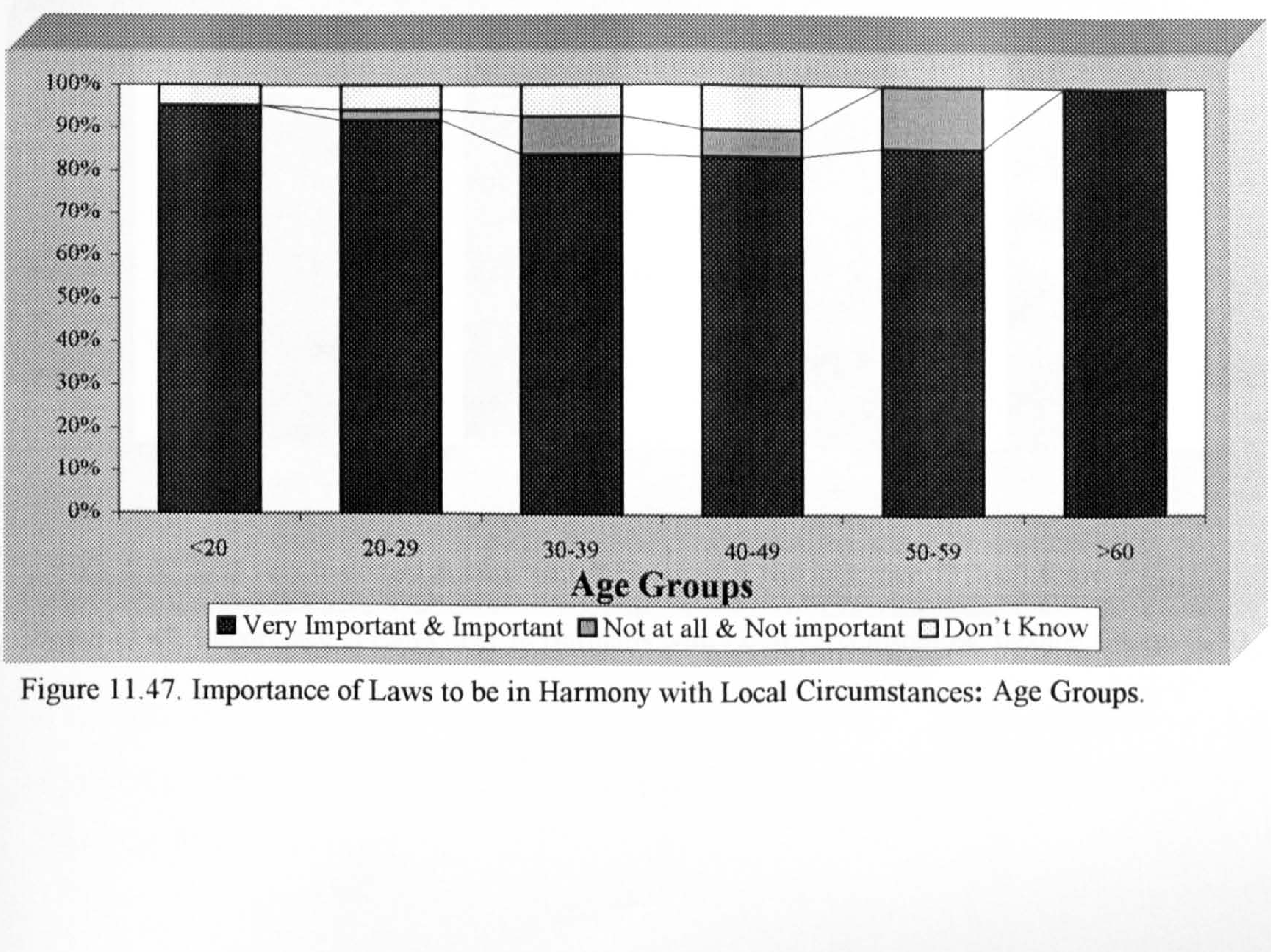

Figure 11.47. Importance of Laws to be in Harmony with Local Circumstances: Age Groups.

Income seems to have the same influence as education: those on lower incomes care more about fines while those on middle incomes about the nature of the law and equity (Figures 11.48, 11.49 and 11.50).

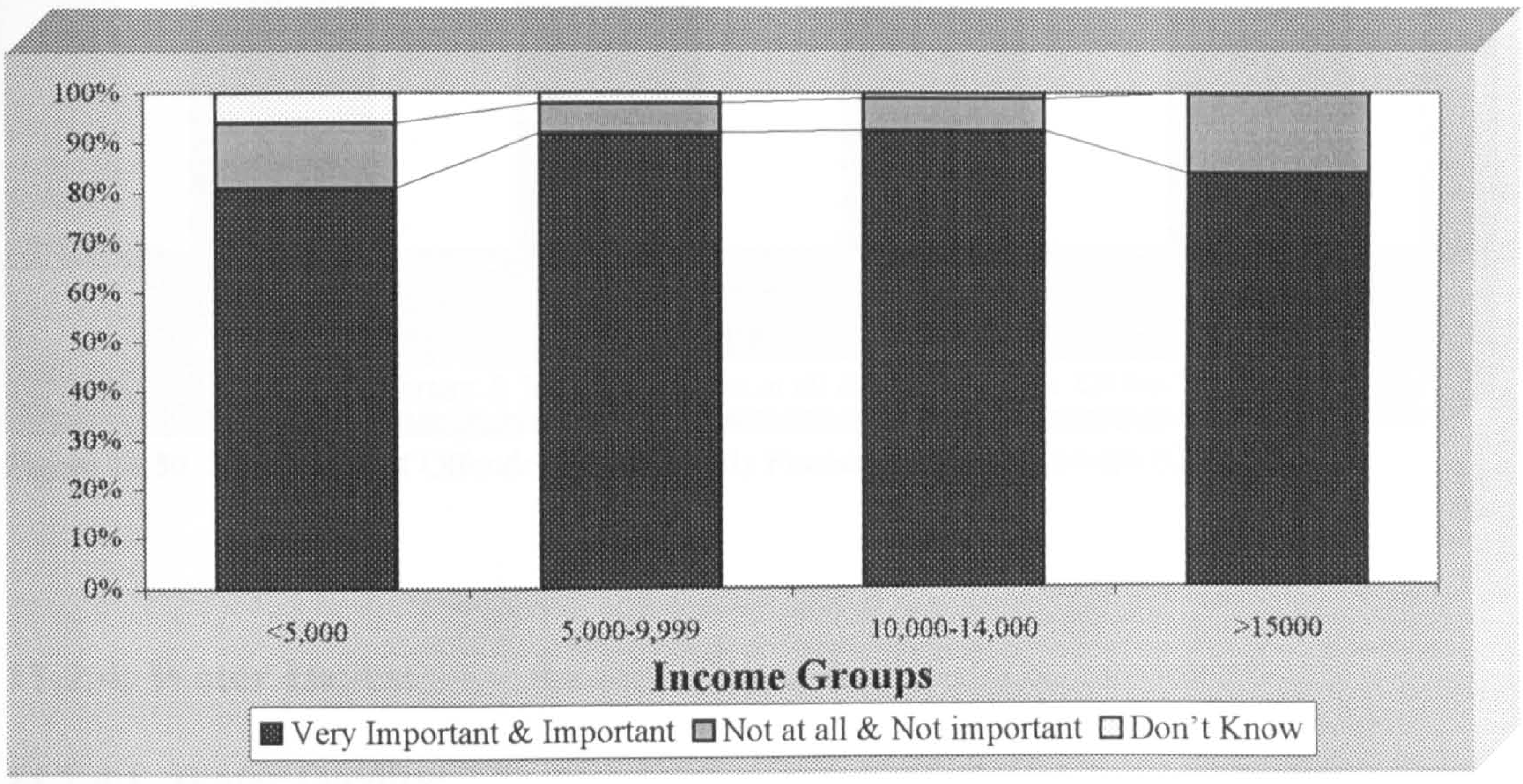

Figure 11.48. Importance of Laws to Applying to all People: Income Groups (QR).

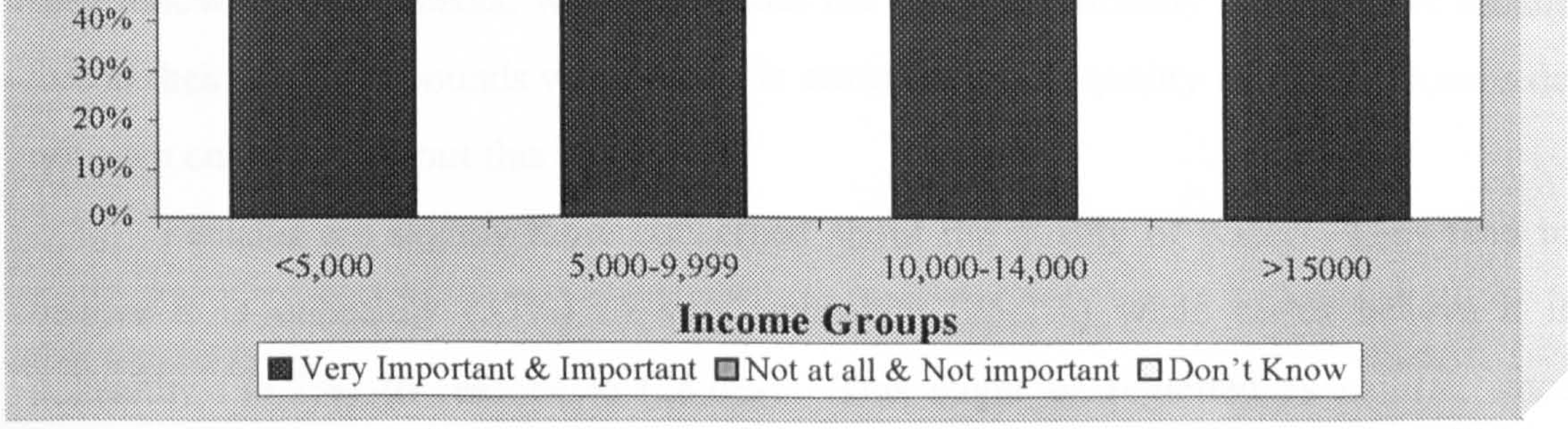

Figure 11.49. Importance of Laws to be in Harmony with Local Circumstances: Income Groups (QR).

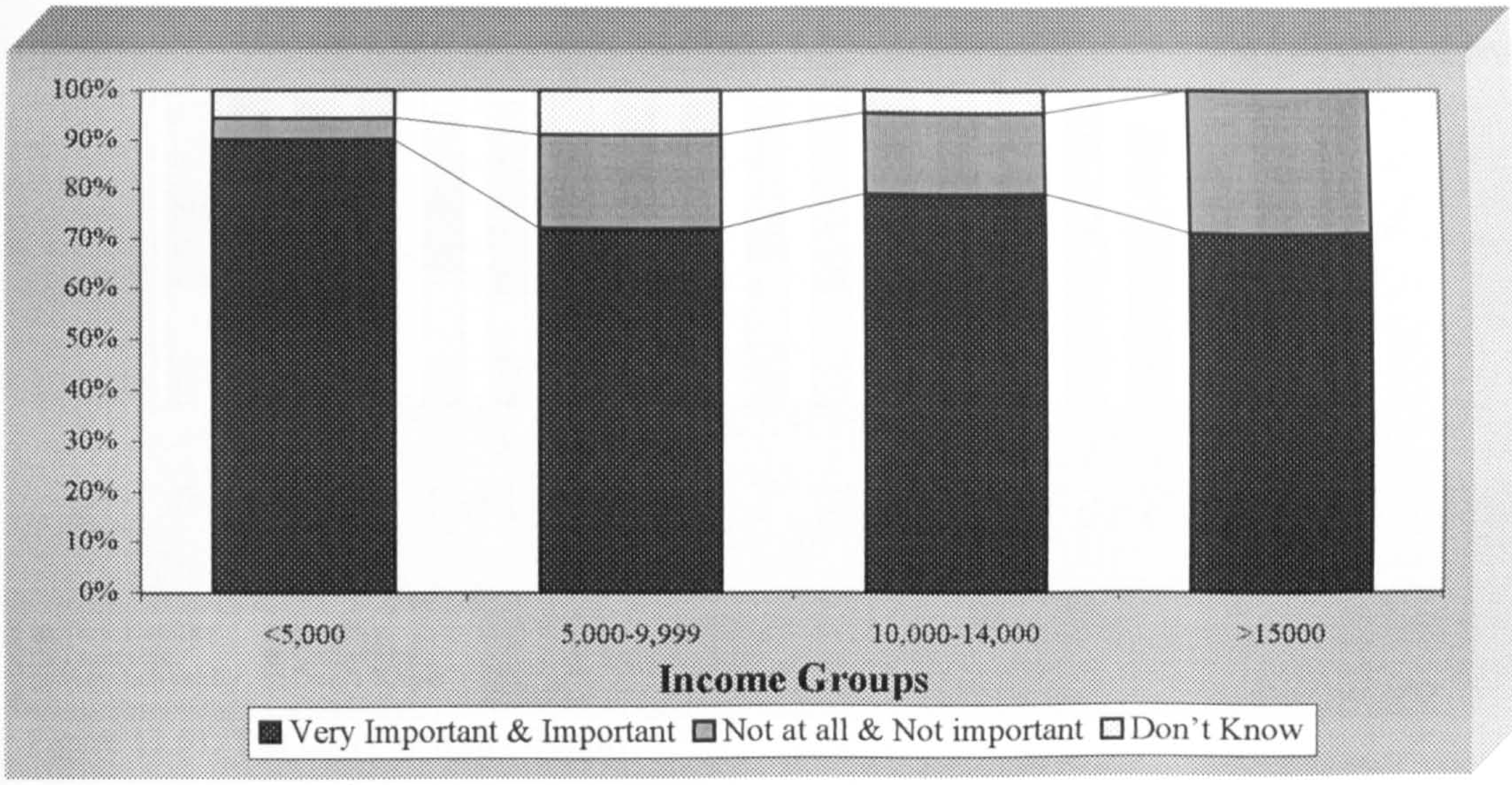

Figure 11.50. Importance of Offenders to be Strictly Punished: Income Groups (QR).

11.2.4. Water Issues:

11.2.4.1. Water Quality:

Many Qataris (58.5%) and Arabs (57.9%) tend to believe that water is unhealthy, while Westerners do not seem to have a definite opinion (Figure 11.51). Many Asians seems to believe that the quality of water is reasonable (38.2%), while a moderate member (17.3%) express no opinion. Qataris and Arabs tend to be consumers of water provided by the responsible agency, sometimes from highly saline groundwater which may be distributed through water tankers, and hence is more susceptible to pollution. These groups are also more knowledgeable about local issues including water quality and they follow the local media, which discusses the issue occasionally. Westerners usually live in their own compounds where there is attention to the quality of water. Asians do not seen concerned about this issue.

Females are slightly more concerned about the quality of water. They tend to believe it is unhealthy (37%) to very unhealthy (25.2%) while males believe it is unhealthy (35.2%) to reasonable (28.6%). This might be regarded as natural, since females are more concerned about the health of their families than males. A high proportion of the females are Qataris, while among the males Asians constitute a higher proportion. On the other hand, elementary and high school groups tend to believe it is unhealthy more than other.

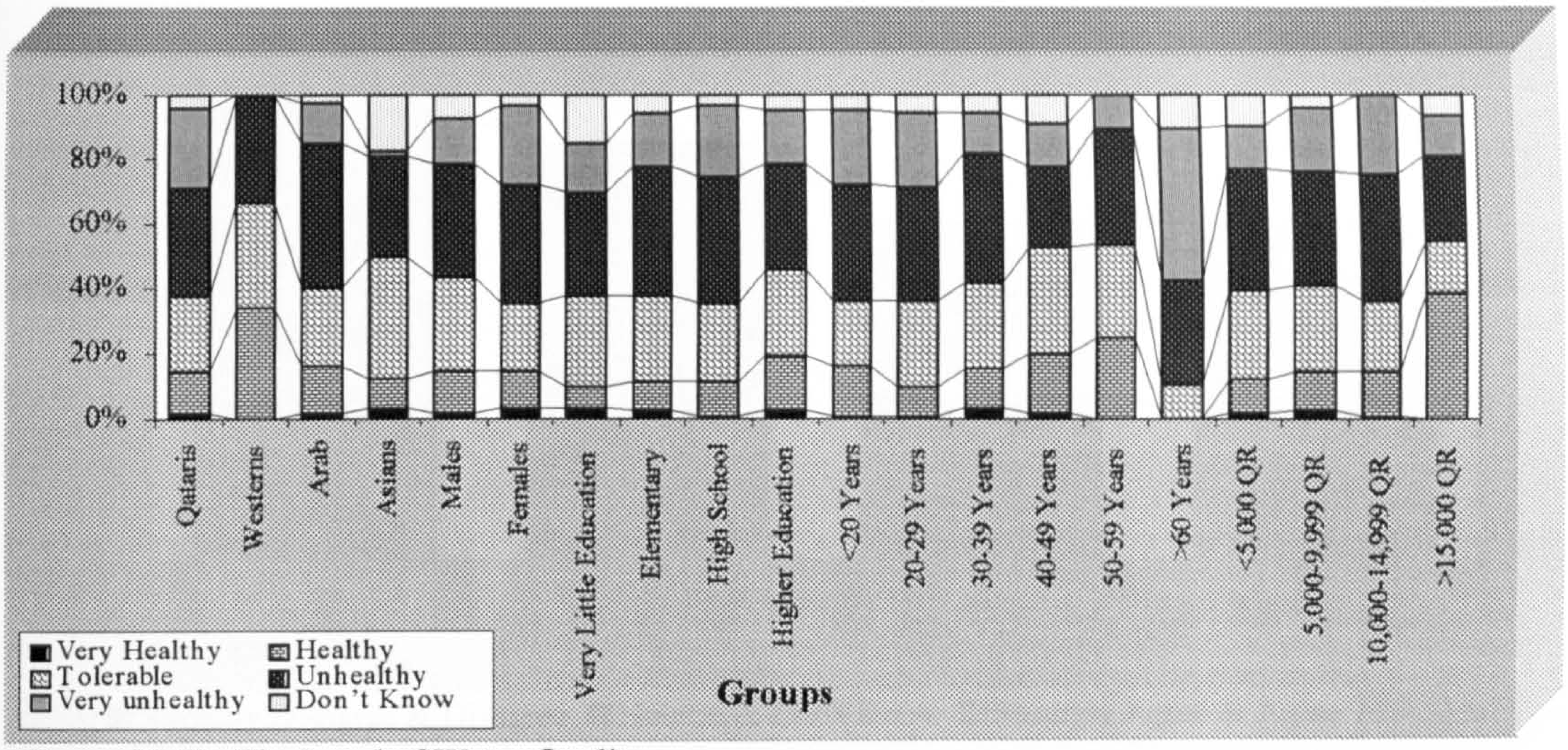

Figure 11.51. The Level of Water Quality.

11.2.4.2. Recycling:

There appears to be no clear pattern from factors such as citizenship, gender, age and income to attitudes on the possibility of using recycled water in all sectors (Section A14.3.3.2). There is, however, an apparent relation between education and altitudes to using this type of water (Figures 11.52 and 11.53). The higher the level of education especially high school, the higher is the tendency to support its use in a variety of sectors. Ignorance about the treatment of this water encourages people to oppose its usage or to be reluctant about accepting it as an alternative resource.

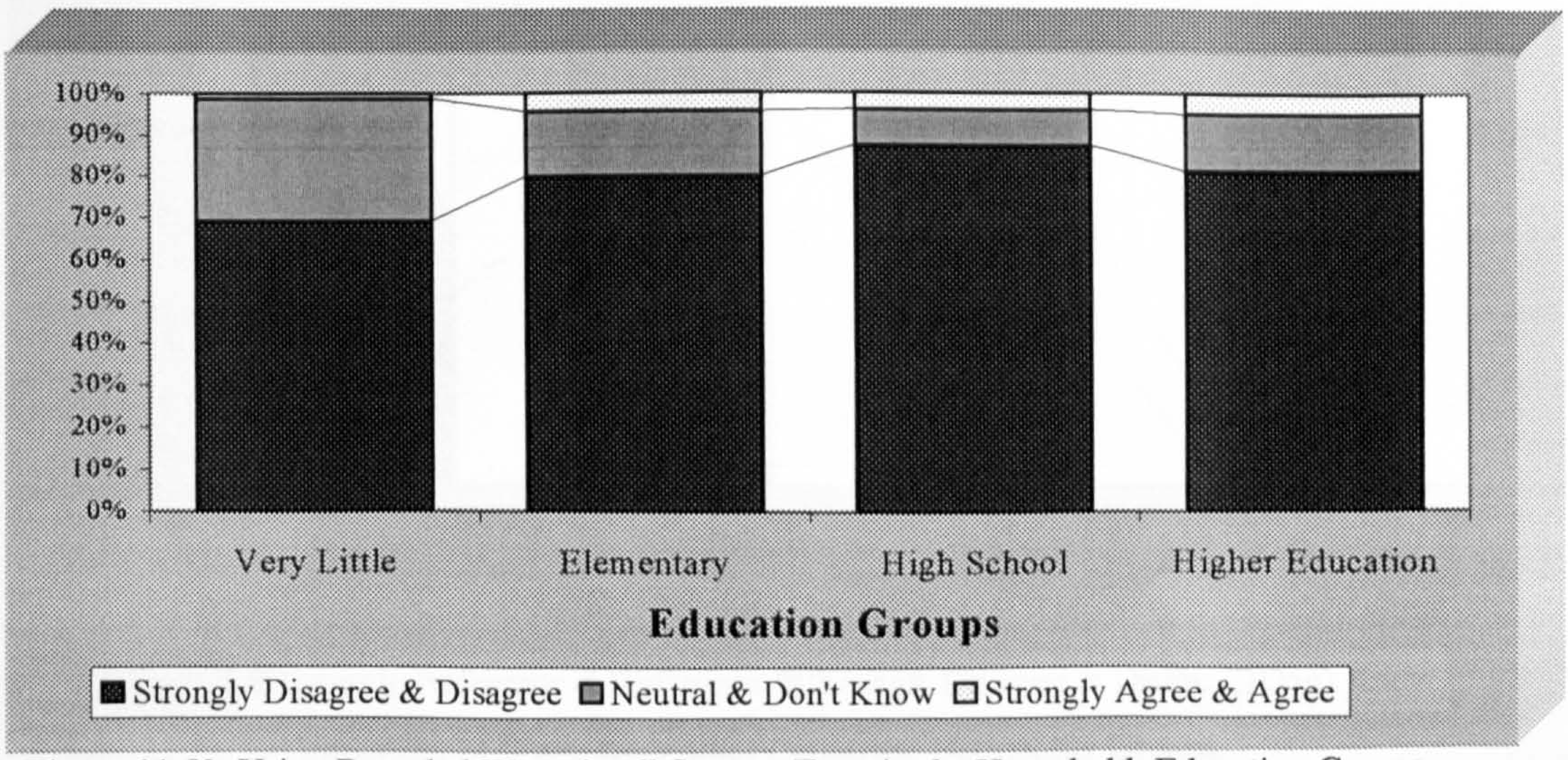

Figure 11.52. Using Recycled Water in all Sectors, Even in the Household: Education Groups.

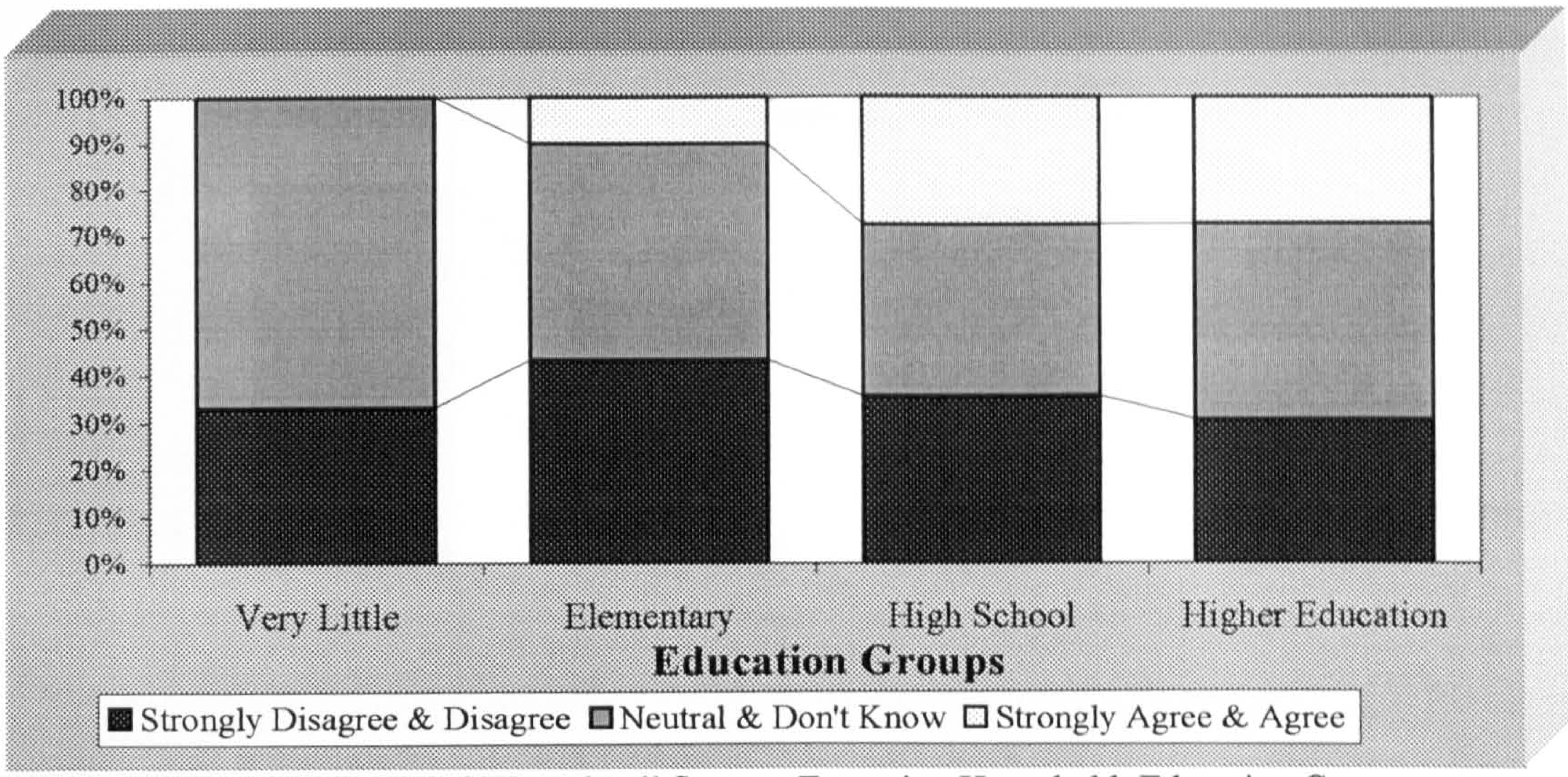

Figure 11.53. Using Recycled Water in all Sectors, Excepting Household: Education Groups.

11.2.4.3. Water Importation:

There is no strong relation between citizenship and altitudes to the possibility of importing water (Figures 11.54 and 11.55). While the majority rejected the idea, some important points were highlighted, such as the relative support among Qataris of the idea of importing water from Iran, maybe because it is a famous project. Arabs tend to support importing water from other Arabs countries, Asians show no knowledge of the matter.

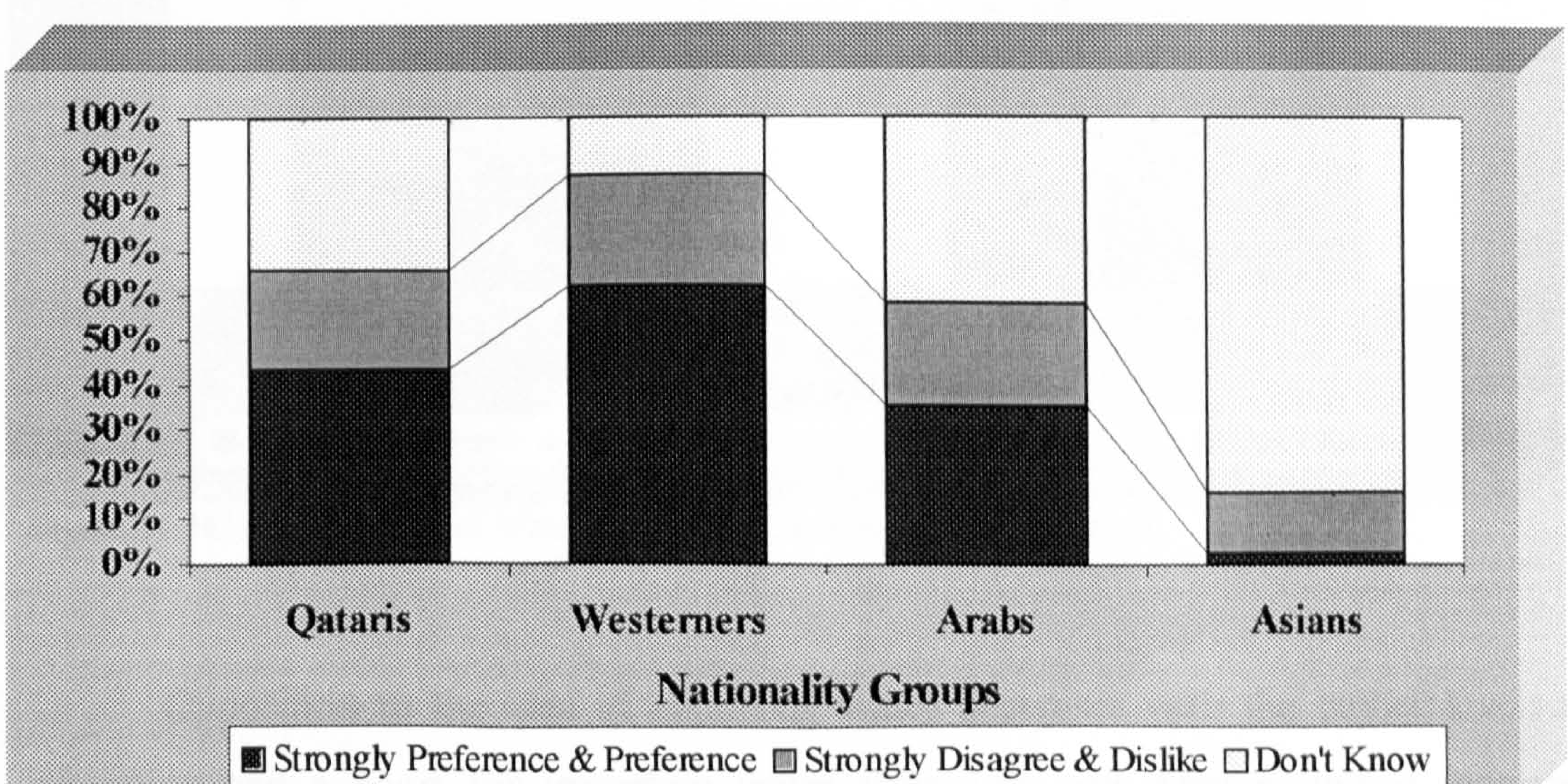

Figure 11.54. No Importing of Water from other Countries: Nationality Groups.

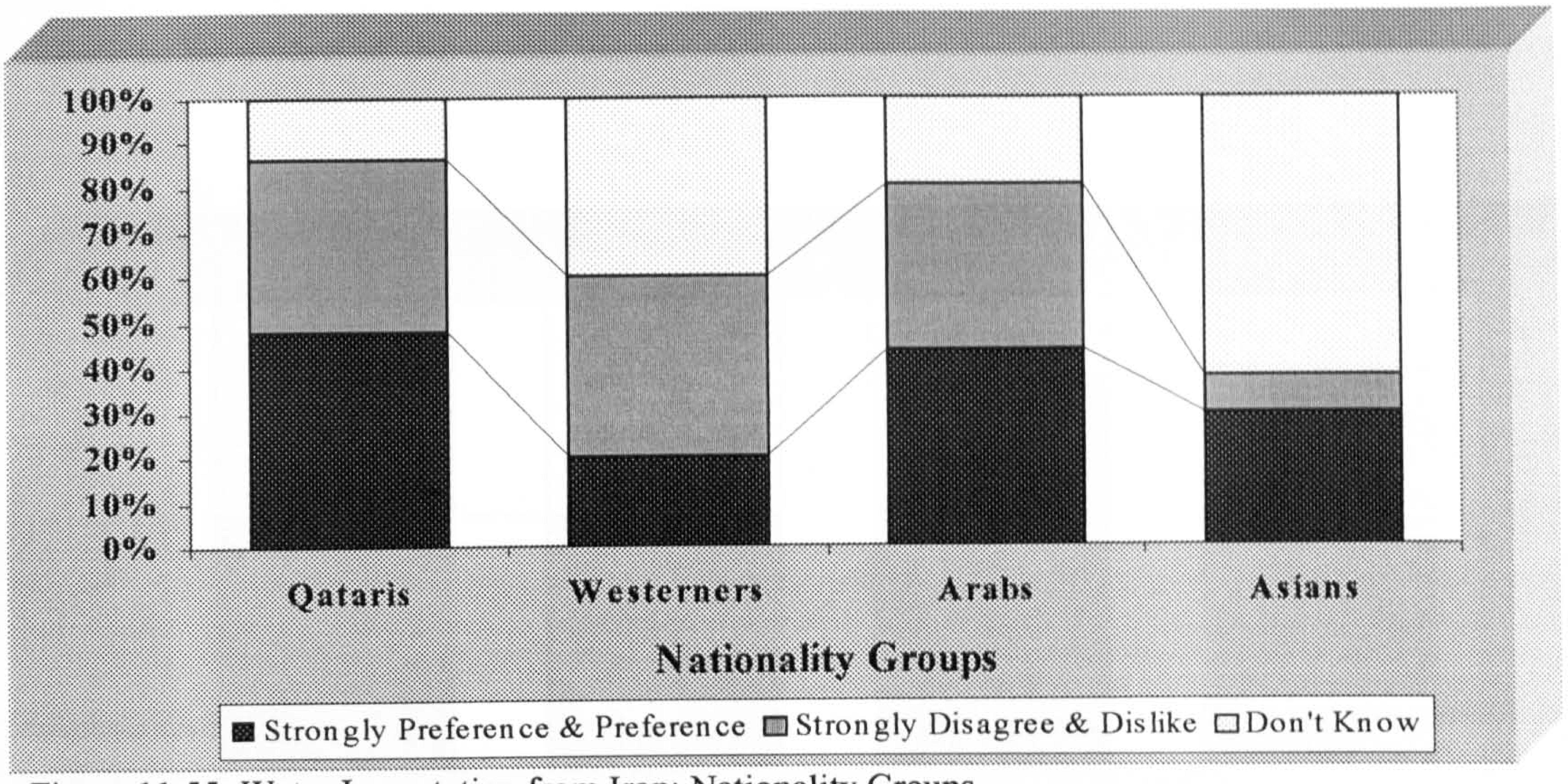

Figure 11.55. Water Importation from Iran: Nationality Groups.

Females show more opposition to the idea than males. They seem to be more knowledgeable about the dangers of importing water for national security (Figure 11.56). Since the majority of women are Qataris, a concern for security is more pronounced among them.

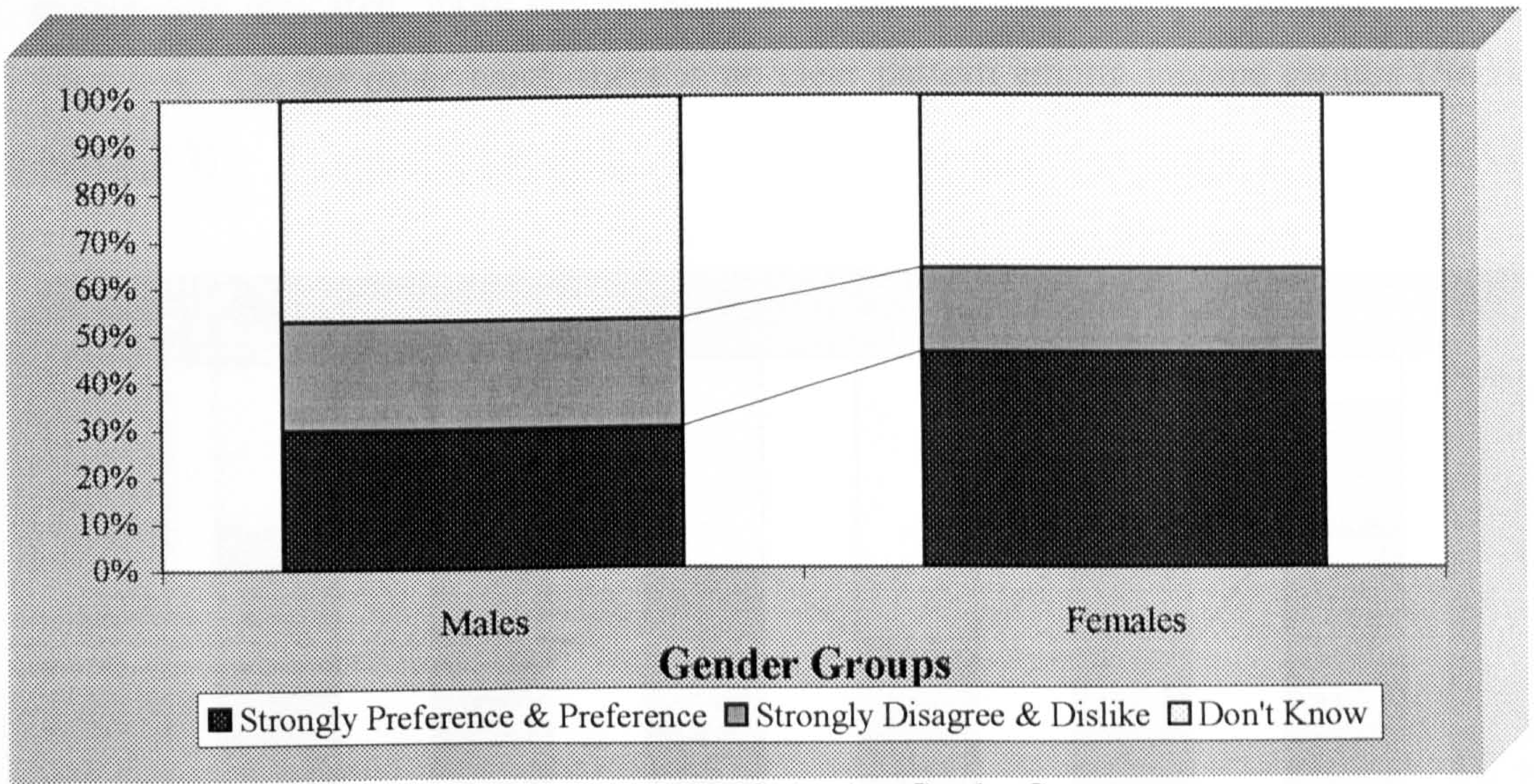

Figure 11.56. No Importing of Water from other Countries: Gender Groups.

Opposition to the idea of importing water decreases with the higher levels of education and support for importing water from Iran and Arab countries increases

(Figure 11.57). The educated appear to be aware of proposed projects and are most likely to be aware of the water issue.

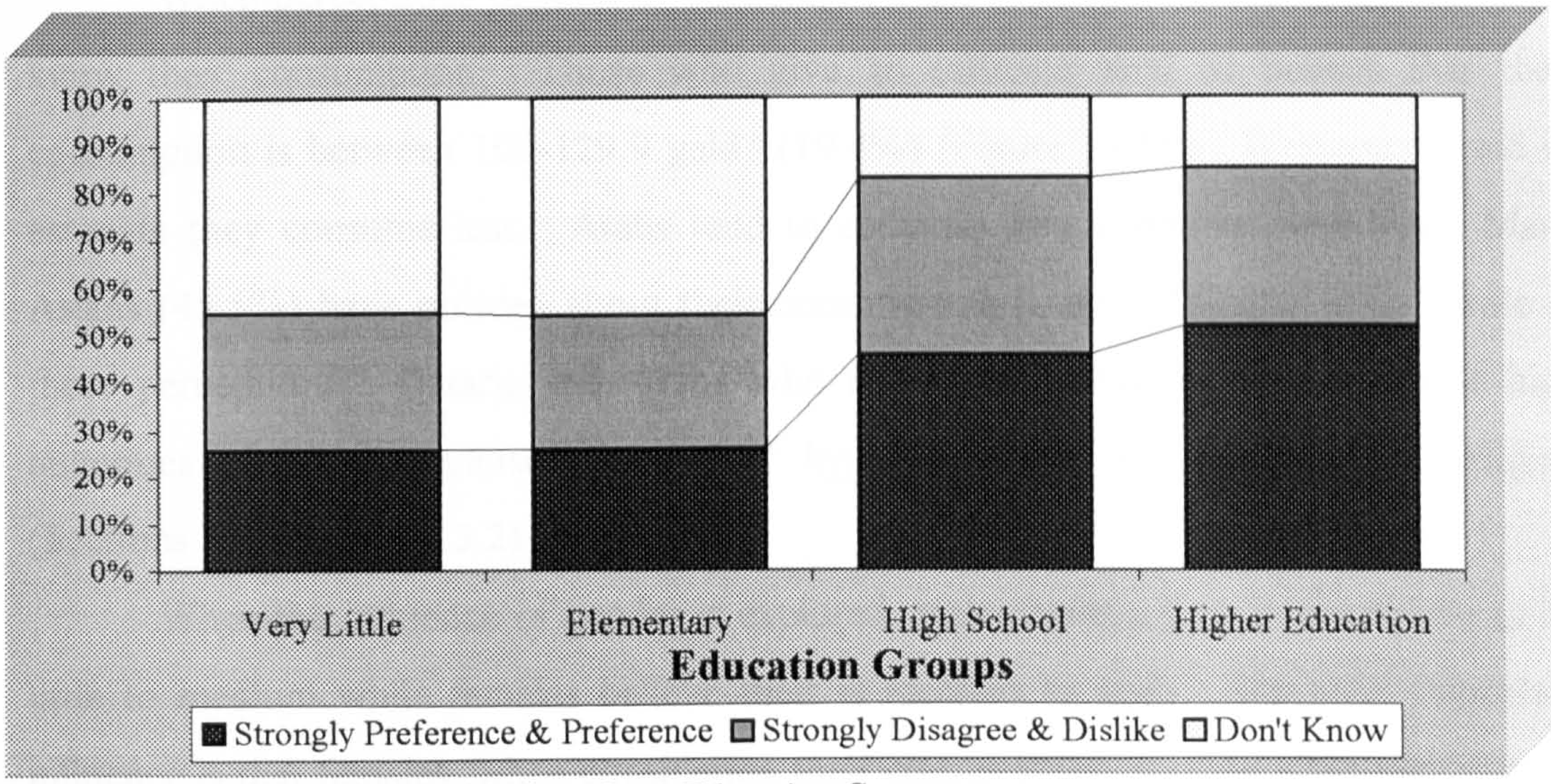

Figure 11.57. Water Importation from Iran: Education Groups.

When the influence of age was explored, the only clear pattern was that the older the respondent the higher was the objection to the idea (Figure 11.58). Older people are usually less educated, more conservative and reluctant to become dependent on others countries. On the other hand, there is no clear pattern among income groups (Section A14.3.3.3).

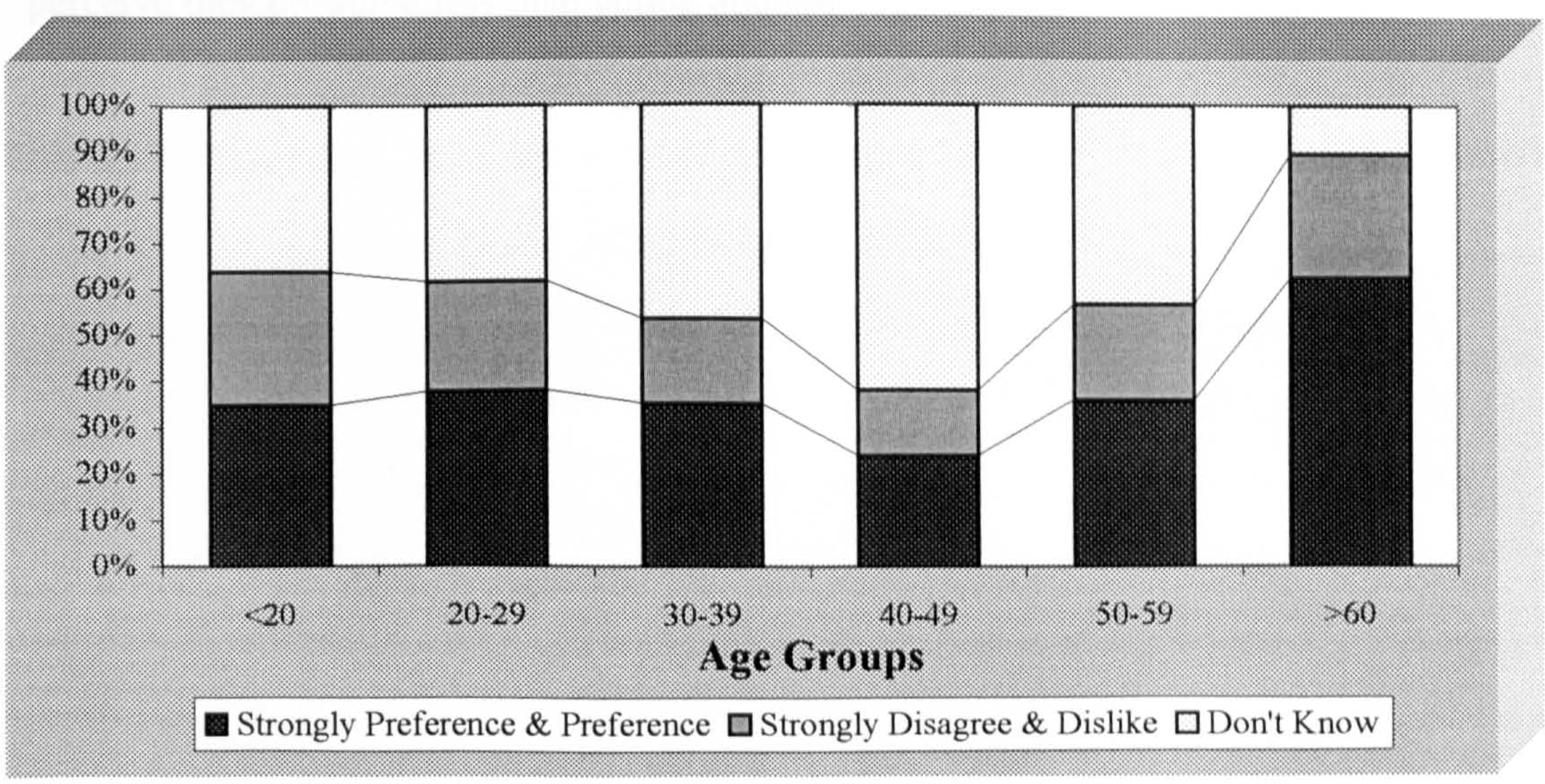

Figure 11.58. No Importing of Water from other Countries: Age Groups.

11.2.5. Water Consumption:

11.2.5.1. Perceptions of Consumption:

When perceptions of level of consumption are explored, 42.5% of Qataris don't know their consumption. Those who give an estimate tend to believe that their consumption is between 100-129.9 $gald^{-1}$ (19.4%) (Figure 11.59). Westerners tend to estimate they consume less. Arabs tend to estimate they consume even less. Many Asians (45.5%) have no idea about their consumption levels. Religion plays a role in these perceptions. Qataris and Arabs who are Muslims believe they consume high quantities of water because of personal hygiene, which is emphasised by religion (Sections 11.3.1 and 11.3.2).

When the influence of gender is explored, males believe their consumption to be little to medium while females believe their is medium to high. The most important influence is that females, when considering their consumption, include what they use for cooking, cleaning etc. Males usually do not consider these purposes.

There is a clear relationship between income and consumption. The higher the income the higher is the consumption. High living standards increase demand for water because of factors such as the size of house, number of cars, presence of gardens. Perceived consumption also increases with higher levels of education. This is because the poorly-educated group including many Asian and Arab workers who believe their consumption is low. Middle aged people again, many of whom are Asians and Arabs perceive they consume less than young and old.

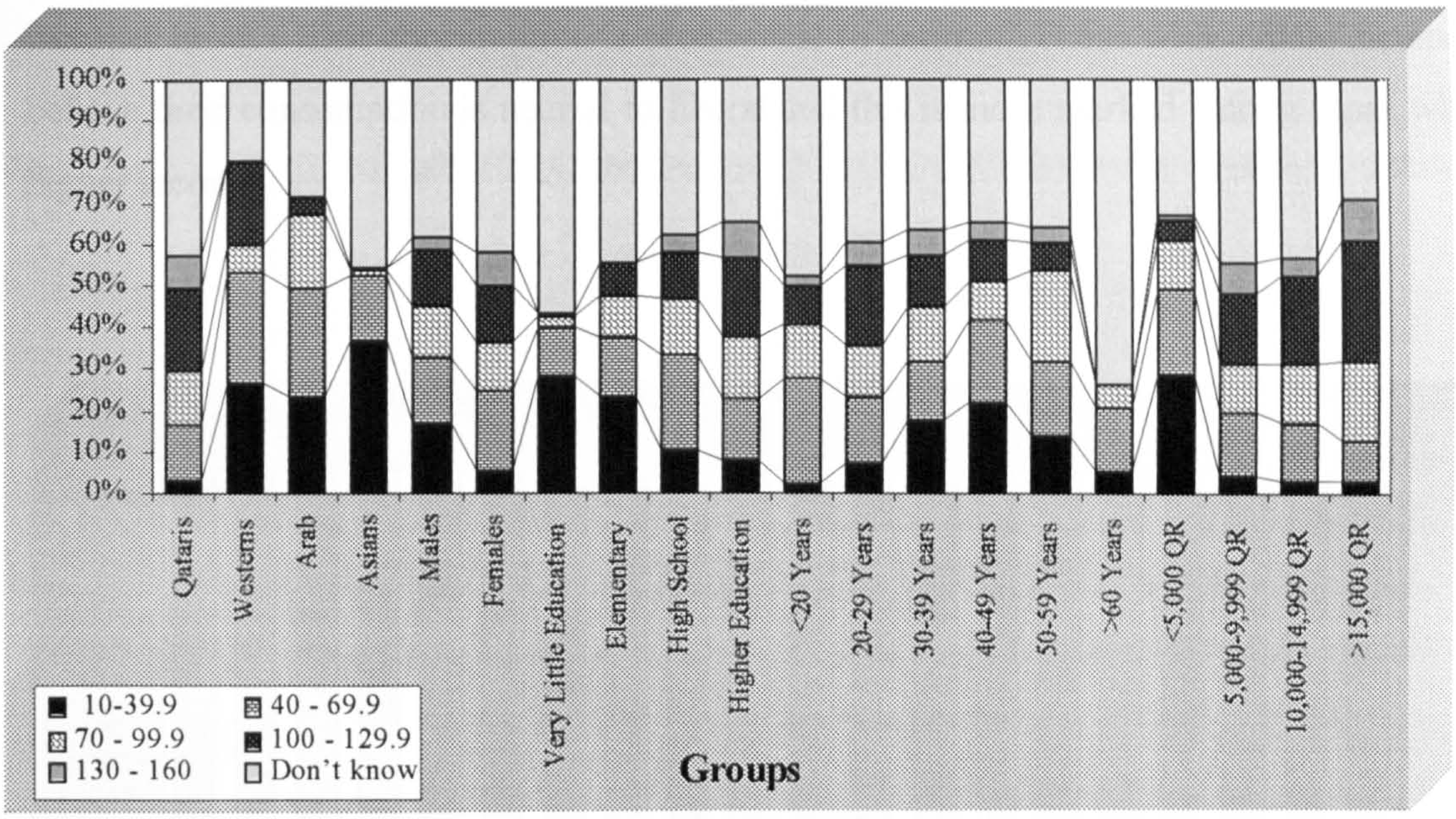

Figure 11.59. The Level of Groups Estimated Water Consumption in Gallon per Day.

11.2.5.2. Perception of Consumption Behaviour:

Qataris and Westerners tend to believe that their consumption behaviour is normal to excessive, while Arabs and many Asians consider it normal to economical (Figure 11.60). The major factor influencing these perceptions is the high standards of living of Qataris and Westerners, especially in comparison with Arabs and Asians. Westerners have the means to pay for water and Qataris are exempted from paying tariffs. Asians and Arabs have usually a lower standard of living and less ability to pay for water, and so economise.

The majority of males (42.1%) think that their consumption is normal with a tendency (34.1%) towards being economical, while females think is normal (54.5%) with a tendency (24.7%) for excessive consumption, probably because many men are poor migrants (Section 11.2.5.1). There is a clear relation between education and the perception of consumption. Most poorly-educated respondents believe their consumption to be normal to economical, while the highly educated feel theirs is normal to excessive. This has been mentioned also in the section discussing the levels of consumption.

Income appears to be the strongest influence on the behaviour. Those with low incomes believe their consumption is economical to neutral. Those with middle incomes believe their consumption is neutral to liberal and this is more marked among those with higher incomes.

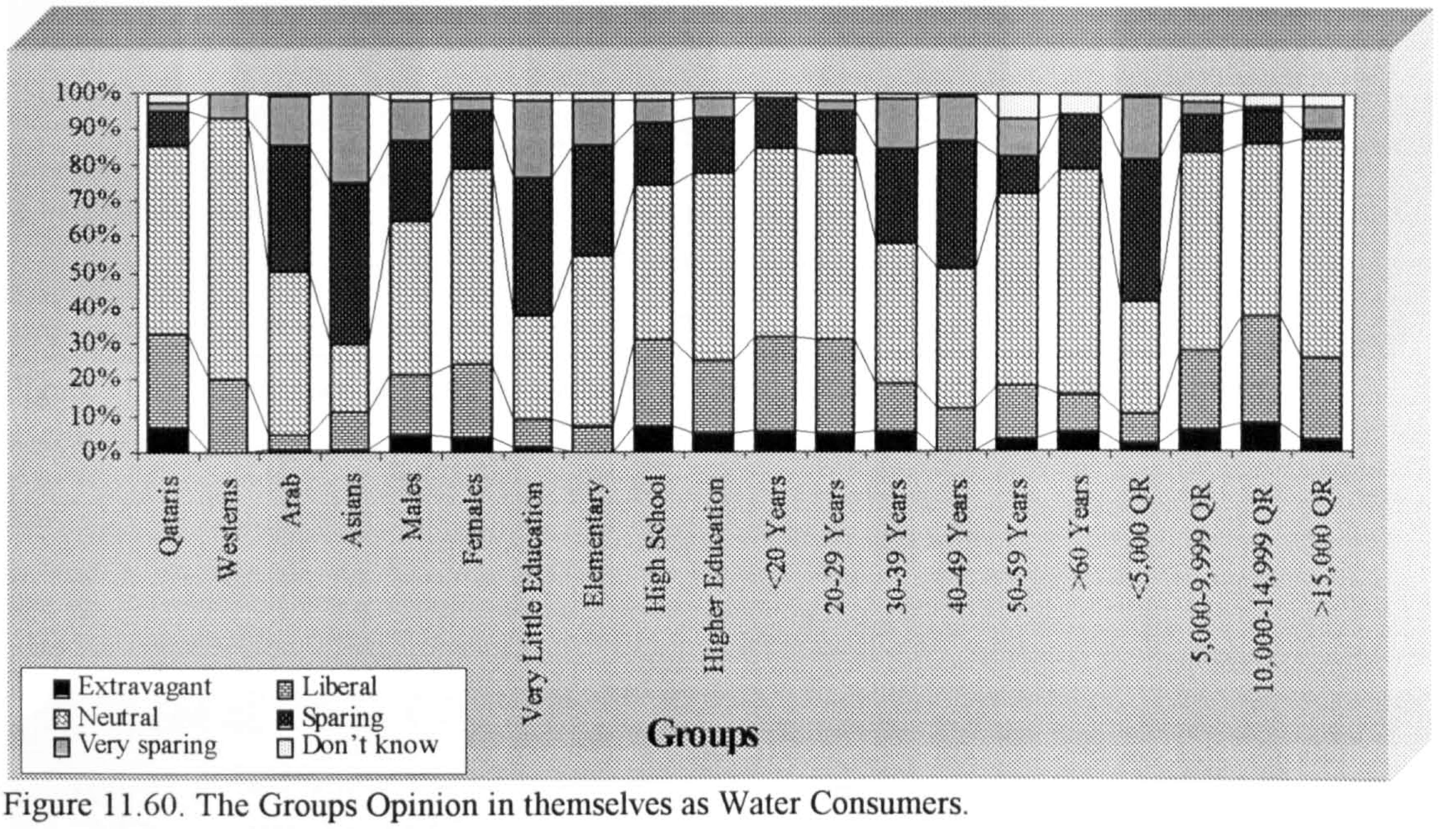

Figure 11.60. The Groups Opinion in themselves as Water Consumers.

11.2.5.3. Reasons for Consumption Patterns:

The availability of water, the ease of obtaining it, customs, traditions and living standards are, according to all nationality groups, especially Qataris and Westerners, the most important influences on consumption behaviour (Figures 11.61, 11.62, 11.63 and 11.64). Asians, some Westerners and Arabs put water tariffs as the most important factor influencing their behaviour, in addition to the availability of water and customs.

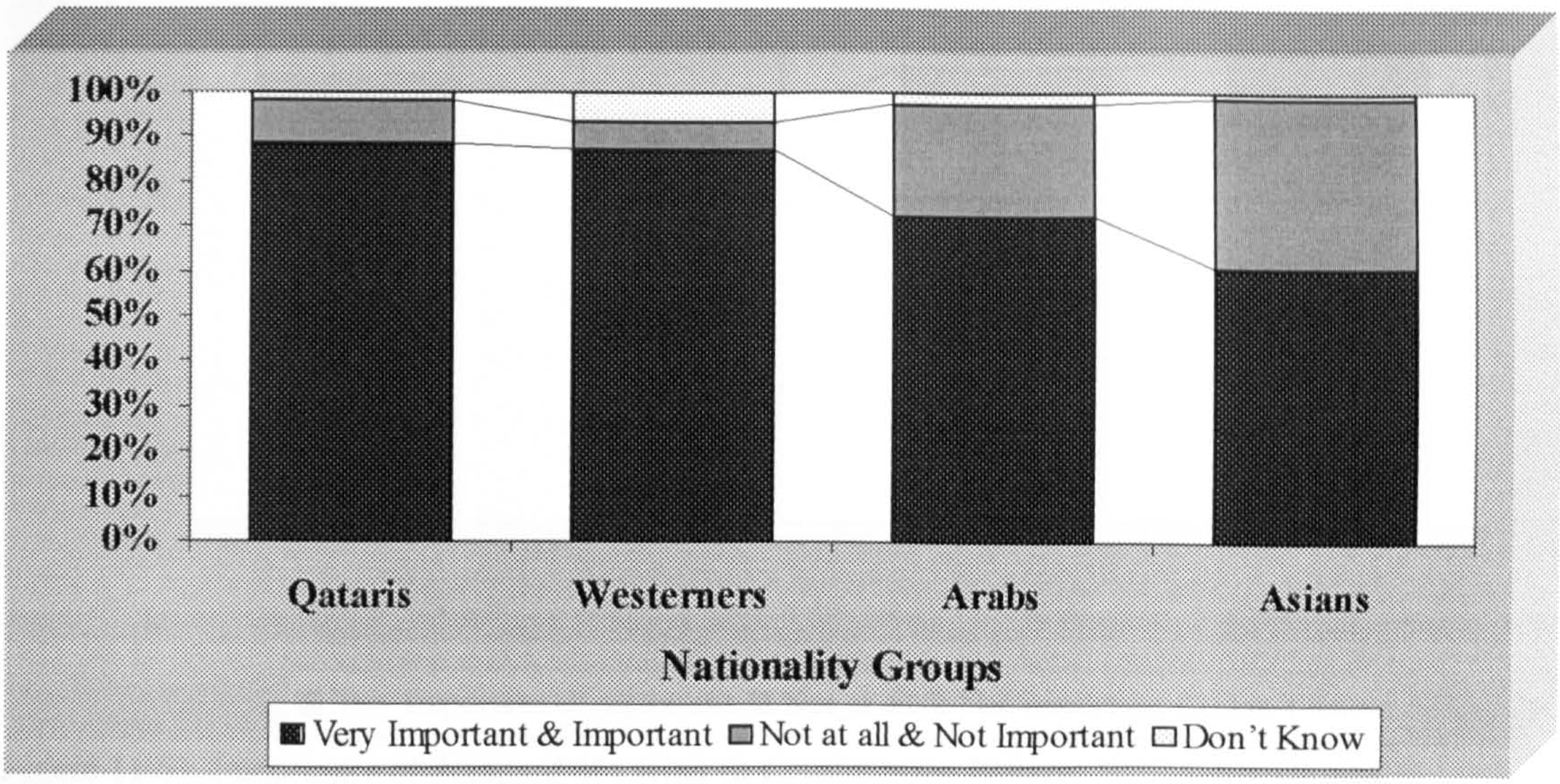

Figure 11.61. Importance of Water Availability in Consumption Pattern: Nationality Groups.

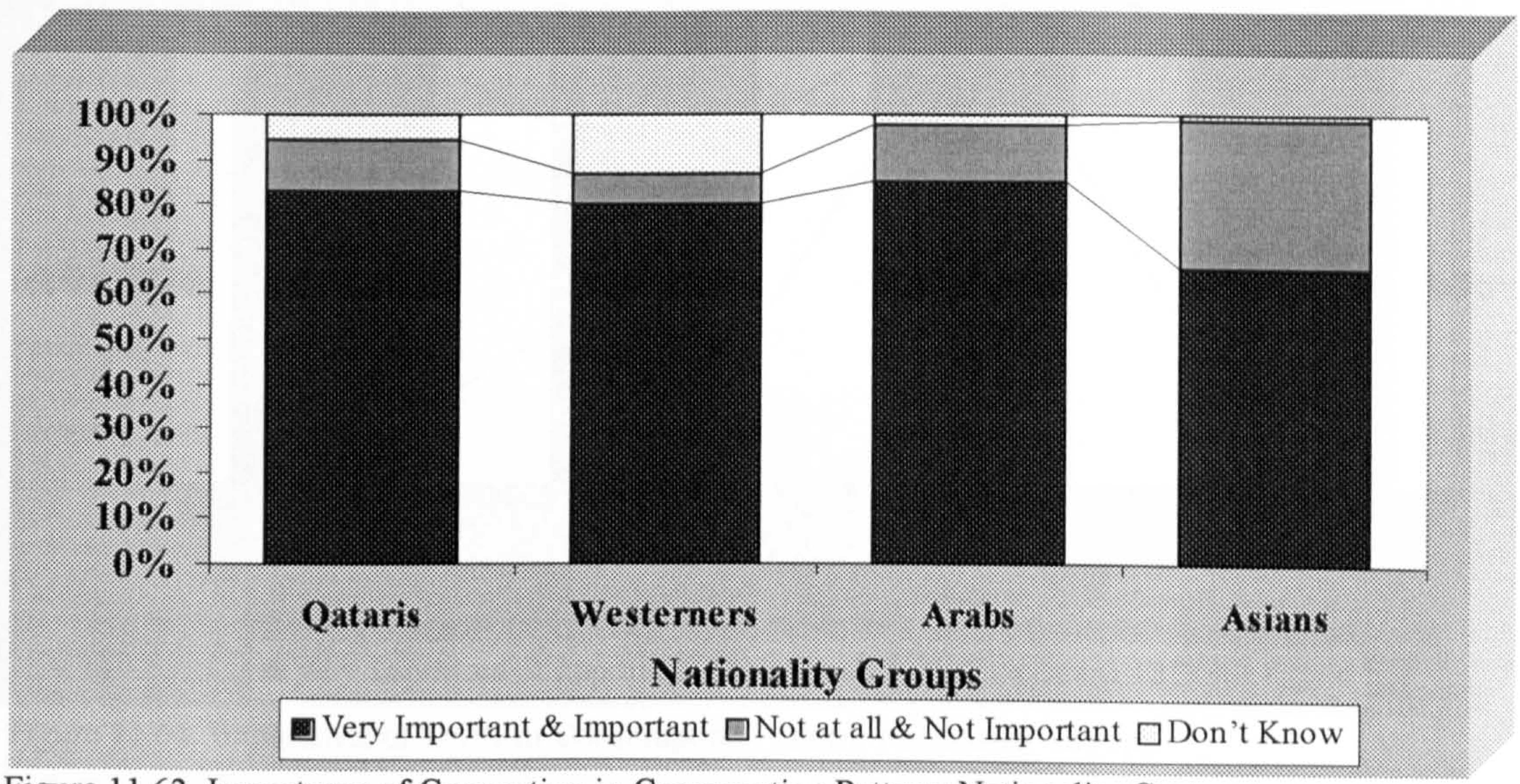

Figure 11.62. Importance of Convention in Consumption Pattern: Nationality Groups.

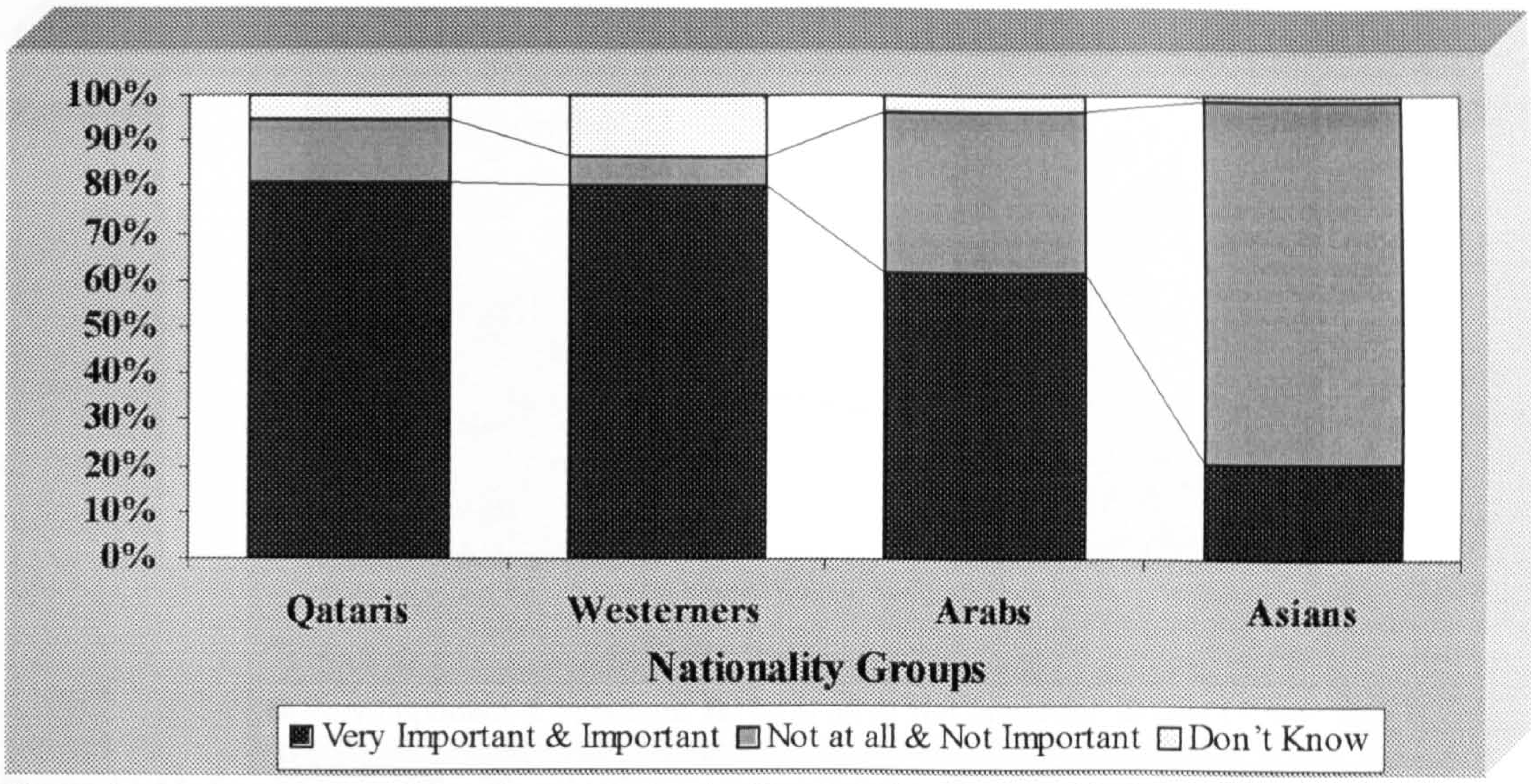

Figure 11.63. Importance of Standard of Living in Consumption Pattern: Nationality Groups.

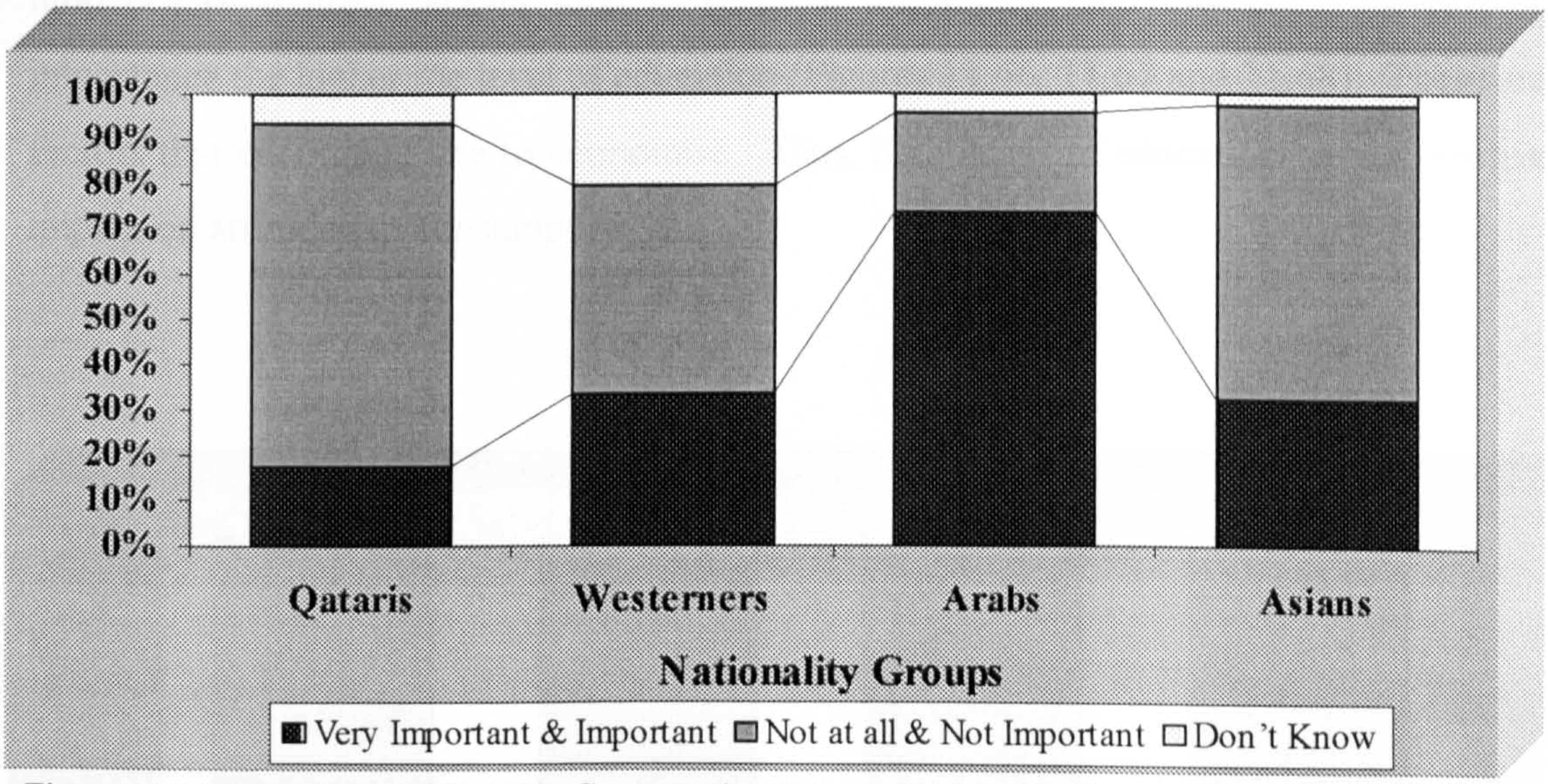

Figure 11.64. Importance of Tariff in Consumption Pattern: Nationality Groups.

There is a little pattern between gender groups, although water tariffs have a greater influence on male behaviour than females (Figure 11.65). Females list factors such as religion, upbringing, education, awareness, water availability and convention as most influential.

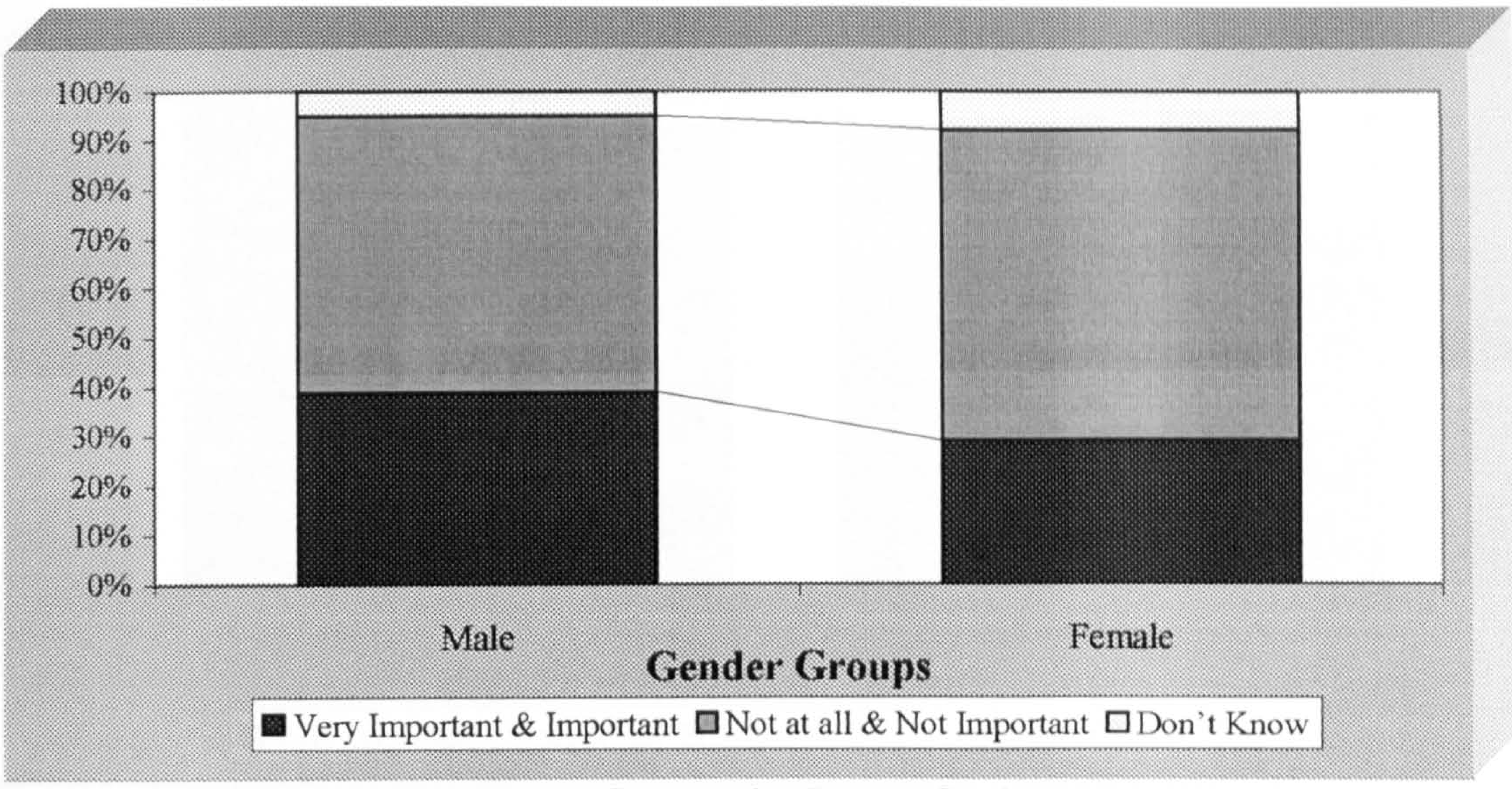

Figure 11.65. Importance of Tariff in the Consumption Pattern: Gender groups.

When considering education, most factors carry similar importance. The influence of indirect factors such as religion, upbringing, and awareness increase in importance the higher the level of education (Figures 11.66, 11.67 and 11.68). These are factors that encourage one to economise. Thus, high levels of education have a positive impact on attitudes to consumption.

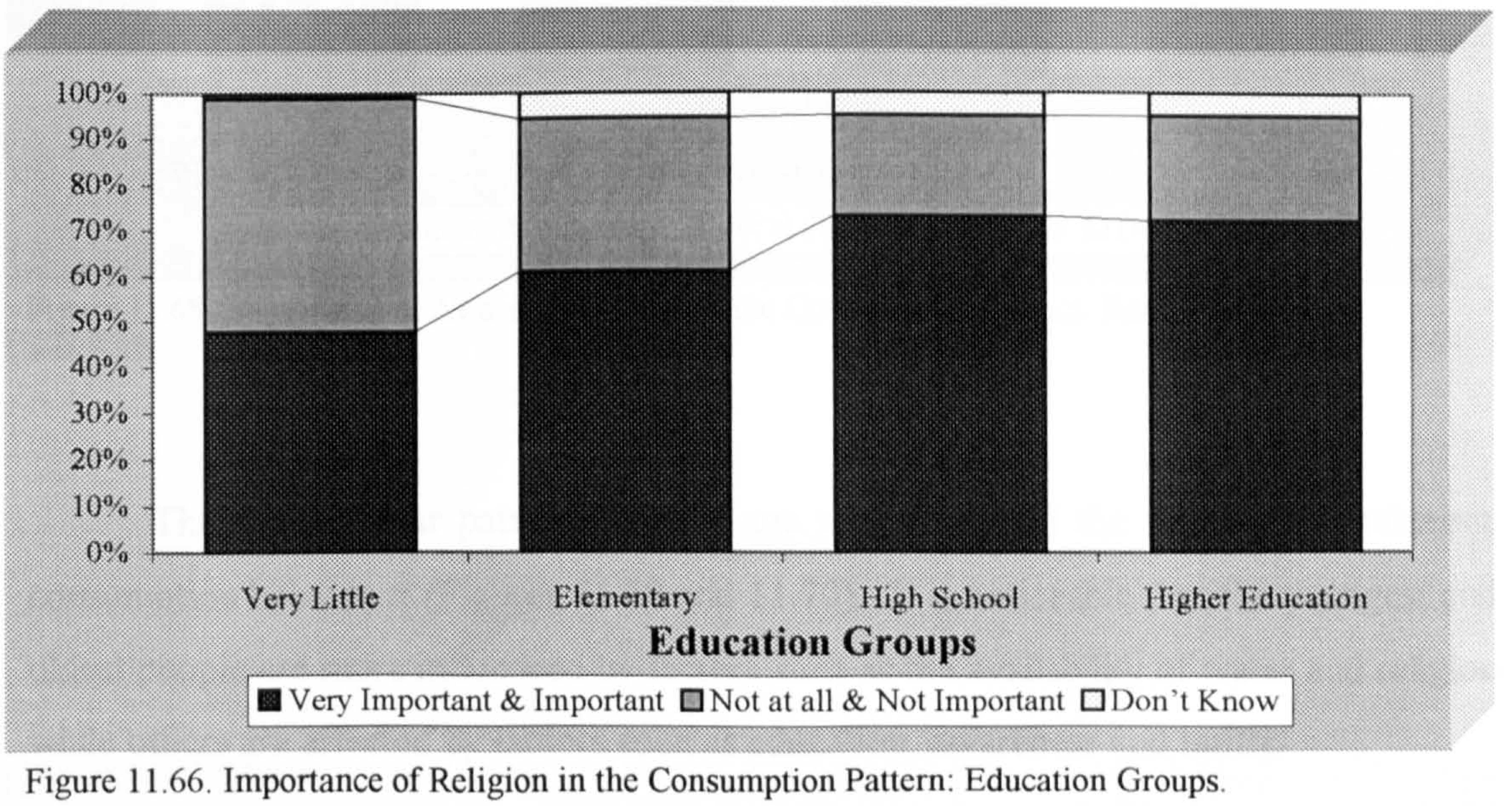

Figure 11.66. Importance of Religion in the Consumption Pattern: Education Groups.

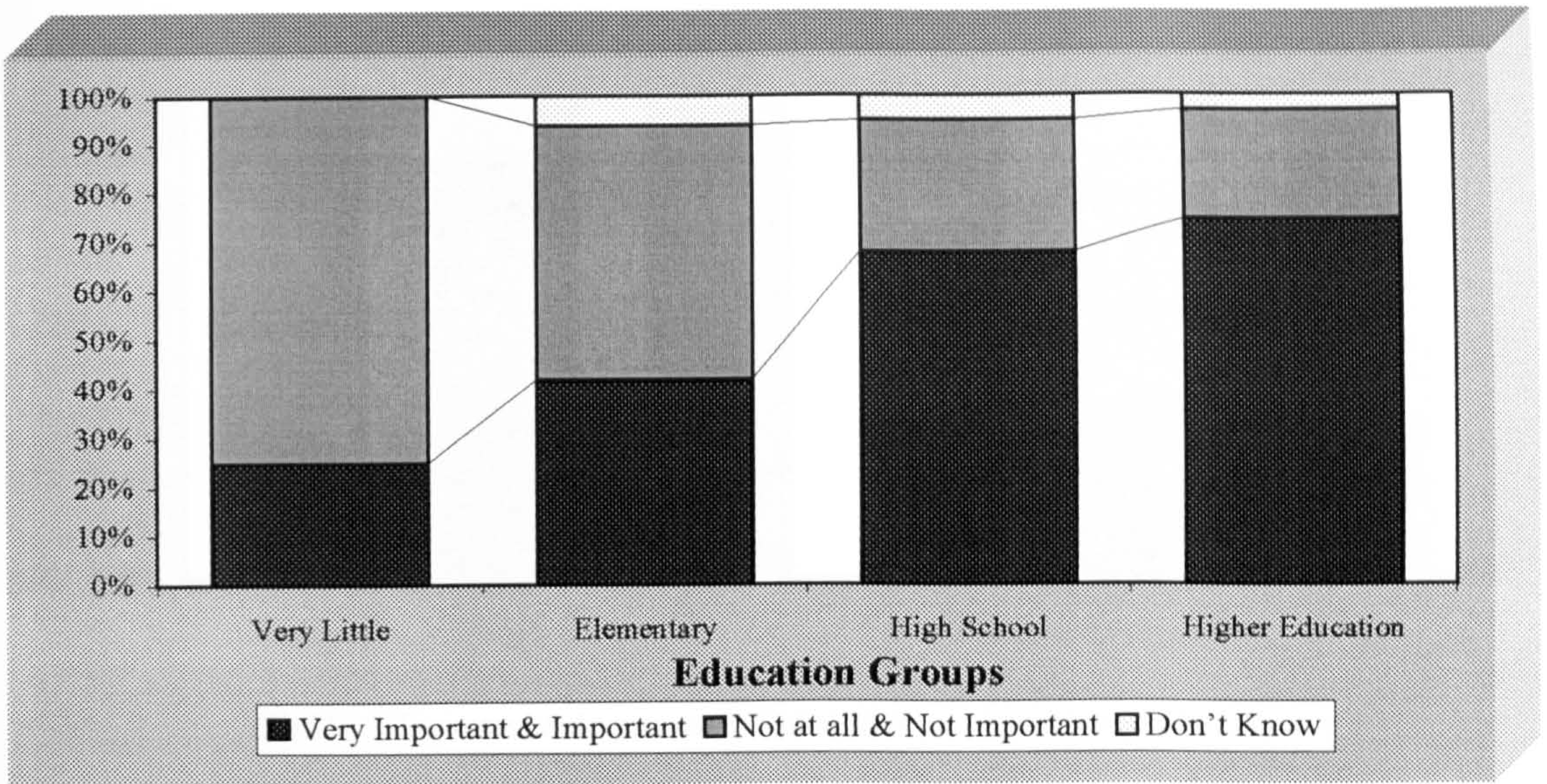

Figure 11.67. Importance of Family Attitude in the Consumption Pattern: Education Groups.

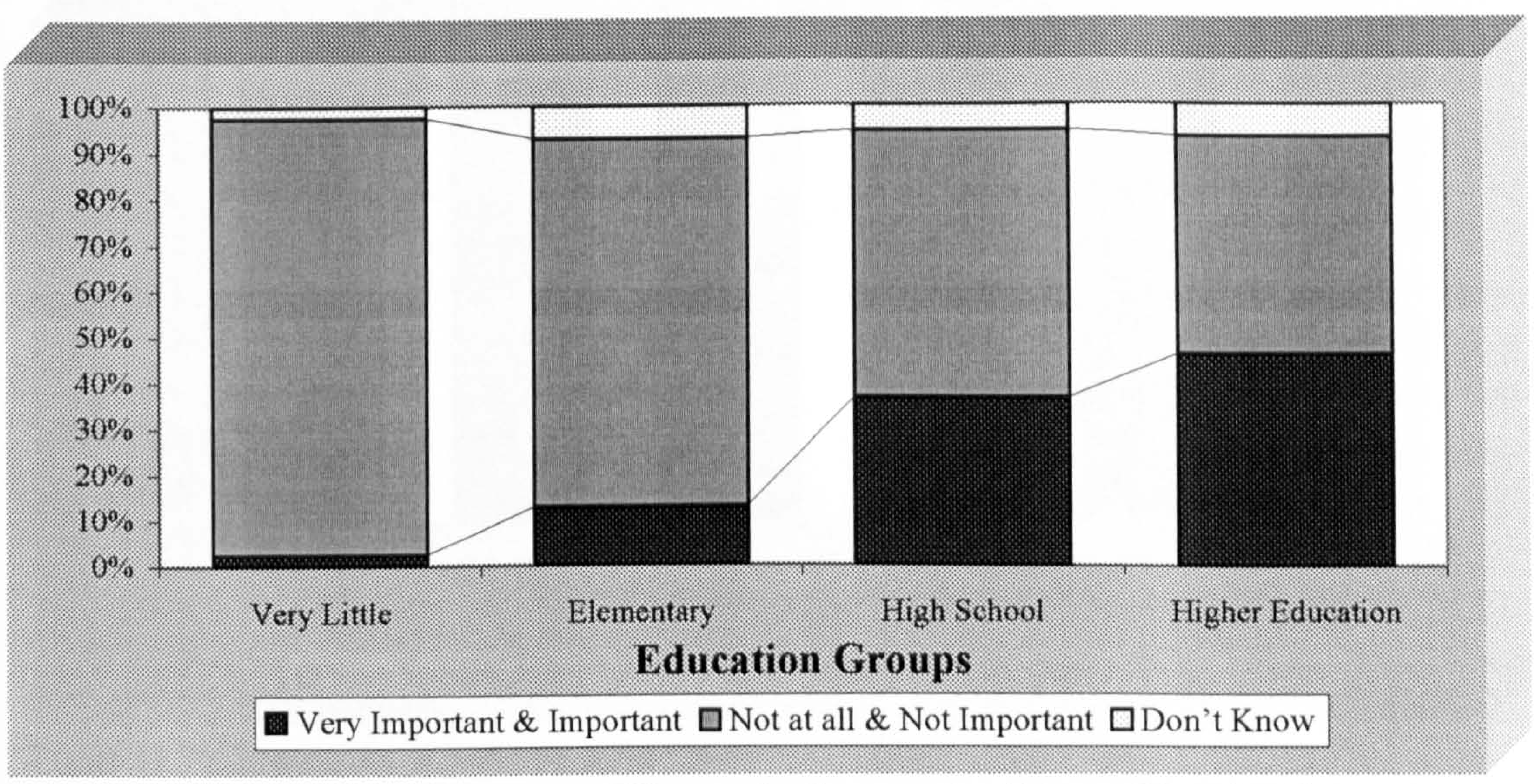

Figure 11.68. Importance of Awareness Efforts in the Consumption Pattern: Education Groups.

There is no clear pattern between age groups and all the factors that influence consumption behaviour (Figures 11.69 and 11.70). It is noticeable that the youngest and oldest people are more influenced by factors such as the availability of water and religion while others are affected by factors such as education, awareness and tariffs.

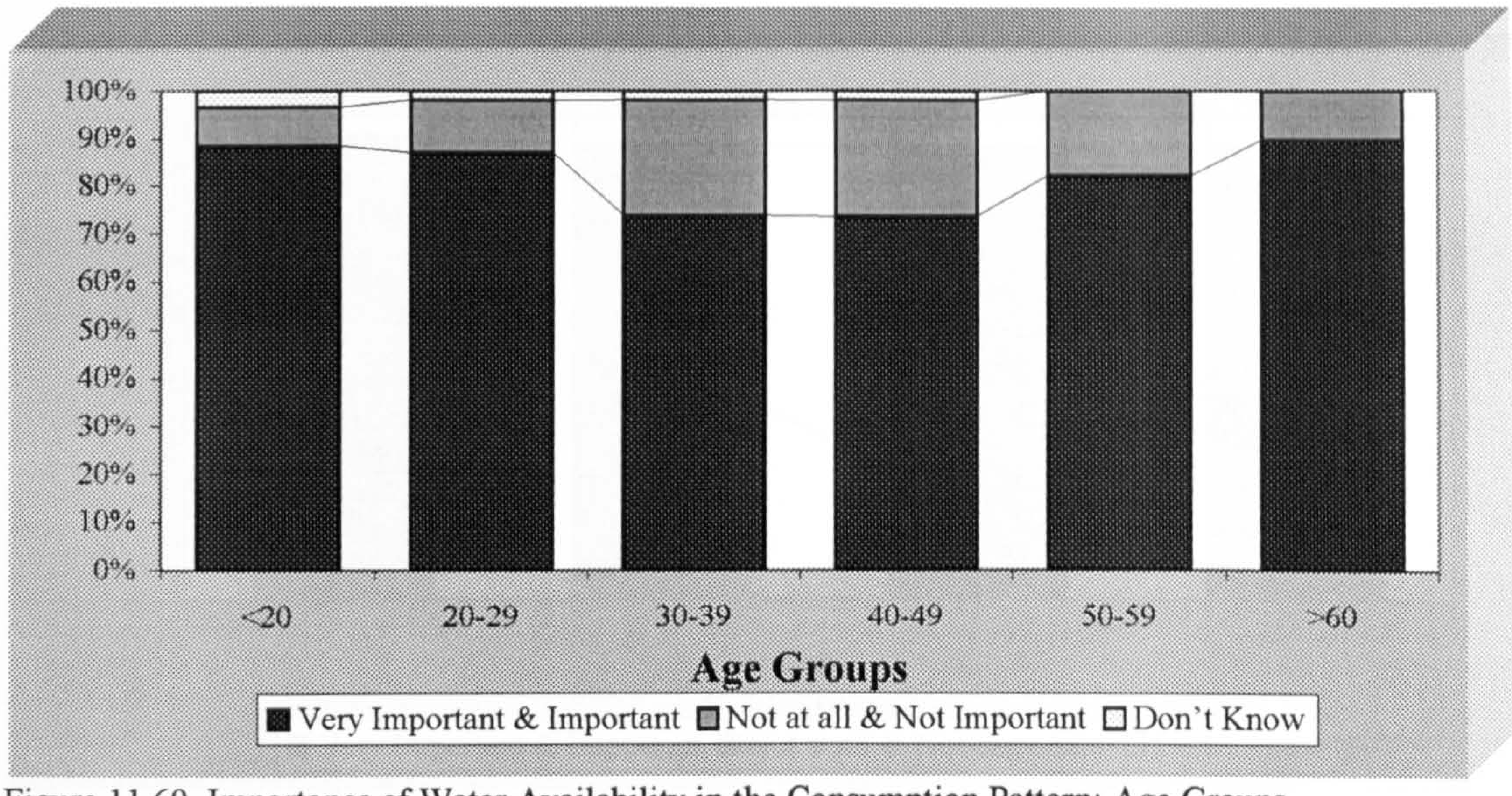

Figure 11.69. Importance of Water Availability in the Consumption Pattern: Age Groups.

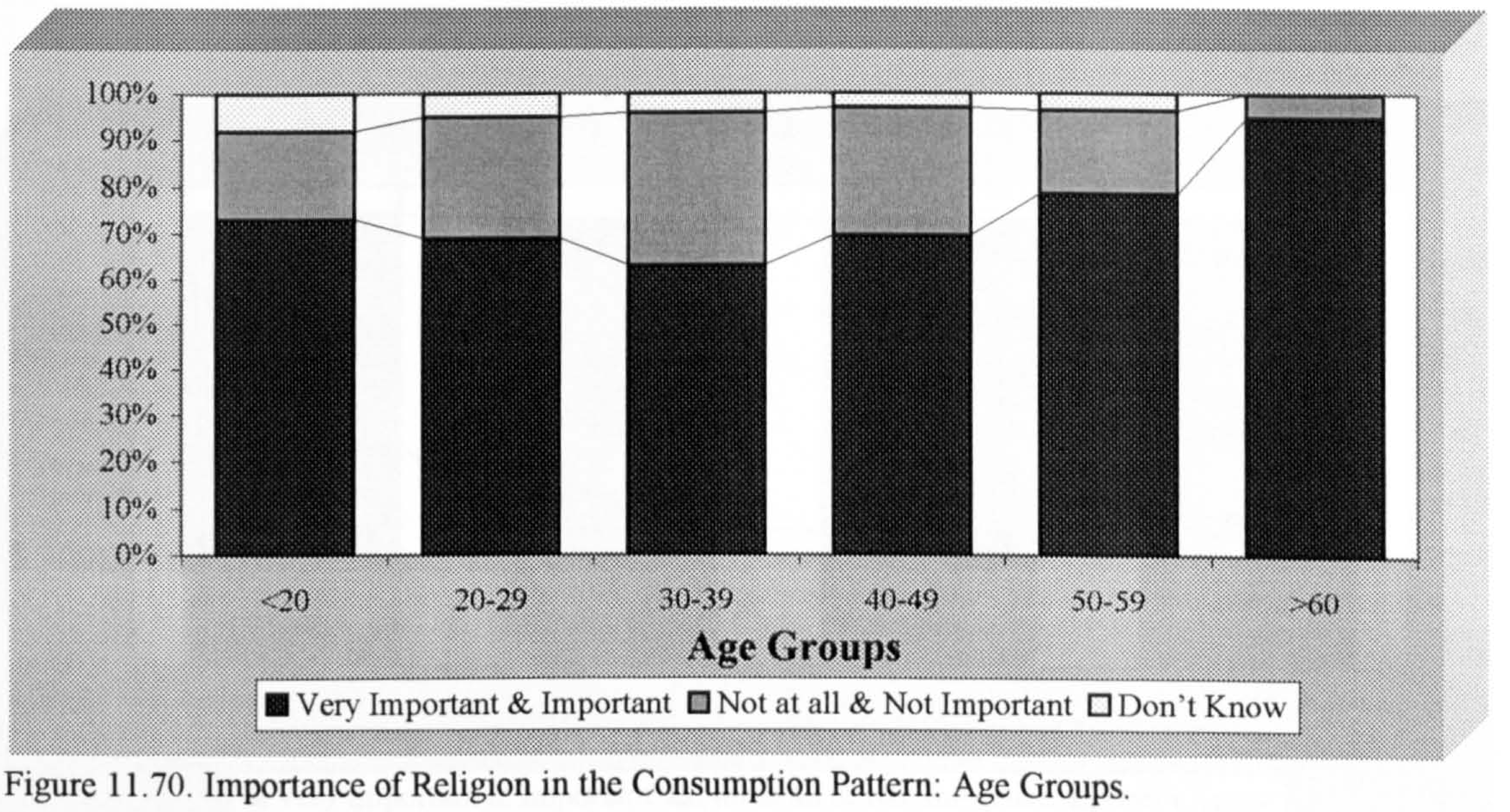

Figure 11.70. Importance of Religion in the Consumption Pattern: Age Groups.

The middle incomes are less affected by tariffs and laws, while factors such as upbringing, awareness, religion and availability of water increase in impact (Figures 11.71 and 11.72). This is normal because the poor are less able to pay water rates and fines and are thus more sensitive to such influences, while people with high incomes are not much affected. Middle income people also tend to be more educated and hence more responsive to factors such as education and raising awareness.

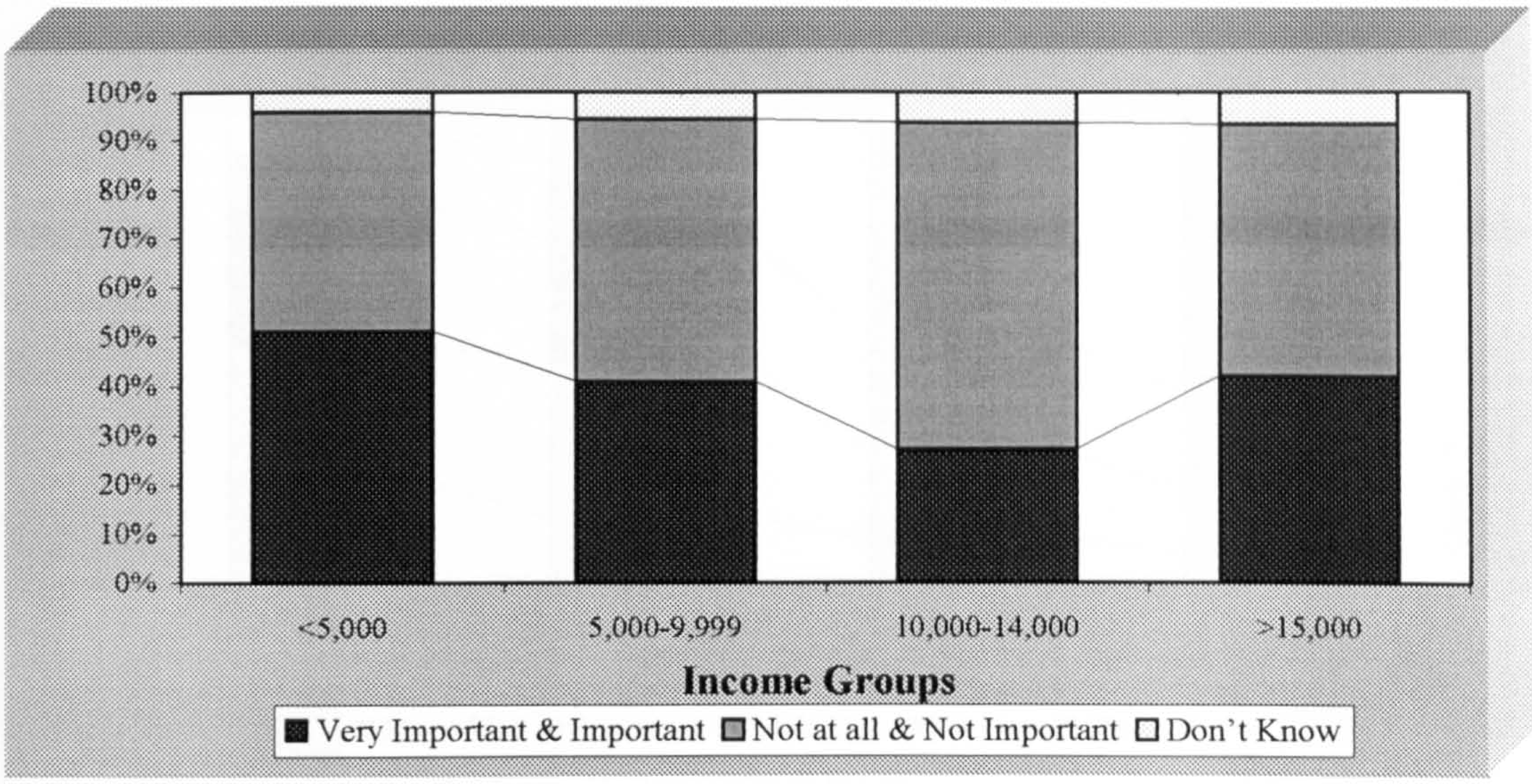

Figure 11.71. Importance of Water Tariff in the Consumption Pattern: Income Groups (QR).

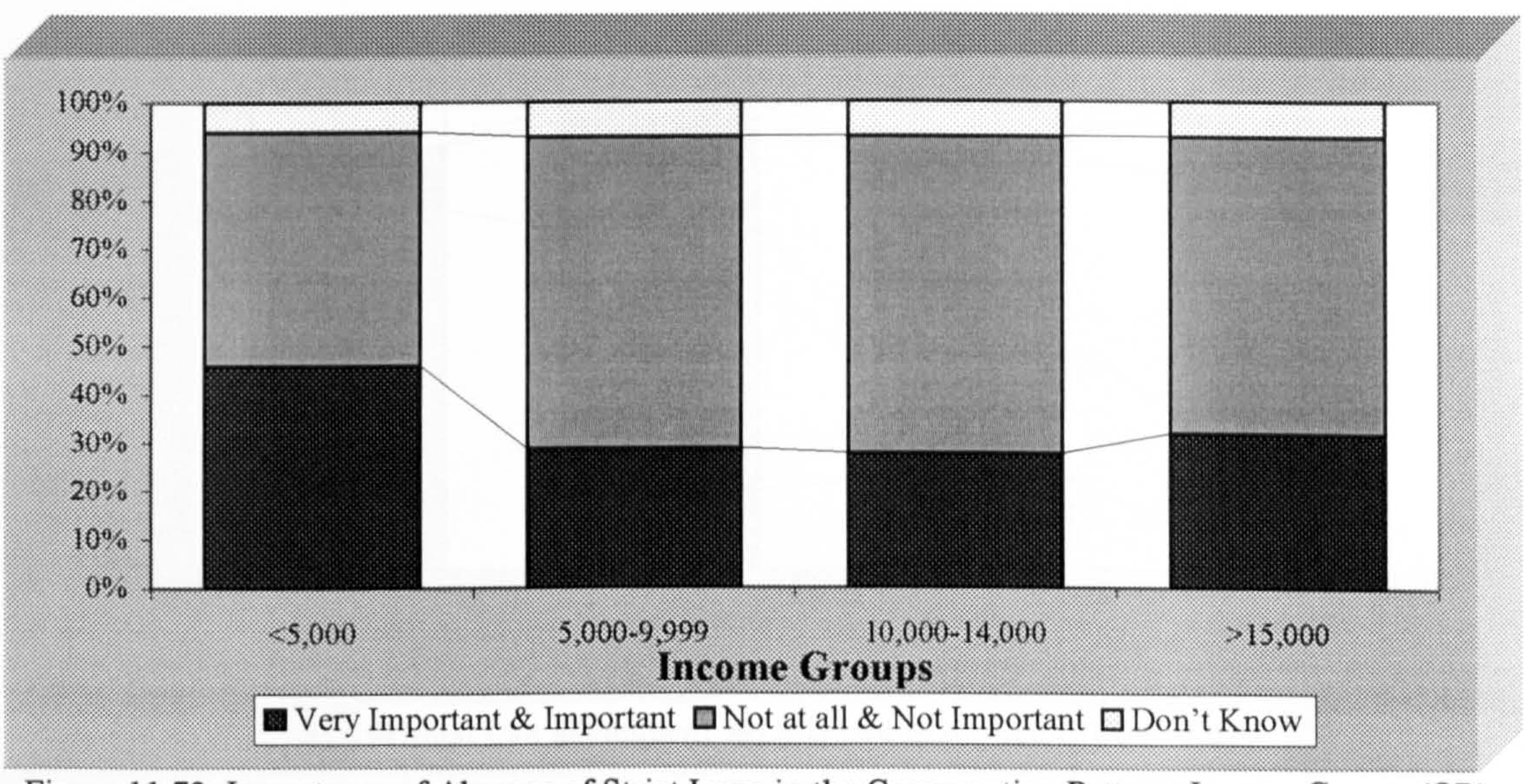

Figure 11.72. Importance of Absence of Strict Laws in the Consumption Pattern: Income Groups (QR).

11.2.5.4. Patterns of Water Use:

There is no a clear pattern between nationality and patterns of water use, except that Asians and some Arabs used little water for watering gardens and washing (car, clothes, floor and dishes) (Figures 11.73 and 11.74).

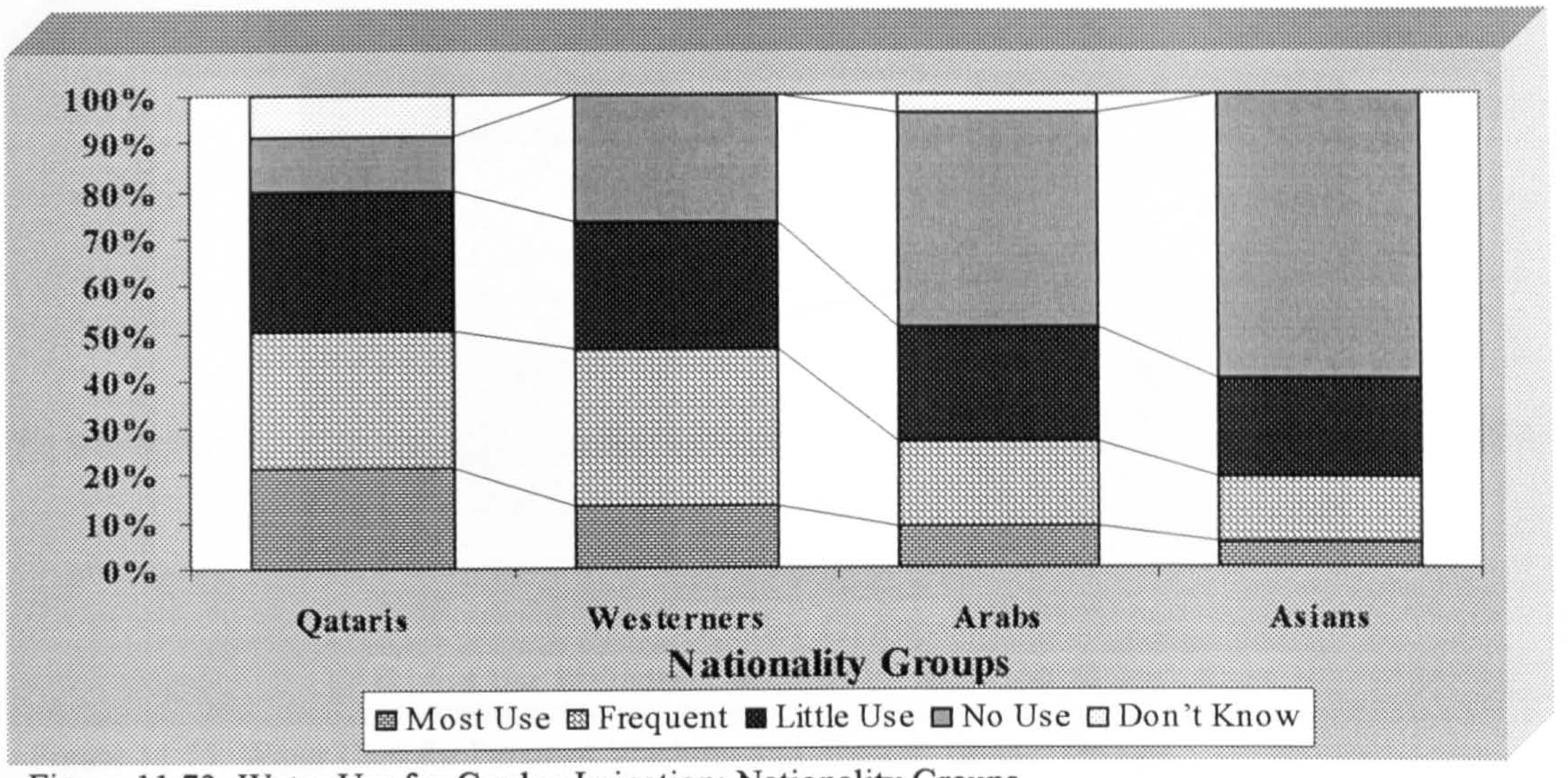

Figure 11.73. Water Use for Garden Irrigation: Nationality Groups.

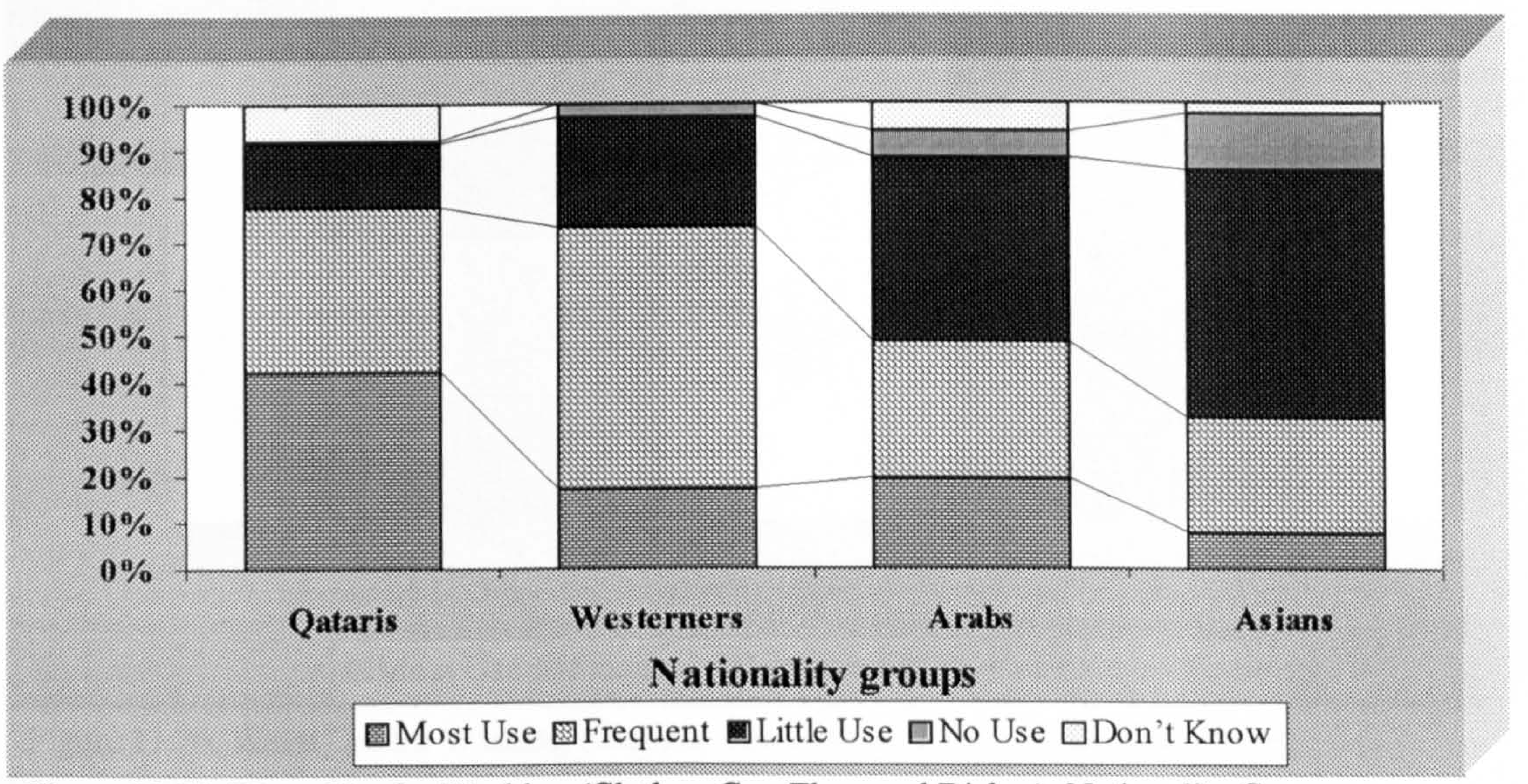

Figure 11.74. Water Use for Washing (Clothes, Car, Floor and Dishes): Nationality Groups.

The most important difference is seen with gender: females are more concerned with personal hygiene (shower and personal washing) and washing (clothes, dishes and floor) for the reasons mentioned before (Section 11.2.2) (Figure 11.75 and 11.76).

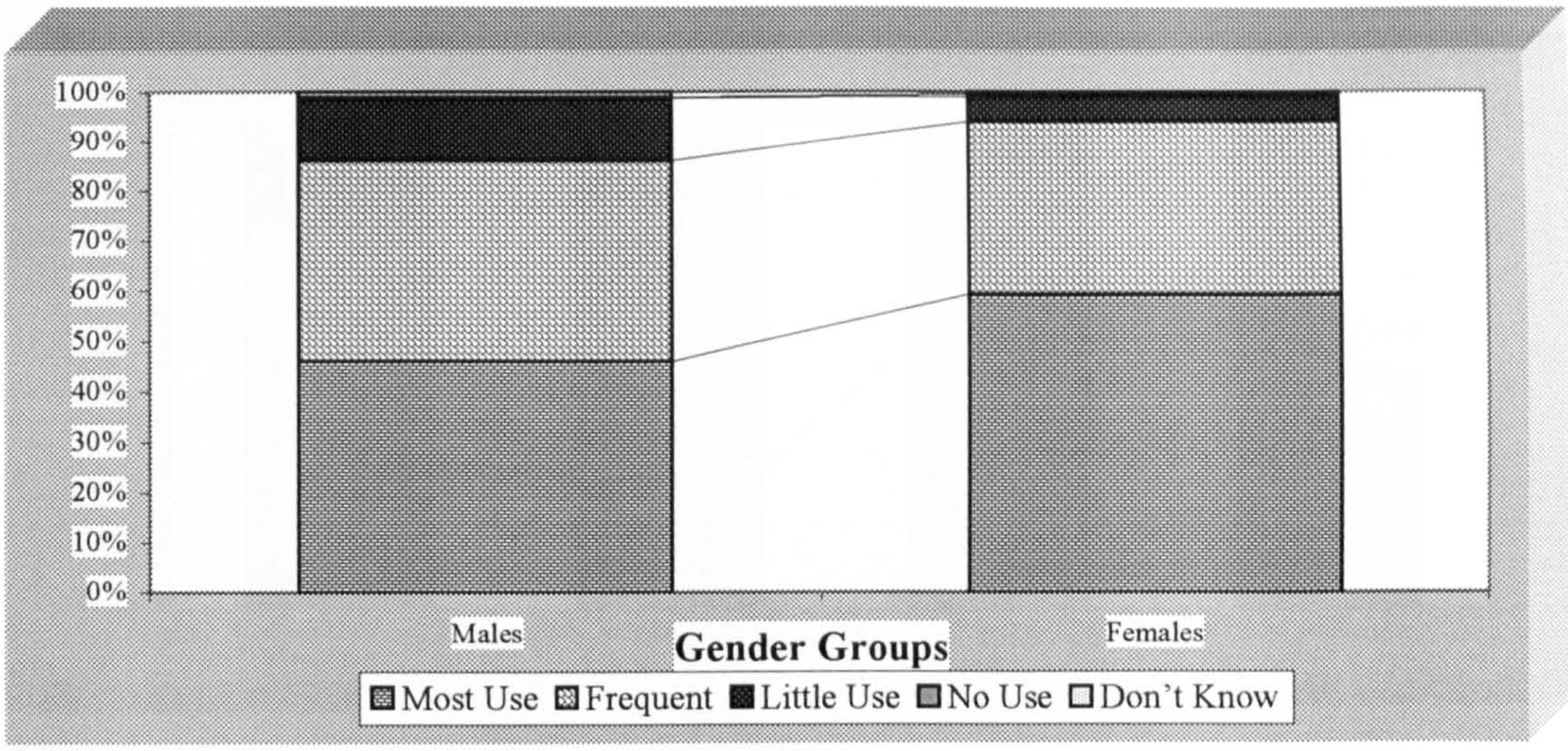

Figure 11.75. Water Uses for Personal Washing and Shower: Gender Groups.

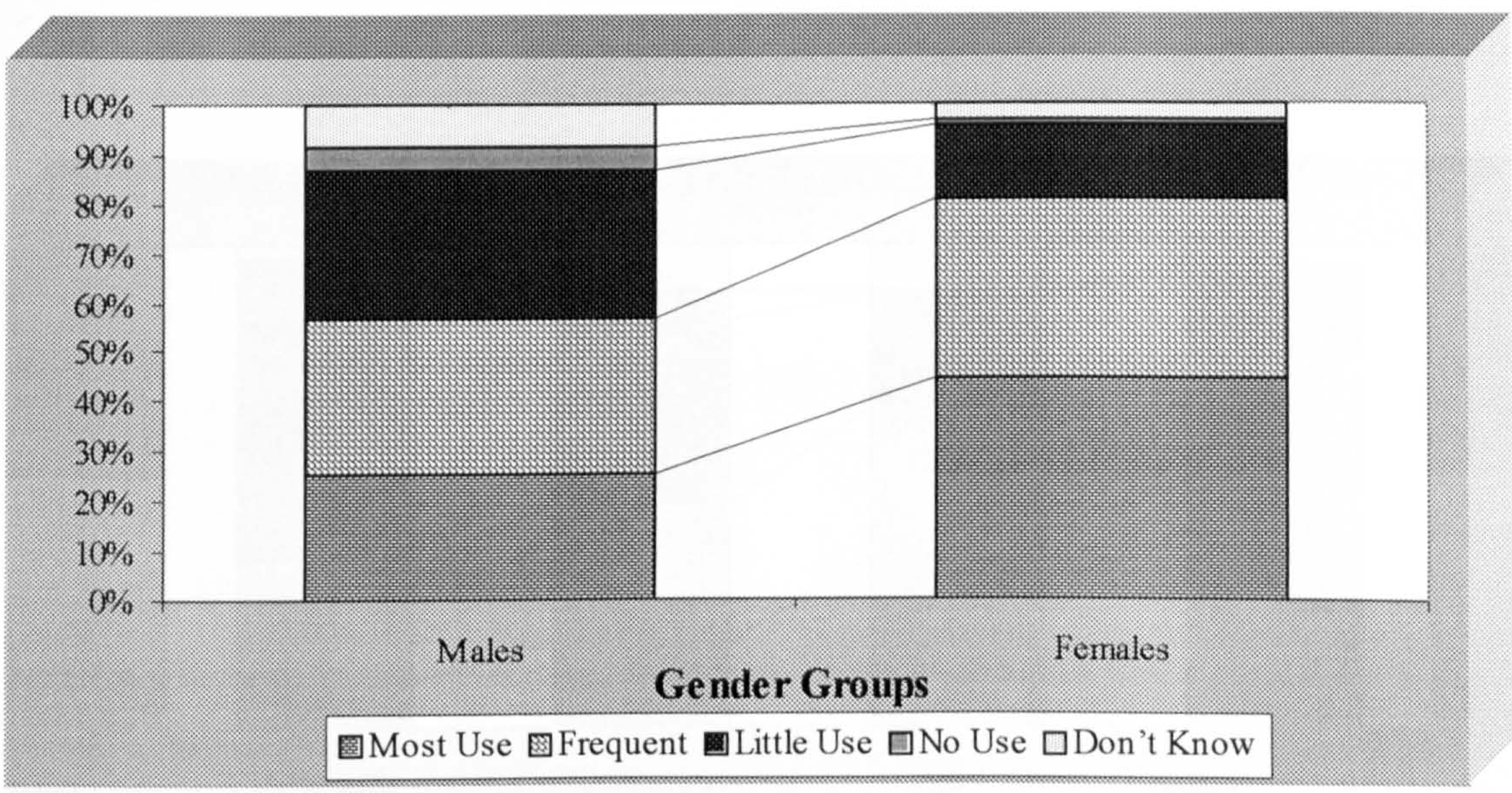

Figure 11.76. Water Use for Washing (Clothes, Car, Floor and Dishes): Gender Groups.

With level of education, there is a clear increase in use of water, especially for personal hygiene, washing and watering gardens (Figures 11.77, 11.78 and 11.79).

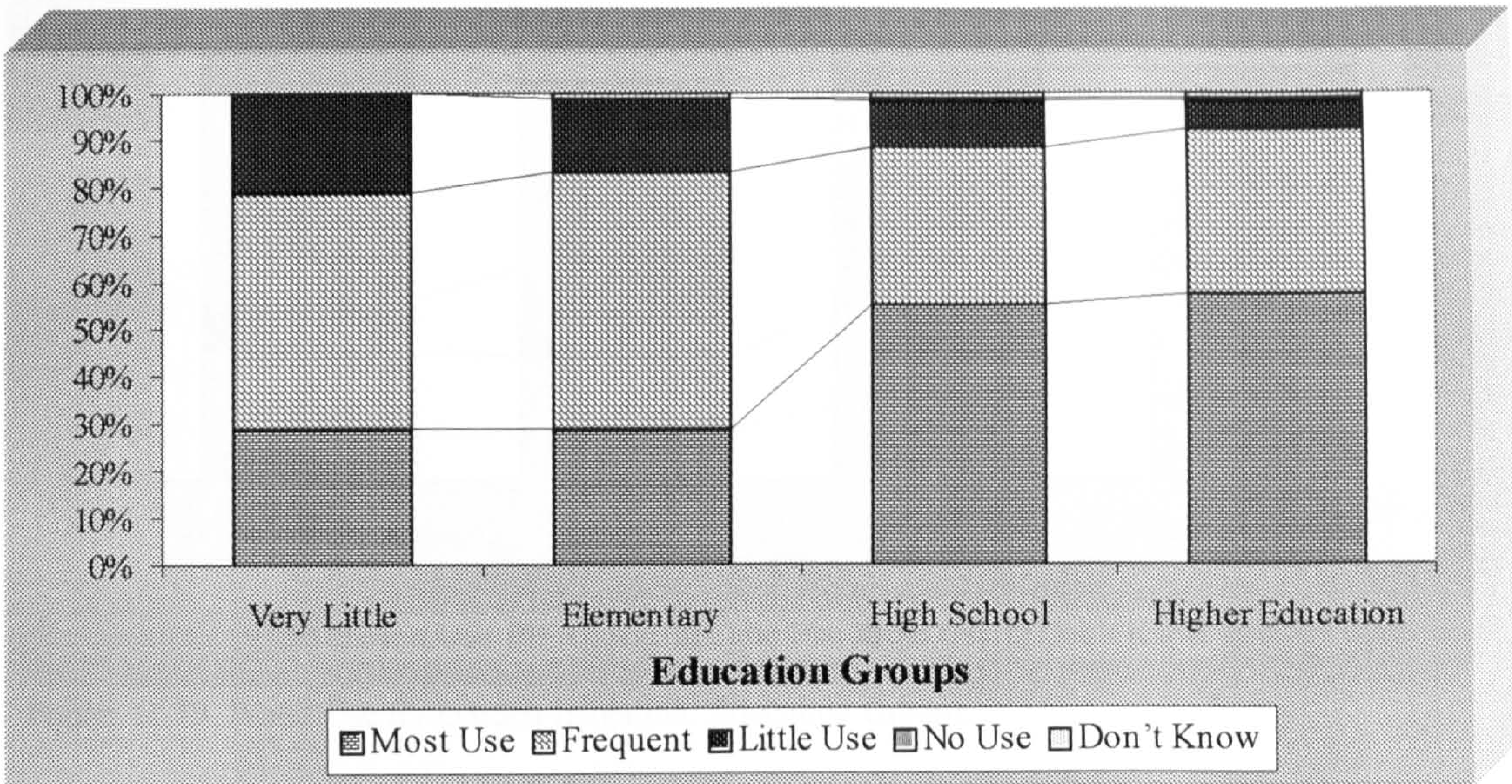

Figure 11.77. Water Uses for Personal Washing and Shower: Education Groups.

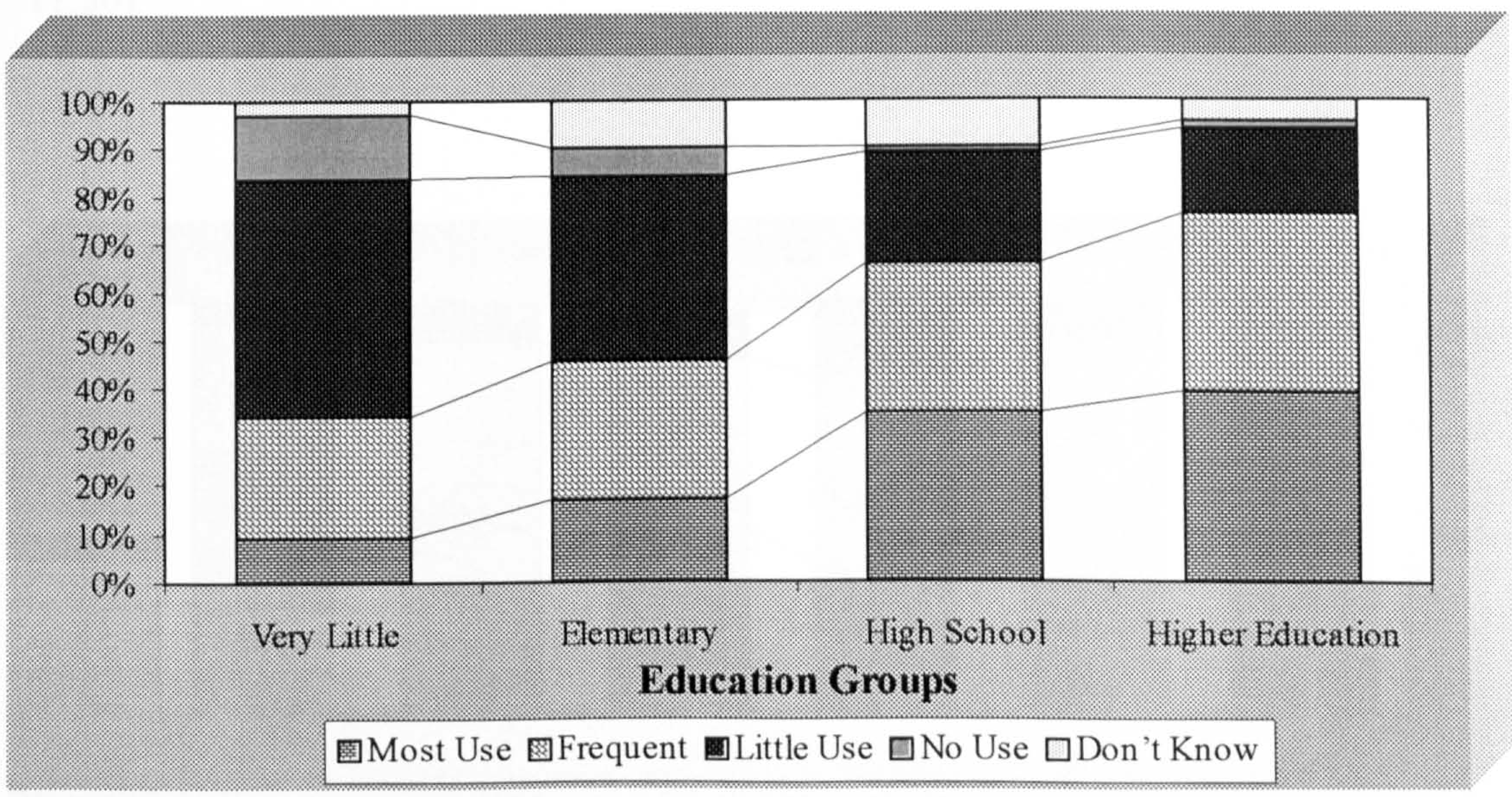

Figure 11.78. Water Use for Washing (Clothes, Car, Floor and Dishes): Education Groups.

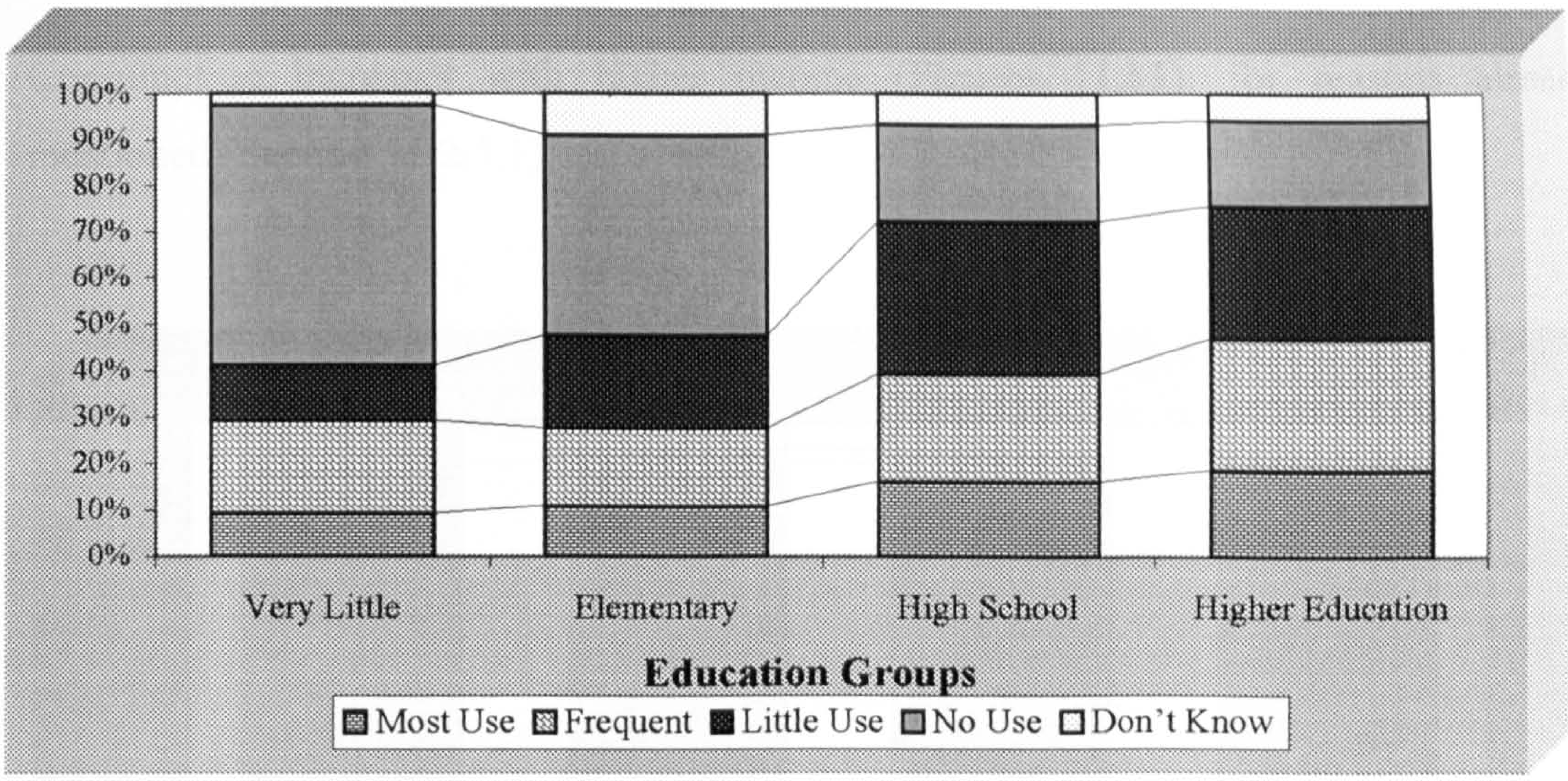

Figure 11.79. Water Use for Garden Irrigation: Education Groups.

Age dose not have clear influence except that the proportion of water consumption for personal purposes is greater for the younger and older people (Figures 11.80).

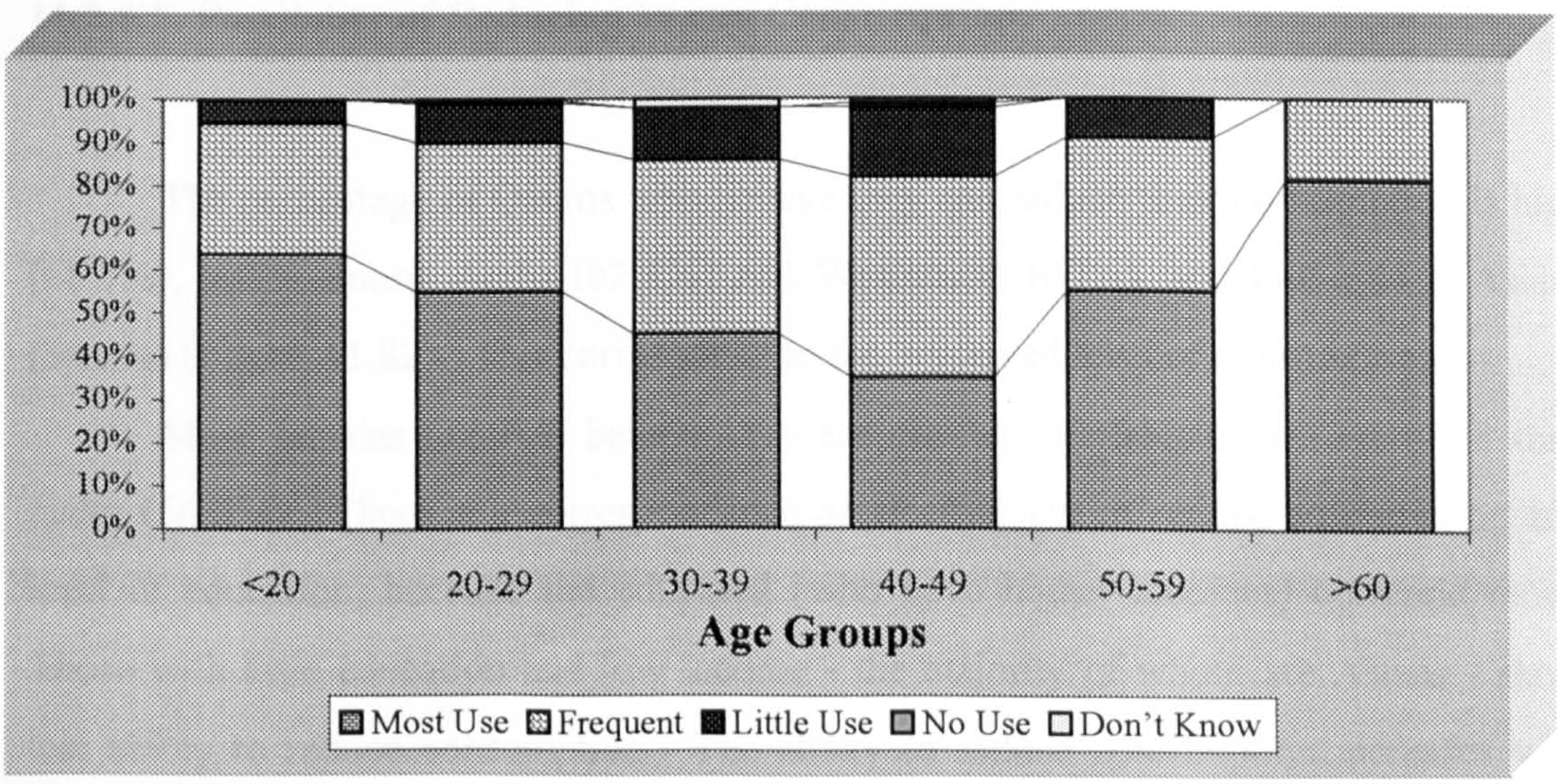

Figure 11.80. Water Use for Personal Washing and Shower: Age Groups.

Income is one of the main determinants of the level of consumption. Consumption increases with higher income (Figures 11.81), for reasons already mentioned (Section 11.2.5.1).

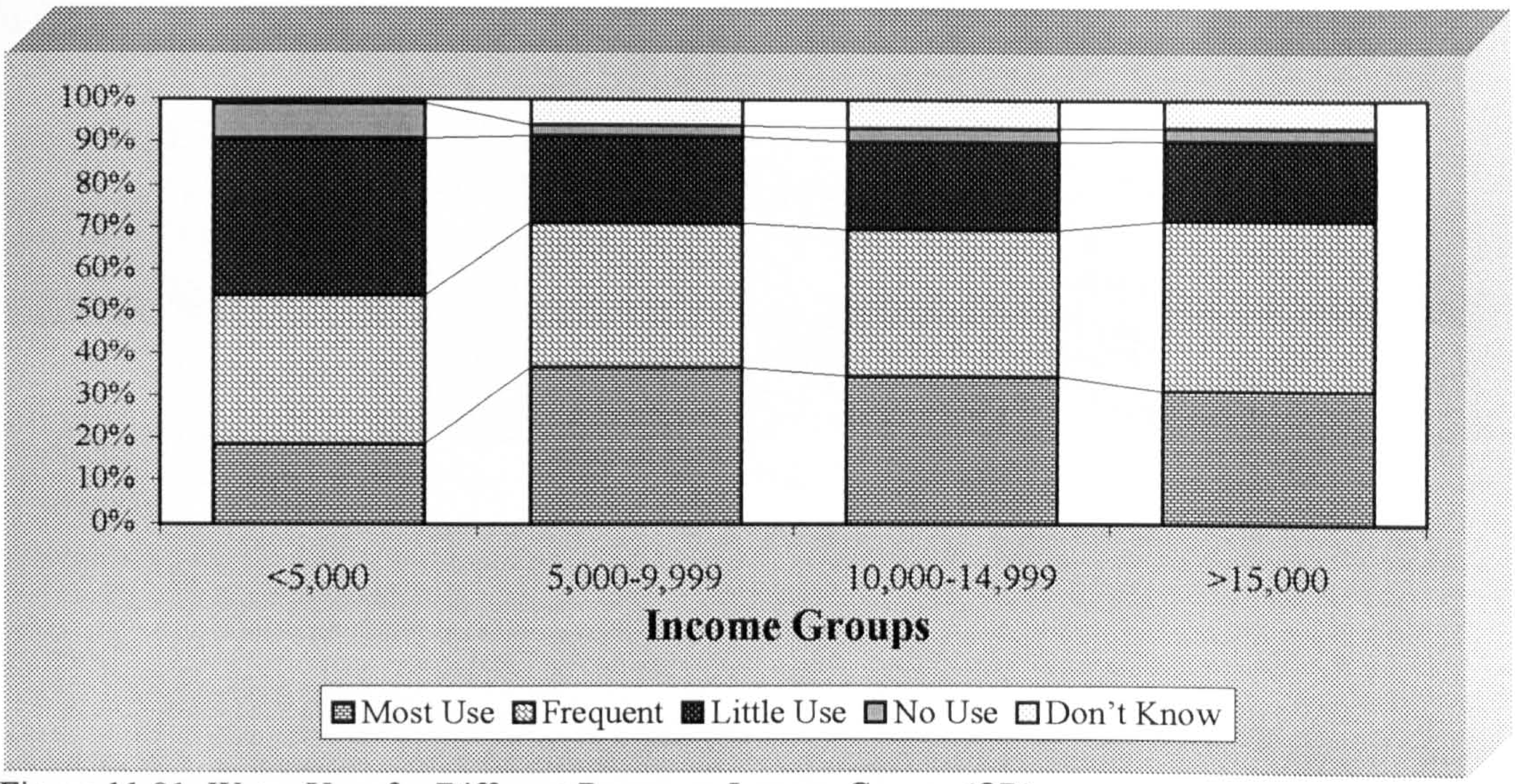

Figure 11.81. Water Uses for Different Purposes: Income Groups (QR).

11.2.5.5. Possibility of Reducing Water Consumption:

The percentage of Qataris who believe they can reduce their consumption is high (68.3%), lesser among Arabs (62.3%) and Westerners (60%), and low among Asians (34.5%) (Figure 11.82). This corresponds to the perceived level of consumption.

More females (72.3%) believe they are capable of reducing consumption than males (56.2%). There is a correspondence between ability to reduce consumption and level of education, because the educated (who have higher incomes) consume more. Those with little education and low income - the majority of whom are Asians - show less ability to reduce consumption. The ability to reduce consumption increases with age.

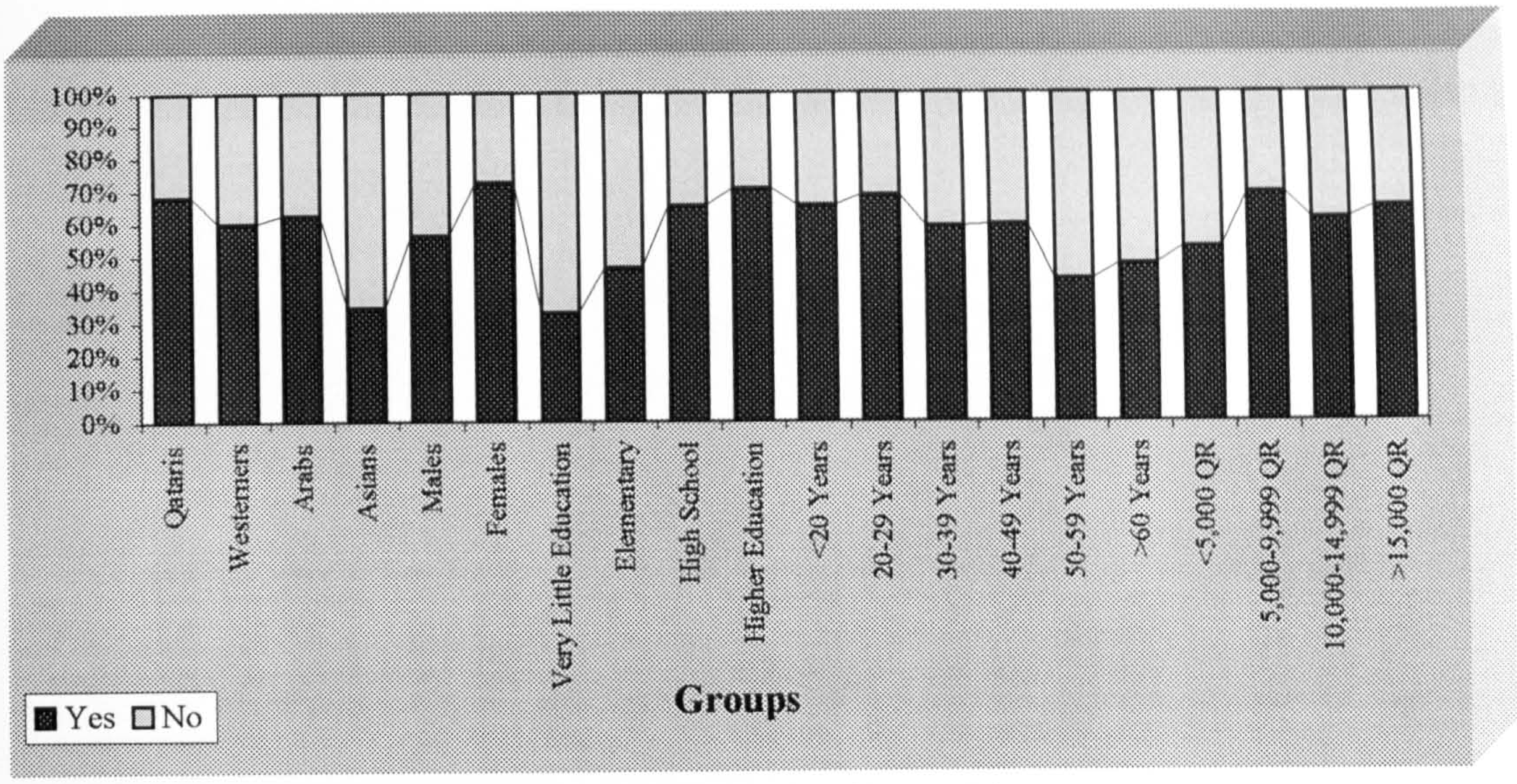

Figure 11.82. Opinion toward Possibility of Controlling Consumption.

Qataris believe they are capable of most reduction in personal hygiene, cooking, washing, and watering gardens (Figures 11.83, 11.84 and 11.85) - areas where most perceived consumption is concentrated. Arabs show a similar but weaker pattern. Westerners find it difficult to reduce consumption for personal hygiene and washing, while they can reduce the watering of gardens easily. Asians find it difficult to reduce consumption in all areas.

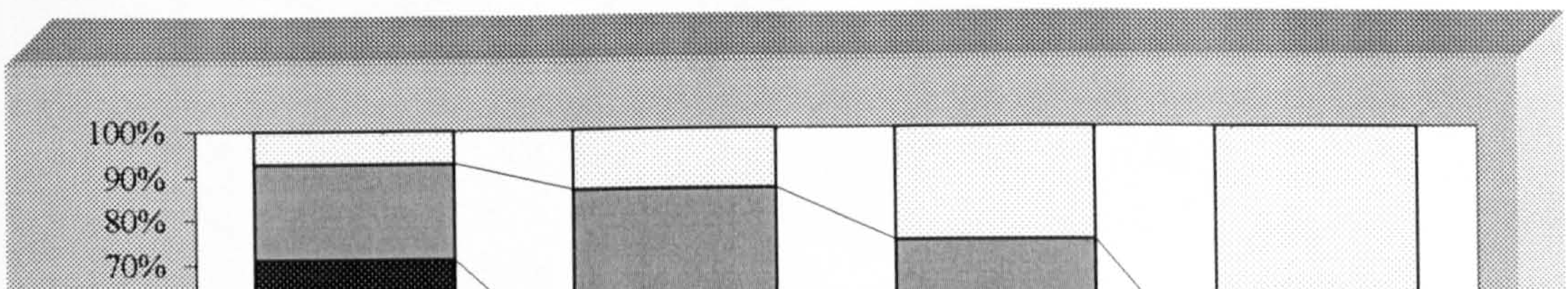

Figure 11.83. Possibility of a Decrease in Consumption for Personal Washing and Shower: Nationality Groups.

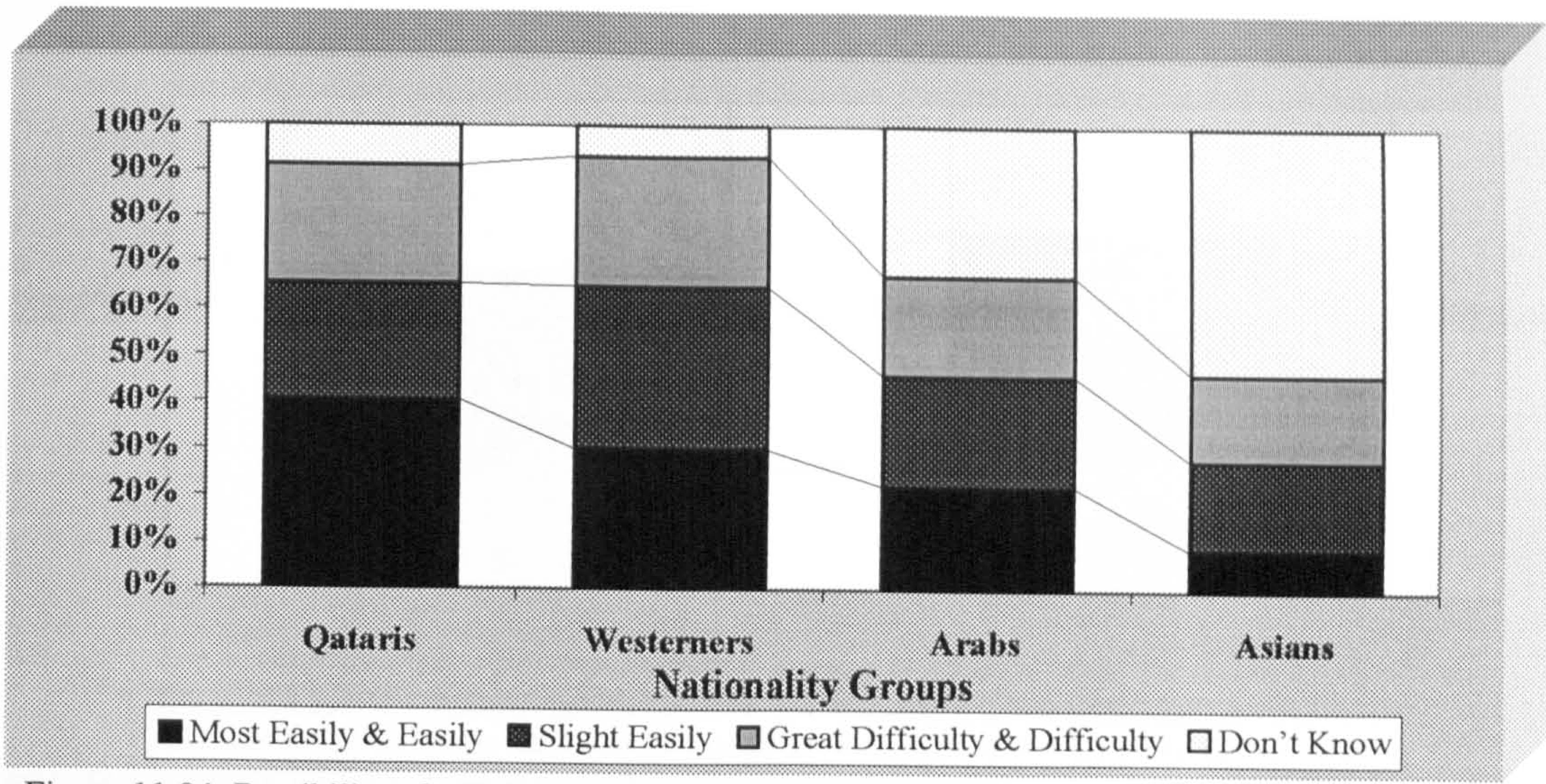

Figure 11.84. Possibility of a Decrease in Consumption for Washing (Clothes, Car, Floor and Dishes): Nationality Groups.

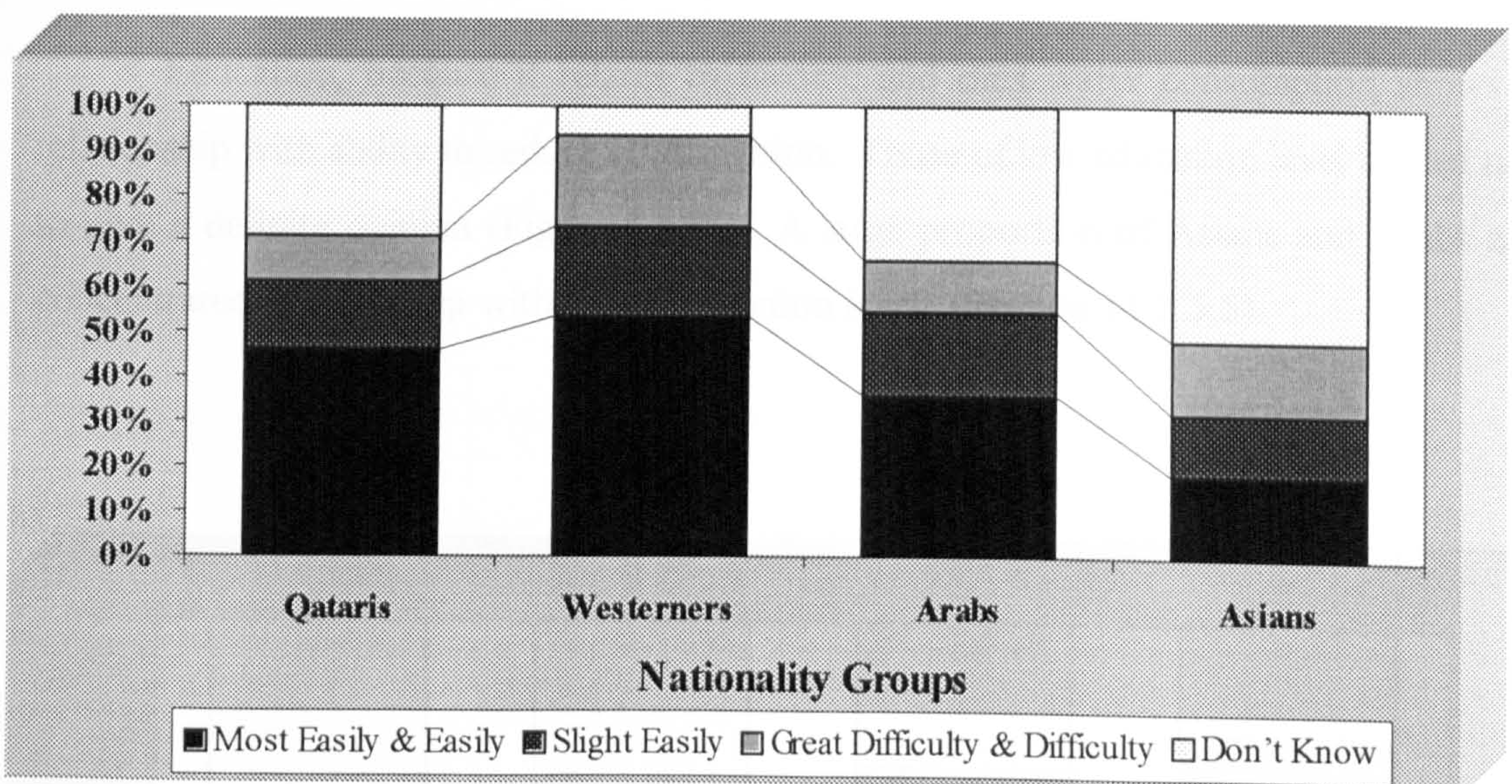

Figure 11.85. Possibility of a Decrease in Consumption for Garden Irrigation: Nationality Groups.

Females find it slightly easier to reduce consumption more than males, probably because many males are poor migrants (Figure 11.86).

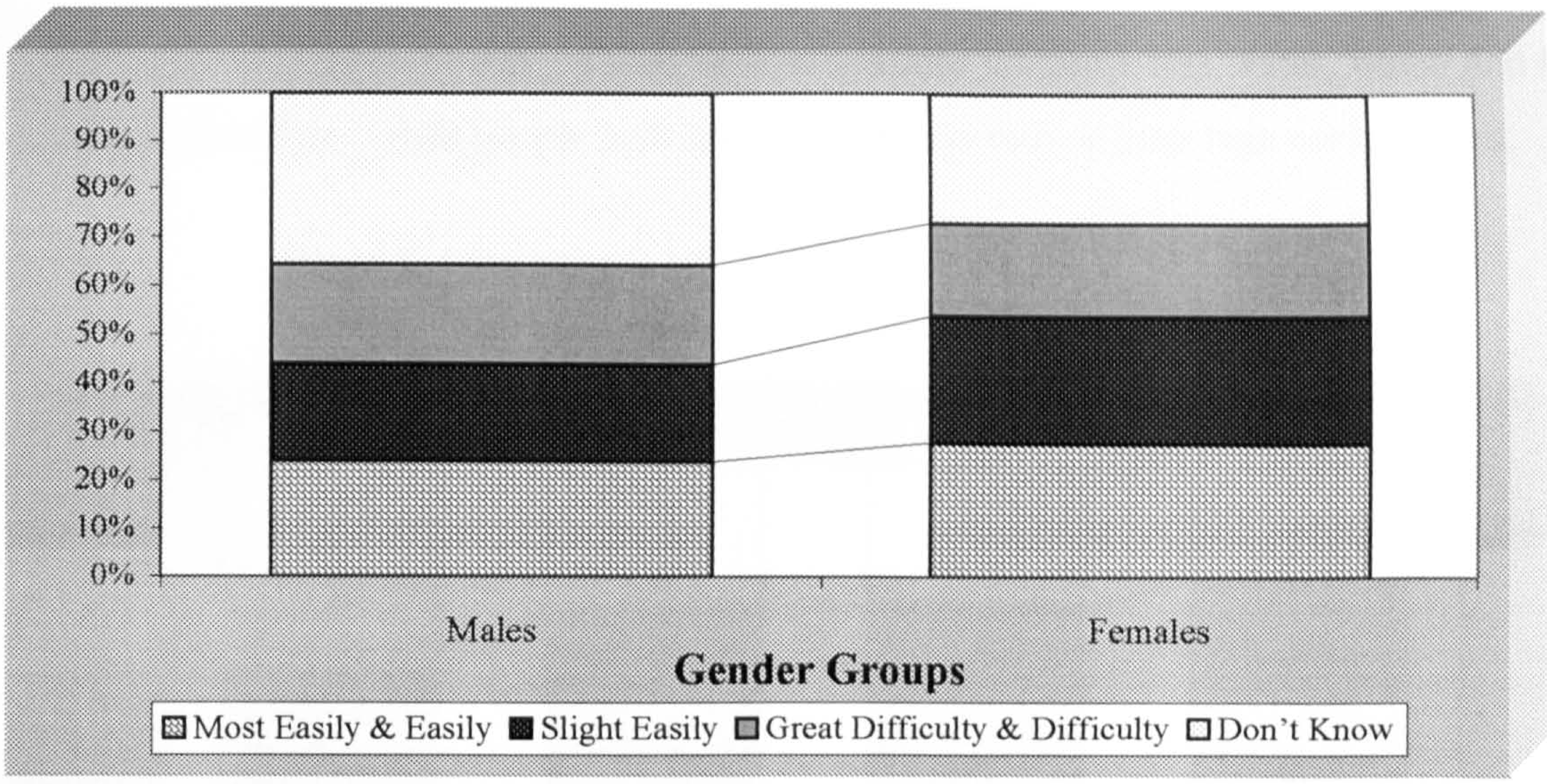

Figure 11.86. Possibility of a Decrease in Consumption for Washing (Clothes, Car, Floor and Dishes): Gender Groups.

Education, because it relates to income and thus water consumption shows a relationship with ability to reduce consumption. Those of low education level tended not to give a definite opinion (Figure 11.87). A large proportion of Asians and Arabs are concentrated in the group with lower education levels (Section 11.2.5.5).

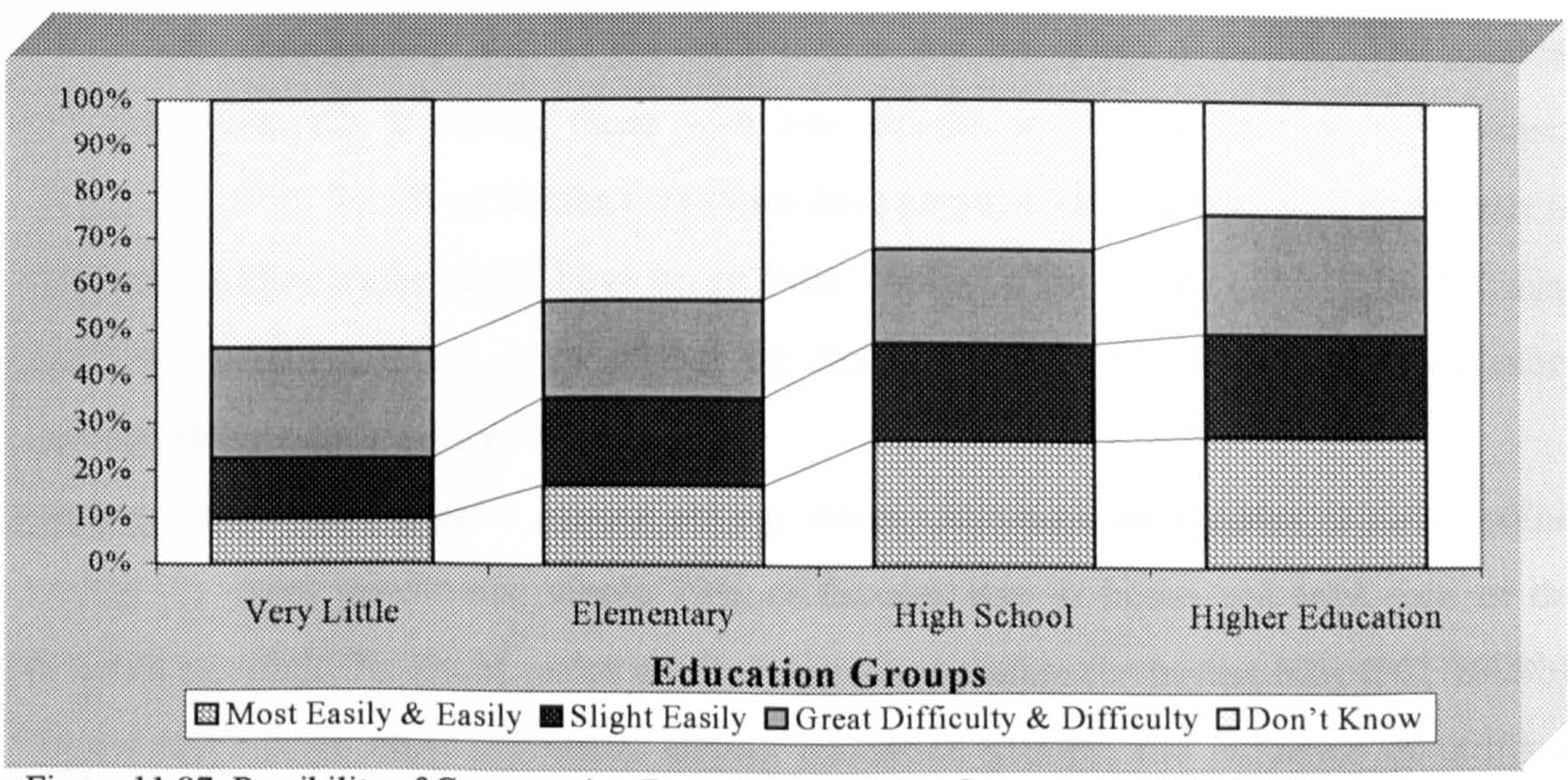

Figure 11.87. Possibility of Consumption Decrease: Education Groups.

There is a correspondence between income and potential reduction of consumption (Figure 11.88). Those on low incomes consume less water, hence find it difficult to reduce, while people with high incomes can reduce their high consumption.

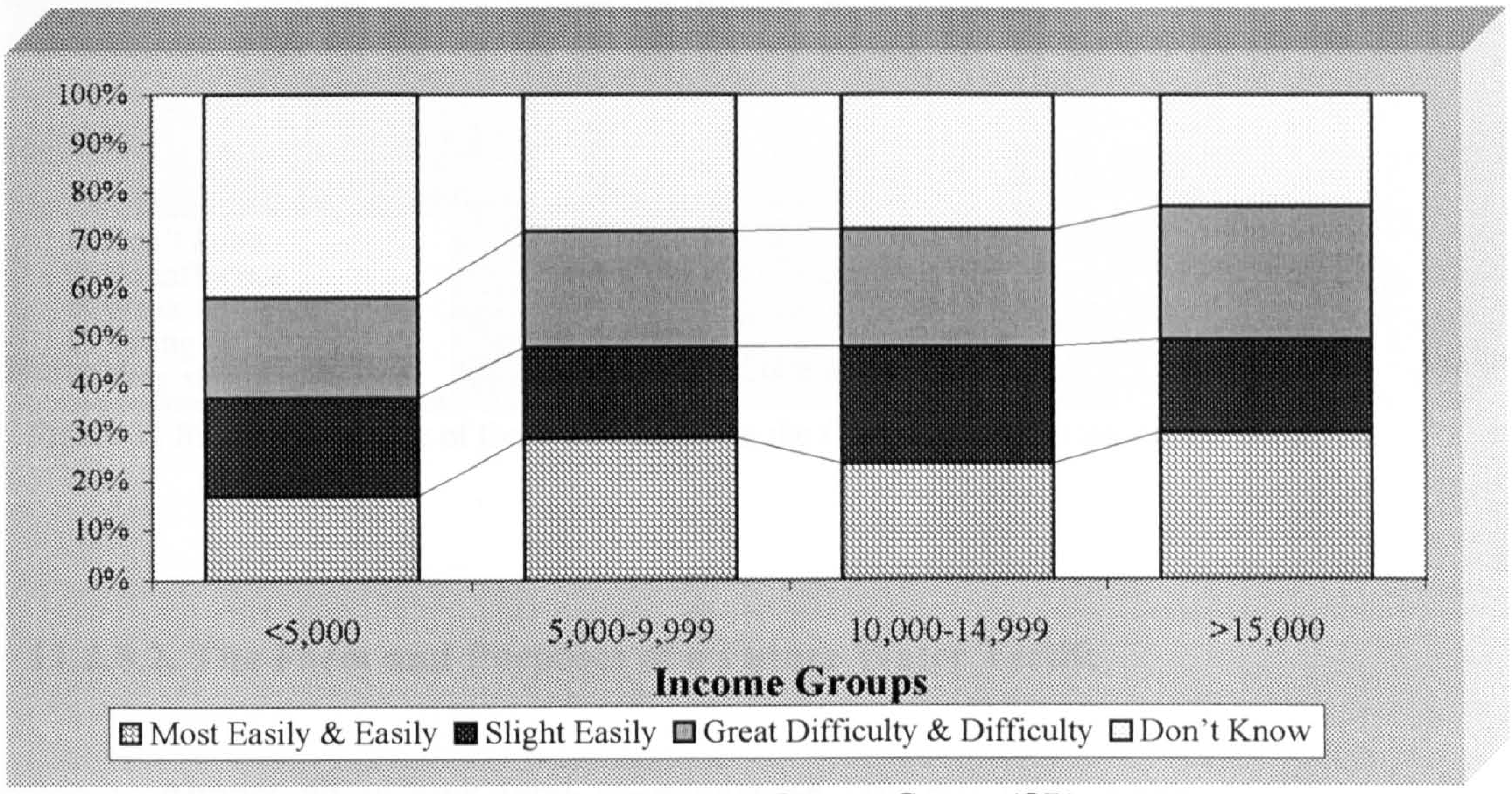

Figure 11.88. Possibility of Consumption Decrease: Income Groups (QR).

11.2.6. Water Tariff:

11.2.6.1. The Influence of the Current Water Tariff:

The relationship is clear between income and the effect of tariffs. The greatest influence naturally is among those with low income and lowest among high earners (Figure 11.89). 73.3% of Westerners (who have amongst the highest living standards of all) believe that water tariffs have no or little impact, while Arabs (58.4%) and Asians (40.9%) believe it has a great impact on their consumption behaviour and are more susceptible to changes in water tariffs.

Tariffs have greater impact among males (23.5%) than females (12.8%). This relates to social conditions, where 79% of females stay at home and take care of the household, while 70.7% of males work and are responsible for paying bills (PC, 1999b). While there is no clear difference among education groups, the influence of tariffs is greatest among the middle aged, because this segment is where the proportion of poor migrant workers is highest.

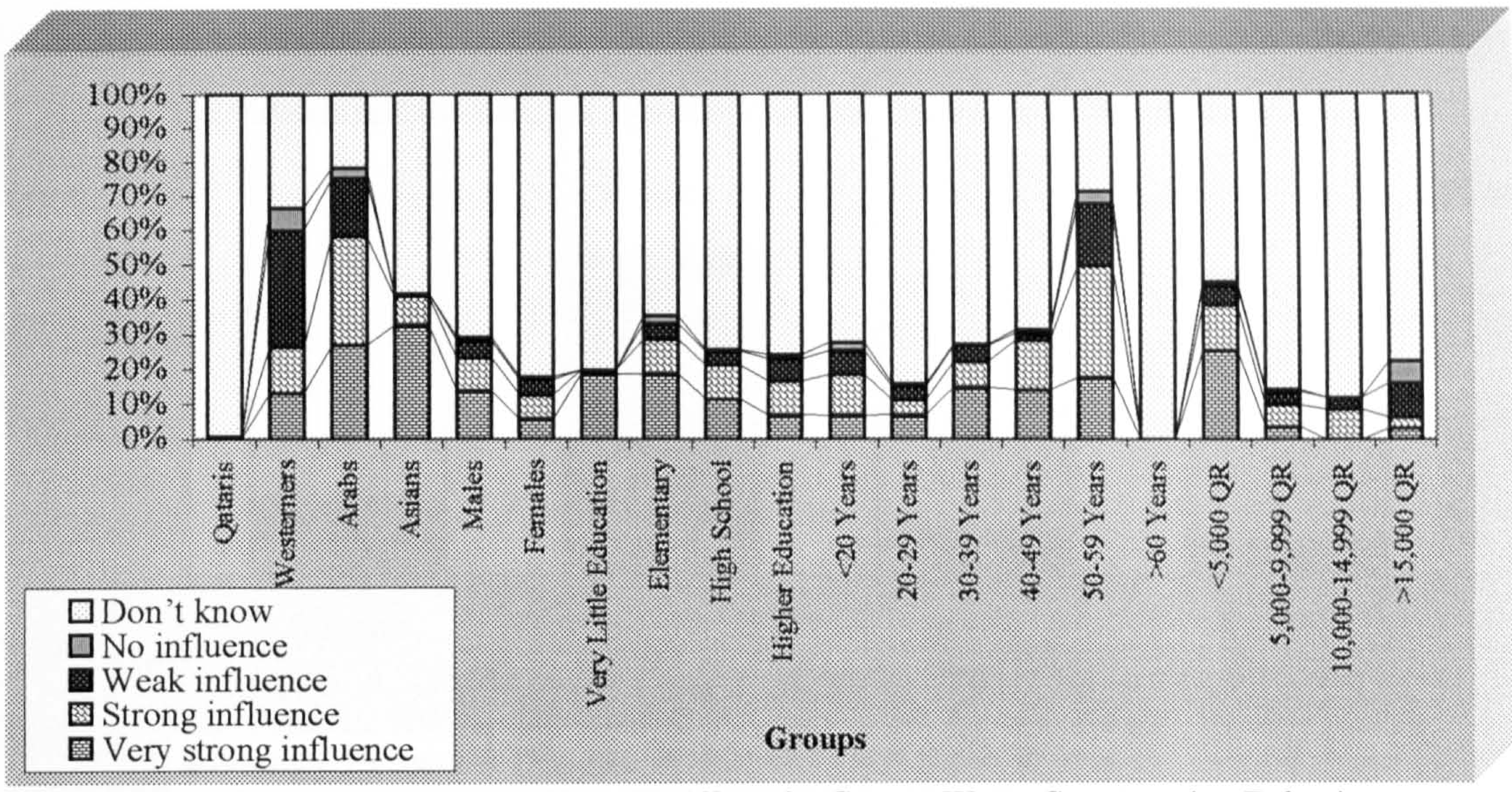

Figure 11.89. The Influence of the Water Tariff on the Groups Water Consumption Behaviour.

11.2.6.2. The Form and Purposes of a Future Water Tariff:

Almost all groups tend to emphasise concern over water quality and family circumstances as the most important factors (Figures 11.90. 11.91 and 11.92). Arabs and Asians stress the reduction of tariffs, and linking them to levels of consumption. Similar views were held by Westerners but less strongly. This is a function of living standards (Section 11.2.3.5). The lack of interest in tariffs among Qataris is a natural consequence of them being exempt from payment, hence their concern is elsewhere.

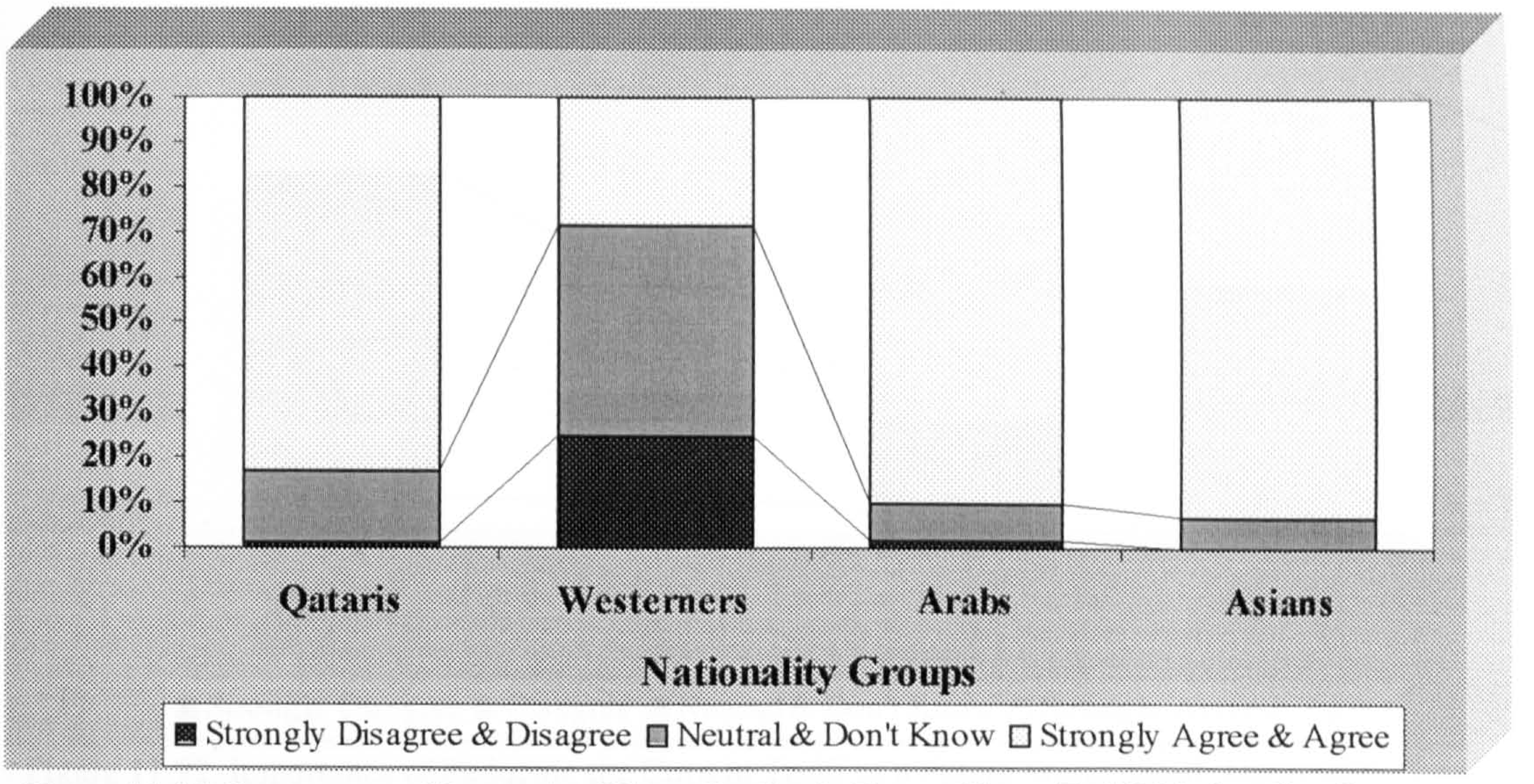

Figure 11.90. Importance of Improving Water Quality in Future Water Tariff: Nationality Groups.

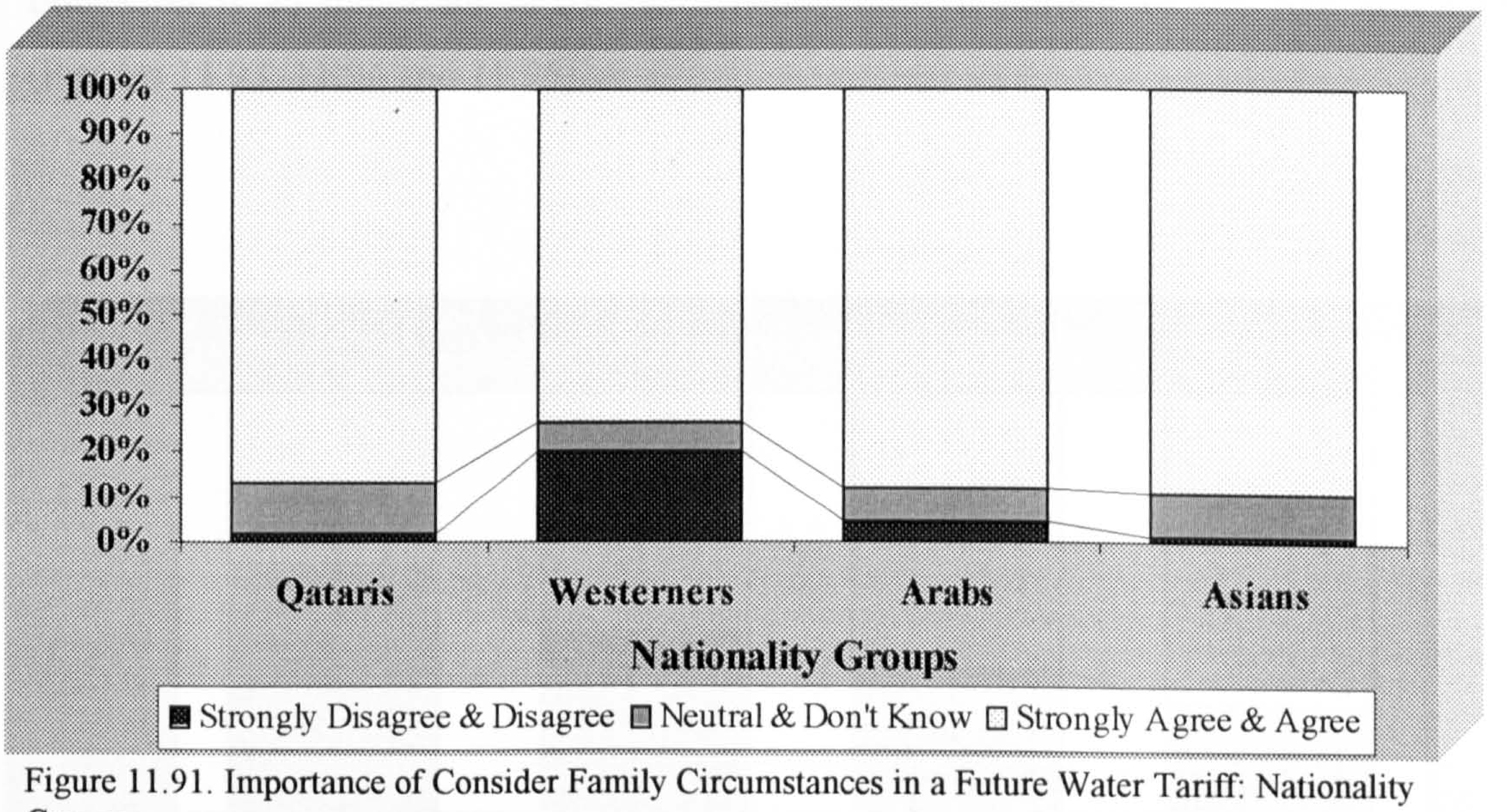

Figure 11.91. Importance of Consider Family Circumstances in a Future Water Tariff: Nationality Groups.

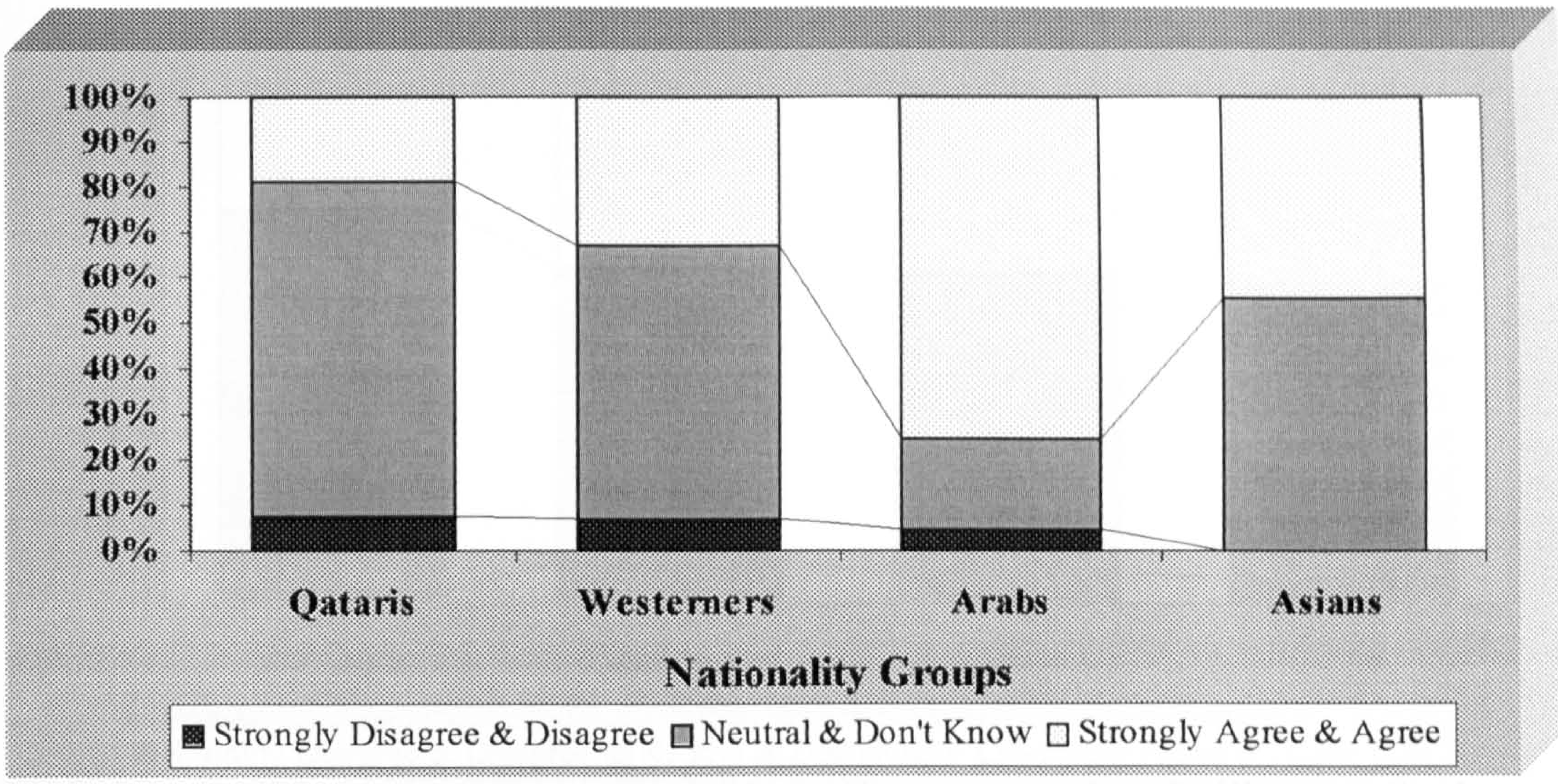

Figure 11.92. Importance of Reducing the Current Tariff in a Future Water Tariff: Nationality Groups.

There is no clear pattern among gender and age groups (Section A14.3.6.2). Education is an important factor, with equity most important to the well educated (Figures 11.93, 11.94 and 11.95).

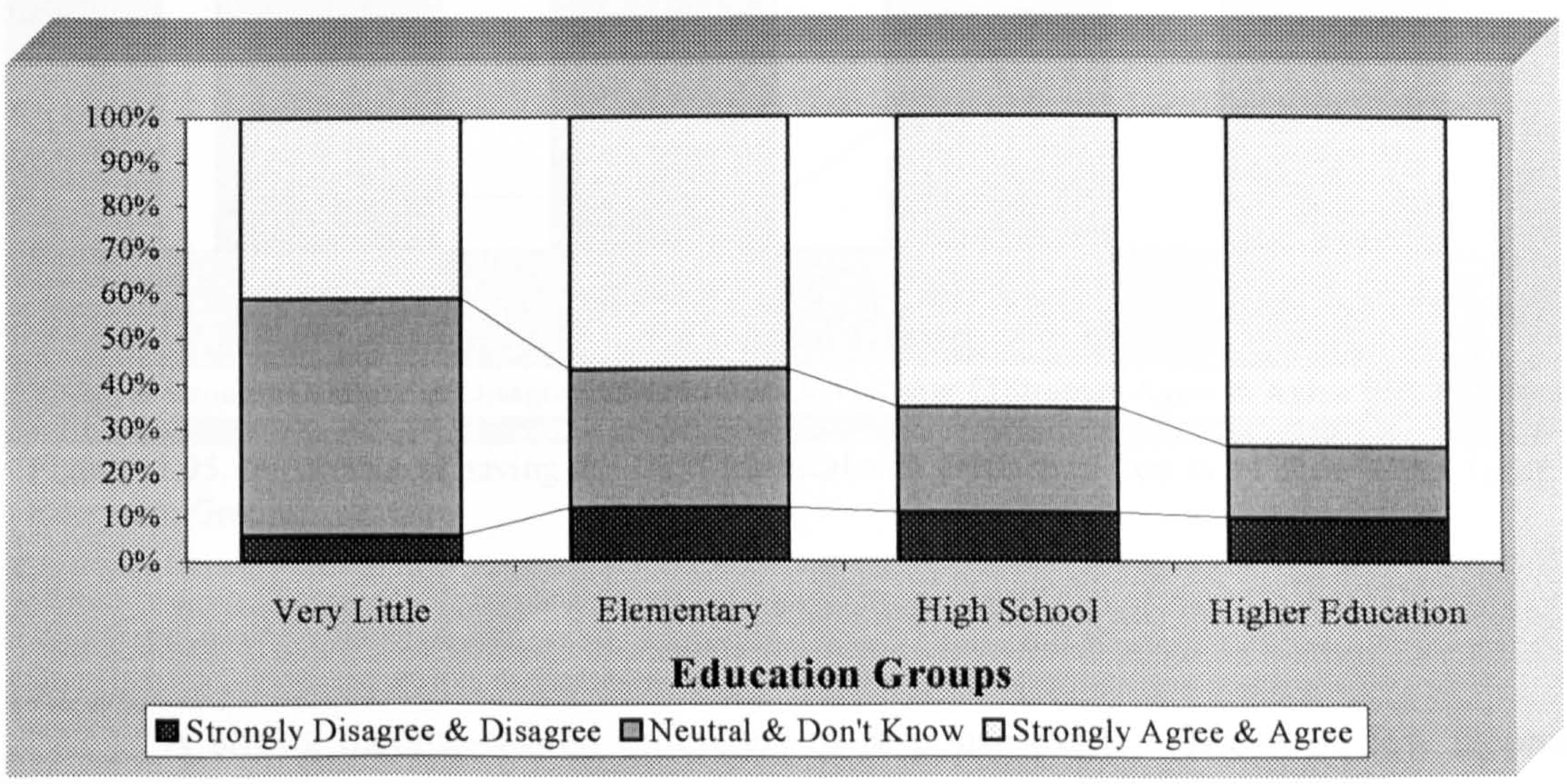

Figure 11.93. Importance of Tariff Enforcement on all Society Individuals in a Future Water Tariff: Education Groups.

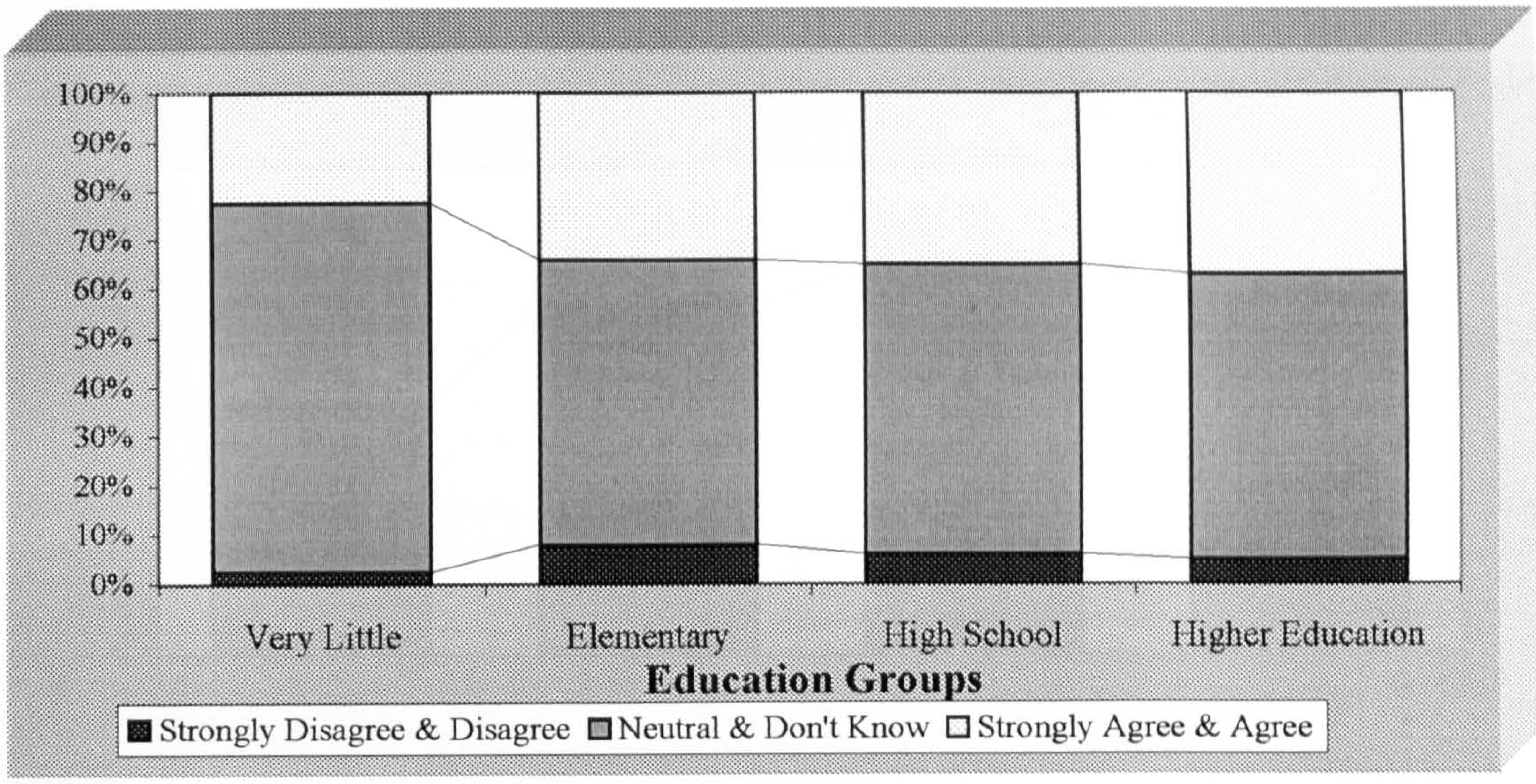

Figure 11.94. Importance of Reducing the Current Tariff in a Future Water Tariff: Education Groups.

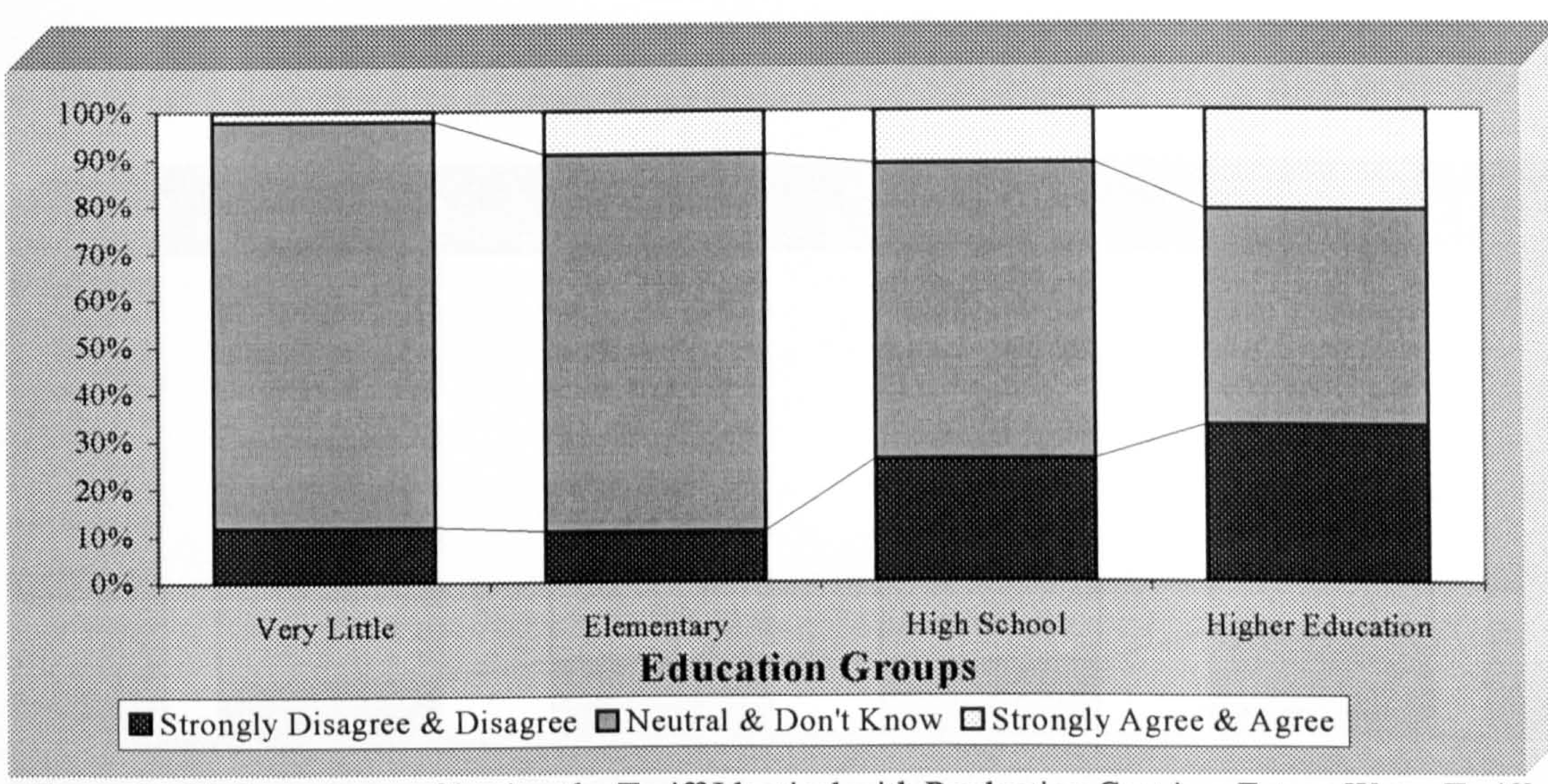

Figure 11.95. Importance of having the Tariff Identical with Production Cost in a Future Water Tariff: Education Groups.

A strong income-related difference in response exists. Those on low incomes emphasise the reduction of tariffs, improvement of water quality, appropriateness of the rate to family circumstances and level of consumption. Those on high incomes identify quality of water and level of consumption (Figure 11.96, 11.97 and 11.98). There is no significant difference among age groups (Section A14.3.6.2).

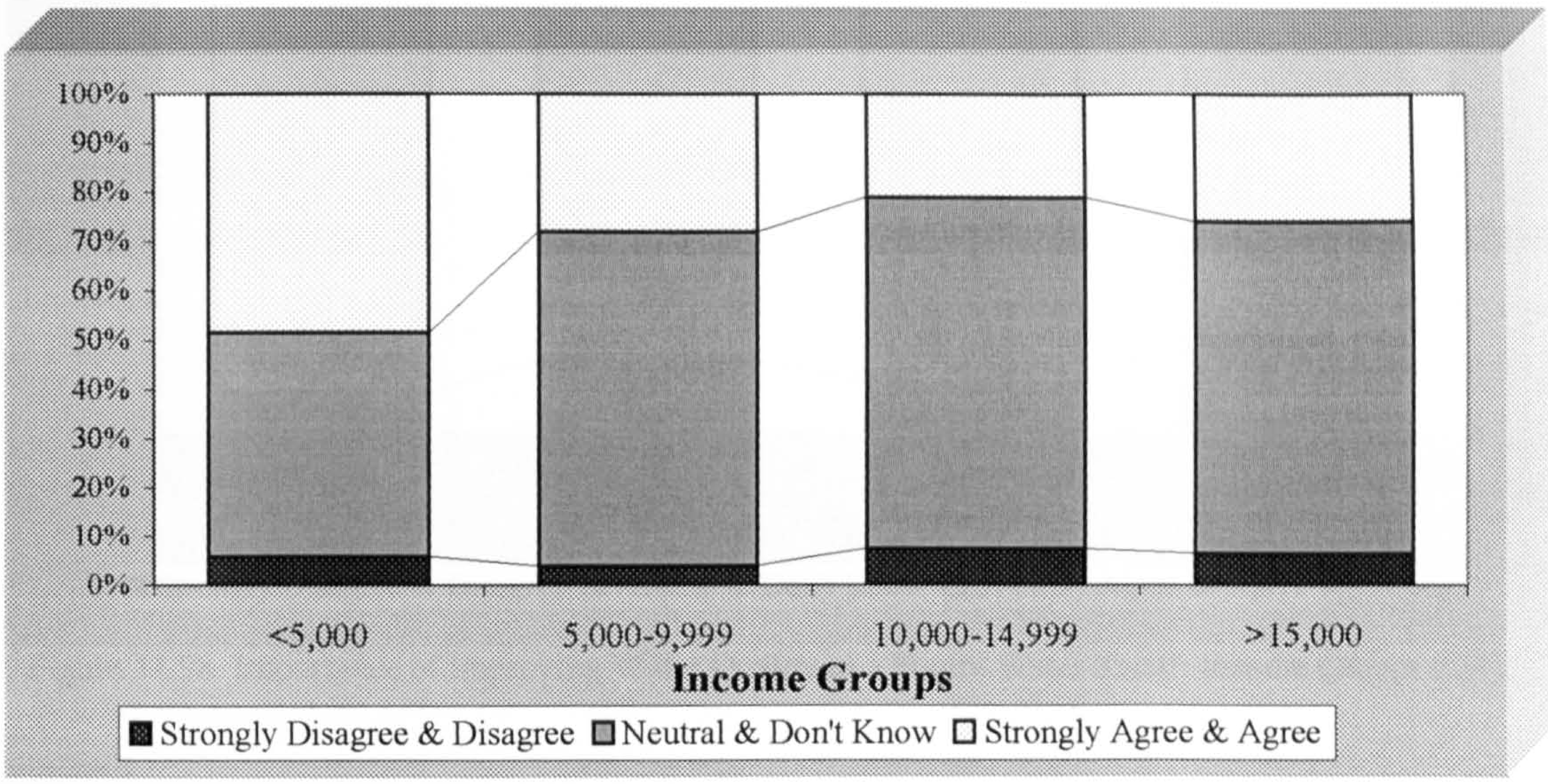

Figure 11.96. Importance of Reducing the Current Tariff in a Future Water Tariff: Income Groups (QR).

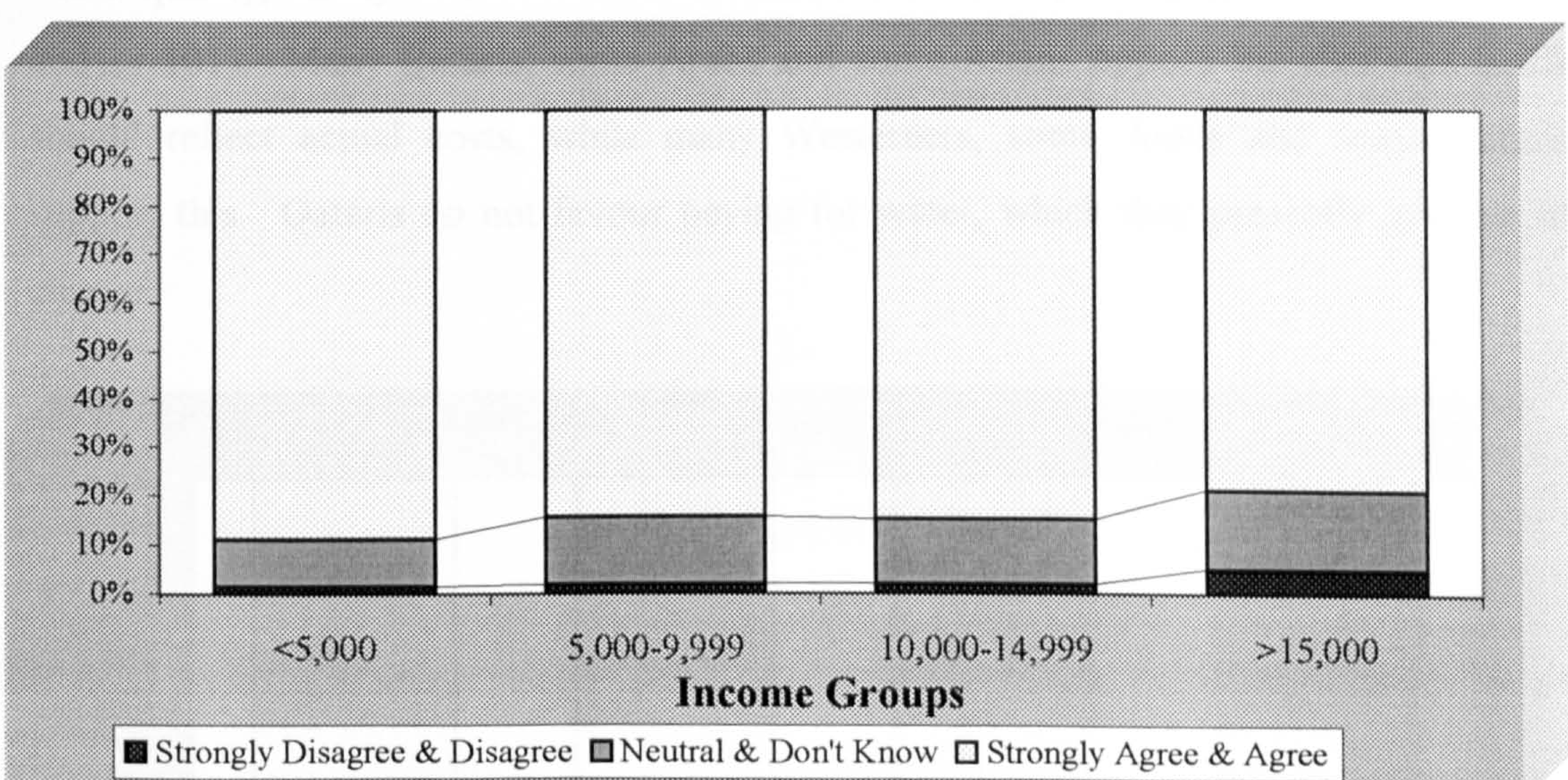

Figure 11.97. Importance of Family Circumstances and Level of Consumption in a Future Water Tariff: Income Groups (QR).

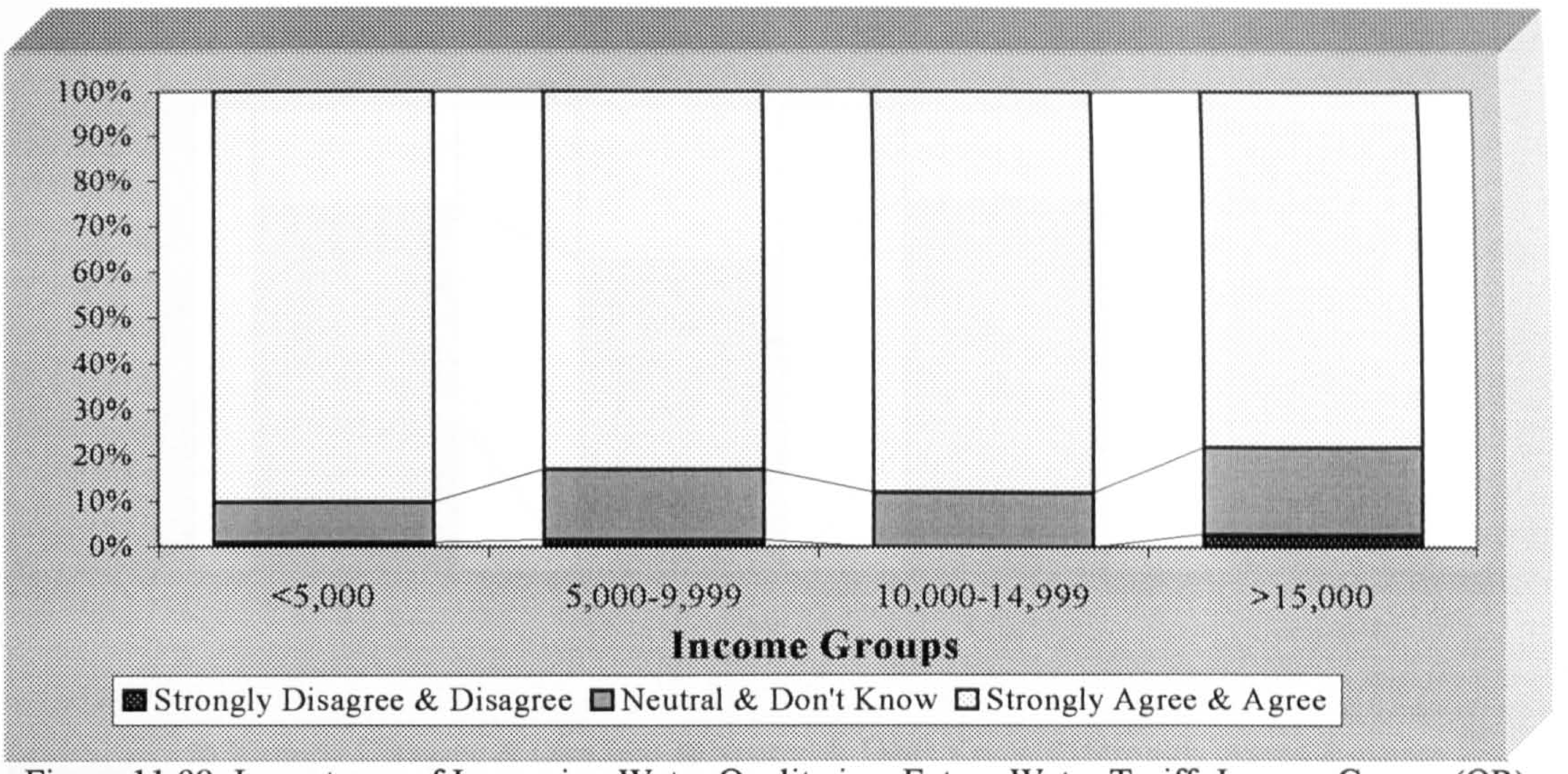

Figure 11.98. Importance of Improving Water Quality in a Future Water Tariff: Income Groups (QR).

11.2.6.3. Responsiveness to Water Tariff:

When asked what makes them more willing to pay tariffs, all groups emphasise water quality, family circumstances and levels of consumption (Figures 11.99, 11.100 and 11.101). Many Qataris, some Arabs and some Asians oppose the idea that tariffs should reflect actual costs, while many Westerners, some Arabs and some Qataris support this. Qataris do not favour paying for water, which they presently get free of charge.

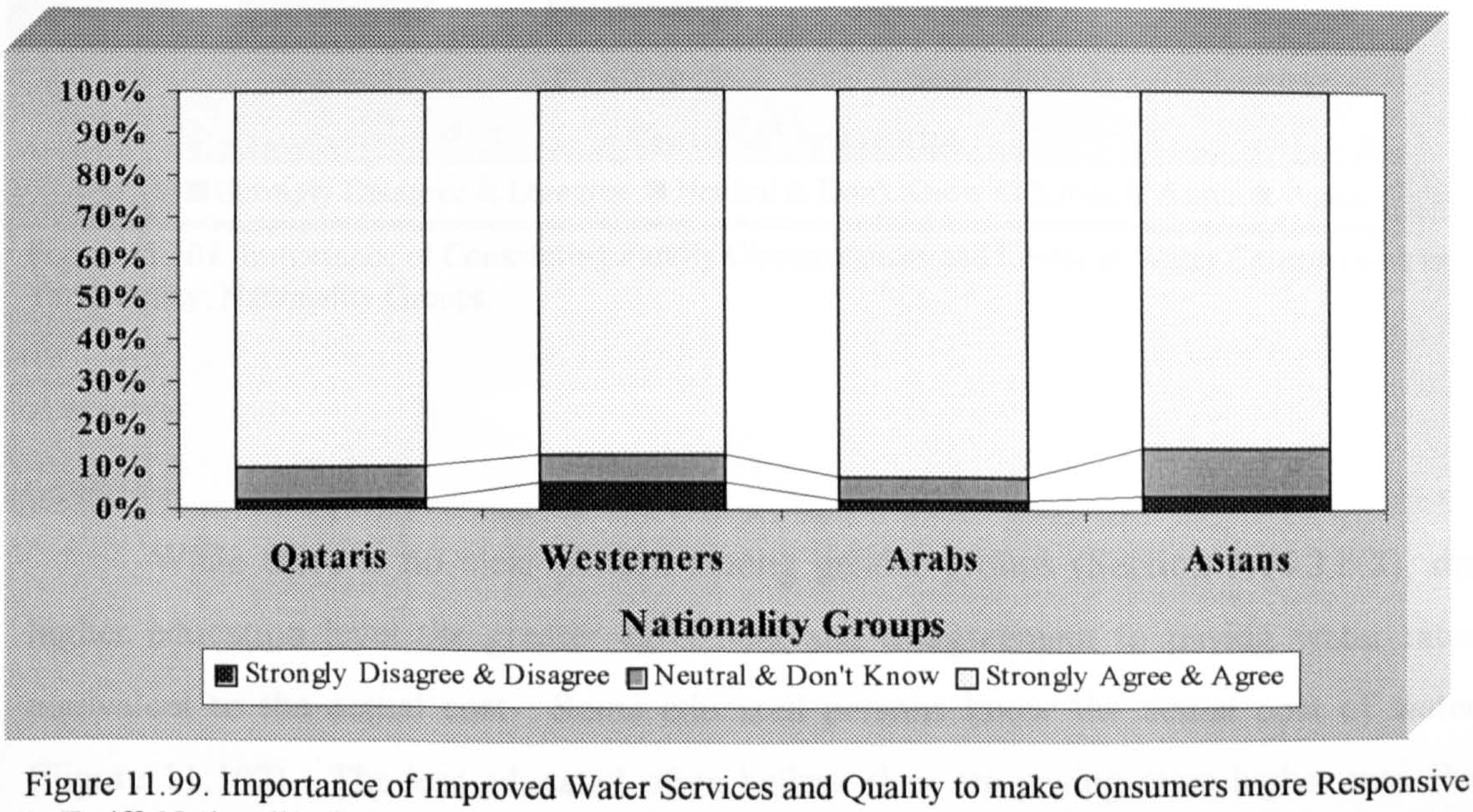

Figure 11.99. Importance of Improved Water Services and Quality to make Consumers more Responsive to Tariff: Nationality Groups.

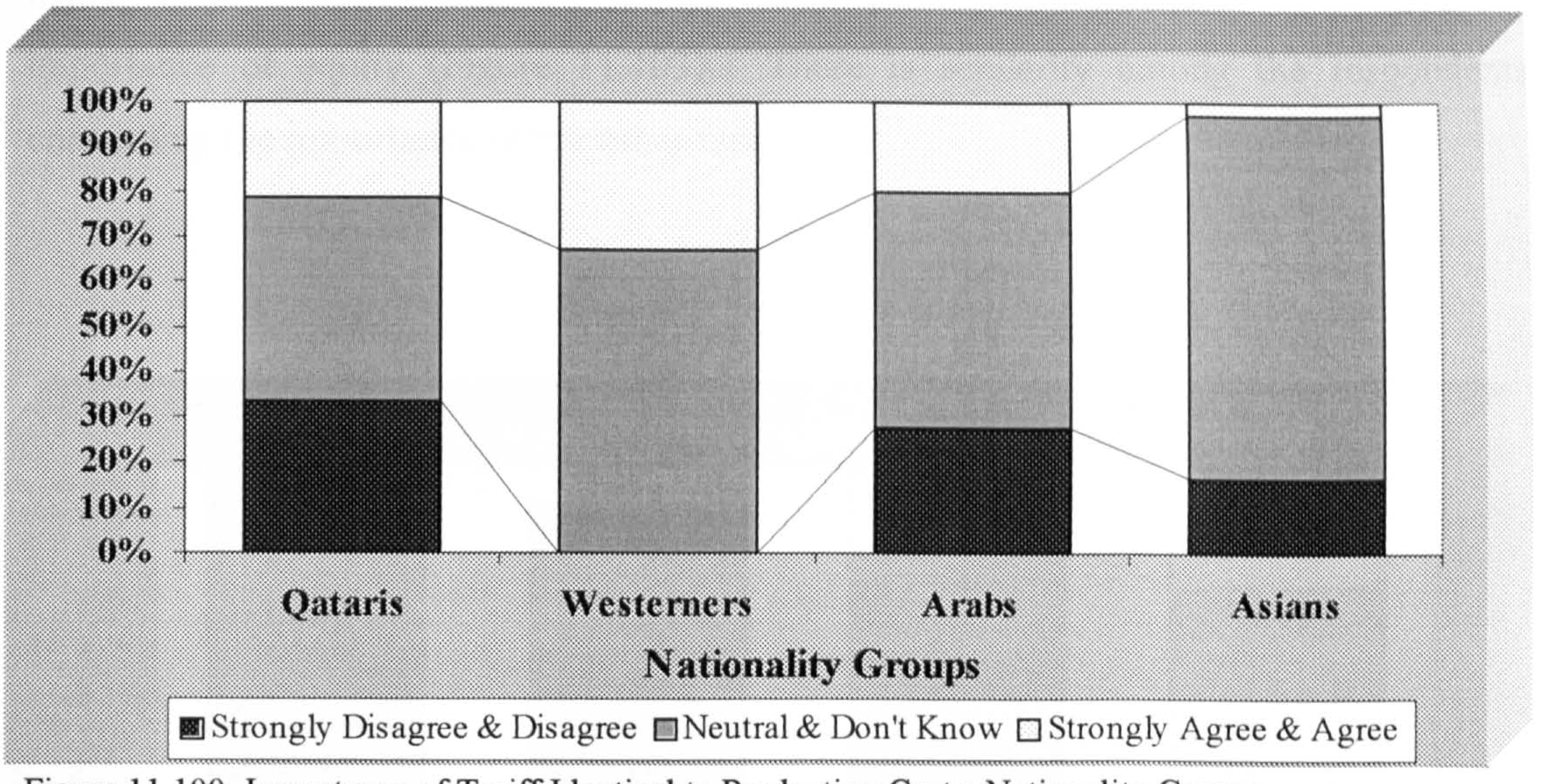

Figure 11.100. Importance of Tariff Identical to Production Costs: Nationality Groups.

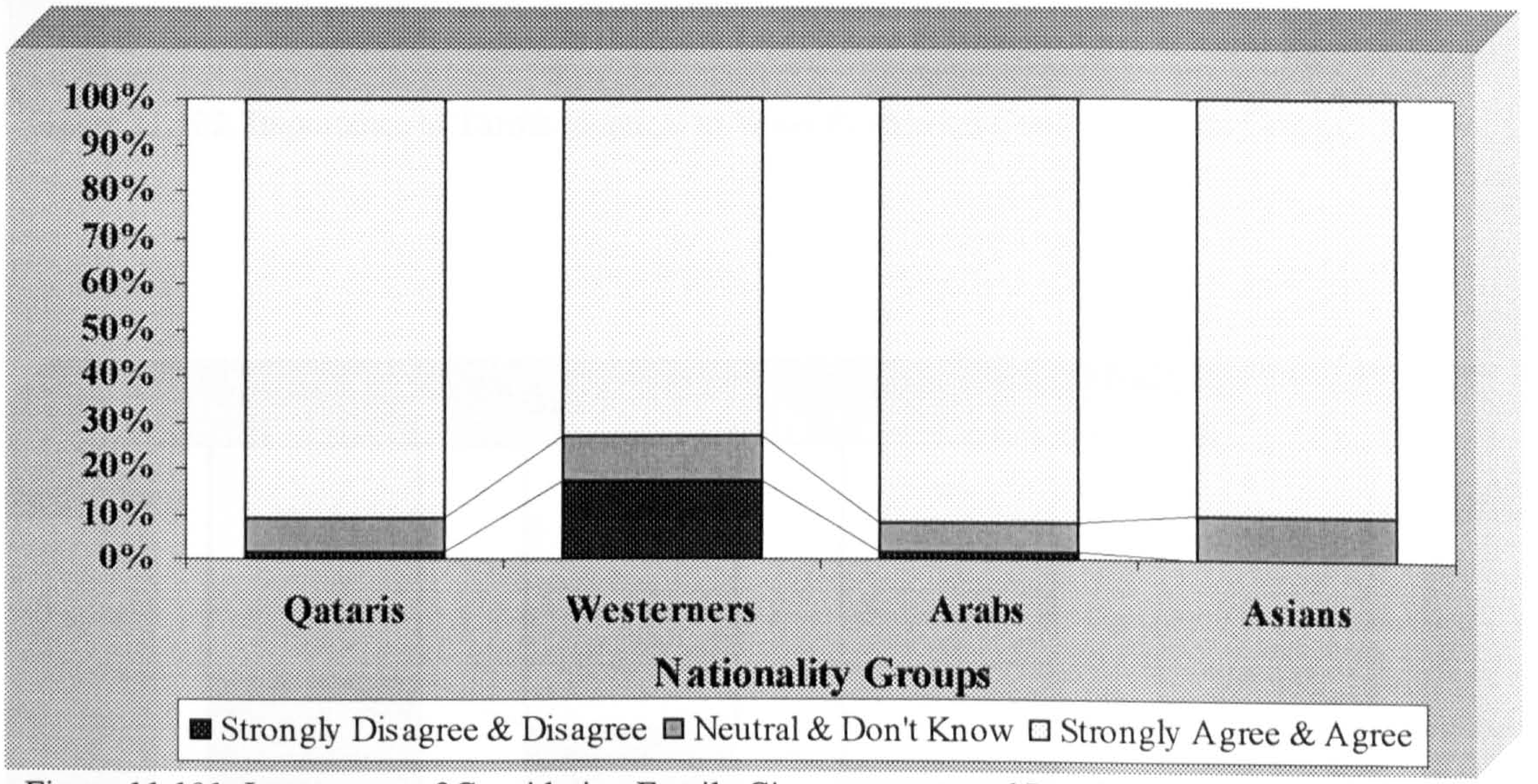

Figure 11.101. Importance of Considering Family Circumstances and Levels of Water Consumption in Tariff Policy: Nationality Groups.

While there is no clear pattern among gender groups (Section A14.3.6.3), the higher education level the greater agreement and disagreement to paying water rates equivalent to the actual cost. Some educated persons know the actual cost of water (Figure 11.102). The less educated often believe they are paying rates higher than the actual cost. Additionally, all groups but especially the educated emphasise the importance of equity (Figure 11.103). There is similarity among the respondents concerning the importance of the other factors.

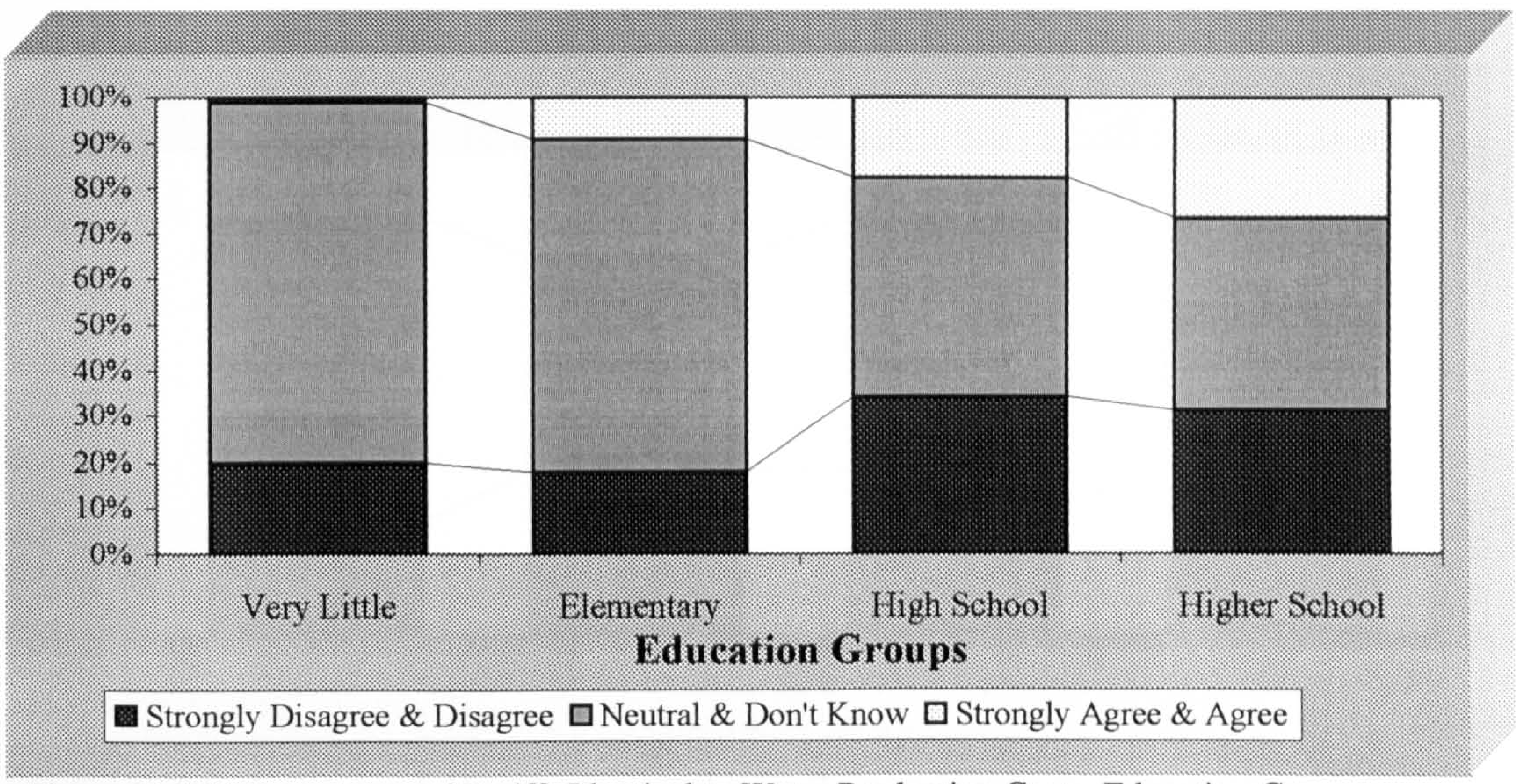

Figure 11.102. Importance of Tariffs Identical to Water Production Costs: Education Groups.

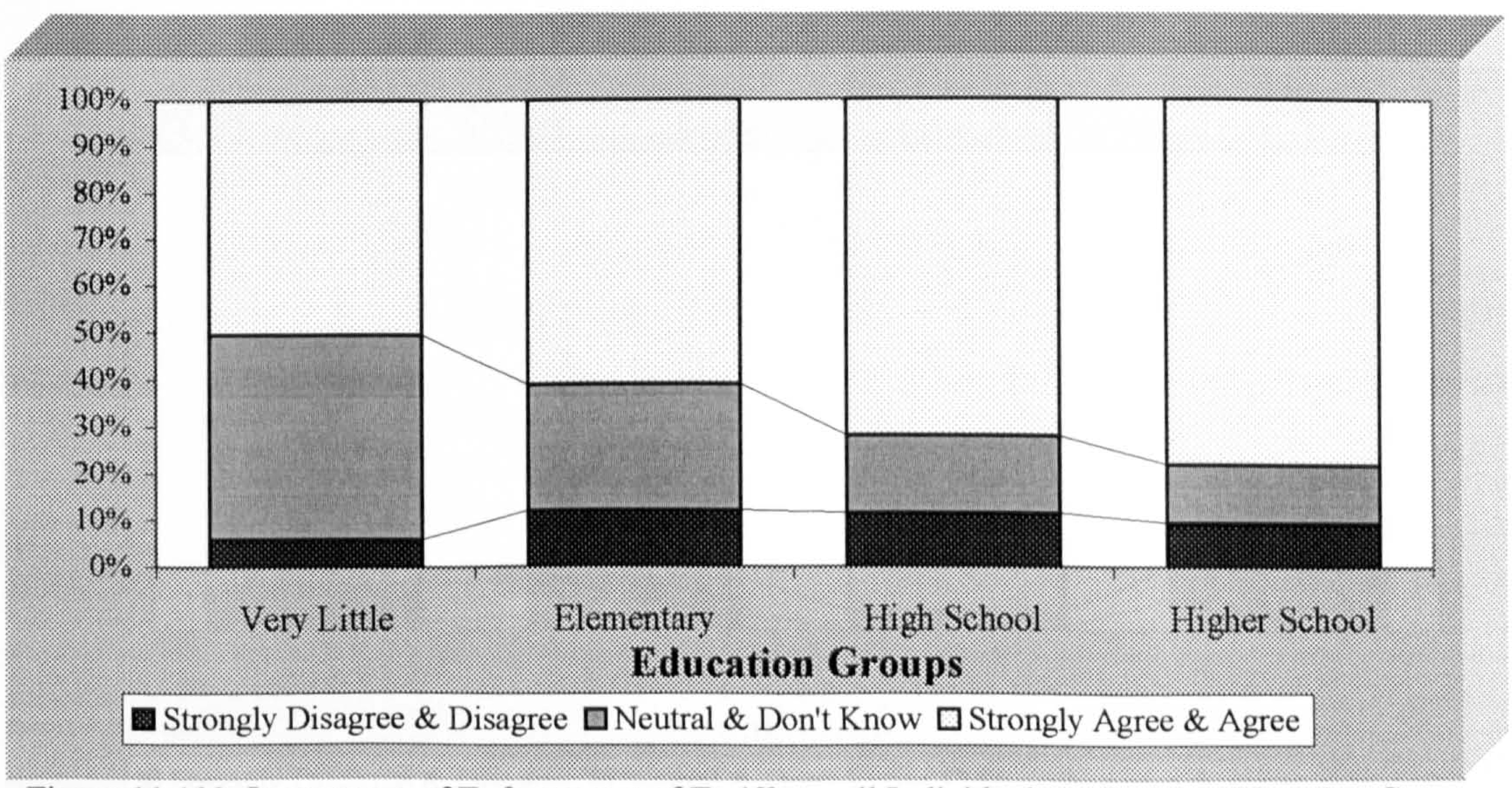

Figure 11.103. Importance of Enforcement of Tariffs on all Individuals in Society: Education Groups.

While there is no clear pattern among age groups (Section A14.3.6.3), some on middle incomes do not wish to equalise tariffs with actual costs (Figures 11.104 and 11.105). All emphasise the need to take family circumstances into account and the need to improve the service.

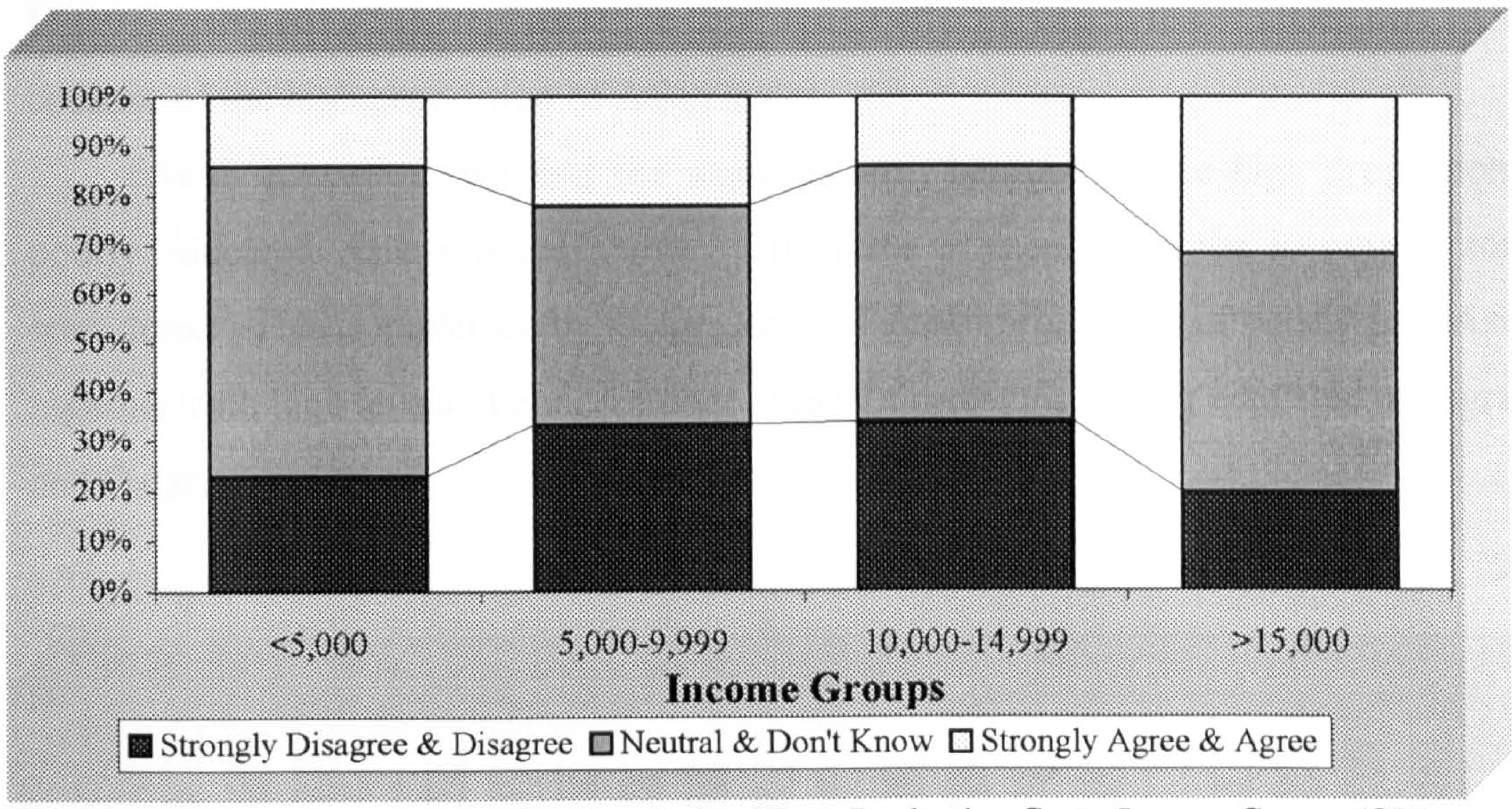

Figure 11.104. Importance of Tariffs Identical to Water Production Costs: Income Groups (QR).

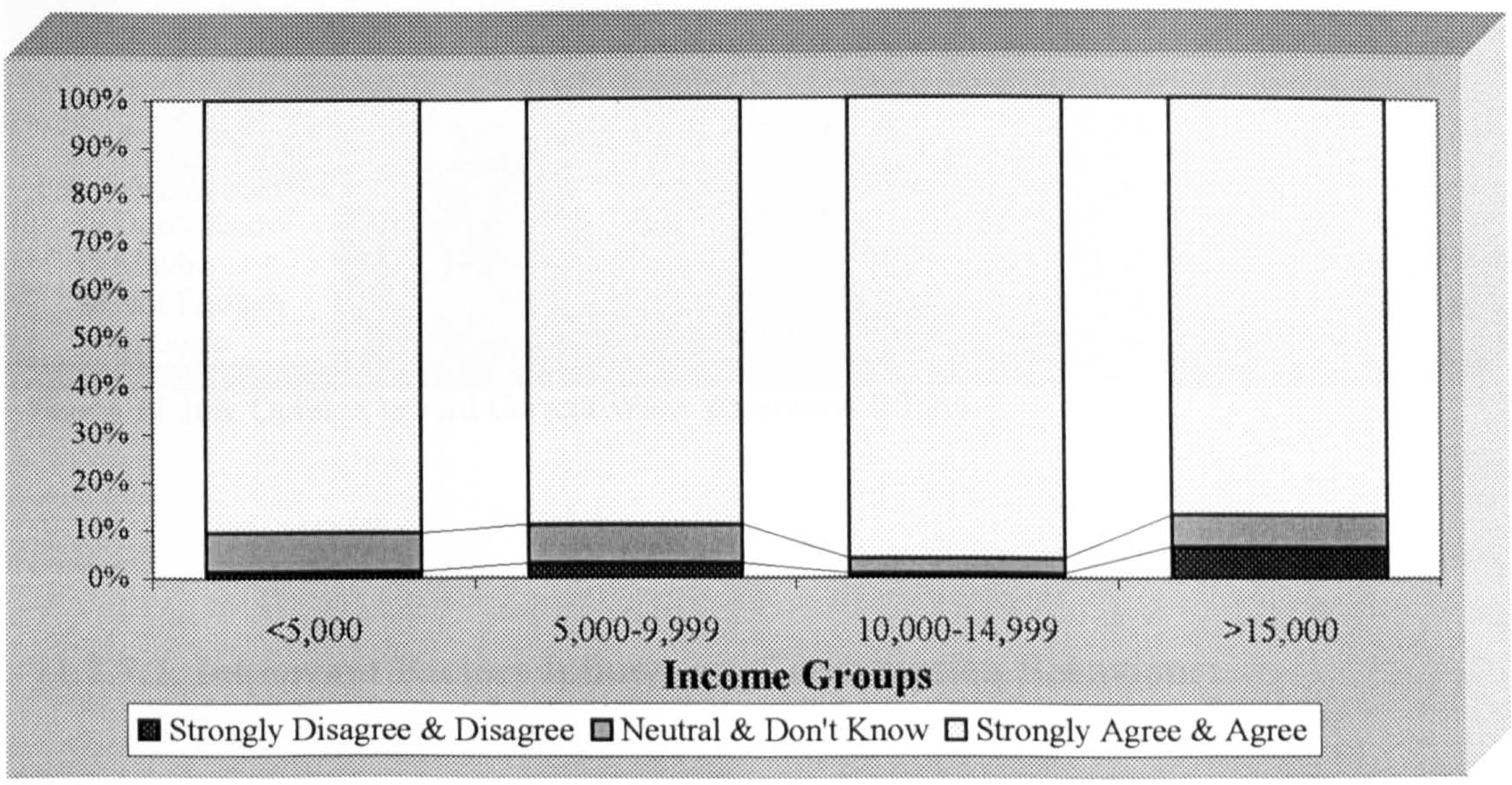

Figure 11.105. Importance of Considering Levels of Family Circumstances in Tariffs Policy: Income Groups (QR).

11.2.7. Public Relations:

11.2.7.1. Awareness of Existing Efforts:

Qataris (64%), Westerners (60%) and Arabs (54.7%) tend to emphasise the insufficiency of efforts to raise awareness, while only 15.4% of Asians have a definite opinion (Figure 11.106), most probably because of language and educational barriers. Many females (66.4%) emphasise the shortage of efforts, which fewer males do (50.9%) because of the high proportion of Asian males.

With education, we find the same pattern, because of the high proportion of poorly educated Asians noted above. The same is seen when the income factor is considered. This is explained by the presence of a high proportion of poorly-paid Asians together with high levels of concern over society's problems among educated immigrants and Qataris.

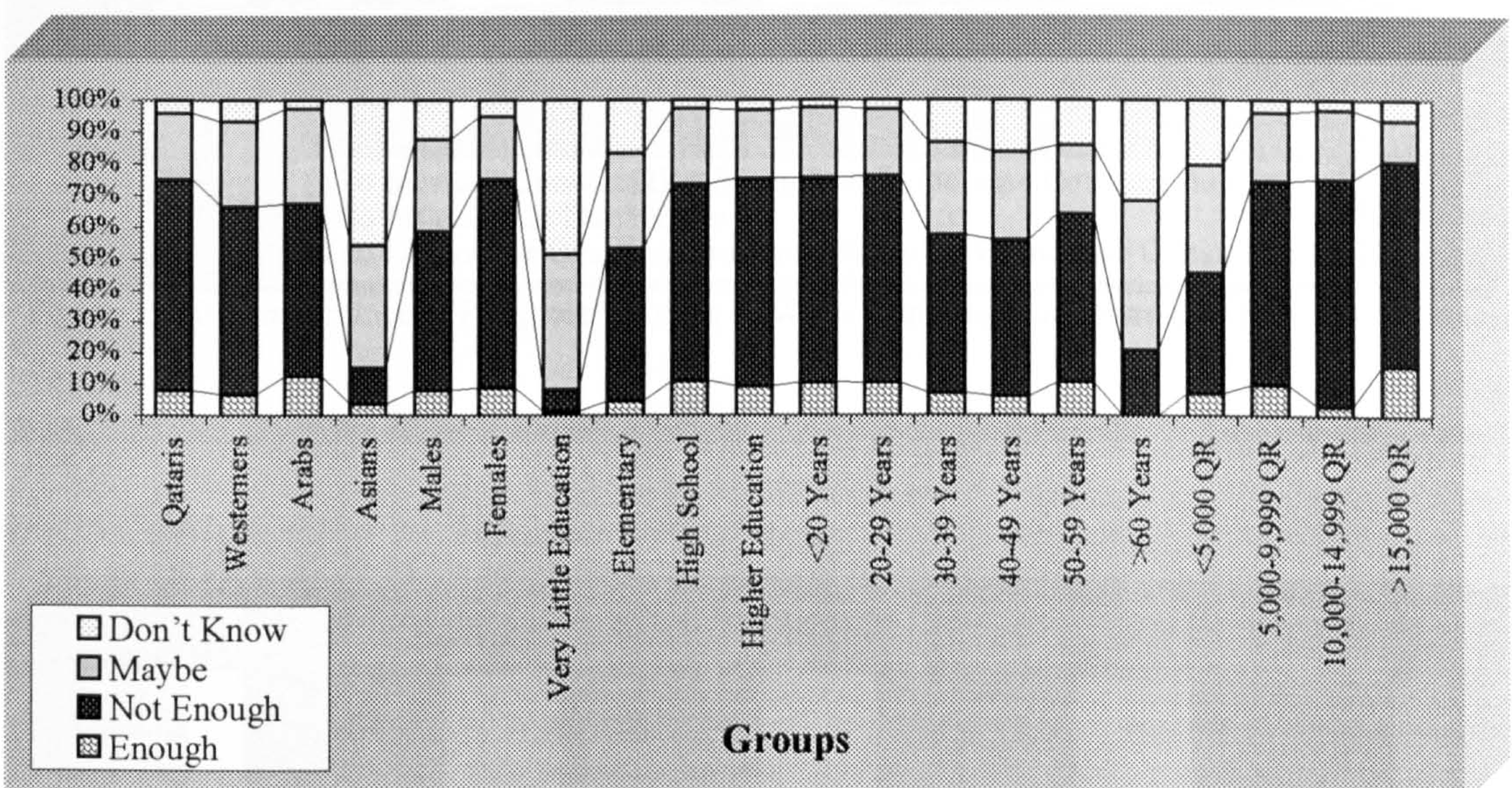

Figure 11.106. Opinion toward Current Water Awareness Efforts.

11.2.7.2. Important Factors Influencing Consumption Behaviour:

Qataris consumption behaviour is strongly influenced by religion and education, followed by the media (Figures 11.107, 11.108, 11.109, 11.110 and 11.111). Westerners are mostly affected by upbringing, education, cutting the water supply and tariffs. Arabs showed some similarities with Qataris except that tariffs and water laws have a stronger influence. Asians showed a weak response to most influences except tariffs, cutting supply and religion. The major difference among these groups is the weak influence of religion among Westerners. Tariffs and water laws have the strongest influence on Arabs and Asians, while it is the weakest among Qataris because they are exempted from paying tariffs.

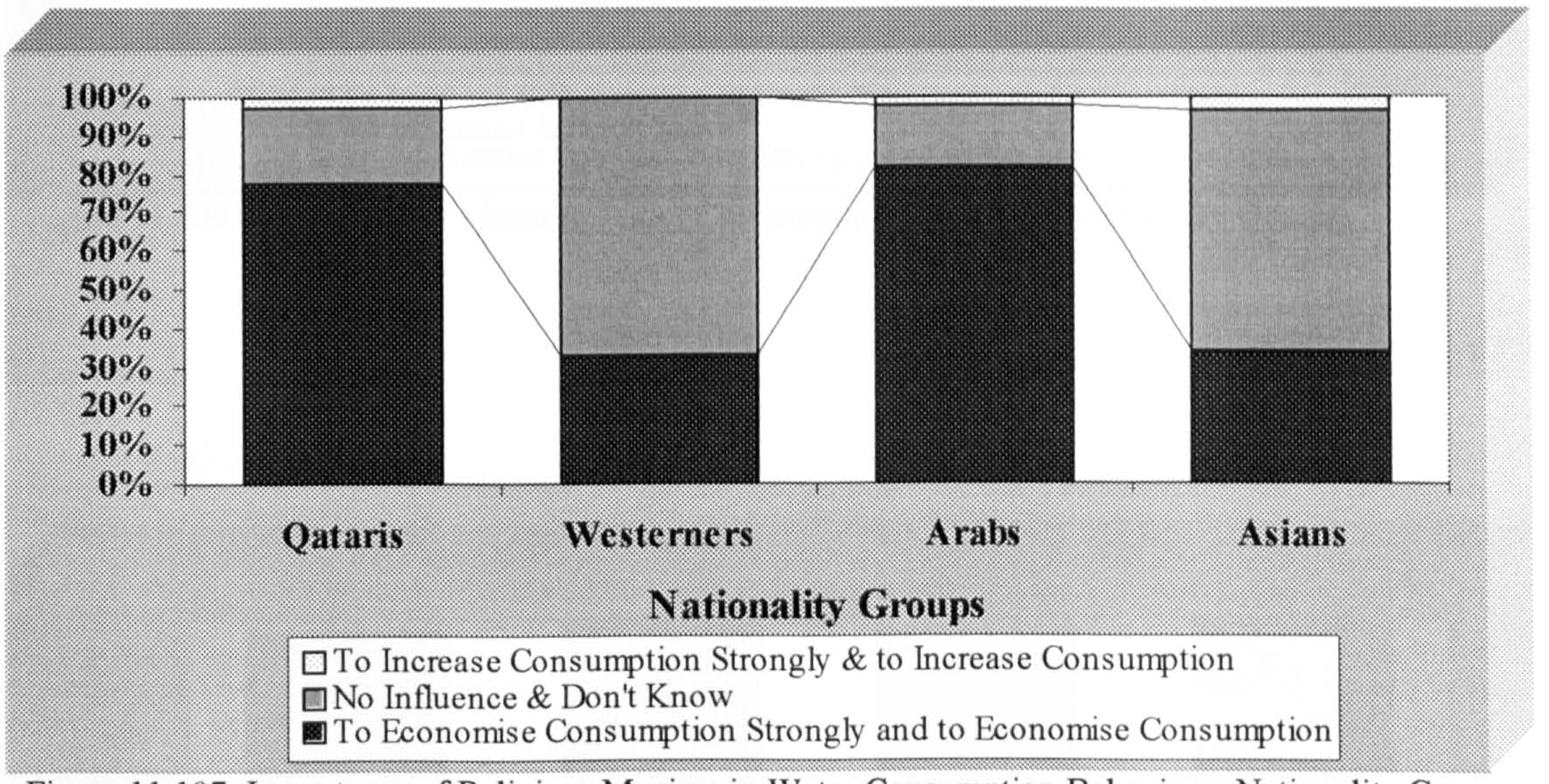

Figure 11.107. Importance of Religious Maxims in Water Consumption Behaviour: Nationality Groups.

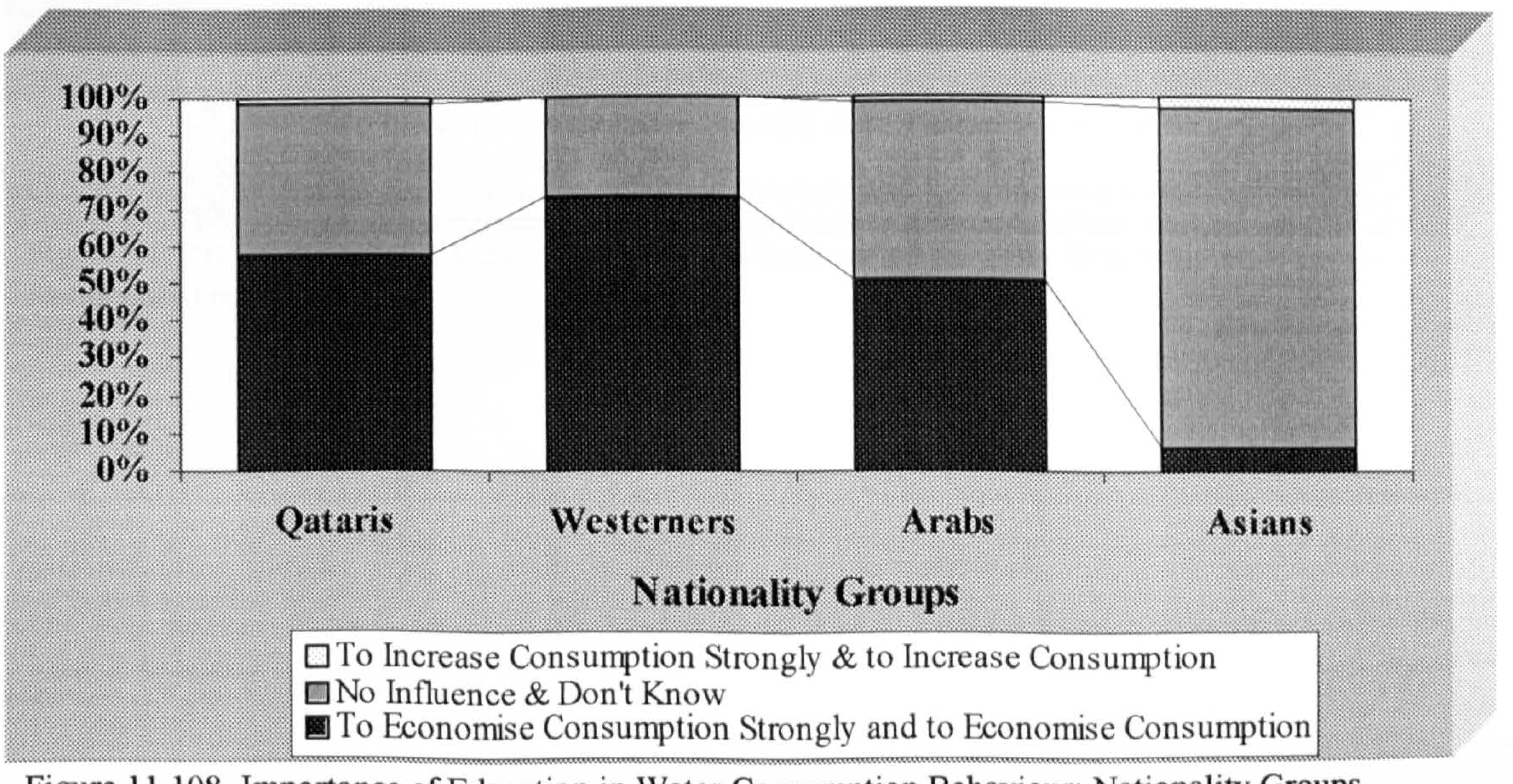

Figure 11.108. Importance of Education in Water Consumption Behaviour: Nationality Groups.

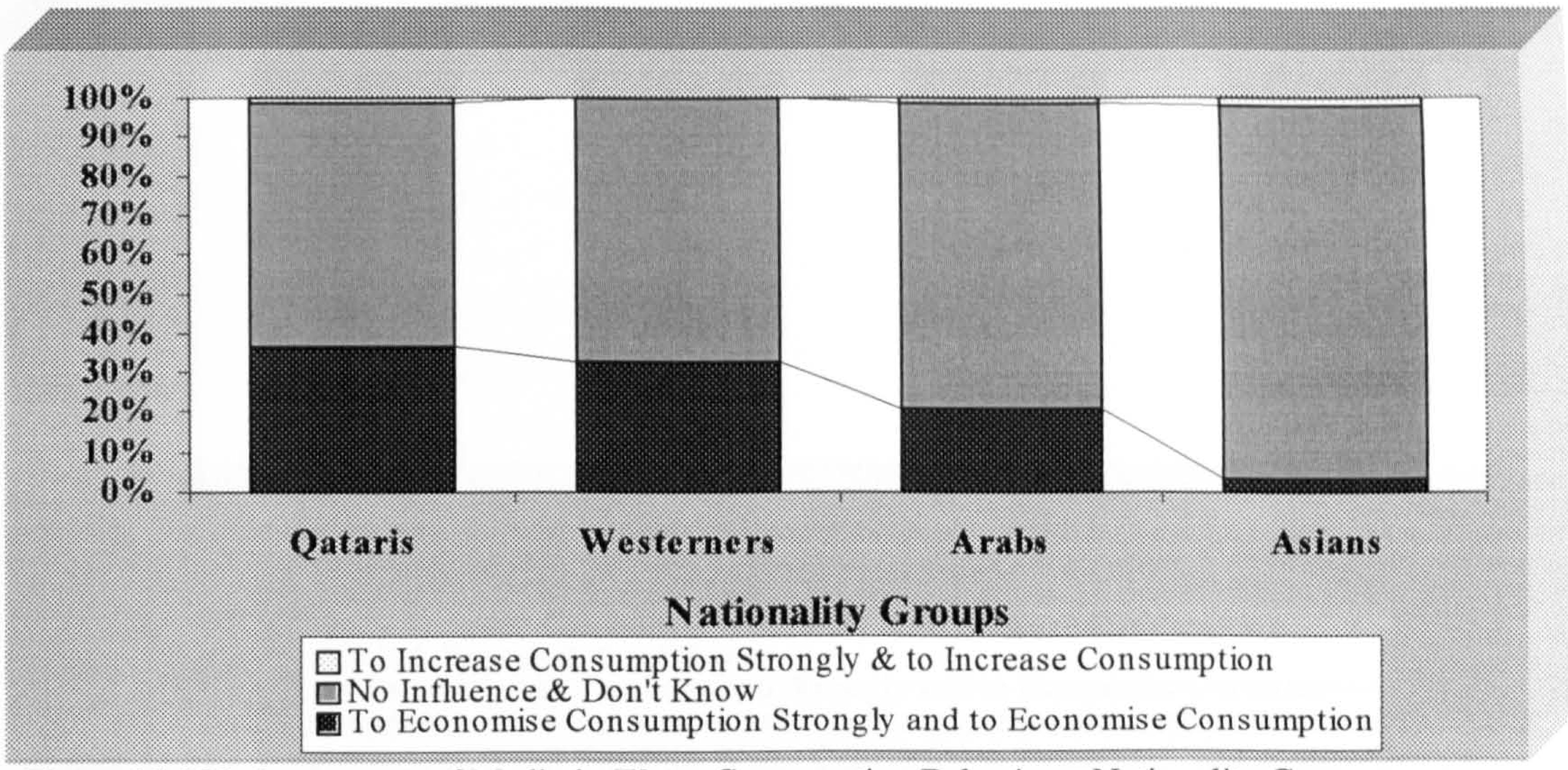

Figure 11.109. Importance of Media in Water Consumption Behaviour: Nationality Groups.

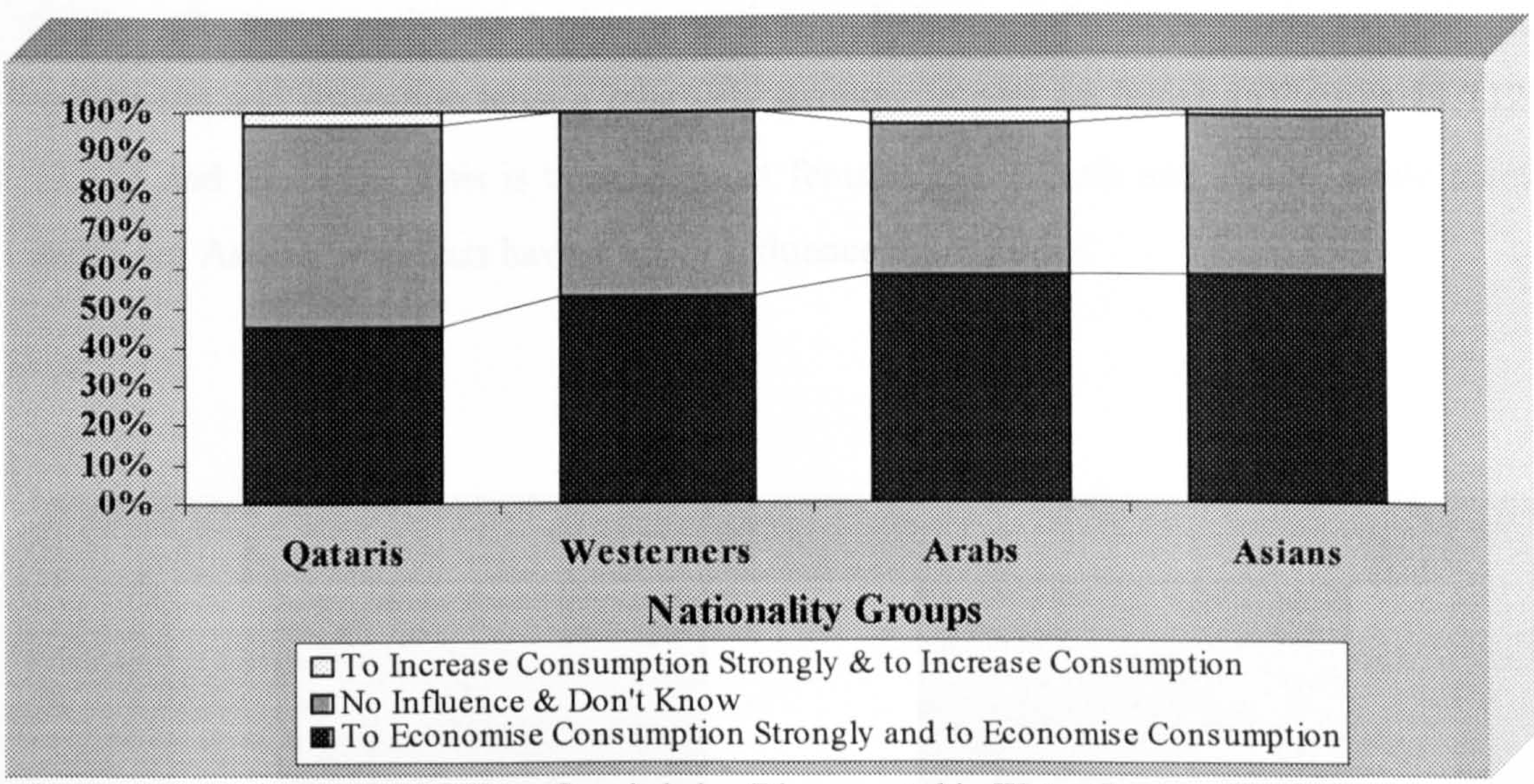

Figure 11.110. Importance of Water Supply being Disconnected in Water Consumption Behaviour: Nationality Groups.

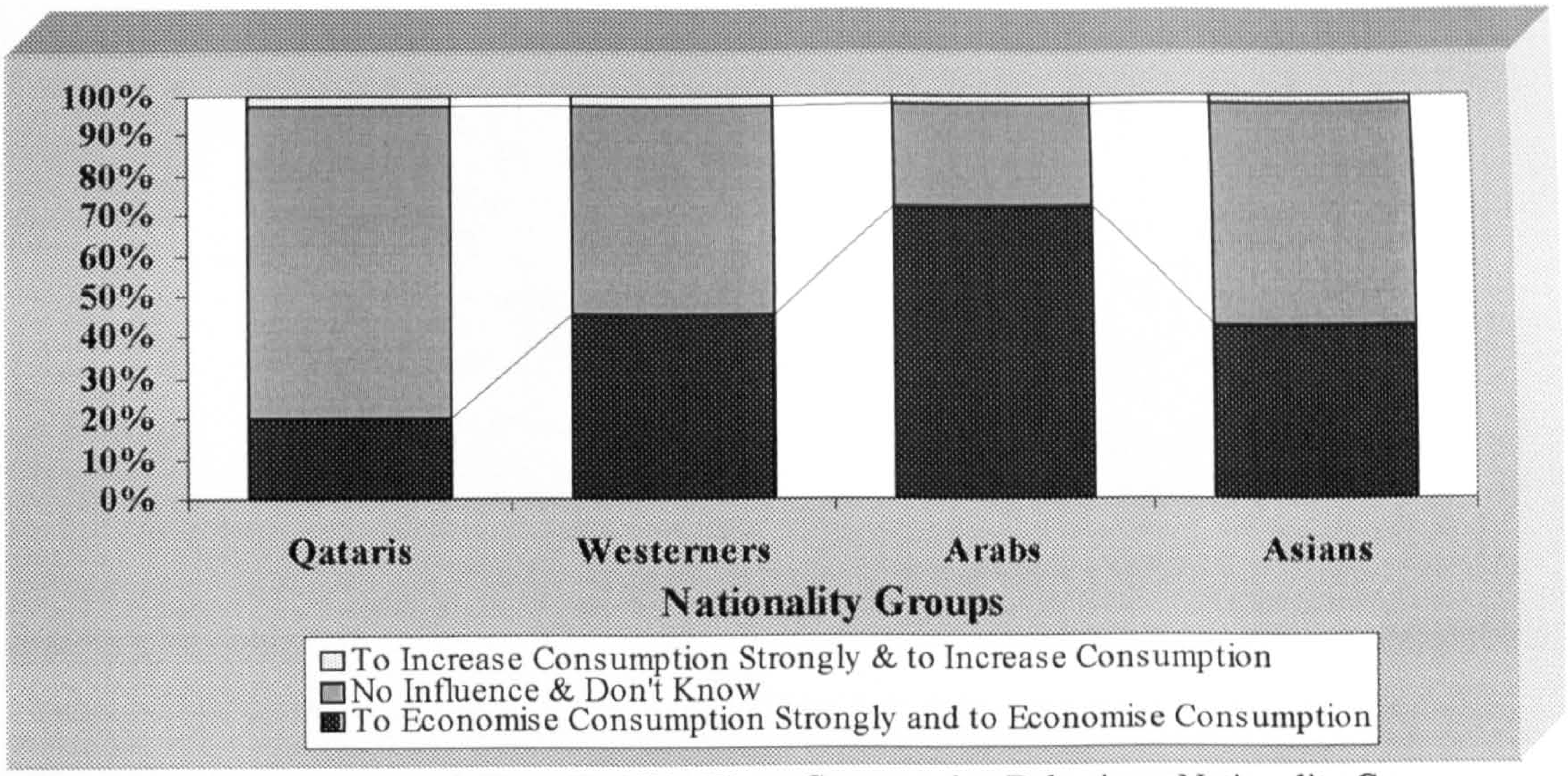

Figure 11.111. Importance of Water Tariff in Water Consumption Behaviour: Nationality Groups.

All factors appear to have a weak impact on males, with the exception of religion, family education and water disconnection. Indirect influences such as religion, upbringing and education have a relatively stronger impact on females (Figures 11.112, 11.113 and 11.114). This is because most females are Qataris and Arabs, while many males are Asians, who thus have a major influence on attitudes.

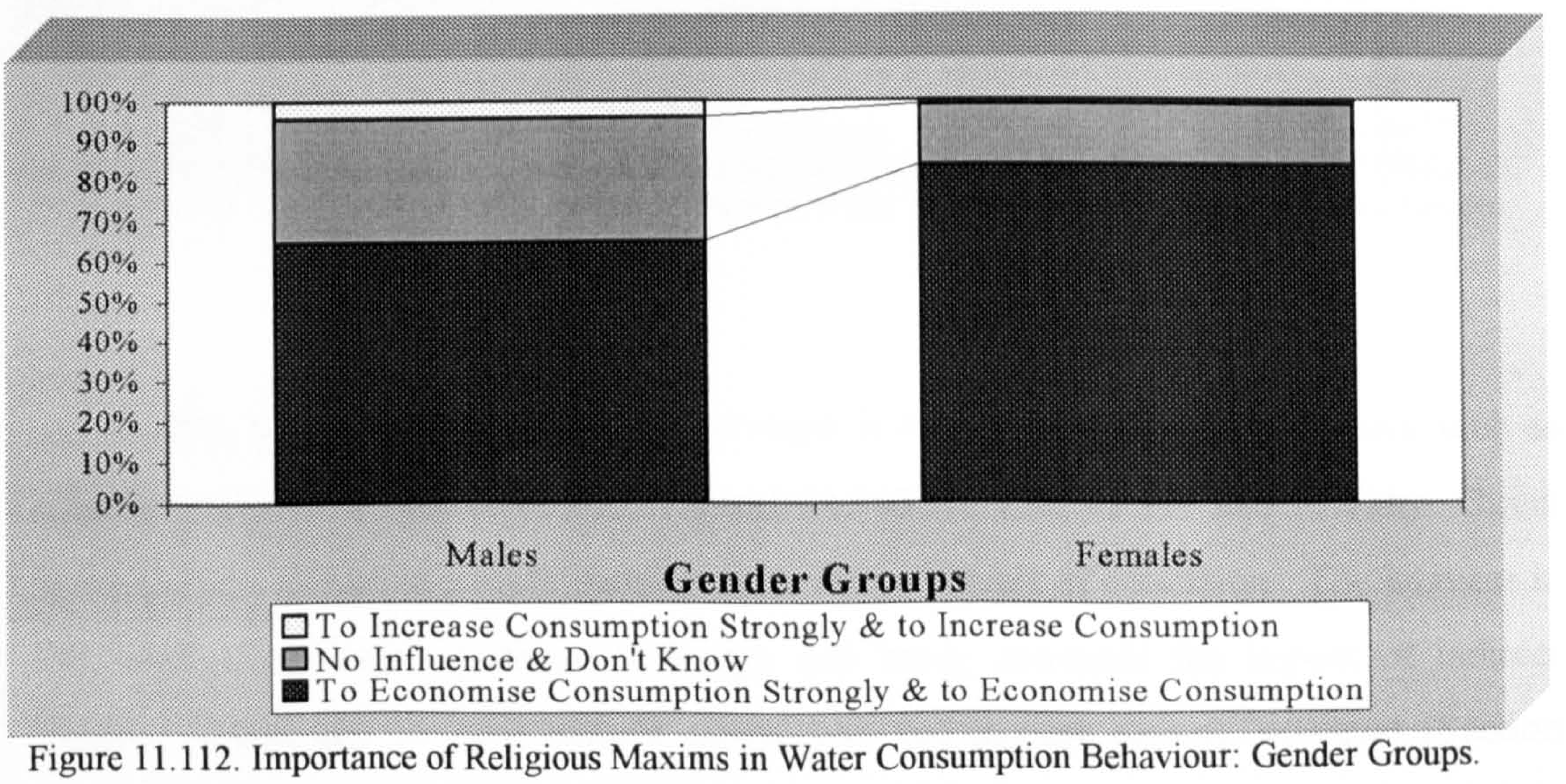

Figure 11.112. Importance of Religious Maxims in Water Consumption Behaviour: Gender Groups.

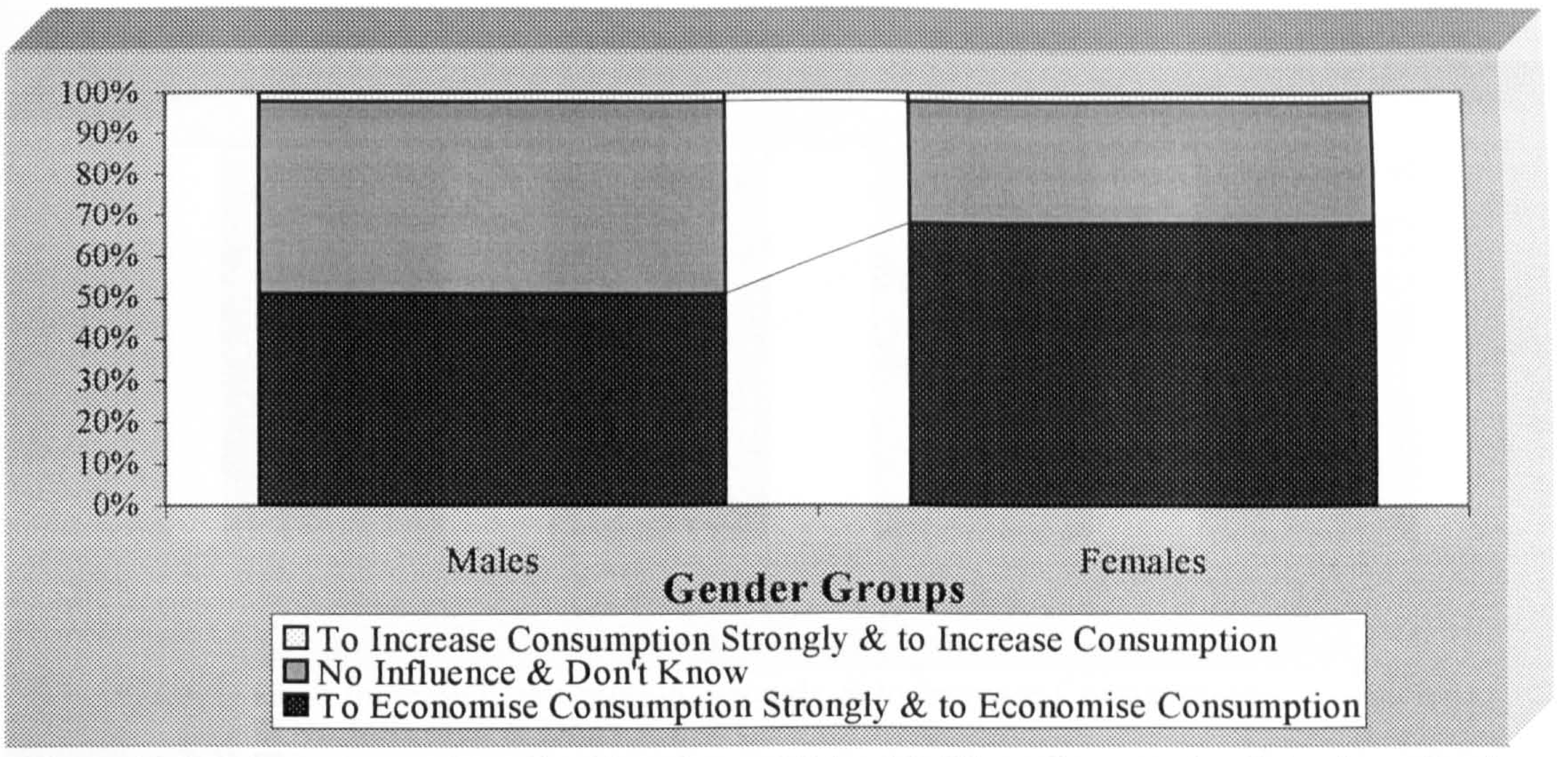

Figure 11.113. Importance of Family Education and School in Water Consumption Behaviour: Gender Groups.

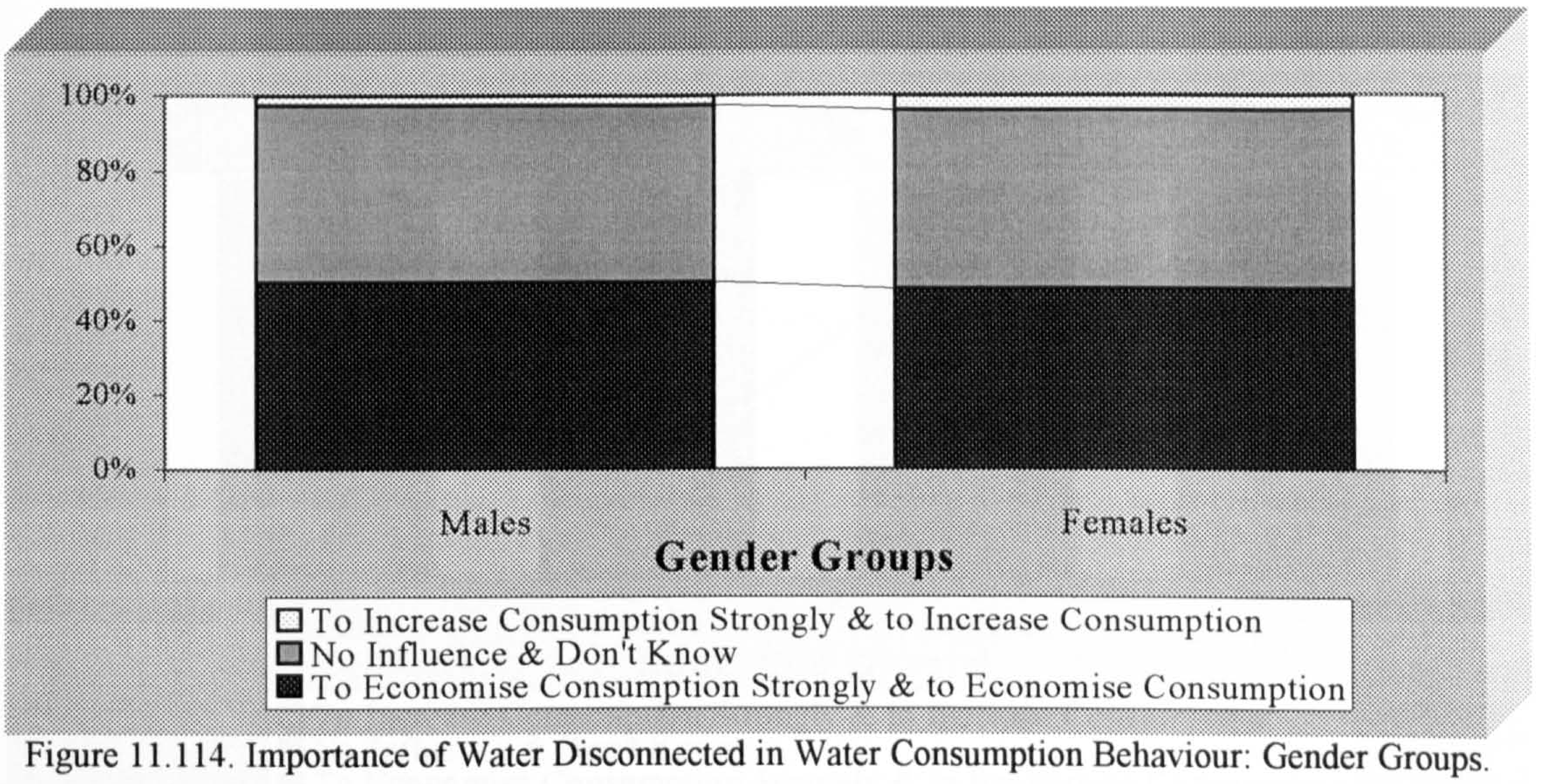

Figure 11.114. Importance of Water Disconnected in Water Consumption Behaviour: Gender Groups.

The higher the education, the stronger is the impact of indirect factors such as religion, upbringing, and education (Figures 11.115, 11.116, 11.117 and 11.118). Direct factors, such as cutting supply, remains high with all levels of education. The increase in the level of education widens knowledge and hence increases the impact of indirect factors. There are no clear pattern among age and income groups, however (Section A14.3.7.2).

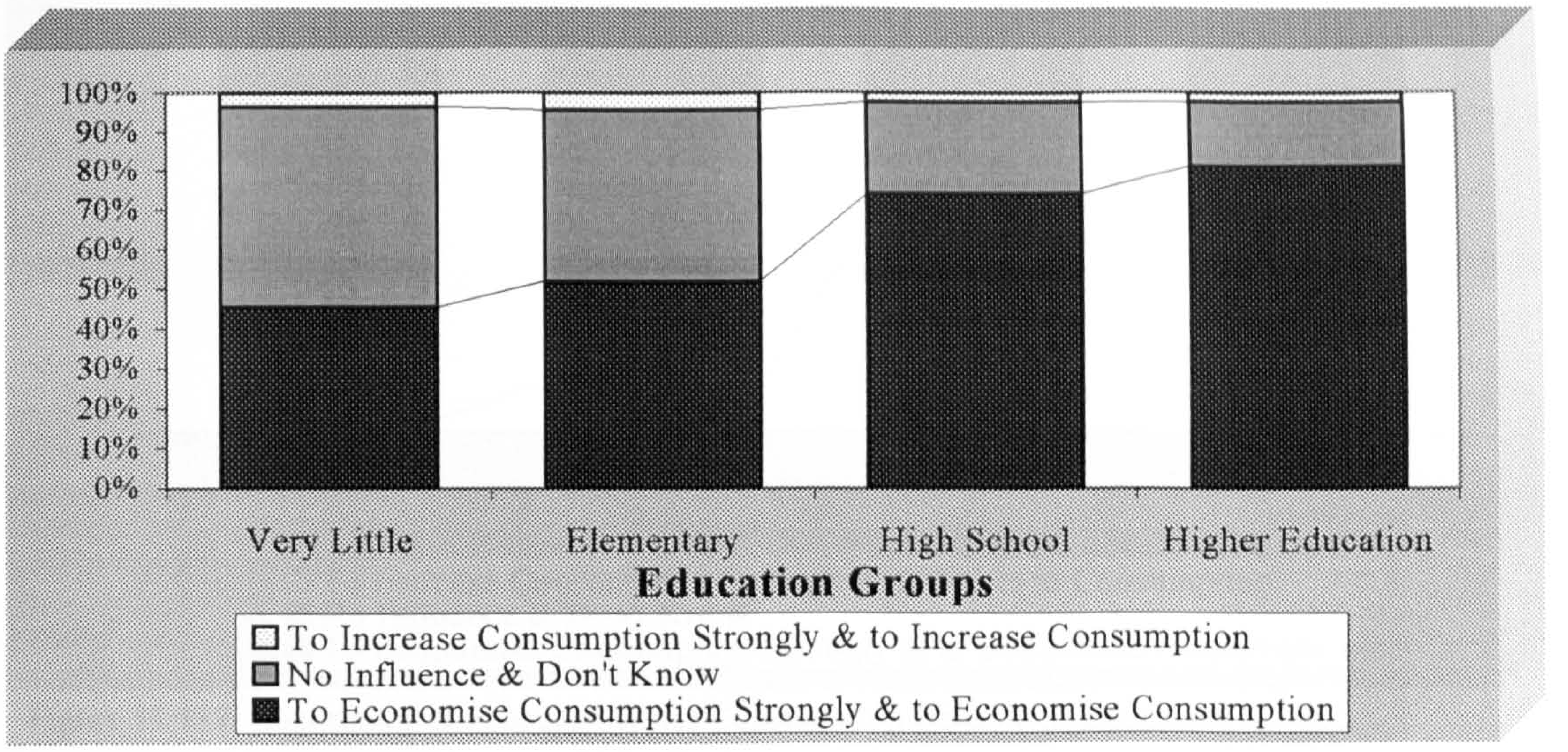

Figure 11.115. Importance of Religion Maxims in Water Consumption Behaviour: Education Groups.

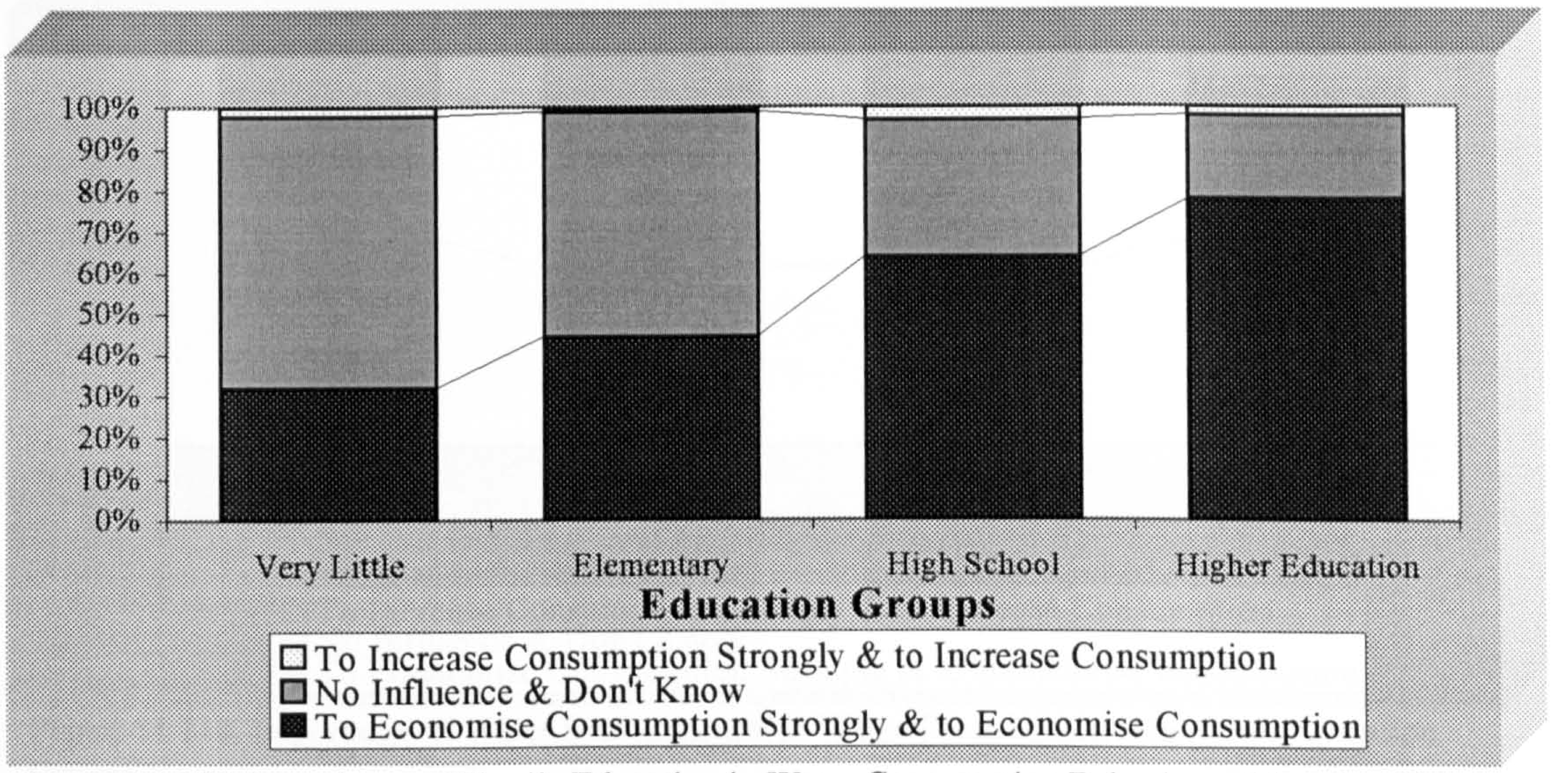

Figure 11.116. Importance of Family Education in Water Consumption Behaviour: Education Groups.

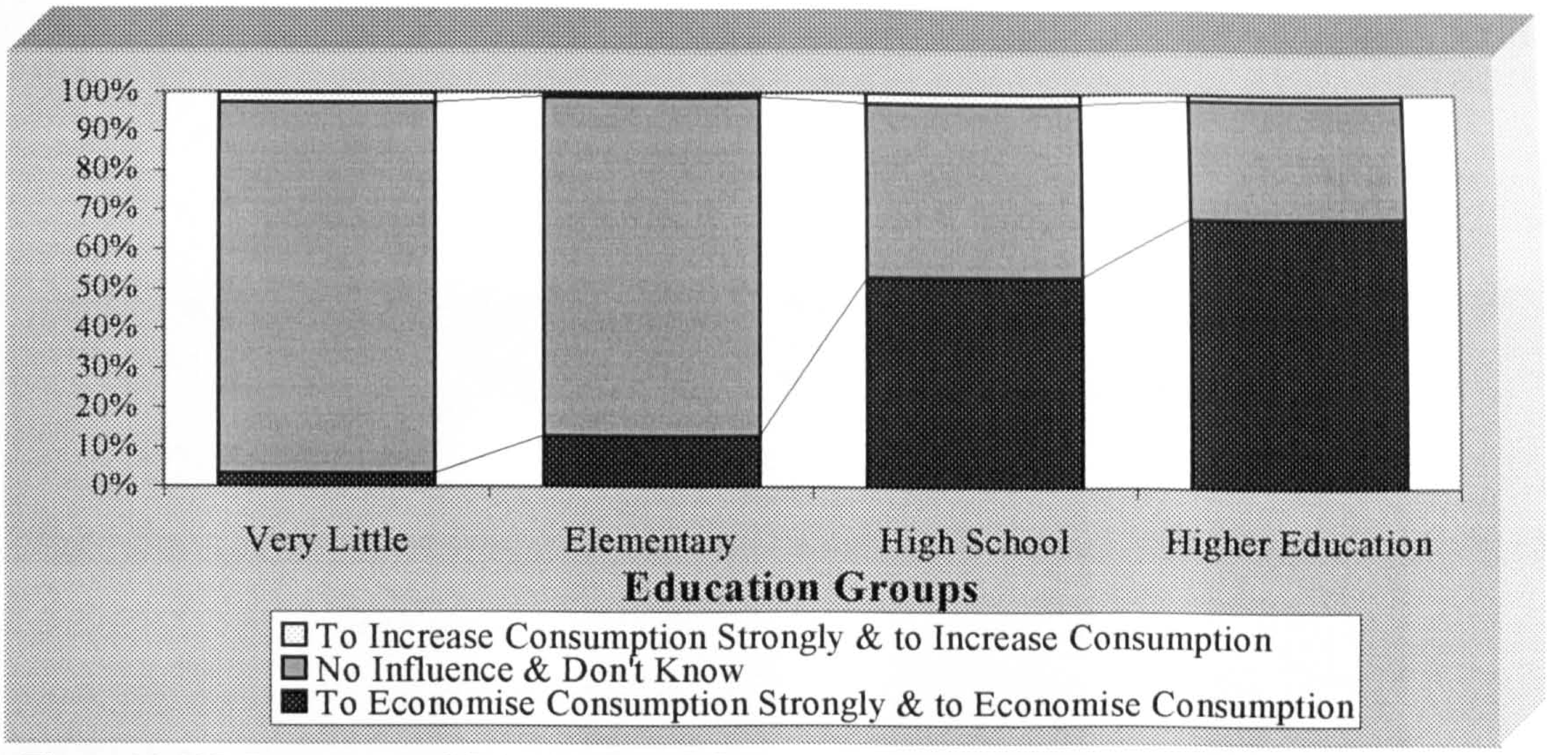

Figure 11.117. Importance of School in Water Consumption Behaviour: Education Groups.

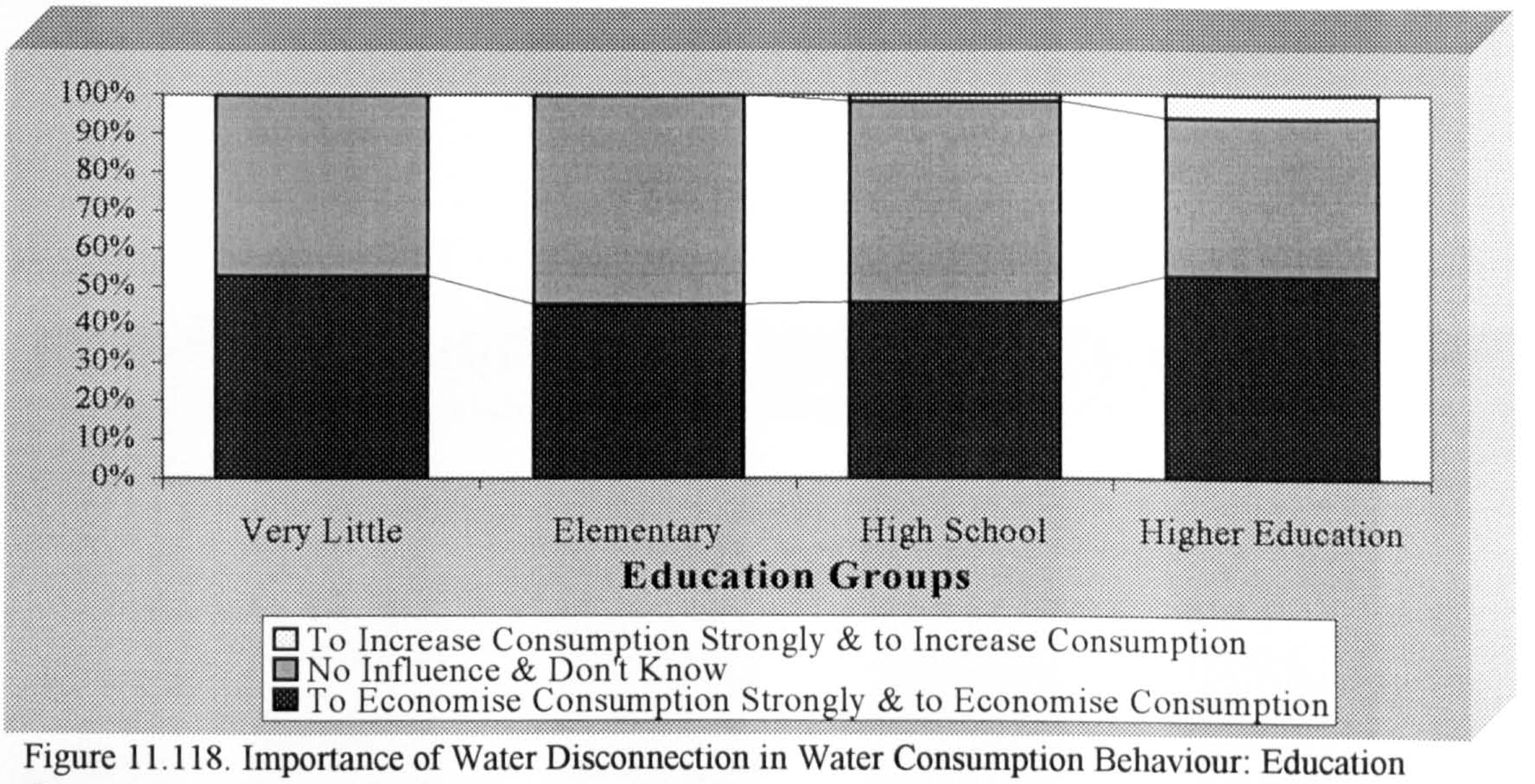

Figure 11.118. Importance of Water Disconnection in Water Consumption Behaviour: Education Groups.

11.2.7.3. Methods to Raise Awareness:

To enhance public awareness, Qataris and Arabs cite factors such as upbringing, education and religion, with a particular emphasis on tariffs and laws among the Arabs (Figures 11.119, 11.120, 11.121, 11.122 and 11.123). The same factors, except religion, have a similar impact on Westerners. Non-governmental institutions (club and association) have little influence. Asians are most affected by family, education, tariffs and laws.

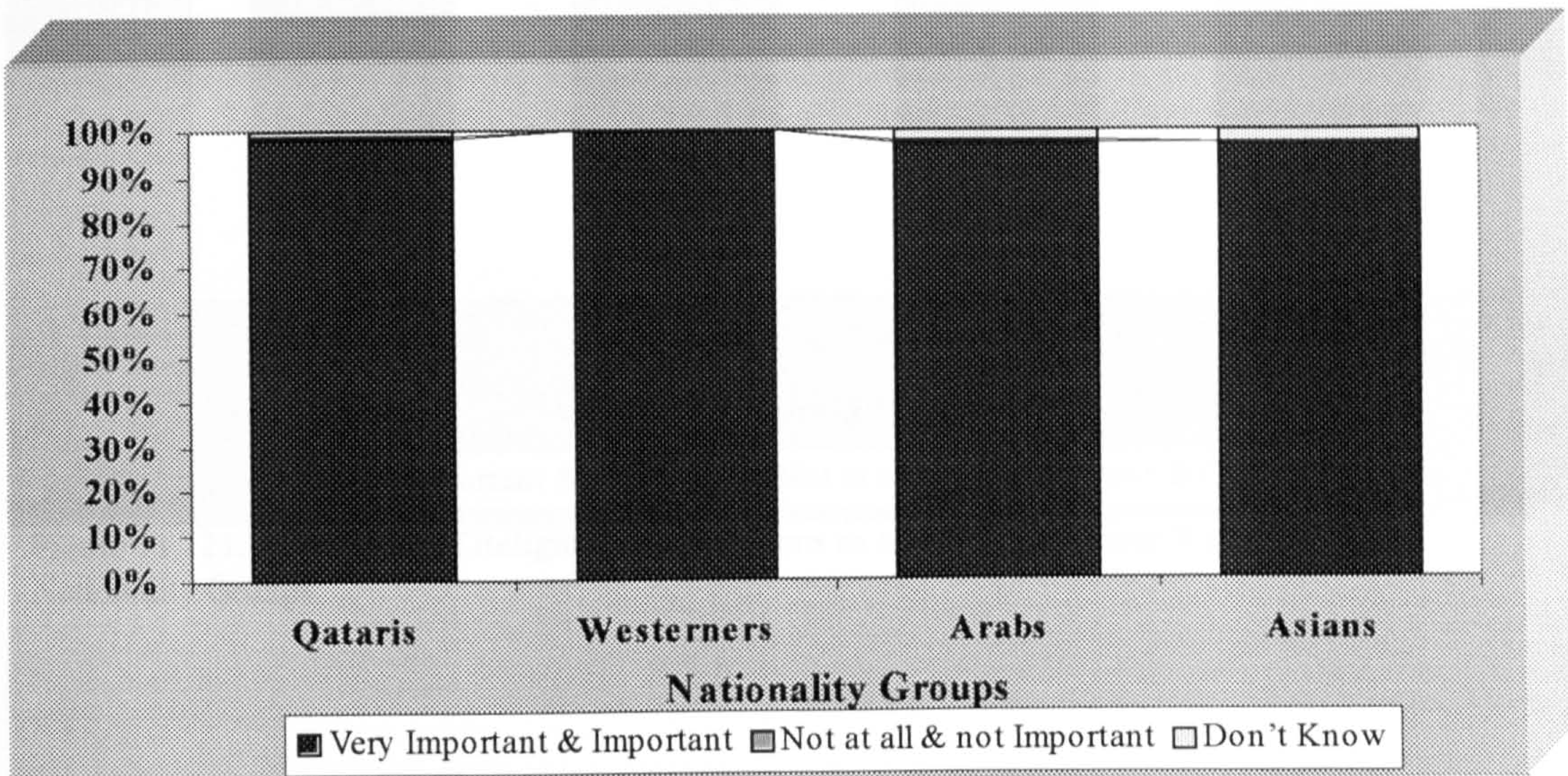

Figure 11.119. Importance of Family Education as a Method to Create Water Awareness: Nationality Groups.

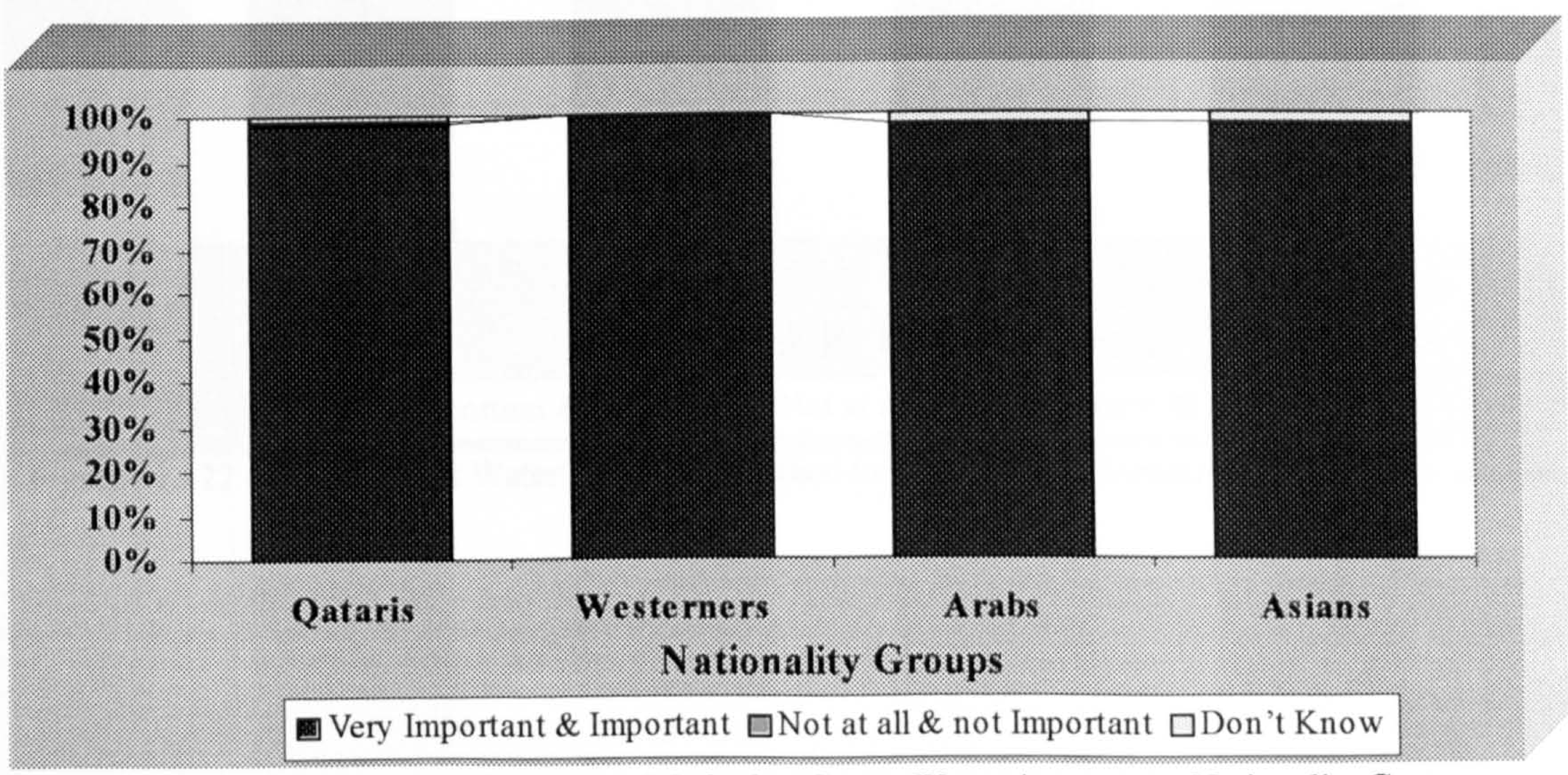

Figure 11.120. Importance of School as a Method to Create Water Awareness: Nationality Groups.

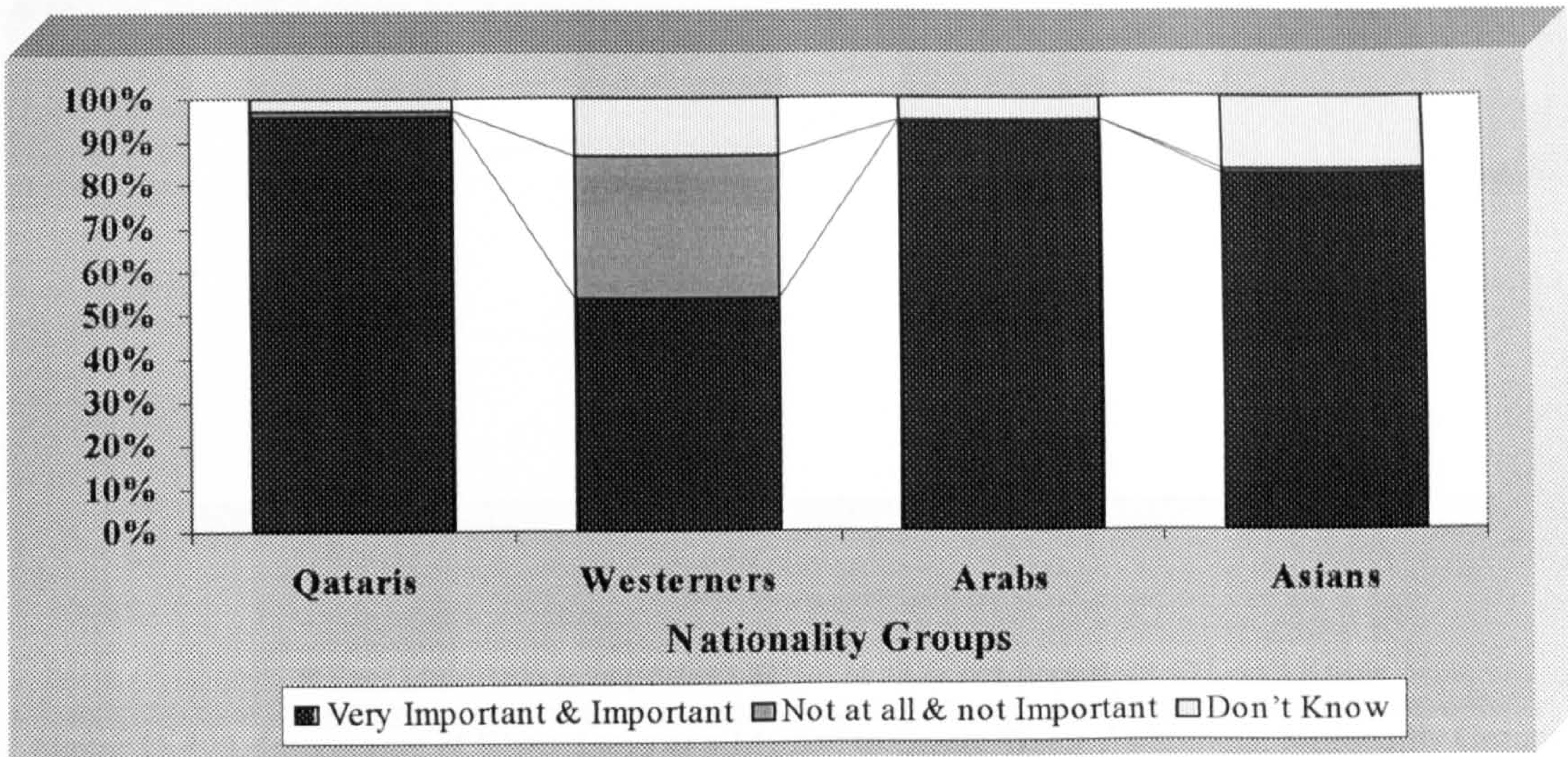

Figure 11.121. Importance of Religious Organisations as a Method to Create Water Awareness: Nationality Groups.

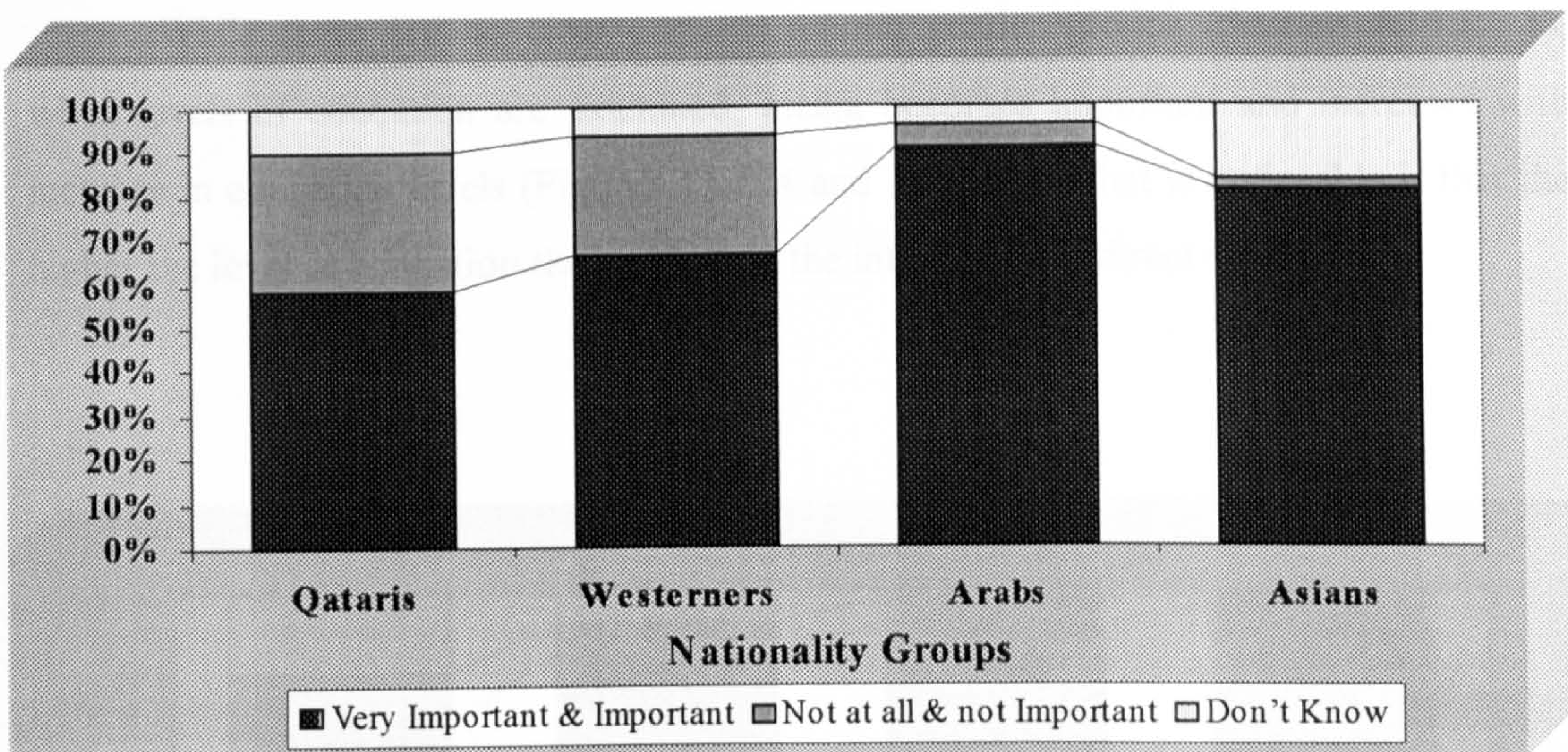

Figure 11.122. Importance of Water Tariff as a Method to Create Water Awareness: Nationality Groups.

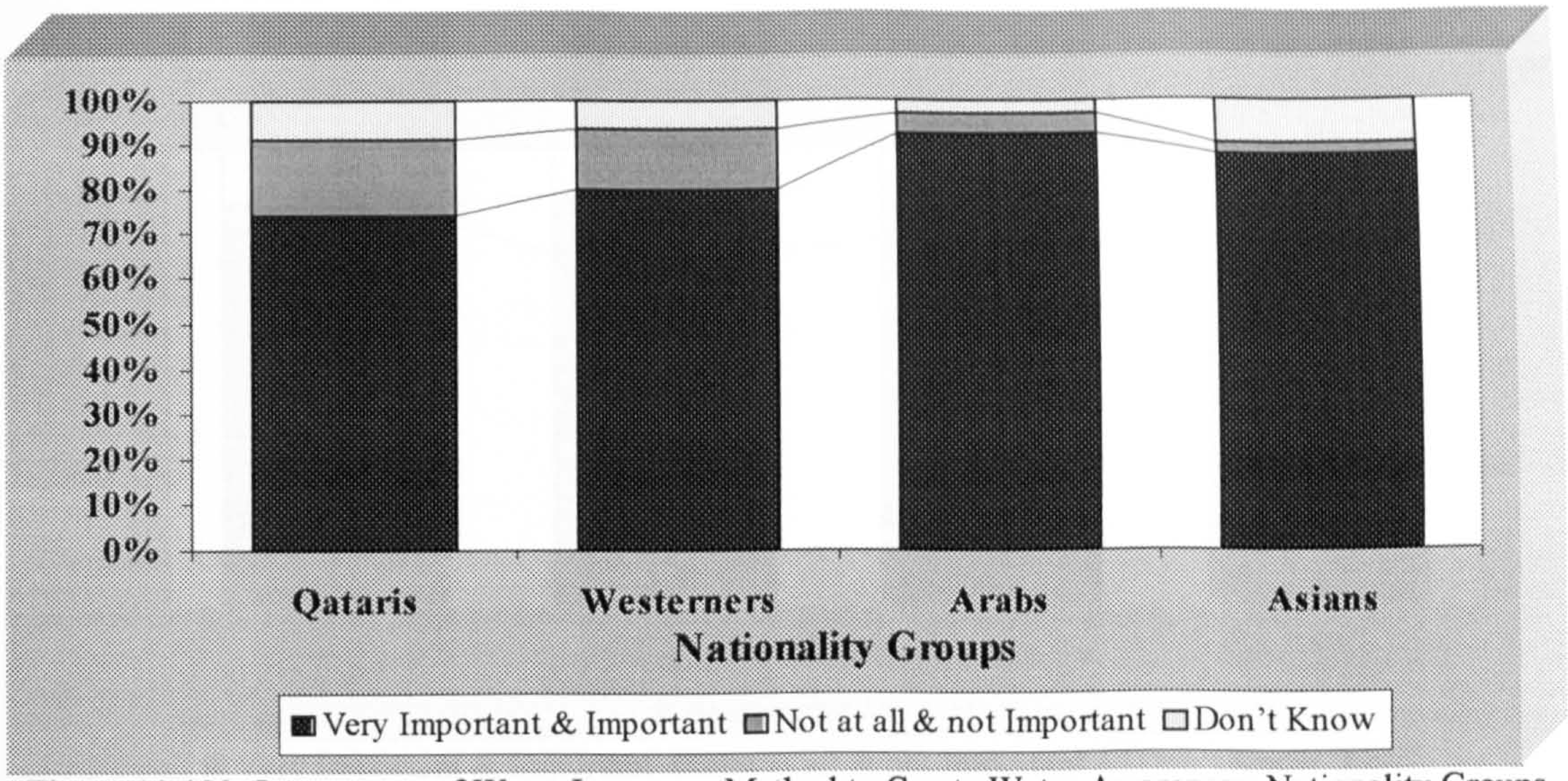

Figure 11.123. Importance of Water Laws as a Method to Create Water Awareness: Nationality Groups.

While there are no clear patterns among gender groups (Section A14.3.7.3), when levels of education are examined, media becomes important and increases with increase in education levels (Figures 11.124 and 11.125). What is noticeable is that the higher the level of education the stronger is the influence of indirect factors.

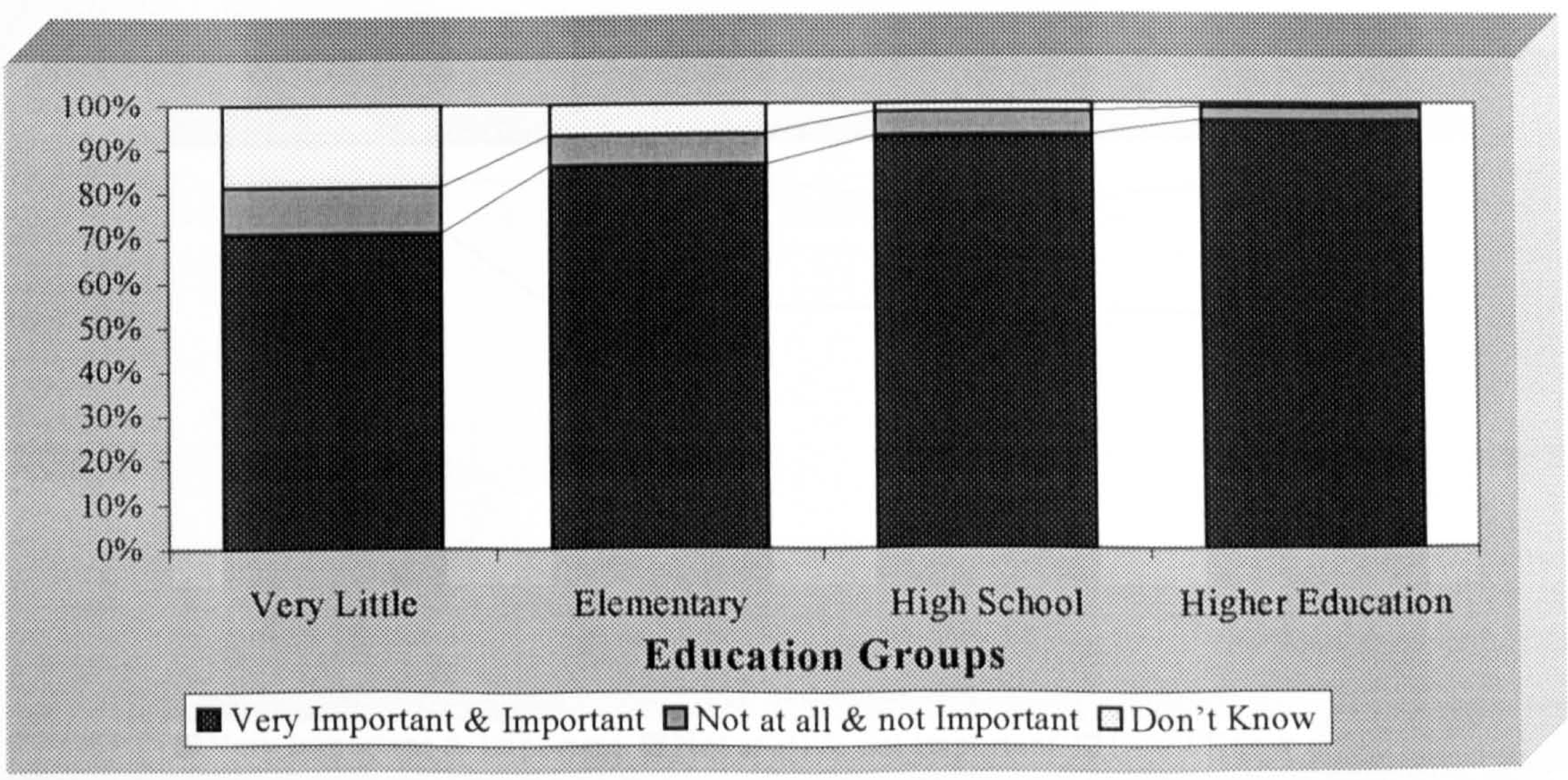

Figure 11.124. Importance of Media as a Method to Create Water Awareness: Education Groups.

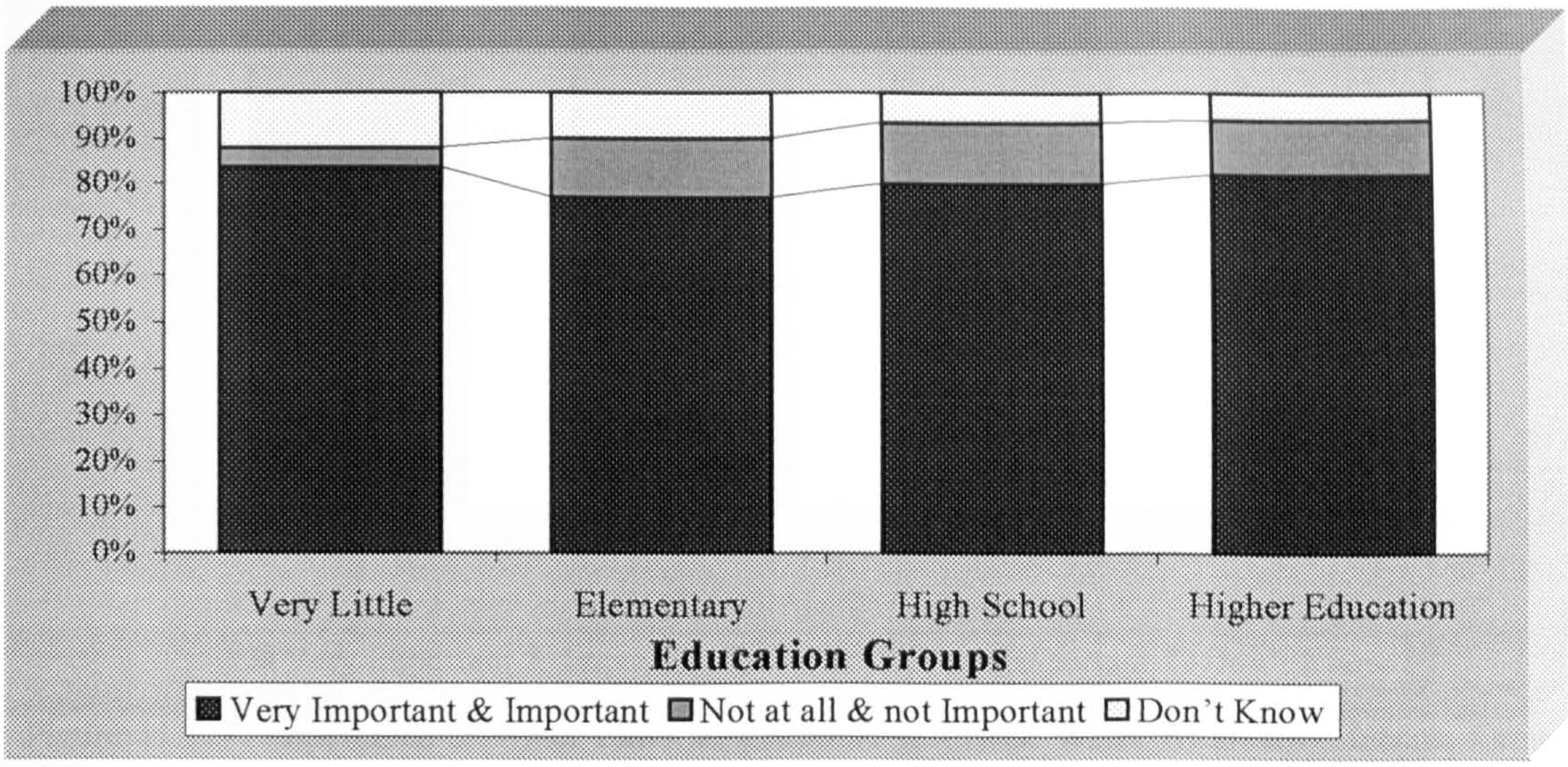

Figure 11.125. Importance of Water Laws as a Method to Create Water Awareness: Education Groups.

While there are no clear pattern among age groups (Section A14.3.7.3), upbringing, education and religion have influence on all income groups (Figures 11.126, 11.127 and 11.128). Indirect factors, such as the media, are more important, the higher the income, while low income people are more influenced with direct means such as tariffs.

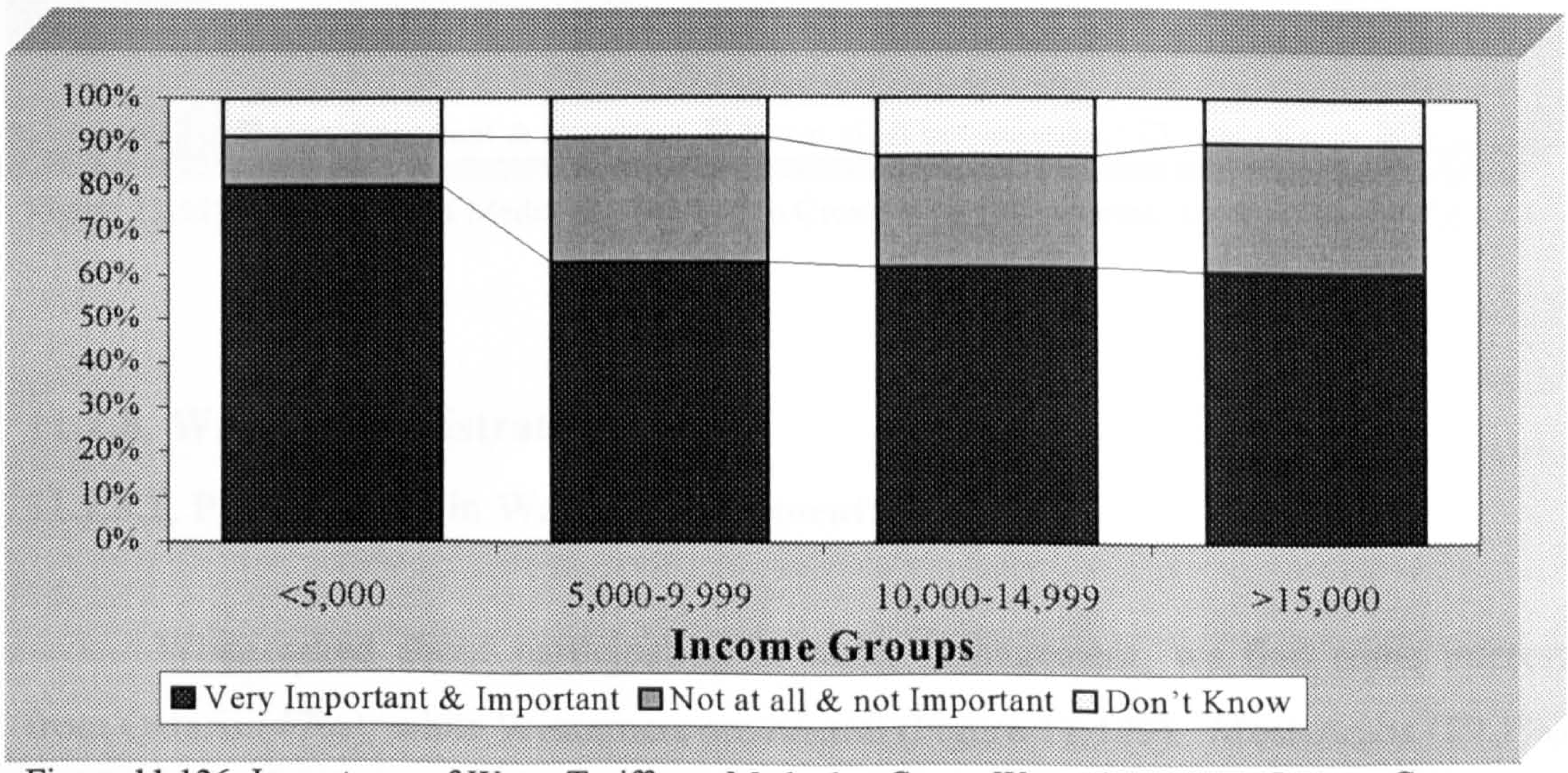

Figure 11.126. Importance of Water Tariff as a Method to Create Water Awareness: Income Groups (QR).

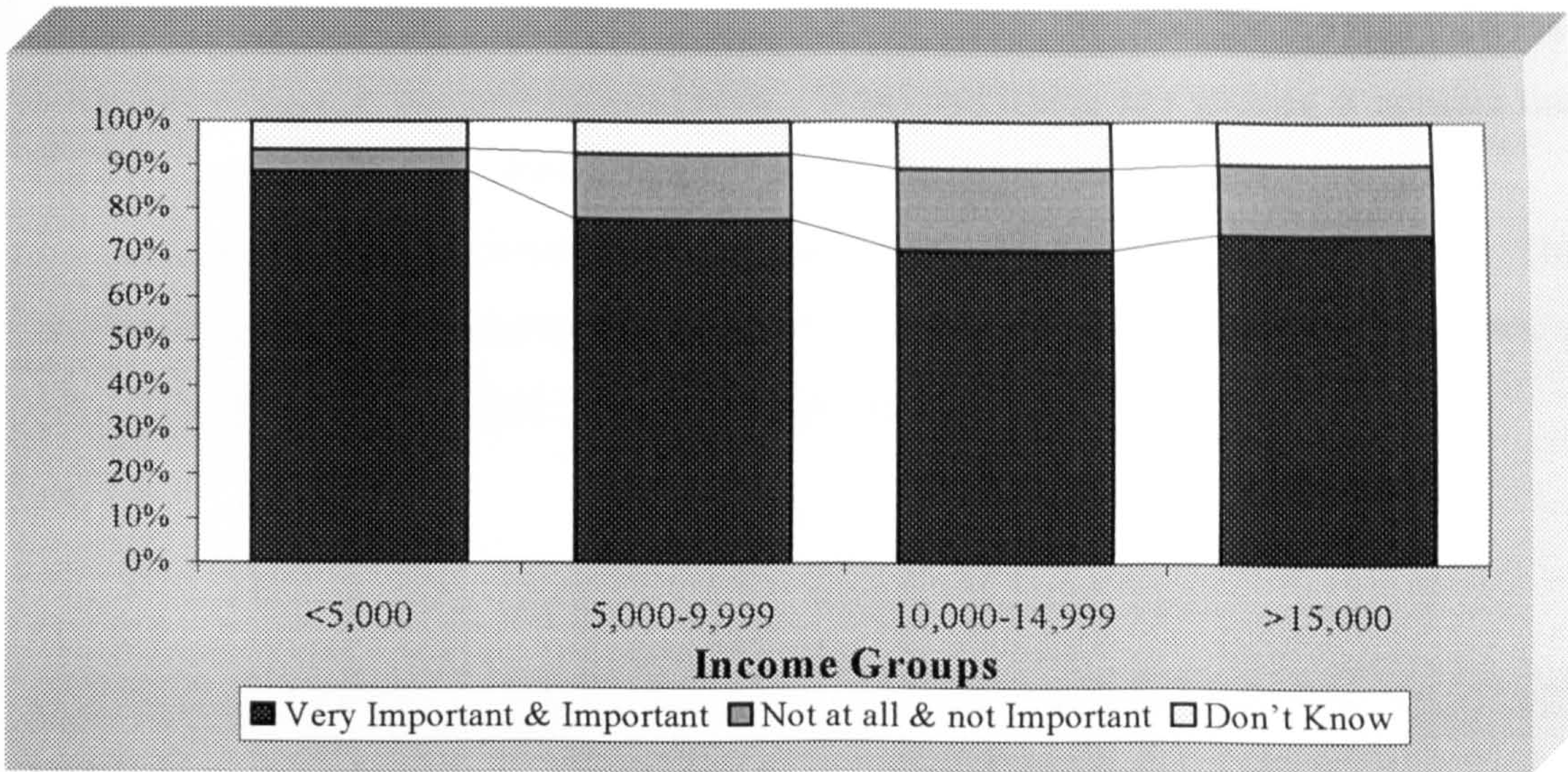

Figure 11.127. Importance of Water Laws as a Method to Create Water Awareness: Income Groups (QR).

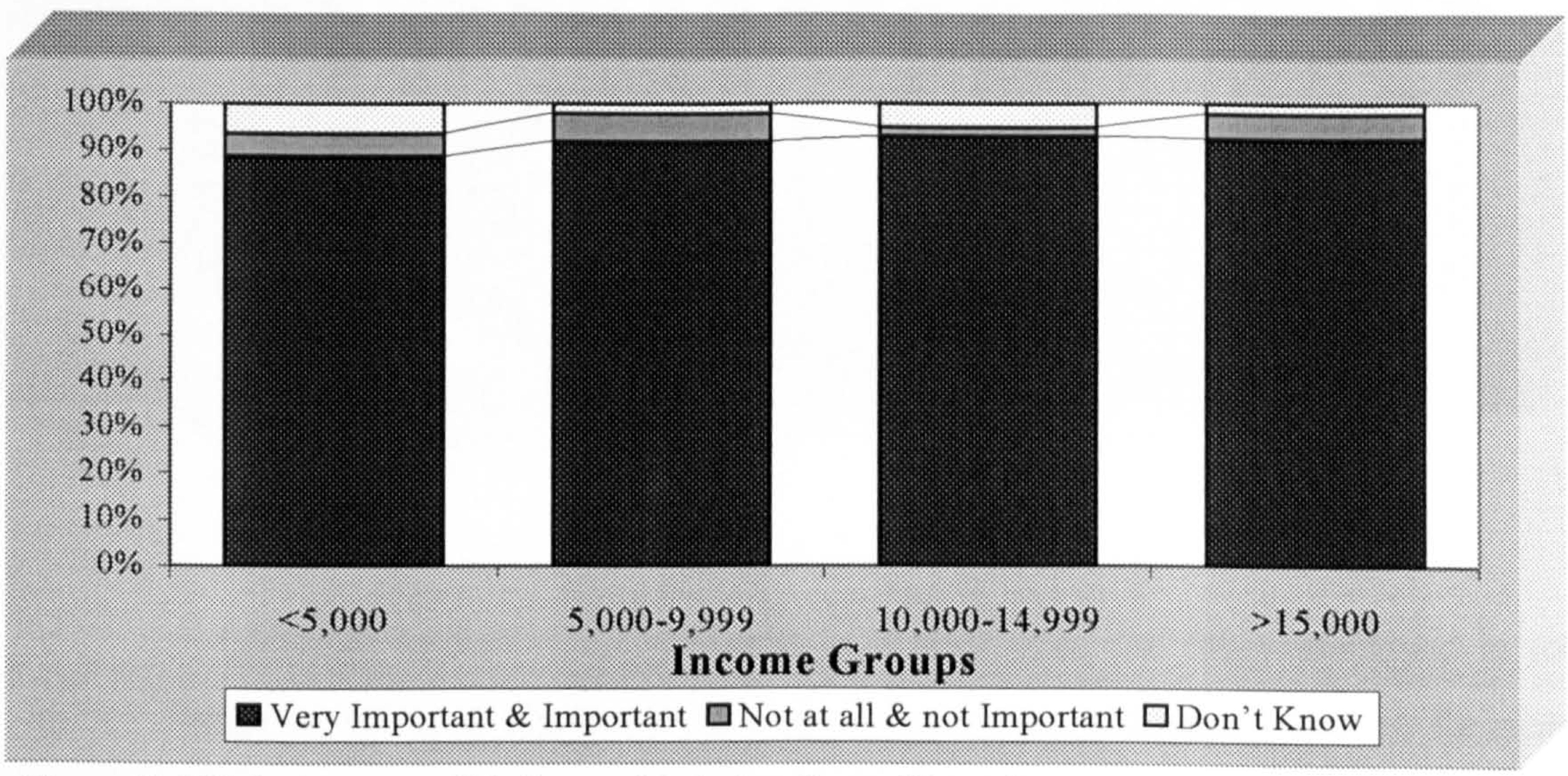

Figure 11.128. Importance of Media as a Method to Create Water Awareness: Income Groups (QR).

11.2.8. Water Administration:

11.2.8.1. Participation in Water Management:

When asked about participation in water management, we find some interest from Qataris (47%), while Westerners are neutral (Figure 11.129). Most Arabs (59.1%) and Asians (54.5%) reject the idea. The reason behind these attitudes will be discussed later (Section 11.2.8.4). Females (50.6%) welcome the idea more than males (45.6%)

probably because of the large number of immigrant males. Support for the idea increases with the increase in the level of education. When examining age groups, it appears that the young are enthusiastic about the idea, while this decreases with age.

The desire to participate increases with the increase in the level of income. This is directly linked to citizenship and level of education, since Qataris and high levels of education are concentrated in the groups with middle and high income.

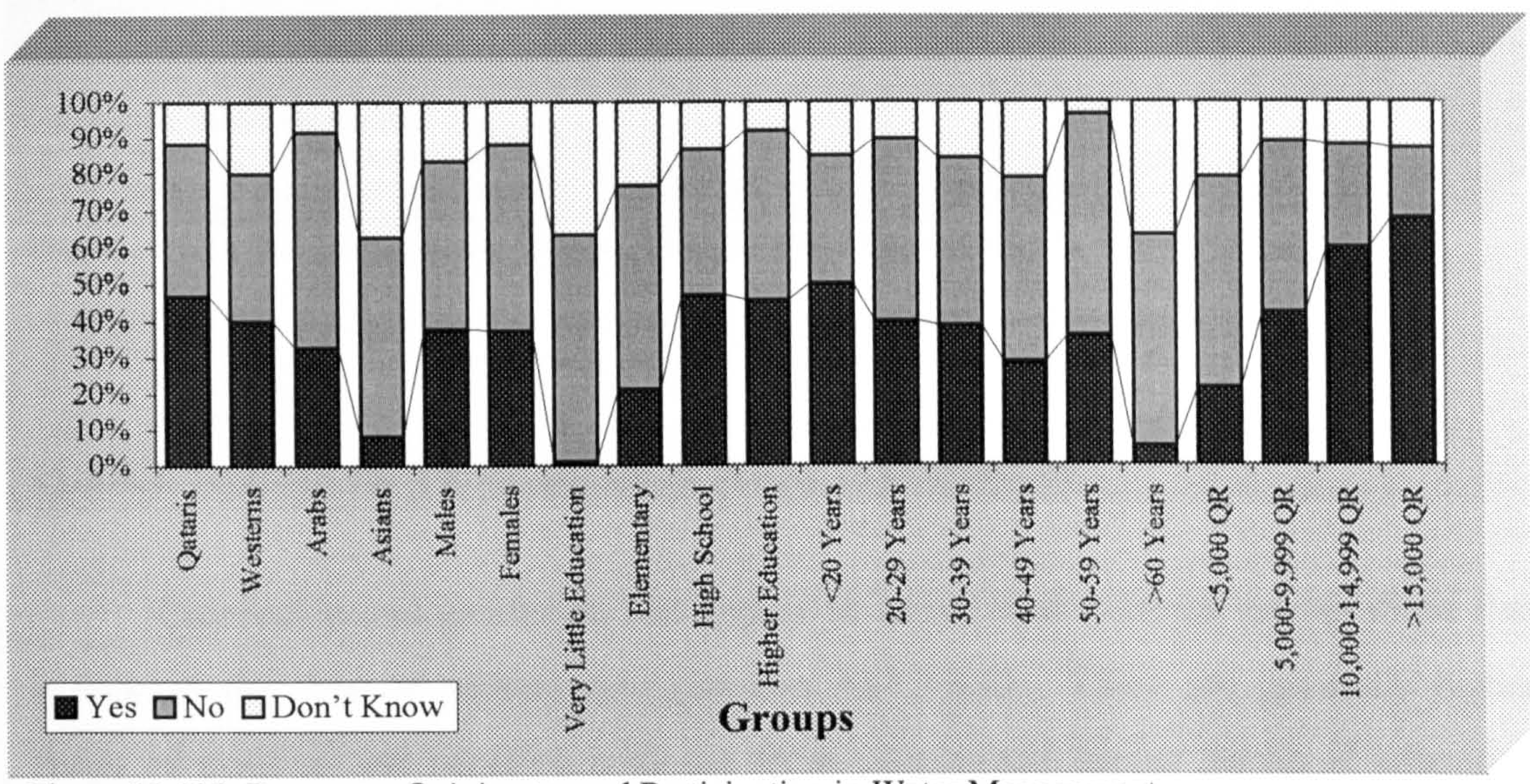

Figure 11.129. Responses Opinion toward Participation in Water Management.

Concerning the type of employment, it is noticeable that those employed in the governmental sector (e.g. teachers, students, officials and policemen) tend to be more supportive of participation, since the majority are Qataris (Figure 11.130). Those in technical positions - usually in the mixed sector - also tend to support the idea. The majority of these are either Westerners or Qataris. Those in the private sector tend to oppose the idea of participation, however. The majority of these are Asians and some Arabs. Thus, one can see the influence of citizenship on the attitude of people in the various types of employment. Those that work in the public sector or the joint sector often work fewer hours than those in the private sector, and hence have more time, with which they could support participation.

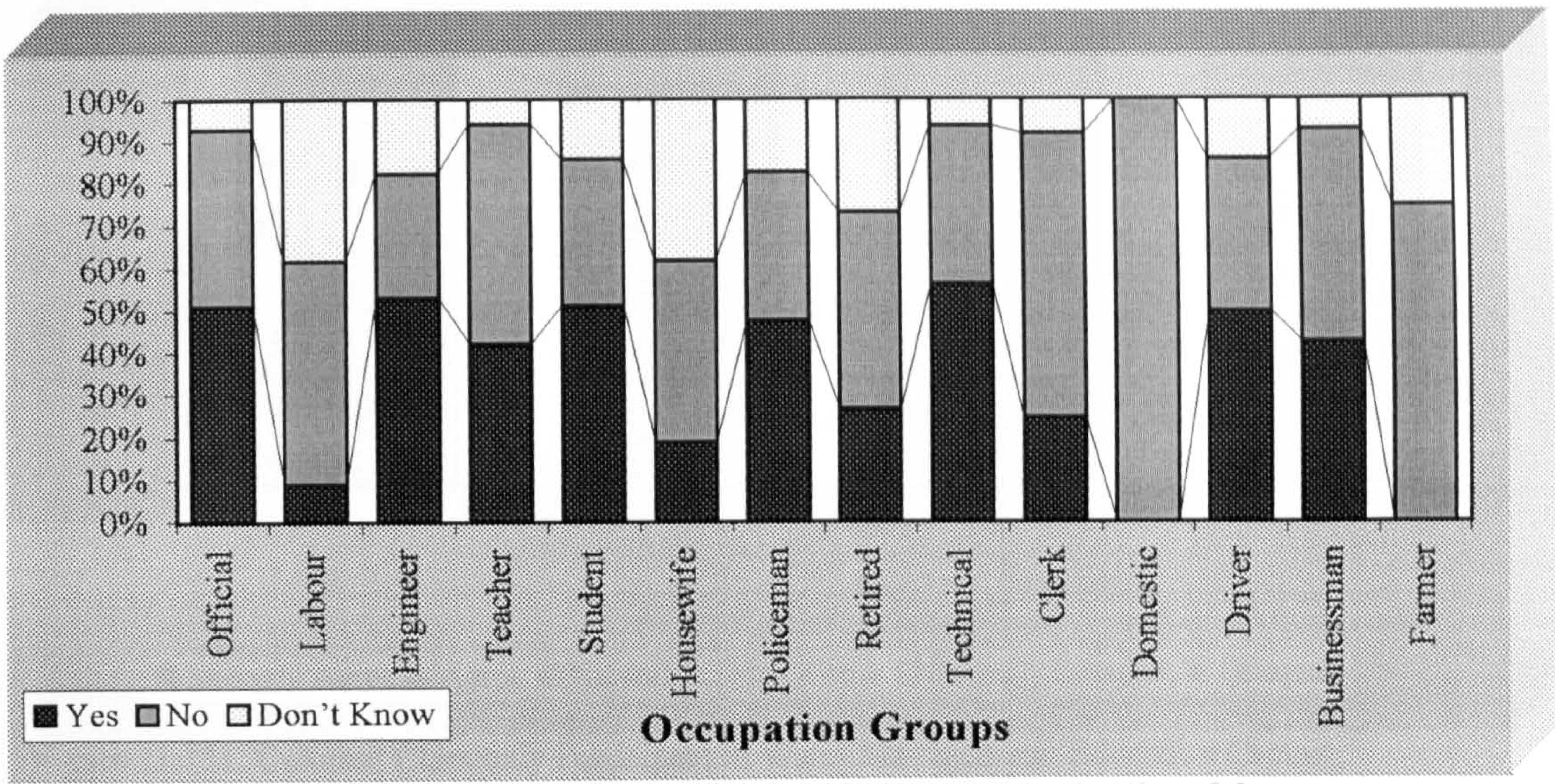

Figure 11.130. The Occupational Groups Attitude toward Participation in Water Management.

11.2.8.2. Reasons for Participation in Water Management:

Citizenship and gender do not appear to cause clear patterns among those that supported the idea of participation (Section A14.3.8.2). There are generally higher levels of positive and negative response from people with higher levels of education probably because the less educated are likely to be immigrant labourers. People whose education finished at high school are most likely to insist that only the cultured class should participate in water management. Major motivations for the well-educated are to improve water services, raise water awareness, equitability and improving water administration (Figures 11.131, 11.132, 11.133 and 11.134).

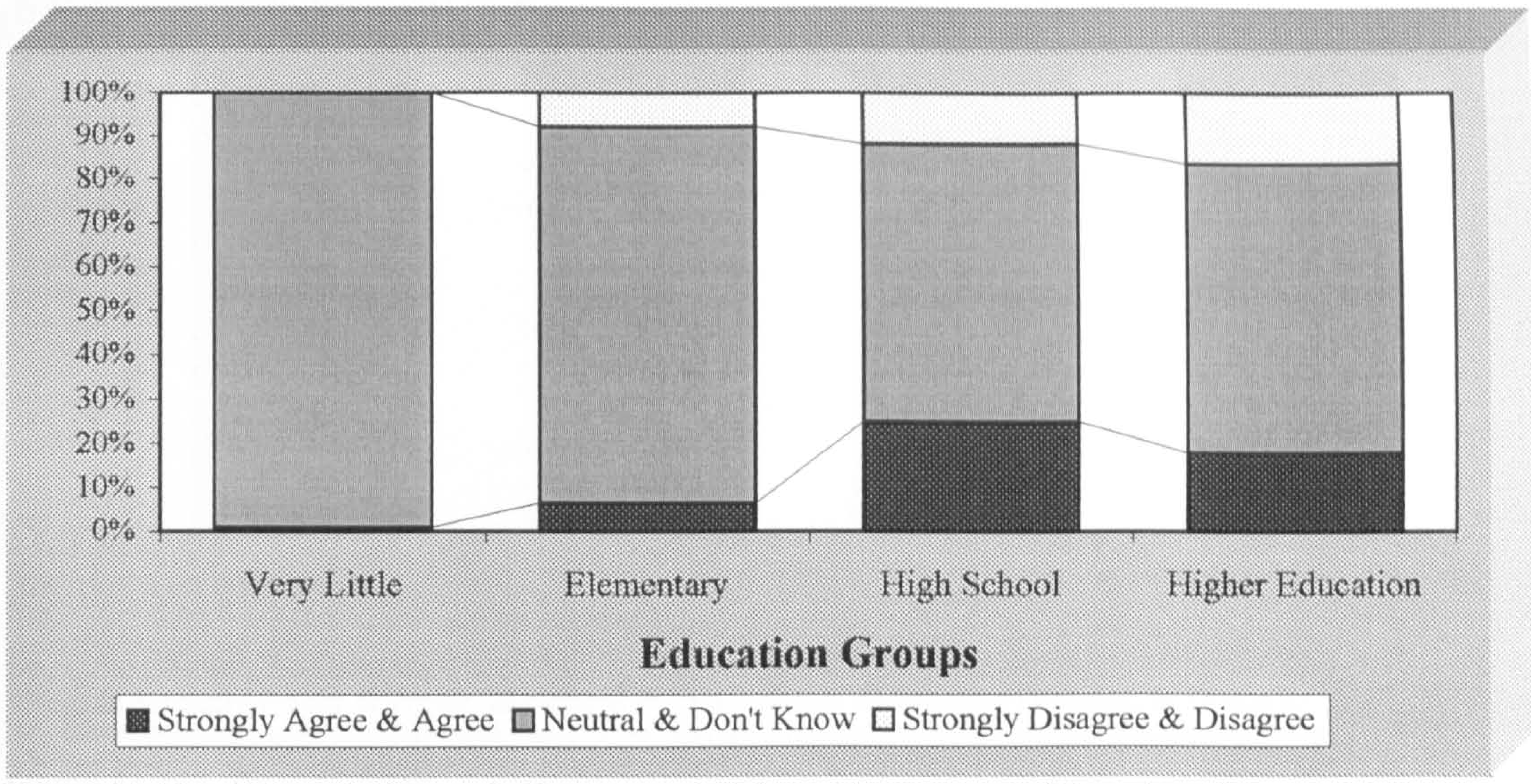

Figure 11.131. Cultured Class only Participate in Water Management: Education Groups.

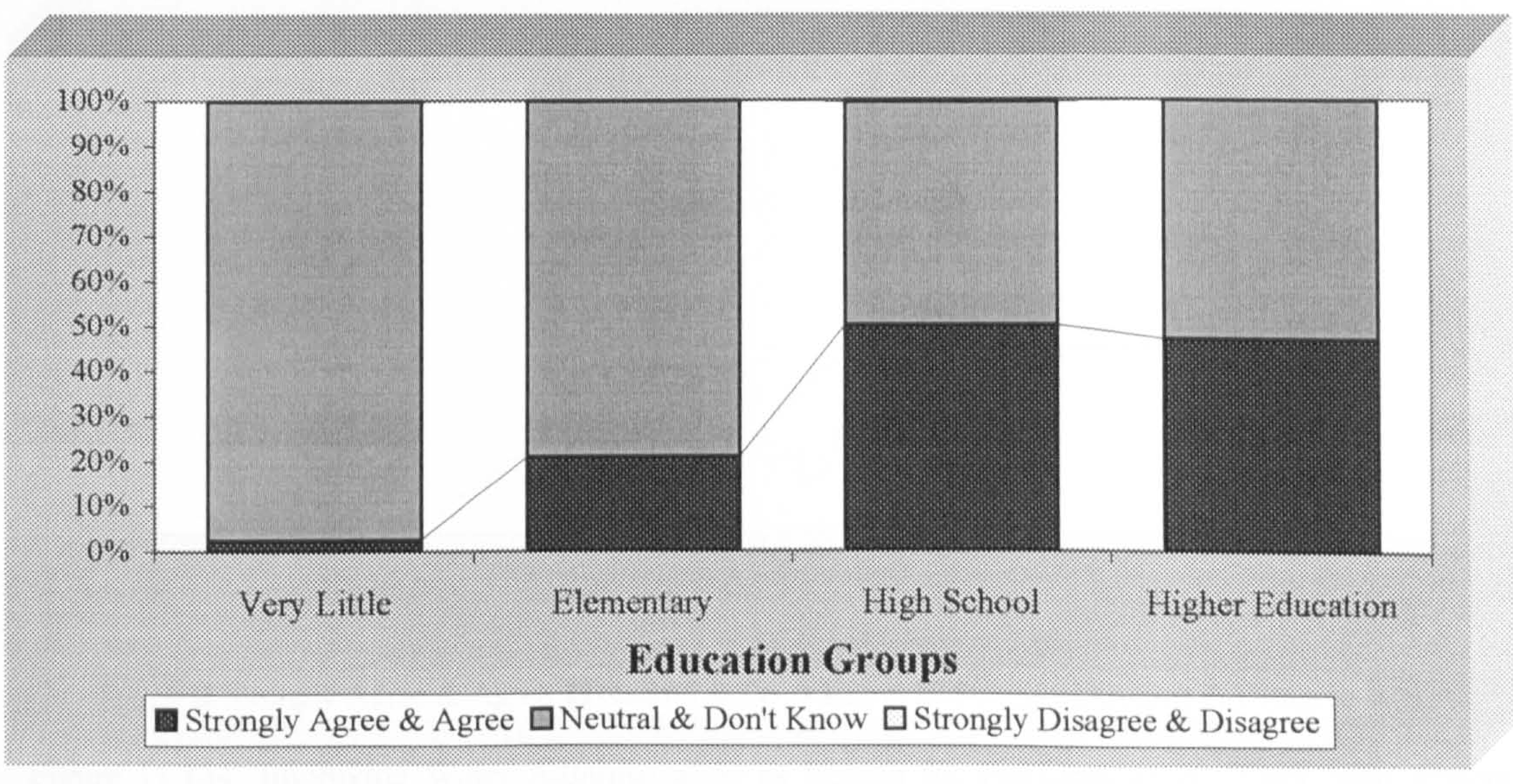

Figure 11.132. Improving Water Services as Reason for Participation in Water Management: Education Groups.

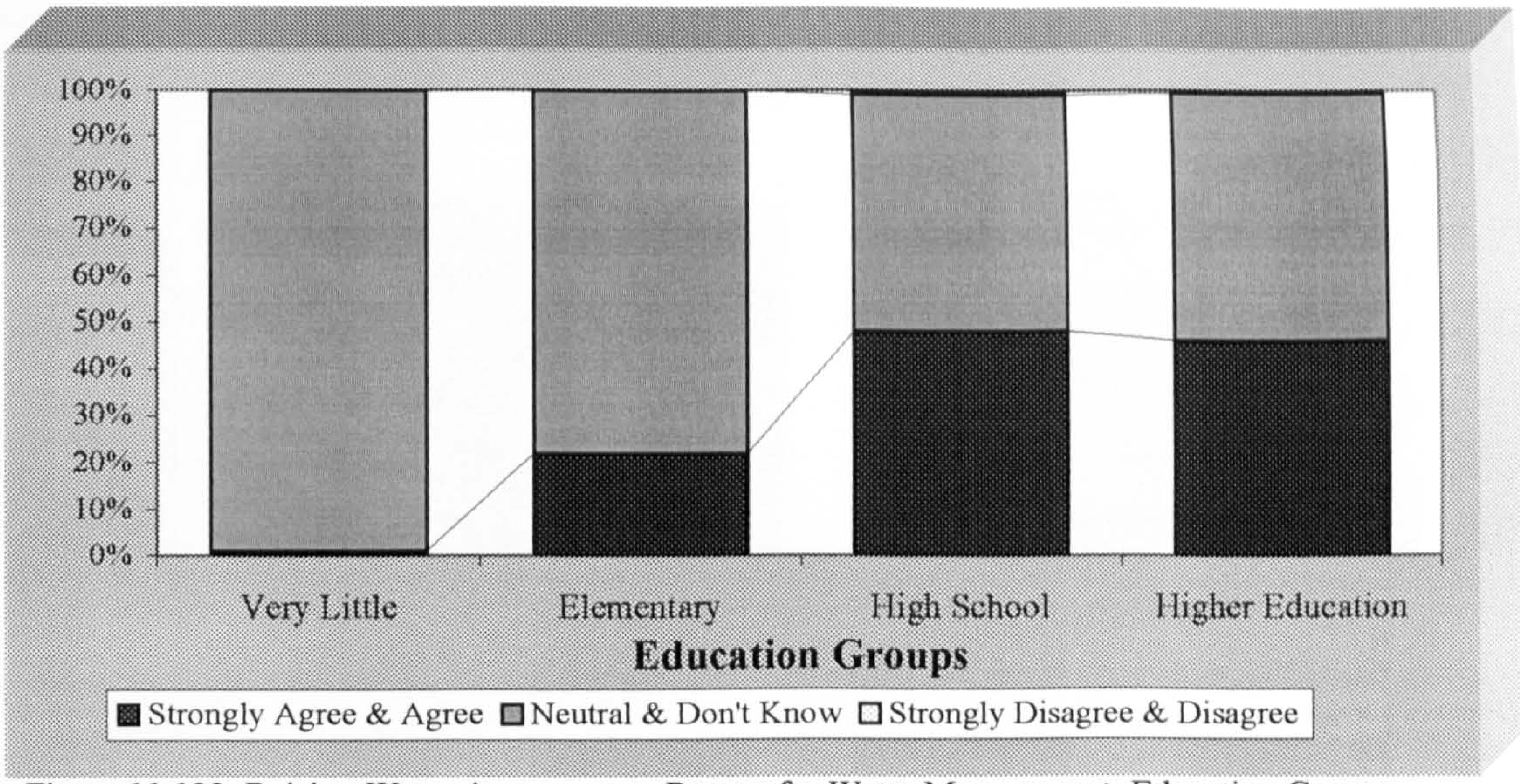

Figure 11.133. Raising Water Awareness as Reason for Water Management: Education Groups.

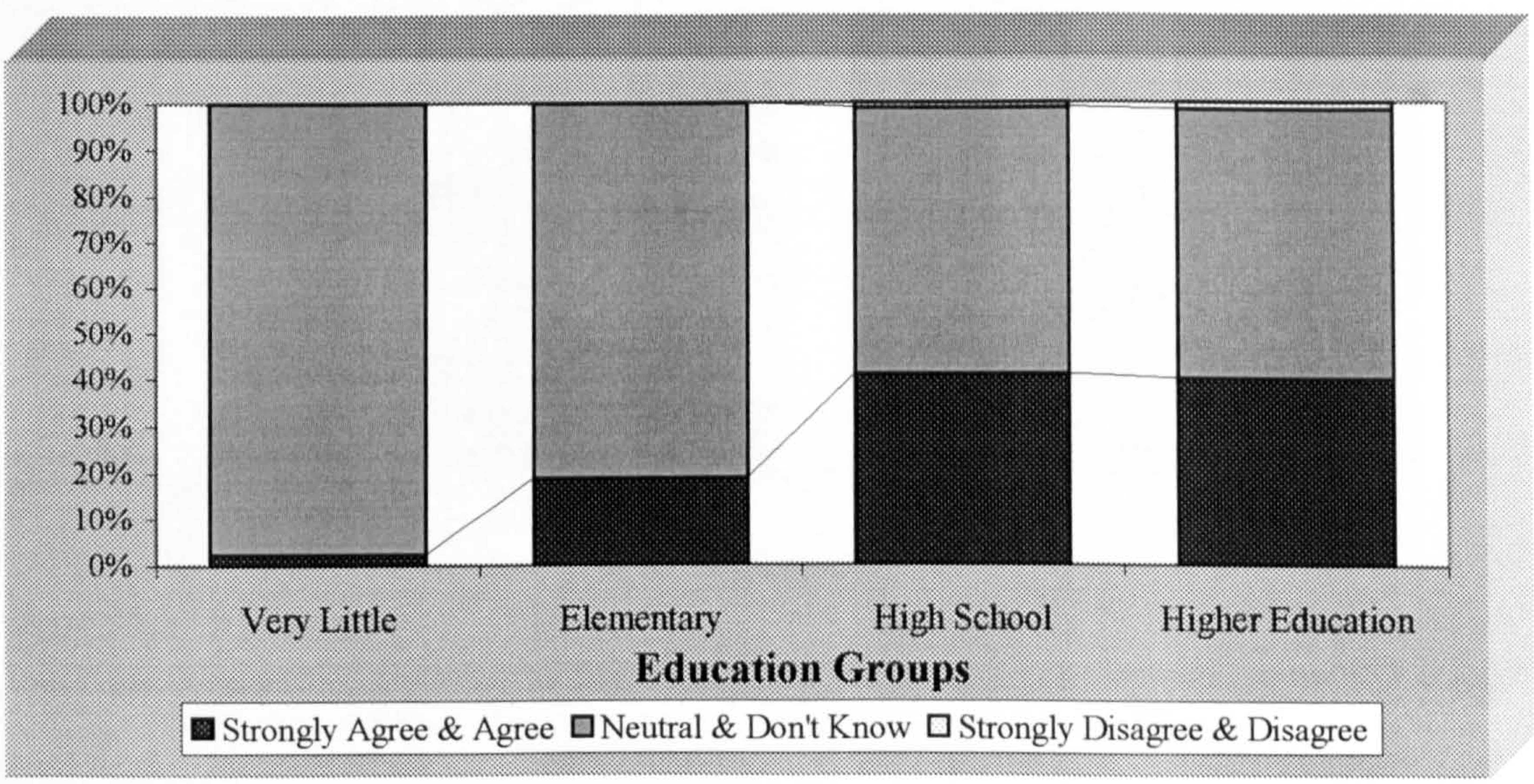

Figure 11.134. Improving Water Administration as Reason for Participation in Water Management: Education Groups.

For age, it is noticeable that decreased importance of factors such as curiosity and reserving participation to the educated occur with increasing age, while the other factors remain strong (Figures 11.135 and 11.136). On the other hand, there are no clear patterns among income and occupation groups (Section A14.3.8.2).

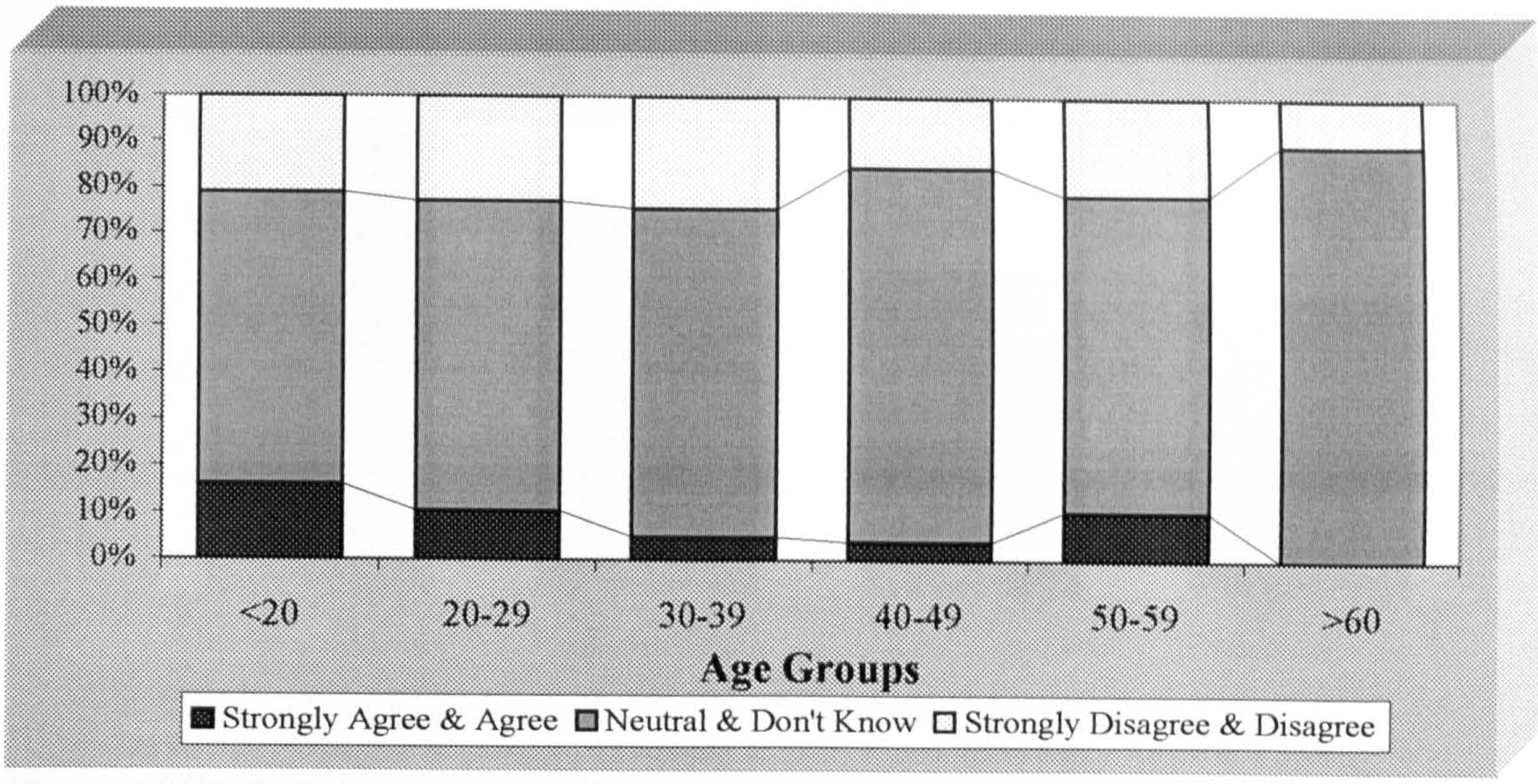

Figure 11.135. Curiosity as Reason for Participation in Water Management: Age Groups.

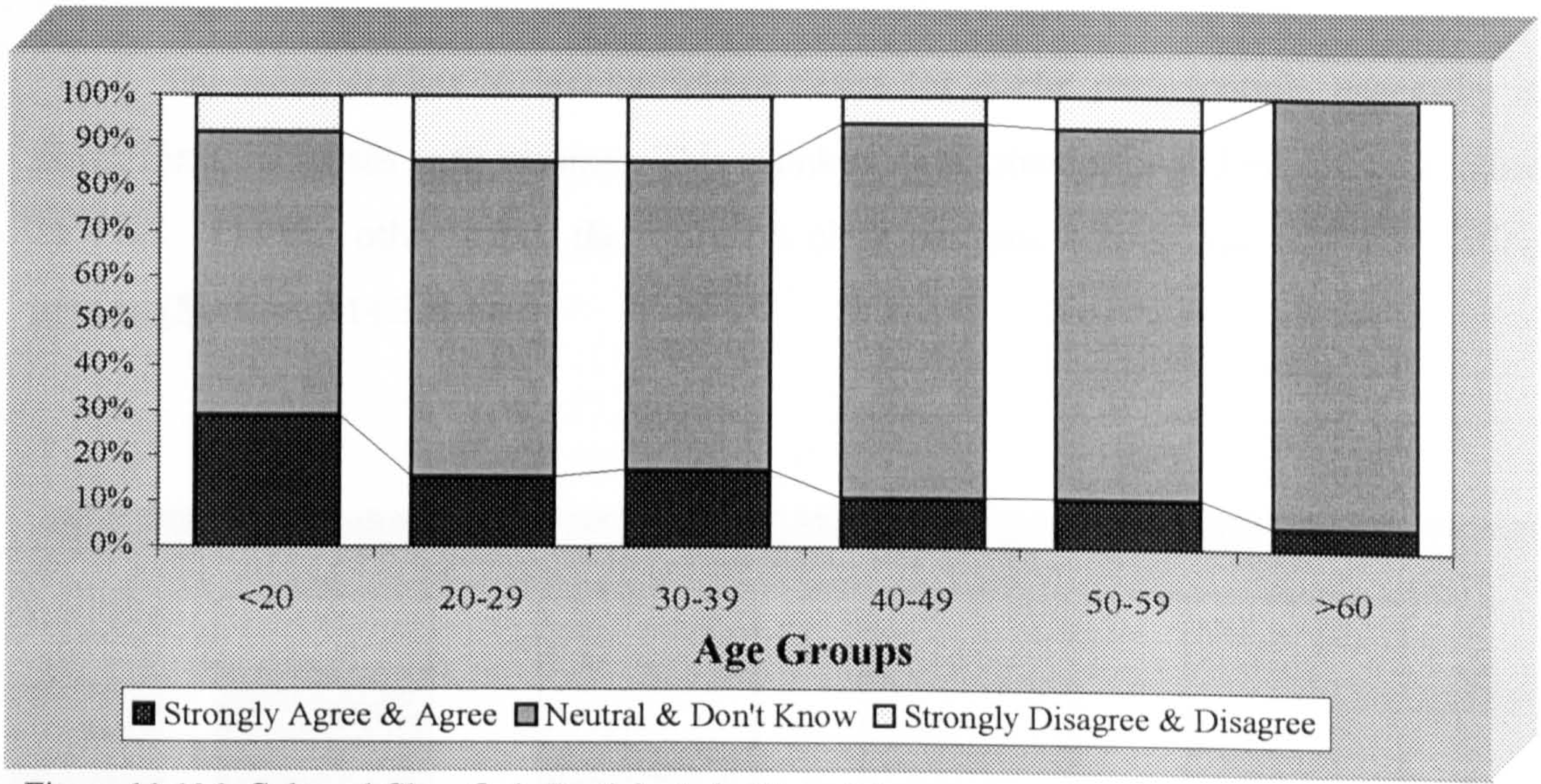

Figure 11.136. Cultured Class Only Participate in Water Management: Age Groups.

11.2.8.3. The Form of Participation in Water Management:

There is no clear pattern concerning the shape wanted for public participation in relation to factors of citizenship and gender (Section A14.3.8.3). The higher the education, the stronger is the support for participation (Figure 137).

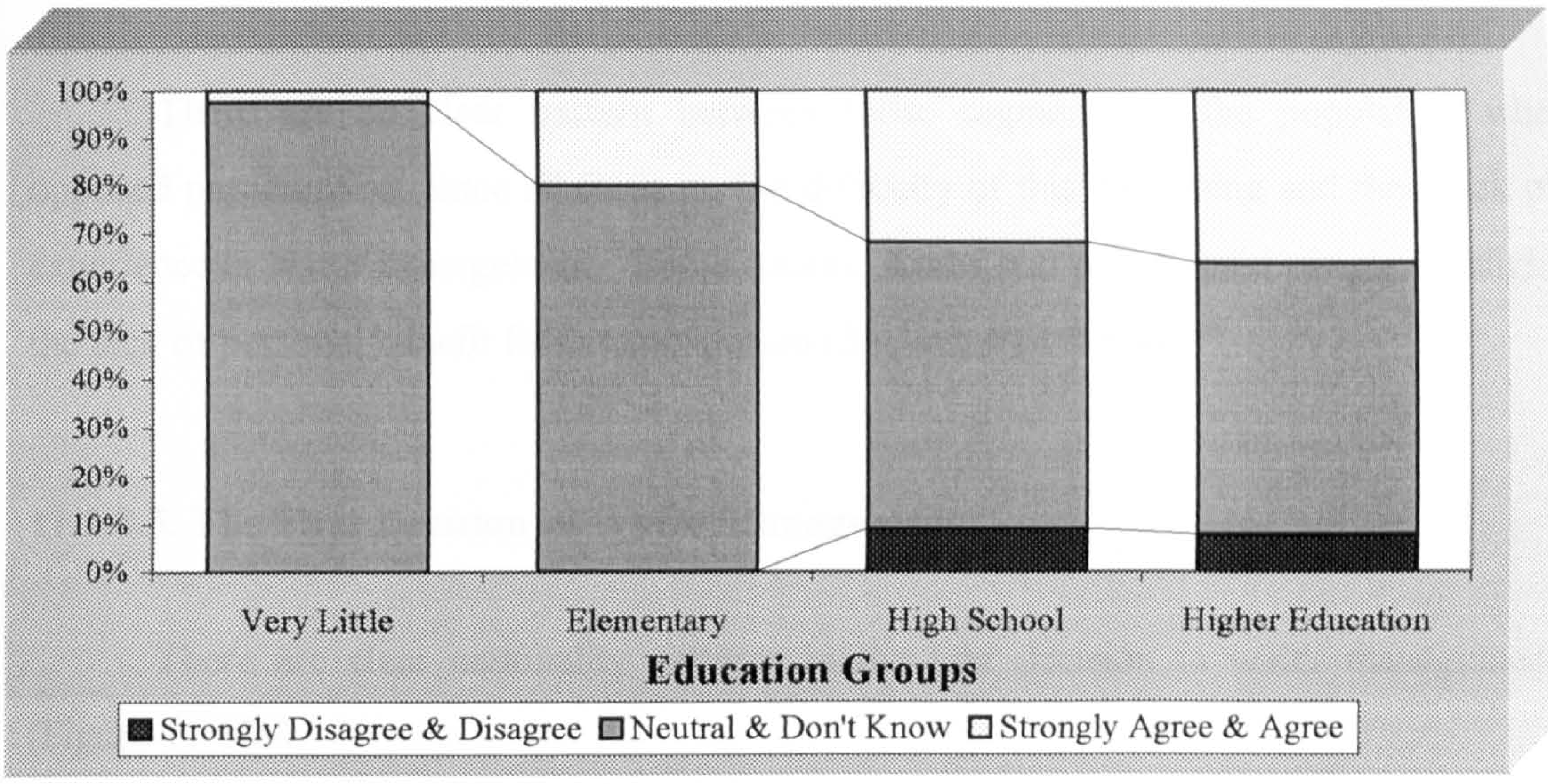

Figure 11.137. Importance of Desired Forms of Public Participation in Water Management: Education Groups.

The same applies to income where desire for public participation, especially in direct form, increases with income. This is linked with citizenship and education (Figure 11.138). On the other hand, there are no clear patterns among age and occupation groups (Section A14.3.8.3).

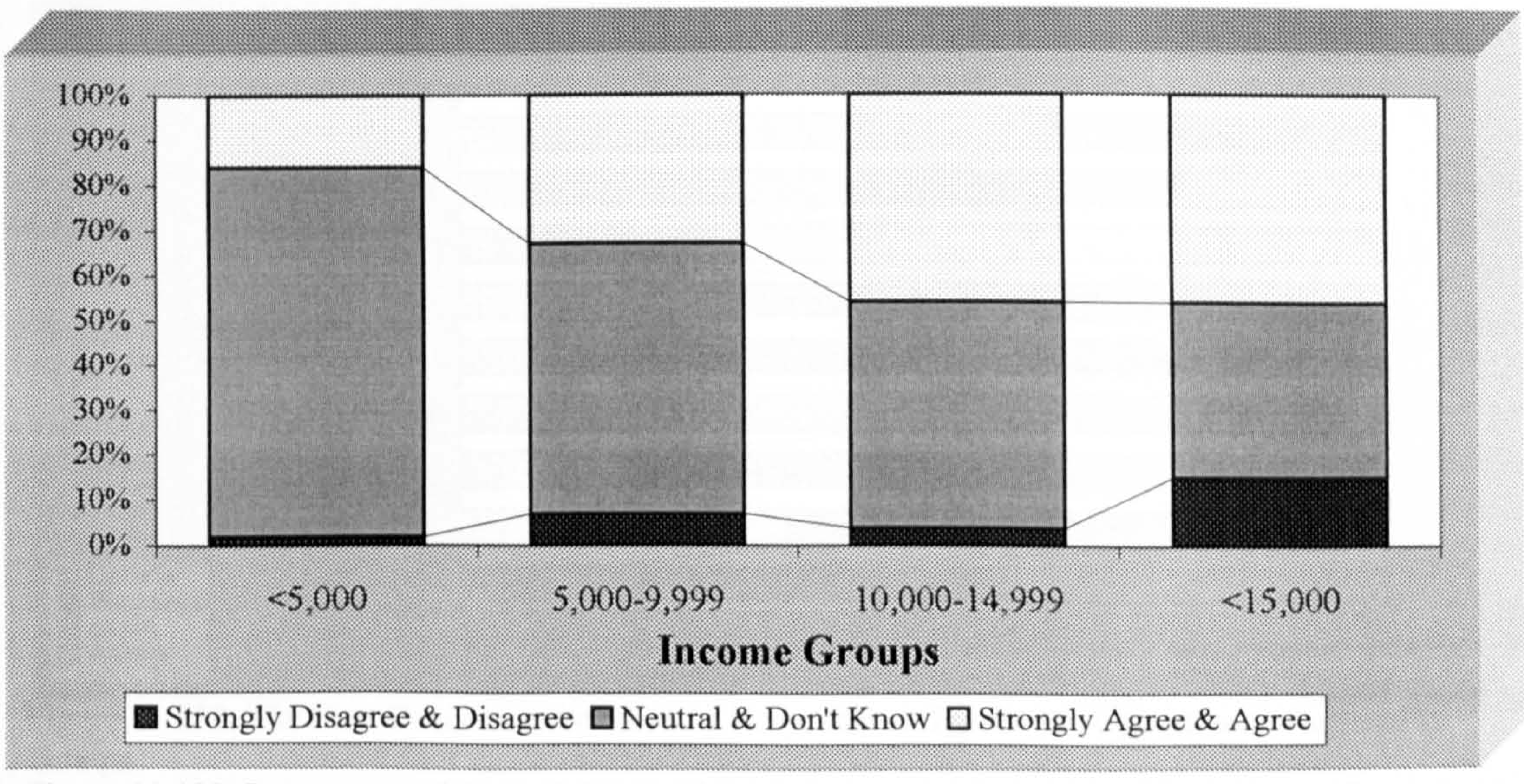

Figure 11.138. Importance of Desired Forms of Public Participation in Water Management: Income Groups (QR).

11.2.8.4. Reasons for Opposing Participation in Water Management:

There are no clear pattern between those segments of the population who opposed participation, since all focus on the difficulty of this happening and their lack of experience in water management. Some Asians, Arabs and poorly paid people highlight the lack of personal benefit from participation (Section A14.3.8.4).

11.2.8.5. The First Decision in Water Management:

There are clear nationality patterns in the first decision in water management (Figure 11.139).

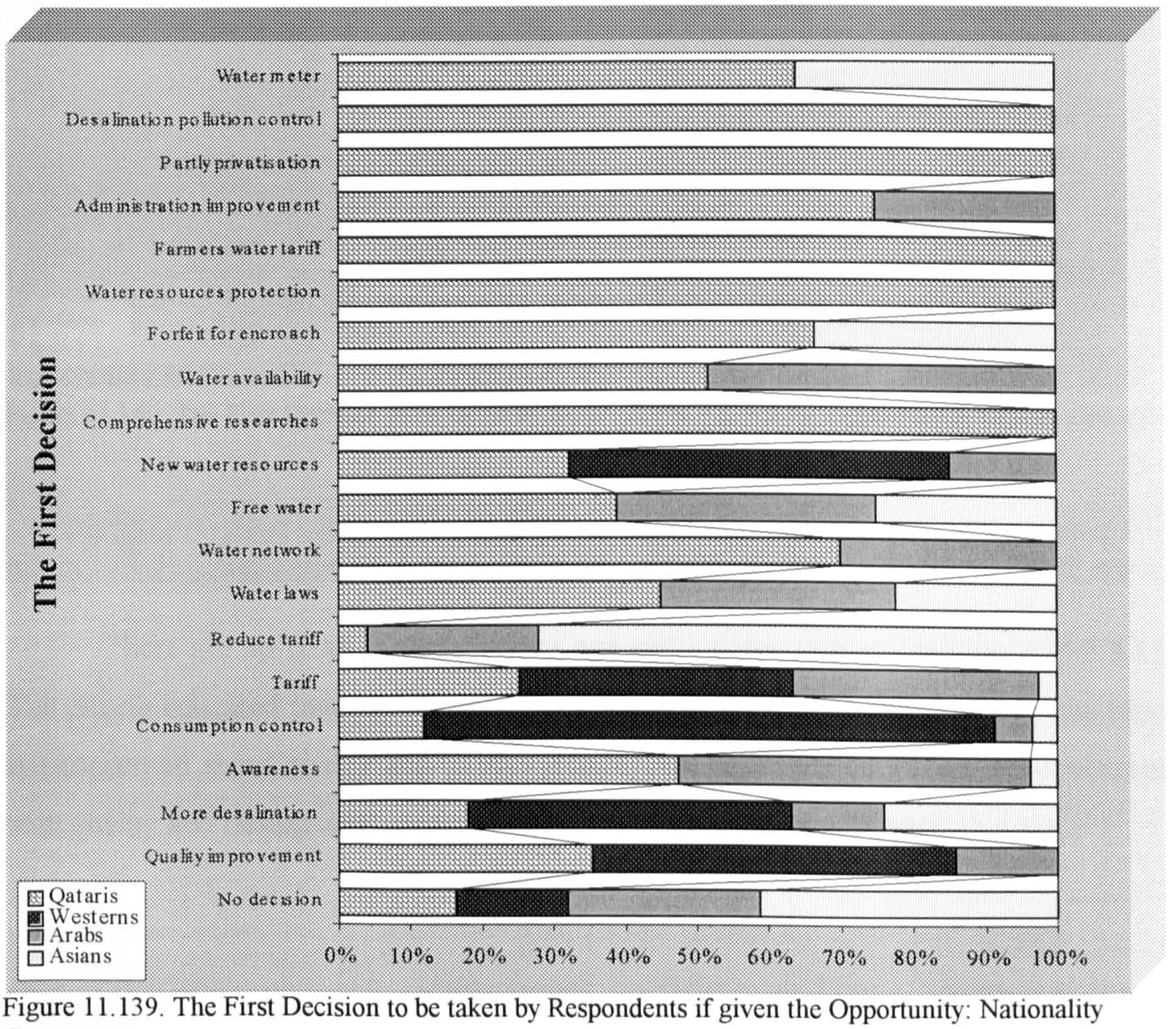

Figure 11.139. The First Decision to be taken by Respondents if given the Opportunity: Nationality Groups.

Similarly, there are strong gender influences to the same question (Figure 11.140).

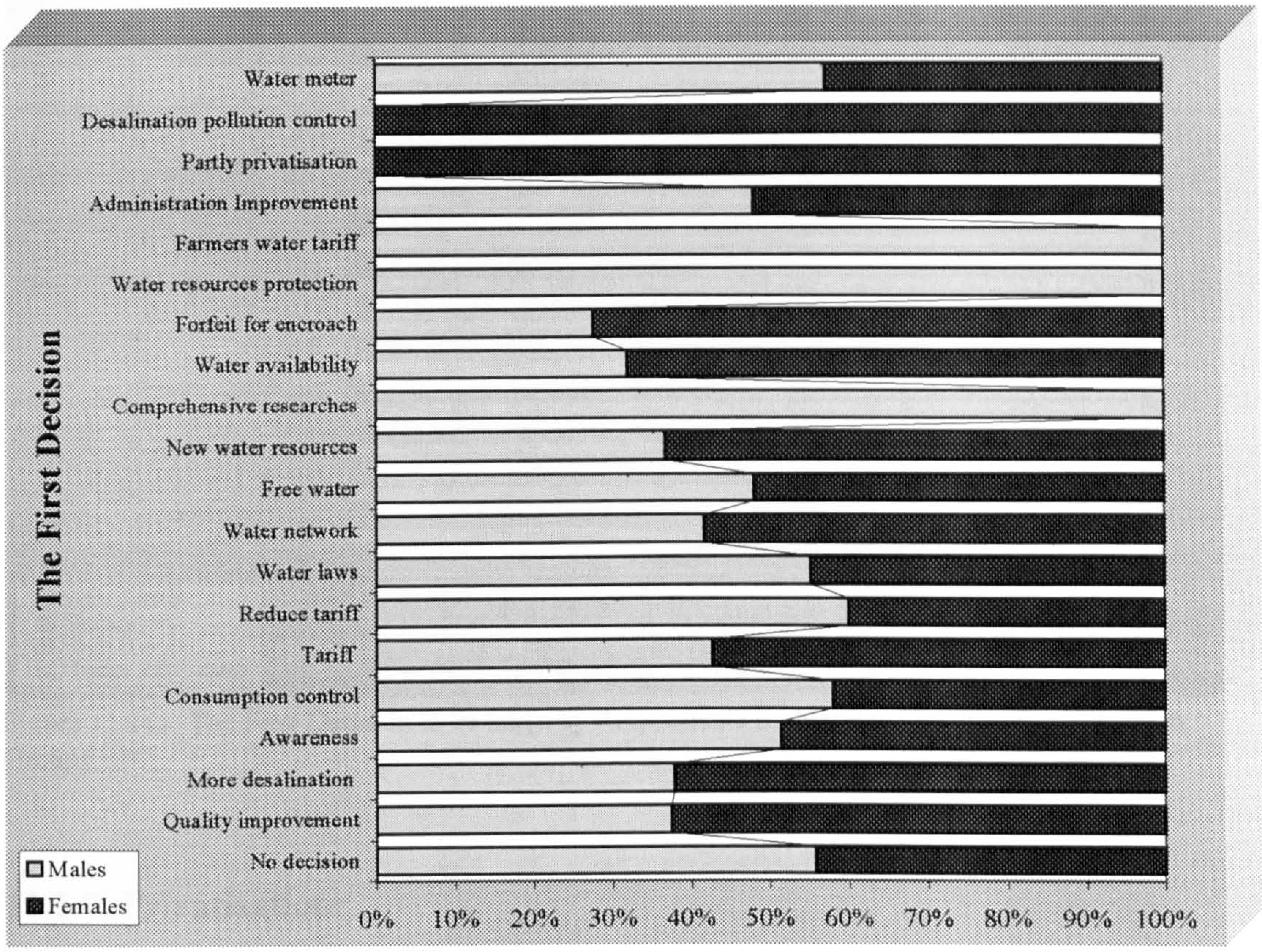

Figure 11.140. The First Decision to be taken by Respondents if given the Opportunity: Gender Groups.

There are no clear patterns among age and income groups (Section A14.3.8.5). The poorly educated tend not to express an opinion, those with middle level education are concerned about quality and tariffs. Those with high level education are concerned with quality and raising awareness to reduce water consumption (Figure 11.141).

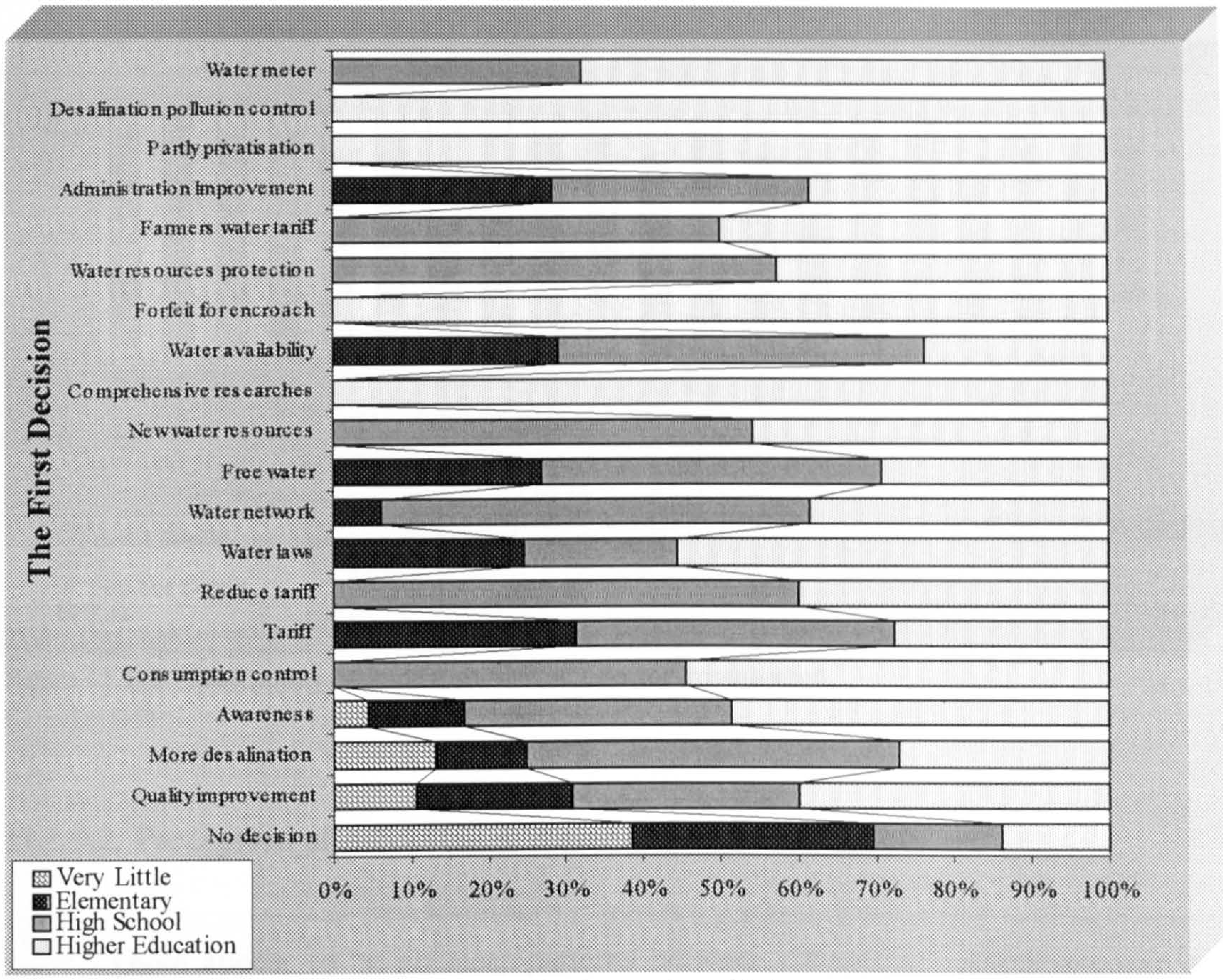

Figure 11.141. The First Decision to be taken by Respondents if given the Opportunity: Education Groups.

11.2.9. Privatisation:

11.2.9.1. Possibility of Water Sector Privatisation:

Concerning privatisation, Qataris (54.8%) and Arabs (46.5%) oppose the idea although some favour partial privatisation (21.5%) and (25.2%) (Figure 11.142). Westerners tend to support partial privatisation (46.7%). Many (54.4%) Asians have no position on the matter with some (23.6%) opposing it. The reasons for these positions will be discussed later (Section 11.2.9.3).

While there is slight difference among gender groups, the higher the education level the greater is the opposition to privatisation, though some accept partial privatisation. Education clearly enables understanding of disadvantages associated with privatisation and makes available knowledge of deleterious effects. There is a decline in popularity of the idea among older people. There is a clear relationship between income and support for privatisation, since those with high income are not afraid of higher tariffs, which appear to be the dominant reason to oppose privatisation.

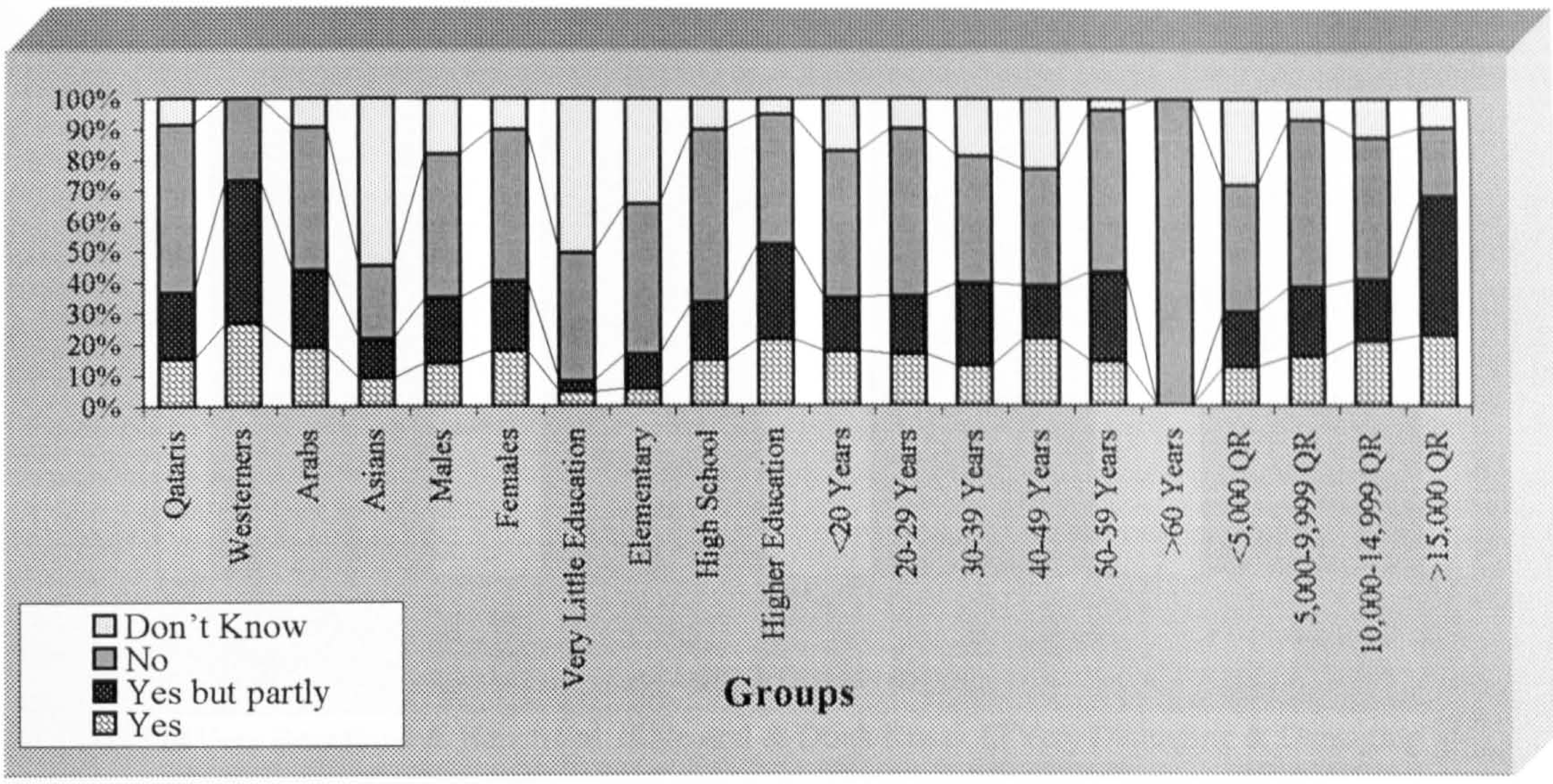

Figure 11.142. The Groups Attitude toward Water Sector Privatisation.

11.2.9.2. Perception of Advantages Water Sector Privatisation:

There appear to be no clear patterns between citizenship, gender and age and perception of the advantages of privatisation (Section A14.3.9.2). The more highly educated and the better paid are more likely to perceive all the benefits of privatisation and are less hesitant in giving a firm opinion (Figures 11.143, 11.144, 11.145 and 11.146).

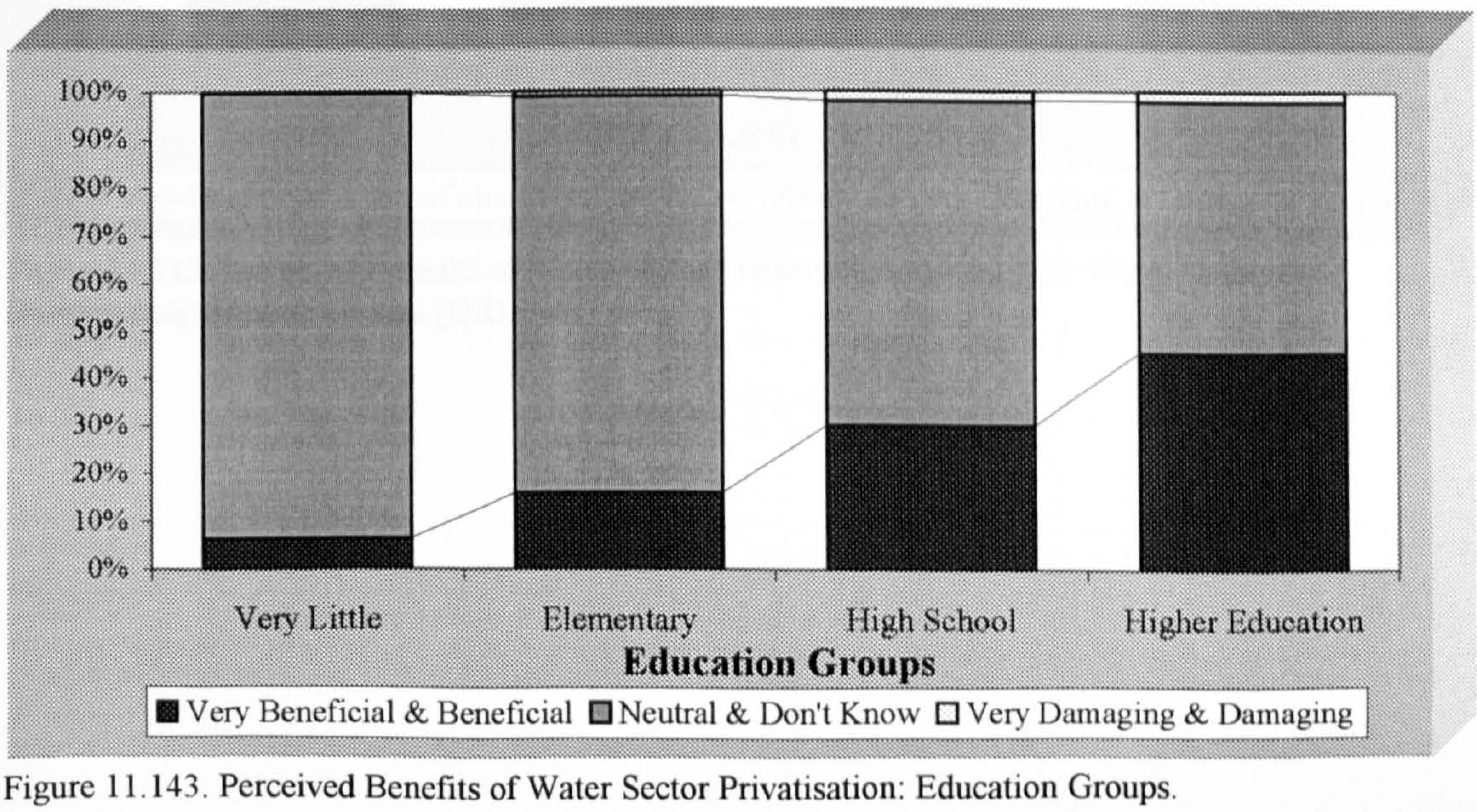

Figure 11.143. Perceived Benefits of Water Sector Privatisation: Education Groups.

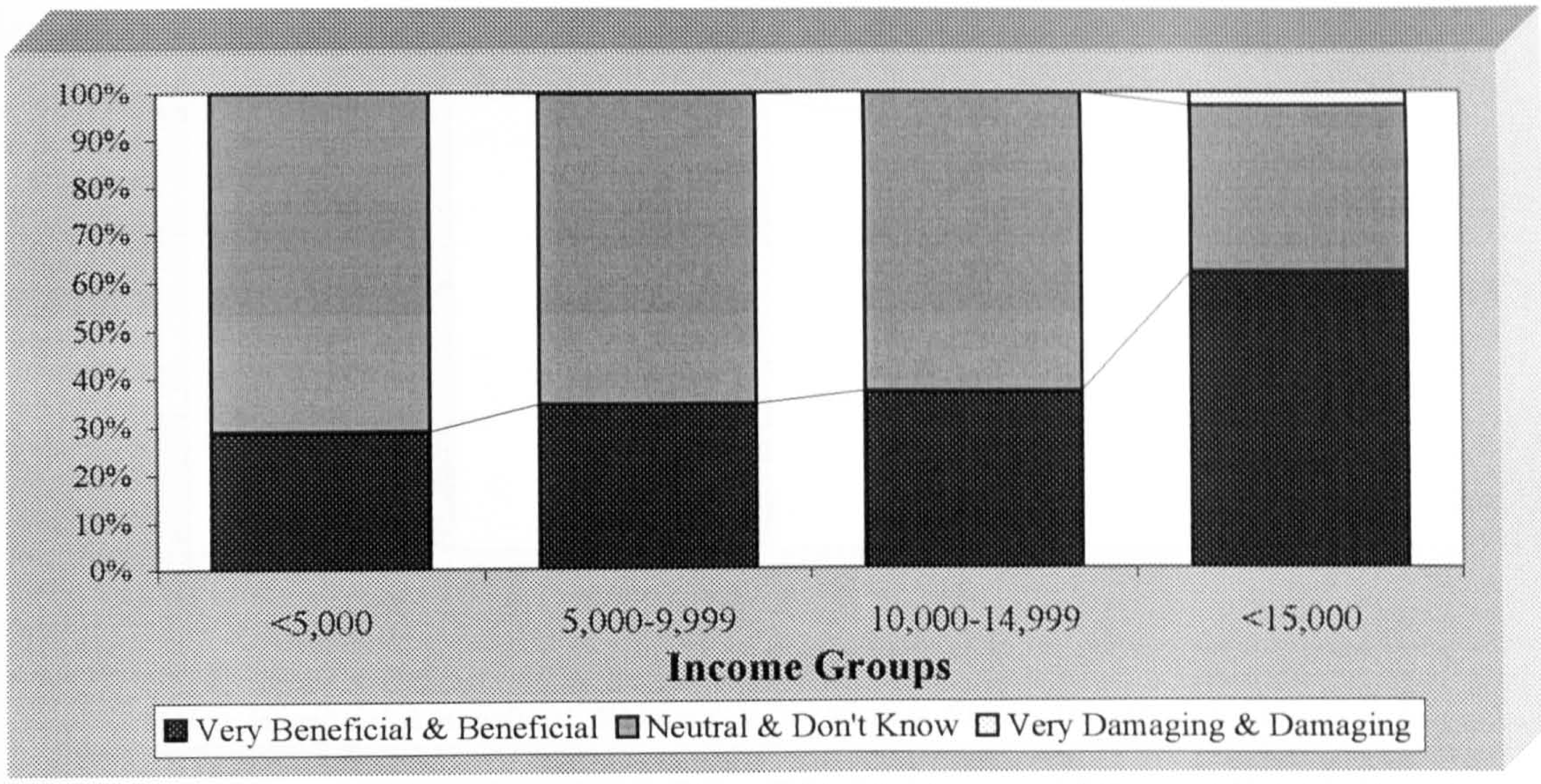

Figure 11.144. Perceived Benefits of Water Sector Privatisation toward Better Administration: Income Groups (QR).

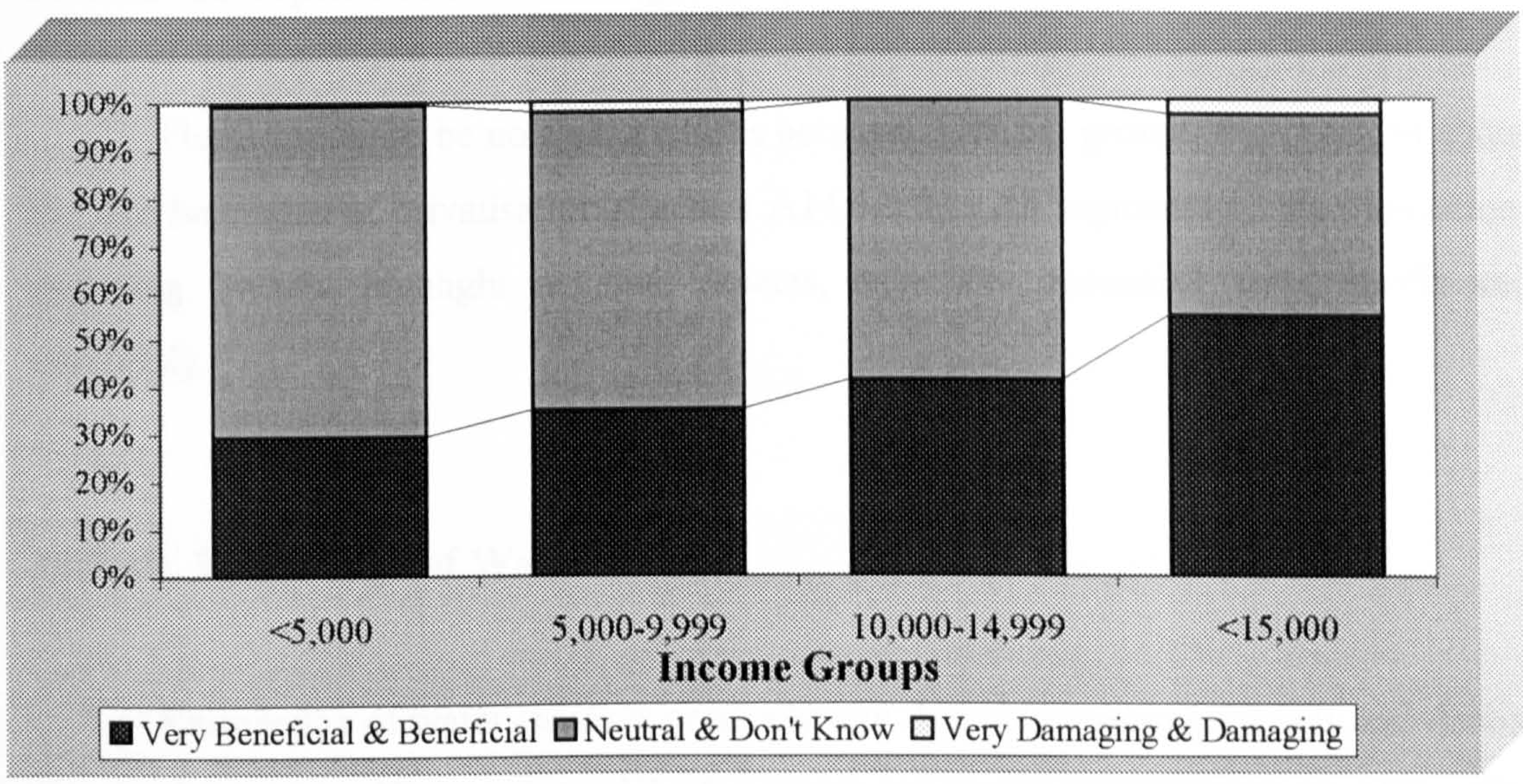

Figure 11.145. Perceived Benefits of Water Sector Privatisation toward New Water Resources Development: Income Groups (QR).

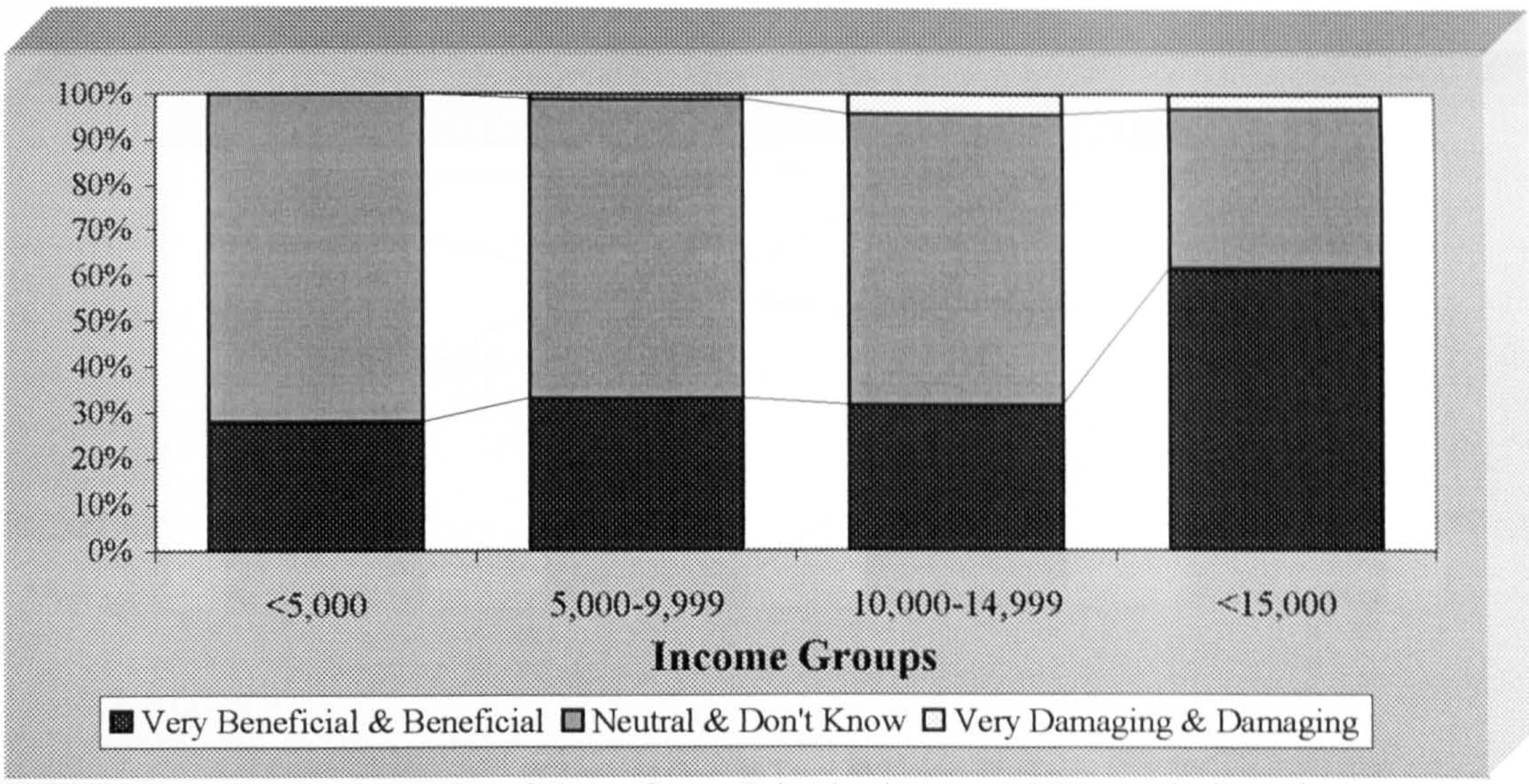

Figure 11.146. Perceived Benefits of Water Sector Privatisation toward Economic Growth: Income Groups (QR).

11.2.9.3. Perception of Disadvantages to Water Sector Privatisation:

There appear to be no clear patterns between different groups and opinions about the disadvantages of privatisation (Section A14.3.9.3). All segments of the population, including Qataris, highlight negative aspects, especially increasing water tariffs and monopoly.

11.2.10. Knowledge of Water Issues:

Knowledge of water issues is generally low, but better among Qataris and Arabs. It is unclear among Westerners, while Asians are mostly ignorant (Figure 11.147). The language factor plays a role in distancing the Asians and some Westerners from local issues, while concern among Qataris, Arabs and some Westerners is more prominent.

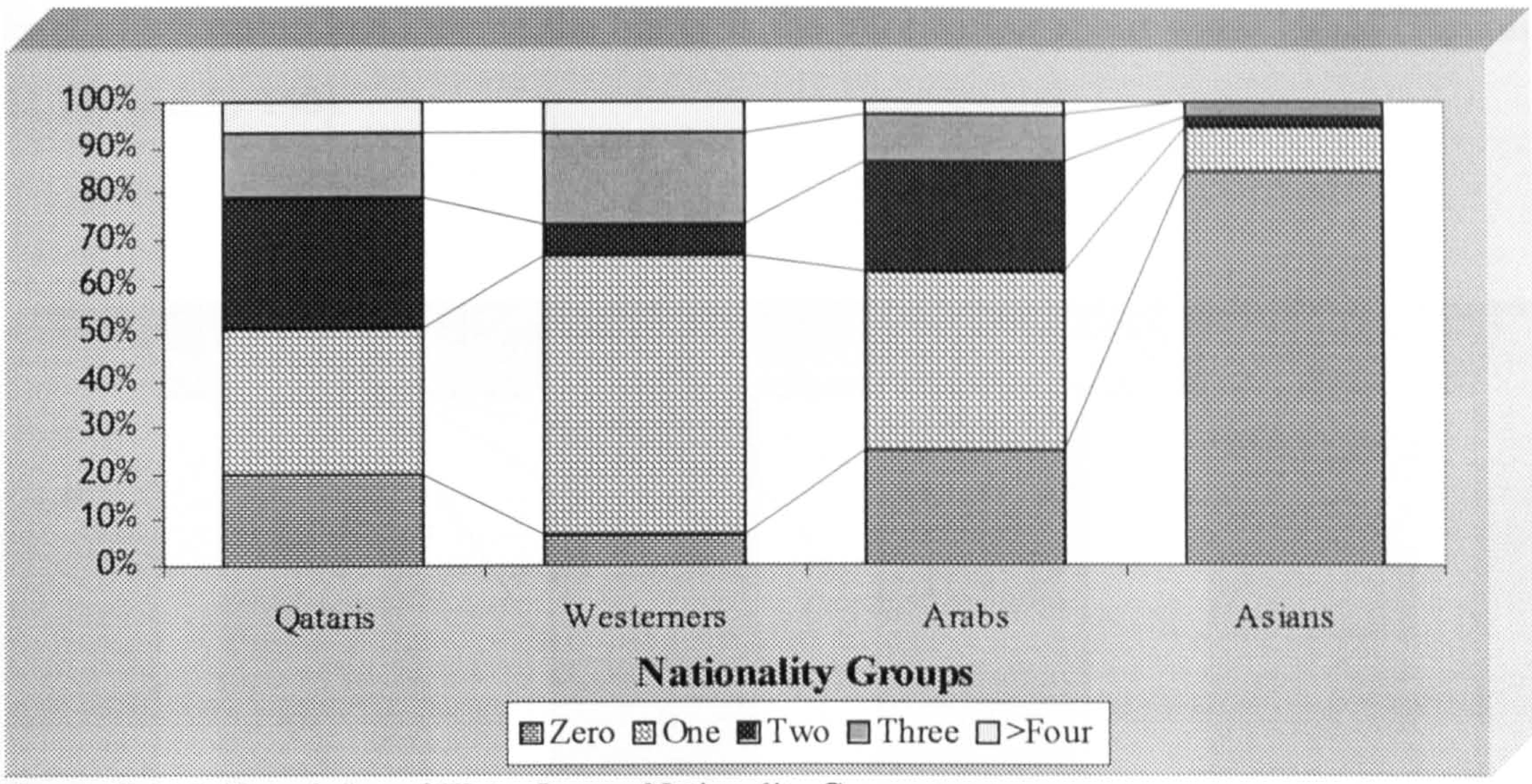

Figure 11.147. Knowledge of Water Issues: Nationality Groups.

Knowledge among females is better than among males. A large proportion of males are Asians, which influences the result (Figure 11.148). It is known in Qatari society, however, that usually females are keener on reading and general knowledge than males (for instance Gareeb, 1999).

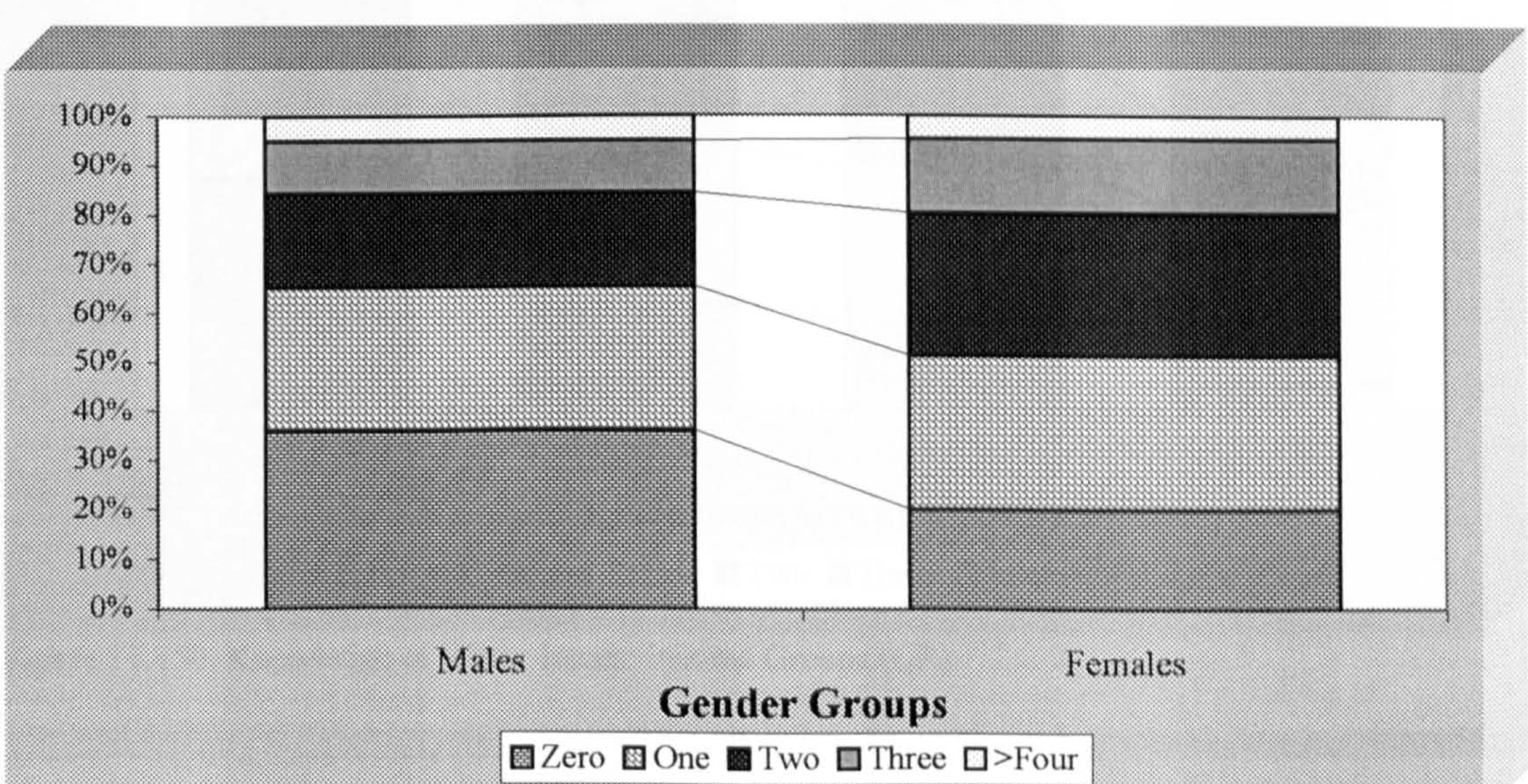

Figure 11.148. Knowledge of Water Issues: Gender Groups.

The difference between education and income groups is very clear: the higher the level of education and income the better is the information about water issues (Figures 11.149 and 11.150).

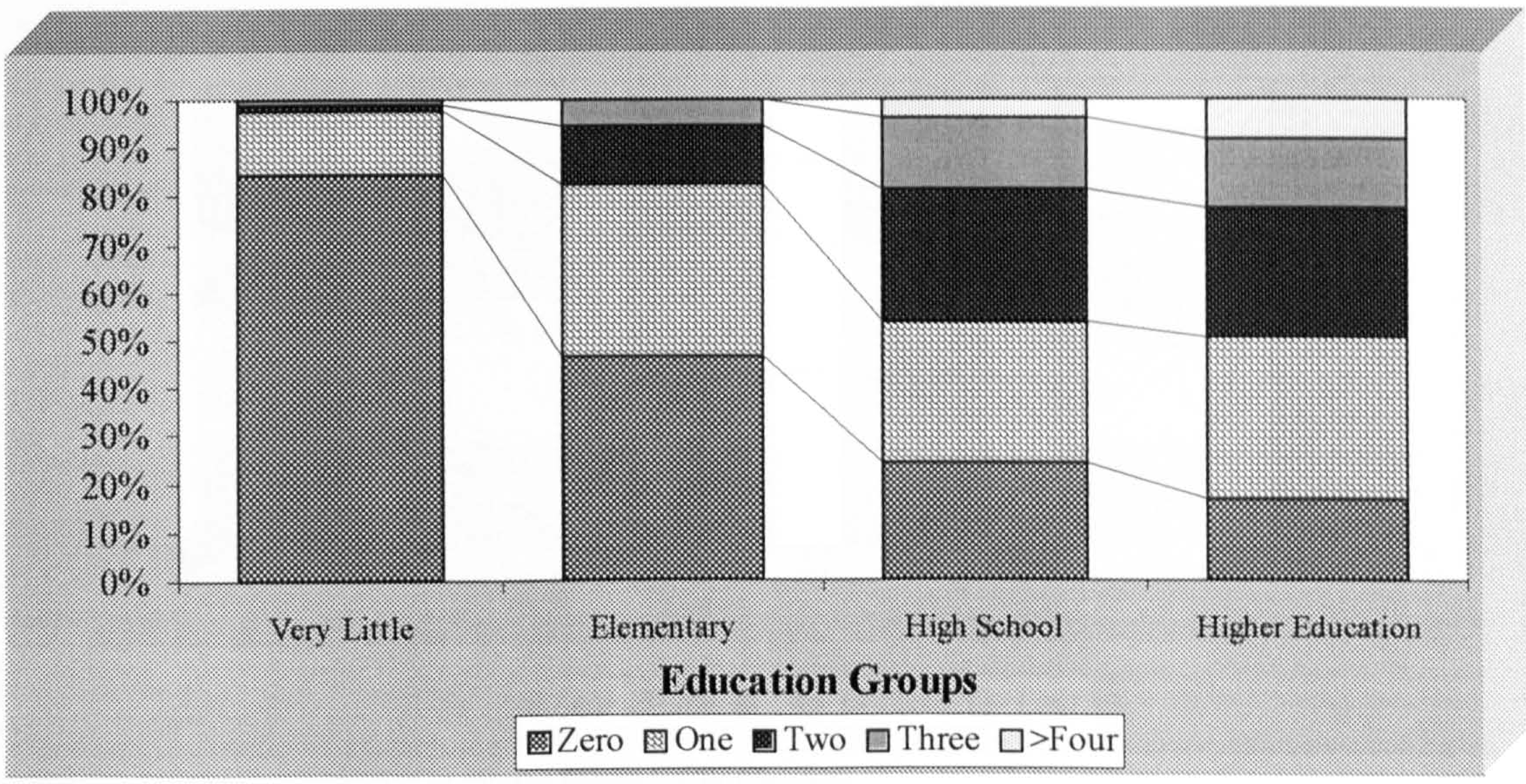

Figure 11.149. Knowledge of Water Issues: Education Groups.

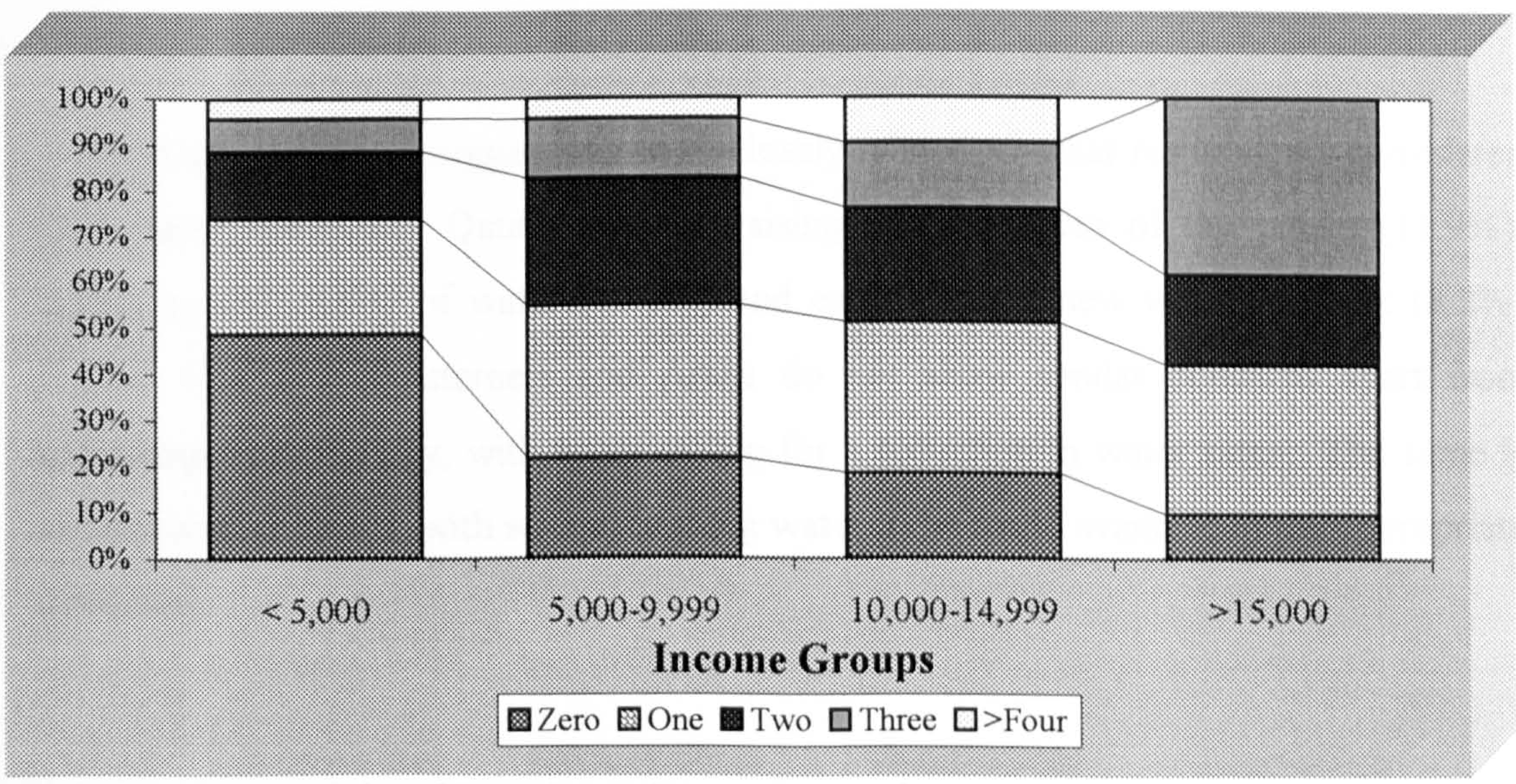

Figure 11.150. Knowledge of Water Issues: Income Groups (QR).

Knowledge is better among the young than the oldest. The lack of knowledge amongst the middle aged is due to large percentage of Asians in these groups (Figure 11.151).

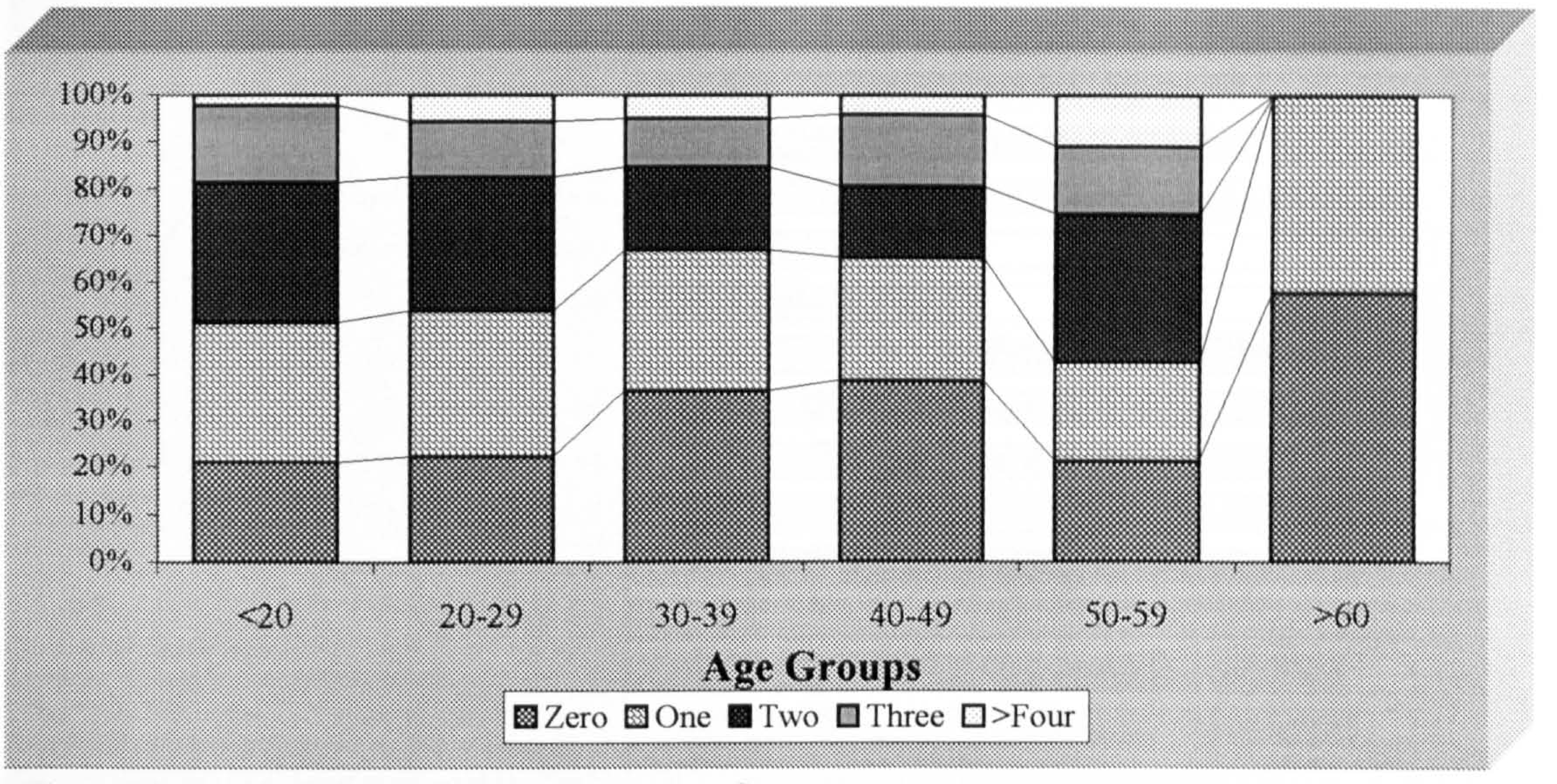

Figure 11.151. Knowledge of Water Issues: Age Groups.

11.2.11. Overall Comments:

Comments and suggestions were closely related to what respondents considered their major concerns. Qataris call for raising the awareness of the public (11.9%), improving the quality of water (10.5%) and establishing a new water network (8.2%) (Figure 11.152). Westerners and Arabs do not show similar concerns apart from improving water quality, with many calling for a reduction in water rates. The same is emphasised by Asians, with several wishing water to be made available in the appropriate quantities.

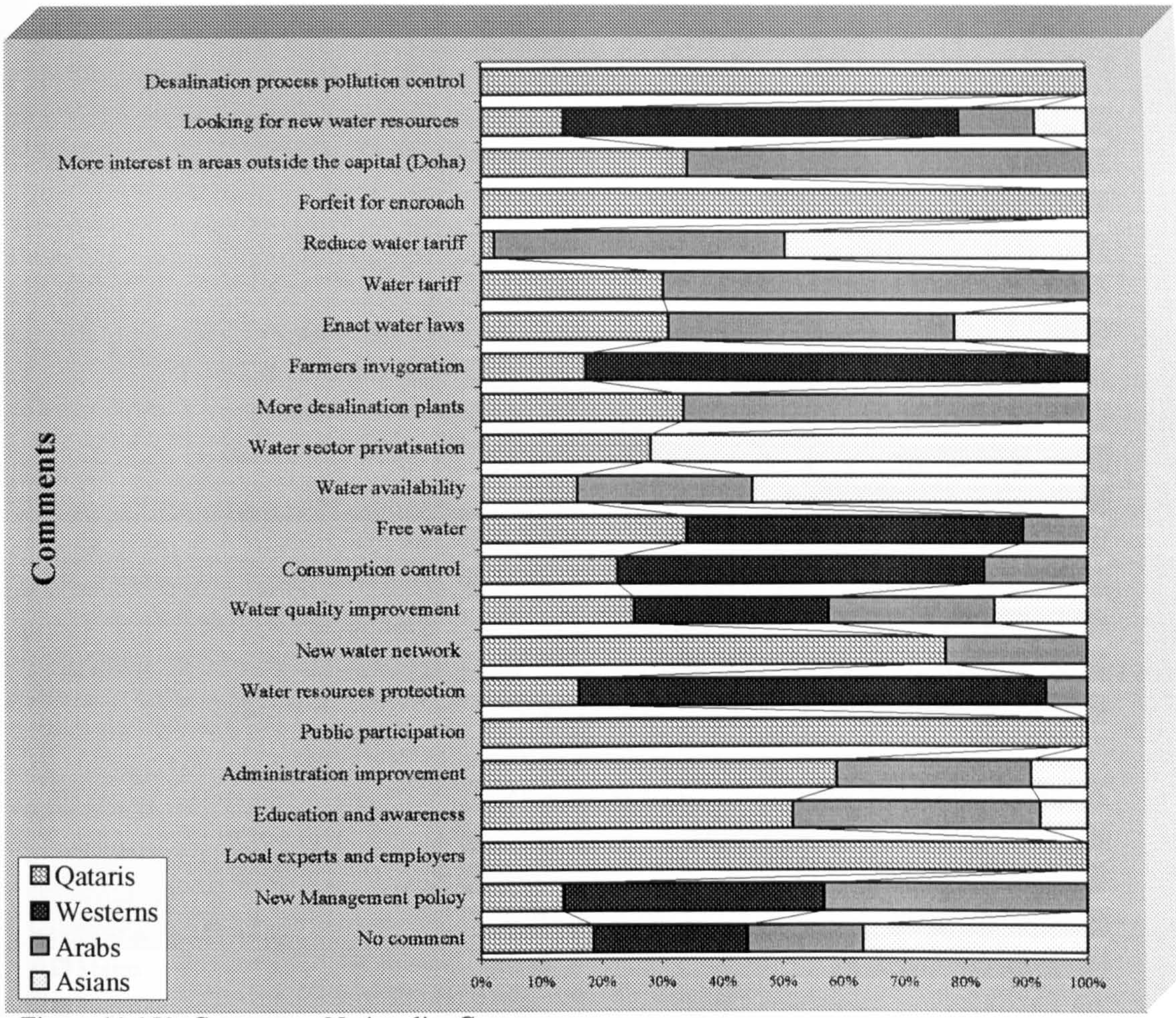

Figure 11.152. Comments: Nationality Groups.

Females are more likely to give opinions concerning water quality (15.3%) and awareness issues (13.6%) (Figure 11.153). Males also highlight these issues and some comments about reducing water rates (5.1%). This can be explained by the fact that a large proportion of males are foreign workers.

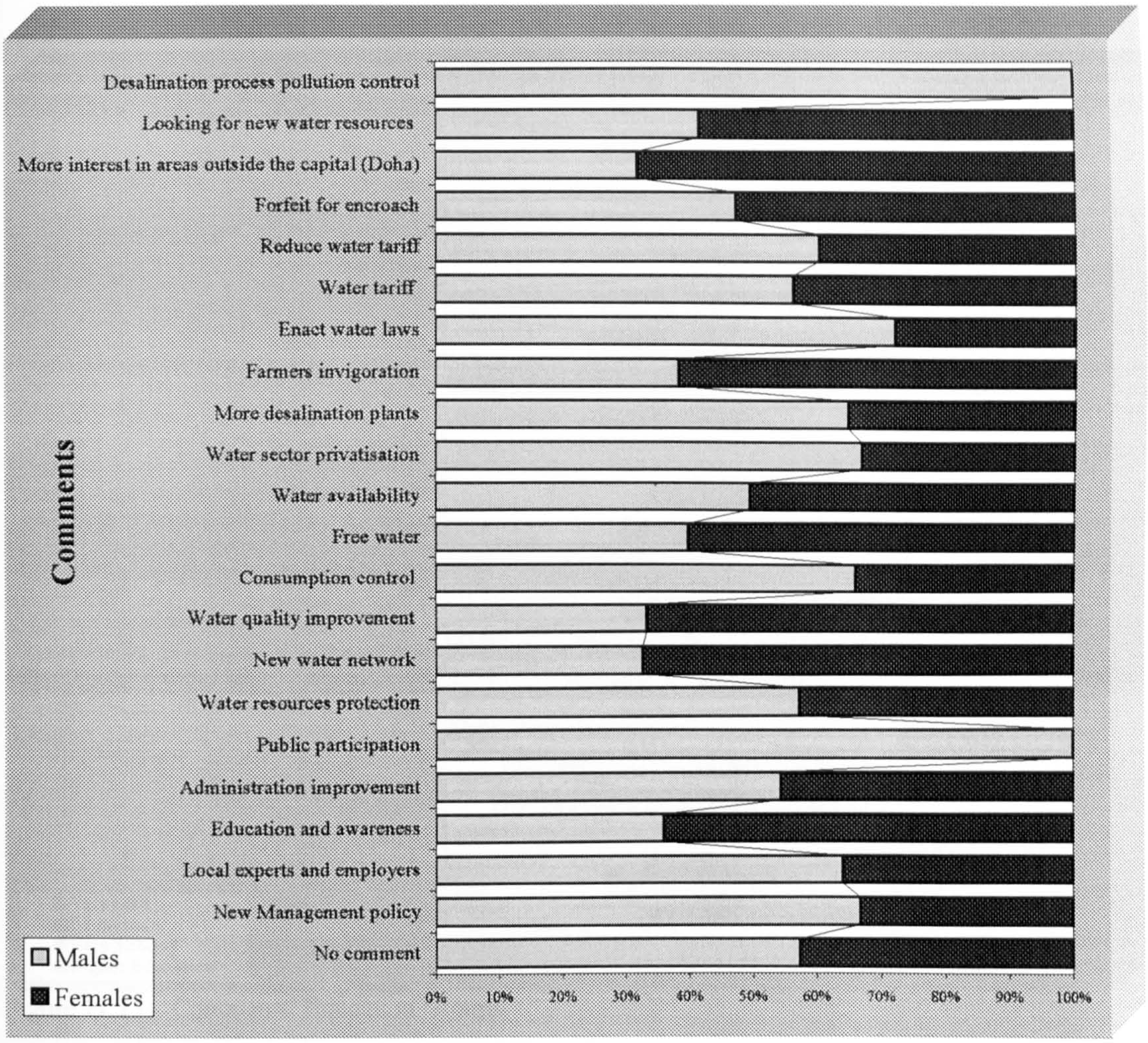

Figure 11.153. Comments: Gender Groups.

Apart from a general interest in water quality improvement, suggestions increase with the level of education, especially concerning education and administration (Figure 11.154). Suggestions such as reducing water rates and improving water availability are mostly made by those of low educational level. The rest of the suggestions generally are not affected by levels of education.

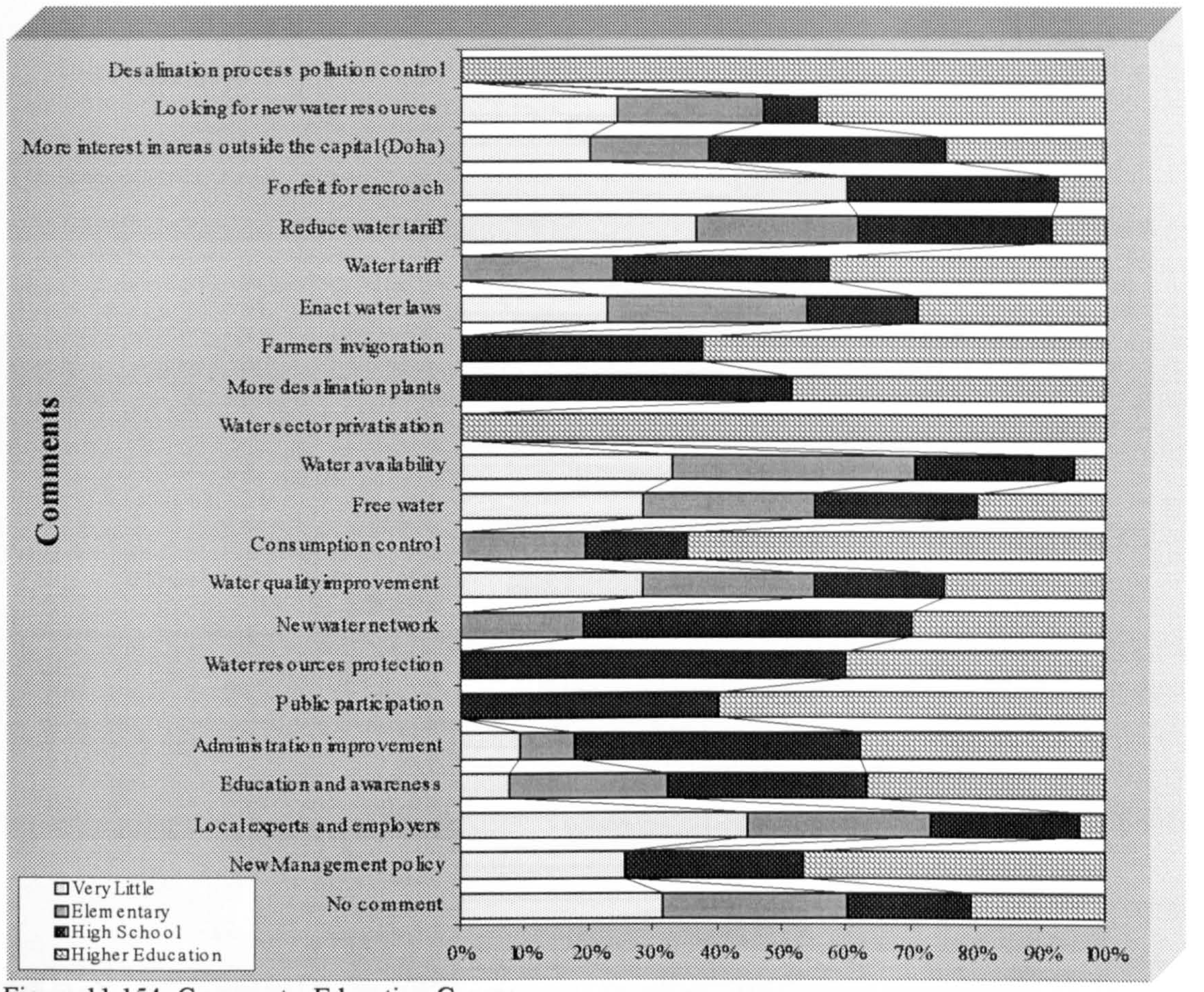

Figure 11.154. Comments: Education Groups.

Water quality, education and awareness are issues, which exercise particularly the young and the old (Figure 11.155). The young, particularly, wish for tankers to be replaced by a water network. The old fear dependency on foreigners experts, hence the call for local experts. Many middle-age people have no opinion: these are mostly immigrant workers.

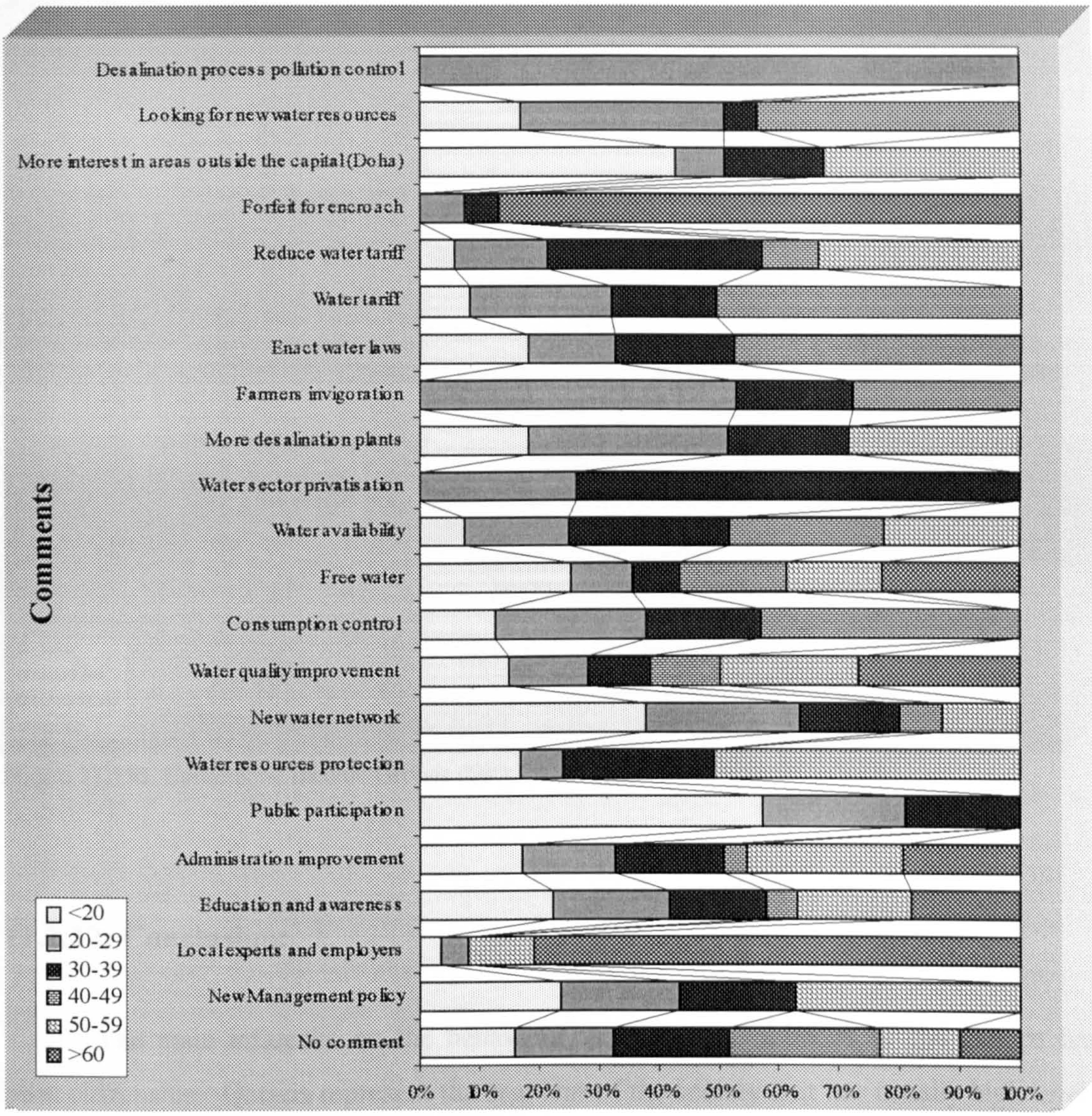

Figure 11.155. Comments: Age Groups.

Those on low income are most concerned with a reduction of tariffs (Figure 11.156). The middle income groups were more likely to respond to this section and are most likely to call for water quality improvement. The concern of people with high income is to improve water administration and find new ways to raise awareness.

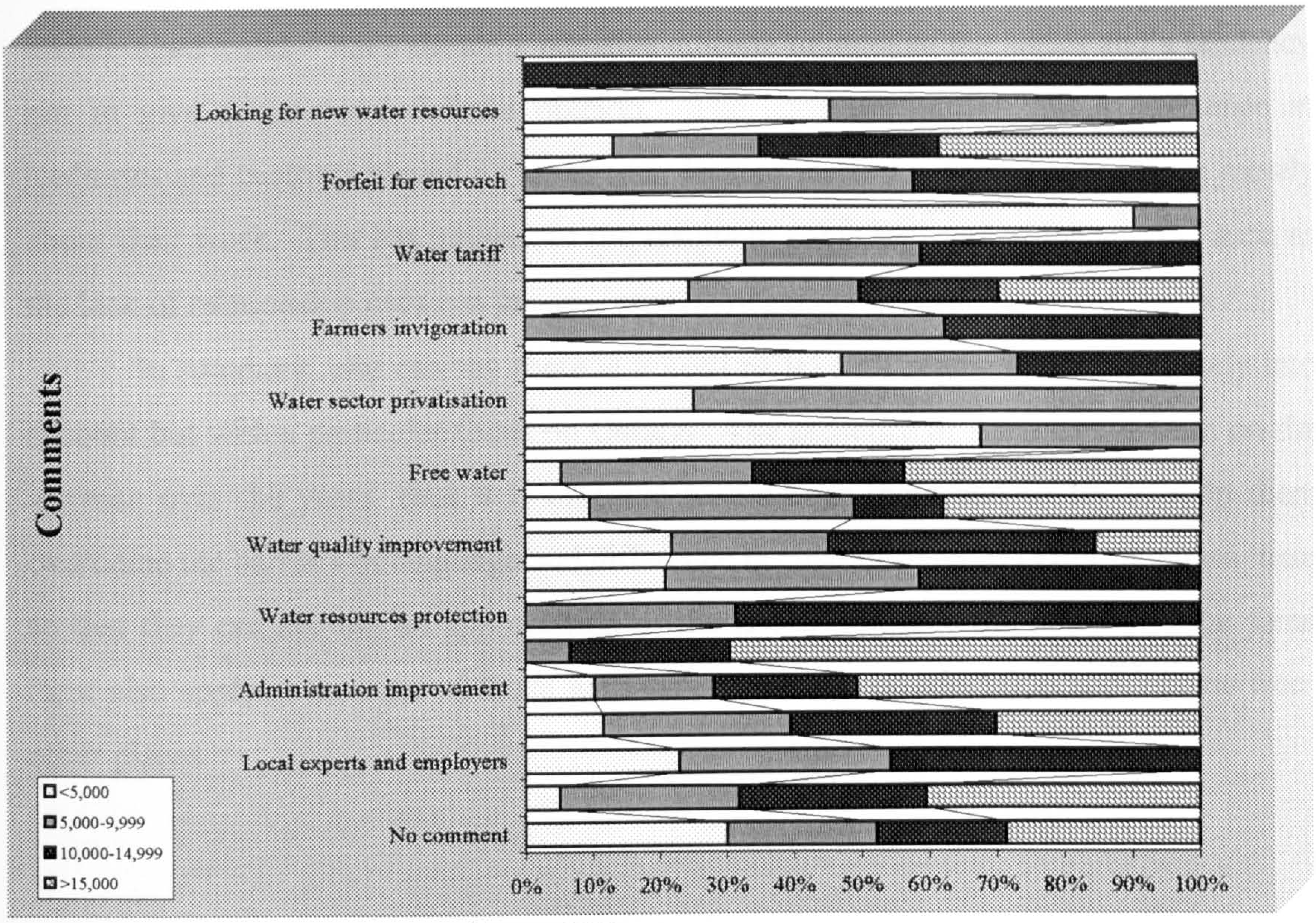

Figure 11.156. Comments: Income Groups (QR).

11.2.12. Conclusion:

The main influence on the behaviour, attitude and opinions of the groups has been citizenship. Qataris represent the segment of the society that has usually high levels of education and income, hence then consume more, and are also more aware of the problems and issues. Their opinions consequently were clear when it came to issues such as privatisation, law and participation in management. The majority of Westerners are middle aged males with high levels of education and income. Although there is a gap between them and Qataris in relation to language, customs and traditions, they have an ability to understand the water issue and give opinions about it because of their education. On the other hand, they have little interest in local issues. The involvement and understanding of the Arabs - who are mostly middle-aged males with a variety of levels of education and income - should have been more positive, especially considering the closeness in language, customs and traditions with the local society. This can be attributed to the presence of many among them with low educational levels.

Asians - who usually have low levels of education and income and are mostly middle-aged males – have shown a negative attitude to most of the issues and a tendency not to give a clear and definite opinion. The language barrier and a difference in traditions and customs played a role in their lack of interest. Their concerns are mostly about their work. This has influenced the results in some sections of the survey, such as the lack of relationship between groups, especially gender and age for some issues.

In summary, one can say there is a need to take all segments of the society into account but with a particular focus on Qataris. The presence of Asians have been on the increase over the years, thus it is essential to consider them and to try to help them overcome the barriers of language and difference in customs, and to better integrate them so that they can acquire an appreciation of the issues that face the country. The same must also apply in the case of those with very low levels of education and income from other places.

11.3. Data Exploration: Reasons for Behaviour Patterns:

11.3.1. Introduction:

This part aims to find out the reasons behind the behaviour, attitude and opinions of respondents. To do that it was necessary to integrate all the different sections of the sample survey together. The most important findings about the habits of consumers and their opinions and impressions are as follows.

Table 11.3 summarises groups of statistically significant cross-tabulations using chi-squared found in data exploration of reasons for behaviour patterns. In all the relationships discussed in the following text, the Chi-squared values are significant at the 95% level or higher. More details can be found in Section A14.3.

Table 11.3. Summary of Statistically Significant Cross-tabulation using Chi-square.

Subject	Data Exploration: Reasons for Behaviour Patterns							
	Service. 1	Service. 2	Consumption. 2	Administration. 1	Tariff. 1	Knowledge	Privatisation. 1	Public Relations. 1
Service. 3	+	+						
Service. 4	+							
Law. 1						+		
Law. 2						-		
Issues. 1	+	+						
Consumption. 1	+							
Consumption. 2	+				+			
Consumption. 3			+	-			-	+
Consumption. 5	+							
Tariff. 1				+				
Tariff. 2					+			
Public Relations. 1						+		
Public Relations. 2						-		
Public Relations. 3						-		
Administration. 1					+	+		
Administration. 2						+		
Administration. 4						-		
Privatisation. 1					+	+		
Privatisation. 2					+	-		
Privatisation. 3					+	+		

(+ All statistically significant relationships at 95% level or greater).

(- Most tests statistically significant at more than 95% level).

11.3.2. The Relationship between Water Service and Quality:

11.3.2.1. The Relationship between the Source of Water and its Use for Drinking:

This section examines respondents opinions toward the quality of water. Most who use groundwater (66%) do not drink it, while 63.5% of those who depend on desalinated water drink it (Figure 11.157). 71.1% of those who do not know the source (mostly Asians with low income) of their water drink it.

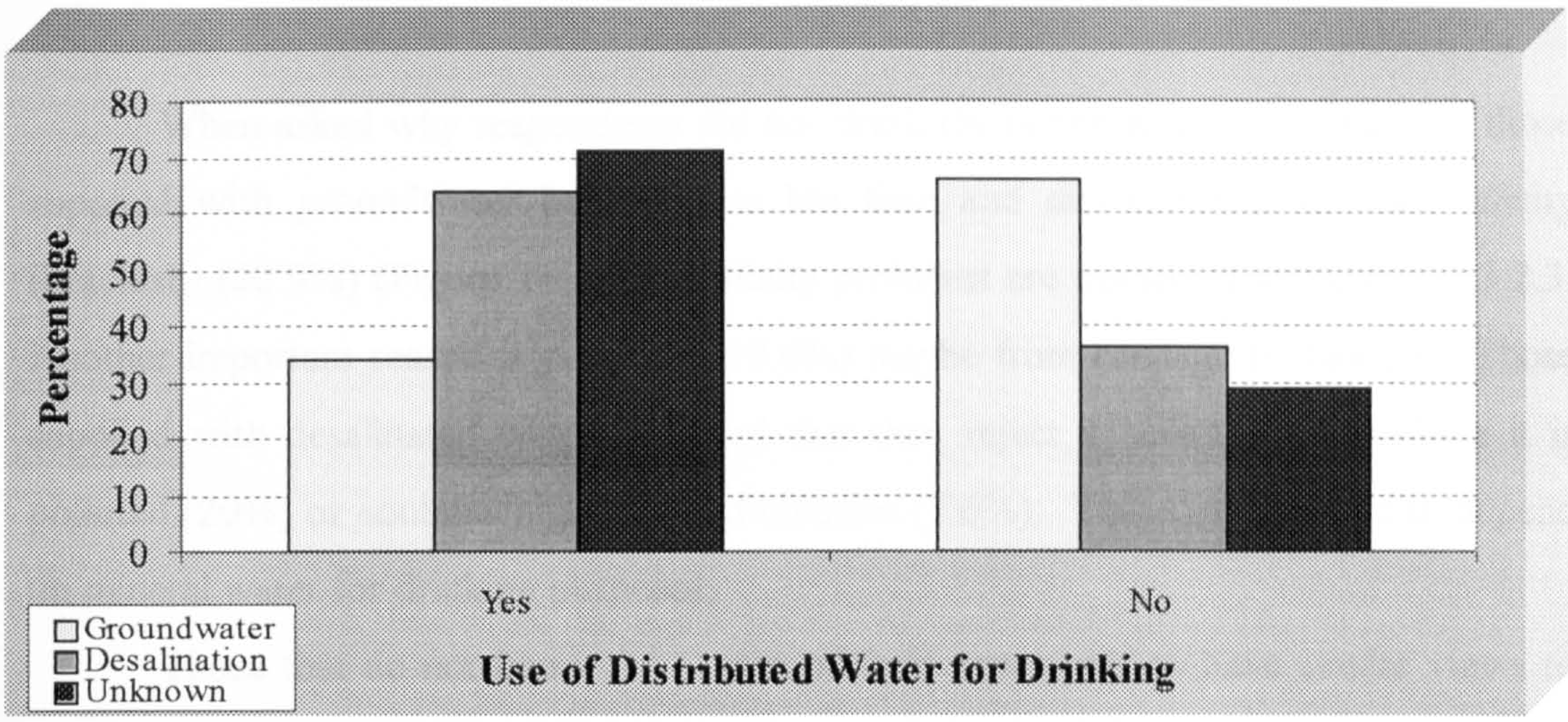

Figure 11.157. Use of Distributed Water for Drinking and the Source of Water.

11.3.2.2. The Relationship between the Method of Water Distribution and its Use for Drinking:

Groundwater and a little desalinated water is transported by water tankers, while desalination water is piped concentrated in Doha, the industrial cities and their suburbs (Section 7.3.4.2). The majority of those whose water is transported by water tankers (54%) tend not to drink it (Figure 11.158). 63% of those that depend on the water pipeline network drink the water.

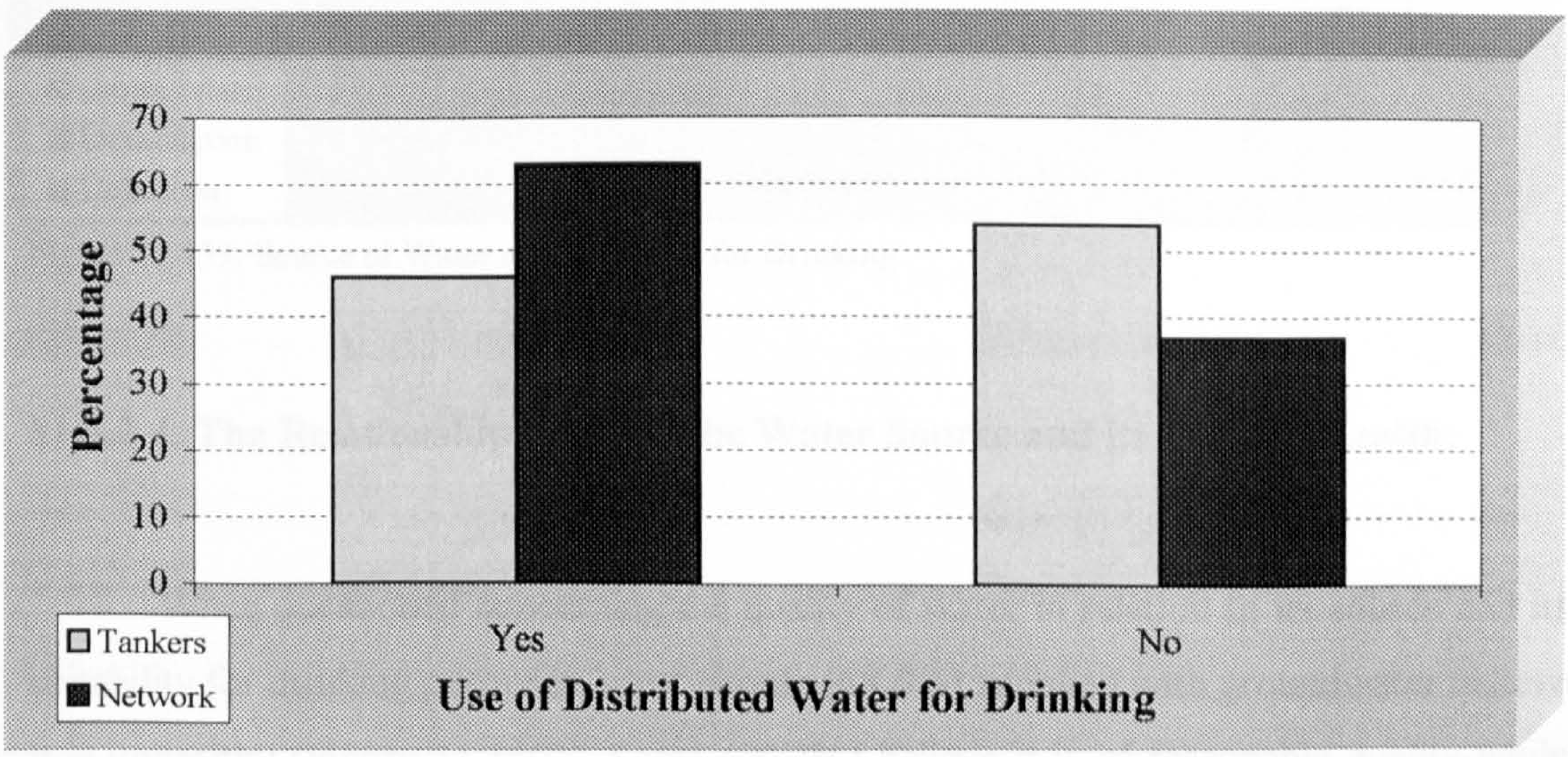

Figure 11.158. The Relationship between Use of Distributed Water for Drinking and the Route of Water Distribution.

11.3.2.3. The Relationship between the Source of Water and Perceived Quality:

When asked why respondents did not drink the distributed water, many of those supplied with groundwater believe it is has lime and dirt (29.8%) or high salinity (brackish) (22.9%) (Figure 11.159). Salinity problems are discussed in Section 7.3.2.3. Another important reason is pollution (10.6%) maybe from carriage by tankers. Those supplied with desalinated water indicated that they reject it because they believe it is polluted (20%) or contains high levels of chlorine (7.6%). These people tend to depend on mineral water for drinking purposes.

Those that do not know the source of their water tend to have similar views to those supplied with desalinated water and believe it to be polluted (17.1%). Most in this category are foreigners on low wages. 6.6% of them have no alternative but to drink water that they believe is polluted.

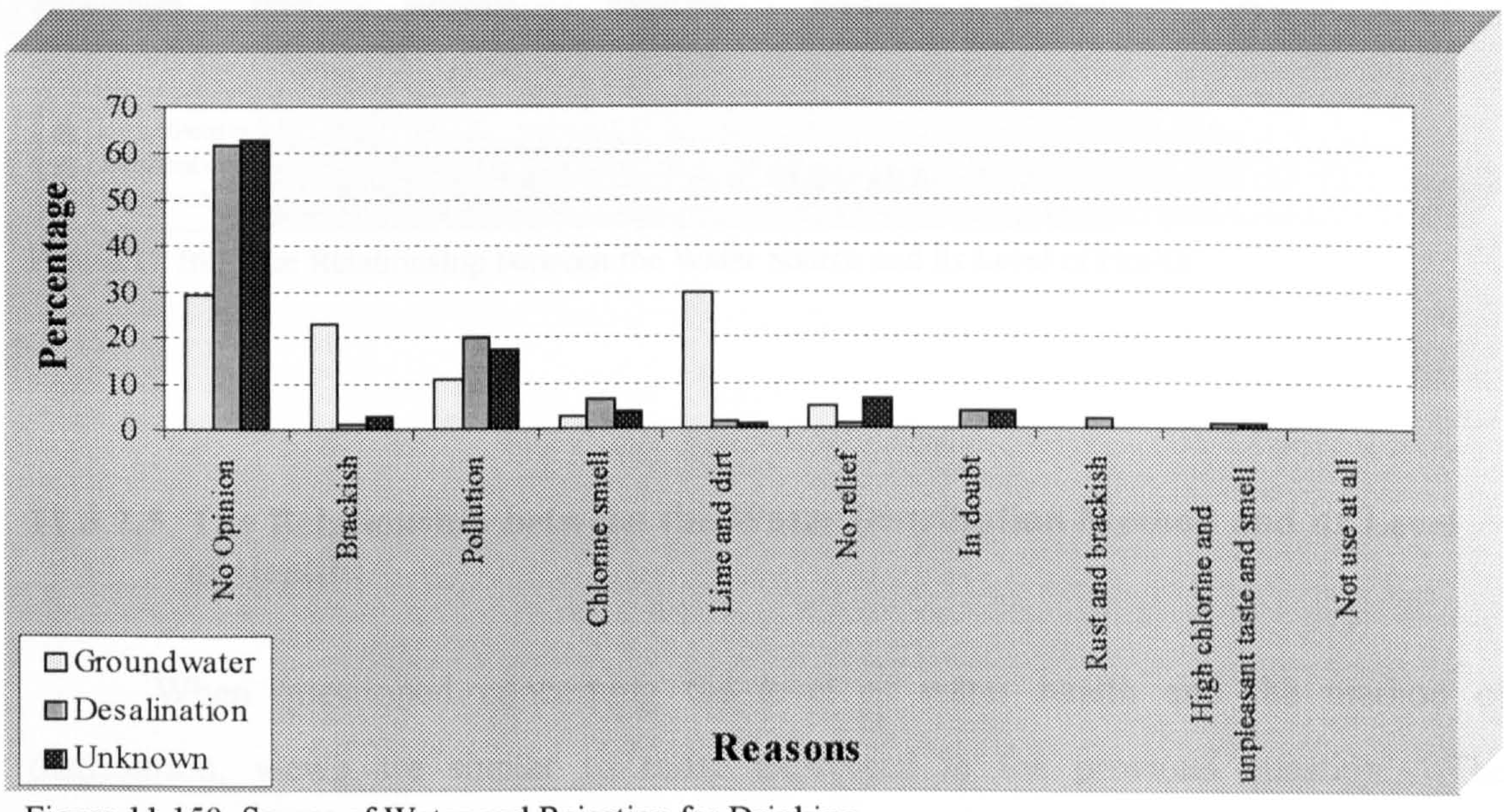

Figure 11.159. Source of Water and Rejection for Drinking.

11.3.2.4. The Relationship between the Water Source and its Level of Health:

When questioned concerning the quality of water in relation to its source and its suitability for drinking purposes, most people (68.6%) supplied with groundwater believe it is unhealthy (Figure 11.160). Some (20.7%) believe it is of reasonable quality while only 6.9% believe it is healthy. Fewer people (48.9%) supplied with desalinated water believe it is unhealthy while 27.8% believe it is of a reasonable quality. Almost the same view is held among those that do not know the source of their water: 47.4% believe it is unhealthy and 27.6% believe it is of tolerable quality.

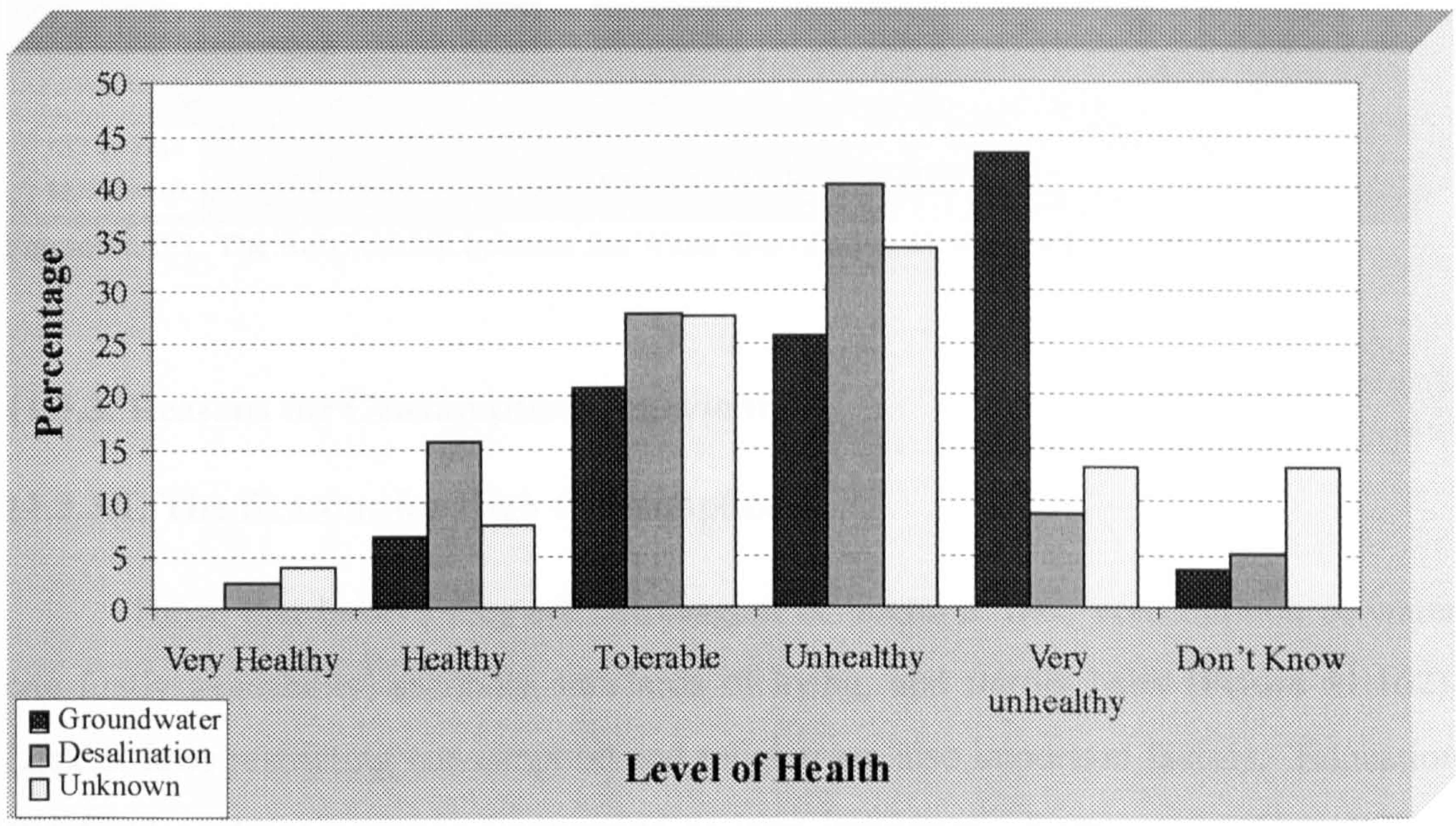

Figure 11.160. The Relationship between the Water Source and its Level of Health.

11.3.2.5. The Relationship between the Water Distribution Method and its Level of Health:

When questioned concerning the level of water health and the method of distribution, views are similar to those expressed in the previous question. The difference is that some of those that consume water delivered by tankers believe it is healthy (10.1%) or tolerable (20.5%) (because some desalinated water is distributed by tankers) (Figure 11.161). Generally speaking, those that consume groundwater, which depends on tankers for delivery to consumers (62.6%), suffer from low water quality. Thus, they do not drink it. Consumers of desalinated water, which is provided through the water network (17.2%), tend to believe it is of healthy or tolerable (29.4%), although a good number feel, that it is unhealthy (48.4%).

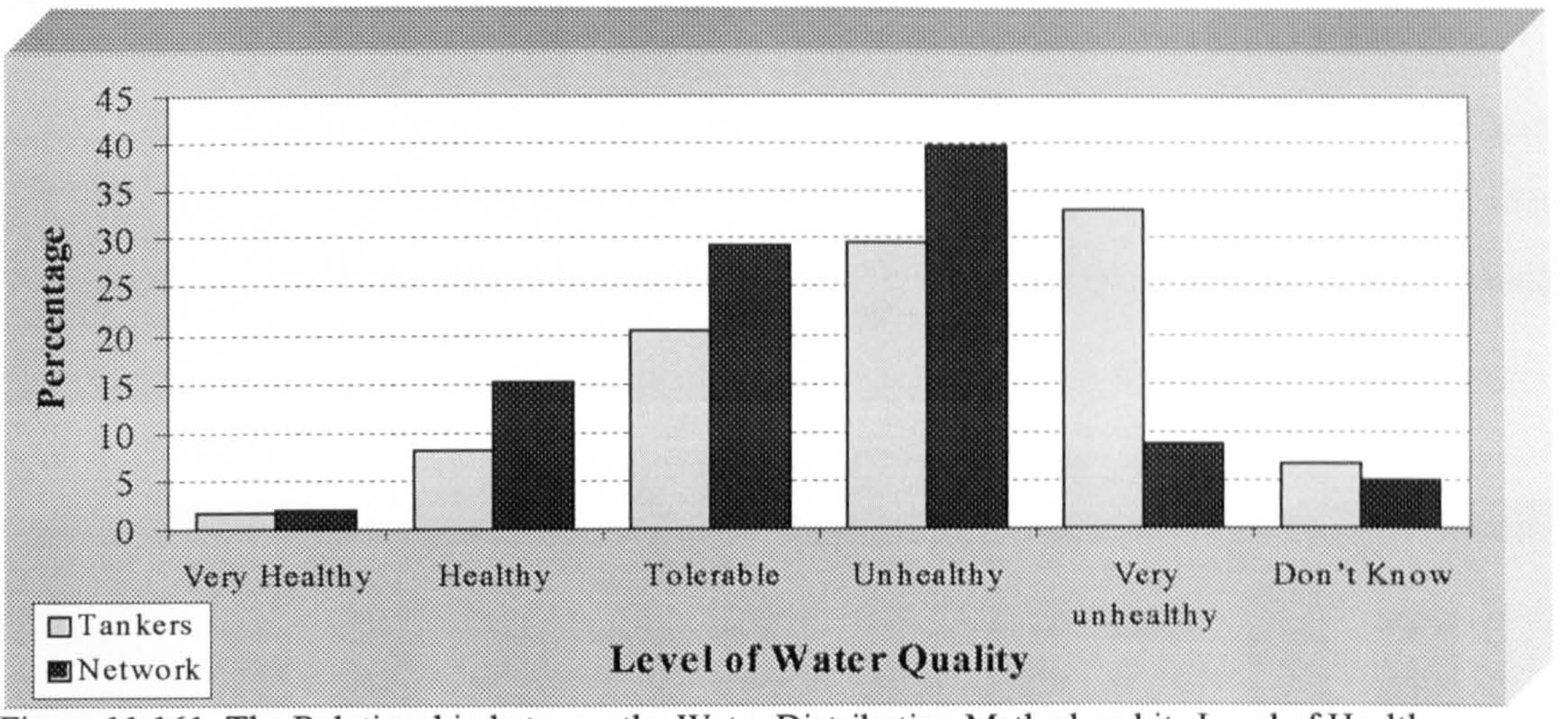

Figure 11.161. The Relationship between the Water Distribution Method and its Level of Health.

11.3.3. Reasons for Consumption Behaviour:

11.3.3.1. The Reasons for High Consumption:

Those that believe they are extravagant or liberal in their consumption of water cite firstly availability, secondly standards of living, and thirdly habit (Figure 11.162). Lack of laws restricting consumption and religion are also important factors. Education and family upbringing were enumerated as least important. Some respondents believe that religious observance encourages water consumption. Awareness and concern about the problem are very low among these people.

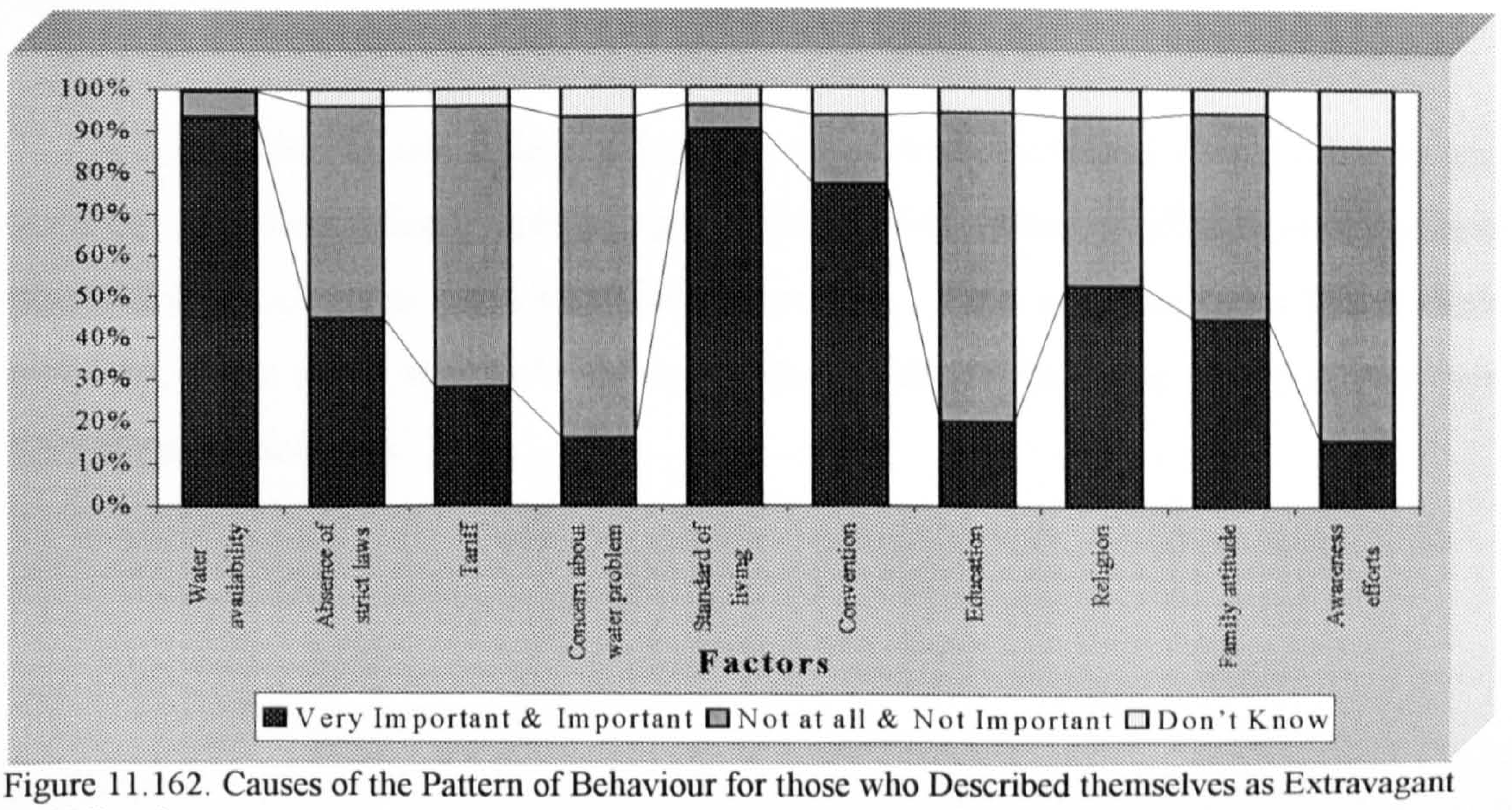

Figure 11.162. Causes of the Pattern of Behaviour for those who Described themselves as Extravagant and Liberal.

11.3.3.2. Reasons for Neutral Consumption:

Those that considered their consumption neutral held similar views (Figure 11.163). They counted religion and family upbringing as strong influences on their attitude towards water. Awareness and concern of the problem of the water were middle ranked.

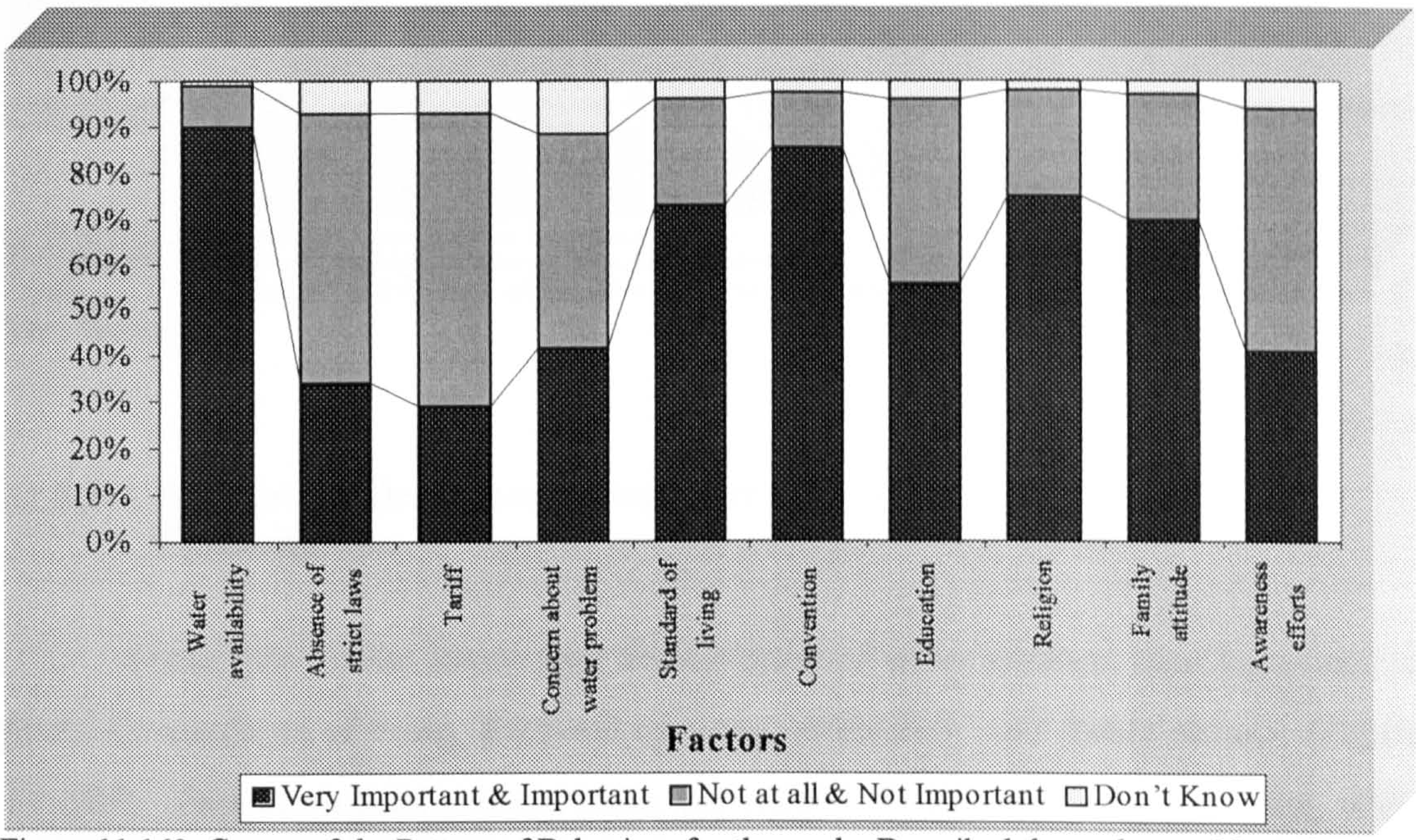

Figure 11.163. Causes of the Pattern of Behaviour for those who Described themselves as Neutral.

11.3.3.3. Reasons for Economical Consumption:

Those that consider their behaviour economical attributed it to traditions and customs, religion and family upbringing (Figure 11.164). Water tariffs and restrictions in the availability of water were considered important. Law and awareness had a slight influence, while living standards had less influence than with those who consider their consumption excessive.

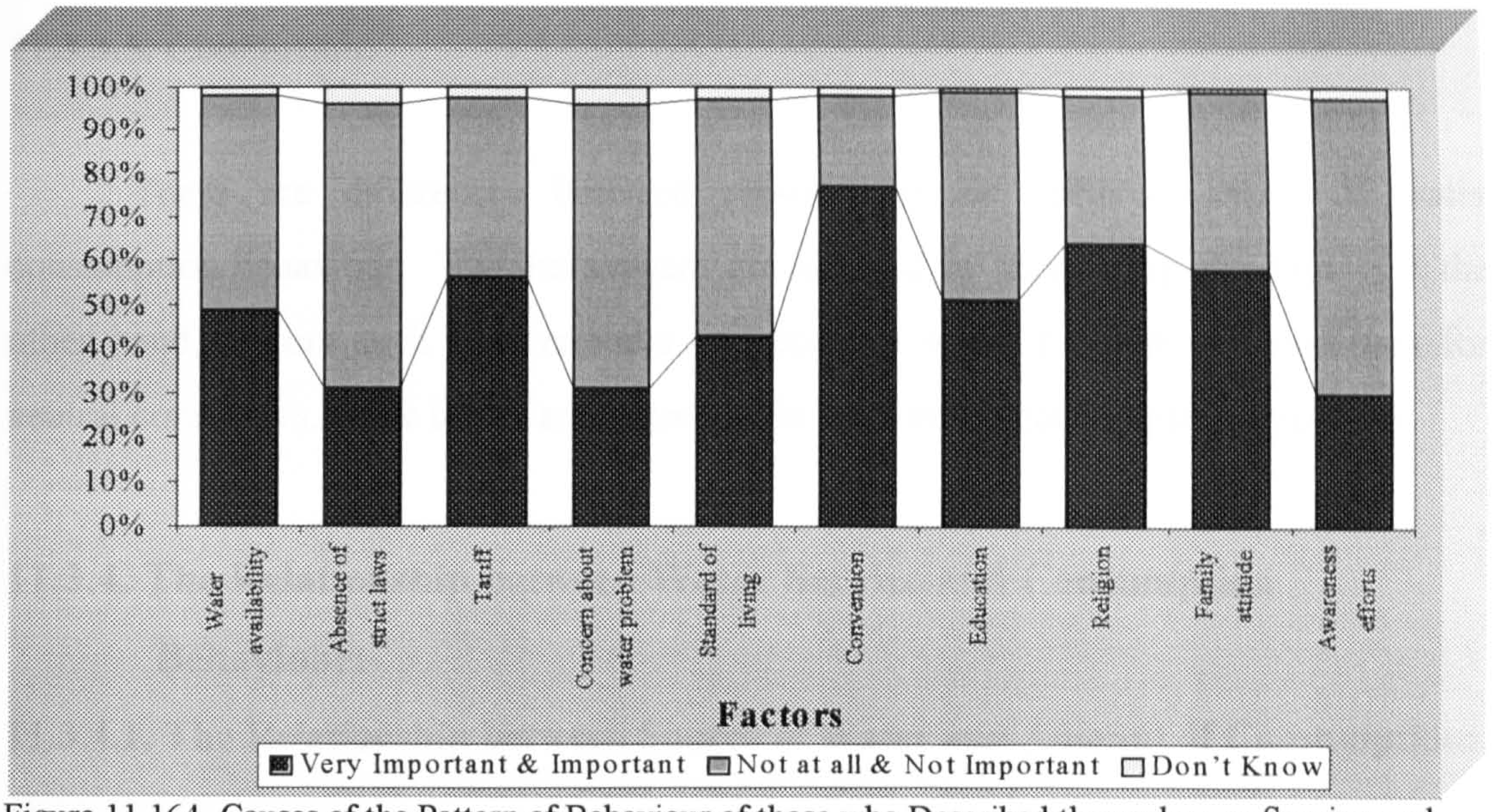

Figure 11.164. Causes of the Pattern of Behaviour of those who Described themselves as Sparing and Very Sparing.

11.3.3.4. Reasons for Behaviour Patterns for those who do not Know their Consumption:

Those that do not know their consumption of water attribute their behaviour to firstly to standards of living, followed by water availability, and family attitude (Figure 11. 165). Factors such as concern about the water problem were least important, while absence of strict laws and convention fell in the middle.

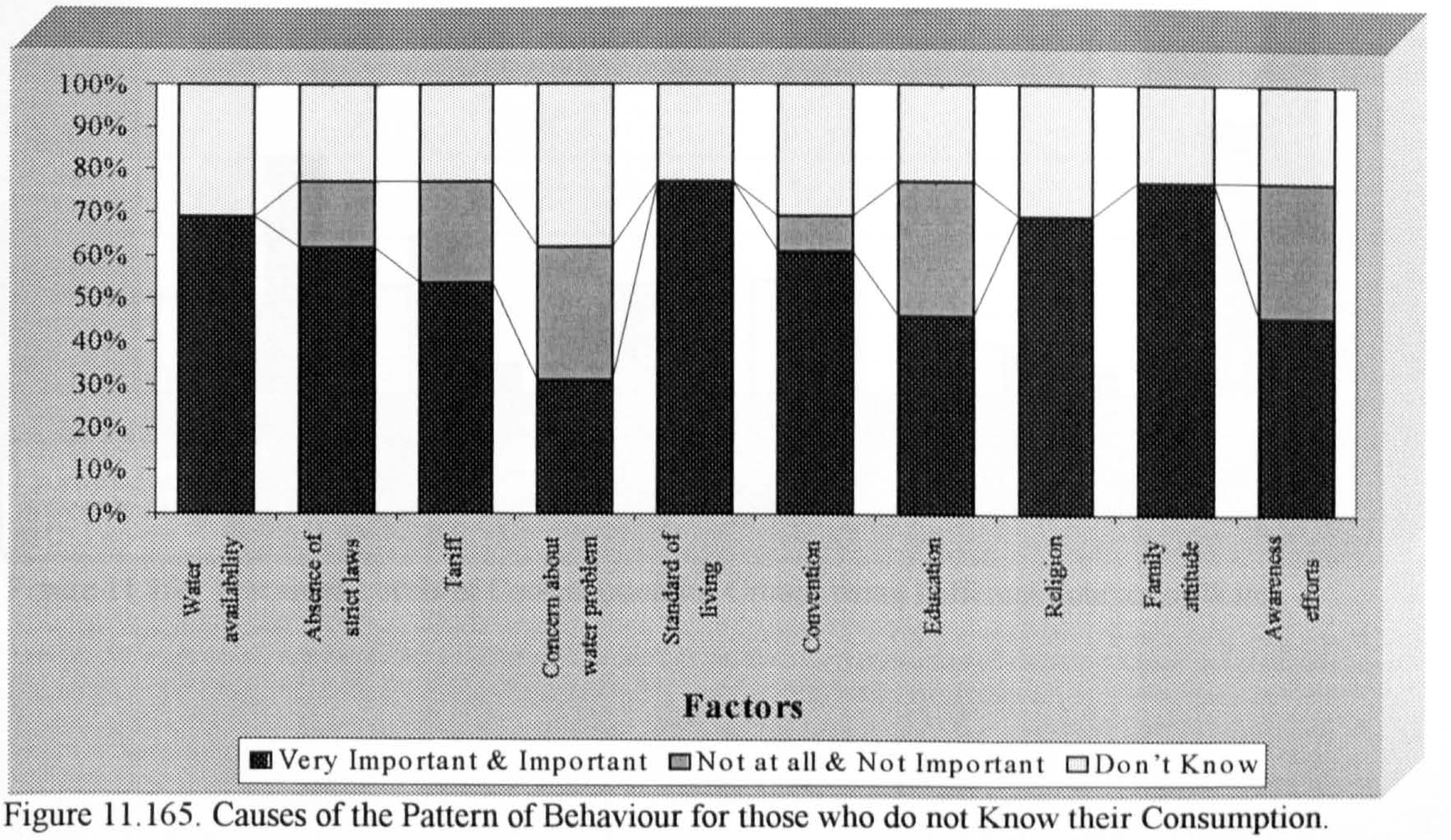

Figure 11.165. Causes of the Pattern of Behaviour for those who do not Know their Consumption.

11.3.3.5. Conclusion:

There are differences between reasons for the different types of water consumption behaviour. The extravagant are affected by their living standard. On the other hand, factors such as awareness and concern about problem are important for neutral consumers, while tariffs are influential in economical consumption behaviour.

11.3.4. The Relationship between Water Service and Consumption Behaviour:

11.3.4.1. The Relationship between Source of Water and Amount of Consumption:

There is no significant pattern between the level of consumption and source of water (Figure 11.166). Some consumers of desalinated water connected to the pipeline network have meters and many pay tariffs. Most of the 39.2% who not know their water source state their consumption is very low, 30.3% believe they consume only 10-39.9 $gald^{-1}$. They are mostly low-income Asians (Section 11.3.2.1).

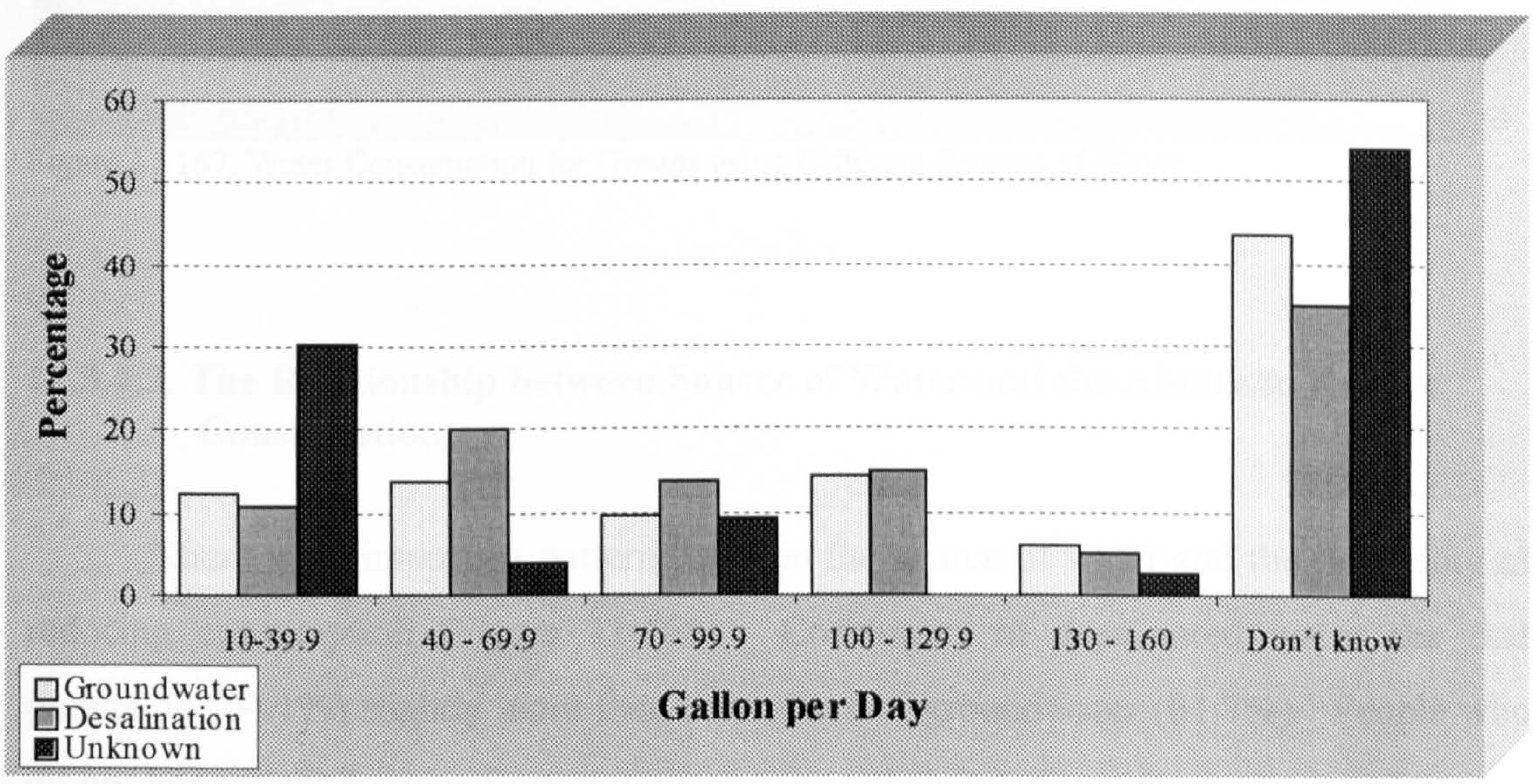

Figure 11.166. Perceived Levels of Consumption for Groups using Different Sources of Water.

11.3.4.2. The Relationship between Source of Water and Consumption Behaviour:

There is little difference in consumers perception of behaviour in relation to the source of water (Figure 11.167). 52.1% of consumers of groundwater and 46.1% of consumers of desalination water believe they are liberal or extravagant, while slightly more believes they are sparing or very sparing. The opposite is found among those who do not know their water source, who think their consumption is economical (57.9%) or normal (31.6%). Most of these are poorly paid foreign workers.

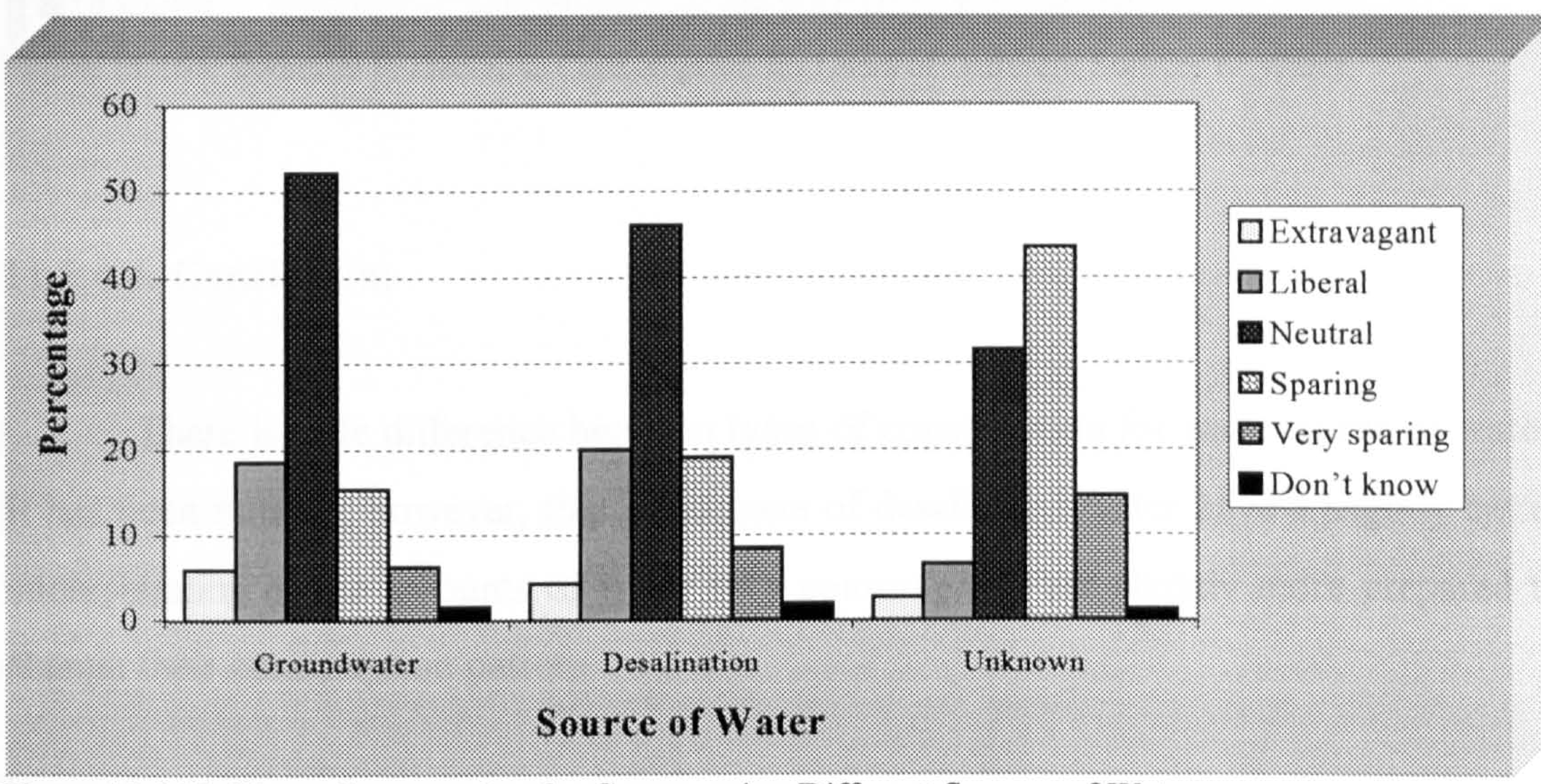

Figure 11.167. Water Consumption for Groups using Different Sources of Water.

11.3.4.3. The Relationship between Source of Water and the Ability to Reduce Consumption:

There is no important pattern between the source of water and the possibility of reducing consumption (Figure 11.168). Consumers of desalinated water see that possibility (64.1%) slightly more than consumers of groundwater (61.7%). People who do not know their source of water can not reduce their consumption.

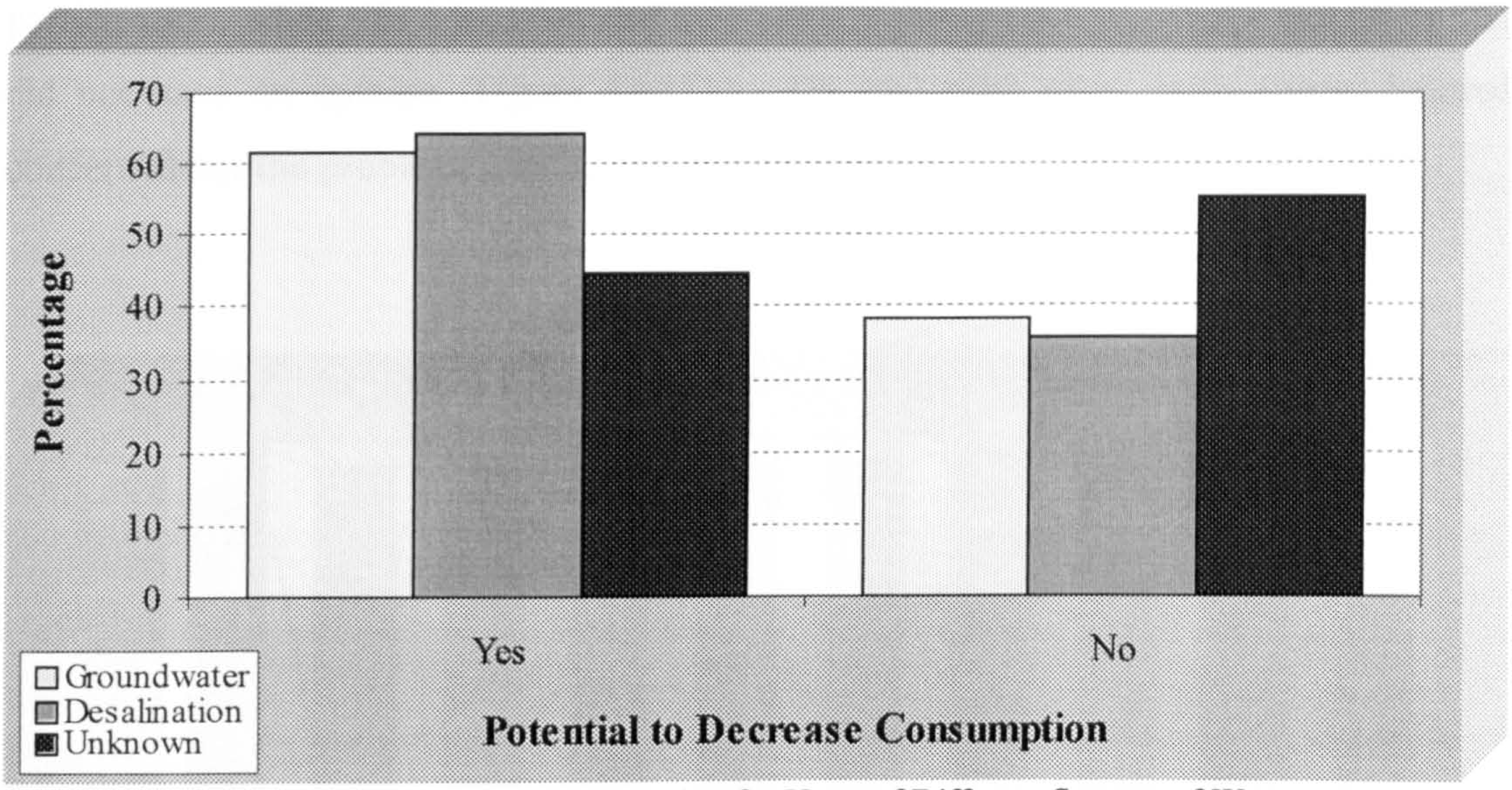

Figure 11.168. Potential to Decrease Consumption for Users of Different Sources of Water.

11.3.4.4. Conclusion:

There is little difference between types of consumption for each source of water. It has been noticed, however, that consumers of desalinated water have a slightly better understanding of the amounts of water they consume and are slightly more prepared to change their consumption pattern.

11.3.5. Support for Participation in Management and Different Consumption Groups:

There is remarkable similarities in the motivations of water use among groups who are, and are not interested in participation in water management (Figures 11.169 and 11.170). Availability of water, customs and traditions, religion and living standards are considered important influences to the behaviour of both groups. Slightly more of those that supported participation believe that education and awareness are important influences.

Slightly more of those that objected - mostly foreign workers - believe water tariffs are important influences. They also think participation is difficult to implement. Concern over the water problem was middle ranked by those that supported participation, while this education and awareness were of low importance for those that did not have an opinion (Figure 11.171). On the other hand, both groups ignored concern about the problem, tariffs, laws and awareness.

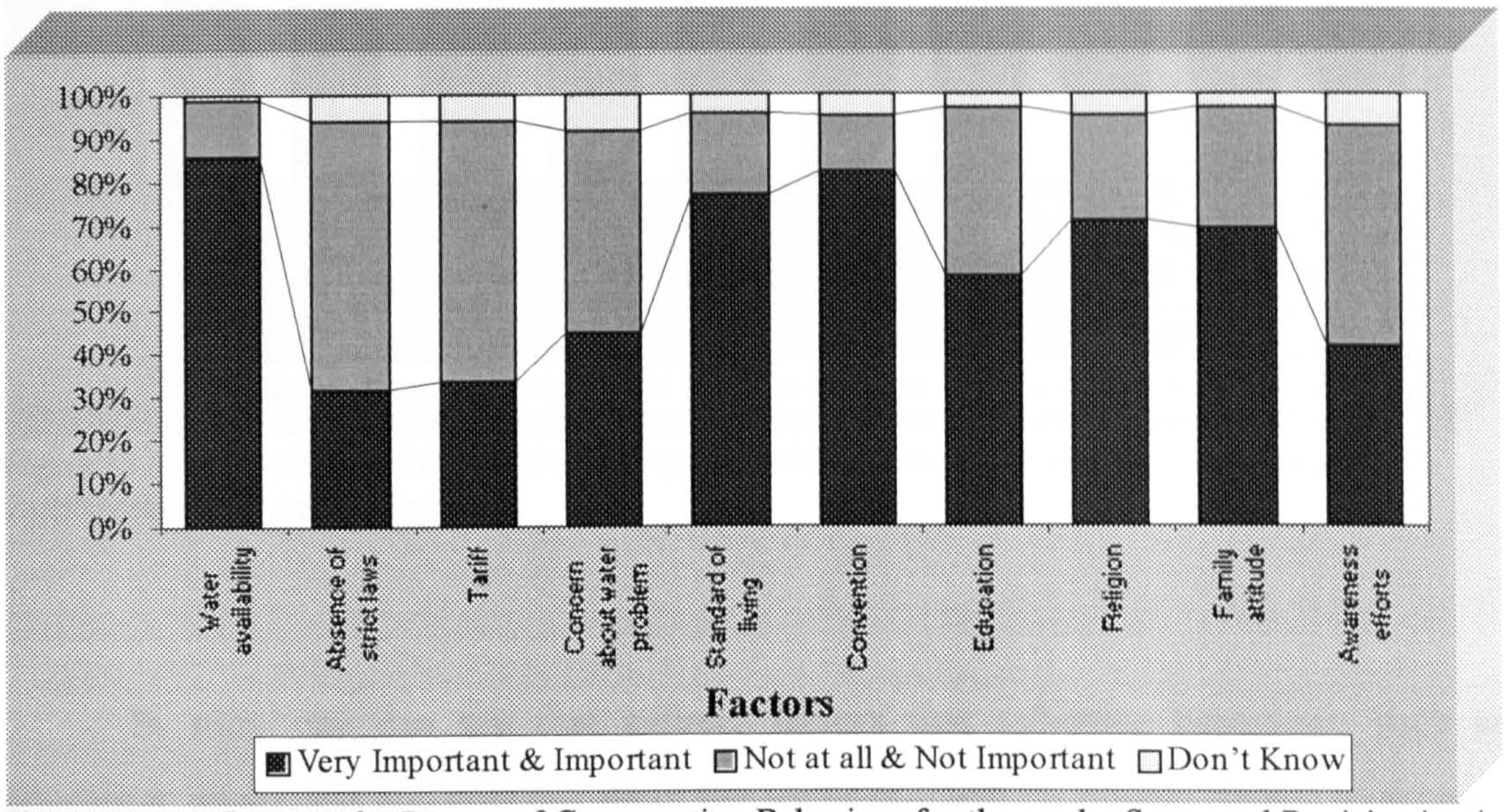

Figure 11.169. Reasons for Pattern of Consumption Behaviour for those who Supported Participation in Water Management.

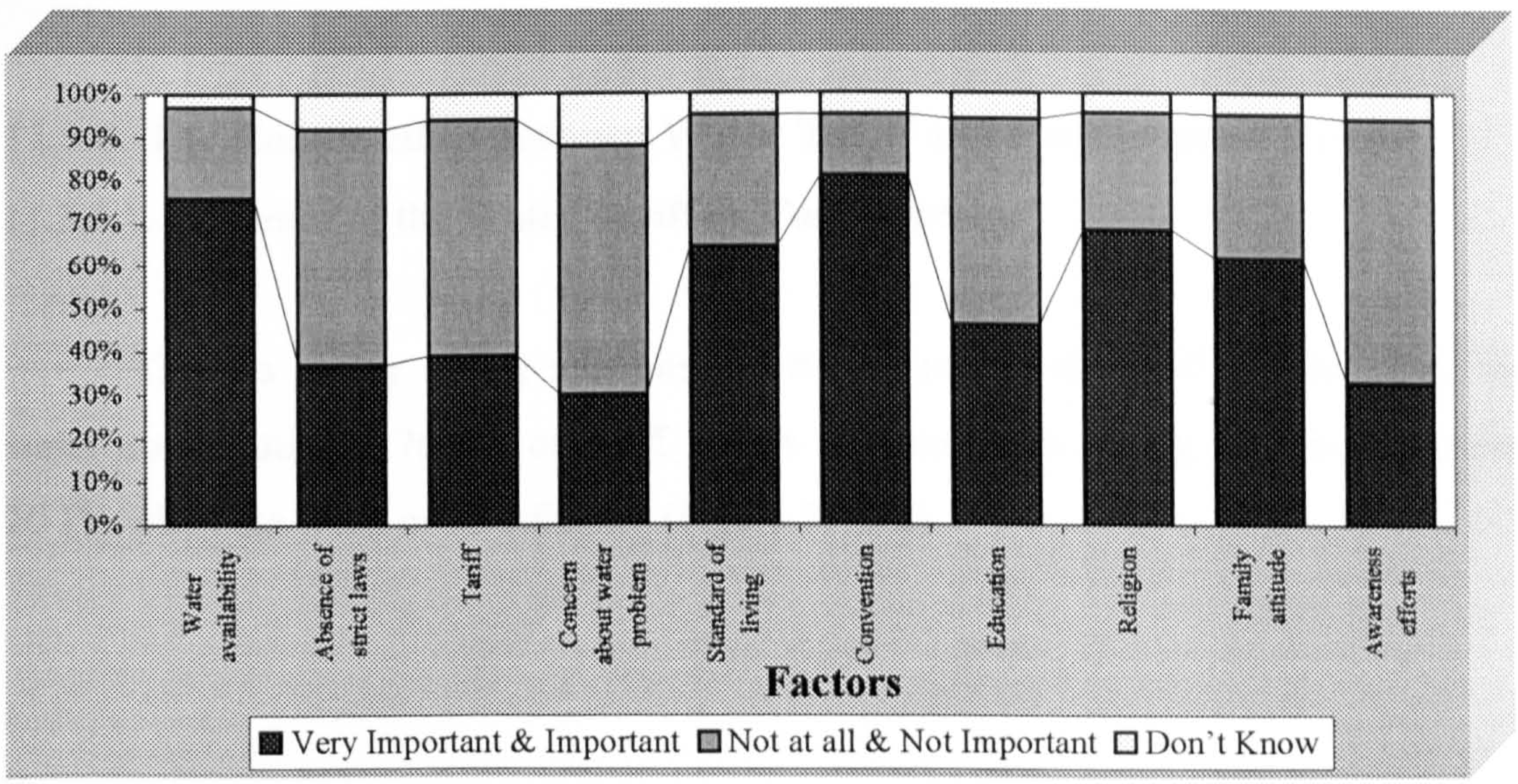

Figure 11.170. Reasons for Pattern of Consumption Behaviour for those who Objected Participation in Water Management.

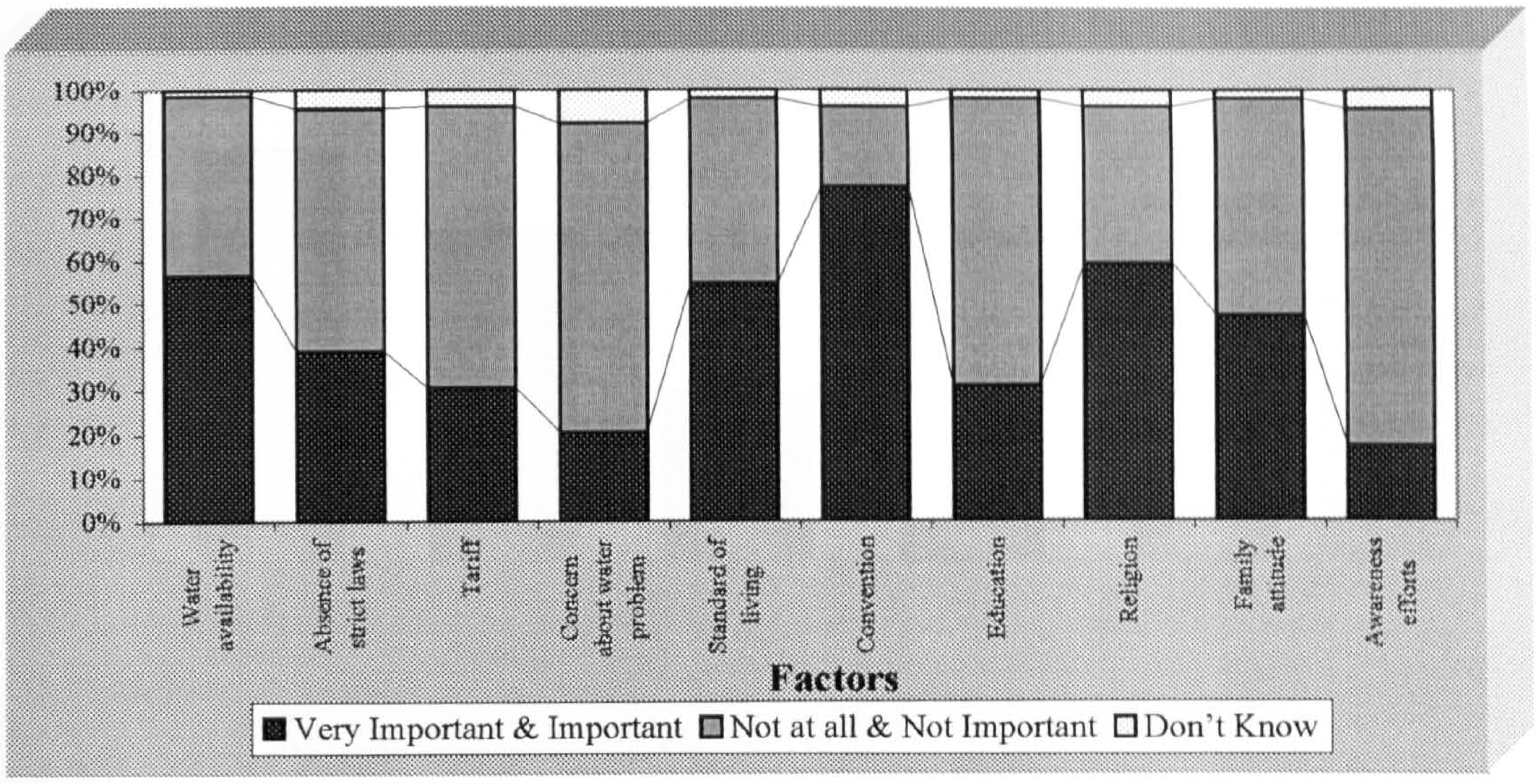

Figure 11.171. Reasons for Pattern of Consumption Behaviour for those who have No Idea about Participation in Water Management.

In sum, one can say that indirect factors that influence behaviour, such as education, awareness and concern about the water problem encourage people to support the idea of participation in water management. On the other hand, people who regard such factors as unimportant have a negative attitude towards participation.

11.3.6. The Relationship between Water Tariff and Consumption Levels:

11.3.6.1. Influence of the Water Tariff on Consumption:

There is a very strong relationship between paying the tariff and its effect on water consumption. 76.1% of tariff payers accentuate its strong influence, against 20.1% who note weak or no influence (Figure 11.172).

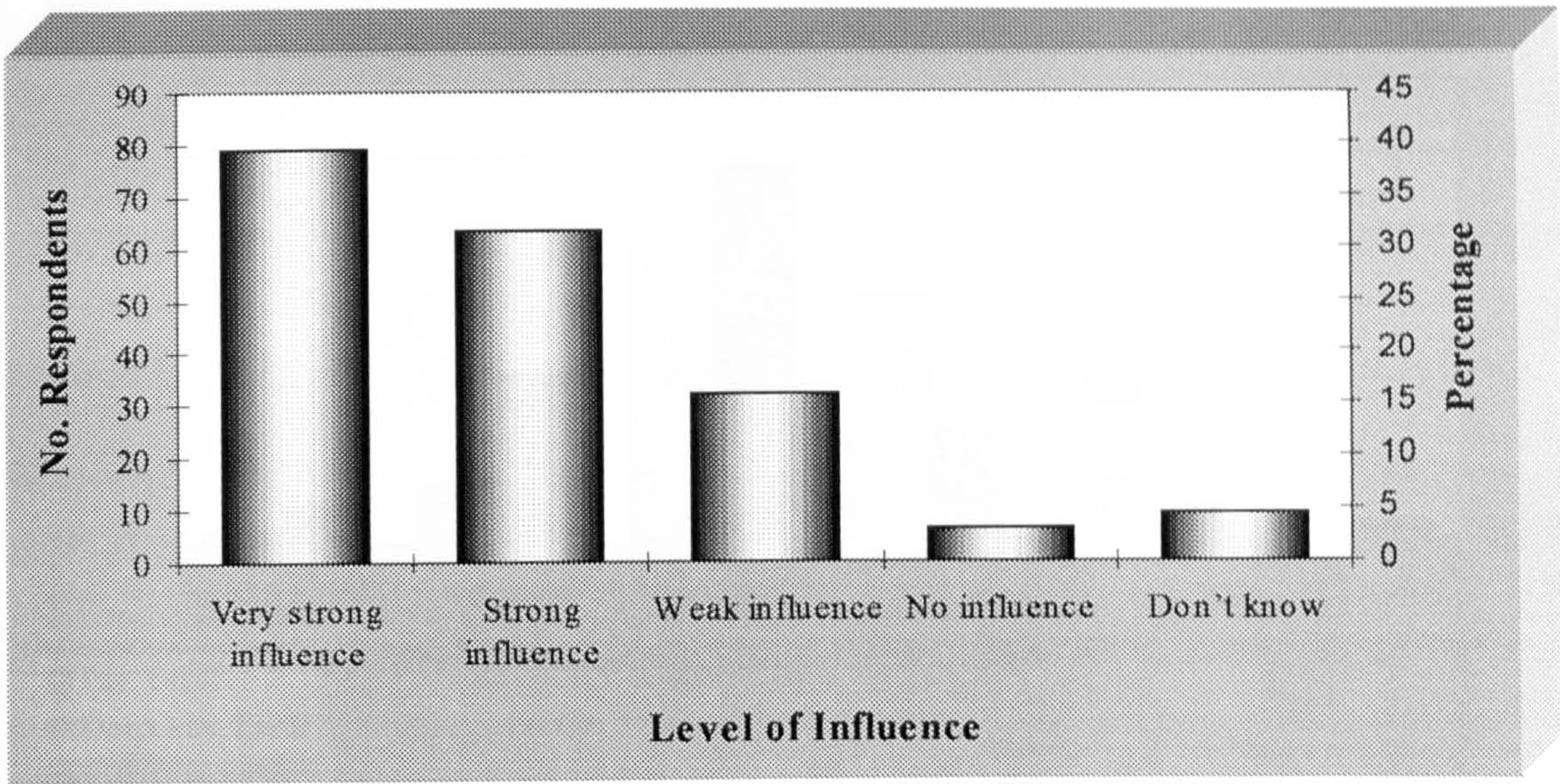

Figure 11.172. The Level of Influence of the Water Tariff on Tariff Payers.

11.3.6.2. The Relationship between Water Tariff and Perception of Consumption Behaviour:

A significant relationship exists between the influence of tariffs and perceived water consumption behaviour. The stronger the influence of water tariffs, the less the consumption. For those that believe their consumption is very sparing and sparing (51.3%) tending towards being neutral (38.6%), the influence of water tariffs is high, while for those that do not pay tariffs their consumption is neutral (48.8%) tending to extravagant and liberal (27.5%) (Figure 11.173). There is no doubt that water tariffs play a significant role in decreasing consumption, especially in combination with other factors. For instance, Qataris (who usually have high income and high living standards) do not pay tariffs, while most foreigners of medium or low income pay tariffs. Here the influence of tariffs on their consumption behaviour is great.

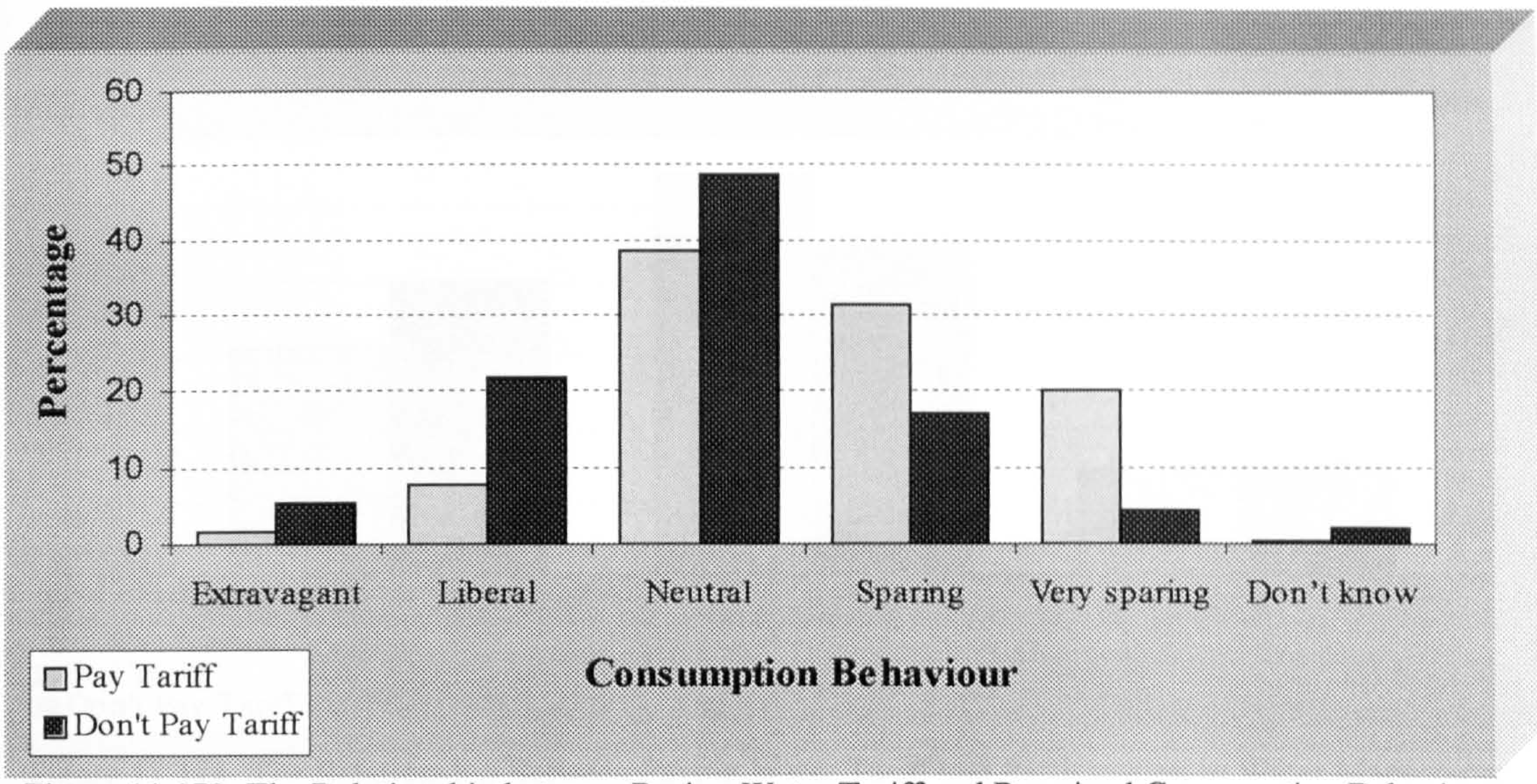

Figure 11.173. The Relationship between Paying Water Tariff and Perceived Consumption Behaviour.

11.3.7. The Relationship between Paying the Tariff and Attitude to Participation in Water Management

11.3.7.1. The Relationship between Paying the Tariff and Attitude to Participation in Water Management:

The relationship between paying or not paying water tariffs and attitude to participation in water management is weak. However, a slightly higher number (40.2%) supported participation and do not pay tariffs, against the 31.2% at who pay tariffs and supported participation (Figure 11.174). This might be linked with citizenship and the perceived remote possibility of foreigners attaining a share in the decision-making process.

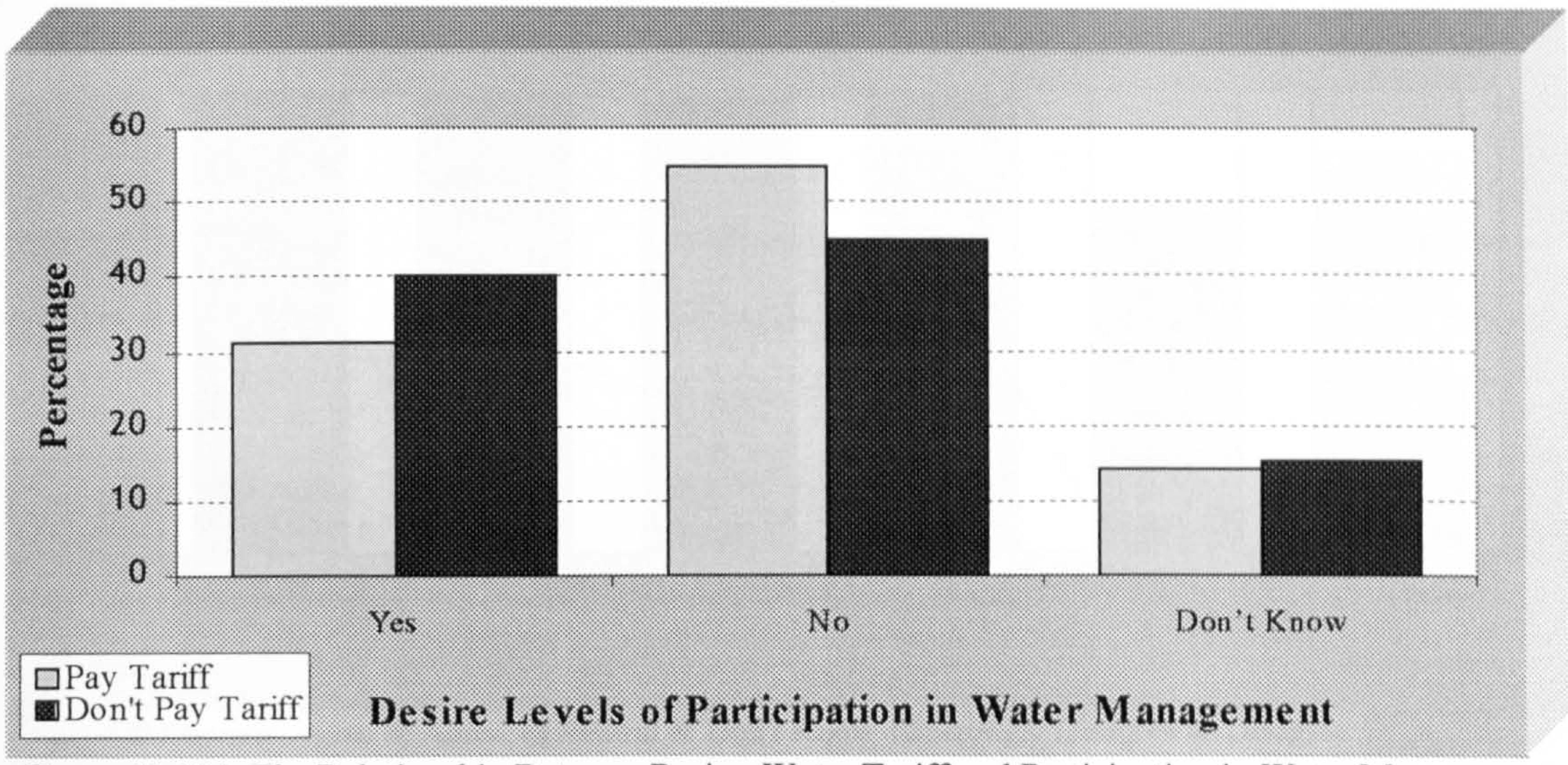

Figure 11.174. The Relationship Between Paying Water Tariff and Participation in Water Management.

11.3.7.2. The Relationship between Reasons for Supporting Participation and Tariff Payment:

For those who support participation in water management, the payment, or otherwise, of a water tariff makes little difference (Figures 11.175 and 11.176). The group that pay tariffs and the group that do not both believe that priorities are raising the level of awareness, improving the service, and improving water management. Many tariff payers that supported participation state that only the cultured classes should participate.

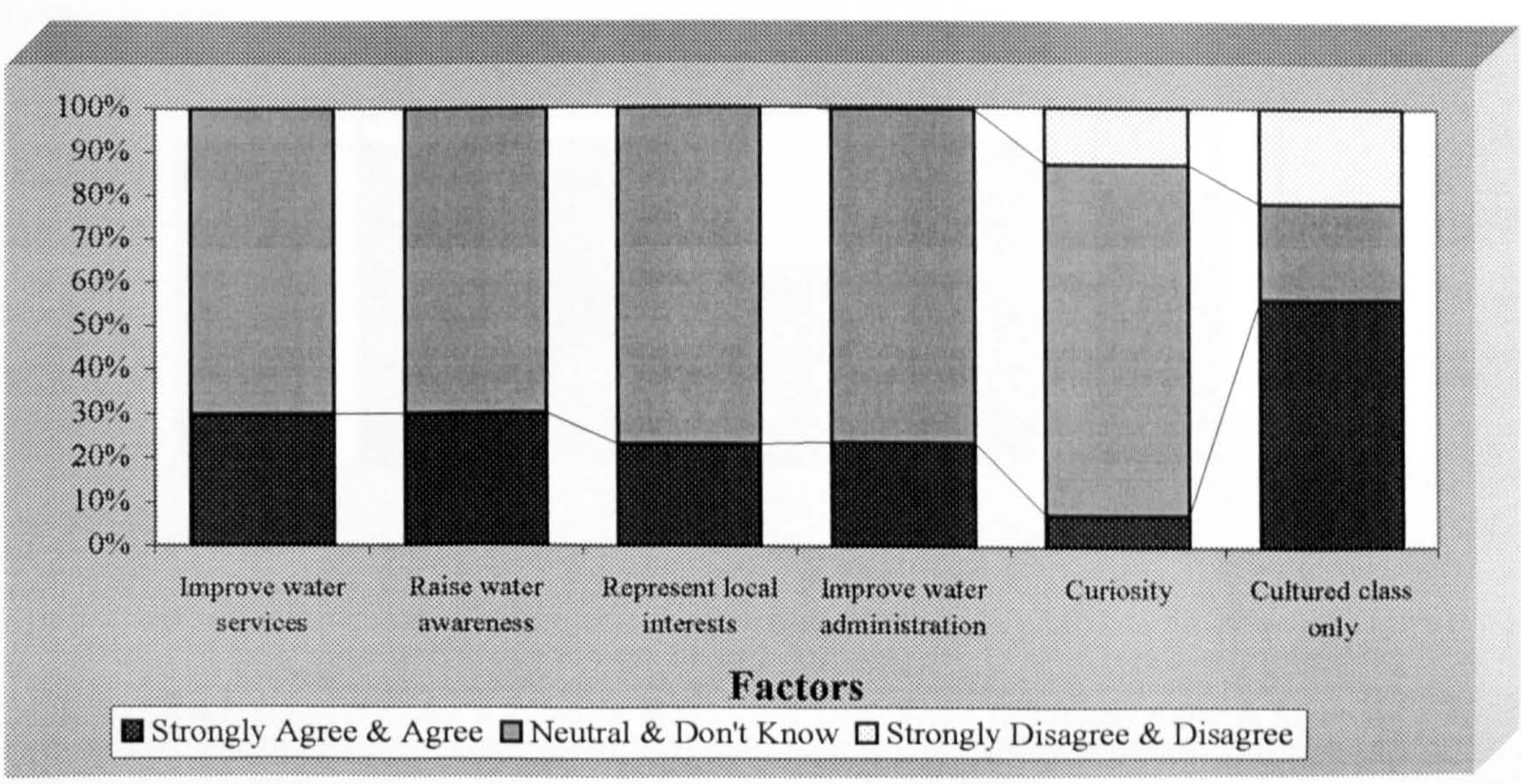

Figure 11.175. Motives for Participation for those who Pay the Water Tariff.

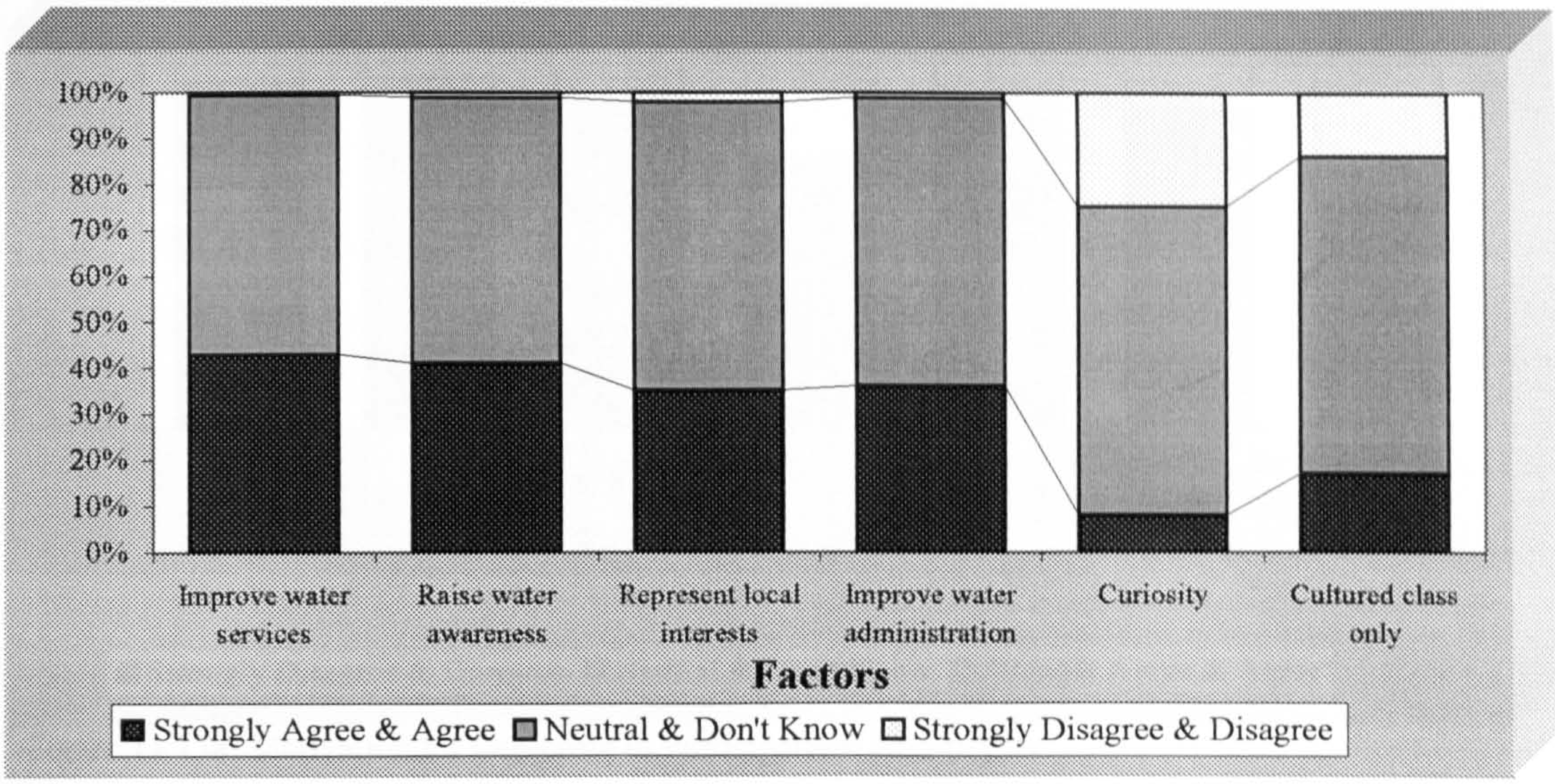

Figure 11.176. Motives for Participation for those who do not Pay the Water Tariff.

11.3.7.3. The Relationship between Objections to Participation and Tariff Payment:

The profile of responses for those not wishing to participate in the water industry was similar, whether or not a tariff was paid. Both groups see difficulty in implementation it, lack of experience and a lack of personal benefit from such participation (Figures 11.177 and 11.178). In both cases, there is a conviction that present water policy and management is not successful but that participation will have a negative influence. Some also hold that there is no public concern over the water issue.

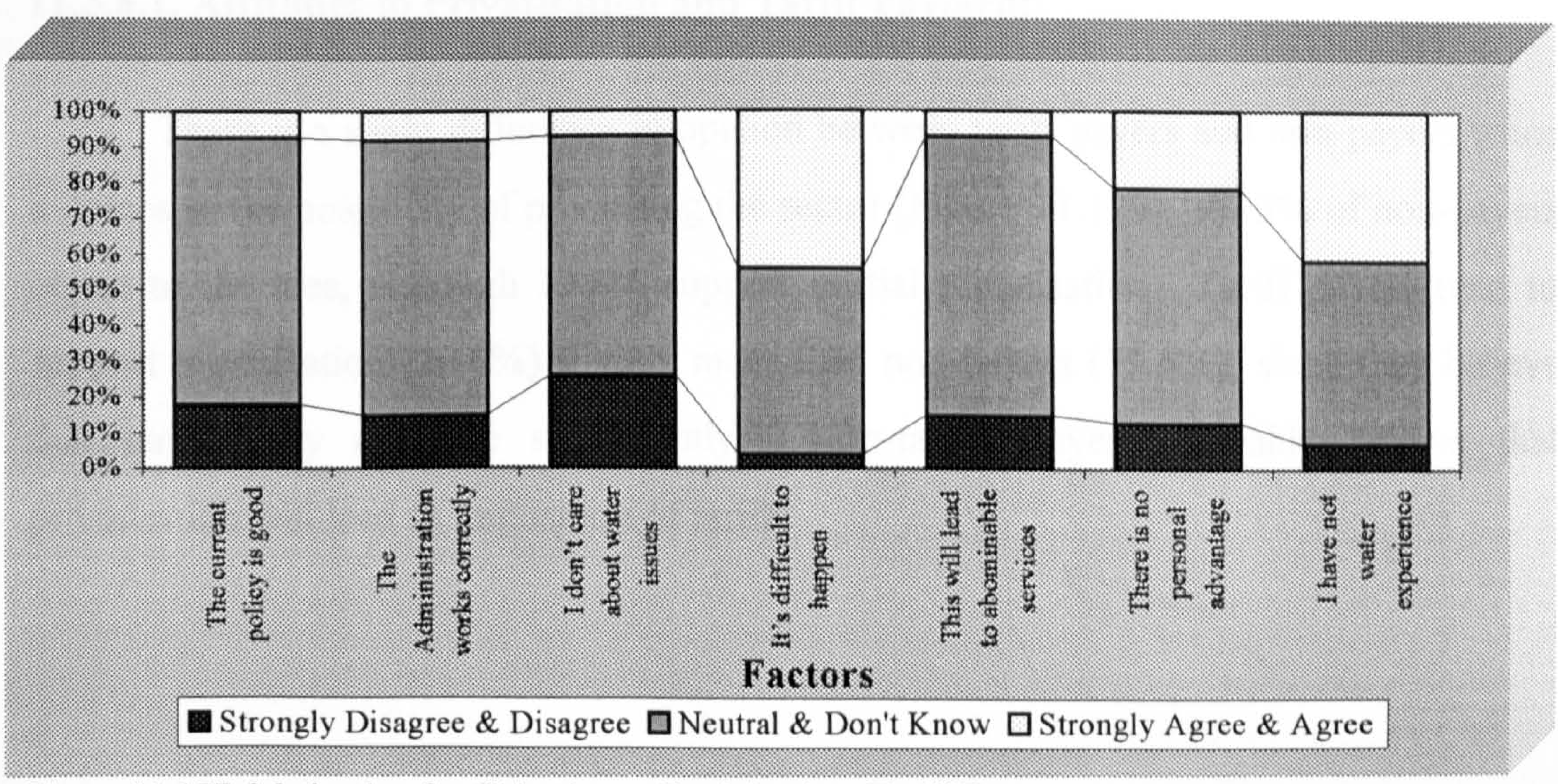

Figure 11.177. Motivation for Objecting to Participation: Tariff Payers.

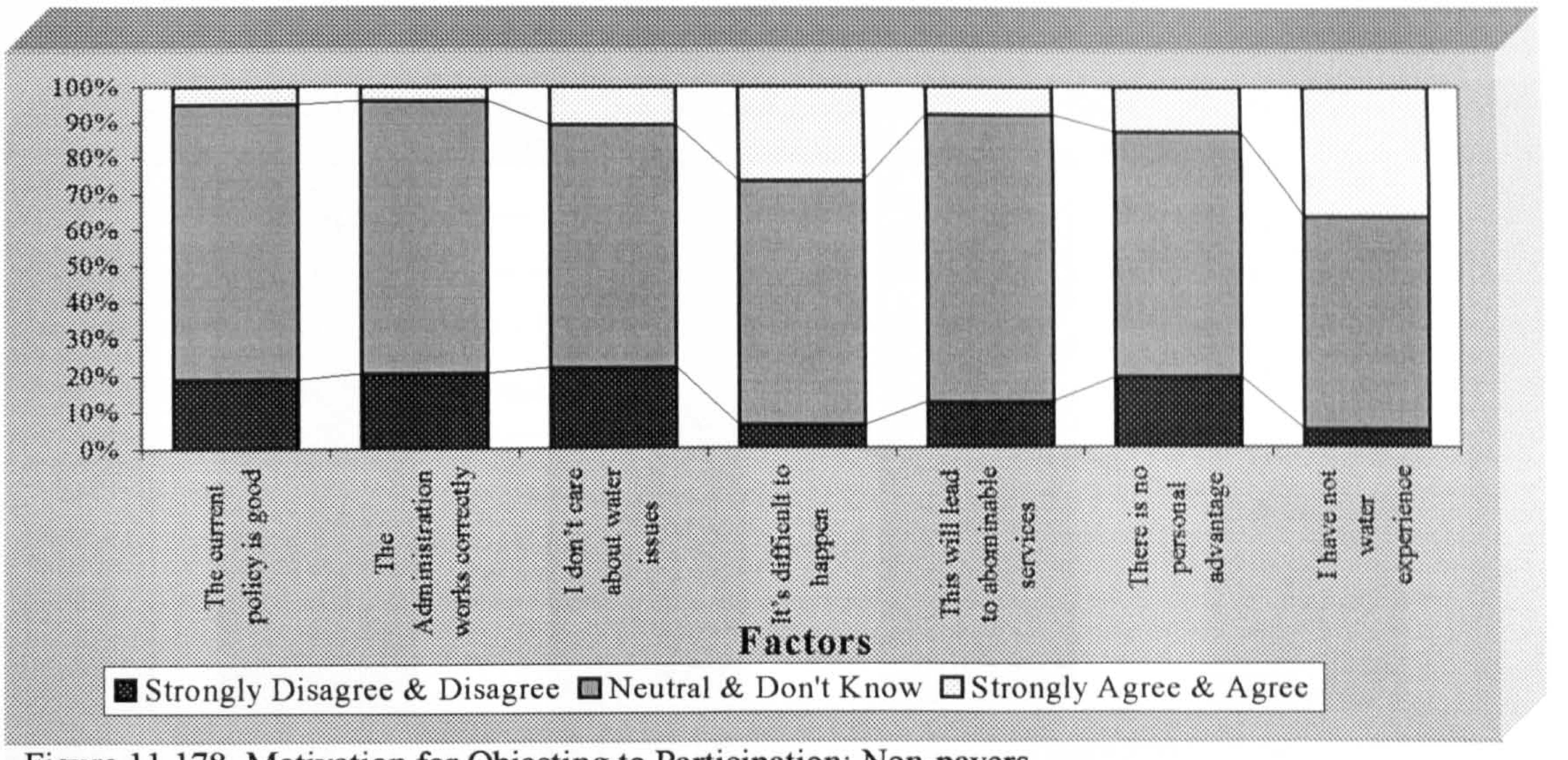

Figure 11.178. Motivation for Objecting to Participation: Non-payers.

11.3.7.4. Conclusion:

In sum, there is a relationship between water tariffs and nationality. Those that support participation, the majority of which are Qataris and some Arabs with high education, are concerned with improving the service, while many foreign workers believe it is difficult to implement participation because of citizenship issues, lack of knowledge and experience of local conditions.

11.3.8. Attitudes to Water Sector Privatisation and the Influence of Water Tariff Payment:

11.3.8.1. Attitudes to Privatisation and Tariff Payment:

There is a slight difference in opinion between tariff payers and non-payers when it comes to the possibility of privatising the sector (Figure 11.179). 49.3% of non-payers object to the idea, although 19.8% support partial privatisation. Tariff payers tend to support privatisation (20.6%) slightly more than non-payers (13.5%), since they believe that tariffs may not rise significantly. Non-tariffs payers probably believe that privatisation will lead to imposition of tariffs.

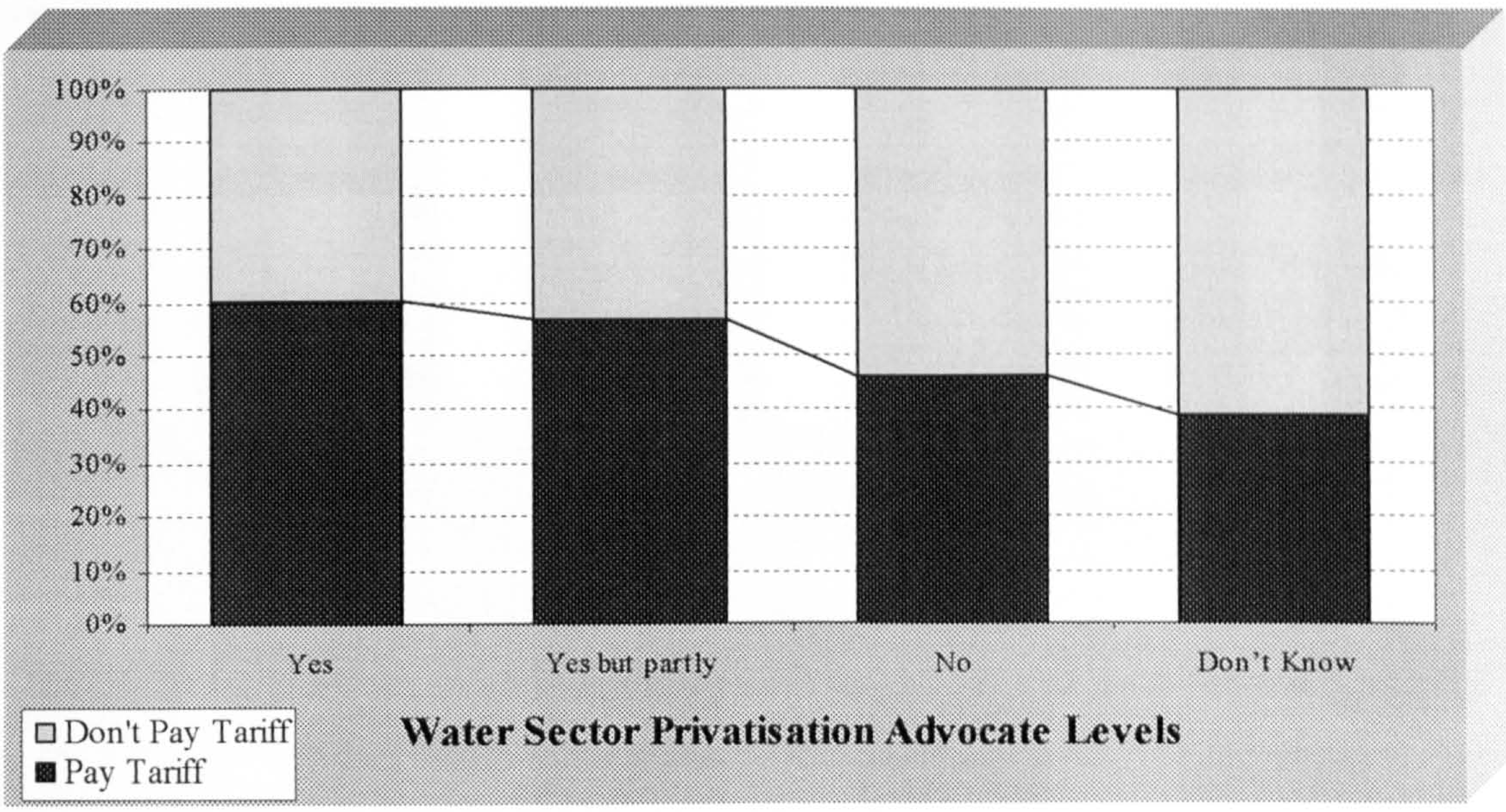

Figure 11.179. The Relationship between Water Tariff and Water Sector Privatisation.

11.3.8.2. Influence of Tariff Payment on Perceived Advantages of Privatisation:

Not much difference exists between the two groups when it comes to the benefits of privatisation (Figures 11.180 and 11.181). Both put improvement of the service, including the quality of water, improvement of water management and development of new sources of water as the most important benefits of privatisation. Non-tariffs payers have reservations about the benefit to the Government from privatisation by reducing its financial burden. They believe they will be at the mercy of private companies and that the Government will not subsidise the cost to the public.

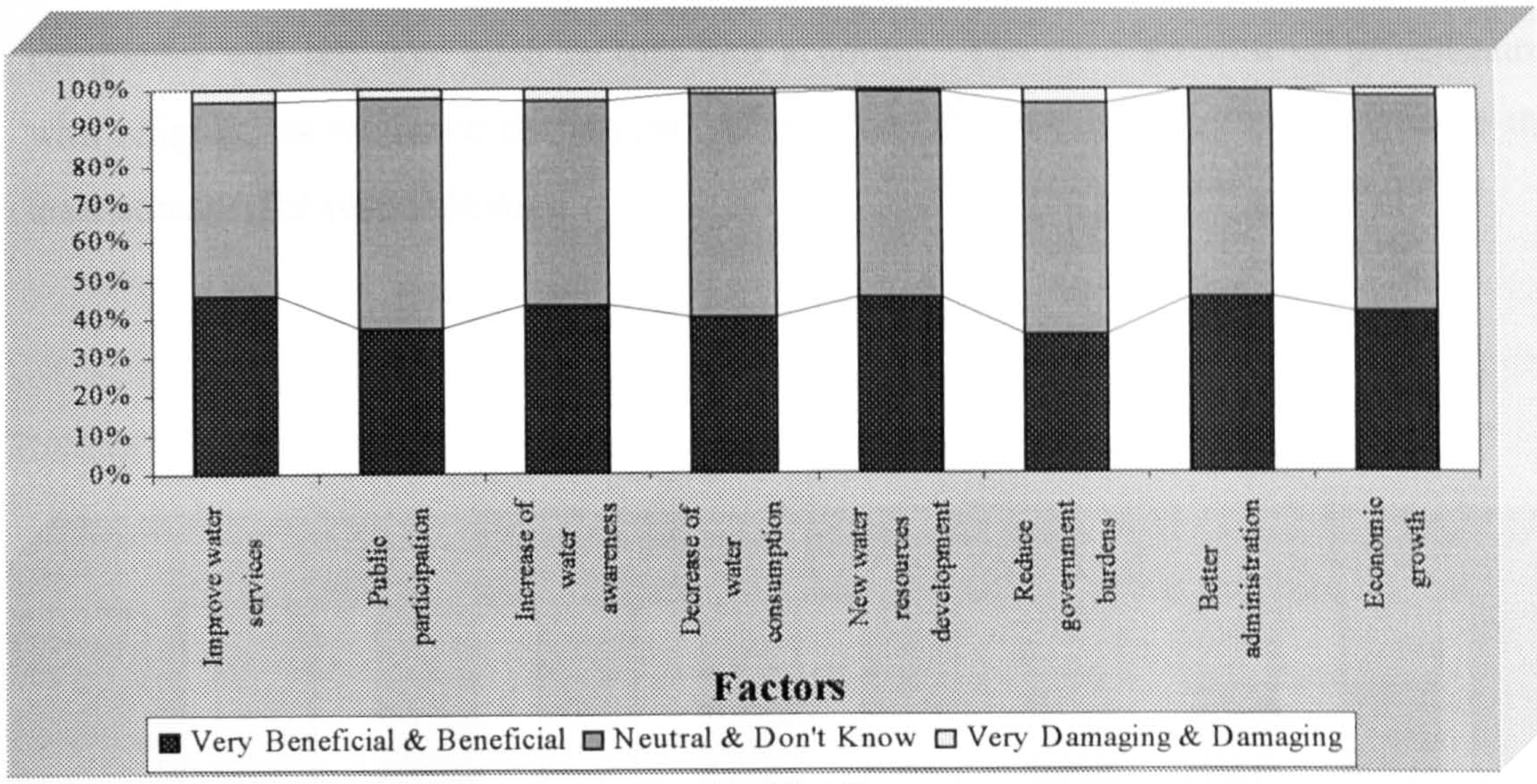

Figure 11.180. Perceived Benefits of Privatisation: Tariff Payers.

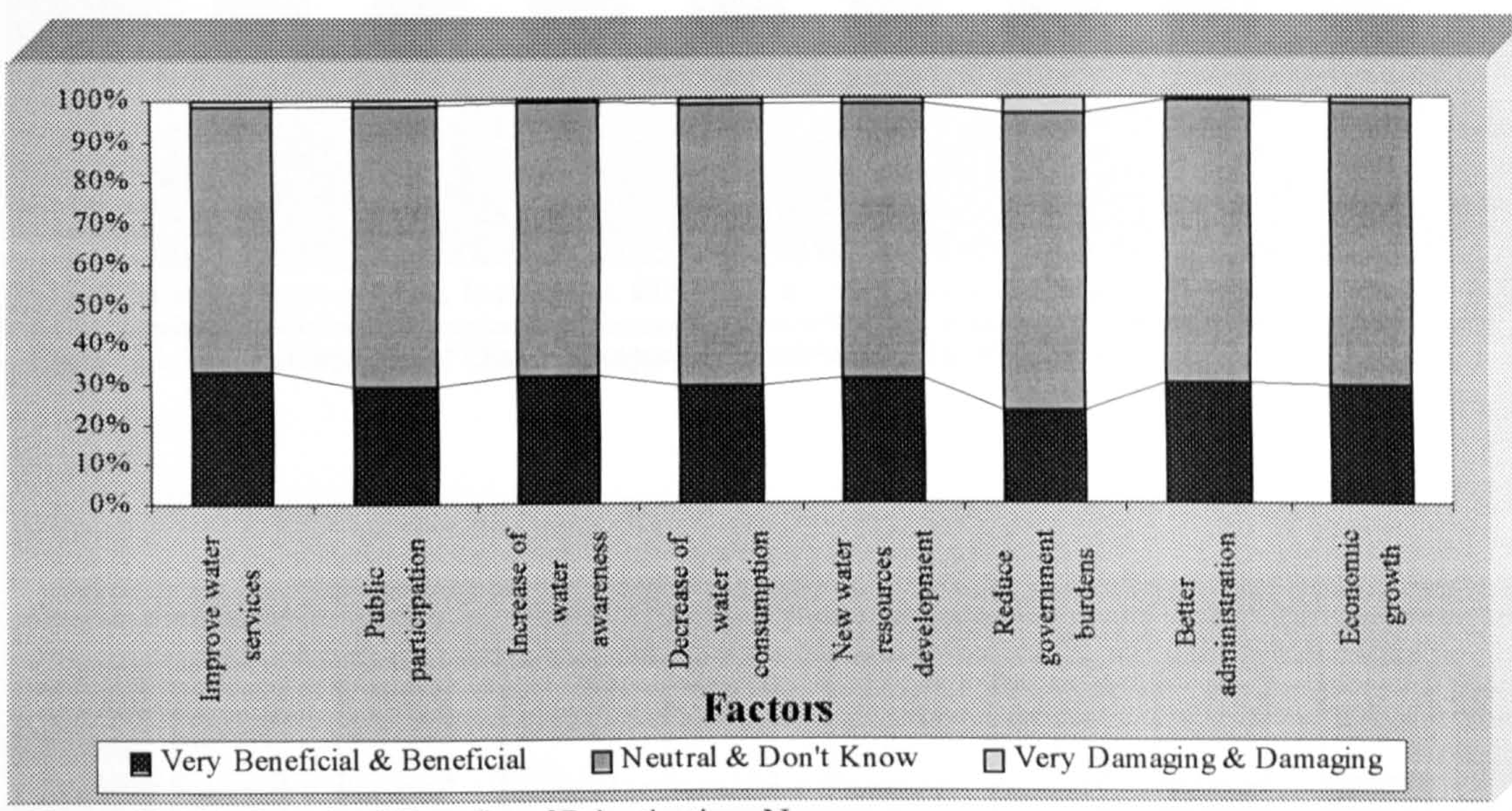

Figure 11.181. Perceived Benefits of Privatisation: Non-payers.

11.3.8.3. Influence of Tariff Payment on Perceived Disadvantages of Privatisation:

No significant difference exists between tariff payers and non-payers when asked about perceived disadvantage of privatisation (Figures 11.182 and 11.183). They agree that the rising cost of water, loss of jobs and monopoly of the sector are the most important negative consequences of privatisation. They believe that state ownership secures jobs and low cost water in order to avoid social upheaval, whereas private companies will not take such factors into account. The contradiction of privatisation with religion, its influence on national security and the possibility of conflicts were the least concern for respondents.

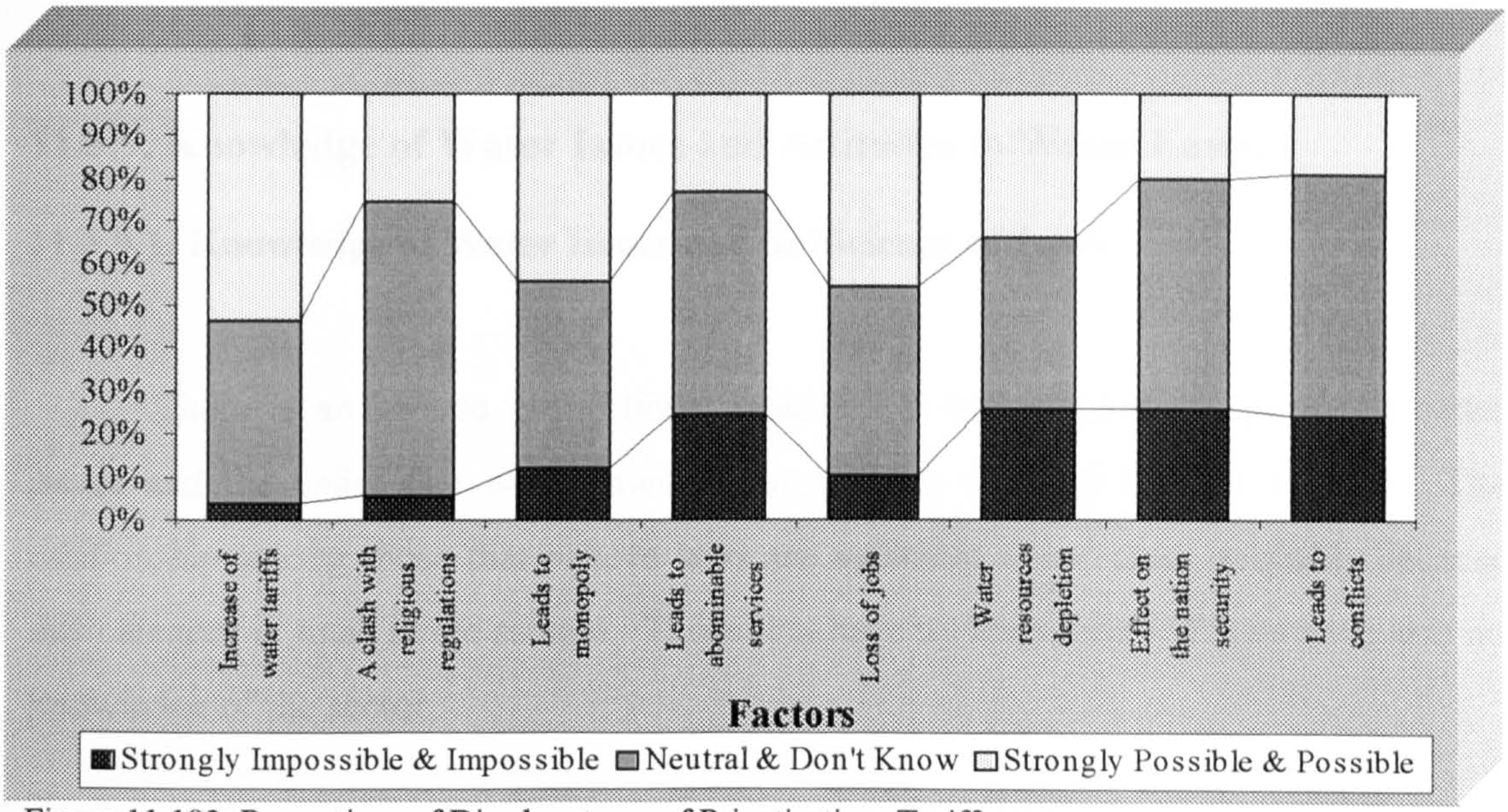

Figure 11.182. Perceptions of Disadvantages of Privatisation: Tariff-payers.

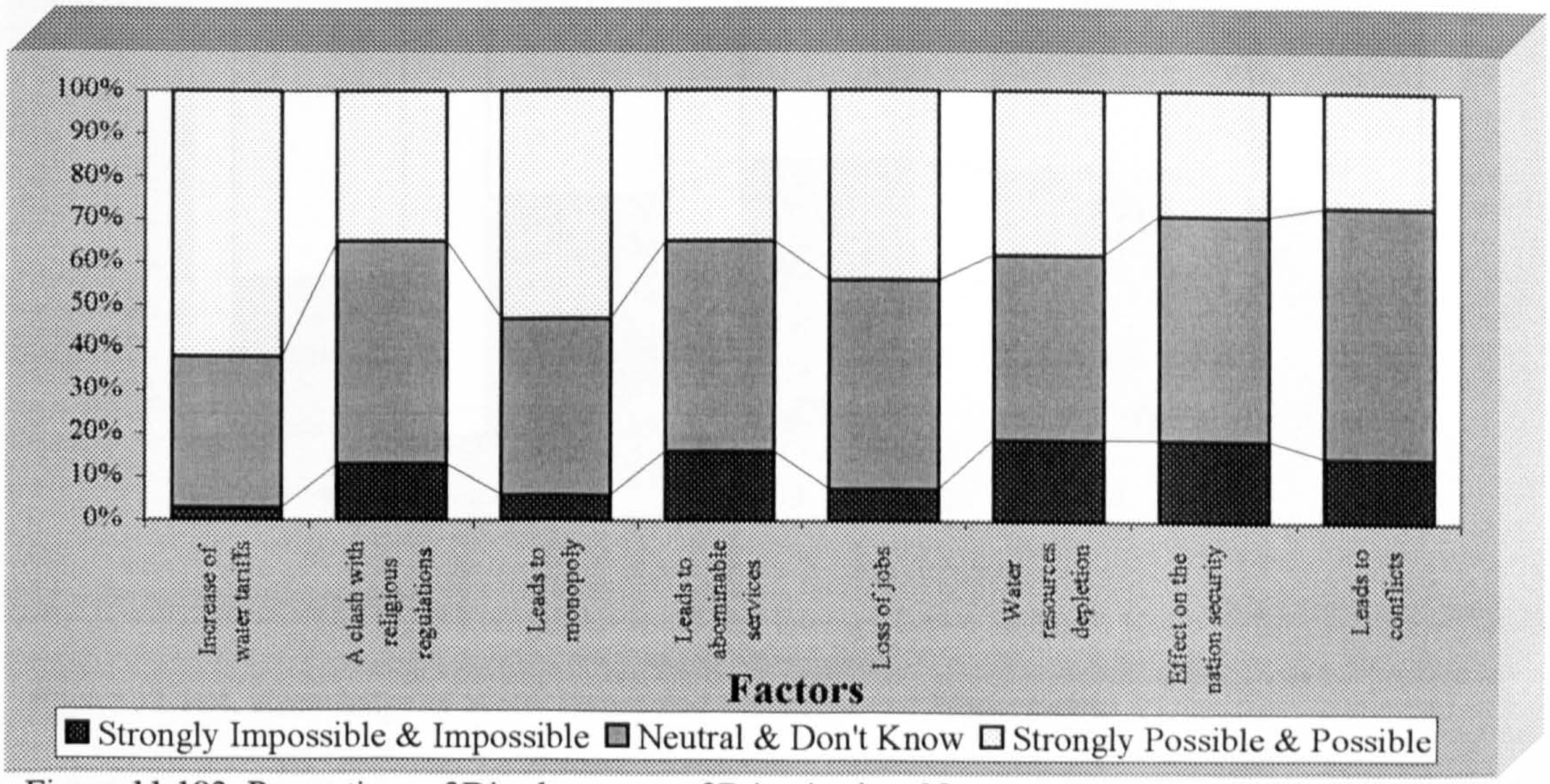

Figure 11.183. Perceptions of Disadvantages of Privatisation: Non-payers.

11.3.8.4. Conclusion:

Every one agrees that there is a need to develop the service and its management as well as raise the awareness of the importance of water. Those that support privatisation believe it can deliver such changes. Many tariff payers have no idea about the real cost of water in Qatar and believe they are paying the full cost, yet many are fearful of the effect of privatisation on water costs (Section 11.1.10).

11.3.9. Knowledge of Water Issues and Attitudes to Water Laws:

11.3.9.1. Knowledge of Water Issues and Sufficiency of Laws:

There is an inverse proportional relationship between knowledge about water issues and the belief that water laws are insufficient in Qatar (Figure 11.184). The relationship among those that believe laws are sufficient is not clear, probably because this category is small in the sample. Those that have no knowledge of laws have also no knowledge of the sector.

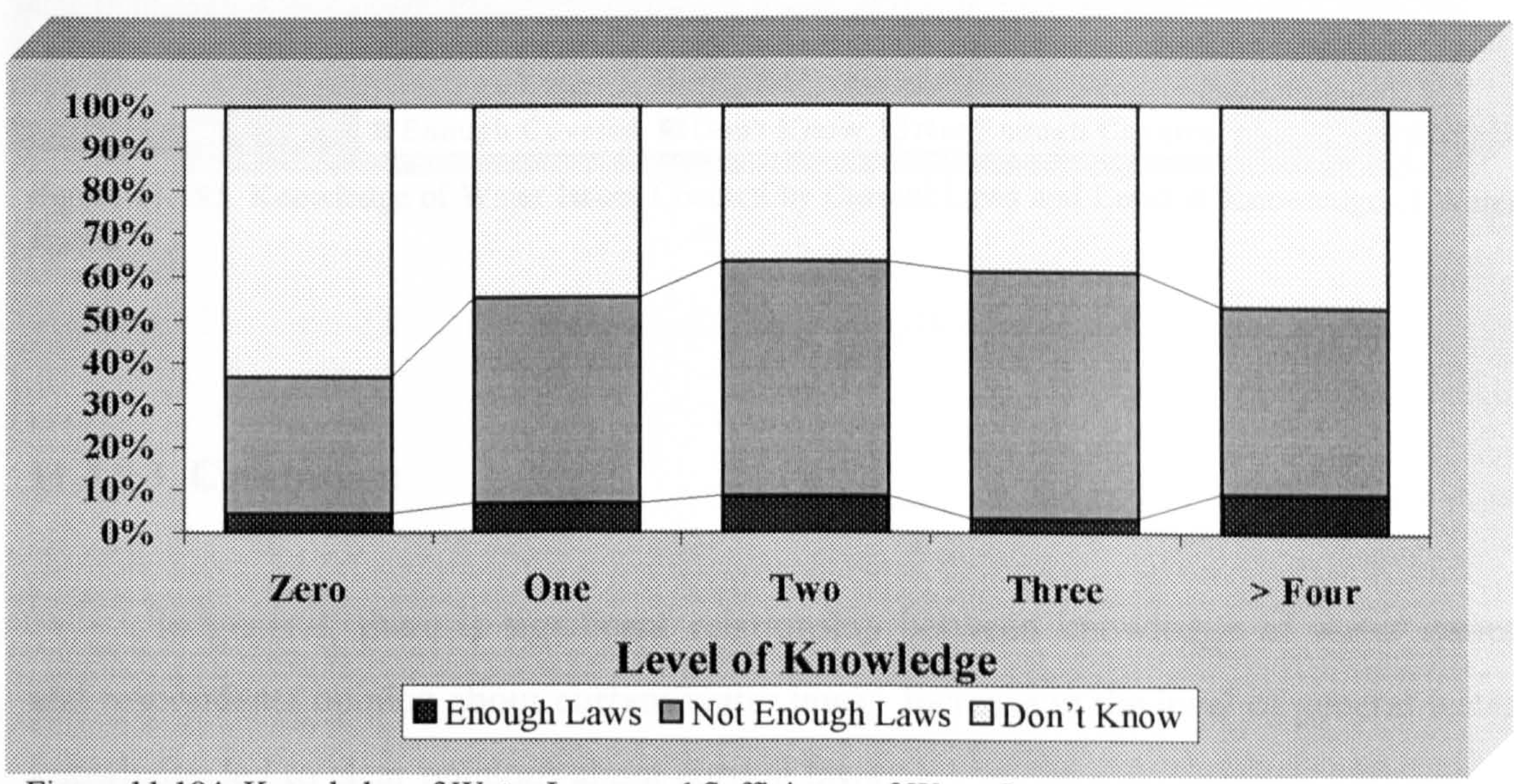

Figure 11.184. Knowledge of Water Issues and Sufficiency of Water Laws.

11.3.9.2. The Relationship between Knowledge of Water Issues and Issues Covered by Water Laws:

This relation becomes even clearer when a comparison is made between people's general knowledge of water issues and their knowledge of the issues that the laws cover (Figure 11.185). People that have greater knowledge of water issues tend to give clear opinions, especially on issues such as quality and consumption control. Those that do not have this knowledge know little of the laws and the issues they cover. This relationship between the extent of general knowledge and knowledge of laws is due to personal, often nationality and education-based differences rather to the strength or implementation of the laws.

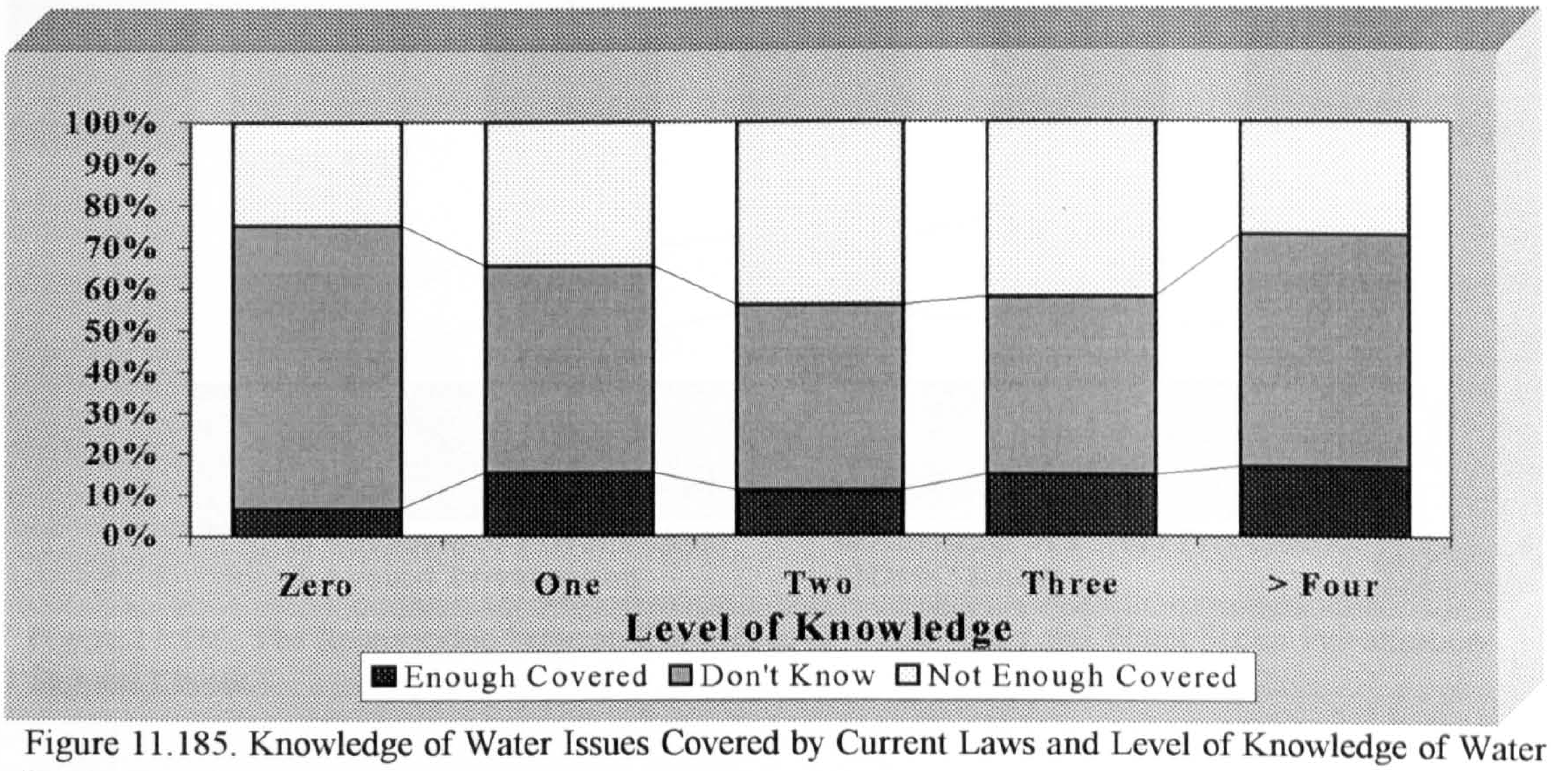

Figure 11.185. Knowledge of Water Issues Covered by Current Laws and Level of Knowledge of Water Issues.

11.3.9.3. Conclusion:

In general, there is significant relationship between knowledge of water issues and respondents opinion about current water laws. Increase in the level of general water knowledge led to clear opinions about current laws.

11.3.10. Knowledge of Water Issues and Attitudes to Water Sector Privatisation:

11.3.10.1. The Relationship between Knowledge of Water Issues and Attitudes to the Possibility of Privatisation:

There is no clear relationship between the extent of knowledge and support for the privatisation of the sector, although people with little knowledge are less likely to have an opinion. There is however a proportional relationship between knowledge and support for partial privatisation (Figure 11.186), which increases with the increase in the respondent's knowledge of water issues.

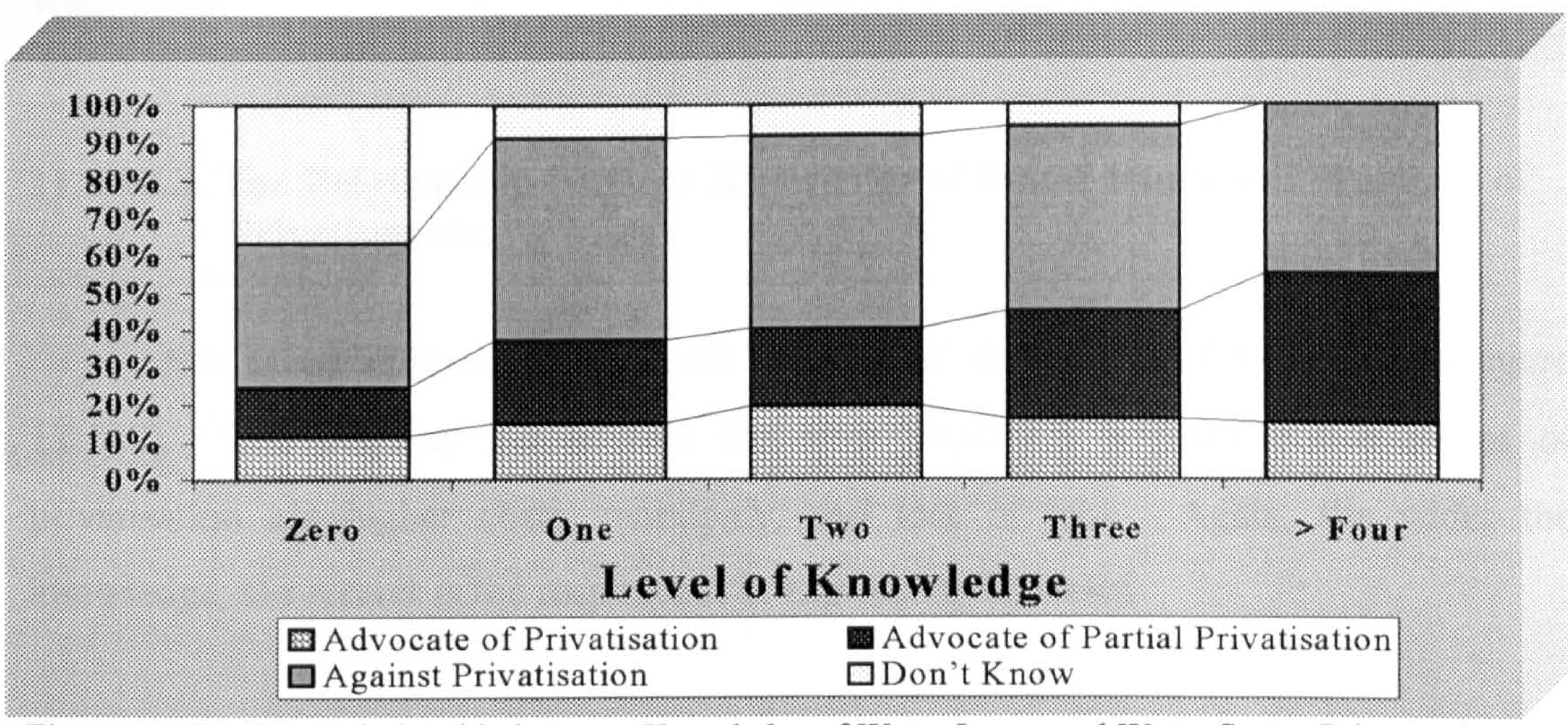

Figure 11.186. The Relationship between Knowledge of Water Issues and Water Sector Privatisation Support Levels.

11.3.10.2. Knowledge of Water Issues and Perceptions of the Benefits of Privatisation:

All respondent groups agree that the most important benefits of privatisation are improvement of the service, its management and raising water awareness (Figure 11.187). Being able to express clear views increased with an increase in knowledge. There was more support from respondents with general knowledge for factors such as administrative improvement and economic growth.

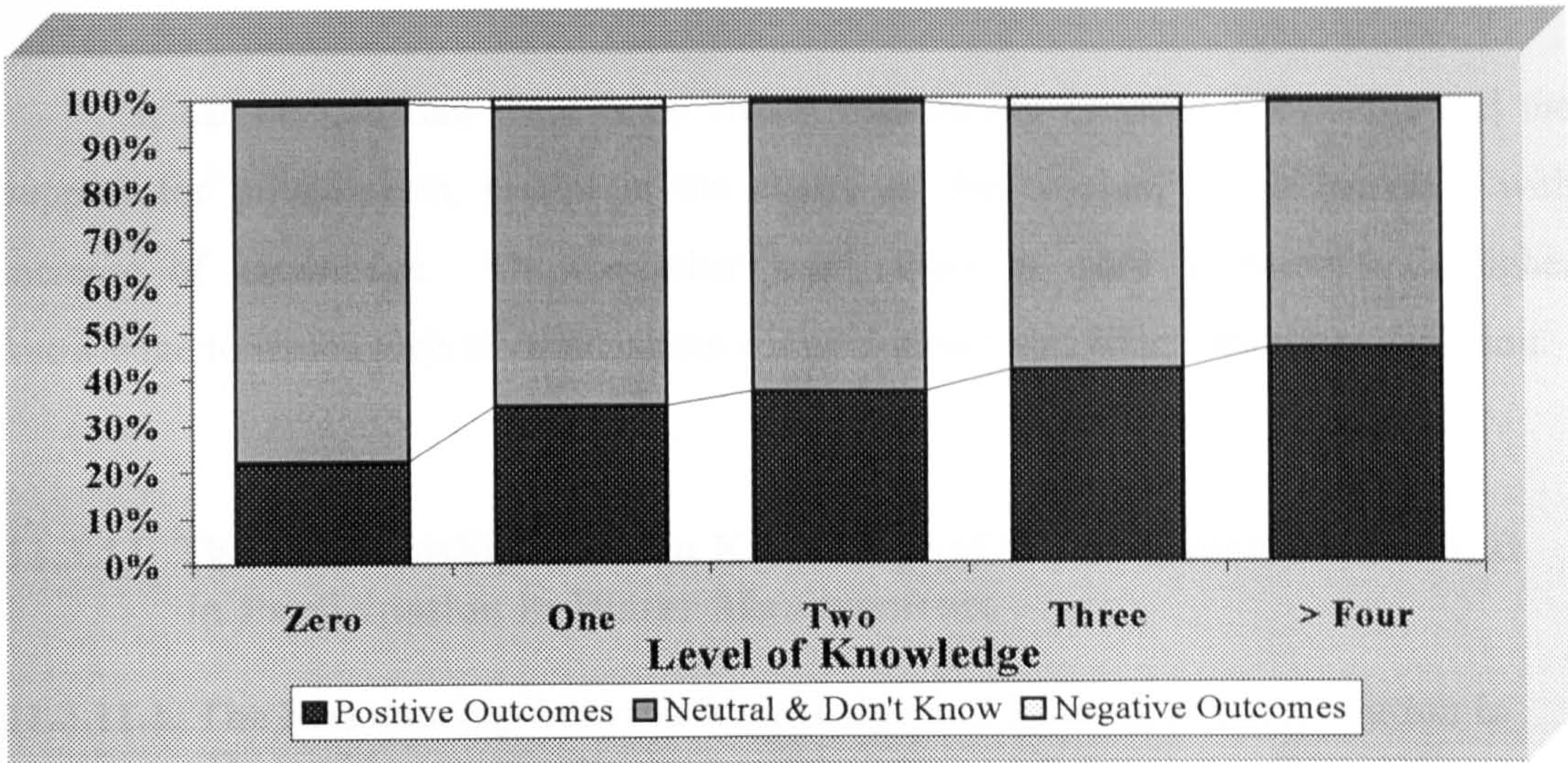

Figure 11.187. Attitudes of Supporters of Water Sector Privatisation and Level of Knowledge of Water Issues.

11.3.10.3. The Relationship between Knowledge of Water Issues and Problems of Privatisation:

Not many differences appeared because of the extent of knowledge (Figure 11.188). The majority agreed that the most important negative consequences of privatisation are higher costs, monopoly, and loss of jobs. Again, the wider the knowledge, the clearer is the respondent in expressing his views.

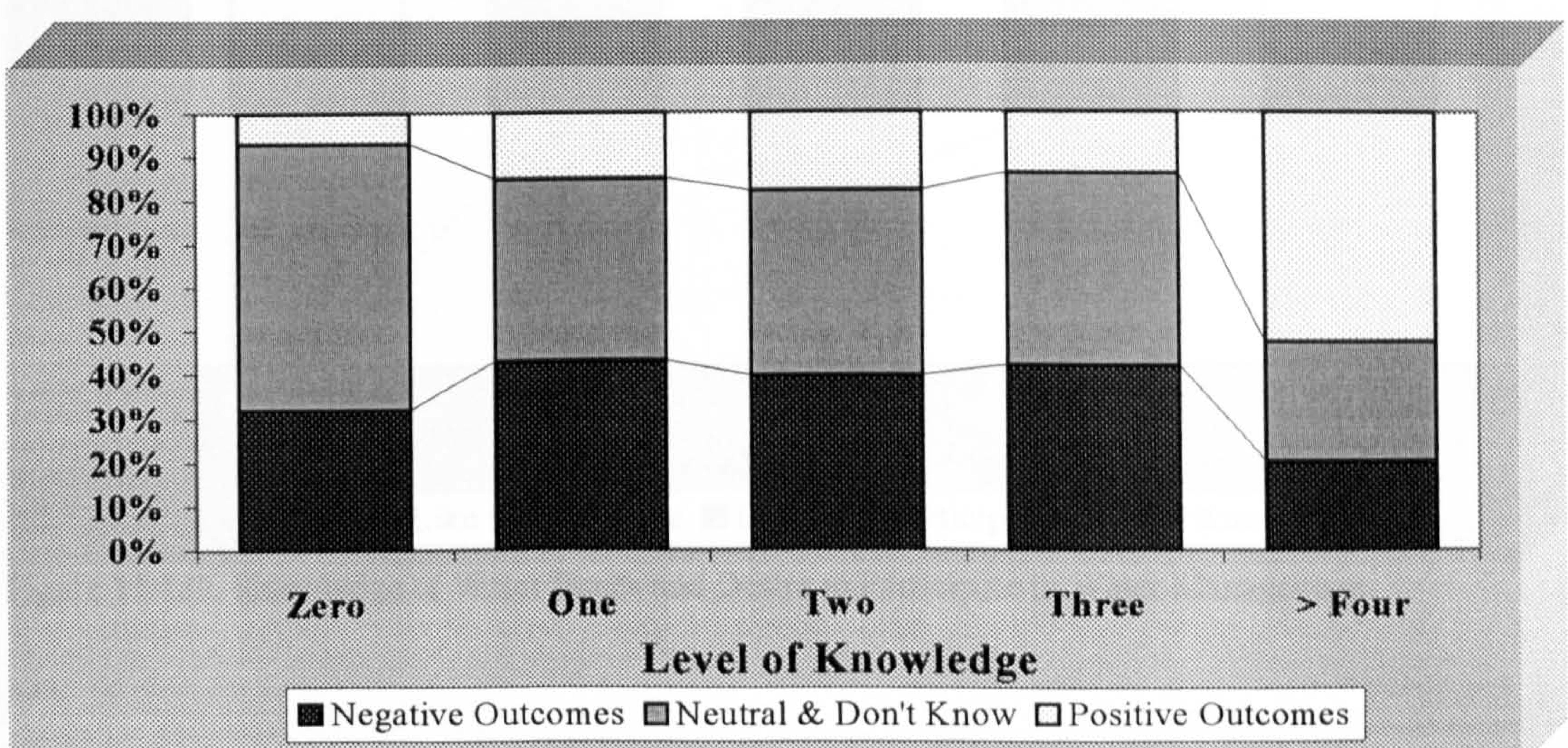

Figure 11.188. Attitudes of Rejecters of Water Sector Privatisation and Level of Knowledge of Water Issues.

11.3.10.4. Conclusion:

It can be said that there is no strong relationship between knowledge and the support for privatisation, except in the clarity of the opinion, which increases with increase of knowledge. On the other hand, there is more attention with higher knowledge to issues such as administrative improvement and water resources depletion.

11.3.11. The Relationship between Knowledge of Water Issues and Interest in Participation in Water Management:

11.3.11.1. The Relationship between Knowledge and Interest in Participation in Water Management:

There is a proportional relation between knowledge and interest in participation in the management of the water sector (Figure 11.189). The higher the level of knowledge the higher the number of those interested in participation. For Qataris the level of knowledge is linked to level of education and concern about local issues. Qataris are more supportive of the idea of participation. Foreigners believe it is difficult or virtually impossible.

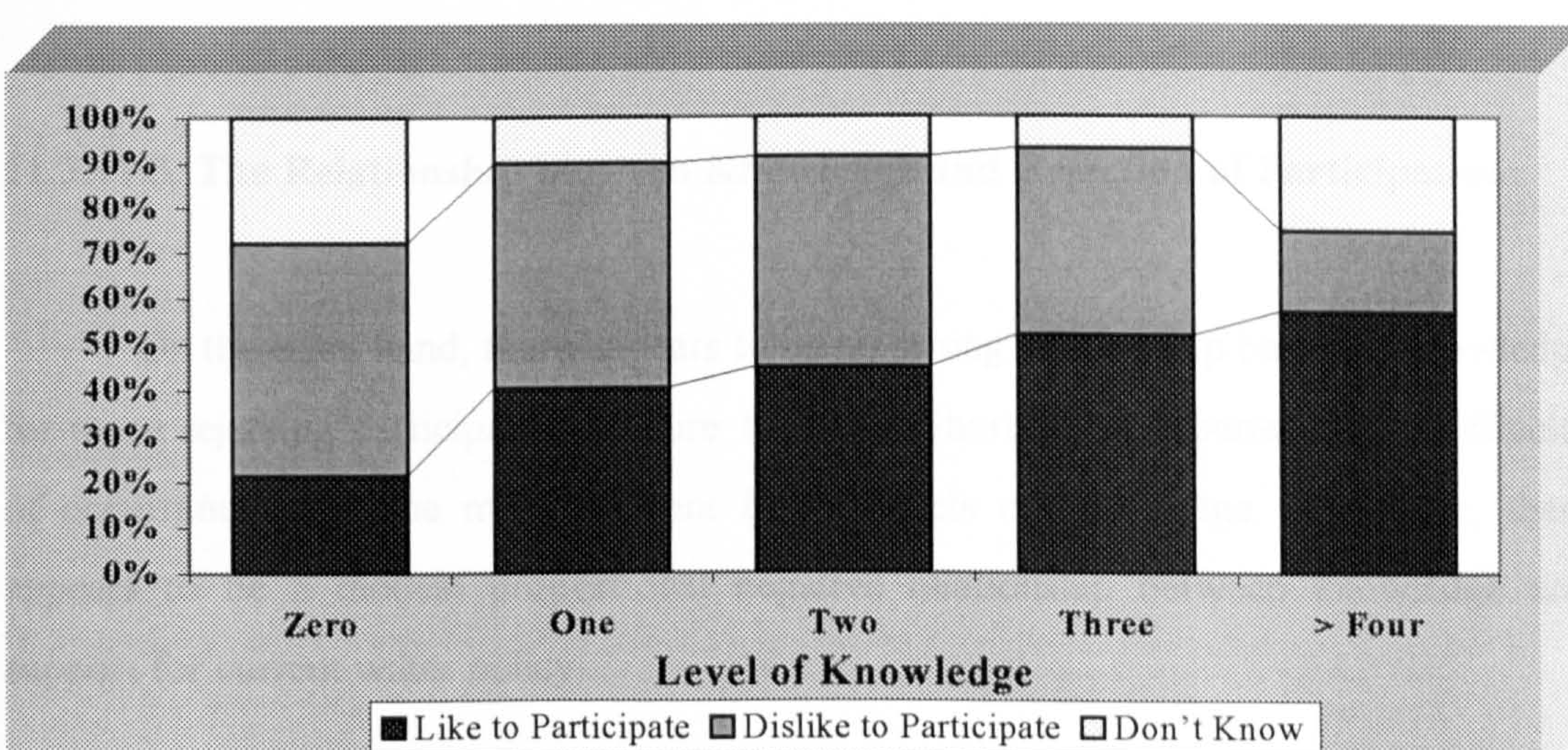

Figure 11.189. Knowledge of Water Issues and Desire to Participate in Water Management.

11.3.11.2. The Relationship between Knowledge and Support for Participation:

There appears to be no clear relationship between knowledge and the motivations for supporting participation (Figure 11.190). Improvement of the service, administration and raising awareness came at the top. However, there appears to be a modest proportional relationship between knowledge and support for participation.

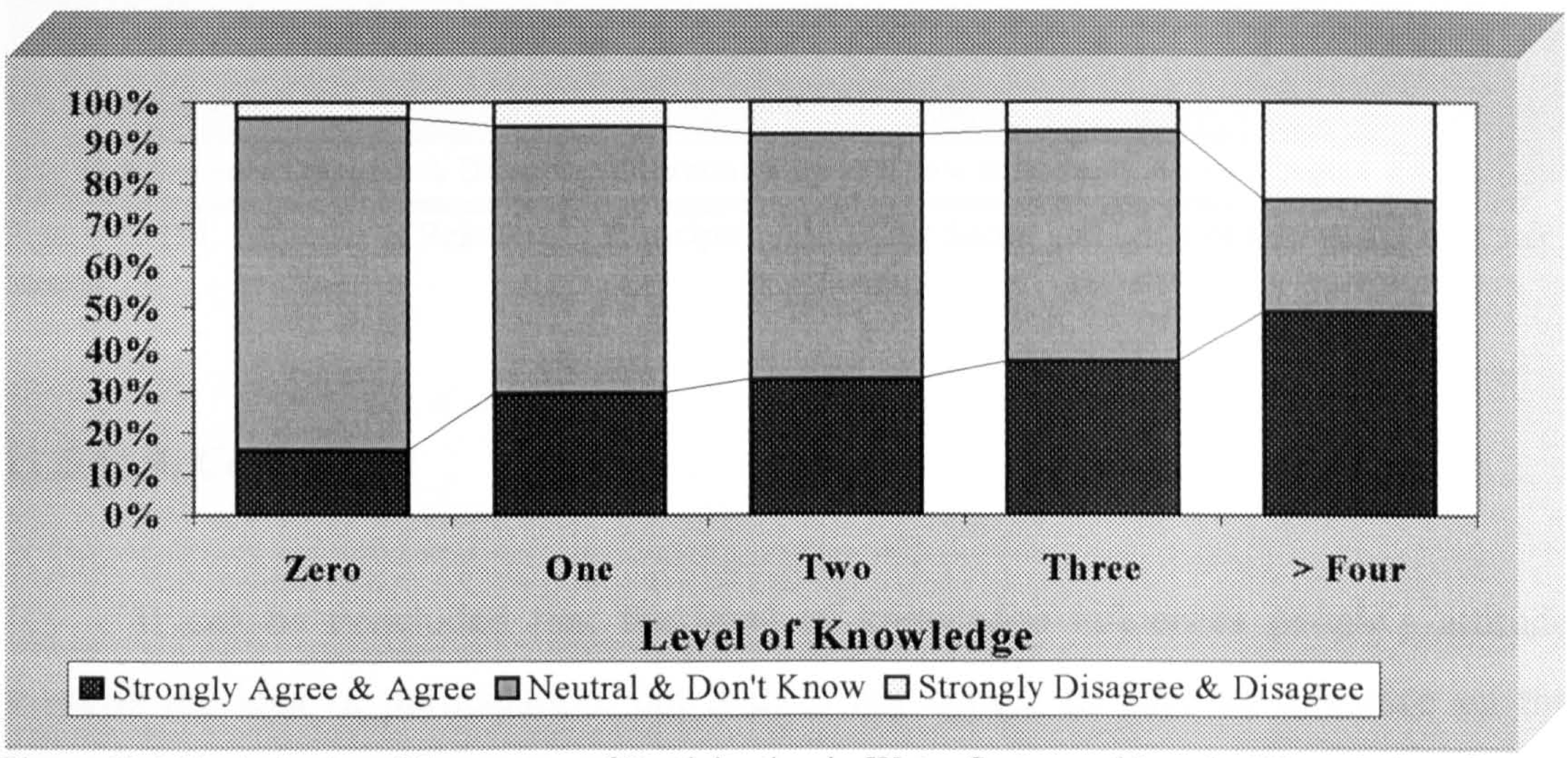

Figure 11.190. Attitudes of Supporters of Participation in Water Sector and Level of Knowledge of Water Issues.

11.3.11.3. The Relationship between Knowledge and Rejection of Participation:

On the other hand, there appears to be no strong relationship between knowledge for those rejecting participation (Figure 11.191). Shortage of experience and difficulty of occurrence were the most frequent for all levels of knowledge. However, there appears to be a modest proportional negative relationship between knowledge and support for current water policy.

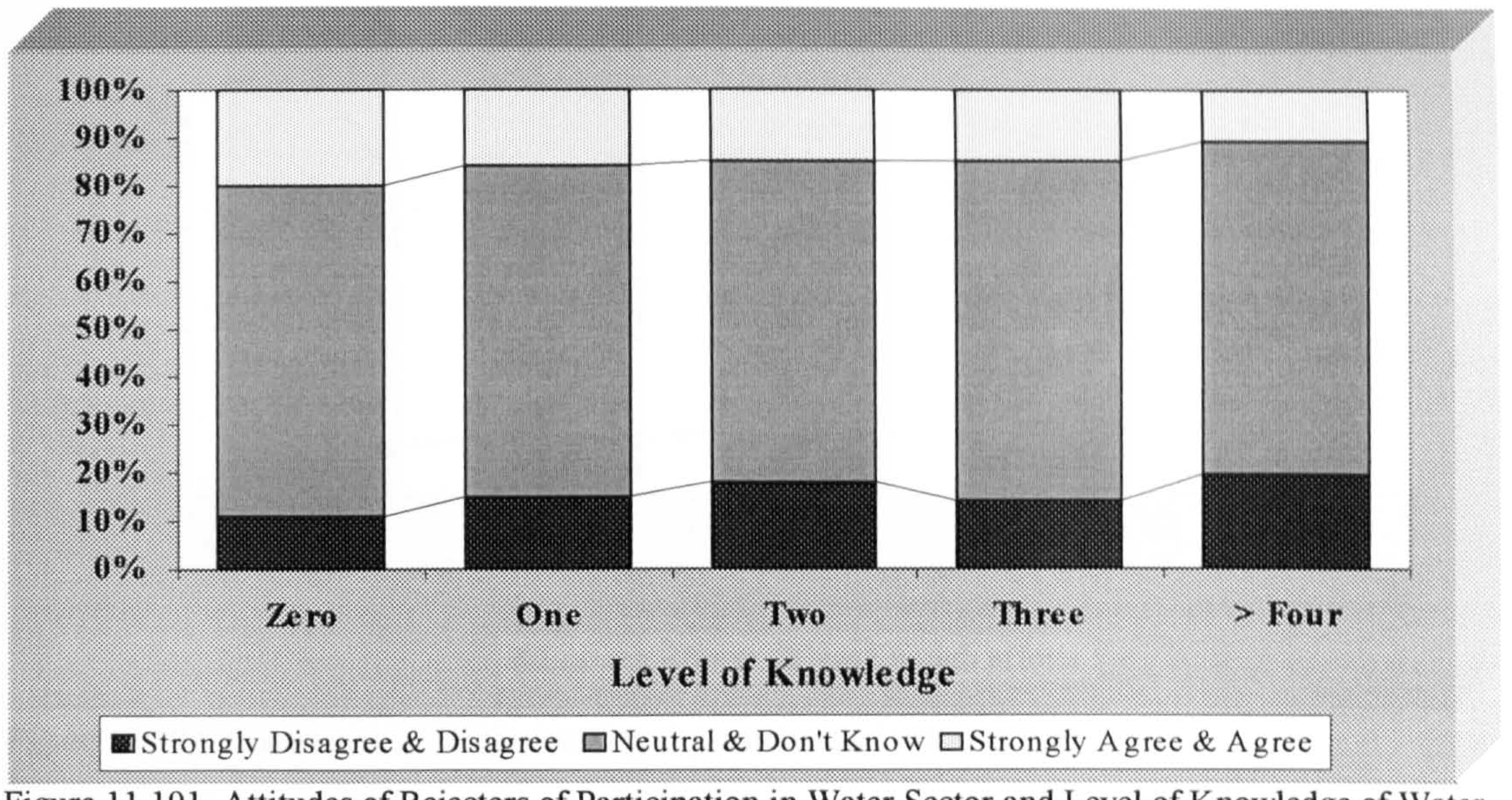

Figure 11.191. Attitudes of Rejecters of Participation in Water Sector and Level of Knowledge of Water Issues.

11.3.11.4. Conclusion:

It can be concluded that the level of knowledge influences people's attitude towards the idea of participation, but it does not appear to have an influence on the reasons for such support or rejection.

11.3.12. The Relationship between Knowledge of Water Issues and Public Behaviour:

11.3.12.1. The Relationship between Knowledge of Water Issues and Awareness Efforts:

There is little relationship between level of knowledge and the perception that there are not sufficient efforts to raise awareness of the water issue (Figure 11.192), below the level of 5 correct answers.

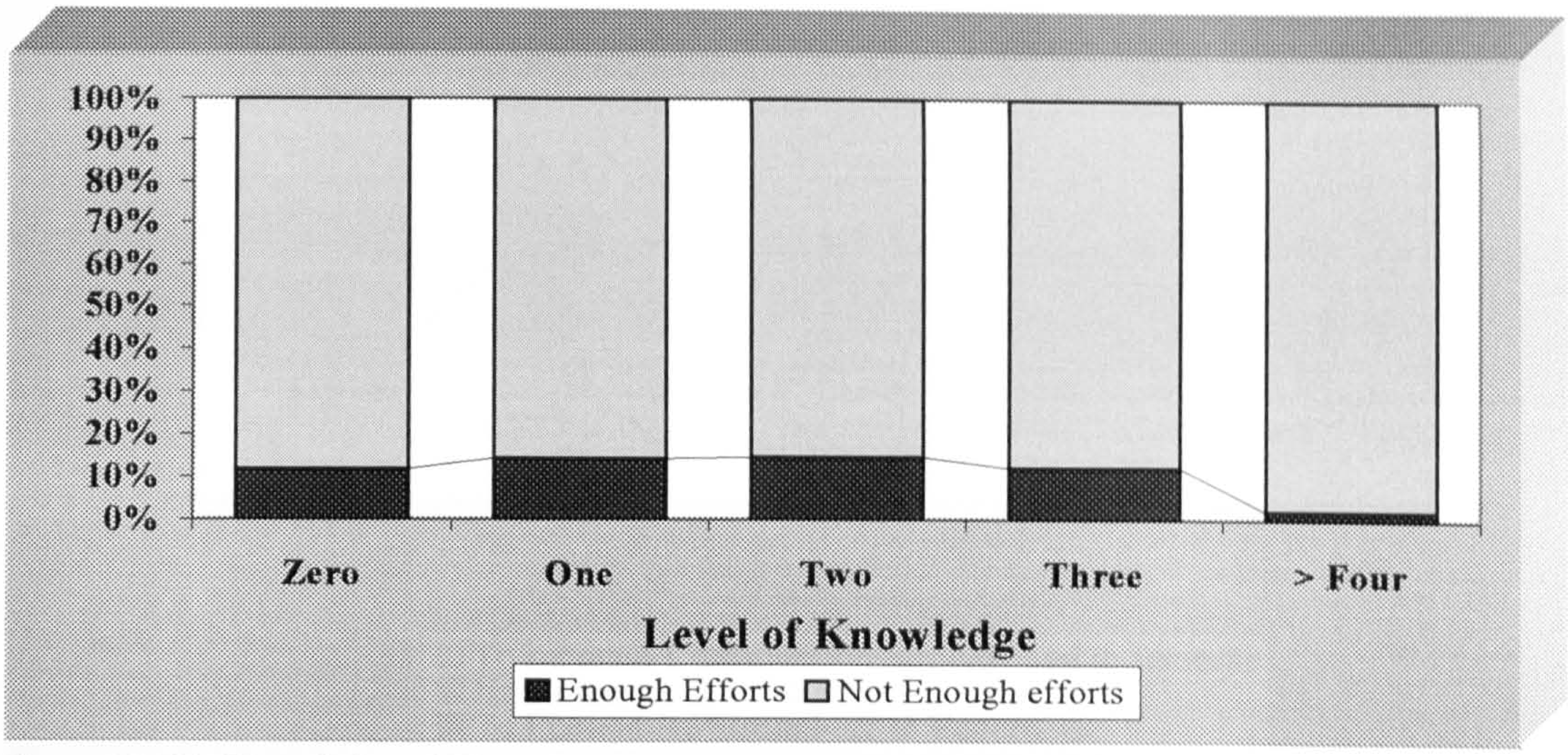

Figure 11.192. Knowledge of Water Issues and Awareness of Water Efforts.

11.3.12.2. The Relationship between Knowledge and Consumption Behaviour:

When investigating the relationship between knowledge and factors influencing economical consumption behaviour the most important factors are religion, education and awareness from the media (Figures 11.193, 11.194 and 11.195). Level of knowledge is less significant for those citing religion as an important reason for economical behaviour than for family education and media. Other factors have less influence.

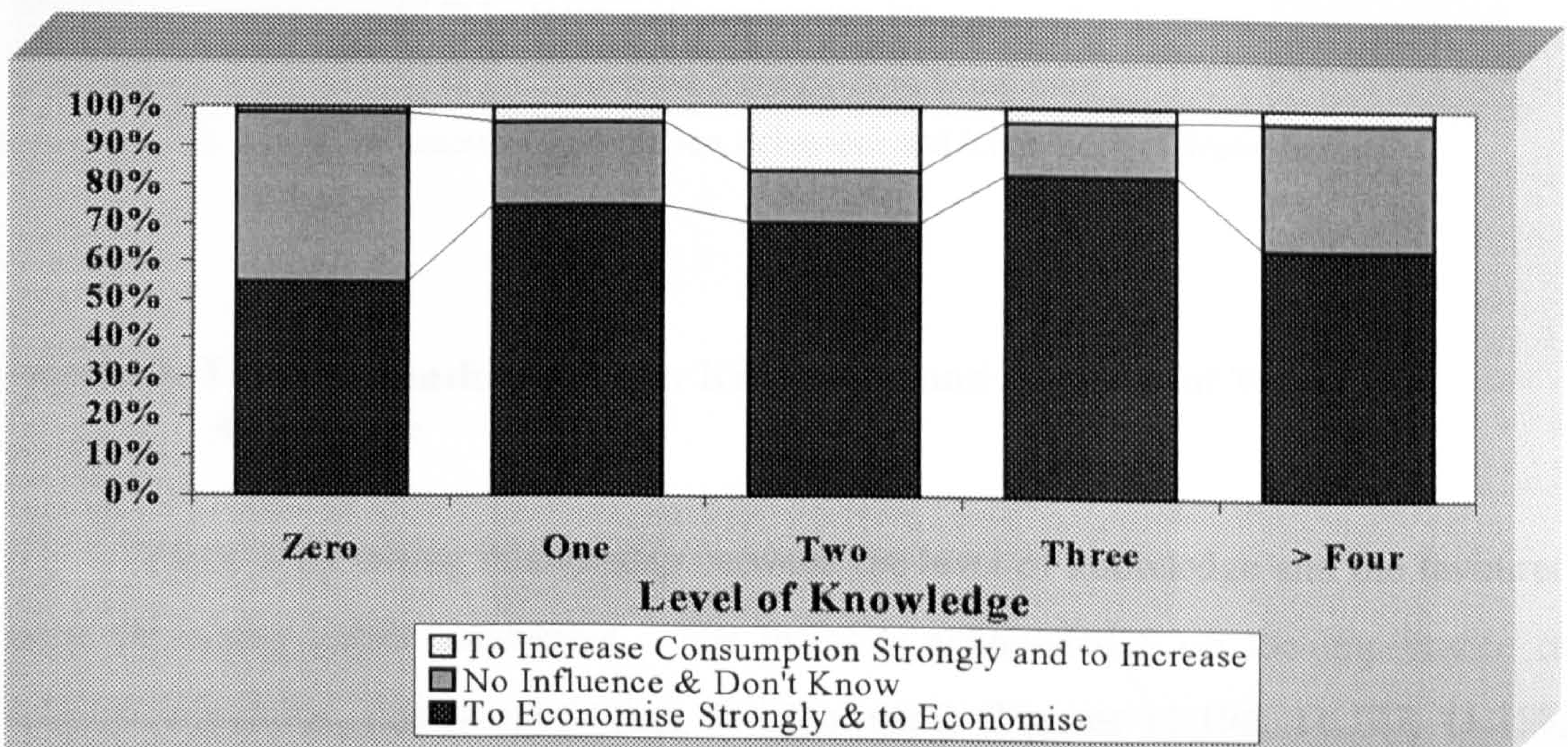

Figure 11.193. Religion Influencing Consumption Behaviour and Knowledge of Water Issues.

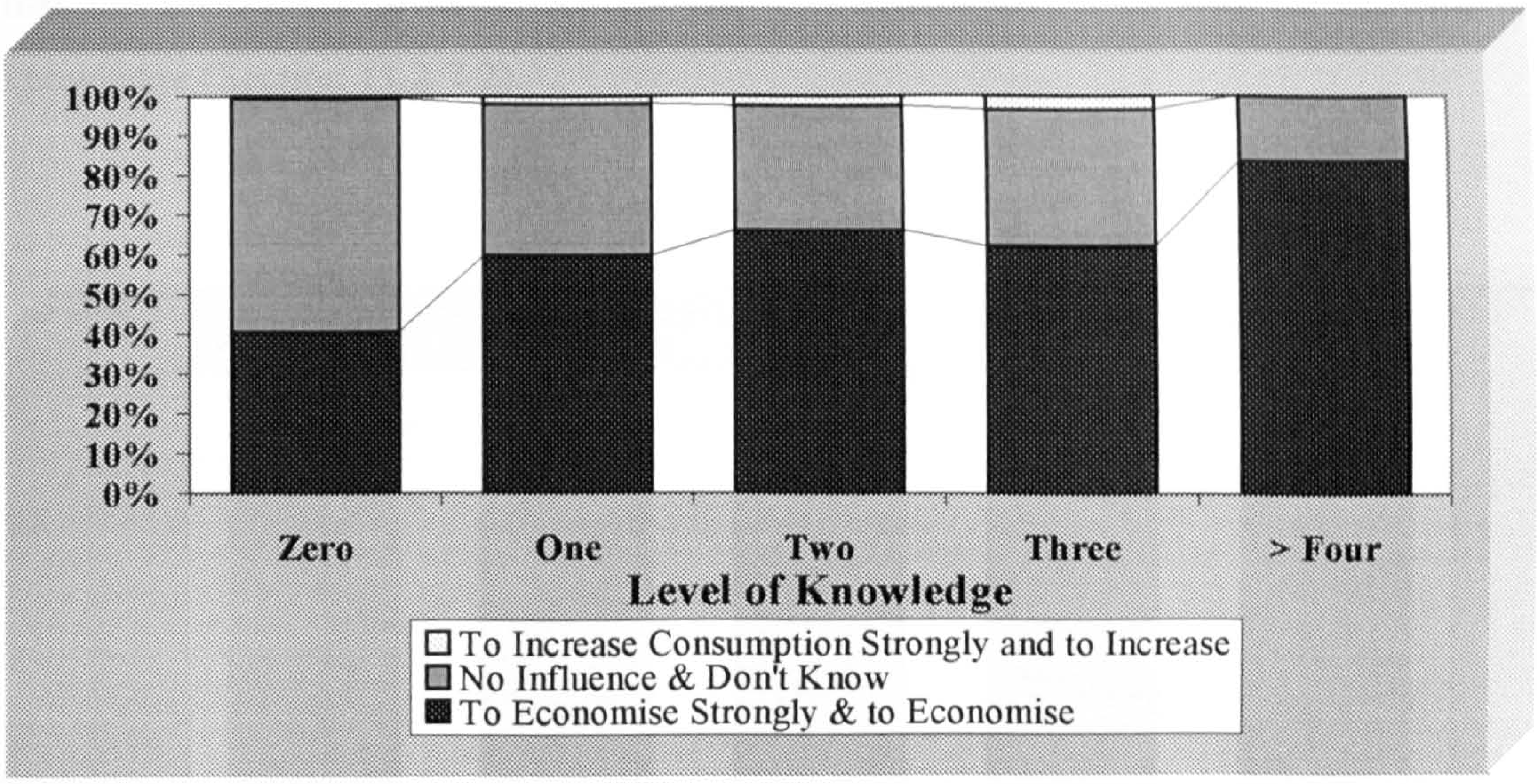

Figure 11.194. Family Education and School Influencing Consumption Behaviour and Knowledge of Water Issues.

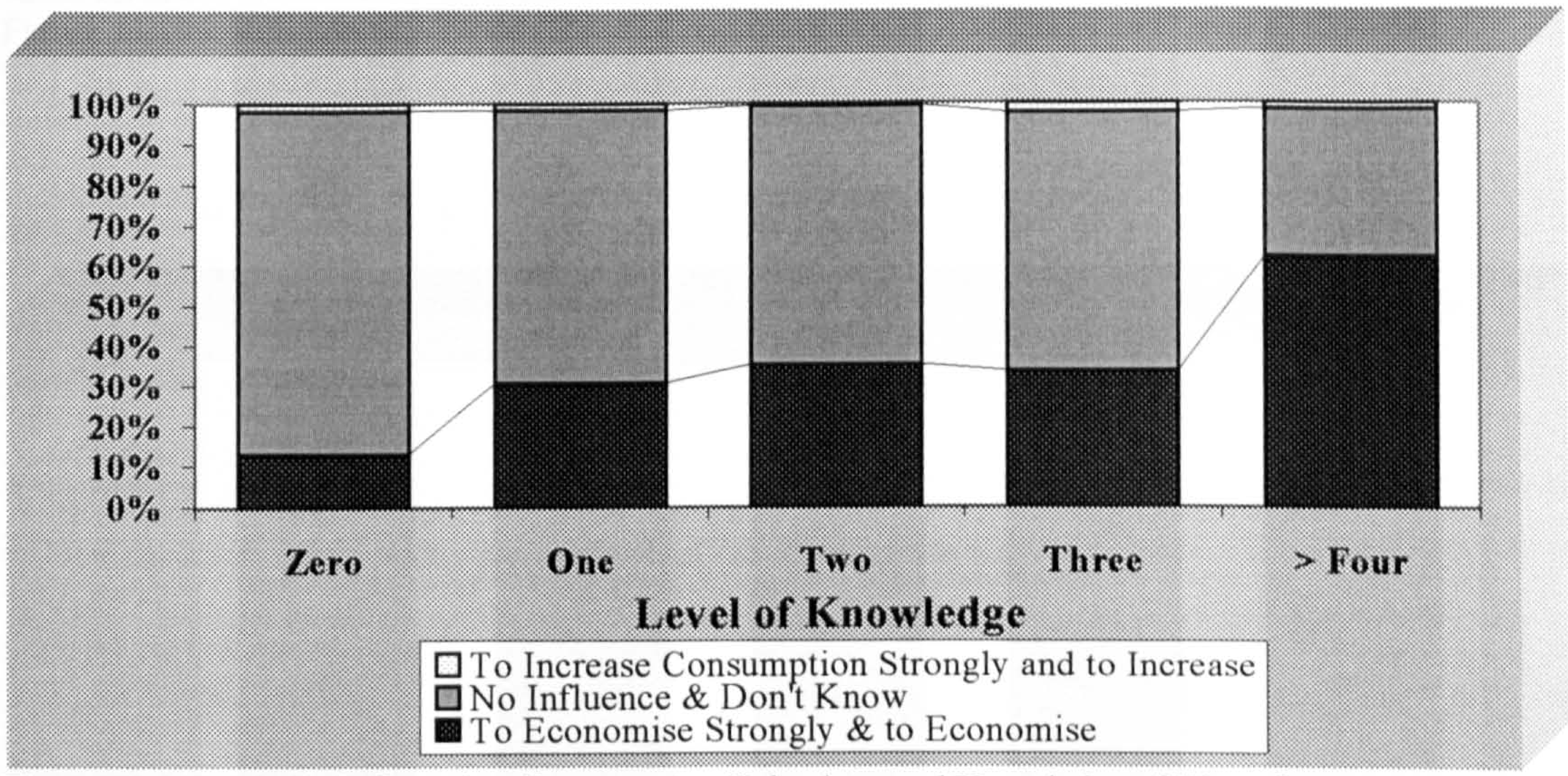

Figure 11.195. Media Influencing Consumption Behaviour and Knowledge of Water Issues.

11.3.12.3. The Relationship between Knowledge and Creation of Water Awareness:

There is no strong relationship between the level of knowledge and the favoured ways of raising public awareness. The majority acknowledge on the importance of religion, education, family upbringing, and the media (Figures 11.196, 11.197, 11.198, 11.199 and 11.200). Other factors were regarded as less important. It was noticeable that the importance given to reports and conferences decreases with an increase of knowledge (Section 11.2.7.2).

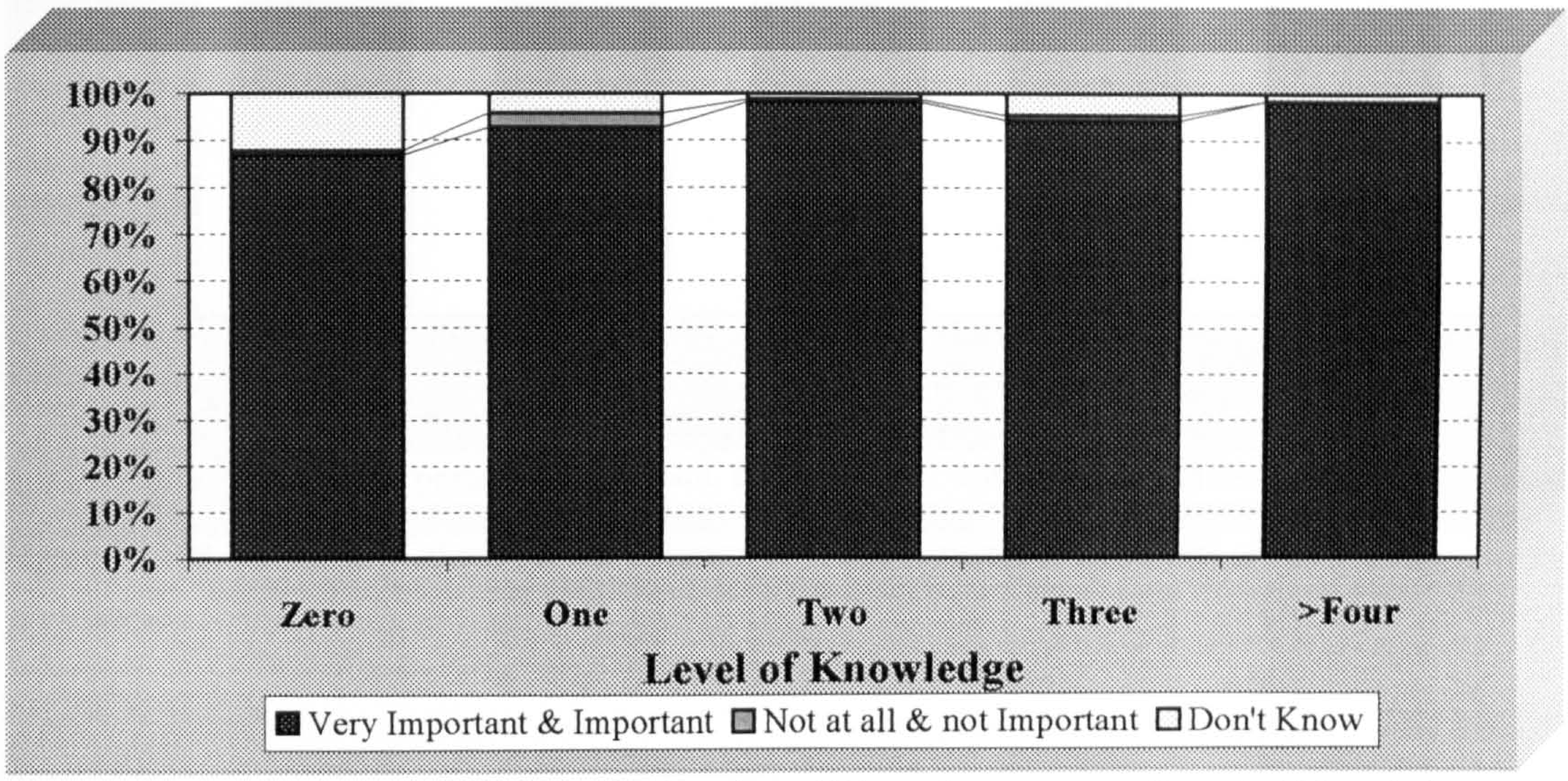

Figure 11.196. Religion as Methods for the Creation of Water Awareness and Level of Knowledge.

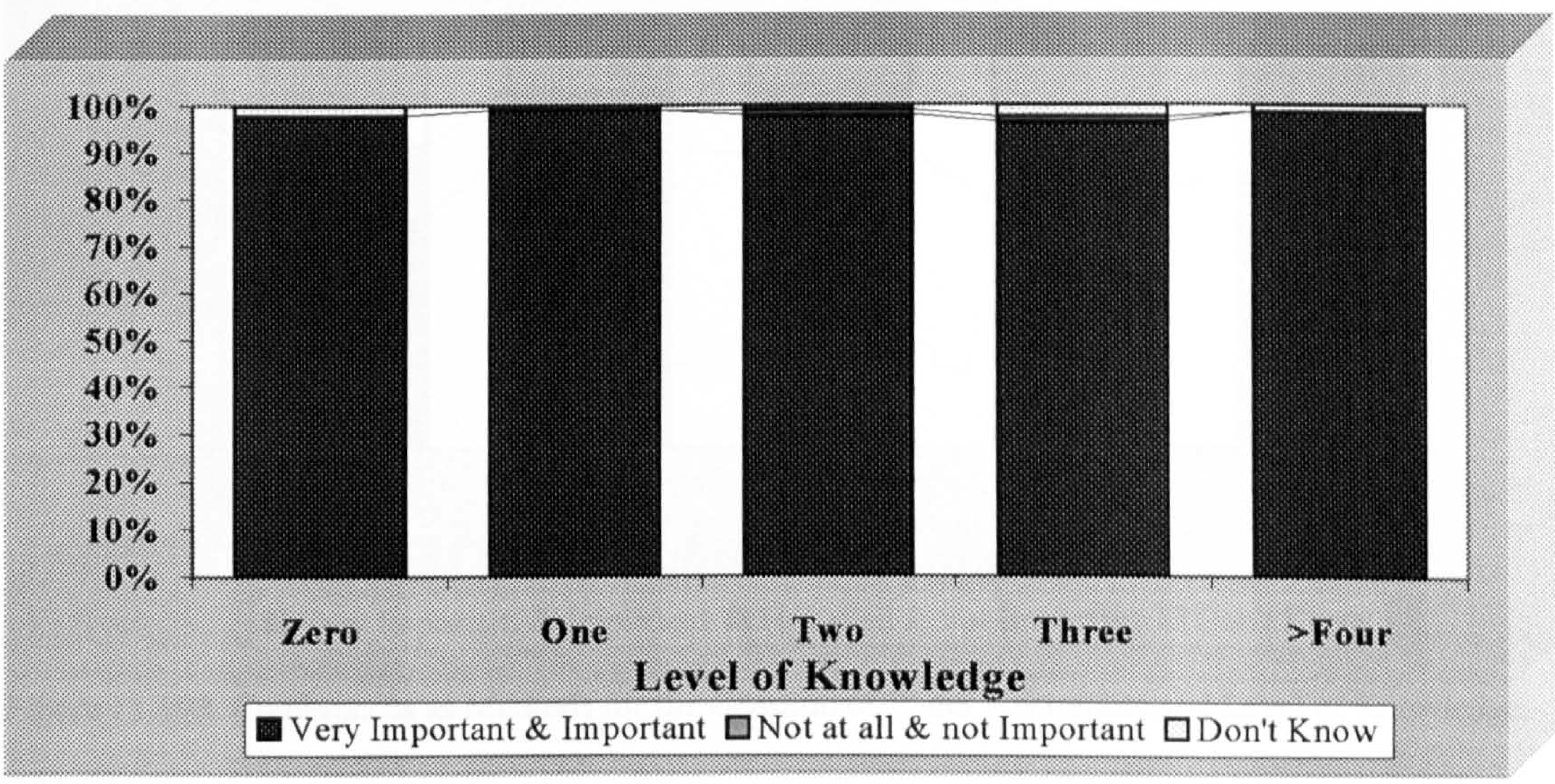

Figure 11.197. Family Education and School as Methods for the Creation of Water Awareness and Level of Knowledge.

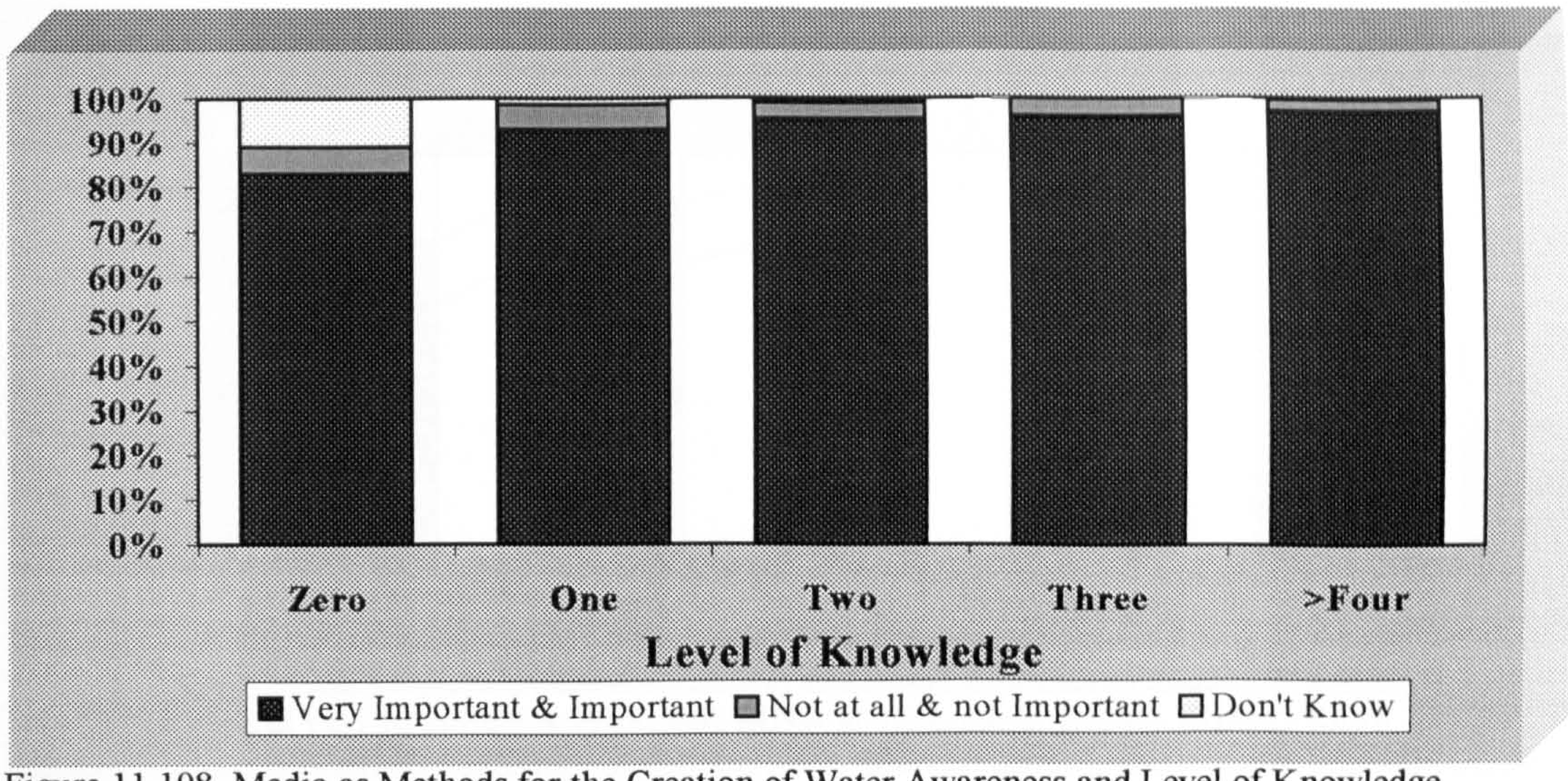

Figure 11.198. Media as Methods for the Creation of Water Awareness and Level of Knowledge.

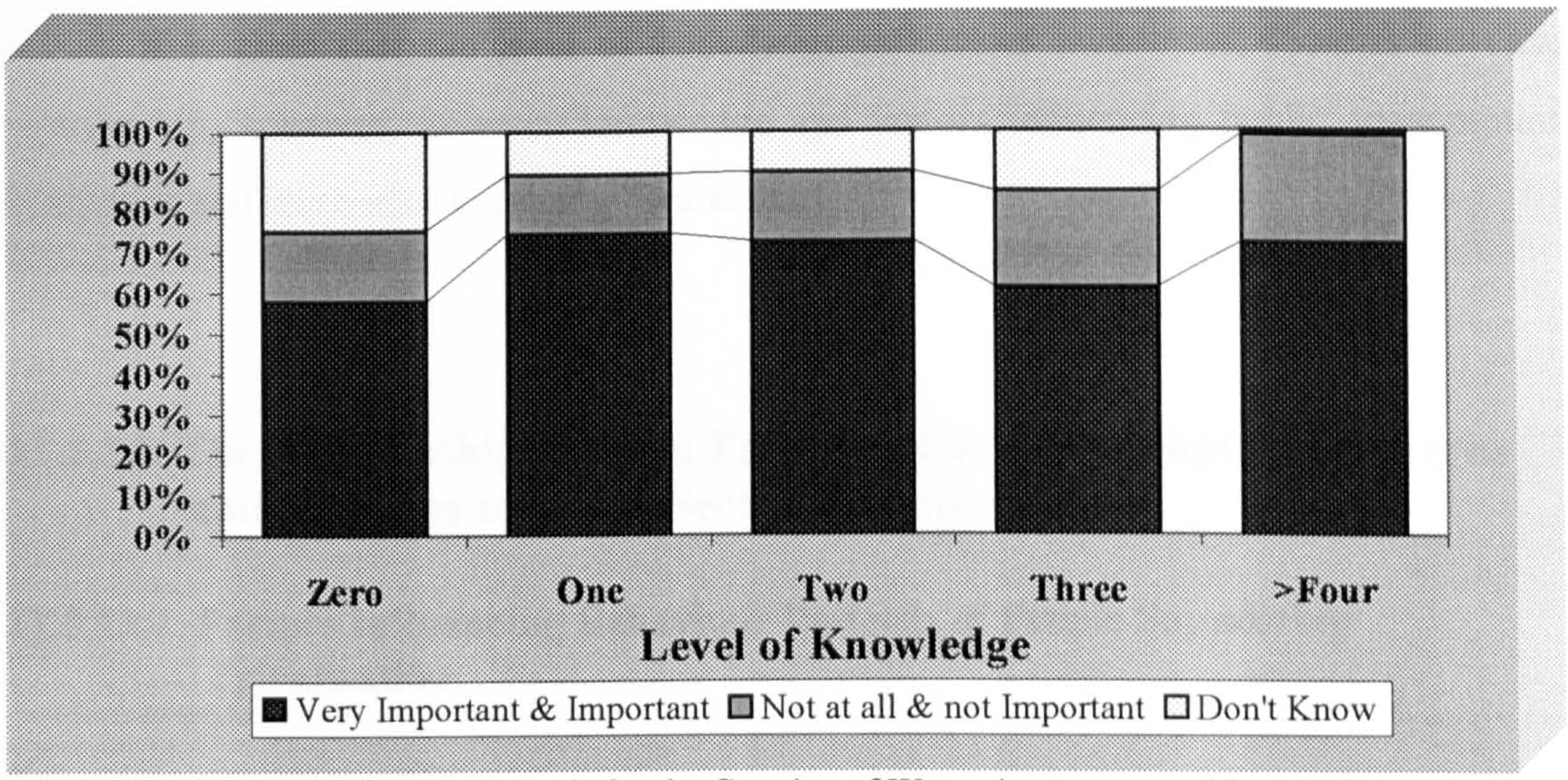

Figure 11.199. Conferences as Methods for the Creation of Water Awareness and Level of Knowledge.

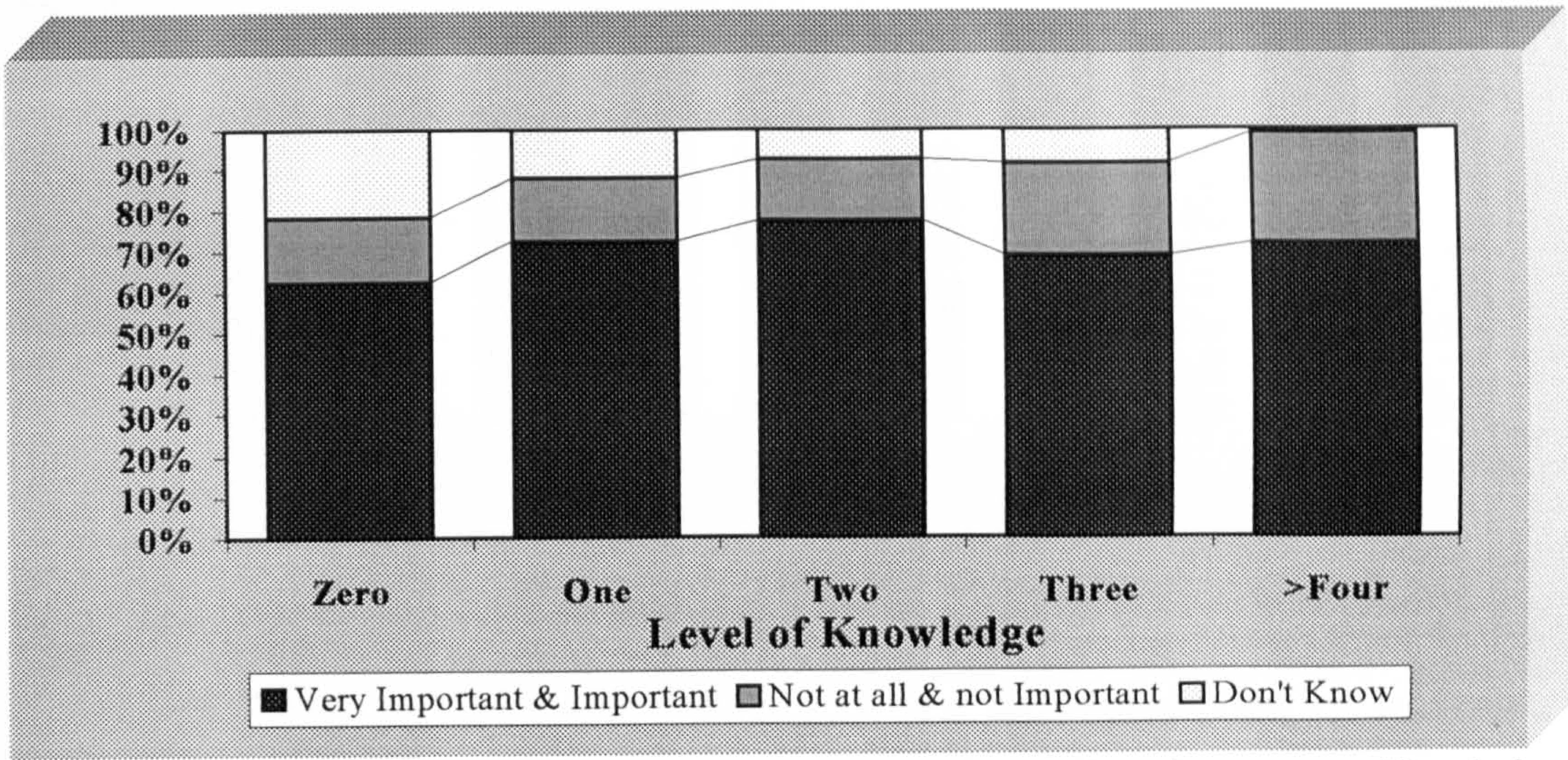

Figure 11.200. Prospectus and Reports as Methods for the Creation of Water Awareness and Level of Knowledge.

11.3.12.4. Conclusion:

It is clear that the level of knowledge influences awareness; there is no clear relationship, however, between knowledge and factors influencing public consumption behaviour and methods of creating awareness.

11.3.13. The Relationship between Factors Influencing Behaviour Patterns and Attitudes to Water Sector Privatisation:

11.3.13.1. Factors Influencing Behaviour Patterns of People Supporting Privatisation:

There is not a strong relationship between support for complete or partial privatisation and factors shaping consumption behaviour, which are availability of water, customs and traditions and living standards (Figures 11.201). Education, awareness, religion and tariffs are more important to supporters of partial privatisation.

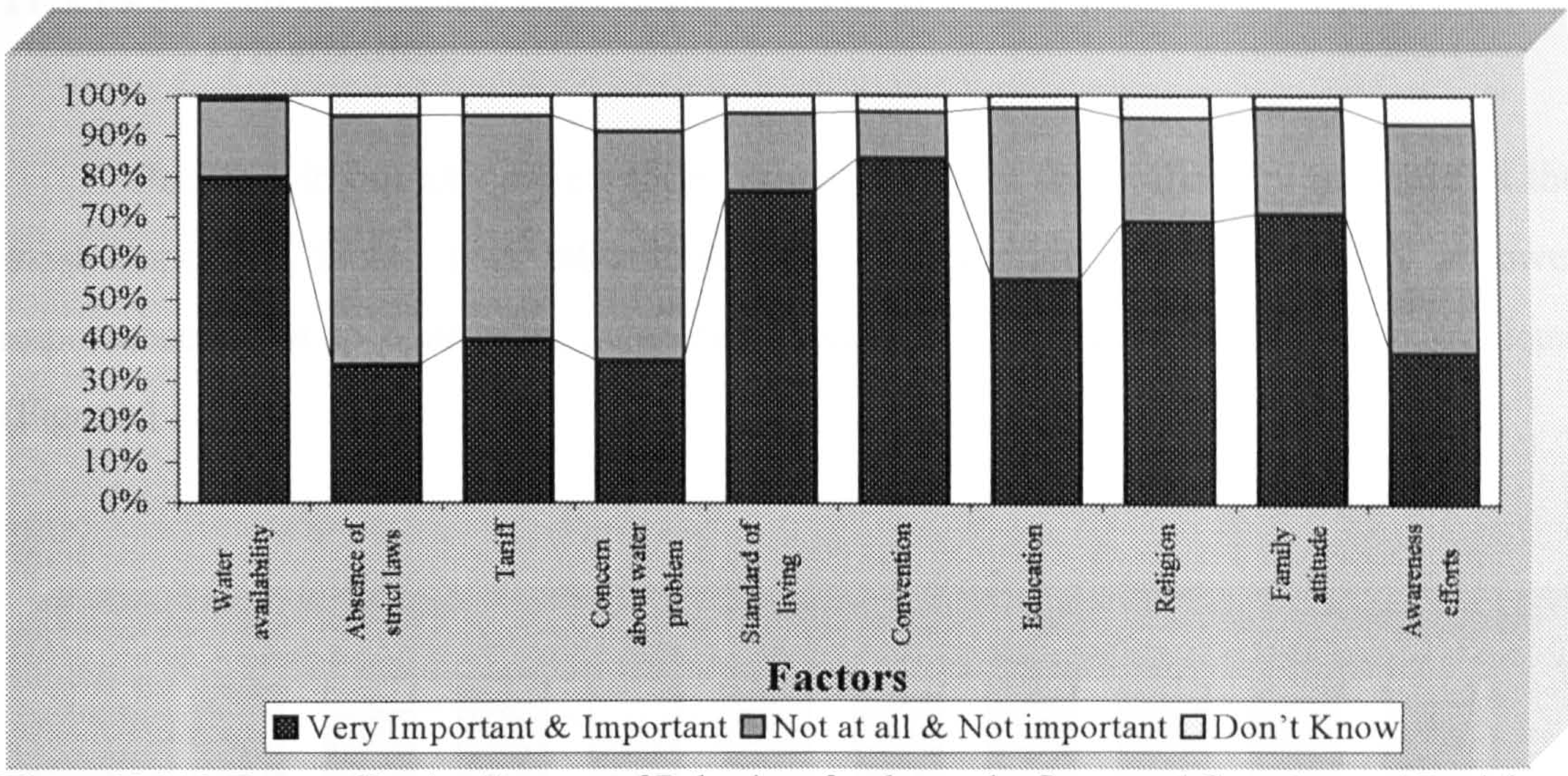

Figure 11.201. Factors Shaping Patterns of Behaviour for those who Supported Complete and Partial Water Sector Privatisation.

11.3.13.2. Factors Influencing Behaviour Patterns of People Rejecting Privatisation:

There is little significant difference in factors influencing behaviour between people who reject and accept privatisation (Figure 11.202). The higher is the level of objection to privatisation, the greater is the importance of education, awareness and religion. These people are aware of the negative aspects of privatisation feel that it contravenes religious maxims.

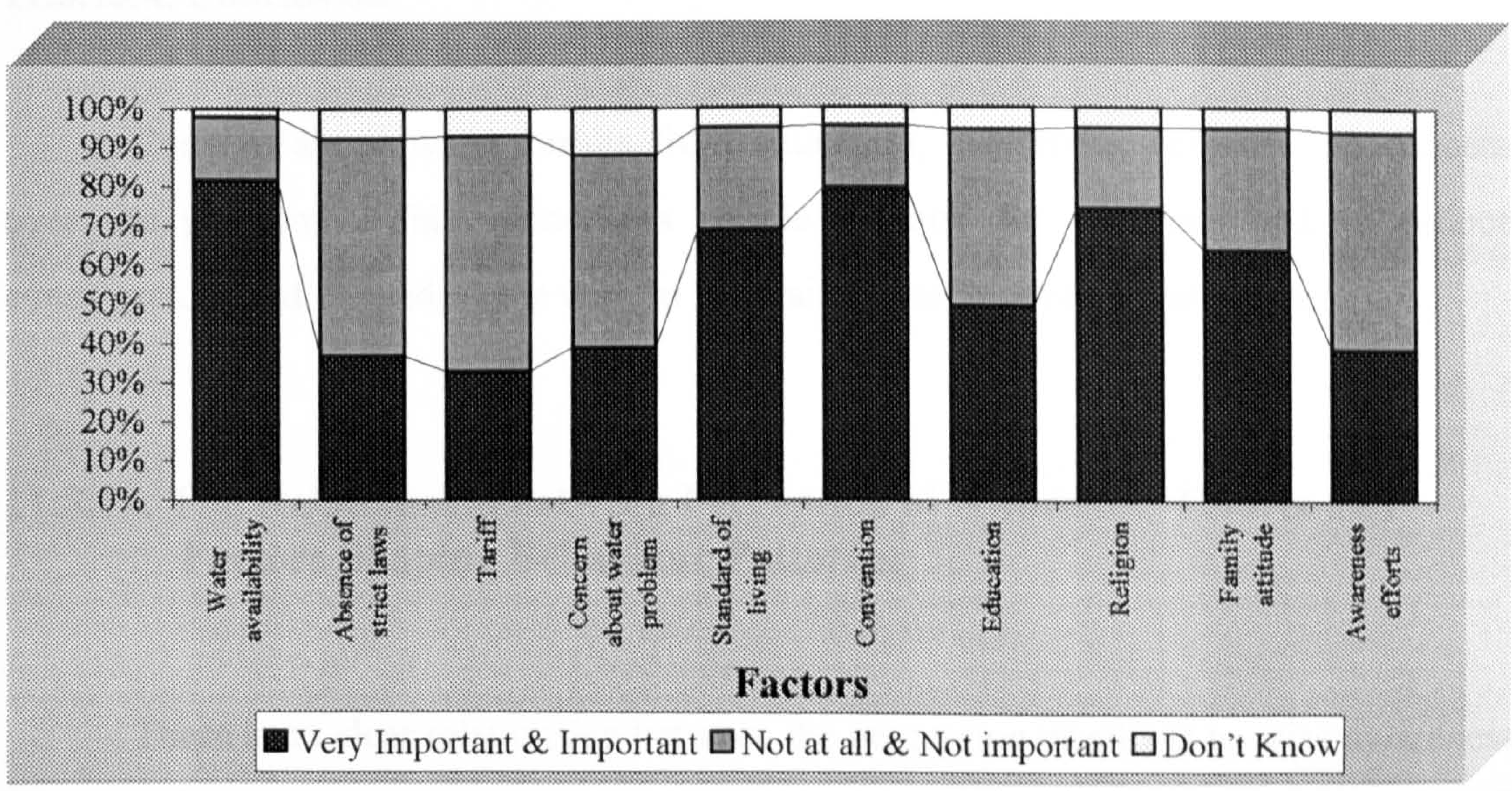

Figure 11.202. Factors Shaping Patterns of Behaviour for those who Rejected Water Sector Privatisation.

11.3.13.3. Factors Shaping Behaviour Patterns of People with No Opinion about Privatisation:

People without an opinion about privatisation list the availability of water as the most important factor that influences their consumption behaviour, with a lower importance given to education, awareness, religion and concern about water problems (Figure 11.203).

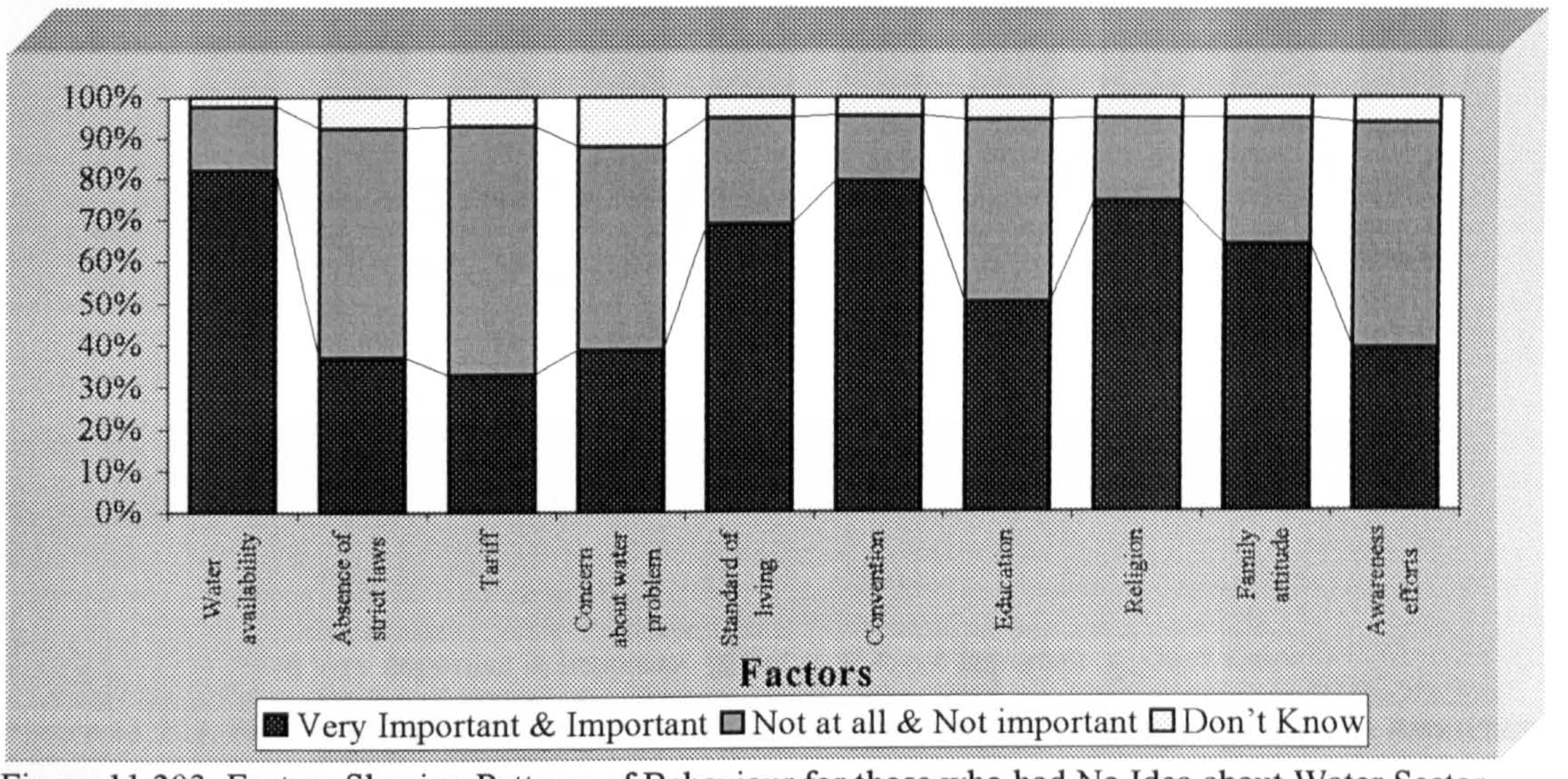

Figure 11.203. Factors Shaping Patterns of Behaviour for those who had No Idea about Water Sector Privatisation.

11.3.13.4. Conclusion:

Concern about water results from education, awareness, religion and concern over the problem. This encourages people to look for solutions and to reduce consumption, and engenders the wish to maintain water in government hands.

11.3.14. The Relationship between Perception of Awareness Efforts and Factors Shaping Behaviour Patterns:

There is no clear relationship between the perception of efforts to raise awareness and attitudes to the factors influencing consumption behaviour (Figures 11.204, 11.205 and 11.206). People who have not perceived enough attempts to raise water awareness put education and concern about the water problem before other factors, unlike those who feel that enough has been done, and to a larger degree those who don't know. In general, those who did not know or expressed no opinion are less likely to acknowledge any factor.

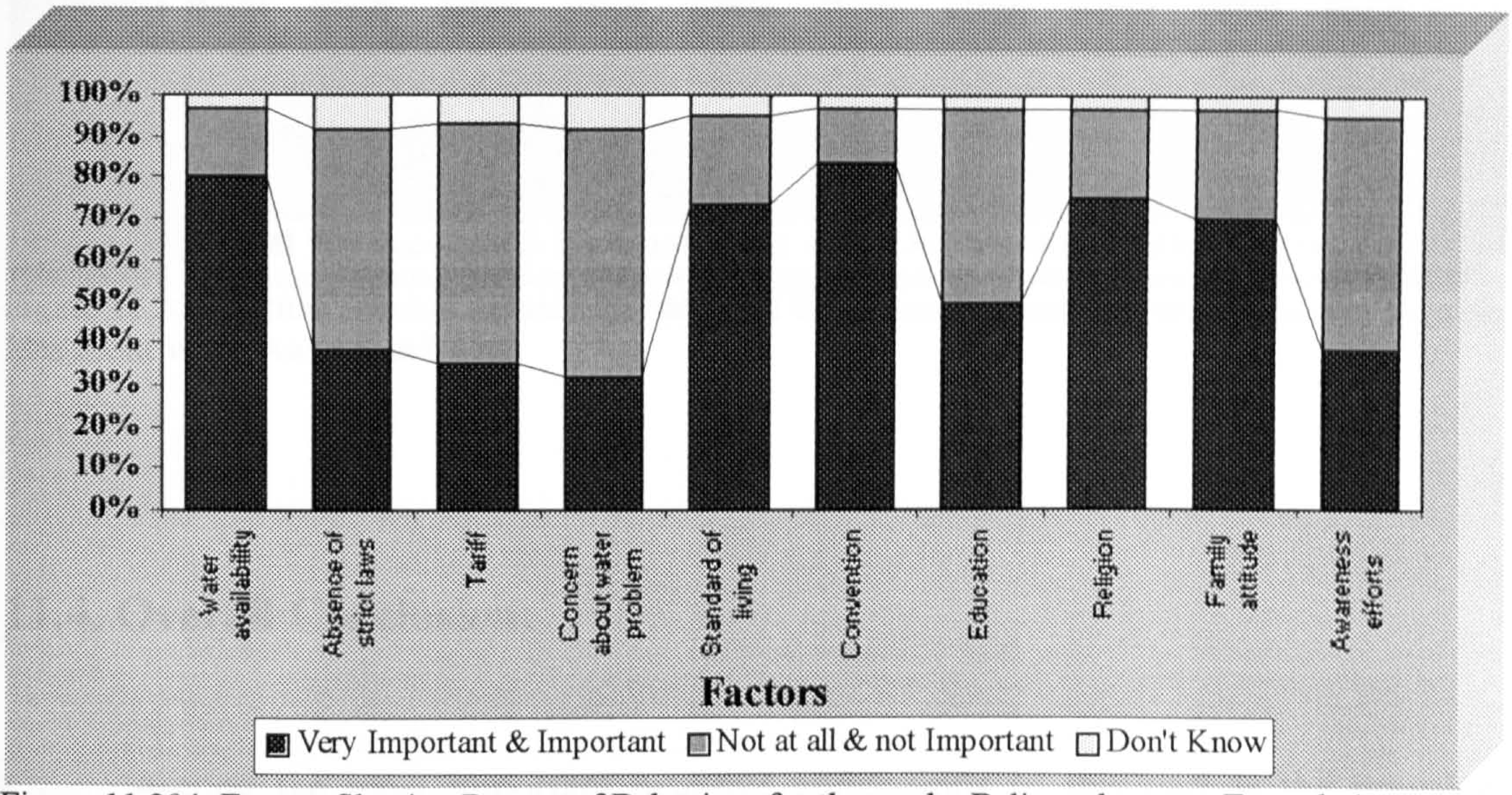

Figure 11.204. Factors Shaping Pattern of Behaviour for those who Believe there are Enough Awareness Efforts.

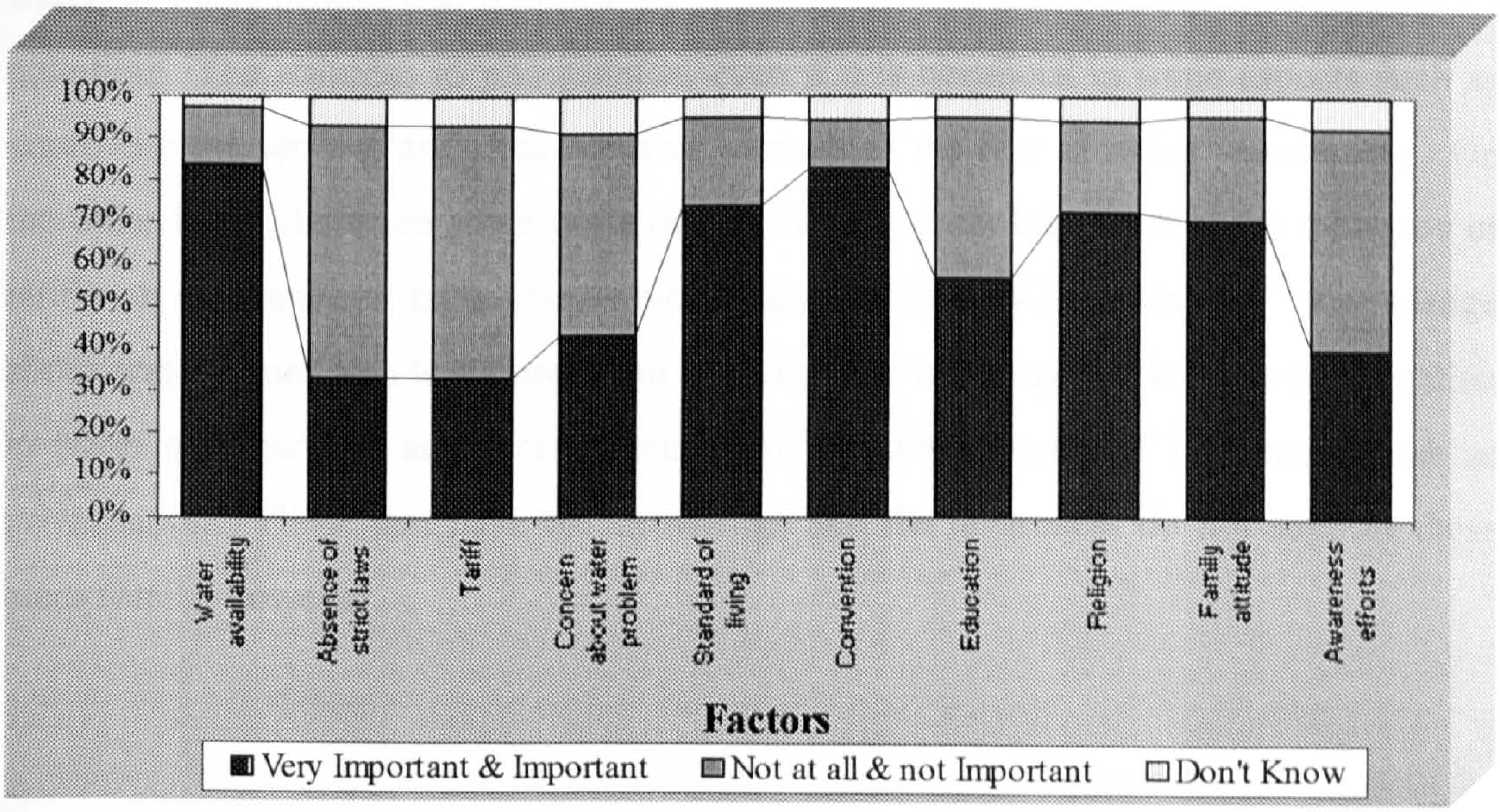

Figure 11.205. Factors Shaping Reasons for Pattern of Behaviour for those who Believe there are Not Enough Awareness Efforts.

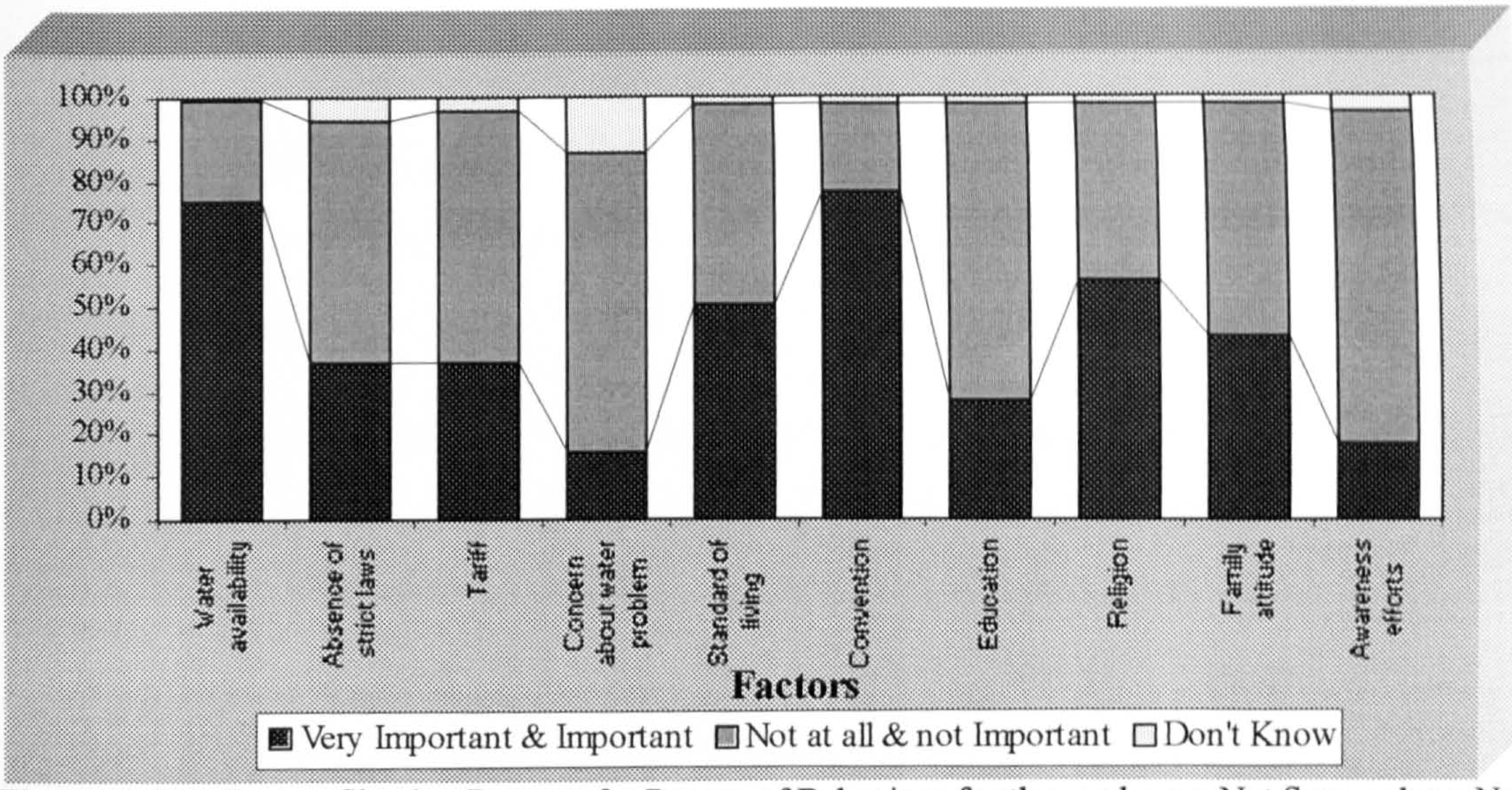

Figure 11.206. Factors Shaping Reasons for Pattern of Behaviour for those who are Not Sure or have No Idea about Water Awareness Efforts.

11.4. Overall Conclusion:

Among the most important negative conclusions of this part is the prevalent perception among the public of the bad quality of water, especially groundwater and to a lesser degree desalinated water. This is partly linked to the method of transporting the water, as many believe that transporting water by tankers is one of the main reasons for pollution. The attitudes to privatisation, even if it is beneficial in some aspects such as improving the service, are often negative because of the fear of rising water costs. On the other hand, there are some positive conclusions: most important is the influence of tariffs on consumption behaviour, which leads to economy in water use. Knowledge about water issues also leads people to express clear opinions and support participation in water management, and accept ideas about the development of the sector, such as privatisation. Those that have the knowledge and the awareness do not support these ideas totally, however.

CHAPTER TWELVE:

SUSTAINABILITY OF WATER MANAGEMENT IN QATAR

Sustainability of Water Management in Qatar

12.1. Introduction:

This project was formulated to address water sustainability issues in the State of Qatar. Qatar is an arid country with a growing population, high standard of living and rapid economic development. Present uses of water are unsustainable. In this Chapter the findings of the research project are synthesised, discussed and compared with previous work. On the basis of results from this research and in the light of earlier research, policy options are formulated to address the pressing water issues facing Qatar.

12.2. The Water Situation in Qatar:

Qatar suffers from a very arid climate, with rainfall of only 73 mma^{-1} and mean evaporation of 9 mmd^{-1} (Section 5.3). Consequently, there is no surface water in Qatar. Before the 1950s, water was managed by a traditional Islamic approach in Qatar in the absence of a central administration. This approach was effective because water demand balanced the limited supply (Section A8.2). A gap between supply and demand appeared after the 1950s, caused by uncontrolled population increase and a rapidly rising standard of living (Section 5.4), agricultural policy for food self-sufficiency (Section 5.5) and industrial development linked with oil production (Section 5.6).

The quantity of rainfall influences two major groundwater reservoirs in Qatar. The northern reservoir is less saline than the southern (e.g. al-Mahmoud, 1992; Hashim, 1995; Section 6.2.2). Freshwater, moreover, is only available in the Rus and the upper part of the UER in the north (e.g. Rukin *et al.*, 1995; Drost *et al.*, 1995).

The groundwater deficit reached 1,121,323 Mm^3 in 1997-1998 (Hashim and Ibrahim, 1999) and groundwater will be depleted completely during next 20-30 years (e.g. Jones and Dutton, 1983; Marcoux, 1996; Section 7.3.2.3) (Figure 12.1). Salinisation of groundwater has occurred across Qatar (e.g. al-Mohannadi, 1997b; Hashim and Ibrahim, 1999; Section 8.5). Furthermore, reduced freshwater drainage into the sea has affected coastal marine life such as shrimps (Kotoub and Abdulrab, 1995).

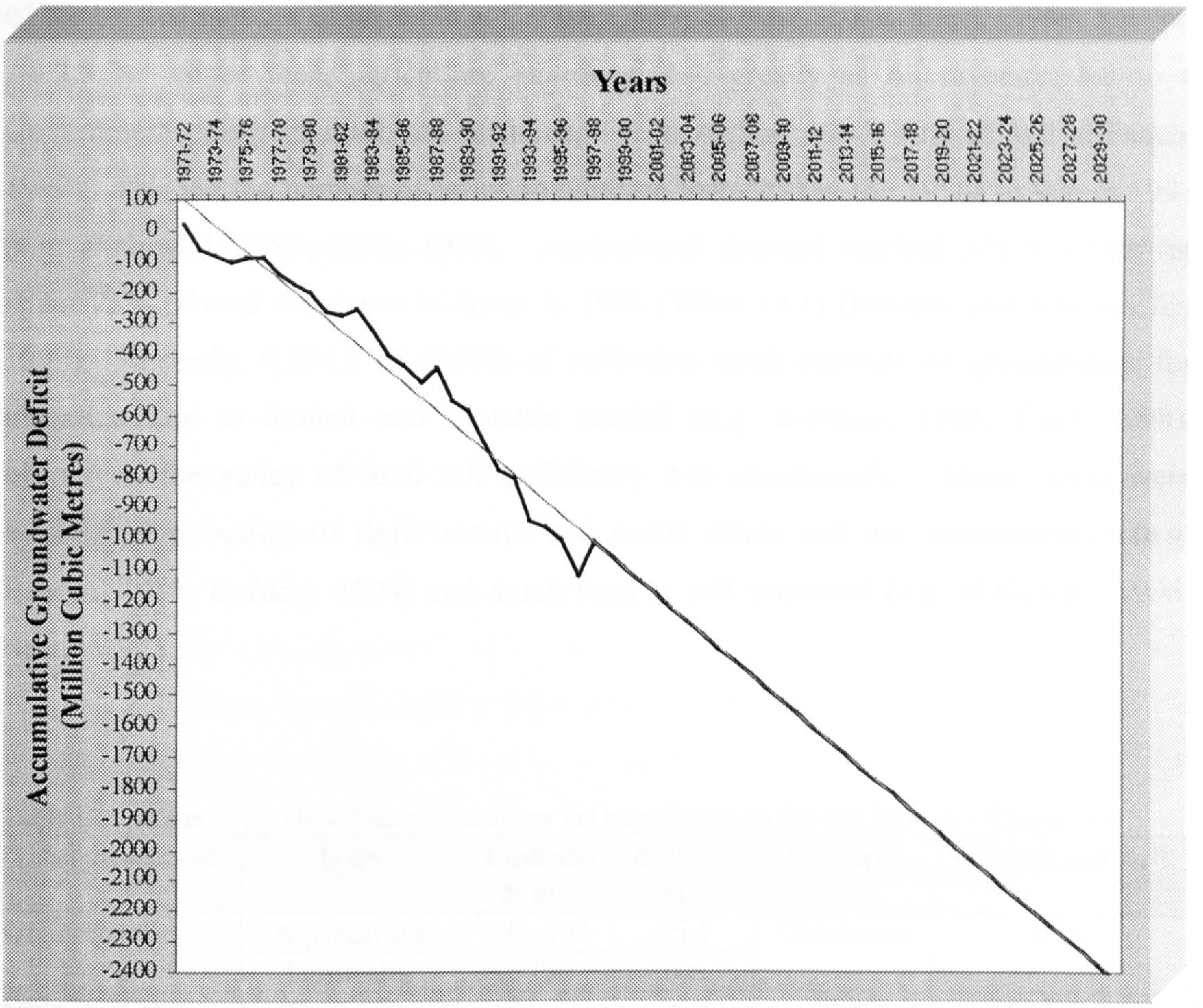

Figure 12.1. Future Groundwater Depletion Forecast (Data from 1971 to 1997 after Hashim and Ibrahim, 1999).

Since 1954, the domestic sector in Qatar has shifted from dependence on groundwater to desalination water (e.g. MEW, 1987; MEW, 1994; el-Mallakh, 1985; Section 6.2.3). The MSF method, used for all seawater desalination in Qatar, covers over 97% of domestic demand (PC, 1999a). RO is in limited use for brackish groundwater desalination (e.g. al-Diab, 1994; MEW, 1994; CSO, 1998; Section 6.2.3).

Increased water demand led the Government to expand use of recycled water. This will protect the environment (Section 6.2.4) and is cheap when compared with desalination (e.g. MMAA, 1994; Cowan and Johnson, 1985; Section 7.3.4.5). Existing plants produce about 120,000 m^3d^{-1} (MMAA, 1994; al-Sharafi, 1998; al-Diab, 1994) but only half of this quantity is used (Hussin, 2001). Recycled water is in restricted use on some public gardens and fodder crops (e.g. Ahmad, 1991b; al-Hajri, 1995).

Before the 1950s, agricultural demand for water in Qatar was very low because of the limited number of farms (e.g. Zahlan, 1989; al-Nasr and al-Sheeb, 1999; Section A8.2.5.2). Since then, agriculture has developed greatly as oil revenues led to a Government policy of food self-sufficiency (e.g. Arthur, 1997; Ahmad and al-Faqeh, 1999). This led the number of farms to increase from 250 in the 1950s to 906 in 1997 (e.g. al-Kuwari, 1996; CSO, 1998). Agricultural demand reached 309.508 Mm^3 or about 75% of total water use in Qatar in 1998 (Table 12.1) (Hashim and Abdulmalik, 1999). Recently, 9,554.8 ha (100% of cultivable land) depends on groundwater for irrigation due to limited and unstable rainfall (e.g. al-Naser, 1988; CSO, 1998). Moreover, the policy of food self-sufficiency was unsuccessful. Many farms were established primarily to show wealth and social status and are uncommercial (e.g. Besesu, 1987; al-Akry, 1994) and much food is still imported (e.g. al-Kuwari, 1996; Section 5.5).

Table 12.1. Water Type, Uses, Quantity and Cost in Qatar (Based on Several Sources – Chapter 6).

Type of Water	**Uses**	**Quantity in 1998** Mm^3	**%**	**Leakage**	**Cost ($ per m^3)**
Groundwater	Agriculture	291.408	65.7	Unknown	0.06
	Domestic	2.790	0.6		
Desalination	Domestic	131.33	29.6	40 %	1.06-1.64
Recycled	Agriculture	18.100	4.07	Unknown	0.34

Domestic, especially residential, consumption is the second largest consumer (15.9% in 1998) and has increased steadily. The government sector is also important (3.5% in 1998) (CSO, 1996; PC, 1999a). In recent years, per capita water consumption in Qatar has reached a level similar to that in some water-rich developed countries. It is expected to increase in future (Bahar, 1997; PC, 1999a; Abu Arafat, 2001). Per capita water consumption in Qatar was found to be 445.62 ld^{-1} (Section 10.3). The most important reasons for heavy domestic water consumption are natural population increase and immigration (e.g. al-Khayat, 1988; Fakro, 1998), living standard increase (e.g. Riad, 1992; Abdulrazzak, 1995) with the appearance of domestic equipment with high water consumption, and changes in housing size (MEW, 1996a; PC, 1999b).

Industrial demand in Qatar was very low because of limited development (e.g. al-Kuwari, 1978; Zahlan, 1989; Section 8.2.5.3). Since oil production started in the early 1950s, energy availability has driven substantial development (e.g. MEI, 1996; al-Shafai, 1996; EIU, 1998b). Even so, industry is still the lowest consumer with 2.2% in 1998 (CSO, 1998). This is because enterprises are small and high water consuming industries such as paper are absent. Some industrial areas have their own desalination plants (al-Mohannadi, 1997a).

In Qatar, no precious studies exist about freshwater pollution except those about conductivity increases due to the mixing of brackish groundwater and seawater with fresh groundwater (e.g. MMAA, 1997c; al-Mohannadi, 1997b; Babikir, 1998b). The Qatari media contain many complaints about water quality, especially away from Doha. In rural areas, complaints revolve around the competence of water company employees, the distribution systems and the chemicals, like chlorine, that are added to water. Moreover, the cleanliness of the tanks and reservoirs are a source of worry (al-Qahtani, 2000; al-Jeadah, 2000; Section 7.3.4.2; Chapter 8).

Doha citizens also complain about water quality, especially the chemicals added to the water, and the distribution network (Section 7.3.4.2). As was outlined by a stakeholder (Section 9.12), health problems such as hair-loss are often attributed to poor water. If this is the case for the domestic sector water, the situation in the agricultural sector (where less attention and concern is shown by the authorities) must also be questioned, especially regarding the effect of this water on the soil and agricultural productivity. Moreover, irrigation water and its contained chemicals leaches into groundwater, influencing its quality.

12.3. Current Responses to the Water Situation and the Current Impasse:

In this section the discussion focuses on what has so far been done to remedy the serious problems faced in water management in Qatar. It also examines the outcomes of the attempts to remedy the problems.

Decision-making and Administration:

Before, the 1950s, decision-making in Qatar was in the hands of the Amir (e.g. Zahlan, 1989; al-Kuwari, 1996). Since the 1950s, at a technical level water sector management is divided between domestic and agricultural administrations. The important decisions, such as construction of desalination plants and import of water are still in the hands of the Amir, sometimes in consultation with the unelected Advisory Council (el-Mallakh, 1985; al-Kuwari, 1996).

Unsustainable water development policies were adopted (e.g. Nyrop, 1984; Ahmad and al-Faqeh, 1999) in the absence of public participation in decision-making. Public concern about water was limited, and in practice, few members of the public would have been able to forecast the present problems (e.g. Filho, 1995; Bahar, 1997). There are now two avenues for public participation: the Advisory Council (nominated by the Amir) and the elected Municipal Council (Kreeshan, 1999; Gardner, 1999). Both have very limited power over decision-making.

The shortage of water in Qatar led the decision-makers to choose expensive seawater desalination as the major solution for municipal supplies since 1954 (e.g. Agnew and Anderson, 1992; al-Diab, 1994). Dependence on desalination was clearly recognised and since 1960 the decision-makers turned toward international companies and organisations to investigate the groundwater resource. The results were disappointing due to poor groundwater quality (Harhash and Yousif, 1985; al-Kuwari, 1996).

The decision-makers concentrated on providing water by expensive methods and neglected other important issues, especially restricting consumption (e.g. al-Kuwari, 1996; al-Mohannadi, 1997a). The decision-makers also ignored the use of important tools such as laws and regulations to restrict consumption (e.g. al-Harmi, 2000b), water tariffs (e.g. al-Alawi and Abdulrazzak, 1994) and raising public awareness (e.g. Filho, 1995).

Presently, due to the size of the country and its water resources, there are two institutions. Firstly, the QGEWC, which appeared after many changes (al-Attiyah, 2000; Abu Arafat, 2001), is responsible for municipal water development, production and distribution (Saleh, 1999; MJ, 2000). Secondly, the MMAA deals with water for agriculture and sewage collection and treatment (e.g. al-Hajri, 1995; al-Mahmoud, 1999).

Skilled staff in water and electricity administration accounted for 23% of total employees in the industry in 1995, increasing to 35% in 2000 (al-Attiyah, 2000). The citizens (42% of water industry employees) are concentrated in the top positions, which are usually administrative, while the rest are technicians or unskilled foreign workers (Filho, 1995; Khuraibet and al-Attar, 1997). It is worth mentioning that nearly all the rather low water administration budget is spent on secondary expenditure, such as rent for their dispersed buildings rather than on improving staff skills (al-Harmi, 1998).

The lack of qualified staff who can design and enforce policy means that important decisions are made by unskilled people (al-Kuwari, 1996). As a substitute the water institutions asked international organisations to study water issues and suggest suitable solutions (e.g. Harhash and Yousif, 1985), brought advanced technology (e.g. al-Mohannadi, 1998), but made little effort to manage quality (e.g. Judah, 1994) and demand (e.g. al-Kuwari, 1996). Moreover, institutions have insufficient finance to address their responsibilities (al-Harmi, 1998).

Additionally, the water institutions suffer from a lack of co-ordination, which requires a linking institution to consolidate effort and exclude conflict (al-Mugran, 1992; Abdulrazzak, 1992). Additionally, co-operation with related water institutions in neighbouring countries is very weak (e.g. al-Mugran, 1992), in spite of the GCC rules for co-operation in water management and especially for common aquifers and seawater pollution (e.g. GCC, 1998a).

Moreover, the water institutions in Qatar have neglected most aspects of water management, especially for groundwater (Section 7.3.2.3) and demand management also received less attention than supply and even quality (e.g. Ali, 1999; Saleh, 1999). There were efforts to estimate future demand, especially by the FAO in the 1970s and early 1980s, but the estimates were not accurate. The Government's decision not to follow the FAO plan (e.g. establish new desalination plant and reappraisal of the food self-sufficiency policy) led to an increased gap between supply and demand (e.g. Harhash and Yousif, 1985; al-Kuwari, 1996). Recently, serious groundwater problems have emerged, making it impossible to depend on this in the future (Kotoub and Abdulrab, 1995; Hashim and Ibrahim, 1999). Therefore, policy will have to focus on non-traditional resources, especially desalination and recycling. By 2025, the total estimated water to meet demand might be 2,755 Mm^3a^{-1}, with stable population growth and 2,340 Mm^3a^{-1} with unstable growth (Figure 12.2) (ACSAD, 1997).

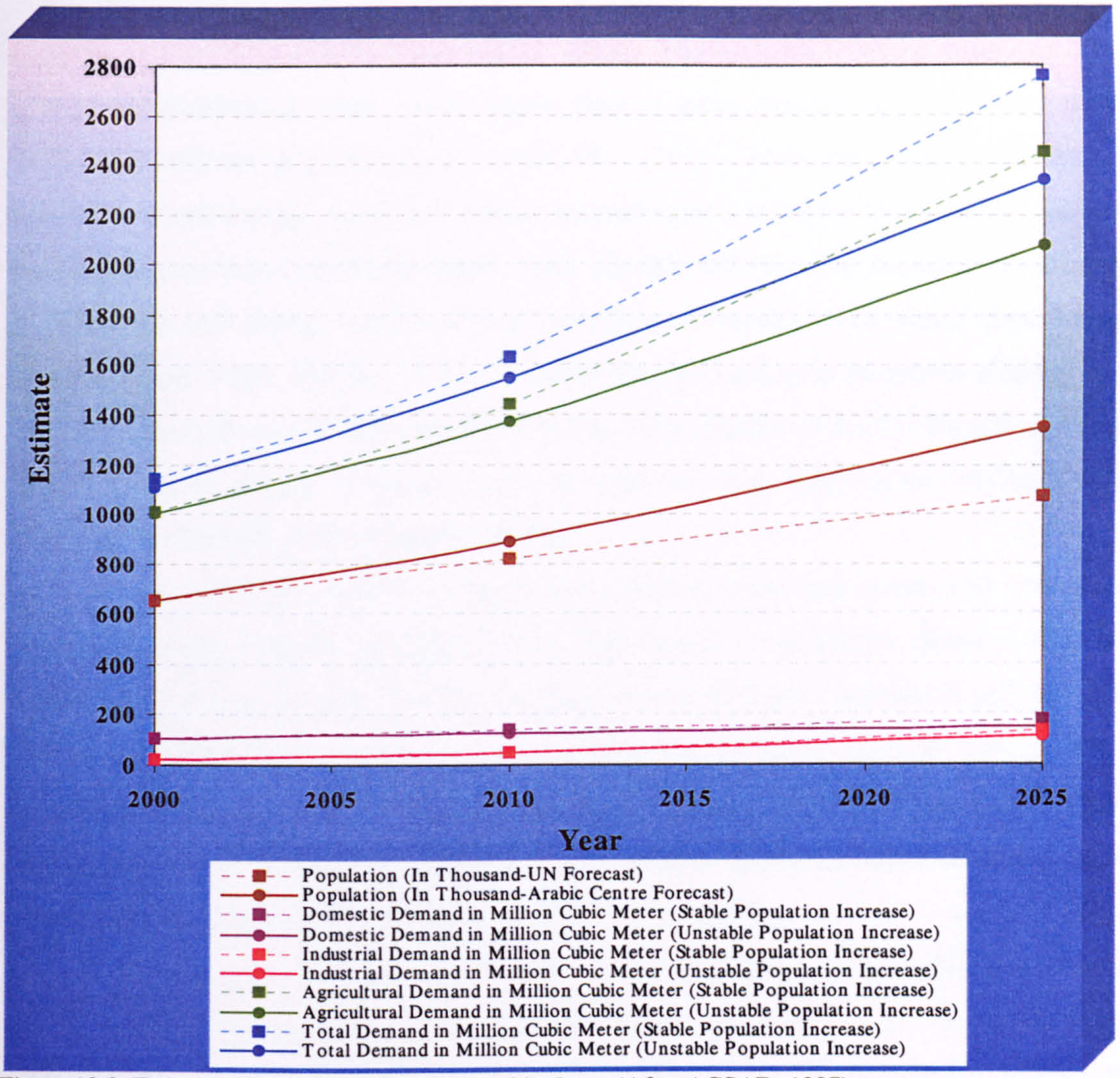

Figure 12.2. Estimated the Future Water Demand in Qatar (After ACSAD, 1997).

Technical Fixes:

Since the 1950s, the technological approach became the preferred solution for decision-makers in Qatar, especially as the huge oil revenue allowed import of technology (e.g. al-Kubaisi, 1986; Zahlan, 1989). Qatar's water supply is now dominated by technical solutions with water production by expensive seawater desalination (e.g. Kotoub and al-Mahmoud, 1997; al-Mohannadi, 1998), deep groundwater wells (e.g. MMAA, 1992; al-Kuwari, 1996) and recycled water (e.g. MMAA, 1994; al-Sharafi, 1998). Water distribution technology suffers from using tankers (al-Qahtani, 2000; Rushdi, 2001a) and an old and leaky pipeline network (Section 7.3.4).

Pipeline networks now cover 83% of domestic consumers and the rest receive water by tankers (e.g. MEW, 1994; MEW, 1998). The network loses an estimated 40% of the total distributed water - much higher than in many modern networks - and costs $165-$192 million (e.g. al-Attiyah, 2000; PC, 2000). Moreover, water loss during distribution and sewage collection caused groundwater rise under Doha and erosion of building foundations (e.g. Mohammad, 1990; Rushdi, 2001b). The distribution network is of closed end design, which causes collection of residues and water cuts during repairs (Judah, 1994; al-Biati, 1998a). Distribution by tankers is moreover a costly and unhealthy method (e.g. al-Qahtani, 2000; Saleh, 2000; Section 7.3.4.2). Finally, a major weakness of the system is limited reservoir capacity, with reserves for less than four days supply (Kotoub, 1998; Babikir, 1998b).

The municipal sector is the second largest water consumer and still uses equipment (e.g. washing machines) with high water consumption (Riad, 1992; al-Mohannadi, 1997a; Section 7.3.6.3). On the contrary, industrial demand is still low and two of the four industrial areas own desalination plants (al-Mohannadi, 1997a). The Government plans industry to undergo major development (QGPC, 1997a; EIU, 1998b) using costly desalinated water (al-Diab, 1994; MEW, 1998), therefore reducing water consumption using technical tools is required.

In spite of huge amounts of water consumption by the agricultural sector in Qatar, efforts to control it using technical tools are still limited to small scale experiments - using recycled water for certain plants (e.g. MMAA, 1994; al-Sharafi, 1998) and brackish groundwater (MMAA, 1998a). Sprinkle and drip irrigation are limited to 18.9% of Qatari agricultural land and the rest is still irrigated using traditional methods which require huge amounts of water, which is lost through leakage and evaporation (e.g. Kotoub and Abdulrab, 1995; Hashim and Abdulmalik, 1999). Despite limited use, modern irrigation in Qatar has had success in reducing water requirements and increasing crop production (e.g. AOAD, 1994; MMAA, 1998b). The most important obstacles for expansion of modern technology are the expense when most farms are uncommercial (e.g. al-Barghouti, 2000) and most farm labourers unskilled (Hashim, 1995; al-Kubaisi, 1999).

Economic Issues:

Since the 1950s, the financial control and funding of municipal water production and distribution have been undertaken by the Government (e.g. al-Mugran, 1992; MIC, 1996). The Government provides water for the domestic sector without giving water an economic value (al-Alawi and Abdulrazzak, 1994; al-Biati, 1998a). Uneconomic water management costs Qatar a huge amount every year (al-Kuwari, 1996). For example, the RAF "B" plants cost the Government about $1,614 million for construction and every m^3 of water produced costs about $1.64 (al-Diab, 1994; MEW, 1998). For comparison, construction of two small plants RO method groundwater desalination, cost about $550,000, where production of water costs $1.06 per m^3 (e.g. ESCWA, 1987; al-Sofi, 1994). Moreover, desalination plants require continued maintenance, especially during seawater pollution episodes (e.g. al-Tayaran, 1992; al-Alawi and Abdulrazzak, 1994).

In Qatar, recycled water costs about $0.34 per m^3 to produce - considerably less than desalination but higher than groundwater production costs (al-Diab, 1994; al-Mohannadi, 1997a). Use of recycled water is limited in Qatar due to technical, religious, social and health obstacles, however. Moreover, there have been many projects to import water from water-rich countries to Qatar, especially Iran, but none were implemented for economic and security reasons.

In the early stages of state water management during the 1950s, the Government endeavoured to collect a water tariff to cover the production cost, but most citizens refused to pay. The policy failed because it did not take the situation into account (most people were poverty stricken in that time and in their culture water should be a public good) and social equity was not achieved because the policy was not applied to powerful groups (al-Kuwari, 1996; Section A8.2.6). Currently, the water tariff is limited to non-citizens and the commercial and industrial sectors (e.g. al-Alawi and Abdulrazzak, 1994; al-Sumori, 2001a). The current water tariff, at $1.20 per m^3 is only 33.4% of the water service cost (al-Attiyah, 2000). It therefore does not cover production costs or reduce consumption amongst Qatari citizens (e.g. Khuraibet and al-Attar, 1997; al-Attiyah, 2000).

Privatisation is a potentially important economic solution. Privatisation could potentially cover production costs, especially when reduced oil income reduces the ability of the Qatar state to pay (e.g. Anon, 1998a; Anon, 1998d). Currently, privatisation is limited to the RAF Plant (B) desalination plant, which is managed by QEWC (a public/private finance (PPF) company with the private taking a 57% share and the government 43%). The plant works under state direction (e.g. Anon, 2000a; al-Mohannadi, 2000). The new desalination plant at Ras Laffan will be built with 60%

finance from foreign investors and 40% from Qatari companies (Anon, 2000b; EIU, 2000).

Legislative Fixes:

Qatar still has a traditional regime, therefore laws are made by the ruler (*Amir*) after non-committal consultation with the Advisory Council (el-Mallakh, 1985; al-Kuwari, 1996). Only one law has been enacted recently, in 1988, to control groundwater development (e.g. MMAA, 1998c; al-Mahmoud, 1999). The most important article, section 18, emphasises that groundwater is owned by the state (e.g. al-Rufaai, 1989; MMAA, 1998c) but this is broken with impunity because the most farm owners belong to powerful groups (e.g. al-Kuwari, 1996; Safar, 1998b).

Laws to control consumption have received little attention in Qatar. For the domestic sector, several regulations were enacted during the 1960s to govern consumption (al-Harmi, 2000b) but never enforced, especially when the regulations clashed with the benefits of powerful groups (e.g. al-Kuwari, 1996; Safar, 1998b).

Qatar shares groundwater aquifers with some Arabian Gulf states, especially Saudi Arabia. There are local international agreements, which include water resources protection (e.g. GCC, 1996a; GCC, 1998a). These rules have not been applied because this issue is not yet a serious concern for these countries, unlike political and economic matters (e.g. Abdulrazzak, 1995; Khuraibet and al-Attar, 1997).

Social Fixes:

Qatar resembles other developing countries in lacking awareness efforts (e.g. al-Kuwari, 1996; al-Attiyah, 2000). The Government is providing water from very expensive sources, but gives little attention to demand management, except some unassuming awareness programmes which are insufficient to change public behaviour (e.g. al-Khatib, 1999; Sideq, 1999). Awareness programmes are ineffective due to inexperience and use of traditional methods. Moreover, these efforts concentrate on citizens, when most of the population are foreigners with different languages (e.g. Filho, 1995; Bahar, 1997). These parts of society should be considered, especially as many are working where they can cause water loss, as farm labourers, workers and servants (Filho, 1995).

Conclusion:

It is clear that the current water management in Qatar is facing multiple problems and is unsustainable, therefore a long-term holistic policy should be established to reduce these difficulties and to give attention to water supply, quality and demand. These issues are discussed in detail in the next sections.

12.4. Water Management Views and Approaches:

Water management aims to balance supply and demand (e.g. Agnew and Anderson, 1992; Berkoff, 1994; Kandiah, 1999). There are many water management approaches and every country applies one consistent with its socio-economic situation (Sections 3.2 and 3.3).

Islamic View:

Among approaches are firstly the Islamic view which tends to the frugal consumption of water (e.g. al-Tarabulusi, 1999; al-Najar, 1999; Section 3.2.3). Moreover, Islam considers water as a public commodity and encourages the wealthy to provide water for poor people in the society (e.g. Hamed, 1993; al-Qarrdauy, 1995).

Other Traditional Approaches:

The traditional approach in non-Islamic countries considers water as a communal resource which is strongly linked with religion (Crook, 1997; Jones *et al.*, 1998; Section 3.2.2). Management is controlled by rules, which provide equity and proportionality (Spiertz, 1991; Mahendrarajah and Warr, 1991). Sustainability is implicit because of the necessity to pass the resources on to the next generations. Equity and knowledge of the local environment are the most important factors underlying this view, but other features, especially inheritable membership, are not always suitable for modern society (Crook, 1997; Jones *et al.*, 1998).

The Social View:

It is argued that everyone can benefit from social provision of water through a state approach enabling long-term water resources protection (e.g. Cvjetanovic, 1986; Pearson, 1999). In the social view, the state should control most water management for the good of all sections of society, with sometimes popular participation. This latter is absent in most developing countries (e.g. Agnew and Anderson, 1992; Smith, 1996; Reiss, 1998; Sections 3.2.4 and 3.3.3). Globally, increased water demand in the second part of the 20th century required long-term management in order not to leave it liable to misuse (Clarke, 1993; UNESCO, 1999). Any problem of provision of water may lead to collapse of governments (Mansour, 1998; Anon, 1998b).

The Market Approach:

Recently, the idea of water as an economic commodity has been spreading (e.g. Sadik and Barghouti, 1997; Beekman, 1998; Abdulqafar, 1999; Sections 3.2.5 and 3.3.4) because unrestricted use of water has led to water shortage and depletion (e.g. Shadi, 1999; Brown *et al.*, 1996; Lees, 1994). Water resource development requires huge capital, but the consumers in most developing countries are unaware of this because they do not pay, or pay only a nominal tariff (e.g. al-Sofi, 1999; Sayed, 2000). Therefore, the economic view and market approach would suggest covering water production and distribution by raising tariffs (e.g. Moore and Diner, 1995; Allan, 1995). The economic view and market approach faces difficulties because many social classes are not able to pay, especially in poor developing countries (e.g. Biswas *et al.*, 1997; Badauy, 1999). Moreover, in capitalism the aim is to maximise profit and minimise cost (Pierson, 1989; al-Nabhani, 1990). In some developed countries such as the UK, the water price is determined by regulation (e.g. Porter, 1978; Gray, 1994) without attention to people's situation. It is important therefore to take into account the consumers situation as groups and individuals before applying this approach (e.g. Knapp, 1992; Woo, 1992).

The Technological Approach:

The technological approach arises from 19th and 20th century scientific cornucopianisn – the idea that there is always a technical solution to every problem, engendered by the success of the western scientific - industrial complex (Polevoy, 1996). It uses modern science for water resources development (Polevoy, 1996; Benian, 1994; Sections 3.2.6 and 3.3.5) and became necessary, especially to reduce costs (e.g. Grigg, 1996; Mukemer and Hijazi, 1996). In modern times, technology is difficult to avoid and rapidly developing (Gray, 1989) but it is increasingly argued to be important to link technology with people and nature to arrive at a viable solution (Lynn, 1989; Speight, 1996).

Environmental Approach:

The environmental approach looks for water resource development without causing environmental damage (e.g. Fox, 1981; Hardin, 1968; Meadows *et al.*, 1972; Section 3.2.7). This view is especially strong in developed countries (e.g. Tolba, 1995; Johnson, 1993). The environment should be taken into account when water resources are developed (e.g. Biswas *et al.*, 1997; Reuss, 1992). In developing countries, weak management and absence of environmental concern sometimes led to dangerous damage to the environment (e.g. Park, 1997; Sadek *et al.*, 1997). The most serious environmental damage by water resource development in arid countries is to groundwater levels and quality (e.g. Brown *et al.*, 1996; Micklin, 1996). Project managers and the public often lack environmental awareness (e.g. Ekmekci and Gunay, 1997; al-Biati, 1998a).

Sustainability Approach:

It is clear that because water is complex it needs a holistic-management approach to achieve sustainability. Current approaches to water management in Qatar are demonstrably unsustainable (Chapters 6 and 7). To achieve sustainability, nearly all aspects of the management of water in Qatar will need to be modified, to some extent. Sustainability requires a long-term viewpoint, since sustainable development should meet "the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987, 43; Sections 2.2, 3.2.8 and 3.3.6). Further, at the moment current approaches to water management in Qatar are focussed only on a technological approach to improving supply. This neglects effective alternatives: sustainable management must be holistic and address all technical, economic, legislation, social, institution, decision-making issues and consider local conditions and circumstances. Policy options will be discussed in detail in the next sections, related to benefits, difficulties and likely outcomes.

12.5. Potential Policy and Institutional Arrangement for Resolving the Current Impasse:

12.5.1. Introduction:

In this section, using the findings of the research project and in the light of earlier research, policy options are formulated to address the pressing water issues facing Qatar and design a holistic policy for future water management in this country so that sustainability is achieved. Some of these policies are required urgently such as improving the water distribution network and irrigation technology and others are long-term policies such as changing public attitudes and behaviour.

12.5.2. Technical Policy Options:

Recently, technology has been not only important for development of natural water resources but also for finding new sources of water, such as desalination (Polevoy, 1996; Rogers, 1990; Section 3.4.2.1). In arid countries, technical tools are used for water production and protection in many ways. Technology is used to develop deep aquifers (e.g. Alam, 1989), monitor quality and quantity (e.g. Jones, 1997) and artificially recharge wells (e.g. Meldrum, 1995; Soliman *et al.*, 1995). Technology is used for surface water development using runoff and flood control (e.g. Biswas *et al.*, 1997; Hunt and Gilbertson, 1998). Moreover, modern technology enables new sources of water from desalination (e.g. Dabbagh and Faraj, 1997), recycling (e.g. Boller, 1997), water transfer (e.g. Gleick, 1997) and rain-making (Mussa, 1993).

On the other hand, technology is used in distribution and consumption equipment in domestic, industrial and agricultural sectors. Technical tools can be used to reduce water waste during distribution and consumption (Section 3.4.3.2).

Groundwater:

To reduce impact on groundwater, some arid developing countries, including Saudi Arabia, established artificial recharge wells to exploit limited rainfall (al-Mugran, 1992; al-Mahmoud, 1992; al-Akry, 1994). In Qatar, **expansion of artificial recharge wells** (Table 12.2a) is one option to conserve groundwater but is not popular among stakeholders (Section 9.7.2). Moreover, **improving the current groundwater**

monitoring network (Table 12.2b) using remote sensing and exchanging data with neighbouring countries could improve groundwater management.

Table 12.2. Strategies for Reducing Impact on Groundwater.

Table 12.2a. Expansion Use of Artificial Recharge Wells: Advantages and Difficulties.

Advantages	Difficulties
Take advantage of small amount of rainfall before evaporation.	A long-term strategy.
Acceleration of rainfall leakage to groundwater aquifers.	Need for technical expertise and experience, especially about locations.
Reversal of groundwater salinisation.	

Table 12.2b. Improve Groundwater Network Monitors: Advantages and Difficulties.

Advantages	Difficulties
Improved and continuous data about quantity and quality of groundwater will enable closer control.	Requires suitable budget for monitoring equipment and workforce.
	Requires high technology equipment.
	Requires highly skilled staff to deal with the network equipment and data.

Desalination:

Desalination water has became a major source of water for the domestic sector in many arid developing countries, especially the oil-rich Arabian Gulf states and Libya (e.g. Clarke, 1993; Duetch, 1999; Section A3.1).

To meet domestic demand, expansion use of seawater desalination is one important option (Table 12.3 and Figure 12.3), **especially in the north of the country, which still depends on limited groundwater.** 86% of stakeholders believe that expansion depends on adoption of new advanced desalination technology. Only 14% wished to expand desalination in spite of limited alternatives (Section 9.8.2).

Table 12.3. Expansion Use of Desalination for Domestic Sector: Advantages and Difficulties.

Advantages	Difficulties
Renewable source of water.	More expensive than groundwater.
Better quality than groundwater.	Environmental pollution.
Protection of groundwater from excessive use	Need for trained personal.
	Distribution will be more expensive, because groundwater wells are usually established near consumers, but a desalination plant will be in a central position on the coast.

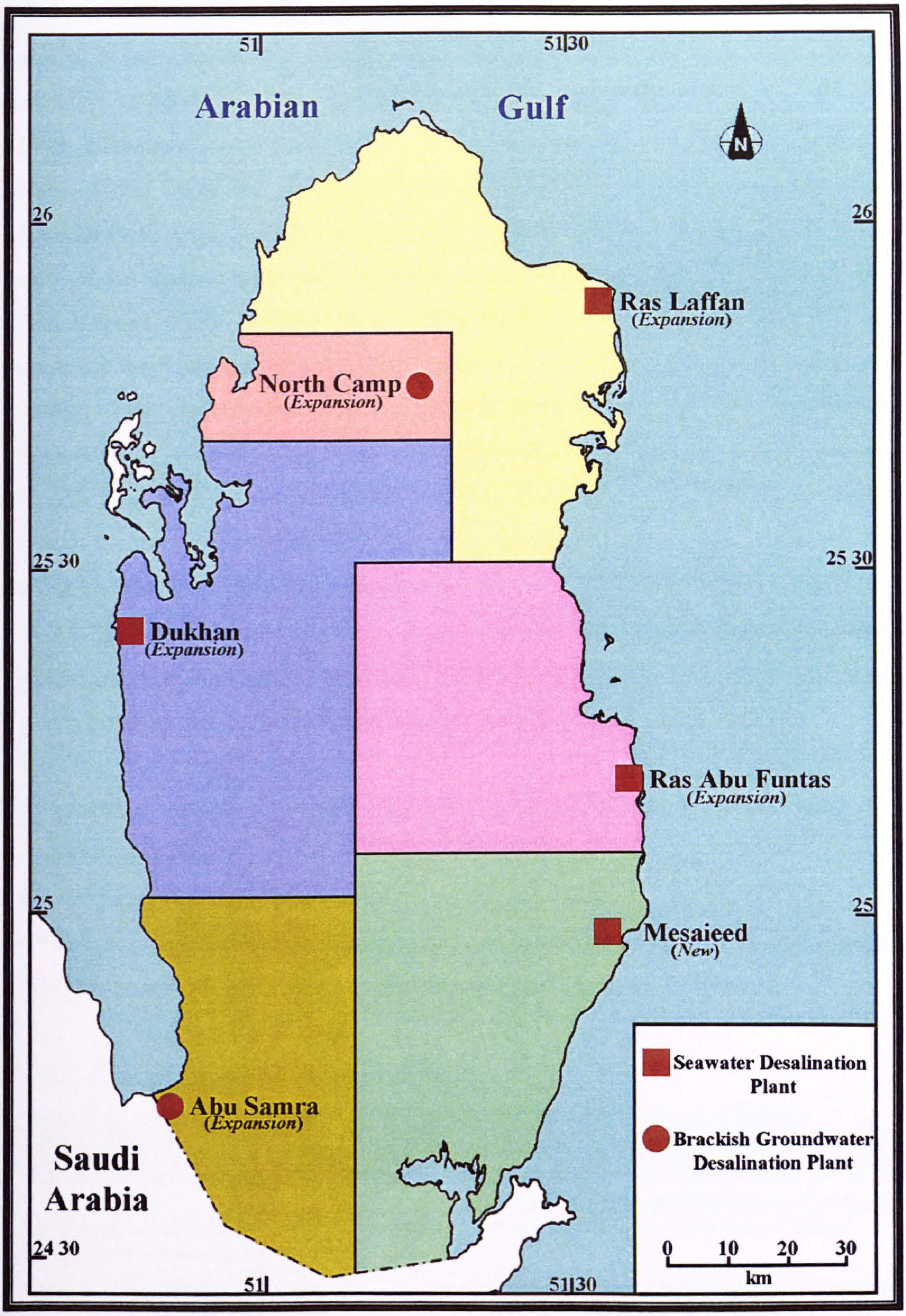

Figure 12.3. Suggested Areas for Future Expansion and New Desalination Plants in Qatar.

Recycling:

There are major opportunities to use recycled water, especially where high water quality is not needed (e.g. Pearce, 1992; al-Salum, 1999; Appendix 4) for irrigation, industry, recharging groundwater and domestic purposes like fire fighting (Beekman, 1998; Mahmoud and Sadeqi, 1997). Recycled water is used in many countries (e.g. Uqba, 1991; Dean and Lund, 1981; Beekman, 1998). In other arid countries, e.g. Arabian Gulf states, recycled water is used for limited irrigation - for landscape, parks, agricultural produce not eaten directly and animal feed (e.g. Ahmad, 1989; al-Alawi and Abdulrazzak, 1994; Othman, 1999). This source of water is still limited in Qatar, therefore most stakeholders supported using recycling for irrigation after improving its quality with modern treatment technology (Section 9.10.1). Most of the public respondents opposed the domestic use of recycled water although there was support for related uses such as public garden irrigation (Section 11.1.5). The most important reason for this attitude is the lack of knowledge about modern high quality recycling - the more educated respondents supported this idea more than the less educated (Section 11.2.4.2). Therefore, it is important to **establish tertiary stage sewage water recycling plants around the country especially in the north** (Table 12.4a) **and use all water production by these plants** (Table 12.4b). Recycled water can be used for:

- Irrigation, especially for public gardens, parks, landscapes, plants not eaten directly and fodder crops.
- Industrial uses, especially cooling.
- Domestic, e.g. private garden irrigation, car washing, fire fighting and road cleaning.
- Other uses, e.g. recharging groundwater and making artificial lakes.

Table 12.4. Strategies for Recycled Water.

Table 12.4a. Expand Use of Advance Water Recycling Plants: Advantages and Difficulties.

Advantages	Difficulties
Protection of the environment against pollution.	High cost of sewage treatment plant construction, sewage collection and distribution after treatment.
An alternative source of water will help to reduce the current pressure on groundwater.	Need for experience, which is still limited.
Treated sludge can be used for fertiliser.	Some obstacles, especially fears of religious groups and the public about the quality of recycling.

Table 12.4b. Use all Water Production from Water Recycling Plants: Advantages and Difficulties.

Advantages	Difficulties
Provide new water source to reduce the current pressure on desalination and groundwater.	Need for high technology to produce high quality water for different crops.
Less expensive than desalinated brackish groundwater and seawater.	Possible misuse of recycling, such as irrigation directly eaten plants or in the food industry.
Good quality water when compared with most groundwater used for agriculture (Chapter 8).	Requires strict monitoring, because use of untreated sewage will lead to groundwater contamination.
Unnecessary to import water from other countries, which has security and economic implications.	Misuse will lead to plant diseases or transfer of diseases to animals and human.

Water Transfer:

Recently, there have been many water transfer project proposals, especially in the Middle East, for example the Peace Pipeline to transfer water from Turkey to several countries (e.g. Berkoff, 1994; Dabbagh *et al.*, 1994; Luelmo, 1996). Other projects include importing water by pipeline though the Gulf of Oman from Buluchistan to the UAE and from the Euphrates River in Iraq to Jordan (e.g. Schliephake, 1992; Marhon, 1994; Hadad, 1994). The most recent project is the transfer of water from the Karun River in Iran to Kuwait (al-Mutairi, 2000; al-Qurashi, 2000; Awdah, 2001). All these projects are still without application, due to political, economical and security difficulties, especially the Turkish project (e.g. Gregory, 1991; Ahmed, 1991a; Mukemer and Hijazi, 1996). Towing of icebergs to arid areas faces technical difficulties due to the size of icebergs and the difficulty of moving them (e.g. al-Faisal, 1982; Gray, 1994; Williams *et al.*, 1995). One successful water transfer schemes, but in the same country, is the Great Man-made River in Libya (e.g. Allan, 1994; Lee and Woodford, 1994; Abu al-Fatih, 1997).

The idea of water transfer is not completely popular: 57% of the stakeholders called for strong security and economic guarantees before starting any project, and 25% rejected the idea due to its high cost. Other stakeholders believe that the idea needs more studies. Only 4% supported the idea unequivocally, but for agriculture only (Section 9.9.1). When the guarantees are achieved and water imported, 50% of stakeholders believe that the country should depend on this source for agricultural purposes but domestic demand should be met by seawater desalination (Section 9.9.2). 57.5% of the stakeholders believe that it is better to limit agriculture rather than import water from another country and 28.5% wished to improve irrigation technology rather than import water or limit the agricultural sector (Section 9.9.3). Similarly, most of the public rejected water importation, though some supported import from Iran (Section 11.1.5). This found more support from Qataris and the higher educated than other social groups (Section 11.2.4.3). Therefore, **importing water from other countries requires economic and security guarantees. If these conditions are achieved it may be worth importing water, perhaps Iran for use in agriculture and for groundwater injection** (Table 12.5).

Table 12.5. Importing Water: Advantages and Difficulties.

Advantages	Difficulties
Agriculture sector development.	An outside source reduces freedom of action for the Qatari Government.
Groundwater conservation and building a strategic source of water.	Confirmed political problems between Iran and some of Qatar's allies, such as the UAE and the USA.
The water is natural, unlike desalination and recycling.	The pipeline would ran through a tectonically active zone and therefore would be vulnerable to damage.
Good historical relationship between the two countries.	
The short distance from the Karun River in Iran to north Qatar makes it preferable to Turkish sources, for example.	

Novel Water Resources:

Technology may offer many novel possibilities, such as rain-making (Appendix 6). There was **support for studies to find new non-traditional water resources** (Table 12.6) fund some support from stakeholders (Section 9.22) and the public (Section 11.1.12).

Table 12.6. Support studies to Find New Non-traditional Resources: Advantages and Difficulties.

Advantages	Difficulties
Less expensive and polluting than the current desalination.	Requires experience, which may not be available locally.
	Difficulties in getting enough water in predictable times and quantities.

Irrigation Technology:

Population growth needs an increased food supply, so projects such as dams and deep wells (e.g. Williams *et al.*, 1995; al-Tarabulusi, 1999; Section A7.4) are needed to provide irrigation water in arid countries. Irrigation technology has developed subsequently (e.g. James and Lee, 1971; al-Thani, 1991) and been adopted in arid countries (Hansen *et al.*, 1980; Stansfield, 1997).

One serious problem caused by irrigation is groundwater depletion (e.g. Brooks, 1993; Young, 1997). In some arid developing countries such as Saudi Arabia, a policy of food self-sufficiency has caused a drop in groundwater levels (e.g. al-Ibrahim, 1991; al-Mugran, 1992). There are often problems associated with irrigation. These include damage to groundwater quality, rise of shallow saline groundwater (Stansfield, 1997) and diseases carried by surface irrigation water, especially Bilharzia (e.g. Chapman, 1996; Polevoy, 1996)

Recently, agricultural demand has become the most serious problem facing water management in Qatar, due to the agricultural policy for food self-sufficiency, which according to all stakeholders is responsible for deficit and increased the groundwater salinity (Section 9.7.1). 75% of total water used in Qatar goes to agriculture.

The most important technical tool is improving irrigation by using modern methods such as sprinkler, bubbler and drip (for more details see Table 3.11, Figures 3.6 and 3.7) (e.g. Sadik and Barghouti, 1994; Mukemer and Hijazi, 1996). In some developing countries, Saudi Arabia for example, use of drip and sprinkle method led to reducing consumption to 62% and 42% respectively (Ibrahim, 1991). Much the same happened in Jordan, where consumption was reduced to 70% using similar methods (Sadik and Barghouti, 1997). An important technical tool to reduce agricultural consumption is using wastewater after treatment, especially for irrigation of crops that are not eaten directly, for instance animal fodder (e.g. Arar, 1997; al-Salum, 1999). Another possibility is crop breeding to produce plants requiring a short growing the period with high productivity (Joumah and Abu al-Ainian, 1990; UNESCO, 1999) or crops requiring lower quality or saline water (e.g. Jiusheng and Kawaro, 1996; Sayed, 1999; Fang and Chen, 1997; Arar, 1997). Using 2% chicken manure will reduce soil salinity by 30% (Mukemer and Hijazi, 1996). Spraying ammoniac acid on plants which will increase their ability to consume salty water (e.g. Liu, 1997; Nasr Aldeen, 1998).

Most stakeholders indicated the necessity of adopting modern irrigation methods to reduce agricultural water demand. Some called for Government monitoring and support, because the technology requires experience and financial resources (Section 9.13).

Due to the Qatari water resource situation, **new agricultural policy should depend on water availability and be appropriate for climatic conditions** (e.g. encouraging use of plants that consume less water and have lower sensitivity to brackish water) (Table 12.7a). It should take into account the fact that food self-sufficiency is not an appropriate policy for an extremely arid country such as Qatar. Of urgent and critical importance is the **support for adoption of modern irrigation technology instead of the current traditional irrigation methods** (Table 12.7b). **Research to improve plants to consume less water, have short growth and have lower sensitivity to brackish and seawater should be encouraged** (Table 12.7c). **Commercial farms should be supported to use desalinated brackish groundwater** (Table 12.7d). **Commercial farms should be encouraged to use recycled water** (Table 12.7e), especially ablution water from mosques following the Kuwaiti experience (al-Wehaidi, 2000). **A Continued programme for increasing farmer skills in economic water use is important** (Table 12.7f).

Table 12.7. Strategies for Reducing Agricultural Water Use.

Table 12.7a. New Agricultural Policy to Reduce the Current Consumption: Advantages and Difficulties.

Advantages	Difficulties
Reduce the current agricultural water consumption.	Need for finance for experiments and to change the current agricultural methods.
Benefit from relatively suitable deep groundwater in south-east Qatar for some crops (see Table A2.2).	Need for data and experience in water quality and agriculture, which may not available at present.
Increase the cultivatable land in the country, which could lead to reduced food imports.	Conflict with farmers because many farms are private and non-commercial and this policy may be costly for them.

Table 12.7b. Modern Irrigation Technology: Advantages and Difficulties.

Advantages	Difficulties
Reduces and controls the quantity of groundwater required for irrigation.	Subsidies will be expensive considering that many farms are non-commercial.
Production improvement.	Systems will needing continue maintenance.
Reduce water evaporation.	Needs highly skilled farmers, therefore requires a costly education programmes.
Should be supported by powerful interest groups.	

Table 12.7c. Research to Improve Plant: Advantages and Difficulties.

Advantages	Difficulties
Reduce agricultural water consumption.	Need for finance for experiments and to change the current agricultural methods.
Reduce inequitable groundwater use which has led to changes in its quality and quantity.	Requires highly skilled farmer labour.
Benefit from poor quality groundwater, especially deep groundwater, and seawater.	Requires continued monitoring, especially when using lower quality water, which may cause damage if it leaks into groundwater or food cropland.
Increase the cultivable land in the country, which will lead to reduced food imports.	Requirement for data and experience in water quality and agriculture, which may not be available at present.
Remove necessity for importing water from other countries, which has security and economic implications.	Conflict with farmers, because many farms are private and non-commercial and this policy will be costly for them without Government support.

Table 12.7d. Support Commercial Farms to use Desalinated Groundwater: Advantages and Difficulties.

Advantages	Difficulties
Good water quality.	Expensive when compared with agricultural income and cost of groundwater.
Increase agricultural production.	Need for continual maintenance.
Availability of energy.	Groundwater is not considered as a renewable resource due to limited rainfall in Qatar.
Availability of experience.	

Table 12.7e. Support Commercial farms Using Recycled: Advantages and Difficulties.

Advantages	Difficulties
Less expensive than brackish groundwater and desalinated seawater.	Expensive when compared with groundwater.
Renewable source of water.	Need high technology to produce high quality water for some crops.
Environmental protection.	Need to construct recycled water distribution network.
	Poor quality recycled water will cause groundwater contamination.
	Misuse will lead to human and plant diseases.

Table 12.7f. Programme for Increasing Farmer Skills: Advantages and Difficulties.

Advantages	Difficulties
Improved water use for irrigation.	Implementation of non-traditional and attractive education programmes with different languages due to the fact that the majority of farm labourers are Asians.
Protection of groundwater quality and quantity.	Requirement for experts in fields such water, agriculture, irrigation techniques and public communication.
Improved agricultural production.	Requirement for funding for staff.
Reduction of agricultural pollution by chemicals and poor quality water.	Co-operation of farm owners and farmer labourers will be needed.
	The project is long-term and results will not be instantaneous.

Distribution System Issues:

System leakage increases the effective level of demand. This could also be seen as a supply issue, since it concerns network efficiency. Leakage during distribution may be caused by natural reasons such as soil movement, and human reasons including damage during construction work. Leakage in most distribution networks is estimated at between 25-35% of distributed water (Gray, 1994). In developing countries, leakage during distribution is often 40-50% or even 60% - which is difficult to accept with limited water supplies. Therefore, it is important to use modern distribution methods to minimise leakage (e.g. Mukemer and Hijazi, 1996; Sharaf, 1997). For example, Boston City in the USA reduced leakage from 30% to less than 12% during five years by implementing an effective modern distribution system (Rogers, 1987). Conversely, in Saudi Arabia, the ineffective distribution system leaked, increasing groundwater level and threatening building foundations (Mamo, 1997). Because of highest of leakage from the Qatari network the most stakeholders suggested establishment of an underground network or drilling wells to withdraw brackish groundwater under Doha for reuse after treatment (Section 9.7.3).

Qatar is suffering from an inefficient distribution network (Section 7.3.4.2) with 40% of desalination water lost through leaks. Therefore, most stakeholders wished to update the distribution network and cover all parts of Qatar, with continuous maintenance to control leakage (Sections 9.12 and 9.22). Some 91.8% of the public suffered from water disconnection (Section 11.1.3.5) and improving the network is of high concern (Sections 11.1.9 and 11.1.12). Therefore, it is important **to establish a new pipeline network in all areas for water distribution** instead of the current old network and tankers to reduce waste of water (Table 12.8a). This would ease pressure on desalination plants and is this urgently necessary. Moreover, due to lack of water storage (Section 7.3.4.1), **there is a requirement to establish new water reservoirs around the country** to hold sufficient for one month's consumption (Table 12.8b).

Table 12.8. Strategies to Modernise the Qatari Water Network.

Table 12.8a. Extend and Replace New Water Pipeline Network: Advantages and Difficulties.

Advantages	Difficulties
Easy to control water quality.	Effect on some dependent social groups especially water tankers drivers and owners.
Cheaper than distribution by tankers in the long-term.	Requirement for major capital investment.
Abolition of delay in water distribution.	Need for continued monitoring, requiring staff and equipment.
Leakage reduction by good pipeline network design.	Changed household water reception equipment will be needed for the new system.

Table 12.8b. Establish New Water Reservoirs: Advantages and Difficulties.

Advantages	Difficulties
Increase the current water storage capacity to be sufficient during emergencies such as the failure of the main desalination plants, which may require more than four days for repair.	Requires major funding for reservoir and new network construction.
	Requirement for continued maintenance, especially for water quality.
	Requires increase in the current water production rate.

Domestic Technology:

The domestic sector wastes much water due to poor design and maintenance, especially breakage in pipelines and dripping from taps (e.g. Beekman, 1998; Othman, 1999). Minimisation of water usage in domestic equipment is necessary. Improvement of domestic equipment should reduce loss, especially for washing and bathing which often consumes about 62% of the total consumed in houses (Porteous *et al.*, 1993). Improved recycling will foster the possibility of use in some parts of the domestic sector (Cisneros, 1995; Nurizzo and Nezzanotte, 1994) but many need a separate distribution network.

Most of the public believe their domestic water supplies are efficient or tolerable. Inefficiency is blamed on leakage, shortage of water and poor water quality (Section 11.1.3.5). Therefore, it is important to **encourage people to use economical household water equipment** (Table 12.9), especially for shower, tap and toilet, which consume about 75% of the total per capita domestic water use in Qatar, for example:

- Reduce water consumption for shower and tap by mixing the water with pressurised air (Section A7.2).
- Reduce water consumption for toilet by reducing cistern capacity following the Tucson City experience (see Othman, 1999).

Table 12.9. Establish Regulations for Household Water Equipment Specifications: Advantages and Difficulties.

Advantages	Difficulties
Reduce water consumption by uneconomic equipment especially showers, toilet and clothes washing machines without causing serious consumer inconvenience.	The lower social classes will be less able to change their domestic networks and equipment and this will require Government support.
Reduce water leakage inside houses from poor design of networks, materials and monitoring.	Necessity for co-operation by public and building contractors.
	Powers and strict monitoring require funds.

12.5.3. Economic Policy Options:

The economic tool pertains to the costs of water production and expansion of the supply. The cost of development of a water source depends on size, level of production and technology (e.g. al-Sofi, 1999; Abdulqafar, 1999; Section 3.4.2.2). Good financial management leads to control of budgets and reduction of the cost of water development projects (e.g. Dabbagh *et al.*, 1994).

Moreover, economic measures, especially pricing, are considered as effective tools for control of consumption, economic use of water and reducing the gap between supply and demand (e.g. Draper, 1994; Grigg, 1996; Section 3.4.3.3). Strict pricing will lead people to consider water's economic value especially in water-poor areas (e.g. Sulaiman, 1999; Hejab, 1999). Economic water pricing enables increased production from costly sources and should ideally cover water resources development, pumping, treatment and distribution, which are very expensive in some countries (Juhasz, 1989; Martin and Kulakouski, 1991). Uneconomic water management costs Qatar a huge amount every year (al-Kuwari, 1996). Most stakeholders believe that the current unsettled oil prices will drive Government water management policy toward reducing water sector support (Section 9.15.2).

Water Production Costs:

Desalination is energy intensive, so very costly and therefore, concentrated in energy-rich countries such as the USA and the Arabian Gulf nations (e.g. Dabbagh and Faraj, 1997; Duetch, 1999). In 1994, one m^3 of desalinated seawater cost between \$1-\$8 but a World Bank study suggested it could be reduced to \$0.70 by the year 2000 (Braverman, 1994). This, in fact, has not happened. Finding cheap energy, perhaps solar, will reduce costs substantially (e.g. al-Hajri and al-Misned, 1994; al-Ismaily and

Probert, 1995). Brackish groundwater is cheaper to desalinate than seawater (Arar, 1997) and costs about \$1.06 per m^3 in Qatar (al-Diab, 1994). Moreover, desalination plants require continued maintenance, especially during seawater pollution episodes (e.g. al-Tayaran, 1992; al-Alawi and Abdulrazzak, 1994).

Currently, desalination is the decision-makers favoured solution to provide water for the domestic sector in Qatar but 60% of stakeholders indicated that the current desalination method in Qatar is very costly, limiting its use. 20% wished to use modern methods to produce cheaper water (Section 9.8.1). The cost of production limits expansion of desalination: 86% of stakeholders believe that expansion depends on adoption of new advanced technology. Only 14% wished to expand desalination in spite of limited alternatives (Section 9.8.2). Due to absence of an alternative resource for domestic uses, the Government should **encourage and support desalination research** to reduce cost and pollution (Table 12.10a). **Expand use of cheaper RO instead MSF desalination technology** (Table 12.10b). **Develop solar power sources for desalination plants** (Table 12.10c). **Co-operate with other Arabian Gulf countries to manufacture the desalination plant locally** (Table 12.10d).

Table 12.10. Strategies to Reduce Desalination Costs.

Table 12.10a. Support of Desalination Research: Advantages and Difficulties.

Advantages	Difficulties
Lowering costs of desalination and reducing pollution will lead to complete dependence on this renewable source of water, even for agriculture.	Requires suitable budget to support researchers.
	Need experience in desalination research, which may not available locally.

Table 12.10b. Expand Use of RO Instead MSF Technology: Advantages and Difficulties.

Advantages	Difficulties
Less expansive than MSF desalination.	Environment pollution caused by salt resulting from the desalination process.
Unlike desalination, which is linked with the seacoast, RO desalination can be established in every part of the country.	World-wide, RO is used mostly for brackish groundwater instead of seawater, therefore, it is unsafe to depend on this technology because groundwater is non-renewable.
	Unlike MSF, RO can not generate electricity.

Table 12.10c. Develop Solar Power for Desalination: Advantages and Difficulties.

Advantages	Difficulties
Saves wasting oil and gas.	Expensive to implement.
Renewable technology suitable for climate.	Shortage in native expertise so dependence on foreign specialists.
Reduces the current pollution from desalination plants.	

Table 12.10d. Co-operate with Arabian Gulf Countries to Manufacture Desalination Equipment: Advantages and Difficulties.

Advantages	Difficulties
All Arabian Gulf countries have the same water problems and depend on desalination to meet their domestic sector demand, therefore, co-operation may lead to the desalination industry reducing its costs and pollution.	The Arabian Gulf countries concentrate usually on political and sometimes economics issues more than technical (e.g. al-Thani, 2000).
Most Arabian Gulf countries are rich and can support this project.	The last attempt at co-operation by Arabian Gulf states did not achieve much (e.g. al-Thani, 2000; al-Mahmoud, 2001).
Reduction of the cost of desalination plant and spare parts.	Co-operation in this field need experience which is not available locally.
Development of desalination because this technology is concentrated in water-rich countries which are not concerned about desalination costs and pollution.	
Consolidation of the desalination industry locally for security and self-sufficiency.	

It is necessary to reduce the financial burden of the water industry on the Qatari State, given the current instability of oil incomes and their eventual ending. Among the possible ways to provide non-government funds for water development are borrowing, assistance from international organisation, tariffs and PPF or complete privatisation (Section 3.4.2.2). Some options do not conform to the ethos of the Qatari State, such as complete privatisation, or are not suitable for an oil and gas-rich country, for instance borrowing and assistance from other countries or international organisations. Privatisation is a potentially important economic tool to expand supply. PPF could potentially cover production costs, especially with potentially reduced oil income (e.g. Anon, 1998a; Anon, 1998d).

Privatisation:

Privatisation is still an unpopular idea in Qatar because there is very little stakeholder and public support for complete privatisation of the system. A narrow majority of stakeholders and 21.4% of the public supported PPF, however, (Sections 9.15.1 and 11.1.10). Qataris, the higher educated and people with high incomes were more enthusiastic (Section 11.2.9.1). People who supported privatisation believe that it will lead to improved water services (93%), raise public awareness (89.5%) and develop new resources (89.5%) (Section 11.1.10). Relative benefits such as economic growth are mentioned most by the higher educated and those with high incomes (Sections 11.2.9.2, 11.3.10.1 and 11.3.10.2). In contrast, those who rejected privatisation believe that it will lead to increased water tariffs (81.5%), monopoly (69.4%) and job losses (60.8%) (Section 11.1.10). These reasons are mentioned by all groups, especially the higher educated (Sections 11.2.9.3 and 11.3.10.3). In general, water sector privatisation is not a popular idea, but if the current Government policy concerning public sector privatisation reached the water sector, **it should preferably be PPF, under Government supervision** (Table 12.11) and a part of the sustainable water management policy:

Table 12.11. Water Sector Privatisation: Advantages and Difficulties.

Advantages	Difficulties
Reduce the Government burden and bureaucracy.	Potentially unregulated monopoly for this very vital commodity.
Water service improvement.	Increased water tariff may be inequitable.
Giving water an economic value may lead to reduced consumption.	Loss of jobs and thus social unrest.
	Concentration on economic aspects and disregard of other important issues, especially the environment, which may lead to resource depletion.

Pricing Policy:

It has been argued that water tariffs should only cover the production cost, perhaps following a progressive pricing policy (e.g. al-Alawi and Abdulrazzak, 1994; Othman, 1999) and be part of a flexible management policy which should not have a serious impact on the poor (e.g. Grigg, 1992; Sadik and Barghouti, 1997). This, however, requires subsidy from public funds. Many argue it is important to consider the socio-economic situation of society when deciding the aims of water pricing (e.g. al-Sofi, 1999; Abu Zeid, 1999).

In some countries, such as Arabian Gulf states, the water tariffs are between 5%-15% of the real water production cost, which has led to excessive consumption, especially in the domestic sector (e.g. al-Mugran, 1992; al-Alawi and Abdulrazzak, 1994). Therefore, the water tariffs in these countries are ineffective. Water became an economic commodity in most developed countries by privatisation and there is political and economic pressure on developing countries to follow suit. This may not be applicable to the socio-economic situation in these countries (e.g. al-Yahiawi, 1998; Shadi, 1999).

Similarly, the Government tariff policy in Qatar failed to reduce consumption or cover production costs (Section 7.3.5.3). This analysis was supported by most of the stakeholders (Section 9.15.4). Therefore, they wished to change the current water tariff policy and especially bring its value closer to production costs. Some stakeholders added that research is needed to devise a strict policy with enforcement on all groups without exception (Section 9.15.3).

Even at current levels, the tariff does influence the behaviour of 78% of the paying public (Sections 11.1.7 and 11.3.6.1) especially with people with a low standard of living, mostly foreign male workers (Section 11.2.6.1). The water tariff influenced half of the paying public but would encourage only a quarter of non-payers to be economical in their consumption (Section 11.3.6.2). Tariff payers wished that rates would take into account the family situation, lead to improved quality of water, consider the level of consumption and result in improved water services (83.9%) (Section 11.1.7). The idea of paying tariffs equal to the real production cost had little support, though nearly half have no idea how much this is (Section 11.1.7). Those who are educated with a high standard of living wished to improve water quality and feel tariffs should be set to consider the family circumstances. The little educated with a low standard of living wanted a low tariff, proportional to levels of consumption (Section 11.2.6.2). Everyone will be more willing to pay a tariff if it depends on the level of consumption, family circumstances and improves water service and quality (Section 11.1.7), and support was especially among those with a high standard of living and education. Those with a low standard of living and education however wished to reduce the current tariff value (Section 11.2.6.3). Non-payers supported participation (40.2%) in water management more than payers (31.2%) (Section 11.3.7.1) but are agitated about water sector privatisation (Section 11.3.8.1). Payers and non-payers saw similar benefits of privatisation, especially improved water services, quality and management (Section 11.3.8.2) and similar difficulties, especially raised water tariffs, loss of jobs and resource depletion (Section 11.3.8.3). Therefore, **water tariff policy should be a part of water management** with the objective to cover investment, production and distribution costs, reduce current water consumption and to cover related costs especially awareness. This policy should take into account:

- The production cost, especially as desalination is expensive high and so much water is wasted. The water tariff should correspond to the real cost except for the poor (Table 12.12a).

- Enforcement of tariff on all groups and sectors in society able to pay (Table 12.12b).
- Metering of supplies and establishment of a tariff graduated to level of consumption (Table 12.12c).

Table 12.12. Strategies for Water Tariff Adoption.

Table 12.12a. Water Tariffs: Advantages and Difficulties.

Advantages	Difficulties
Covers production and distribution costs.	Conflicts with those who get free water at present, especially powerful groups in society.
Covers the costs of the Government effort to raise consumer awareness.	Requires staff for monitoring, collection, accountancy and means-testing.
Reduces water consumption among those who do not pay or who pay nominal tariff.	Requires strict regulations.
Raises public and stakeholders awareness about the value of water.	Requirement for new domestic metering equipment.
Encourage the industrial sector to develop new water resources (desalination and recycling).	Difficulties in establishing the real family circumstances.
Water service and quality improvement.	Obstacles to the development of the commercial and small industrial sectors.

Table 12.12b. Water Tariffs for all Social Groups: Advantages and Difficulties.

Advantages	Difficulties
Reduces the huge amount of water consumed by those who do not know its value.	Conflict, especially with citizens who started to complain about multiplicity of tariffs in the period after the oil price boom.
Achievement of social equity.	
Avoid the policy failure of the old tariff.	

Table 12.12c. Metering of Supplies and Graduated Tariffs: Advantages and Difficulties.

Advantages	Difficulties
Encouragement of consumers to reduce the waste of water.	Requirement for meters.
	Require staff for monitoring.

12.5.4. Legislative Policy Options:

During human history, legislation has been an important means to control of water resources (Mather, 1984; Section 3.4.2.3). A legislative framework is considered a pre-requisite for water resources development, as in the British water industry (e.g. Neto, 1998; Parker, 1997), directing both people and organisational development (Harris, 1997; Denham, 1999).

Law-making processes are different world-wide, for example in traditional states, laws are made by the ruler, though locally-applicable laws may be made and enforced by local water - using communities (Crook, 1997). In an Islamic society, laws are made primarily depending on the Holy Qur'an and *Sunnah* (what the Prophet of Islam said, did, or approved), these two sources are called *Shari'a* (Islamic Law) (e.g. Hamed, 1993; al-Qarrdauy, 1995). In a constitutional monarchy and republic laws are made by elected assembly (e.g. Harris, 1997; Banks and Muller, 1998). In a supra-national or regional community, legislation is governed by treaties which may be between only two states, or at the regional level (e.g. GCC, 1998b; Denham, 1999). In Qatar, Islamic law is the basis of the constitution, and new laws consistent with this are formulated by the various ministries and then approved by the Amir, with advice from the Advisory Council (MIC, 1996).

There are deficiencies in water laws and regulations in Qatar (Section 7.3.3). Therefore, all stakeholders wished to develop, moderate and apply the current water laws (Sections 9.16.1 and 9.16.3). Half of the stakeholders recognise that exceptions have caused the law to fall into dispute and therefore wish the law to be applied without exception (Section 9.16.3). This feeling is clearer among the public because most believe that the country's laws are not enough to protect water resources (Section 11.1.4). The more educated public and those who are concerned with local issues called for more water laws (Sections 11.1.4, 11.2.3.1, 11.3.9.1 and 11.3.9.2).

Groundwater Legislation:

In many arid developing countries, such as the Arabian Gulf states, groundwater quality change and deficit is common due to over-pumping (e.g. Kotoub and Abdulrab, 1995; al-Nasr and al-Sheeb, 1999; al-Sumori, 2001b) and poor recharge (e.g. Bouwer, 1994b; Judah, 1994; Merrett, 1997). These problems exist in Qatar, are recognised by all stakeholders and are attributed to the current policy of exploiting groundwater. Depletion of groundwater was identified as the most important problem for Qatar by 27% of stakeholders (Section 8.7.1). Therefore, it is important to **enact a new applicable and effective groundwater law,** which should include (Table 12.13):

- Designation of the quantity of groundwater withdrawal which should not exceed safe yield and enforcement by monitoring each well by meter.
- Enforcement of a groundwater quality standard; closing any well falling below the standard.
- Strong control of groundwater well drilling licences.

- Planning controls to demarcate the urban areas and industrial waste, sewage effluent, landfill deposits, which should to be far from fresh groundwater aquifers.
- Demarcate the quantity and quality of chemical used in agricultural sector.
- Application without exception and harsh penalties.

Table 12.13. Groundwater Law: Advantages and Difficulties.

Advantages	Difficulties
Strict control over the quality and quantity of groundwater.	Requires a suitable budget for equipment and workers to monitor and enforce.
	Needs co-operation with other institutions such as the police.
	Will cause conflict with consumers and a clash with powerful benefiting groups.

Regulation of Desalination:

Desalination caused seawater pollution by raising temperature, concentration of salts and dissolved oxygen (e.g. al-Tayaran and Madany, 1992; Chiras, 1994; al-Alawi and Abdulrazzak, 1994). Seawater pollution also affects of production of desalinated water (al-Tayaran, 1992; Hashim, 2001). The majority of stakeholders were aware of this problem in Qatar (Section 9.8.3). Therefore, **new applicable and effective desalination law is needed** (Table 12.14) which should include:

- Regulation of the temperature, salinity and chemicals in water returned to the sea or groundwater after the desalination process.
- Enforcement of desalination water quality and pollution standards.

Table 12.14. Enact Desalination Law: Advantages and Difficulties.

Advantages	Difficulties
Reduction of the current seawater and groundwater pollution caused by desalination, thus allowing expansion of this very important non-traditional source of water.	Requires experience in desalination and environmental pollution.
Improvement of municipal water quality.	Requires funding for equipment and workers.
	Needs co-operation with other institutions, such as the police.

Regulation of Recycling:

Obstacles to the use of recycled water include diseases caused by poor treatment, as indicated by 30% of stakeholders. Recycling must be improved to produce high quality water, even for drinking (e.g. Pescod and Alka, 1985; WHO, 1989; Cooper, 1991). The purity of domestic water is critical, not only for health but also for religious reasons in Islamic societies (Abu Hggag, 1981; Diamant, 1985; Helmer and Hespanhol, 1997) (although this can be achieved - much water that Londoners drink is recycled: Eden *et al.*, 1977; Dean and Lund, 1981; Marriott, 1996).

Critically, 86% of religious scholars believe that it may be possible to use recycled water in every sector if its natural attributes are restored. Only 14% found it impossible to consider highly processed recycled water as natural and thus rejected it (Section 9.10.2). To avoid these obstacles, it is important to **enact new applicable and effective water recycling law** (Table 12.15) which should include:

- Setting and enforcement of recycling quality standards for different uses or discharge into the sea or groundwater.
- Application without exception and severe penalties.

Table 12.15. Water Recycling Law: Advantages and Difficulties.

Advantages	Difficulties
Control over use of recycled water.	Need for specialists.
Reduction of the current seawater and groundwater pollution caused by partially recycled water.	Requires funding for equipment and workers.
Protecting the consumer.	Need for continued supervision in sewage treatment plants and end-uses.
	Needs co-operation with other institutions, such as the police.

Regulation of Water Quality:

Recently, enhancement of awareness of drinking water quality has accompanied the general increased awareness of public health matters (e.g. Bartram and Ballance, 1996; Polevoy, 1996; Spray, 1997; Section A9.1). The media has played a major role in highlighting the importance of environmental pollution control, including water quality (Newson, 1995).

Causes of freshwater pollution can be divided into natural and human sources. Natural sources include dissolution of rocks and soil, mixing of seawater with freshwater; precipitation and evaporation (e.g. Train, 1979; Judy and Wilkinson, 1980; Walton, 1969; Appendix 9). Human sources include industrial waste (e.g. Abu Samur and Khatib, 1999; Chapman, 1996), mine drainage waters (e.g. Bartram and Ballance, 1996; Gray, 1994), commercial laundries (e.g. Eichenberger and Chen, 1982; WHO, 1984), fertilisers, sewage effluents, road de-icing (e.g. Twort *et al.*, 1985; Chapman, 1996) and animal waste (e.g. Porteous *et al.*, 1993; Gray, 1994).

Groundwater in Qatar suffers from pollution (Chapter 8). Most stakeholders believe that the sources of groundwater pollution are the oil industry, urban landfills, unplanned urban expansion, wastewater and irrigation return (Section 9.11.2).

This thesis has shown that high concentrations of iron and sodium are found in all water sources in Qatar when compared with the WHO and EC standards (Section 8.13). High conductivity, calcium, potassium, chloride were found in most groundwater used for the domestic sector and high concentrations of magnesium, iron, conductivity, sodium, calcium, chloride and sulphate were found in most groundwater used for the agricultural sector. In general, desalination water quality is better than the groundwater used in the domestic sector, which is in turn better than groundwater used in agriculture (Chapter 8).

On the contrary, 50% of the stakeholders believe the quality of drinking water is acceptable and 29% think it is of high quality, while only 7% believe it is of bad quality (Section 9.11.1). Incidentally, most stakeholders depend on desalinated water. However, 53.9% of the public think that the water is of poor quality, while 26% believe it is reasonably good and only 14.5% believe it is good and healthy (Section 11.1.5). Therefore, only 56.6% of the public use the distributed water for drinking, while 43.3% use bottled water (Section 11.1.3.4), especially the higher educated with high incomes who have a high standard of living (Section 11.2.2). Many of the public gave no opinions about their water quality, but 38.7% felt it was contaminated (Section 11.1.3.4). Complaints about water quality are concentrated among consumers of groundwater (Sections 11.3.2.1 and 11.3.2.4): or people whose water is transported by tankers (Sections 11.3.2.2 and 11.3.2.5). Many (52%) of groundwater consumers complained of contamination, while 29% of desalination consumers believe their water is polluted (Section 11.3.2.3). The complainants are typically from Qataris and Arabs (Section 11.2.4.1). Many consumers indicated they would be more willing to pay a tariff if the water quality improved (Section 11.1.7).

Increasing chemical concentration in freshwater may cause network damage and many health problems. High pH or calcium causes corrosion in the distribution network and household installations (Gray, 1994; WHO, 1984; Appendix 9). High magnesium or sodium concentrations reduce agricultural production by causing uncultivable soil

(WHO, 1984; Twort *et al.*, 1985). High iron concentration causes haemochromatosis (e.g. Eichenberger and Chen, 1982; Bartram and Ballance, 1996) and high nitrate causes methaemoglobinaemia (e.g. Steel and McGhee, 1979; Mason, 1981).

Many of the public (39.8%) wished to enact a water quality law. Therefore, water management in Qatar requires **establishment and application of strict water quality standards for different uses** (Table12.16a). Moreover, **a continued expert programme of water quality monitoring is required** (Table 12.16b).

Table 12.16. Strategies for Water Quality Regulation.

Table 12.16a. Establishment of Water Quality Standards: Advantages and Difficulties.

Advantages	Difficulties
Clear framework for water pollution control.	Need for continued monitoring, requiring staff and equipment.
Reduction of health problems caused by poor quality water.	Requirement for enforcement powers especially in the agricultural sector.
The public will be more willing to obey laws and regulations when the water quality is improved.	Requirements for suitable capital investment to improve inadequate water distribution network and domestic equipment.

Table 12.16b. Water Quality Monitoring: Advantages and Difficulties.

Advantages	Difficulties
Freshwater pollution control.	Requirement for experts in water quality and advanced field and laboratory equipment.
Reduce health, production and equipment damage caused by using poor quality water.	Need for regulations to resolve conflicts between supplies and consumers (e.g. farmers).

International Issues:

At the international level, shared water resources necessitate finding principles to resolve conflict among states. For example, the principles confirmed by the International Law Society, Helsinki Rules and International Law Commission drafts govern shared surface water (e.g. Gleick, 1996; Abu Zeid, 1999). The Bellagio Draft Treaty (1988) governs shared groundwater aquifers and considers that this resource should be treated as surface water, with equity shares among the countries with common aquifers (Hayton and Utton, 1989; Naff, 1994). Qatar shares groundwater aquifers with some Arabian Gulf states and most stakeholders recognise this (Section 11.17.7). Virtually all stakeholders, however, see an opportunity for more co-operation among Arabian Gulf states, especially under the GCC rules, though some of them see this as limited by political and security issues (Section 9.17.6). Therefore, **the Arabian**

Gulf states should enact common laws for shared water management, especially of common groundwater aquifers and seawater pollution (Table 12.17), which should include:

- Agreement of the maximum level of groundwater withdrawal for each country, depending on the size of aquifers, recharge rates and historical uses.
- Establish common groundwater quality standards and a common monitoring system.
- Establish a common seawater quality monitoring system.
- Exchange of data among national administrations.
- Establish a common institution to enforce these rules without exception.

Table 12.17. Co-operate with the Arabian Gulf States: Advantages and Difficulties.

Advantages	Difficulties
Better control over the sustainability and quality of groundwater.	Political tensions, which led to two wars during the 1980s and 1990s.
Help in achieving equity shares for the shared aquifers.	Water resources and environmental issues do not concern the national leaders as much as political, security and economic issues.
More complete and reliable data about the quantity and quality of shared aquifers.	The stakeholders and public in these countries lack environmental awareness.
Prevention of future conflict between these countries.	Absence of enough data about the quality and quantity of shared aquifers.
Reduce marine pollution and the possibility of disruption of desalination during pollution episodes, especially oil field and tanker leaks.	

General Issues:

Legislative tools in water demand management are a partial alternative to economic change to control unreasonable consumption, especially in high consumption sectors like agriculture (Abu Hggag, 1981; Section 3.4.3.4). Without water laws over consumption occurs because people believe they have a right to consume what they wish (e.g. al-Mugran, 1992; Hassan, 1995). Water laws organise the relationship between resources and consumers. The quality of laws and their strict application is critical (e.g. Hames, 1996; Daudi and Heimlich, 1996). Many developing countries do not implement laws and regulations, leading to the failure of most water management policies (e.g. Mukemer and Hijazi, 1996; Hejab, 1999). Critically, it is easy to enact laws but it is difficult to enforce them (Low and Balamurugan, 1991; Rosegrant, 1995). Many issues result from implementation, such as the events in the in the USA with the

Clean Water Act (Rogers, 1987). Strict implementation requires continued monitoring and sometimes recourse to the police for enforcement (Mamo, 1997). This may lead to political problems (Allan, 1994). To be acceptable, laws should to be enforceable and applicable to all and have wide societal support.

Law has received little attention in Qatar (Section 7.3.3). The majority of the public wished to develop the current laws and regulations for water management, while some argued for implementation, because the problem is the absence of serious enforcement (Section 9.16.1). Many wished to enact laws to control consumption (42.4%), consumers rights and duties (41.3%) (Section 11.1.4). This was most marked with increase in general water knowledge (Section 11.3.9.2). Negative opinions about the legal framework were found mostly among Qataris and educated people (Section 11.2.3.1) because they have more knowledge and concern about local issues (Section 11.3.9.1). Some stakeholders wished to enact laws regulating two areas: the volume of consumption and water tariffs (Section 9.16.2). Many concentrated on a strict implementation by a strong institution with penalties for encroachment, while only a few wished to start by raising consumer awareness (Section 11.16.3). The public will be much more likely to obey laws if they apply to all people without exception, are in harmony with the society and culture, are implemented by a strong institution and are publicised, while direct factors such as punishment are slightly less important (Section 11.1.4). Equity and the nature of the law will impact upon those with high standard of living and the educated more than other factors, while fines, penalties and a strong executing authority will influence those with a low standard of living and education (Section 11.2.3.2). Therefore, there is a need to **develop, enact and implement of laws and regulations.** These laws and regulations should take into account:

- Strict monitoring of distribution and domestic equipment (Table 12.18a).
- Application without exception on all groups in society (Table 12.18b).
- Ability to be enforceable by clear demarcation and publicity for consumer rights and duties (Table 12.18c).
- Harmony with the circumstances of society and culture (Table 12.18d).
- Establishment of a programme to raise public awareness toward water laws and regulations (Table 12.18e), jointly with institutions for education, media, youth, women and foreigners.

- New laws and regulation should include a range of penalties (Table 12.18f), for example financial, cutting of water and prison for serious transgressions.
- Regular revision (Table 12.18g).

Table 12.18. General Legal Issues.

Table 12.18a. Monitoring of Distribution and Domestic Equipment: Advantages and Difficulties.

Advantages	Difficulties
Reduce water leakage and consumption.	Need for continued monitoring, requiring staff and equipment.
Reduction of health problems caused by poor distribution network.	Requirement for enforcement powers.
	Requirements for suitable capital investment to change the distribution network and domestic equipment.

Table 12.18b. Application on all Groups in Society: Advantages and Difficulties.

Advantages	Difficulties
Strict control over consumption especially in the domestic and agricultural sectors.	Conflict with powerful groups, especially in the agricultural sector.
The achievement of social equity.	Requires a suitable budget for monitoring staff.
Avoid the failure of current laws and regulations.	Require a powerful institution.
	Needs co-operation with other institutions such as the police for enactment.

Table 12.18c. Enforce Laws by Demarcation and Publicity: Advantages and Difficulties.

Advantages	Difficulties
Reduce water consumption because consumers will be more willing to obey regulation.	Requires co-operation with other institutions, such as legal affairs.
Realisation of the real aims of the laws and regulations.	Requires a suitable budget for adverts.
Avoids conflict between consumers and water institutions about the meaning of laws and regulations.	Requires export communicators.

Table 12.18d. Laws in Harmony with Society Circumstances: Advantages and Difficulties.

Advantages	Difficulties
Adapted to the culture and therefore acceptable to consumers.	Some consumption behaviours in the society are not sustainable.

Table 12.18e. Raise the Public Awareness about Water Laws: Advantages and Difficulties.

Advantages	Difficulties
Will help the consumers to understand their rights and duties.	Need for non-traditional and attractive awareness programmes.
Avoid laws and regulations falling into disrepute due to ignorance.	Requirement for programmes in different languages.
Achievement the real aims of the water laws and regulations (water consumption control).	Requirement for funds for staff, designers and publishers.
	Necessity for expertise in many fields, especially legislation, society and media.
	This is a long-term project: immediate results should not be expected.

Table 12.18f. Laws Include a Range of Penalties: Advantages and Difficulties.

Advantages	Difficulties
Demonstrably effective methods for enforcement of laws and regulations.	The poorest class may not able to pay financial penalties, especially if the water tariff is enforced.
A demonstration of the solemnity of laws and regulations.	Penalties such as cutting of water may lead to consumer deprivation, both physical and for religious tasks.
The large group of the population who may not affected by financial penalty may respond more to other penalties.	Needs co-operation with other institutions such as the police.

Table 12.18g. Revise Laws Regularly: Advantages and Difficulties.

Advantages	Difficulties
Adaption to socio-economic and Government policy changes.	Continue change may lead to confusion of consumers and water institutions.
Rapid response to problems that appear during enforcement.	Requires staff, especially lawyers.

12.5.5. Social Policy Options:

Individual demand differs globally due to climate, culture and standard of living but in general the per capita consumption in developed countries exceeds consumption in most arid developing countries (e.g. Clarke, 1993; al-Yahiawi, 1998; Beekman, 1998; Section A7.2). The situation in Qatar is similar to developed countries and the majority of the stakeholders (65%) saw this massive consumption as due to a sudden increase in living standards (Section 9.3).

Per capita water consumption in Qatar was found to be 445.62 ld^{-1} (Section 10.3). In some developed countries, per capita consumption might reach 300-400 ld^{-1}, which is far more than needed for health and a good quality of life. This high consumption is spreading to some arid developing countries (Berkoff, 1994; Twort *et al.*, 1985; Falkenmark *et al.*, 1990). People have a wide range of perceived water consumption and behaviour patterns (Section 11.1.6) mostly controlled by standard of living. For example, Qataris and Westerners, who are most likely to be highly educated, with high incomes, tend to have the highest water consumption and to believe their consumption behaviour is normal or excessive (Sections 10.4, 11.2.5, 11.3.2.1 and 11.3.2.2). The most important influences on public behaviour are customs, availability of water, religious maxims and standard of living (Section 11.1.6). Non-citizens with low income were also influenced by tariffs and laws. Indirect factors such as family upbringing and awareness also influenced the highly educated with high incomes (Section 11.2.5.3).

In some developed countries, per capita domestic consumption (litre per day) is divided among toilet (50), washing and bathing (45), clothes washing (14); dish washing (14), outside use (8), cooking and drinking (4) (e.g. OECD, 1989; Fittschen and Niemczynowicz, 1997; Shadi, 1999). This varies according to standard of living and size of household (e.g. Gray, 1994; TOU, 1997). In Qatar, personal hygiene is the highest water consumer for climatic and cultural reasons, exceeding consumption for this purpose in Western countries. Per capita water consumption for both shower and personal washing consumes an average of 276.8 ld^{-1}. Qatar has very similar levels of consumption for other purposes to Western countries, except dish washing which consumes 45.98 ld^{-1} and outside uses (car washing and garden irrigation) which consumes 30.9 ld^{-1} (Section 10.3) and are higher than in Western countries. Public perception of consumption gave similar results except for irrigating gardens, which it was believed consumed less water (Section 11.1.6).

Once more, standard of living is the most important determinant of perceived reasons for this pattern of water consumption. Thus, Qataris, Westerners, the higher educated and those with high incomes who expect to have a high standard of living consume more water for personal hygiene, washing and garden irrigation (Section 11.2.5.4). Importantly, the majority (61%) believe they can reduce consumption, especially for irrigation of gardens, personal hygiene and washing (Section 11.1.6). Qataris, females and the higher educated, who expect to consume most water, feel most able to reduce consumption (Section 11.2.5.5).

In many countries, water consumption differs from day to day, week to week and season to season but in general, municipal consumption peaks are between 8-9 a.m. and between 6-8 p.m. Commercial consumption is level all day and drops in the night (Mather, 1984; Sormail, 1990; Steel and McGhee, 1979). In Qatar, there are two main peak times, with two minor peaks. The first peak time is 5-7 a.m. and the second is 9-10 p.m., while the two minor peak times occur between 11 a.m. - 2 p.m. and 4-7 p.m. (Section 10.5).

Stakeholders suggest placing restrictions on domestic demand in Qatar by the establishing a comprehensive water management system taking into account demand, raising public awareness, including important social institutions in water management, improving of distribution network and education (Section 9.20.3). Many stakeholders believe that the current economic situation resulting from oil price instability will reduce water consumption, especially when the Government transfers its responsibility for water provision to the private sector. Some did not believe that this alone can reduce current consumption (Section 9.20.4). All stakeholders were dissatisfied about current institutional efforts to reduce water consumption (Section 9.20.5). They regard participation and awareness as important methods to change public behaviour.

Public Participation:

Public participation has become an important tool in water supply development in many developed countries, such as the USA. Participation enables the public to understand and contribute to projects, so planners consult the public (e.g. House, 1996; Hunter, 1998; Section 3.4.2.5). Participation is absent in most developing countries. This has led to failure of some policies (e.g. Fordham *et al.*, 1991; Ross and Rowan, 1994). The public should participate because projects cost them directly (e.g. taxes) or indirectly through pollution or other outcomes (e.g. Cernea, 1991; Syme and Mancarrow, 1992). In most developing countries, financial constraints cause shortages and poor quality of water. Public participation and participation of non-governmental institutions and related international organisations will therefore reduce opposition toward costly water development by using local workers, materials and technology (e.g. Smethurst, 1988; Sadik and Barghouti, 1997).

Obstacles to achieving public participation exist, however. Some people are not co-operative (e.g. Grigg, 1996; Mamo, 1997). The disadvantaged are often excluded, but it is important to involve all the groups in society, especially youth, women and non-government organisations not only to achieve complete participation but also to increase concern about water (e.g. Smyth, 1997; Moaren and Dent, 1995).

In Qatar, public participation is limited in general (Section 7.3.6.7). Most stakeholders completely support the idea of public participation. They believe that this will lead to increased public awareness and make people care more about their water supply (Section 9.19.6). Most of the public are not satisfied with the current water management, especially the quantity and quality of water (Sections 11.1.3 and 11.1.5) but they have mixed feelings about participation – about half would not personally like to participate (Section 11.1.9). Personal participation got more support from citizens, the educated and people with a high standard of living because they are more concerned about issues in society and believe they should have more opportunity to participate than other groups (Section 11.2.8.1). Education and awareness are among the most important factors influencing the consumption behaviour of those who were prepared to participate (Section 11.3.5). Tariff payers are less motivated to participate (Section 11.3.7.1). There is a strong relationship between supporting participation and general knowledge of water issues (Section 11.3.11.1). People wishing to participate wish to improve the water service, especially water quality, improve their water awareness and improve water management (Section 11.1.9). This leaning is increased with higher level of education (Sections 11.2.8.2, 11.3.7.2 and 11.3.11.2). If the public are given an opportunity to make decisions, the first objective among Qataris, Westerners and the higher educated will be to improve water quality followed by raising awareness and the imposition of water tariffs (Section 11.1.19). Other groups wished to minimise the tariff, or ignored the issue (Section 11.2.8.5).

Most who rejected participation believe it is difficult to achieve and cite their poor experience of water management (Sections 11.1.9 and 11.3.11.3). These arguments highlight the lack of personal benefits for foreign workers (Section 11.2.8.4). Thus, tariff payers saw difficulty in implementation, while non-payers acknowledged their lack of water management experience (Section 11.3.7.3).

Different levels for public participation exist, depending on the socio-economic situation of a society (Pimbert and Pretty, 1995; Section 3.4.2.5). Public participation can be achieved directly (e.g. field visits and workshops) or indirectly (e.g. by post and media). Increased public environmental awareness will raise participation, in turn reducing the gap between planners and local people and improving co-operation (e.g. Pyrovetsi, 1997; Othman, 1999). This requires a public education programme and targeted information to specific groups (e.g. Bultena, 1974; Blackmore, 1995b). Increased environmental awareness in developed countries has led to the appearance of interest groups which campaign to force their opinion on decision-makers (Sewell *et al.*, 1985). A sort of public participation can also be achieved by shifting the water sector from the state to the private sector (Gray, 1989).

Public surveys suggest that many would be satisfied with knowledge of water plans, limited participation by giving recommendations and suggestions or participation through the Municipal Council. Advanced participation found also some acceptance, with personal participation in policy design and direct involvement in direction (Section 11.1.9). The advanced types of participation found more support among those who have high education and income, since water awareness and concern are higher in this group (Section 11.2.8.3). In the Qatari situation elementary levels of participation may be more feasible for most people. Therefore, decision-makers in Qatar should **establish a long-term programme to give the public an opportunity to participate in water management** (Table 12.19). There are many obstacles, so initial participation should be at the elementary level - informing the public about programmes, plans and taking their opinions and recommendations. This programme should take into account different groups in society, especially foreigners who constitute about 78% of the total population.

Table 12.19. Public Participation in Water Management: Advantages and Difficulties.

Advantages	Difficulties
This action will achieve a measure of social equity and conform with culture, according to the Qur'an, a Muslim is characterised as "*...And who (conduct) their affairs by mutual consultation...*". (Qur'an, 24:38).	Require suitable funds for staff and public communication equipment.
Public participation will help the decision-makers to assess the most popular decisions.	Require experts in different fields, especially in water management, sociology and public communication.
The public will be more co-operative with other aspects of water policy, such as observance of water laws, tariffs and the use of water conservation equipment.	Public participation in decision-making is still not a popular idea among the traditional decision-makers or among many members of the public.
Participation will increase public awareness, which should reduce the current stress on the limited water supply.	Most of the public, especially the less educated and foreigners, have not enough knowledge and awareness about water issues.
	Participation of large groups of people in decision-making may lead to obstruction of water management efforts.
	Most foreigners are from non-Arabic countries, therefore, the programme requires staff with foreign language and experience.
	Most foreigners spend only a few years in Qatar. The turnover of population will require a continuous and thus expensive programme and will reduce the efficiency of any programme.

Awareness:

To change the public behaviour by using measures such as education, awareness programmes and participation are considered as effective but among the most difficult methods to control water consumption, because they are long-term and require knowledge of the social circumstances (Smith, 1974; Filho, 1995; Section 3.4.3.6). They use the customs and traditions of society for demand management (e.g. Winpenny, 1994; Othman, 1999). It is worth mentioning that all tools used to control consumption will be ineffective unless they cause changes to consumer behaviour (e.g. Hames, 1996; Ekmekci and Gunay, 1997).

Consumption tools such as laws and tariffs will not succeed without raising public awareness and convincing people through education and advice programmes (Winpenny, 1994). In some developing countries, like the Arabian Gulf states, programmes to increase public awareness failed due to their poor quality and rarity. Continued media programmes are needed to influence public behaviour (e.g. al-Mugran, 1992; Bahar, 1997). It is also important to work within the social culture and with religious institutions, which can raise awareness. For example, Islam forbids excessive water consumption (e.g. al-Qarrdauy, 1995; al-Najar, 1999). Religious leaders can share in these efforts (Filho, 1995), also celebrities (Geisler *et al.*, 1994), and architects (al-Feel, 1981). Furthermore, planners should reject any new policy without a water awareness programme (Doerksen and Pierce, 1976). Moreover, direct tools to raise awareness, especially public participation in water management, enable people to feel ownership of the water resources. Publicity about tariffs, penalties and prizes can also encourage consumers to change unreasonable consumption behaviour (al-Feel, 1981; Simpson, 1994).

Every social group requires a certain type of awareness programme. It is important to establish education programmes to create a responsible spirit in the new generation (e.g. House, 1996; Smyth, 1997). Other important groups are decision-makers, farmers and women due to their vital roles in controlling consumption (e.g. Pre, 1997; Othman, 1999). For instance, farmers are world-wide and in Qatar the largest water consumers, so separate programmes should be established to increase their water use skills. They may include seminars, direct instruction and indirect methods - entertainment programmes and entertaining literature using a combination of media and field visits (e.g. Gooch, 1994; Ahmad and el-Hassan, 1995). Thus, Saudi Arabia spent one million dollars over five years to raise public water awareness, which achieved some success (al-Ibrahim, 1991; Othman, 1999). Critically, awareness efforts require government and public support, which may not be available in most developing countries. Unfortunately, decision-makers in developing countries tend to concentrate on more pressing issues rather than long-term policies such as awareness. Therefore, developed countries and international organisations should support these countries in establishing their awareness programmes (e.g. Assaad *et al.*, 1994; Wolf and Mohood, 1997).

Awareness efforts have secured little attention in Qatar (Section 7.3.6.8). Most stakeholders regard previous awareness efforts as unsatisfactory and requiring further development (Section 9.19.2). Therefore, their most important recommendation to improve water management was to raise public awareness (Section 9.22). Correspondingly, nearly all of the public also think that awareness efforts are insufficient or do not know about them (Sections 11.1.8, 11.1.9 and 11.1.12). The higher educated, the young and those with high incomes tend to emphasise the insufficiency of awareness programmes, while ignorance about the issue is high among other groups (Sections 11.2.7.1, 11.2.8.5, 11.2.11 and 11.3.12.1). Moreover, people influenced by education and concern about the water problem indicated the shortage of awareness programmes more than those impacted by other factors (Section 11.3.14). The most important evidence of the lack of awareness is the weak public information about general water issues in Qatar (Section 11.1.11). This weakness is found most amongst foreigners and the less educated because many are not interested in local issues and have a language disadvantage (Section 11.2.10). These are nearly 78% of Qatari society (Section 5.4).

Most stakeholders explained this situation as being due to unsuitable and unremarkable media adverts, though some identified the lack of expertise (Section 9.19.2). Therefore, many stakeholders suggest that awareness efforts should concentrate on young people by using education programmes and workshops. Some stakeholders even suggested that the Government should make an occasional artificial crisis to raise awareness of water (Section 9.19.4). They suggest that important religious, education, women's and media institutions could share in raising public awareness (Section 9.19.5). The most effective current awareness tools for the public are religious maxims, family upbringing and education, while direct tools such as tariff and laws are less important (Section 11.1.8). Standard of living and education are the key factors determining the effectiveness of current awareness methods. Thus, Qataris, some Arabs, Westerners, the higher educated and those with high incomes identified indirect tools such as religion (excepting Westerners) and education, while other groups were influenced more by direct tools such as tariffs (Sections 11.2.7.2 and 11.3.12.2). The public suggested use of education, family upbringing, religion and media to create awareness (Section 11.1.8). Again, people with a high standard of living and education suggested indirect tools such as education and family upbringing, while people with a low standard of living and education were more likely to select tools such as tariffs (Sections 11.2.7.3 and 11.3.12.3). Clearly, different tools are needed to persuade different groups in society. Therefore, water management in Qatar requires **establishment of long-term awareness programmes to encourage consumers to reduce their consumption.** This programme requires:

- Separate awareness programmes for different social classes and groups, especially the young, women, decision-makers, farmers and foreigners (Table 12.20a).
- Co-operation with educational institutions (Table 12.20b).
- Co-operation with religious institutions (Table 12.20c).
- Co-operation with media institutions (Table 12.20d).
- Co-operation with women's institutions (Table 12.20e).
- Co-operation with foreigner's institutions (Table 12.20f).

Table 12.20. Strategy for Raising Awareness in Qatar.

Table 12.20a. Awareness Programme for Different Social Groups: Advantages and Difficulties.

Advantages	Difficulties
Thus will avoid the dilution of current awareness efforts, which are seen as irrelevant to many social classes.	Need for experts in different fields, especially society and public communication, to create non-traditional and attractive awareness programmes for different social groups and languages.
These programmes will cover all social groups, which should lead to real reduction of water consumption.	Need for a suitable budget for staff, designers and publishers.
	Traditional obstacles especially amongst decision-makers and women.
	Long-term: instant results are unlikely.

Table 12.20b. Co-operation with Educational Institutions: Advantages and Difficulties.

Advantages	Difficulties
The young are more malleable and easier to educate about water issues.	The current financial resources for education will not help to create interesting programmes to cover all groups.
These institutions are the best for arrangement of workshops, short courses and seminars especially, for old people, decision-makers and farmers.	The current education programmes are facile and require experts to design deeper methods.
These institutions benefit for the education of researchers.	
These institutions may have experience in design of other awareness programmes.	

Table 12.20c. Co-operation with Religious Institutions: Advantages and Difficulties.

Advantages	Difficulties
Islam strongly forbids excessive water consumption (Section 9.4).	Most religious scholars use traditional methods, which may not be attractive to the public, especially the young.
Religious teachings are effective in Qatari society.	Influencing public opinion requires continued efforts and the scholars have other important issues to cover.
The diversity of the current religious forums such as mosques, media, public lectures and education reach many groups in society.	

Table 12.20d. Co-operation with Media Institutions: Advantages and Difficulties.

Advantages	Difficulties
Possible to cover all society classes and groups.	Require attractive methods to avoid the fate of the current failed programmes.
Most media are completely or partially Government sector bodies, which may lead to cost reduction.	Requires expertise in water, social, public communications and advertisements.
	Requires the participation of celebrities, which maybe limited in Qatar.

Table 12.20e. Co-operation with Women's Institutions: Advantages and Difficulties.

Advantages	Difficulties
In Qatari society, women are responsible for most water uses in houses, therefore changing their consumption behaviour will lead to large reductions in water use.	Women's institutions in Qatar are very limited.
Women can change their husbands and children's behaviour.	Require co-operation with other institutions such as water and education bodies.
	Many issues may be of more concern to women than water.

Table 12.20f. Co-operation with Foreigner's Institutions: Advantages and Difficulties.

Advantages	Difficulties
Would cover large group of society (more than 78%) which suffered from ignorance of the current awareness programmes.	Foreign institutions in Qatar are very limited.
Avoids some obstacles appeared during the current awareness programmes, especially languages.	Most foreigners are not interesting in local issues such as water.
Considered as the best methods to reach foreigners.	Requires a continued programme because most foreigners remain only for a few years.

12.5.6. Institutional Options:

An administration usually includes a group of specialised people with a budget and a definite purpose, either part of a government ministry or a separate or non-government institution (e.g. Helmer and Hespanhol, 1997; Giannias and Lekakis, 1997; Section 3.5.2). Water administrations aim to develop and implement water plans and can be divided into four types according to the levels of responsibility. Level of responsibility is controlled by geographical location, the functions they carry, the groups they serve and the expertise required (James and Lee, 1971; Biswas, 1990). Most countries require three levels of water administration, although this is dependant on resources and the size of the country. These levels are central, regional and local government (OECD, 1977). A variety of institutional characters depend on whether water is managed by the state or private sector, or by a partnership (Muckleston, 1990; Sewell *et al.*, 1985).

All institutional types have advantages and disadvantages. For example, private companies under state regulation may cover most of the population and improve the quality, but may be monopolies and charge high tariffs (Grigg, 1996; Buller, 1996). Water administration in most developing countries is multiple-institutional under the government, as in Kuwait, or with a water resources council as in Oman (al-Mugran, 1992; Abdulrazzak, 1992). The latter benefited from Government support but suffered from bureaucracy, poor service and a lack of public participation (for more details about organisation characters see Table 3.13). The most important disadvantage of multiple institutions is absence of co-ordination, which leads to policy conflicts. Therefore, this system requires overall co-ordination (e.g. Mitchell, 1990; Rogers, 1993).

Conflict between water institutions occurs when policy is implemented in a shared area between two or more institutions (e.g. Winpenny, 1994; Jellali and Jebali, 1994; Section 3.6.5.2). Therefore, policy should be prepared and implemented efficiently, with the establishment of a new institution for co-ordination (e.g. Calvo, 1990; Burak *et al.*, 1994). In some developing countries, like the Arabian Gulf states, the large number of water institutions led to unclear specialisation for each institution and a need arose for one institution to undertake local and regional co-ordination (Abdulrazzak, 1992; al-Mugran, 1992). On the other hand, the number of water institutions is usually reduced in market water management for minimum effort and maximum financial gain, as in Chile (Bauer, 1997; Sadik and Barghouti, 1997). In this context, it is important, when forming new institutions, to avoid sudden changes in structure which may lead to disruption of service (Winpenny, 1994). Furthermore, conflict can be avoided by forming powerful institutions (Rogers, 1993) because less powerful institutions fall under the influence of influential groups leading to frustration of aims (al-Kuwari, 1996).

Water management works through multiple institutions in Qatar (Section 7.3.7.3) and also requires a linking institution to consolidate effort and exclude conflict. All stakeholders emphasised that the absence of co-ordination between water institutions in Qatar led to conflict and called for co-ordination (Section 9.17.5). Additionally, most stakeholders recognise the co-operation with related water institutions in neighbouring countries as limited (Section 9.17.7) and see an opportunity to strengthen it (Section 9.17.6). Co-operation with some UN organisations, such as FAO, has not been completely successful in the past and most stakeholders regard the international institutions as lacking information about the local socio-economic situation (Section 9.12).

Over half the stakeholders believe that there are enough water institutions in Qatar, when taking into account the size of country, but feel that they require more power to carry out their responsibilities. In contrast, some called for establishment of a separate institution for water management, because the current institutions are responsible for many issues which leads to a dispersal of efforts (Section 9.17.2).

In general, a water administration should identify the problems caused by supply problems and excessive demand, and control them by designing and implementing policies with continued monitoring. Therefore, qualified staff - specialists in engineering, chemistry, biology, law, economic, sociology and geography - and budget are required to enforce policies (e.g. Rogers, 1987; Arar, 1997; Section 3.6.5.4).

Water institutions in many developing countries, such as the Arabian Gulf states, suffer from lack of highly qualified staff because of shortage of investment in water management education and training (e.g. Hamdan, 1989; al-Mugran, 1992). Moreover, current programmes use old methods that are incompatible with modern science and which are consequently ineffective (Niemczynowicz, 1993; Seacrest and Herpel, 1997).

Qatar, like most developing countries, suffers from poorly qualified staff especially those who are citizens (Section 7.3.7.6). Therefore, all the stakeholders wished to see staff skills improved, giving priority to citizens, especially in technical specialities (Section 9.18.1).

Moreover, most stakeholders recognise that the independence of water institutions is limited. This has led to disruption of policies. Only a few are satisfied with the current situation because it conforms with the local regime (Section 9.17.3). Notably, most people do not know the institution responsible for water production or distribution for domestic use. This marks a real failure in public communication (Section 11.1.11).

Most stakeholders believe that the decision-makers in Qatar suffer from lack of expertise because of shortage of practical training and that some are too poorly qualified to take important decisions (Section 9.18.2). Some stakeholders hold that the studies made by some international organisations (Section 7.3.7.10) were useless because the experts spent only a short time in the country and ignored the local socio-economic situation. However, others believe that solutions were found but were not implemented by the decision-makers. Many others had no view (Section 9.21).

It is clear that the most important obstacles facing the water institutions in Qatar are lack of co-ordination, qualified decision-makers and staff. Therefore, they require **establishment of a High Water Council** for overall policy design, co-ordination and training (Figure 12.4).

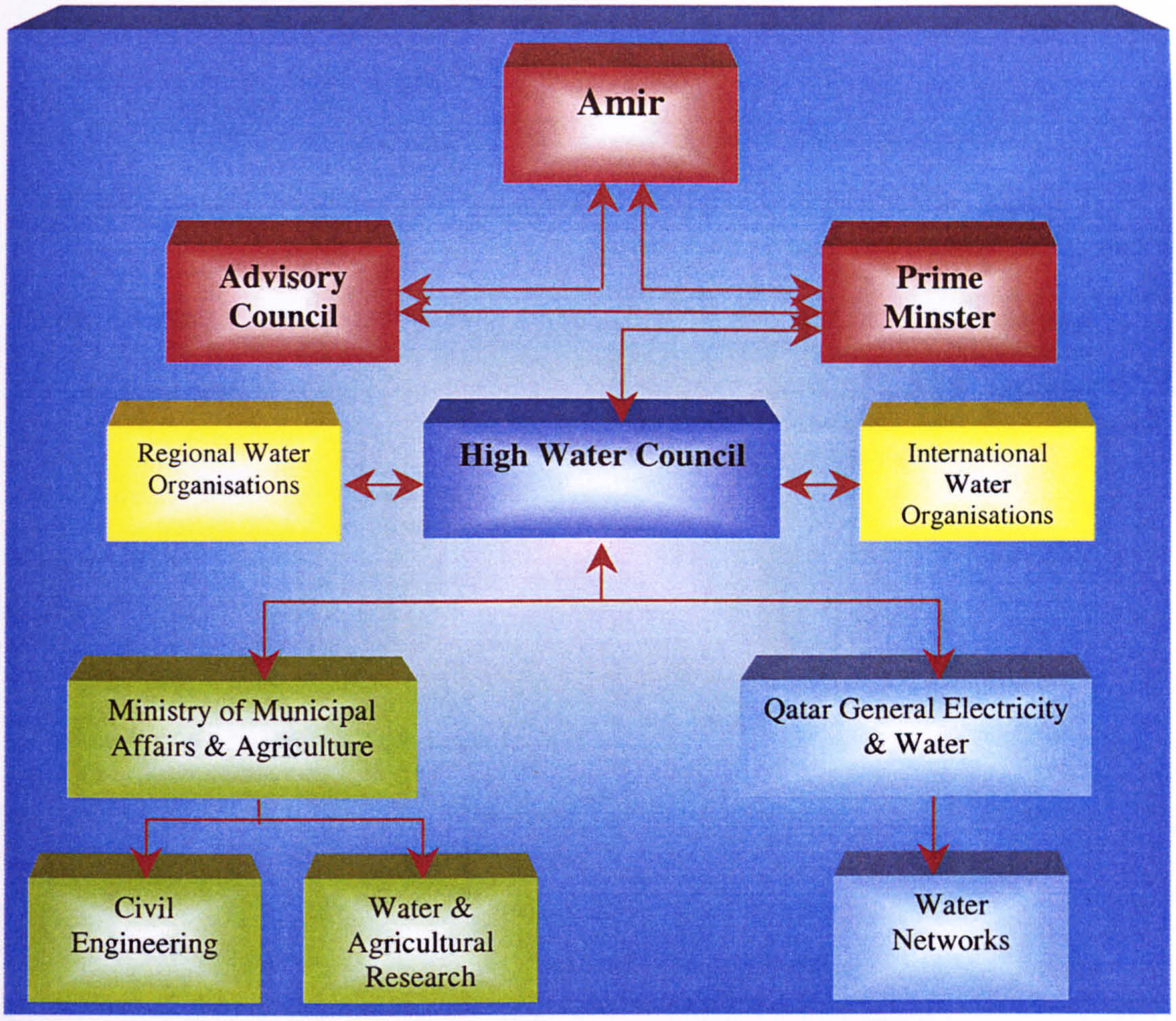

Figure 12.4. The New Suggested Water Institutions Framework (From this Thesis).

The High Water Council is an institution that will oversee the Qatari water industry and ensure co-operation (see Table 12.21). It is relevant to a variety of institutional arrangements (see Section 12.6 and 12.7) and, whatever the structure of the Qatar water industry, will act as a channel between the public and the administration.

Table 12.21. The High Water Council: Responsibilities and Requirements.

Responsibilities	Requirements
Establishment of a long-term water management policy, which is compatible with the general national policy.	A suitable budget with increased Government support.
Water supply, quality and demand monitoring	Strong legal powers able to overcome exceptions.
Development of the available water resources.	A legal framework to clarify the tasks of the new council and to avoid any conflict with other water institution.
Study the nature of water demand and find the most suitable methods to control it, especially by using new technical equipment, laws, tariffs and awareness.	High skilled staff in many specialities, especially administration, engineering, chemistry, geology, biology, agriculture, legislation, economics, sociology, geography and public communication.
Water research.	
Establish unit for an environmental protection against pollution caused by water resources development.	
Establishment of water data bank.	
Improvement of decision-makers and staff skills of the water institutions jointly with local related institutions, such as the University, and international bodies such as the UN organisations.	
Co-ordination between the water institutions.	
Co-ordination between the Government and the water institutions.	
Co-operation with related regional and international institutions.	

12.6. Future Water Management Policy Proposals:

The overall finding of this study is that the current management policy should be developed toward a holistic and sustainable approach, because the current problems have multiple aspects especially regarding supply, quality, demand and institutions.

Whatever the management framework, a number of issues need to be addressed urgently. Groundwater requires a strict policy to minimise damage, especially to enact and implement a law without exception to demarcate the quantity of withdrawal and limit its uses only to commercial farms with modern irrigation equipment (Figure 12.5). Qatar should depend primarily on non-traditional resources, especially desalination to meet future domestic demand. It is important to support studies that aim to reduce desalination costs and pollution, which may lead to its use in every sector. Another possible non-traditional resource is recycling, which is now used in limited areas. There is a major opportunity to expand its use, but only after improving the current technology to produce high quality water and offer an awareness programme to make people, especially farmers, more willing to use it. The opportunity to import water from rich-water countries such as Iran and Turkey is difficult due to political and economical obstacles. If these obstacles are overcome and water is imported, it should be used only for agriculture, because water for the domestic sector should to be a part of national security and not under foreign control. The water institution should work to increase the country's water storage capacity to confront shortages during emergencies.

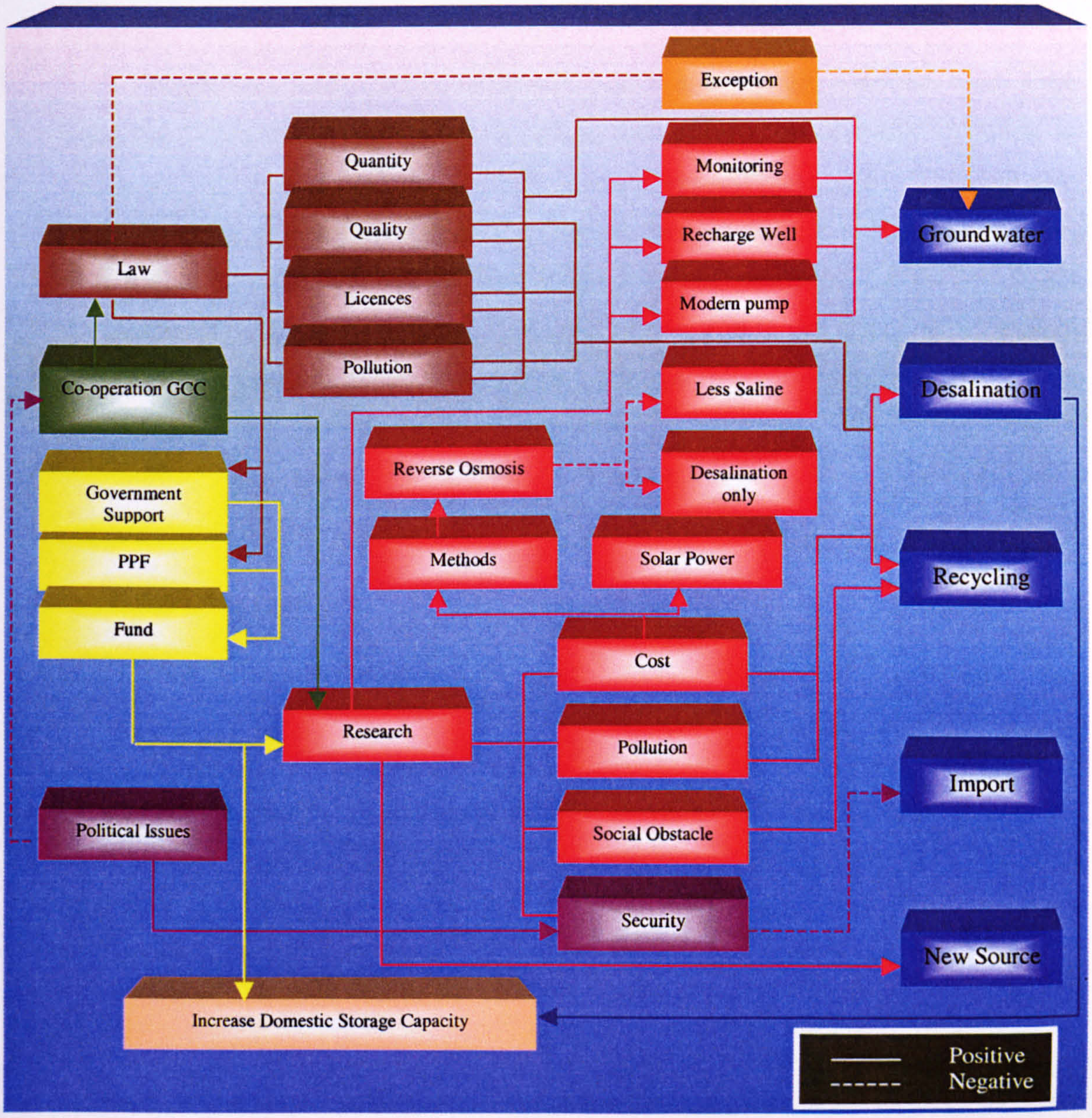

Figure 12.5. Water Supply Management Model (From this Thesis).

The water quality tests showed a serious problem, especially regarding groundwater used for both the agricultural and municipal sectors. Expanding desalinated water to cover the domestic sector, together with minimising the agricultural sector demand, will help to improve water quality. On the other hand, enforcement of strict water quality standards is a necessity, as is improving the distribution network, which is considered as an important source of freshwater contamination in Qatar.

Water demand in Qatar increased dramatically during the last forty years. The development of consumption control underachieves in all aspects. For example, most of the consumption control laws were enacted during the 1960s without enough efforts to develop and adapt them to events in Qatar after that time. Therefore, multiple efforts to control consumption in all sectors by implementing appropriate tools are required urgently.

Firstly, the water institution should coerce and support - perhaps with large subsidies - farmers to use modern irrigation methods and groundwater pumping to counteract the main reasons for agricultural water waste (Figure 12.6). This will also require establishment of a programme to improve farmers skills in economic water use. This policy should be backed by strict laws with great powers to enforce it without exception. This policy requires Government support due to the high cost of modern irrigation equipment for small farms on one hand and to control powerful groups from encroaching on laws and regulations on the other.

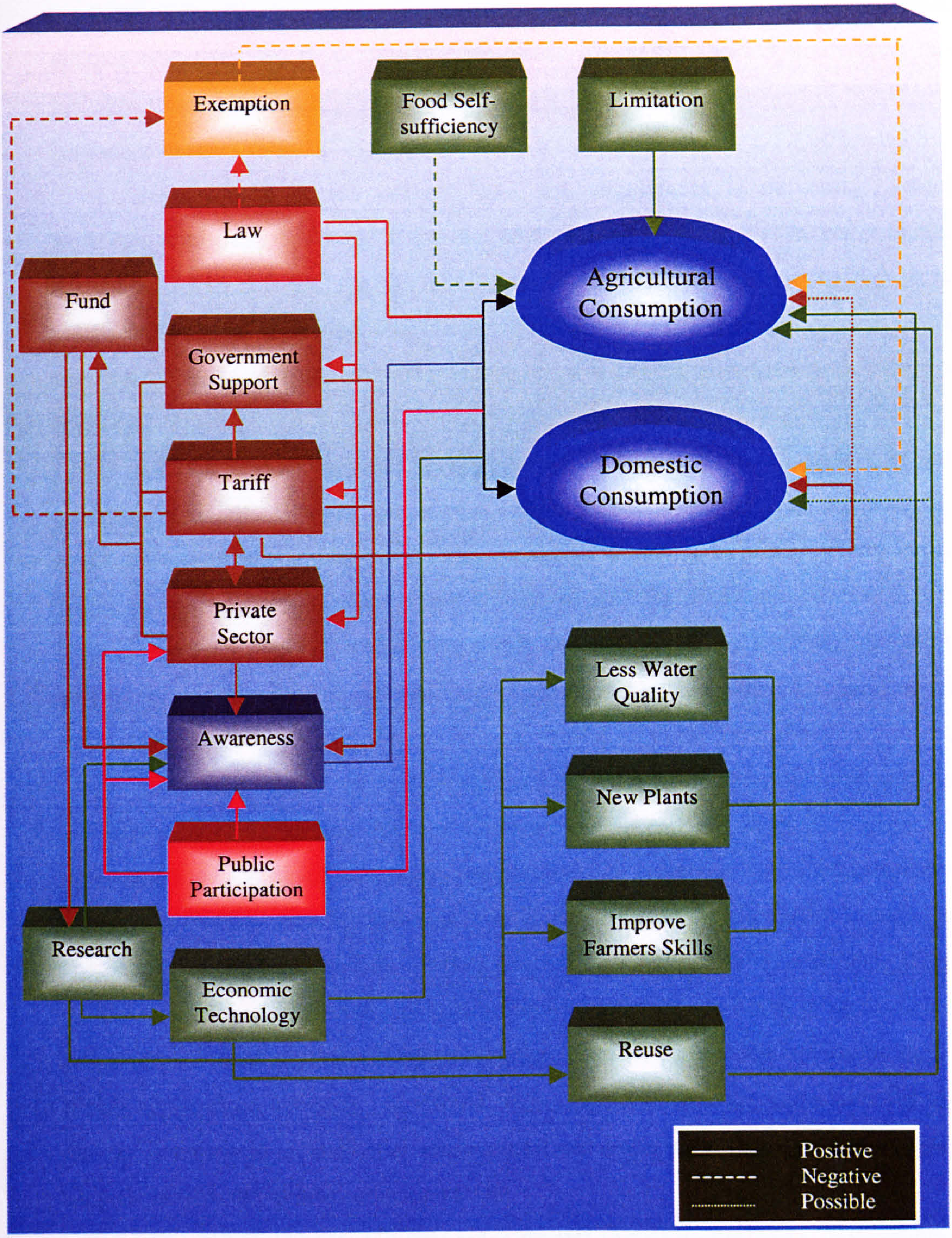

Figure 12.6. Water Demand Management Model (From this Thesis).

Secondly, the municipal sector requires a meticulously mature policy, because the public behaviour requires indirect (persuasion) and direct (enforcement) methods to achieve effective long-term change. Moreover, the study showed that Qatari society includes several different groups with different behaviours and attitudes, therefore it is important to use a range of appropriate tools.

Development of the current laws and regulations is necessary, especially regarding consumer rights and duties and control of consumption. The water institution should establish and enforce specifications for domestic equipment to reduce water waste and leakage. It is clear that the public would be more willing to accept new laws and regulations if enforcement covered all groups in society and if the policy considered traditions.

An effective water tariff policy should be enforced on all groups in society without exception, to avoid the current causes of policy failure. In this context, the study showed that the public are ready to accept a new tariff if this led to improved water services, especially quality, and if it considered the family circumstances and the level of consumption. On the other hand, for reasons of equity the domestic tariff should be less than the high production costs of desalinated water for those unable to pay.

The study showed the low level of public information about general water issues in Qatar, especially among the less educated and foreigners. This is because of the rarity and low quality of awareness programmes, as indicated by the stakeholders and public. Therefore, national effective awareness programmes should be a main part of the water management policy. Many institutions, especially educational, religious, youth, women's, media, and foreigners should participate in these programmes. The programme should consider different languages and cultures in the society by designing media appropriate for each. Moreover, it is important to share experience of experts during programme design and implementation, especially those in water, religion, society, media and public communication.

This holistic and sustainable management should be designed, implemented and monitored by the water institution. The study showed that the water institutions in Qatar suffer from lack of budget, power, co-ordination, decision-makers and skilled staff. Therefore, some proposed policies will be difficult to implement. It is important for Qatar to establish a new institution to control overall policies, research, staff training and co-ordination among the two ministries responsible for water. Therefore, the new institution requires a suitable budget, power and specialised skilled staff. Moreover, laws must be enacted to explicitly identify the responsibilities of the new institution, to avoid the current obstacles. The Government should to give the new institution its support in funding and in freedom to take decisions without intervention during policy design and implementation, since this was the most important reason for the current policy failure.

12.7. Models of Implementation and Management:

12.7.1. Introduction:

A number of possible models could be adopted for the implementation of the management policies described and evaluated above. These follow from the overall decision-making framework summarised in Figure 12.7. Virtually, all of the technical issues would remain the same for any management model. Fundamentally, the choice of model for adoption is a political decision. The alternative is, however, the retention of the status quo, which is unsustainable.

The main options for management are:

- Social/Islamic model.
- Privatisation/stakeholder model.
- Status quo.

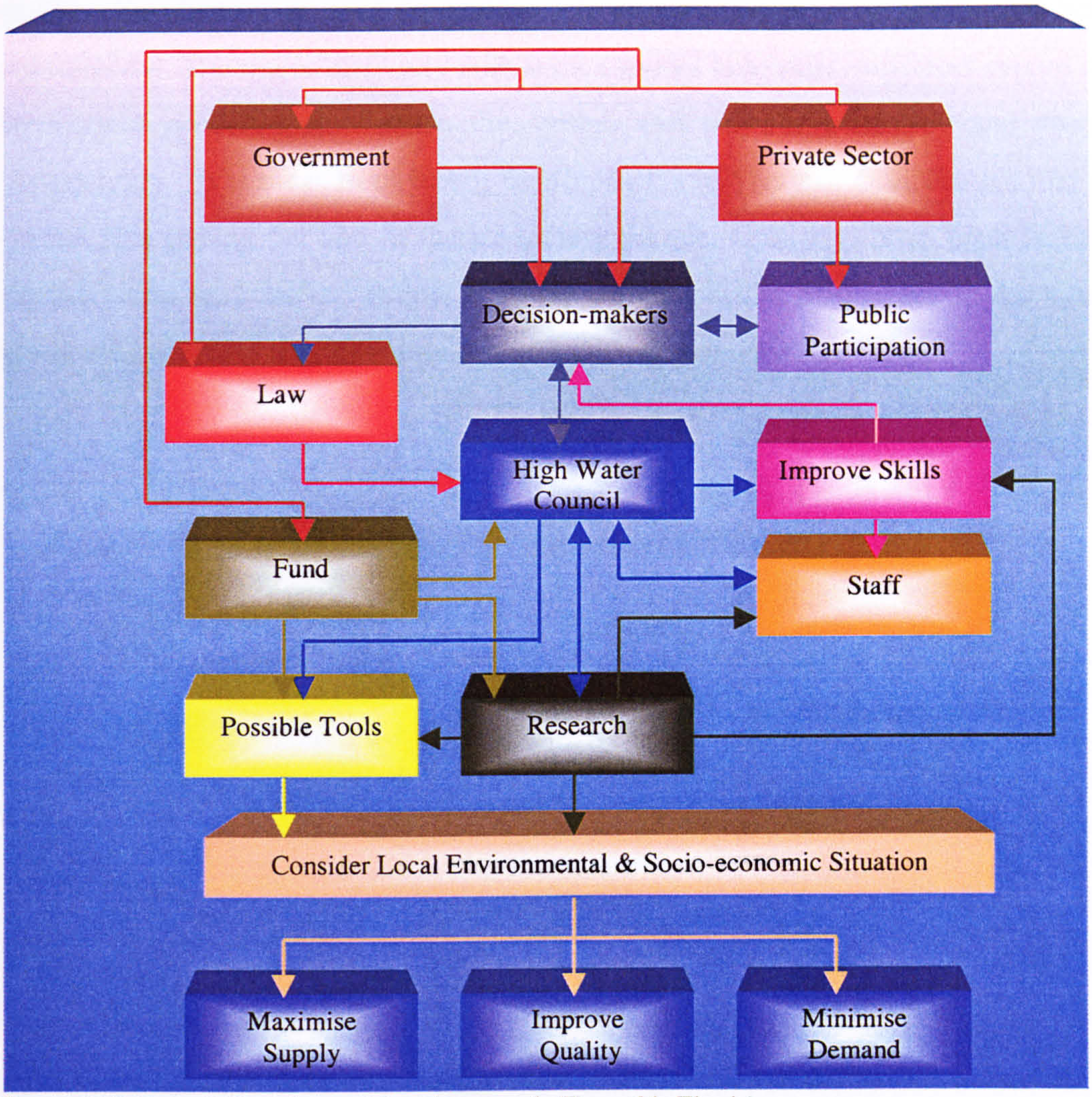

Figure 12.7. Overall Decision-making Framework (From this Thesis).

12.7.2. Social/Islamic Model:

In this model, management of water in Qatar would be through public participation under the guidance of Islam, which is appropriate for a strongly Islamic nation (Figure 12.8). Under this model, water would be seen as a public good, as is customary in Islam, and therefore should be controlled by the people and their representatives. Major investment would be needed in high-impact education and publicity to ensure that the public behaved responsibly with regard to water. The membership of the High Water Council would include a significant proportion of laymen, elected to represent public opinion, alongside the Government's representatives and technical experts. Major decisions of the High Water Council would go out to public consultation, so that the public felt an ownership of decisions and behaved responsibly. The major difficulty with such a model is to raise sufficient capital for the investment needed to modernise the system and pay for education and awareness programmes. It is clear from recent developments in Western democracies that voters do not like paying tax and in Qatari society people, similarly, have been resistant to paying taxies and tariffs. People must be convinced that investment in the country's water infrastructure is worthwhile and will deliver real benefits.

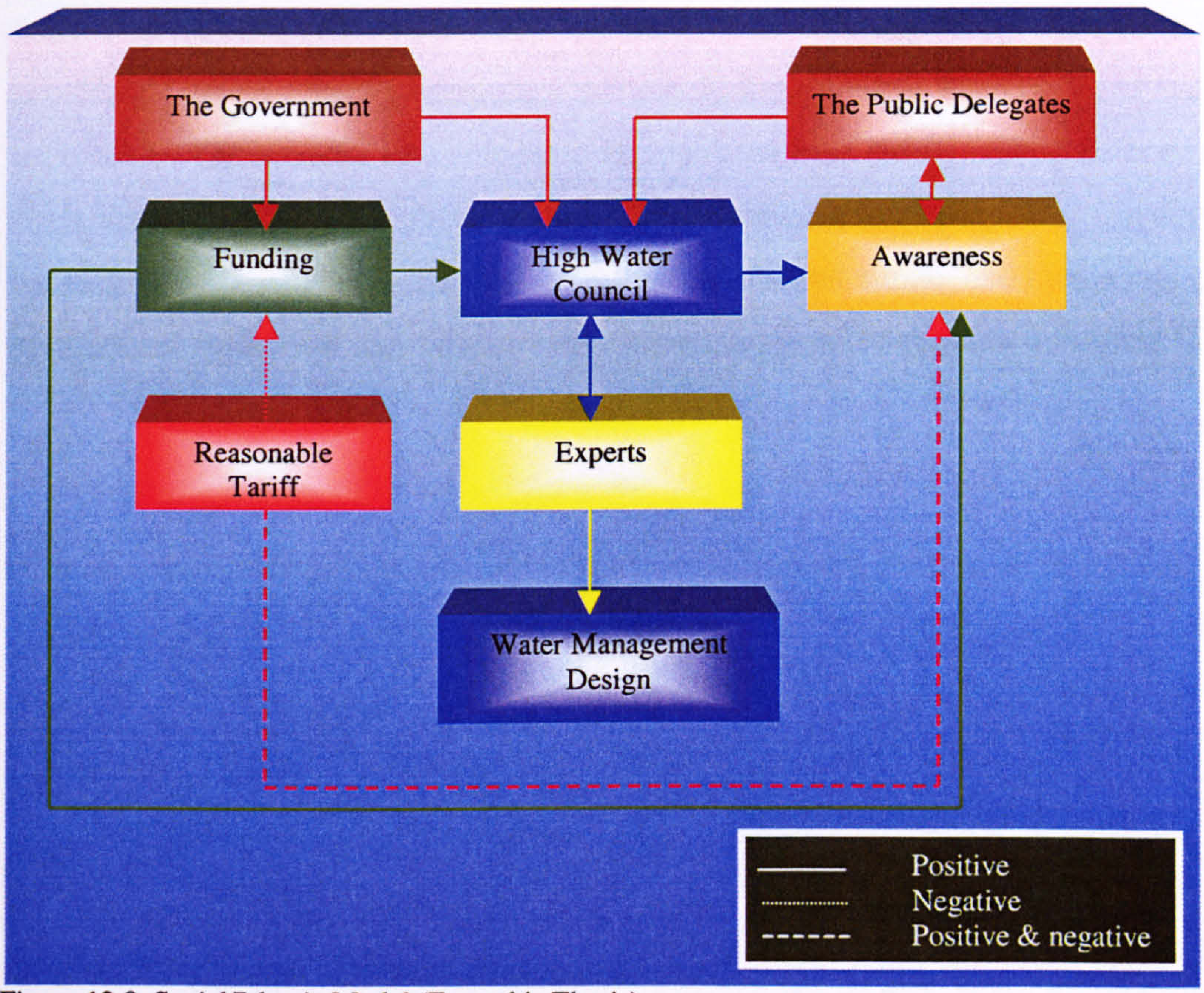

Figure 12.8. Social/Islamic Model (From this Thesis).

12.7.3. Privatisation/Stakeholders Model:

This thesis shows that limited privatisation is acceptable in Qatar, as long as there is improvement to water quality and social equity is observed. Under this model, money would be raised for the modernisation of the Water Industry through the selling of shares (Figure 12.9). If control of the Industry were not to slip away from Qataris, this would mean that in the first instance the shares should be offered to Qatari citizens and foreigners qualified by long residence and investment in the country. Participation could be widened by assigning shares to all Qatari citizens and especially employees – this might be desirable since it would make all concerned into stakeholders who would profit if the industry were successful. The industry would have to cover its costs and make a profit to reward shareholders by charging an economic tariff. The tariff would provide capital for further investment, and would limit demand because water would be expensive. The industry would have to be regulated by a strong central authority – the High Water Council - to prevent abuses. There would also have to be social provision to safeguard the poor. Importantly, privatisation of water supply and monitoring for the agricultural sector will still require Government support for economic reasons (Section 5.5).

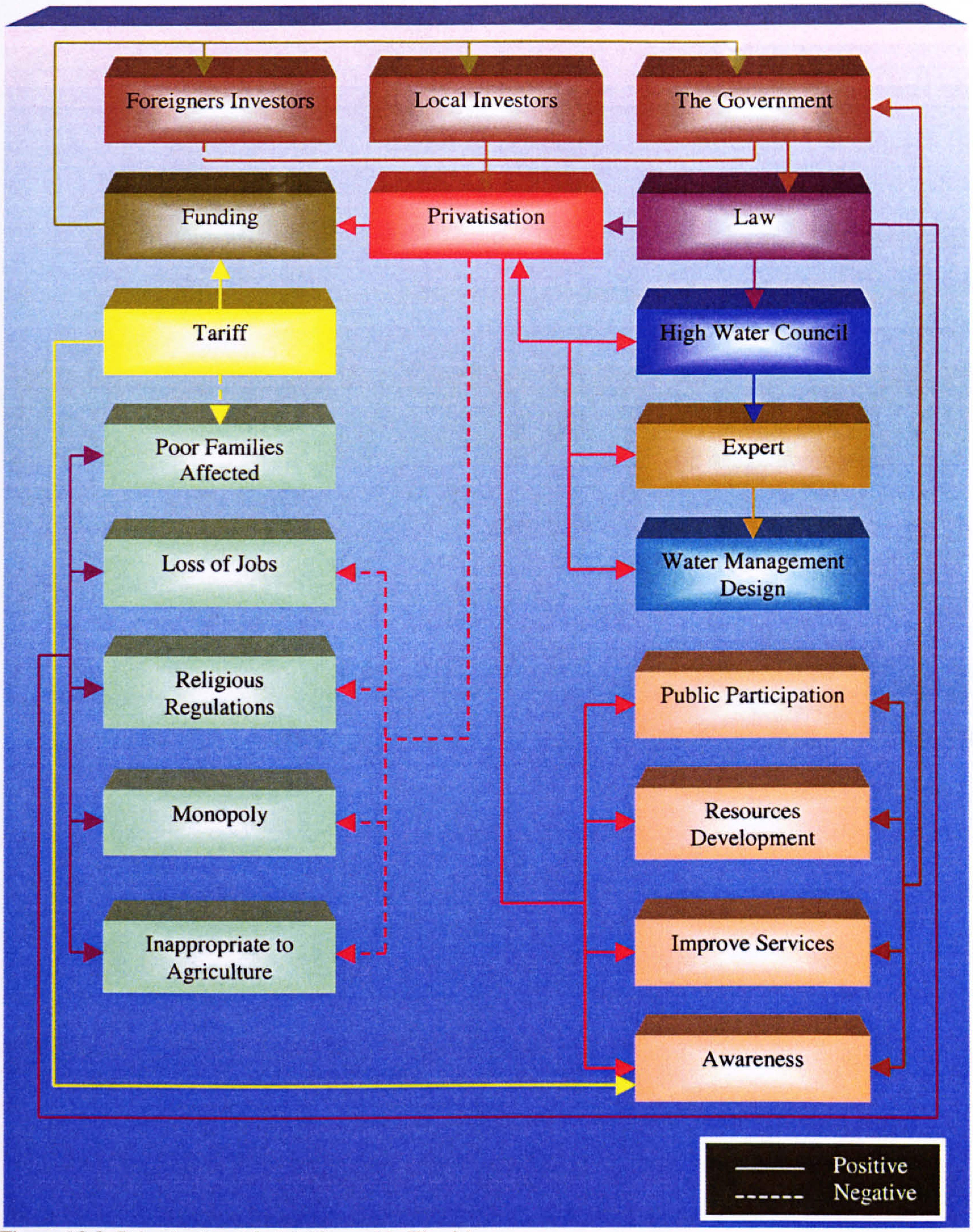

Figure 12.9. Privatisation Model (From this Thesis).

12.7.4. Status quo:

The alternative to change is to leave things as they are. The current position is summarised in Chapters 6 and 7. Groundwater is depleting rapidly and environmental problems are rife. The domestic sector depends on costly desalination water without consumption restrictions. Recycling is neglected. Public participation and awareness are absent. The agricultural policy for food self-sufficiency is incongruous for the country's climate and water resources situation. Water quality is unsuitable, especially groundwater. Water does not have its true economic value due to the current tariff policy, which causes a lack of investment in the Water Industry. Water laws and regulations are out of date and are sabotaged by exemptions. Decision-making is in the hand of a few inexpert people. Water institutions suffer from bureaucracy and lack of co-ordination, funding, skilled staff and freedom of decision-making in important water management issues. None of these things will be ameliorated in the near future. The piecemeal introduction of PPF, as has happened with the new desalination plant at Ras Laffan, will not provide the funds to renew the system.

12.8. Stakeholder and Public Perception of the Policy Options:

Table 12.22 summarises the most important stakeholder and public views, which affect the policy and institutional issues. It would be very difficult to ignore those views completely in the formulation of policy. They therefore constrain the possible options discussed in 12.5. It can be argued that these views amount to the basis of a sustainable system, if implemented.

Table 12.22. The Most Important Stakeholder and the Public Views.

Water Issue	Stakeholder and Public Views
Technology	Water supply development should depend on advanced technology to produce water by desalination and recycling due to limited groundwater and the grave risks of imported water.
	Water distribution network should be changed to reduce leakage and pollution.
	Change the current water using equipment, especially irrigation, to reduce consumption.
Economic	Water tariff should be enforced on all groups in society to cover water production cost and minimise consumption, but it should be associated with improved water service and quality.
	Privatisation is undesirable due to fear of increased water tariffs but there is some support for PPF and dividing water management between the public and private sectors.
Legislation	Enact new laws especially for water resources protection, to restrict demand, to manage pollution caused by desalination and recycling and to enforce water quality standard.
Society	The current water consumption behaviour should be changed by an effective awareness programme that involves important institutions to cover all groups in society.
	Public participation in water management is required to obtain support and change behaviour as stakeholders in the Water Industry.
Institution	Water institutions require co-ordination, funding, qualified decision-makers and staff.
	A revival of collaboration with similar institutions in neighbouring countries, especially touching common groundwater aquifers.

12.9. Overall Conclusion:

Qatar is characterised by the harsh desert environment, limited natural water resources, rapid population growth and development. This situation requires holistic water management: to give similar attention to water supply, quality and demand.

Firstly, current water distribution methods, which are responsible for some water pollution and much expensive leakage, should be updated as a matter of urgency since this effectively increases production substantially. Secondly, Qatar should depend completely on desalinated water for domestic demand with support for research to reduce pollution and costs. The limited fresh groundwater should be used only by commercial farms, with recycled water especially for not-directly eaten crops and for animal feed. Thirdly, water quality should be improved to a strict standard and monitored. Fourthly, water consumption should be controlled by improved implementation methods, such as strict laws, tariffs and strong awareness programmes.

Fifthly, an urgent priority is the introduction of modern economic irrigation equipment to all farms. This will be aided by substantial Government subsidies for the technology. Sixthly, water management requires policy consolidation to avoid unworkable plans and conflicts. This can be achieved by establishing a High Water Council, which will also play a significant role in improving the skill of decision-makers and staff. Finally, the holistic and sustainable policy should be in harmony with society and consider culture, the people's wishes and equity, to avoid policy failure.

The most important obstacles to the suggested policy are providing a suitable budget and lack of expertise in many fields. Therefore, the Government should increase its support to this important part of the public service. Water tariffs and PPF can raise enough funds to cover the financial requirement of the new policy in the longer term. The suggested High Water Council should implement a long-term programme to improve the skill of decision-makers and staff and generate local expertise in a range of water management aspects, especially engineering, geology, chemistry, biology, geography, agriculture, society, economics, law and public communication. The management of the water industry could follow a number of models, which would result in different outcomes. Decisions about the type of model appropriate for Qatar are essentially political and thus outside the scope of this thesis, which does, however, set out the possible options. What is clear, however, is that the status quo is unsustainable.

CHAPTER THIRTEEN:

CONCLUSION

Chapter Thirteen:

Conclusion

13.1. Introduction:

The main aim of this study has been to explore options for holistic and sustainable water management system for Qatar. Water management studies in Qatar are currently limited to some papers focused on the cost of desalinated water and groundwater level changes (e.g. Judah, 1994). Therefore, this study addresses a gap in the literature, especially concerning public and stakeholder behaviour and attitudes toward sustainable water management strategy. Using three surveys and two sets of interviews as primary methods for eliciting empirical data, the study has defined sustainable policy options that are suitable for the local environment and socio-economic situation and will provide appropriate tools to provide safe water and help to control consumption in future.

This Chapter includes five sections to display the study results and conclusion. The first section reviews the aims and objective of the study. The second section summarises the water issues in Qatar and the major results of five surveys and interviews. The third section outlines the future water management proposals. The study limitation and some recommendations for future studies are set out in the last section.

13.2. Objectives of this Study:

This study aimed to design policy options towards a holistic and sustainable water management system for Qatar through analysis of the following issues:

- The way water issues dealt with elsewhere, to provide potential models for Qatar.
- The characteristics of the current water system.
- How Qataris managed water before the 1950s.
- Analysis of the chemical quality of groundwater, desalination and recycling and their suitability for different uses.
- The pattern and reasons for consumption.

- Public opinion about the water service, consumption, laws, awareness, participation in water management, privatisation, importation of water, recycled water uses.
- The stakeholders opinion about the current water management and their suggestions to improve it.
- Analysis of the serious shortcomings in the management policy of water institutions in a number aspects, especially environment, technology, economic, legislation, decision-making, social and institutional frameworks.

13.3. Water Issues in Qatar:

This study started by considering water issues in arid areas, while noting the lack of studies that either address or explore water problems and management in Qatar. Qatar is like other oil-rich and poor-water developing countries, with water shortage due to limited rainfall, seasonal aridity, population growth, and industrial and agricultural development. As with the Arabian Gulf states and Libya, water consumption increased suddenly as oil production in the early 1950s and increased oil prices during the 1970s, increased state revenue and led to massive immigration, and a high standard of living for citizens (e.g. al-Kuwari, 1996).

Like some other countries without surface water, groundwater has depleted and salinised due to excessive pumping without control by strict policy (e.g. al-Nasr and al-Sheeb, 1999). Moreover, the oil-rich countries imported technology for seawater desalination without much regard to costs or pollution and this has largely replaced groundwater for domestic uses (e.g. Dabbagh and Faraj, 1997). Qatar and similar countries have explored using recycled water for irrigation, but in limited areas, especially for public gardens and fodder crops because most of farmers refused to use it. The level of technology and people's attitudes prevents this water being used in other sectors (e.g. Hussin, 2001). They have also explored import of water, but the unstable political situation and economic difficulties have prevented implementation (e.g. Biswas *et al.*, 1997). Therefore, in Qatar, although there have not been shortages of water it is clear that current water management policy is unsustainable (e.g. al-Kuwari, 1996).

An important issue for Qatar and other water-poor countries is the development of a sustainable water management policy. Many people hold that the state approach is the most suitable for the socio-economic situation in these countries when correctly applied, especially with public participation (e.g. Jellali and Jebali, 1994). On the other hand, it is important to consider the need for sustainability of water use in any approach to water management. Moreover, choice of approach leads to the tool need. In contrast to most developing countries, oil revenue in Qatar and similar countries has allowed decision-makers to implement a technical approach (e.g. Polevoy, 1996) to the development of water supply. Lack of expertise and shortages of Government support has hindered full adoption of advanced technology, however (e.g. al-Kuwari, 1996).

Qatar shares with most developing countries an ignorance of effective tools to limit the current demand and conserve non-renewable water resources for future generations (e.g. al-Kuwari, 1996). The first tool that can be adopted for water management is economic. Since the development of water resources is expensive, it becomes necessary to charge tariffs to cover the cost of providing water and to reduce consumption (e.g. Draper, 1994). There are serious doubts about this especially in poor developing countries where most people do not have access to even the minimum water requirements. Conservative societies in many arid countries consider water as a gift from Allah, which no one has the right to own (e.g. Shadi, 1999). In Qatar and many developing countries, the water tariffs are nominal and do not reflect the cost of production and/or are partially implemented (e.g. al-Alawi and Abdulrazzak, 1994).

Strict laws that can help control consumption and conserve resources but the legislative tool in most developing countries is weak and rarely enforced (e.g. Hassan, 1995). Laws and regulations in Qatar and other developing countries must be adjusted to the realities of the situation (e.g. al-Harmi, 2000b).

Social solutions have recently started to gain attention, especially in democratic countries. Some managements have been able to benefit by allowing popular participation in planning and preparation of policies (e.g. Hunter, 1998). Increasing knowledge of individual consumption behaviour and ways to influence it are of growing importance (e.g. O'Rourke, 1992). Qatar and most developing countries have not yet developed strengths in this area (e.g. Khuraibet and al-Attar, 1997).

Decision-making on an international level faces many challenges, especially in the absence of clear international law. Nationally, also, sectoral disputes or regional disputes put pressure on decision-makers (e.g. Grigg, 1996). Qatar shares with most developing countries a lack of skilled decision-makers due to absence of training programmes. Moreover, the traditional regime does not encourage experts or the public to participate in decision-making. Therefore, the current policy encountered obstacles during implementation (e.g. Zubari *et al.*, 1993).

This study discussed institutional characters in developed and developing countries and analysed the most serious obstacles facing water management policies. In general, water institutions in Qatar and most developing countries follow a multiple institutional management system under the central Government, characterised by absence of co-ordination, conflict between policies, few skilled staff, little public participation, poor service and low quality (e.g. al-Mugran, 1992). On the other hand, the advantage of this system is in government support, which is important because people may be poor, as in most African countries, or refuse to pay tariffs, as in some Arabian Gulf states (e.g. Badauy, 1999).

In general, it is necessary for Qatar and similar countries to evolve sustainable policies for water management. A variety of types of policy are available, but it must be stressed that not all policies can be applied successfully in any given environment or society. Clear lines of policy development and rigorous implementation and monitoring are necessary. The success of a sustainable water management strategy on a local, regional or international level requires attention to all aspects. It is important to implement policy that stems from the local conditions in the society, so it can be accepted socially and its chances of success enhanced.

The study therefore tested and explored water quality and the attitudes and opinions of old people, stakeholders and the public towards various aspects of the current water management in Qatar. It also sought suggestions for possible policies to improve it. The empirical data on which this study draws was gathered through five surveys. Firstly, old people were interviewed about water management before the oil era, which stared in the 1950s (Section 7.2 and Appendix 8). It seems to be important to record methods that can be used to manage water when the non-renewable energy runs out. Before the 1950s water resources development, production and distribution was done by communities working together, using limited fresh groundwater and rainfall for important purposes such as drinking and cooking and poor quality groundwater and seawater for washing and industrial purposes such as building construction and turned to the sea for food and trade. Consumption of freshwater was puritanical and houses contained specialised water equipment to prevent waste. In general, the Qatari people in that time understood their difficult environment. It is clear that this system was more sustainable than now.

Secondly, the water samples from different sources and for different uses were tested for quality (Chapter 8). Results were compared with different published standards. In desalinated water, all chemical elements were found within maximum recommended levels except iron and sodium. In groundwater most elements, especially sodium, calcium, magnesium, chloride and sulphate are higher than the recommended levels. Recycled water contained high concentrations of sodium, chloride, iron and calcium. The most serious problems are found in groundwater used for agriculture where most chemical elements were found in higher concentration than recommended levels, which will cause damage to plants and agricultural land.

Thirdly, the stakeholder opinion about the current water management was analysed (Chapter 9) and especially four main issues: supply, quality, demand and institutions. In general, most stakeholders were not satisfied with the current policy and suggested significant development. Most stakeholders opposed the current supply policy, especially pertaining to dependence on costly, old and polluting desalination technology and a leaking and inefficient network, both of which they wished to up grade. They recognised that inequitable groundwater production has caused quality decline and depletion. They wished to enlarge use of recycled water and wished for investment to improve its quality. Most stakeholders were dissatisfied with the current consumption controls and wished to implement awareness efforts, public participation and legal controls and tariffs with strict implementation. The majority of stakeholders recognised shortcomings in the water institutions due to the lack of skilled decision-makers and staff and unclear lines of responsibility, which led to policy conflict. They therefore called for co-operation between local water institutions and between local, regional and international institutions. Importantly, most stakeholders wished to increase the Government support for this very important public service. They acknowledged the possibility of partial privatisation, but felt that policy should to designed and directed by the Government.

In Chapter Ten, domestic water consumption was measured in order to know the level of consumption for different purposes. Per capita water consumption in Qatar corresponds or exceeds that in many rich-water developed countries. Most water is consumed for personal hygiene.

Fifthly, public perception and attitudes were analysed (Chapter 11). Different behaviour patterns and attitudes can be seen. Crudely, many of the Qatari population are well-educated and well-off. They are relatively well-informed about water issues, concerned about water quality, are often liberal in their water use, often for reasons of personal hygiene and feel they can reduce it. They do not pay a water tariff and would expect quality and service improvements if they did. They recognise that substantial improvements could be made to the water industry by improving the legislative framework, awareness efforts and levels of public participation.

On the other hand, the other major group in society are relatively poor immigrant workers from the Indian Subcontinent. They are poorly educated, especially in water issues, and many do not speak Arabic well. They are not greatly concerned about water quality but are already constrained in their consumption behaviour by tariffs. They have little understanding of, or engagement with their host society, including the issues surrounding the water industry.

13.4. Future Water Management Policy Proposals:

Figure 13.1 shows the suggested sustainable water supply and demand management for Qatar. This model depends primarily on the most important and practical elements found in Sections 12.5, 12.6 and 12.7. The important component parts of this policy are:

Supply Management:

- Laws will be made to govern water resources especially groundwater withdrawal, pollution, quality and will apply without exception to all.
- Co-operation with GCC countries will arrange for common management to shared aquifers and minimise the desalination process pollution.
- Technical methods will be used to remedy poor groundwater quantity. These methods included advance monitoring, recharge wells and support for farmers to use modern pumps to withdrawal water.
- Desalination methods will improve toward minimising the cost and pollution.
- Advanced technology will produce high quality recycled water, which will be useful for many purposes.
- Leakage reduction will remove pressure on the production of desalination water.
- The capacity of the domestic sector water storage will be increased by reservoir construction and desalination should increase to replace groundwater.
- Funds for water supply development will be from the Government with possibility for private investment.

Demand Management:

- ✻ Law will be made to govern water consumption and will apply without exception.
- ✻ New agricultural policy will be established depending on the country's circumstances, which will repeal food self-sufficiency policy and limit this sector to the commercial farms.
- ✻ Comprehensive and long-term awareness programmes will be designed to change the consumer behaviour towards economical consumption.
- ✻ The public will be given the opportunity to participate in water management.
- ✻ Technologies and equipment used to minimise water consumption, especially in the agricultural sector should be subsidised to speed uptake.
- ✻ Programmes to improved farmers skills will minimise agricultural water use.
- ✻ Tariffs will be enforced without exemption to affect consumer behaviour and cover water production and distribution cost.
- ✻ Water demand management will be funded by Government support and tariffs with the possibility for private investment.

In general, the study showed that the current water management is unsustainable and should be altered. A variety of management choices can be made (Section 12.7). Firstly, the social/Islamic model which develops the current policy. Here, water management will still be in Government hands but with a broad public participation in decision-making, with establishment of the High Water Council for overall policy design and implementation. This model is more desirable for both stakeholders and the public because it in harmony with the culture, since water is still considered as a public commodity. Secondly, a privatisation model conforms to the current international trend and is already applied in some sectors in Qatar, such as telecommunications. This model will provide funding required to improve the current situation. Government direction could avoid some disadvantages of this model, such as monopoly, but others, especially high tariffs and loss of jobs are unavoidable because the water companies will be looking not only to cover the cost but also to get a good profit. It is possible to consolidate these models by applying partial privatisation for part of the water supply, as has happened with RAF (B) desalination plant recently. A third option is to persist with current arrangement and structures. This option is clearly unsustainable, will lead to further depletion and damage to groundwater and an increasingly dissatisfied group of municipal consumers.

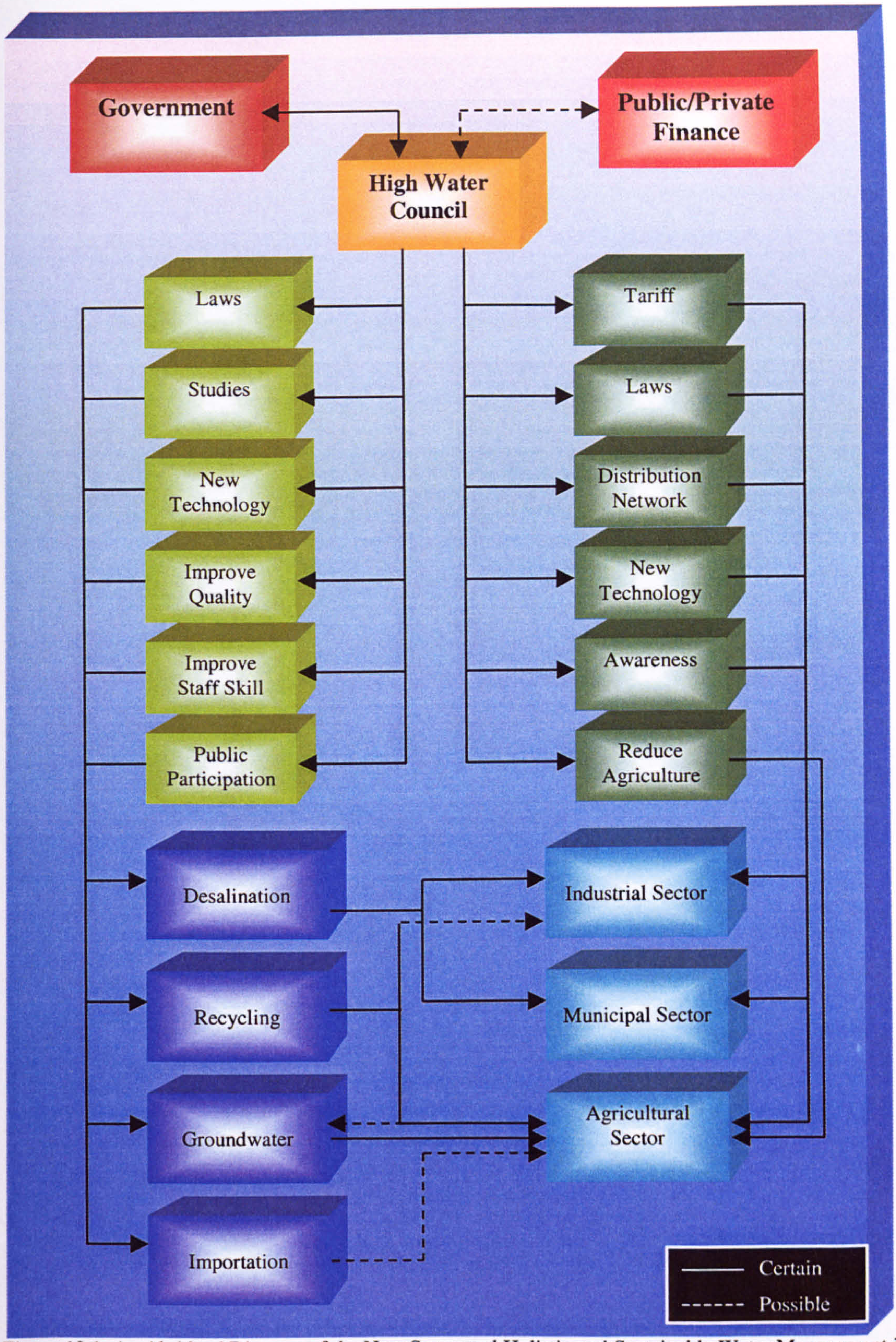

Figure 13.1. An Abridged Diagram of the New Suggested Holistic and Sustainable Water Management in Qatar (From this Thesis). Responsibilities for all Issues should be through the High Water Council, under Government Supervision. If the Private Sector is Involved, then this should be Regulated by the High Water Council.

13.5. Limitations of this Study and Recommendations for Further Research:

Research that depends on empirically-oriented methods usually cannot avoid some limitations. There were many problems during the different surveys. The most important problem is finding stakeholders with enough information about water management and accessing different groups in society who were willing to participate in interviews and questionnaires at specific times. As is well known in developing countries, various difficulties appeared when trying to obtain official data or interviews, especially with the top government officials. These problems are tied up with the bureaucracy, which is widespread in most countries. Moreover, the public surveys required time and some concentration, which led some respondents to answer the questionnaires incompletely or not at all. Furthermore, the public questionnaires were aimed to cover large groups in society, but difficulties were encountered, especially concerning immigrants who used different languages and were not interested in the project.

Nevertheless, the study has been able to address aims of the thesis, especially the role of water supply, quality, demand and institutional problems in Qatar and sustainable policies to reduce their effect at present and in the future. The limitations of this study are unlikely to have impacted the results to any major degree.

The study raised some significant issues that could provide the basis for other studies and which might give some insight into the issues raised here, and help researchers to avoid the major obstacles that are considered as a natural part of this type of study (Section 4.5). The most important issues for future research include:

- Studies that go further with exploring a holistic and sustainable management approach to be carried out groups of specialists, especially in water management, health, geology, biology, chemistry, engineering, technology, economic, legislation, administration and society. Such advanced study should be supported by the water institution to avoid bureaucratic obstacles.

- This study concentrated on personal consumption behaviour and attitudes in the domestic sector, due to its importance and because it is consumes the most costly water and is rapidly increasing. Nevertheless, there are other sectors to consider;

therefore, future research is needed to examine the water consumption behaviour and attitudes of the industrial and agricultural sectors.

- The majority of the public sampled by questionnaire in this study were Qataris. Long-term policy should consider them, but immigrants are now more than 78% of the total population. Therefore, further separate future studies should concentrate on different groups of foreigners defined by culture and language to examine their behaviour and attitudes in more detail.

- This study examined eleven important chemical characteristics only, due to lack of surface water that could be tested using biological methods. This is only a first independent assay of quality. Therefore, future studies are required to examine the other water chemicals as well as microbiological, physical and thermal qualities.

- Future studies are required to examine water quality changes over time, especially of groundwater, by testing samples from the same source on a regular, long-term basis.

- The effect of poor water quality on soils, plants, animals and humans in Qatar should be explored.

- The cost of water resources development, distribution network and programmes to control consumption and improve water institution staff and farmers skills is beyond the scope of this thesis. Therefore, future studies are required to calculate the costs of construction and maintenance.

- Future studies should also monitor developments in sustainable management good practice elsewhere in the world, and test their applicability to the situation as it develops in Qatar.

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APPENDIX ONE:

GLOBAL FRESHWATER BUDGETS

Appendix One:

Global Freshwater Budgets

It is indicated by Abu Samur and al-Khatib (1999); Kandiah (1999); Shadi (1999); UNESCO (1999) that the amount of water available on earth is enough to meet the current needs of human beings and their various activities. But this is conditional on the equal distribution of water among the various regions, making it readily accessible. This draws attention to a problem suffered by some countries where rivers run through them, namely the monopolisation of the water by the source country and its ability to threaten the supply of water available by downstream establishing water projects.

The freshwater on earth does not exceed one two-hundredth of the total available water. The remainder is salty water that can not be used directly. Available water is limited since most freshwater is present as ice sheets and icebergs (for example McDonald and Kay, 1988; Clarke, 1993; Grigg, 1996).

As seen in Table A1.1, the water in lakes and rivers does not exceed 0.025% of the total available water while the share of groundwater stands at 1.0% of total water. These figures by TOU (1997) provide a clear indication of limited extent fresh water, compared with the total available water on the planet.

Table A1.1. Global Water Budget (TOU, 1997).

Reservoir	Volume (km^3)	Volume (%)
Oceans	1,400,000,000	96
Ice and Snow	43,000,000	2.97386
Groundwater	15,000,000	1.0
Lakes and Rivers	360,000	0.025
Atmosphere	15,000	0.001
Plants and Animals	2,000	0.00014
Total	1,460,000,000	100

Gray (1994) and Polevoy (1996) estimates salty water at 96.5% of total water, all concentrated in oceans. The percent of salty water in oceans is 99.995% of total salty waters. Only 2.5% of water is freshwater and not all this is suitable for direct consumption. Around 75% of that is snow and icebergs and 24% groundwater. This leaves only 1% of total freshwater running on the surface of the earth as lakes, rivers, in addition to the water in soil. The conclusion drawn by Gray is that the total surface water available for direct consumption is less than 0.01% (Figure A1.1).

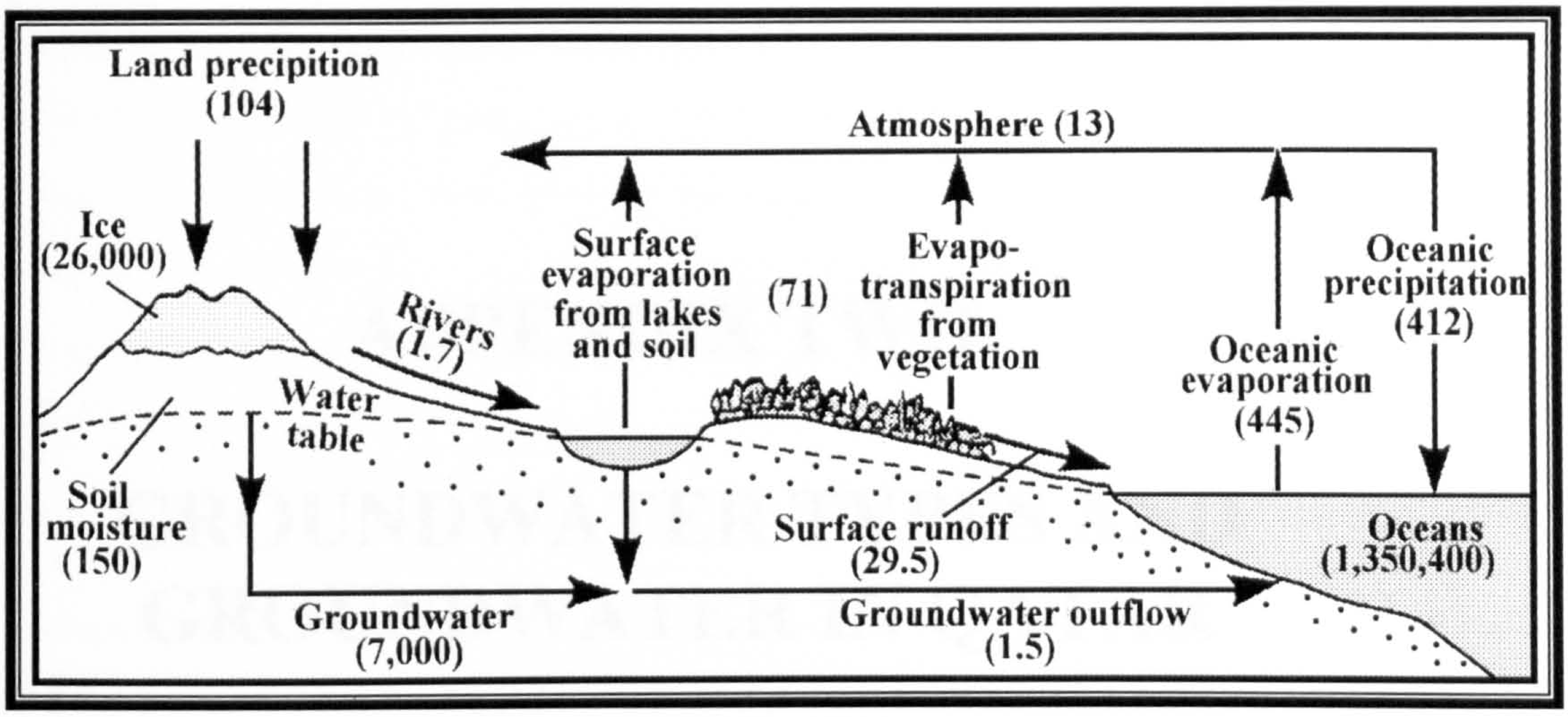


Figure A1.1. The Volume of Water Stored and the Amount Cycled Annually (10^3 km^3) (After Gray, 1994).

Surface water appears to be unlimited and under-utilised, since two third of that water is frozen and only 0.3% is available for human consumption. Even if one assumes that this amount is enough for direct use, the question remains whether it is equally distributed so that each individual is provided with the amount needed for personal and other activities. Most studies validate this position and confirm that the distribution is not equal and that there are regions with water supplies to consumption while other regions do not have enough water to meet the minimum needs of these inhabitants (for instance Dery and Salomon, 1997; Allaby, 1996; Kandiah, 1999).

APPENDIX TWO:

GROUNDWATER TYPES AND GROUNDWATER IN QATAR

Groundwater Types and Groundwater in Qatar

A2.1. Groundwater Types:

The largest amount of freshwater, (according to Gabler *et al.*, 1994; Williams *et al.*, 1995; Beaumont, 1993; Chapman, 1996; Bowen, 1986; Morgan, 1990), is found underground. They emphasise that groundwater is present in soil and passes into rock cavities. It first leaks underground through an area called the "zone of aeration" where porosity is filled with air. Then it passes into another area, called the "zone of saturation" which is an area where water fills the voids. Between the two zones the water table is found. The level of water depends on the amounts entering and the amounts withdrawn and recharging. The authors indicate that the behaviour of the water table varies according to the climate (Figure A2.1).

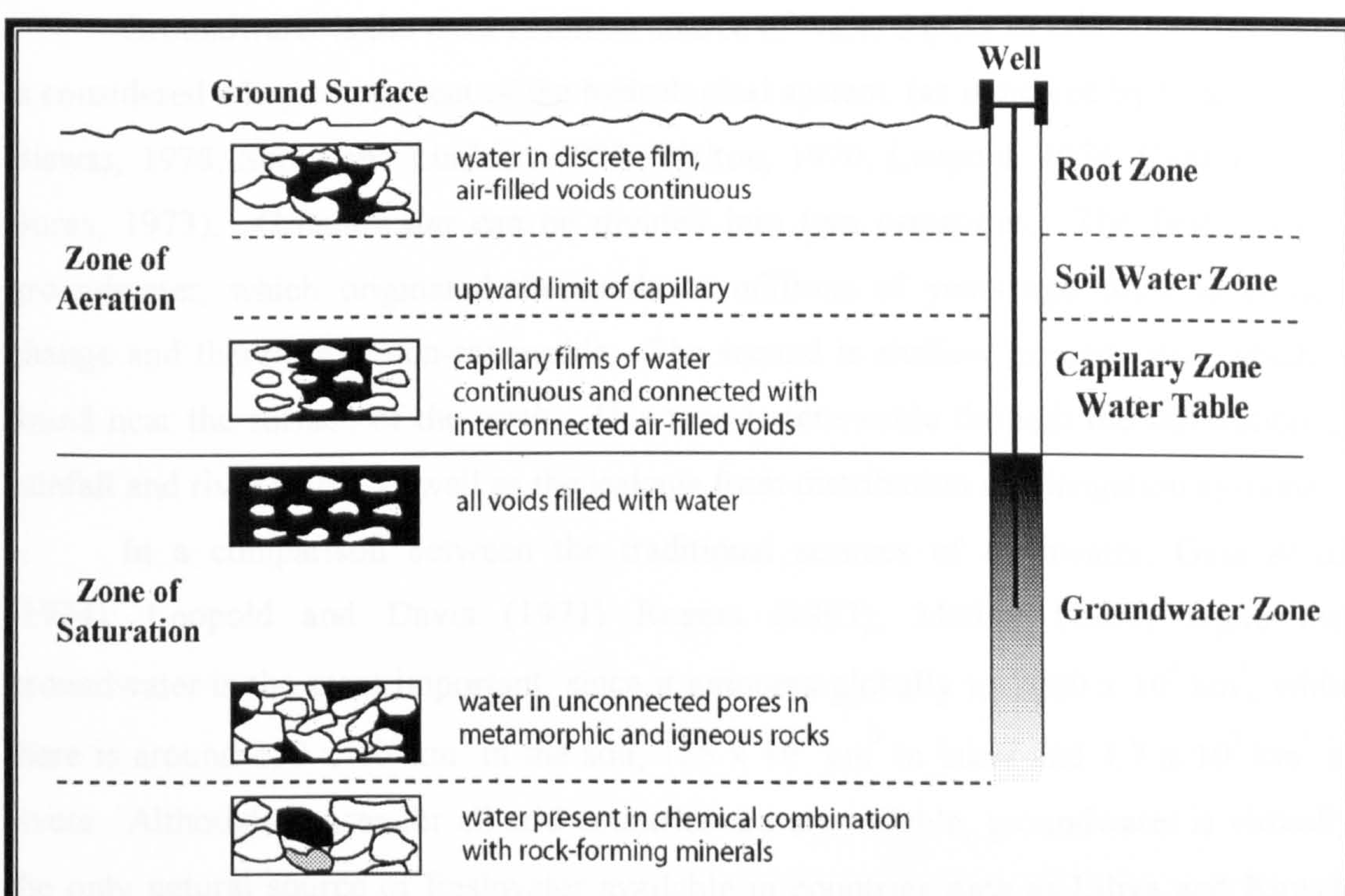


Figure A2.1. Cross-section through Soil and Aquifer Showing Various Zones in the Soil and Rock and their Water-bearing Capacities (After Gray, 1994).

According to Sawyer and Dulam (1998); Polevoy (1996); Huisman (1972); Allaby (1996); Abu al-Fatih (1997) There are three ways get groundwater. Firstly, through springs, there the water intersects with the earth surface. Secondly, through wells, which are widely spread and take many shapes. A well is dug until it reaches the layer that carries the water and then this is pumped to the surface. There is two types of groundwater that can be reached through drilling: the water near the earth surface, that depends on the fluctuation in the water table and deep water found in much lower layers. This can be depended upon as regular source of water, additionally it is not influenced by a dry climate. Lastly, there are artisan wells where the water reaches the surface without pumping, but through the internal pressure of the well from hydrostatic head and by that the water is raised higher than the ground surface.

It is made clear by Arthur (1994); Brown *et al.* (1996); Chapman (1996); Young (1997); Chilton *et al.* (1995) that increased dependence on groundwater is due to the fact that it is often less costly in arid areas than other sources of water, besides being near the source of demand. Groundwater does not require special equipment, such as pipes, reservoirs or any construction and it is usually of good quality, because normally this water is far from pollution sources and so does not contain any bacteria or microbes and hence does not need treatment.

Groundwater is the most common source of water supply in arid countries and it is considered a key component of the hydrological system, (as indicated by Grigg, 1996; Biswas, 1978; Seiler and Lindner, 1995; Walton, 1970; Leopold, 1974; Cantor, 1970; Buras, 1973). Groundwater can be divided into two categories. The first is fossil groundwater, which originated thousands or millions of years ago prior to climate change and therefore is non-renewable. The second is shallow groundwater, which is found near the surface of the earth. This type is renewable through the infiltration of rainfall and river water, as well as the leakage from distribution and irrigation systems.

In a comparison between the traditional sources of freshwater, Gass *et al.* (1974); Leopold and Davis (1971) Rogers (1993); Mather (1984) argue that groundwater is the most important, since it amounts globally to 7000 x 10^3 km^3, while there is around 150 x 10^3 km^3 in the soil, 125 x 10^3 km^3 in lakes and 1.7 x 10^3 km^3 in rivers. Although figures for all arid countries are unavailable, groundwater is virtually the only natural source of freshwater available in countries such as Libya and Kuwait (al-Alawi and Abdulrazzak, 1994; Jellali and Jebali, 1994).

Many authors enumerate the factors that influence the amount of groundwater as follows: rainfall accumulation, evaporation, vegetation and lastly the nature of soil and rocks. They further emphasise that groundwater is useful only when the rocks, in the area that is saturated, provide adequate amounts of water to springs, streams, wells and boreholes. This only happens when the area is saturated all year round or at least for a long period during the rainy season. Another factor influencing the usefulness of groundwater is dissolved minerals, which makes it more or less suitable for a variety of uses, especially for municipal purposes. In some circumstances it is not possible to utilise groundwater. This happens when the source of water is buried deeply (more than 0.8 km) and it is impossible to reach except by very expensive methods. Other occasions include situations such as where the aquifer is salty and can not produce freshwater (Greenwood *et al.*, 1992; Porteous *et al.*, 1993; Bartram and Ballance, 1996; McDonald and Kay, 1988; Thomas, 1951; Polevoy, 1996; Lloyd, 1981; Moore *et al.*, 1995; Foster, 1995; Ward, 1995).

According to Deming (1975); Bowen (1982); Mamo (1997); Chapman (1996) in arid areas, the loss of groundwater through overpumping is compensated by surface recharge through rivers, lakes or irrigation. Rainfall is the only source of groundwater recharge, although its significance is limited because of high evaporation rates in arid areas.

Ecological limitations affect, for instance, attempts to extract more groundwater from an aquifer. These will include the drying up of surface streams and a consequent decline in biodivesity (Kotoub and Abdulrab, 1995; al-Mugran, 1992; Allaby, 1996; Thanh and Tam, 1990a; Beekman, 1998). In many countries, such as Libya, groundwater is being "mined" - it is essentially unrenewable, since the rain that supplied the aquifer fell during the late Pleistocene and early Holocene (Allan; 1994; Abu al-Fatih, 1997; Salem, 1992; el-Asswad, 1995).

According to MMAA (1998a); al-Mugran (1992); al-Akry (1994); al-Mahmoud (1992); Abu Maylah (1999); Arar (1997) it is possible to gather rainfall in arid areas in temporary wells and ponds so it can be used to recharge groundwater. This possibility depends naturally on the rate of evaporation and the quality of soil in the area as well as the amount of rainfall

According to Leusink (1992); Walton (1969); Park (1997); Williams *et al.* (1995) the development of groundwater has accelerated in recent years to rates that ignore the limitation of this important source. They emphasise how this source in many arid and semi arid areas has been put under massive pressure by overpumping. In this context, Bouwer (1994b); Judah (1994); Merrett (1997); Williams *et al.* (1995); Kotoub and al-Mahmoud (1997) emphasise that the recharge of water does not happen quickly and depends on many factors such as the type of soil and rocks in the area and the amount of rainfall that filters underground.

The increased use of groundwater has exceeded the natural recharge in some areas, which has led to the depletion of aquifers. It has also changed the quality of the water. This often involves a salinity problem. For example, the increased pumping of this water in the Arabian Gulf countries caused a drop in its level and the incursion of seawater and mixing, making it saline and unsuitable for direct use (Kotoub and Abdulrab, 1995; Othman, 1999; Abdulqafar, 1999; al-Mugran, 1992; Allaby, 1996).

Many authors consider irrigation as the most dangerous pollutant of groundwater because it contains pesticides and fertilisers, which mix with groundwater. Brines left after the partial evaporation of irrigation water may also enter the groundwater and pollute it (amongst others al-Ibrahim, 1991; el-Asswad, 1995; Lloyd *et al.*, 1991). In addition, human settlement, with its commercial centres, roads etc., as a major source of pollution. Polluted input includes sewage effluent, centres of rubbish collection, and industrial pollutants (Table A2.1) (amongst others Hem, 1978; Beekman, 1998).

Table A2.1. Sources of Groundwater Contamination (After Moore *et al.*, 1995).

Contamination	Source
Contamination sources that discharge substances	Percolation from septic tanks and cesspools Injection wells Land application of wastewater
Contamination sources used to store, treat and dispose of substances	Landfills and open dumps Surface impoundments Waste tailings and waste piles Material stockpiles Graveyards Above-ground storage tanks and underground storage tanks Radioactive-waste disposal sites
Contamination sources during transport	Pipelines Material transport and transfer operations
Contamination as a consequence of planned activities	Irrigation (pesticide, herbicide and fertiliser applications Animal feeding operations Application of de-icing salts Urban runoff Atmospheric contaminants from industrial and municipal sources Mining and mine drainage
Contamination sources providing conduit or inducing discharge	Oil and gas production wells Monitoring wells and exploration wells Construction excavation
Natural-occurring sources of contamination	Groundwater-surface water interactions Natural leaching Saltwater intrusion or upcoming of brackish water

A2.2. Groundwater in Qatar:

Groundwater resource is derived from three primary aquifers (from lower to upper) at the underlying Palaeocene Umm er Radhma (UER) Formation, the Eocene Rus Formation and the Eocene Dummam Formation (Figure A2.2).

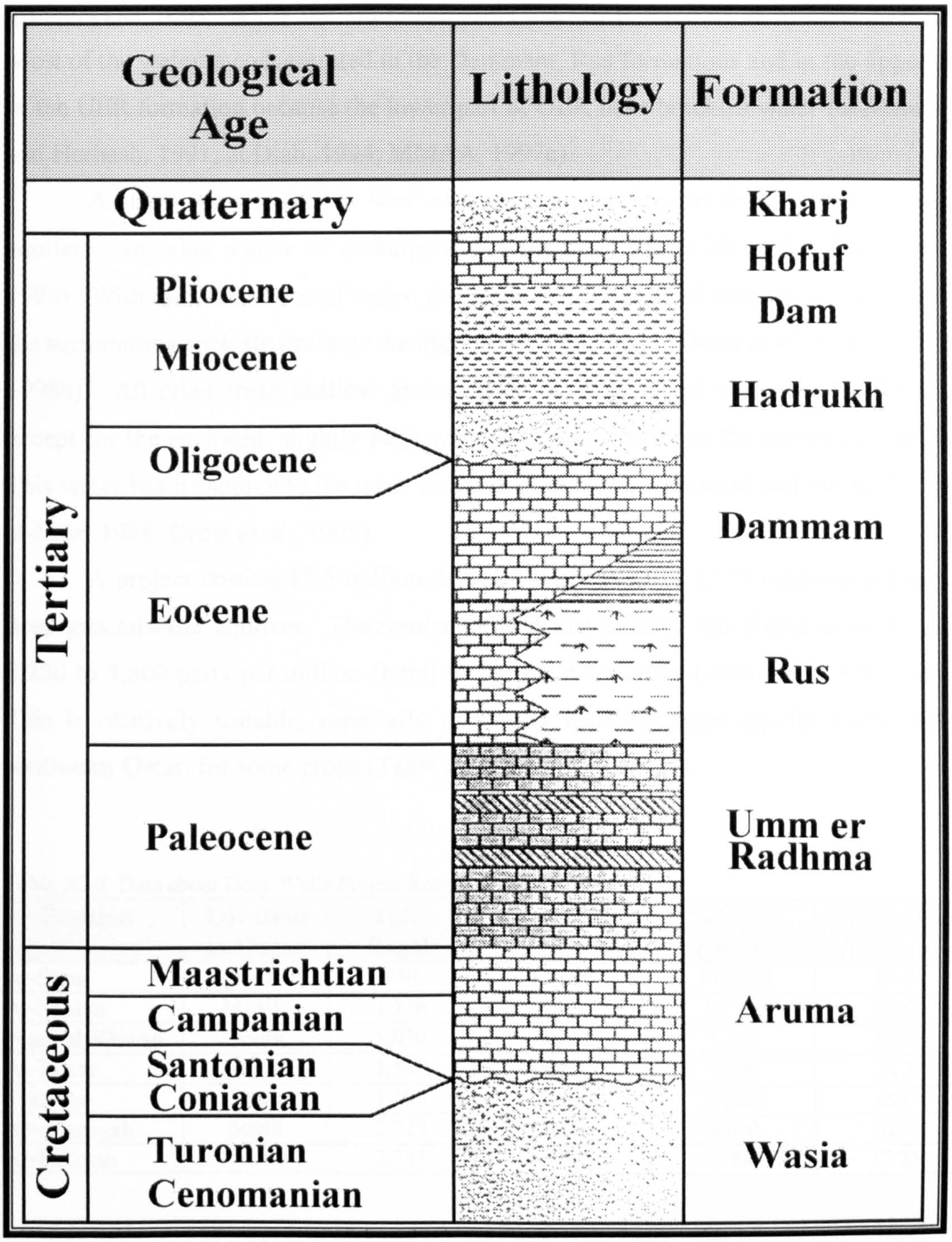


Figure A2.2. Generalised Stratigraphic Column for the Qatari Peninsula (After MMAA, 1997d).

The Dammam aquifer spreads over 80% of Qatar, with a limited thickness (5-30m). The quality of its water is relatively good and it is deemed as a good source of water supply, especially in the coastal areas. The UER covers most of the country, with a much greater thickness ranging between 300-500 m. The thickness of the Rus aquifer falls in between the previous two aquifers and ranges between 70 to 110 m (Llyod *et al.*, 1987; Streetly and Kotoub, 1998). There is hydraulic connection between the UER and the Rus aquifer (FAO, 1981; Harhash and Hassan, 1982). It is estimated that the total groundwater reserves for the Dammam, Rus and UER aquifers is around 2.28 bm^3. Most of the water is concentrated in the Dammam, Rus formations and in the upper part of the UER formation because the lower part of UER have brackish water (al-Mahmoud and Herhash, 1991; al Diab, 1994; MMAA, 1997c).

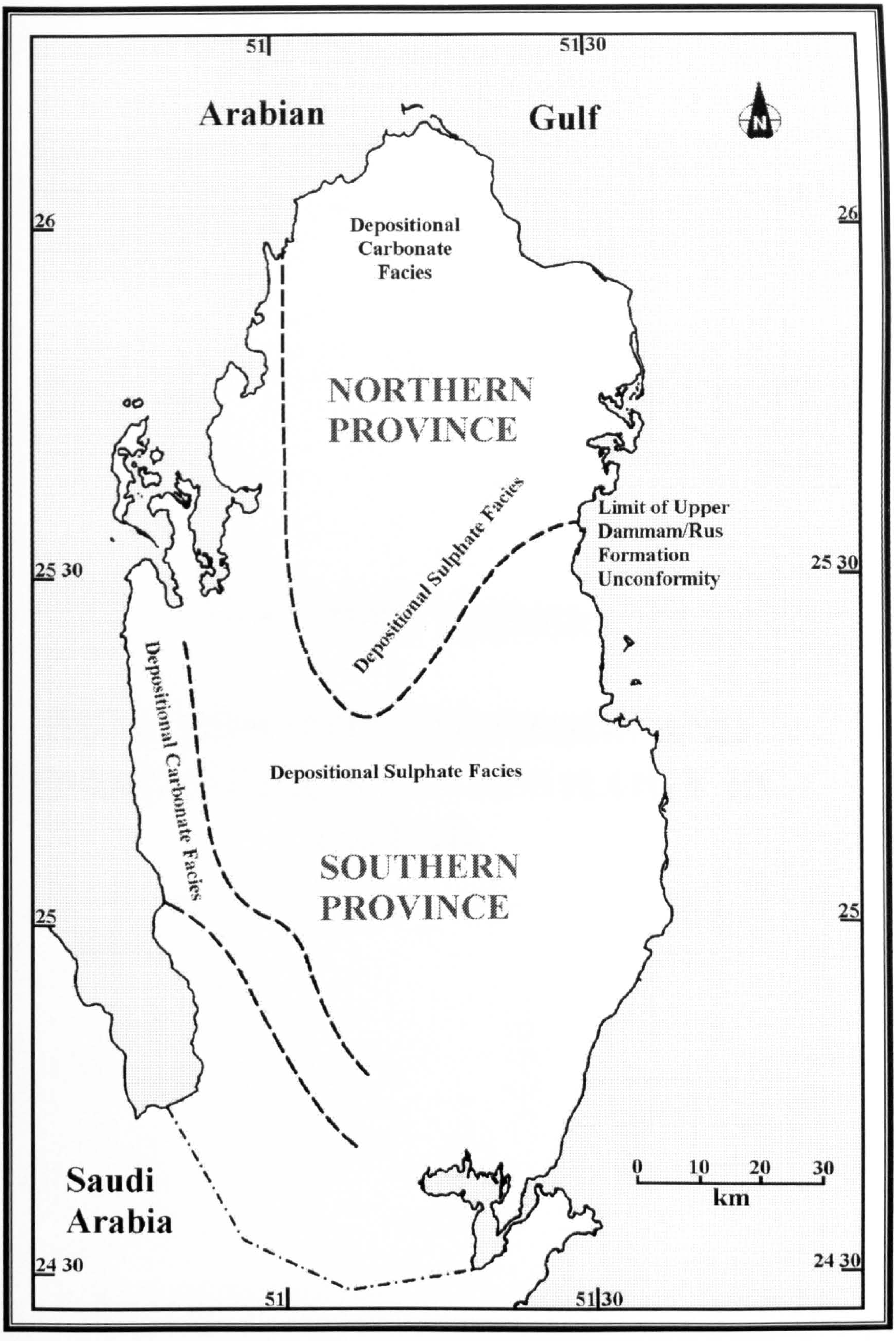
A small transfer of 3-6 Mm^3 of water per year occurs from the Rus to UER aquifer. No other source of recharge exists for the UER (FAO, 1981; Rukin *et al.*, 1995). With the withdrawal of water, the space is filled instead with the compression of the surrounding rock structure or the ingress of saline water (Drost *et al.,* 1995; Babikir, 1998b). All other fresh shallow groundwater in Qatar is fed from rainfall filtration, except for the enclosed, slightly salty water near Abu Samra in the extreme south east. This water has its source to the west, in Saudi Arabia (al-Mahmoud and Herhash, 1991; al-Nasr, 1988; Drost *et al.*, 1995).

A project costing $5.5 million drilled 7 wells (950 to 2,757 metres) to discover deep groundwater aquifers. The results showed that salinity was found to be between 3,250 to 4,800 parts per million (ppm) in the Aruma aquifer (under the UER aquifer). This is relatively suitable, especially compared with the same aquifer elsewhere in south-east Qatar, for some crops (Table A2.2) (MMAA, 1992).

Table A2.2. Data about Deep Wells Project Results (MMAA, 1992).

Position	Location in Qatar	Total Depth	Current Depth	Salinity (ppm)	Production (m^3/hour)
Al-Sunu	North	950	Closed	103,000	89.7
Al-Sahlah	Middle	1,216	560	14,700	69.0
Wadi al-Khwan	South	1,010	637	3,250	80.5
Al-Tiwar	South	1,500	625	4,800	34.5
Turayna	South	1,200	Closed	33,300	69.0
Al-Amiriyah	South	2,729	914	4,800	32.2
Al-Rikiyah	South	2,757	914	7,000	17.25

Qatar has two groundwater reservoirs each consisting of the three aquifers described above. The northern and the southern reservoirs are recharged from rainfall infiltration (Figure A2.3) (al-Qasas, 1991; al-Mohannadi, 1997a). The freshwater of the northern reservoir is estimated at 1.5 bm^3 and over 2,180 km^2 or 20% of the country's area (al-Mahmoud, 1992; Babikir, 1998b). Its salinity ranges from 500 to 4,000 ppm, while the salinity of the southern province ranges from 3,000 to 6,000 ppm. Although the northern groundwater has the best quality water in the country, its total dissolved solids concentration (basically sodium, calcium carbonates and chlorides) is higher than the recommended level set by the World Health Organisation (Harhash and Hassan, 1982; Hashim, 1995). The desirable standard set by WHO for domestic water does not exceed 500 ppm. In tropical areas such as in the Arabian Gulf states, this limit is raised to 1,500 ppm (Drost *et al.*, 1995). A limited aquifer (Alat) occurs in the extreme southwest of Qatar at Abu Samara. This is part of a Saudi aquifer (Harhash and Hassan, 1982). The freshwater here is estimated at 2,000 Mm^3 with a salinity range of 4,000-7,000 ppm (Hashim and Ibrahim, 1999).



FigureA2.3. The Groundwater Aquifers and Provinces in Qatar Peninsula (After al-Mahmoud, 1992).

APPENDIX THREE:

DESALINATION METHODS AND DESALINATION TECHNOLOGY IN QATAR

Appendix Three:

Desalination Methods and Desalination Technology in Qatar

A3.1. Desalination Methods:

According to Gass *et al.* (1974) and Agnew and Anderson (1992), elements of the technology was known more than 2000 years ago by the ancient Greeks, through the method of evaporation from seawater through solar energy. This is the basis of the modern day desalination process, but its widespread use occurred only very recently.

The modest beginning of the large-scale use of desalination (Clarke, 1993; Gass *et al.*, 1974; Burley and Melbourne, 1980; Duetch, 1999), took place in the 1950s. The global production of desalinated water in 1958 stood at 8,000 m^3d^{-1} and by 1964 it increased to 50,000 m^3d^{-1}. Since then, desalinated water production increased threefold every five years. This trend started to slow as the result of the decline in oil revenues, since most desalination occurs in the oil rich countries in the Arabian Peninsula. Between 1980-1985, production grew by 50%, while in 1985-1990 growth declined to 11%. In 1993, the world-wide production was 1.9 Mm^3d^{-1} (Figure A3.1).

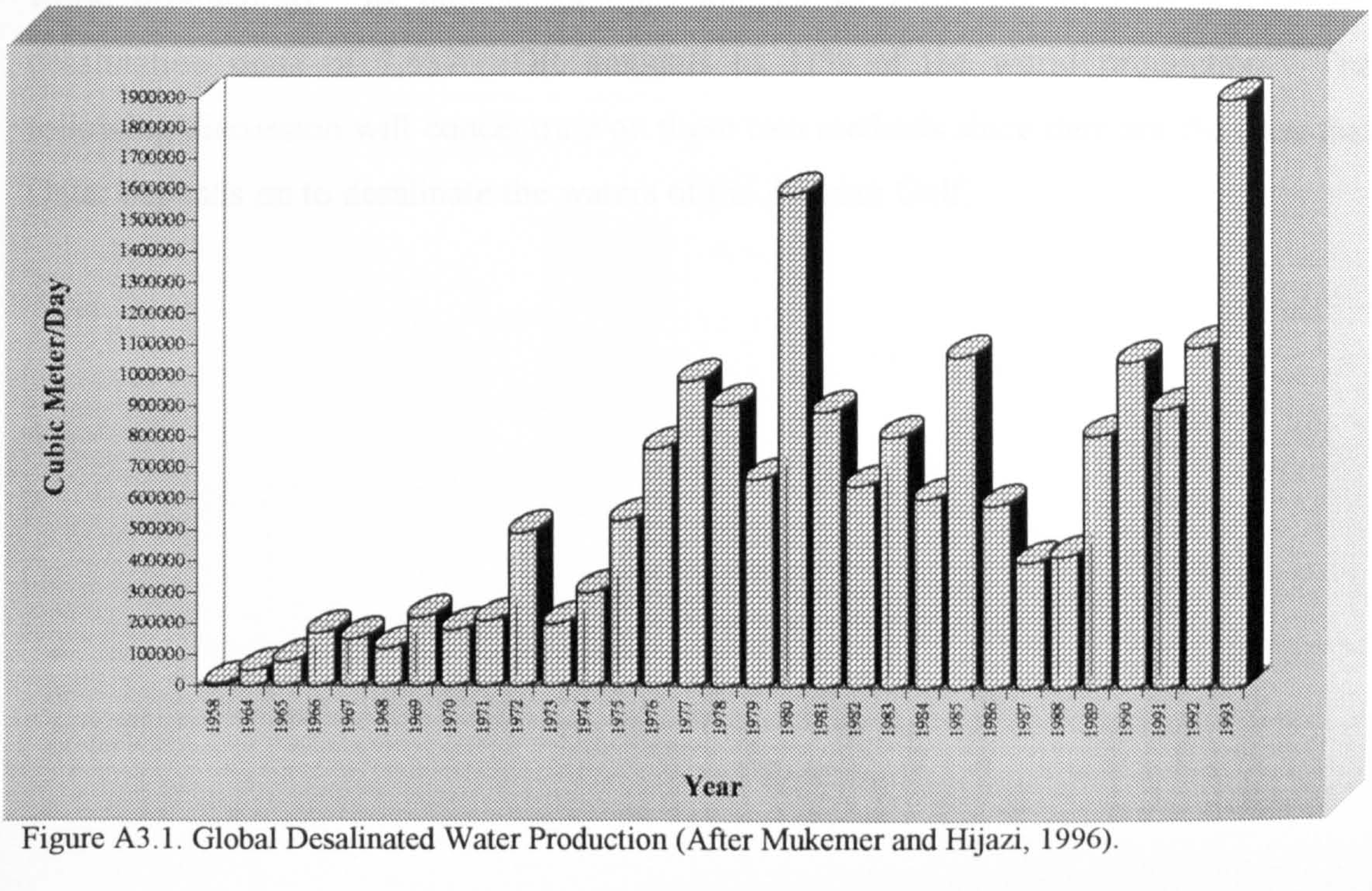


Figure A3.1. Global Desalinated Water Production (After Mukemer and Hijazi, 1996).

There are several ways to achieve the separation of salt from water (for instance Steel and McGhee, 1979; Tebbutt, 1992; Dabbagh *et al.*, 1994; Allaby, 1996). There is not one method that can be signalled as the best economically. The first and most important is distillation. This process uses evaporation, which then is condensed into freshwater. The second is freezing, whereby salts are frozen and then separated as crystals. The problem with this method lies in both freezing and transformation back into liquid form which both require heat energy. The third is reverse osmosis, which depends on the presence of a semi-permeable membrane between the salty solution and the freshwater, whereby the water passes through this membrane but the salt ions do not. All these three methods share basically the same idea, that is the separation of water from salt. There are two other methods where the salt is separated from water. The first is the "ion transport" method. The dissolved salts in the water weakens the bond of ions (Na^+ and CI^-) and hence the structure of crystals is broken. This make ions capable of moving in opposite directions. The second is the "chemical method" which involves ion exchange and precipitation.

Generally speaking, there are two methods that have been used widely in the world and amount to 90% of total production capacity. These are the Multi-Stage Flash (MSF) (Figure A3.2), and the Reverse Osmosis (RO) (Figure A3.3). According to Mukemer and Hijazy (1996); Burley and Melbourne (1980); DTCD (1986); Silver (1978), MSF occupies the first place in terms of its share of production (56% of total world production). Its number of units amount to 1,063 out of total world-wide desalination units of 7,537. OR amounts to 31% of the world production. The following discussion will concentrate on these two methods since they are the ones that Qatar depends on to desalinate the waters of the Arabian Gulf.

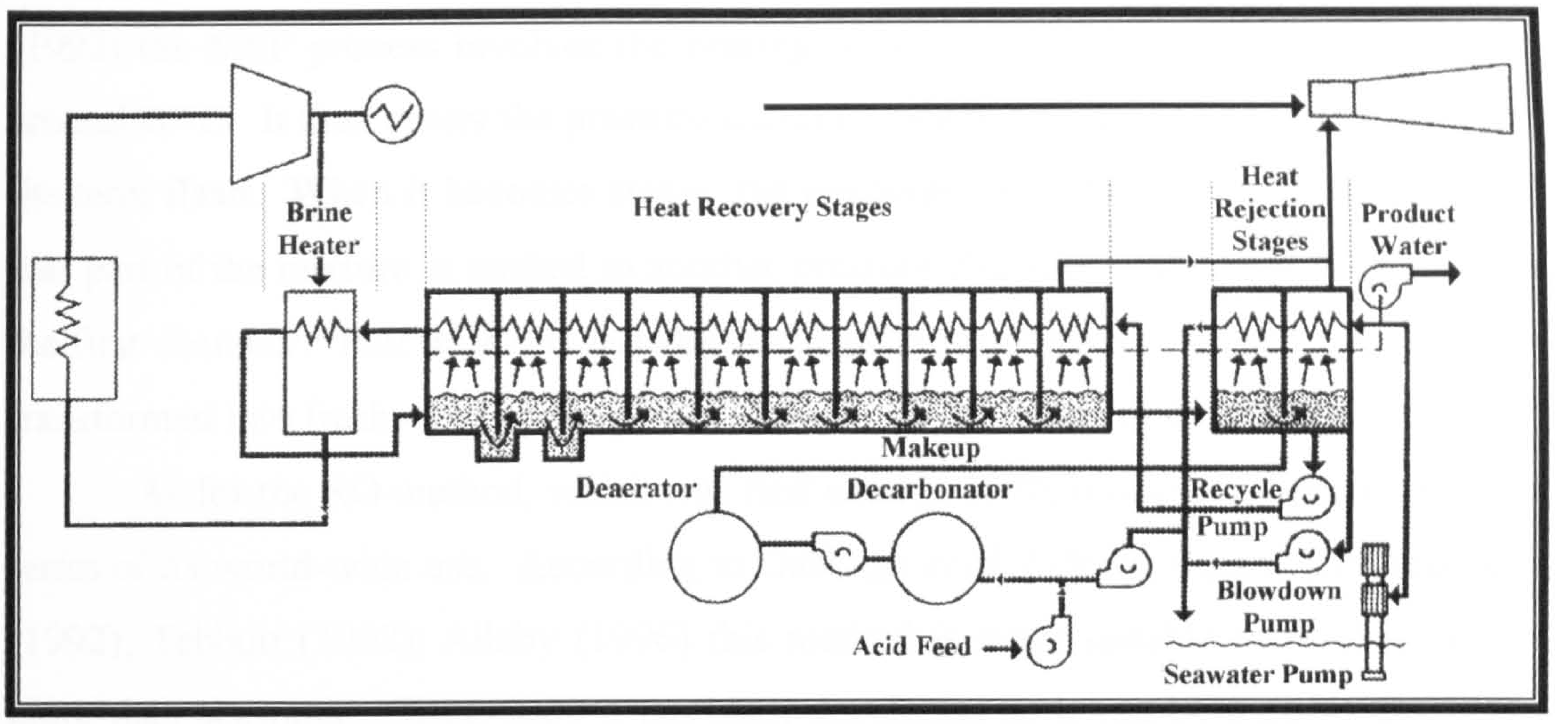


Figure A3.2. Multi-Stage Flash (MSF) Process (After Dabbagh *et al.*, 1994).

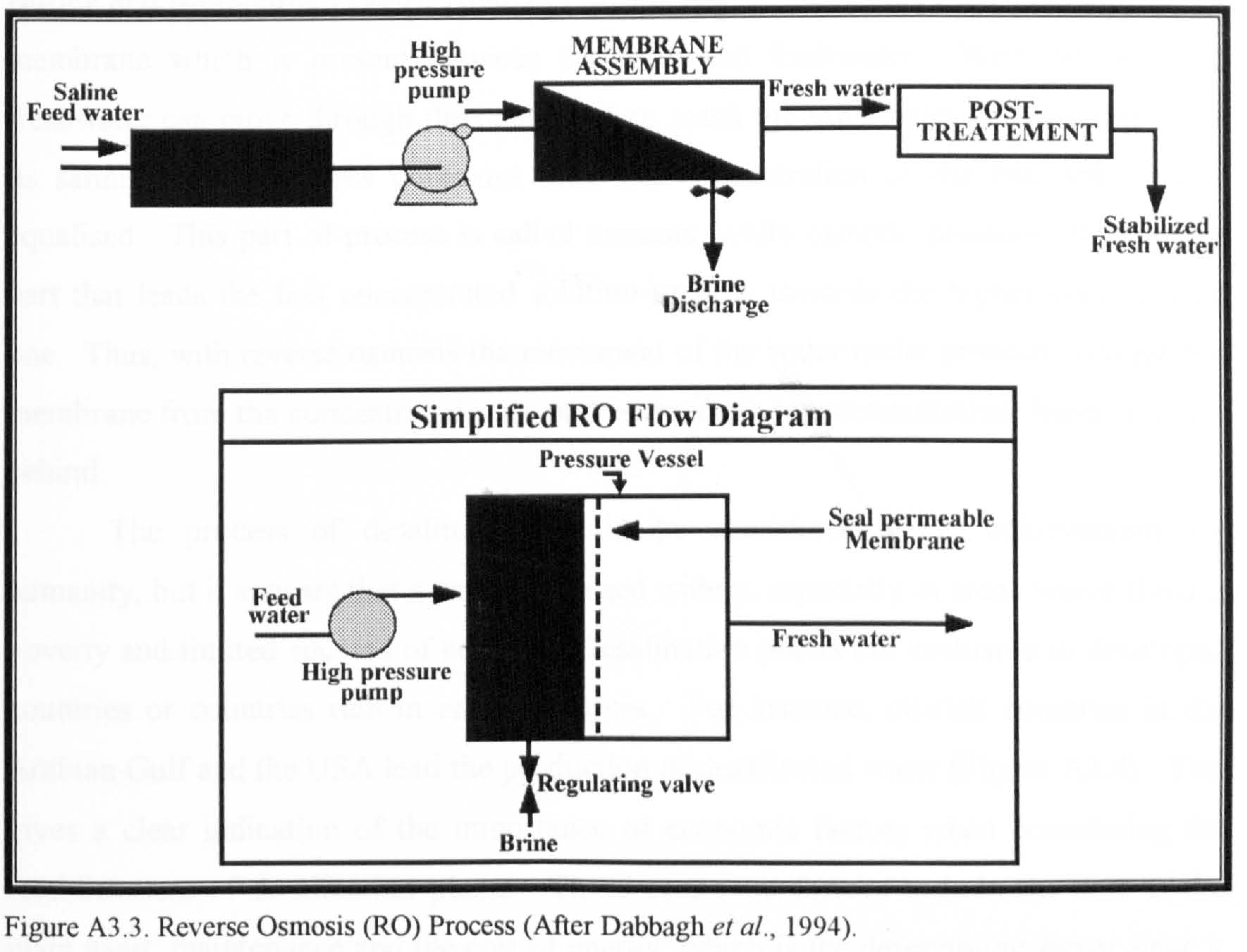


Figure A3.3. Reverse Osmosis (RO) Process (After Dabbagh *et al.*, 1994).

According to Porteous *et al.* (1993); Sangao *et al.* (1994); Agnew and Anderson (1992) the MSF process involves the heating of water to less than 100° C, usually at around 80° C. It then enters the pressure chamber, where boiling occurs instantly, hence the term flash. When it becomes steam, the temperature of the saline water drops and that part of the mixture is pushed to another pressure chamber with lower pressure than the first chamber. Part of that is transformed again into steam and so on. The steam is transformed into freshwater upon contact with the cooling coils in the tanks.

As for the RO method, which was first used in 1970, it occupies second place in terms of its world-wide use. According to Dabbagh *et al.* (1994); Agnew and Anderson (1992); Tebbutt (1992); Allaby (1996) this method is more suitable to brackish water more than seawater. Since 1980 it has been developed so it can be used to desalinate seawater. In this case it uses huge amount of energy, (it needs around 65-70 bar when it desalinates seawater while it needs only 25-30 bar for brackish water). In addition the RO process requires extreme caution.

The RO process is summarised by Porteous *et al.* (1993); Lu *et al.* (1991), Burley and Melbourne (1980); Allaby (1996) it depends foremost on a semi permeable membrane which is present between the salty and freshwater. With osmosis, the freshwater can move through the membrane to reach the salty water and hence reduces its salinity. The process continues until the concentration of the two solutions is equalised. This part of process is called osmosis, while osmotic pressure refers to the part that leads the less concentrated solution to flow towards the higher concentrated one. Thus, with reverse osmosis the movement of the water under pressure through the membrane from the concentrated salty part to the fresh less concentrated, leaves the salt behind.

The process of desalination might be considered a big achievement for humanity, but it appears that it can not be used widely, especially in areas where there is poverty and limited sources of energy. Desalination plants are exclusive to developed countries or countries rich in energy sources. For instance, oil-rich countries in the Arabian Gulf and the USA lead the production of desalinated water (Figure A3.4). This gives a clear indication of the importance of economic factors when considering the establishment of desalination plants. These economic factors include the cost of the plant itself, maintenance and the cost of energy, which is the determining factor since it represents the largest part of the cost of desalination (al-Dabbagh and Faraj, 1997; Flavin, 1995; Schliephake, 1992; Mahmoud and Sadeqi, 1997; Kalogirou, 1997; Ayoub and Alward, 1996). The high cost of desalination is indicated by the fact that the energy required to desalinate 1 litre is 2.8 KJ. Many authors suggest that it is better to depend on energy sources like solar power since the dependence on non-renewable sources such as oil and gas will be very dangerous in the long term (al-Hajri and al-Misned, 1994; Ali, 1993; Ismaily and Probert, 1995; Jones, 1997).

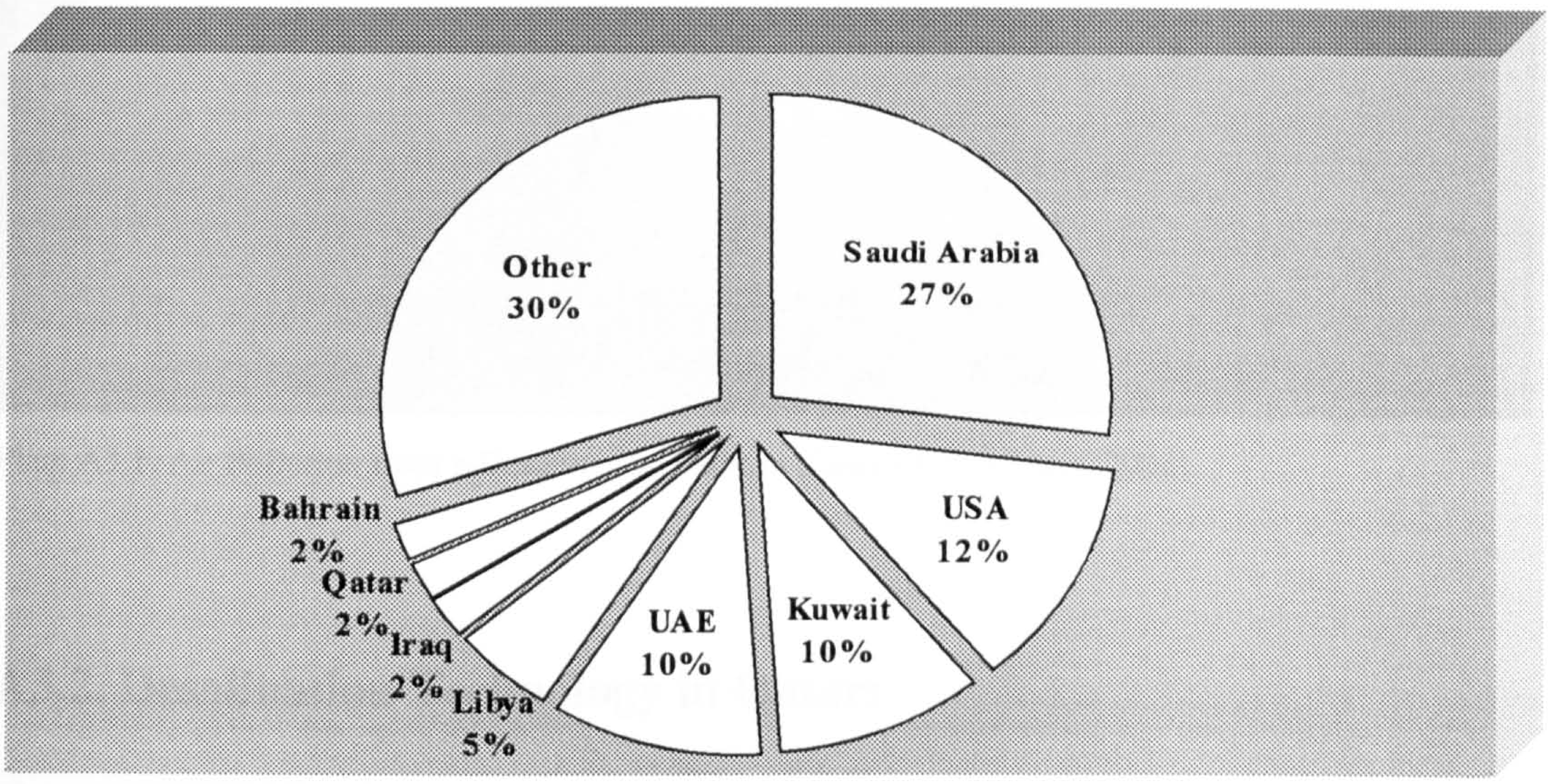


Figure A3.4. The Major Desalination Water Production Countries (Mahmoud and Sadeqi, 1997).

Besides the economic factors of desalination, there is also the environmental aspect. As pointed by al-Tayaran and Madany (1992); Chiras (1994); al-Alawi and Abdulrazzak (1994); Michels (1993); Whaley *et al.* (1989); Hanna and Muir (1990); Jones (1997), desalination plants cause pollution of seawater through raising water temperature, increasing concentration of salts and increasing dissolved oxygen. These pollutants influence sea life, since fish migrate from the polluted areas. In addition, air pollution is released, especially sulphuric acid (Plate A3.1) (al-Sayed, 2001). On the other hand, desalination plants face many problems from pollution of their water supply, especially by oil spills, in enclosed seas such as the Arabian Gulf (al-Tayaran, 1992; al-Mutaz, 1991; Hashim, 2001; Wajdi *et al.*, 2001).

Plate A3.1. Air Pollution from a Desalination Plant in Kuwait City (Anon, 2001).

A3.2. Desalination Technology in Qatar:

The most important desalination plant in Qatar is Ras Abu Funtas (Plate A3.2). This plant was first commissioned in 1977, while its latest extension was completed in 1995.

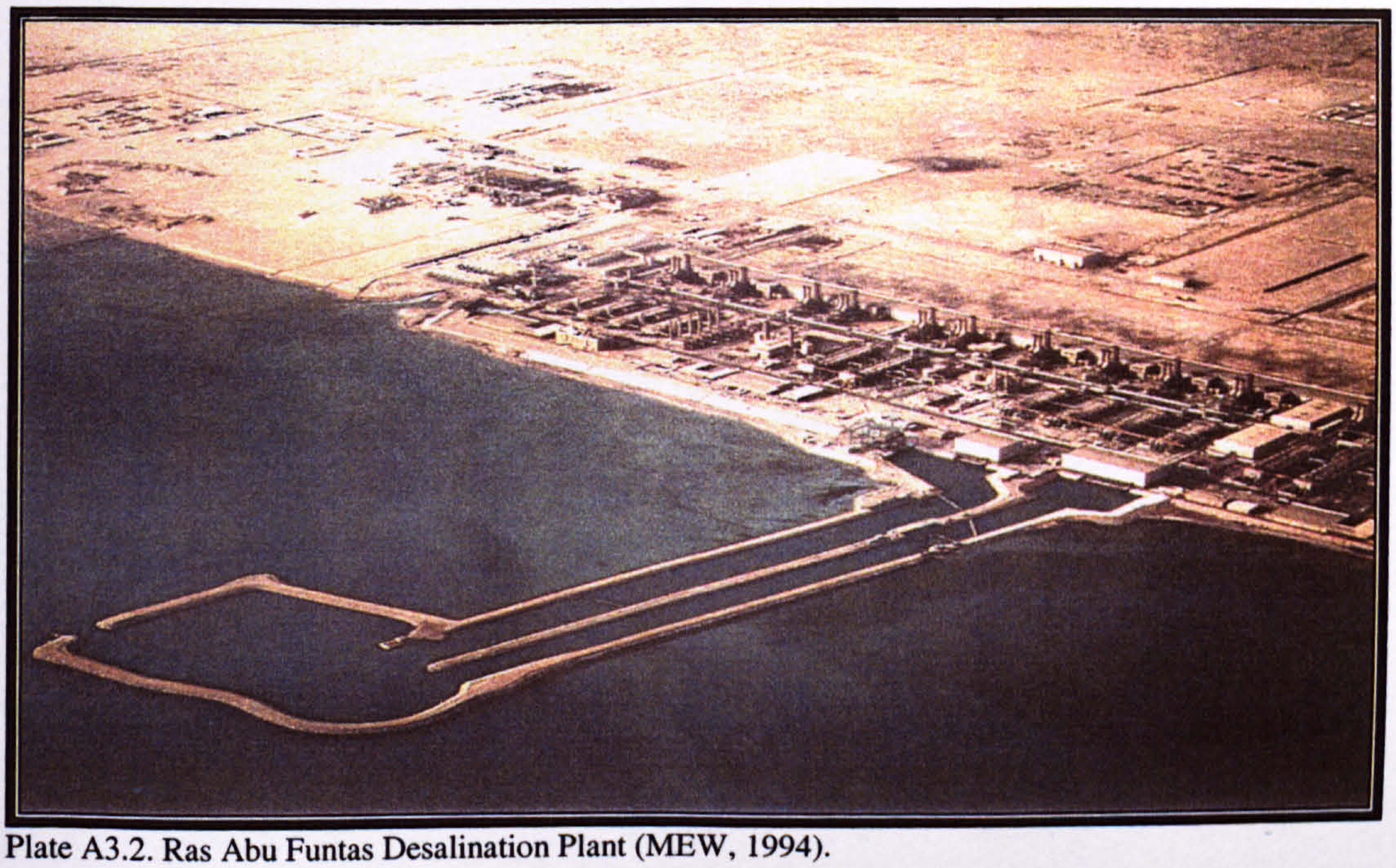


Plate A3.2. Ras Abu Funtas Desalination Plant (MEW, 1994).

The plant is a combined cycle power and water station and has an installed capacity of 620 MW of electrical power. Gas turbines provide the power generating source. On a daily basis, 70 MIG (318,182 m^3) of water are produced by distillation. In total, the station has fourteen gas turbines and generator sets, of which two are for emergency use. The twelve main gas turbines combine with waste heat boilers to produce steam. In case the waste heat boilers are not available, eleven auxiliary boilers are held in reserve to produce steam. The produced steam is utilised by fourteen distillers to make the distilled water. The Electricity generated by the station is distributed to consumers via step down transformers which provide adjustment to the required transmission voltage, 132 KV for overhead lines and 66 KV for buried cables (MEW, 1994; MEW, 1996a).

Under vacuum distillation, water is produced by cross tube MSF distillers. Saturated steam from the boilers heats the incoming seawater. After the seawater evaporates and condenseds as distilled water in various stages of the unit, the produced water is pumped to the treatment plant. At the treatment plant, the quality of the water is enhanced to produce acceptable water. Taste and stability of the water requires reasonable levels of calcium, magnesium, fluoride, and alkaline. The addition of chlorine is also required for sterilisation. The final of drinking water is pumped to the distribution network and on to consumers in the capital Doha (MEW, 1994; MEW, 1996a).

APPENDIX FOUR:

Recycling

Appendix Four:

Recycling

The increased consumption of water and its return to the water system full of various types of pollutants causes massive damage to seas, rivers, lakes and groundwater, to the extent that some of these water sources have been considered totally contaminated (Plate A4.1). Hence, it became necessary to distil or otherwise treat the water before pumping it into the water bodies once more.

Plate A4.1. Tons of Perished Fish on the Kuwait City Coast (al-Sayed and Abduldaym, 2001) due to Discharge of Non-treated Wastewater into the Sea (Ayash, 2001).

There are a difference in the degree of purity of recycled water depending on the method of treatment (Figures A4.1, A4.2 and A4.3). Recycled water when treated through the primary method retains a lot of bacteria, viruses and other organic matter, which carry diseases. Consequently it is necessary to use the tertiary method to guarantee the absence for all pollutants. al-Sharfi (1998); Bowler and Greenhalgh (1985); Steel and McGhee (1979); Horan (1991); Dean and Lund (1981); Mason (1981) summary these two methods as follows:

A- The primary method includes:

1. Elementary filtration,
2. Sedimentation,
3. Preliminary treatment.

B- The tertiary method includes:

1. Oxidisation,
2. Activated sludge,
3. Biological sieving,
4. Physical, biological and chemical treatment.

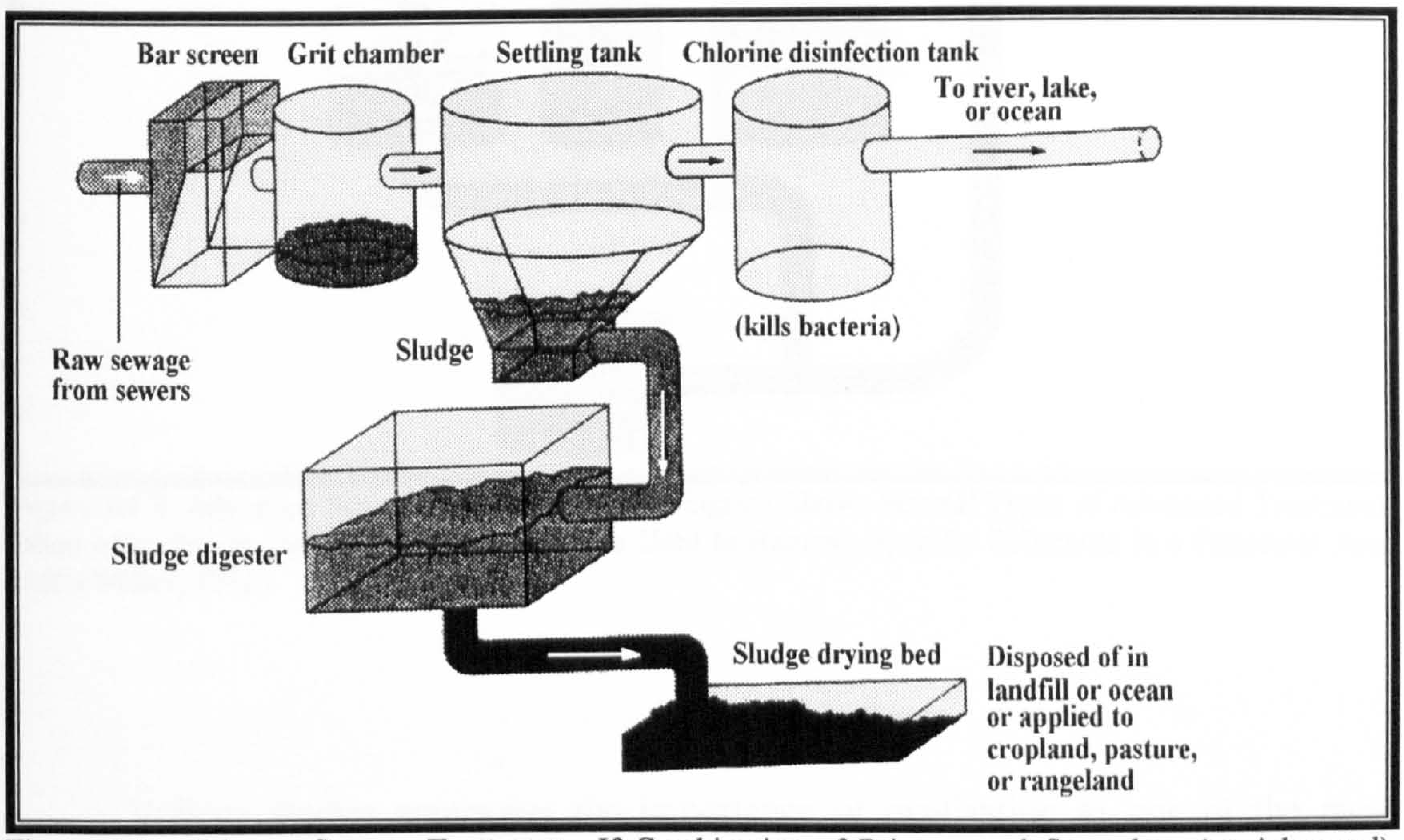


Figure A4.1. Primary Sewage Treatment. If Combination of Primary and Secondary (or Advanced) Treatment is Used, the Wastewater is not Disinfected Until the Last Step (After Miller, 1992).

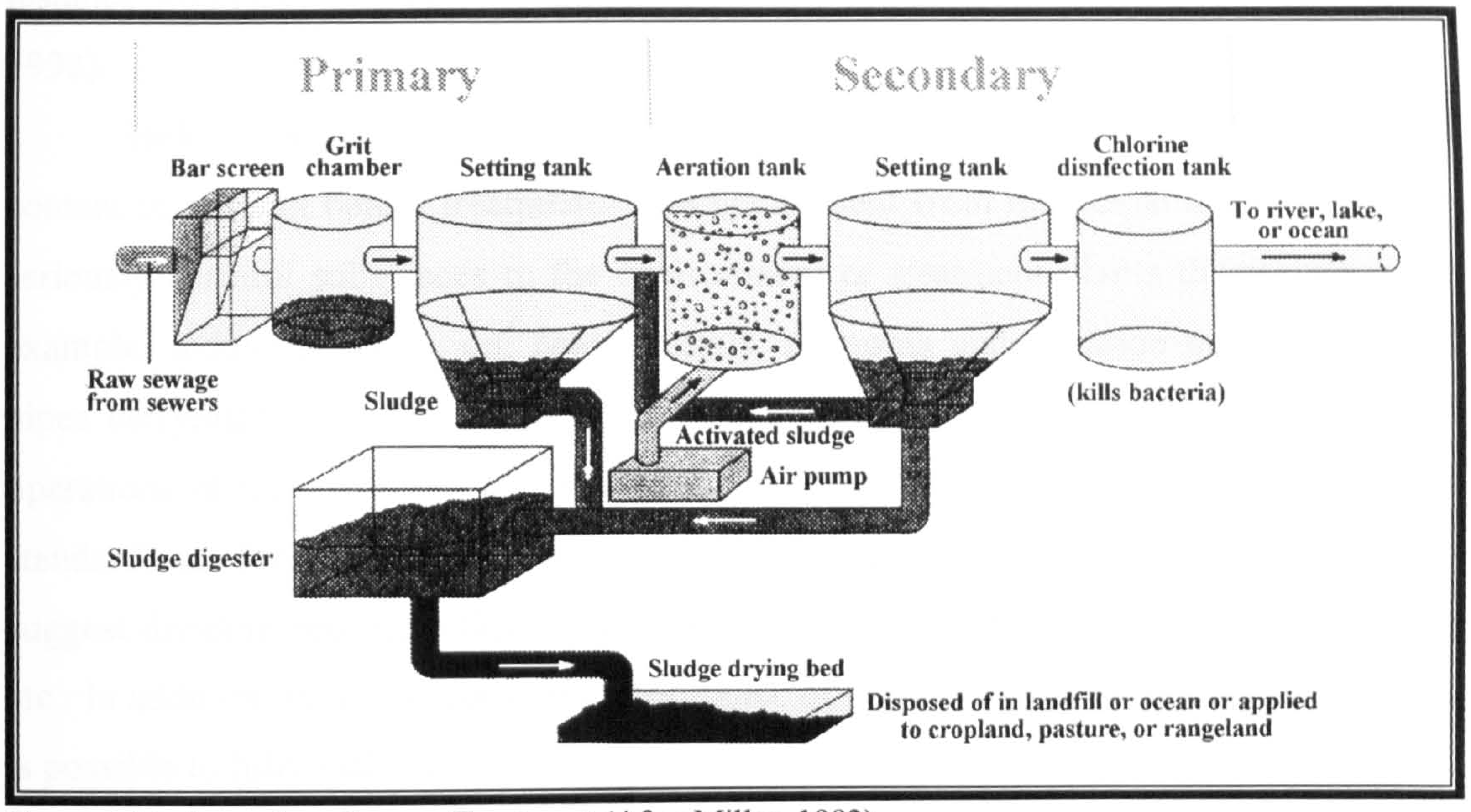


Figure A4.2. Secondary Sewage Treatment (After Miller, 1992).

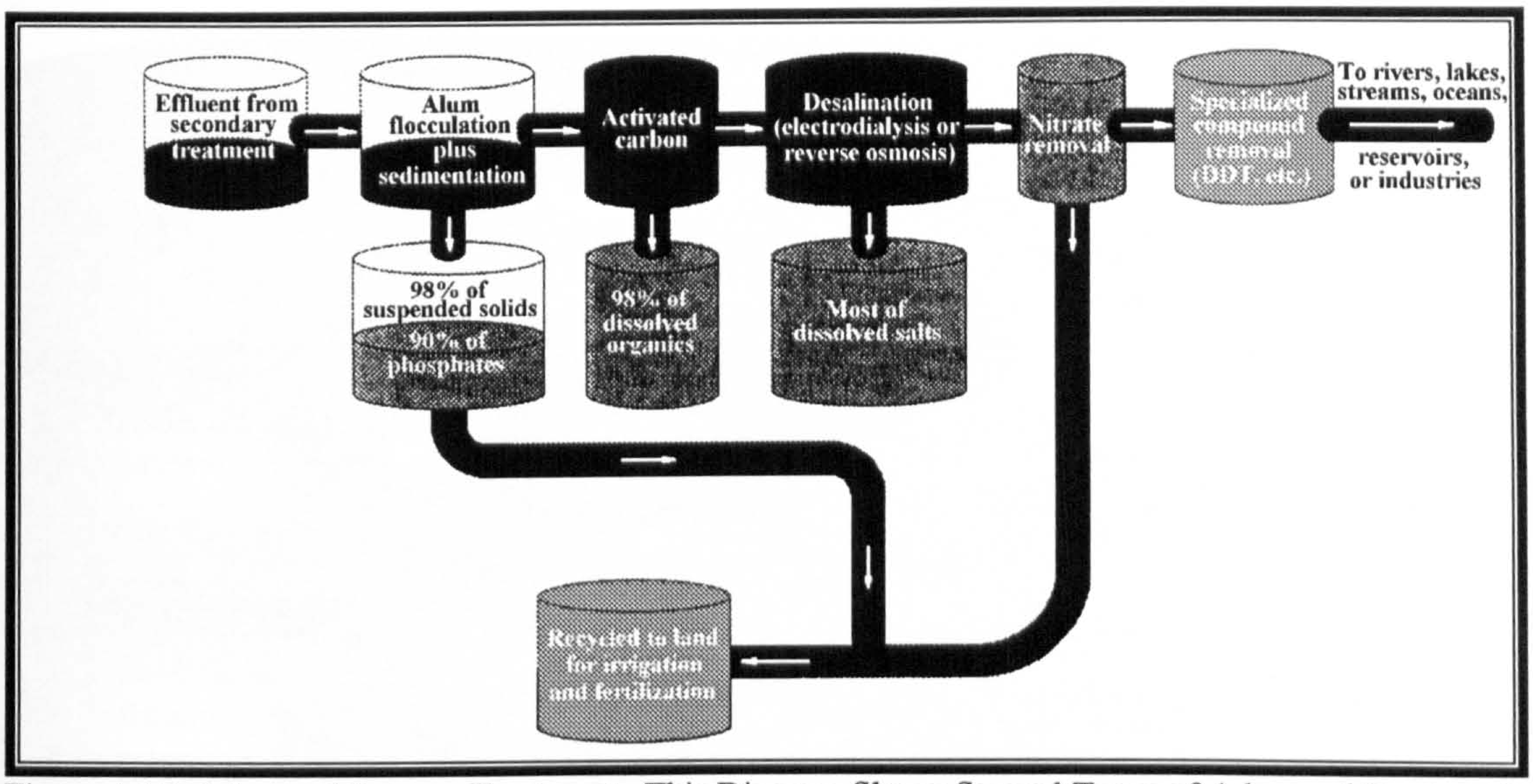


Figure A4.3. Advanced Sewage Treatment. This Diagram Shows Several Types of Advanced Treatment. Often only One or Two of these Processes are Used to Remove Specific Pollutants in a Particular Area (After Miller, 1992).

Various studies emphasise the importance of oxidisation as one of the most important stages in recycled water, since it rids the effluent of viruses, bacteria and smell. After oxidisation it also more appropriate for agricultural irrigation purposes (for instance Mukemer and Hijazy, 1996; Smethurst, 1988; Stephenson, 1988; al-Sharafi, 1998).

Helmer and Hespanhol (1997); Boller (1997); Abu al-Fatih (1997) discuss the content of effluent before treatment. Sewage effluent from municipal use may contain seriously harmful substances to the environment or treatment plants themselves. For example, industrial waste, oil, heavy metals, ammonia and sulphide may destroy the pipes carrying the sewage effluent through corrosion, hence causing stoppage to the operations of these plants. It is therefore, necessary to have additional measures and standards set for the use of effluent produced by industry in such plants. They also suggest dividing sewage effluent according to its source: municipal, industrial, sewage etc. In addition, they emphasise the importance of developing the technology used, so it is possible to fully make use of it.

Recycling has become another non-traditional source for some water-poor countries (Figure A4.4).

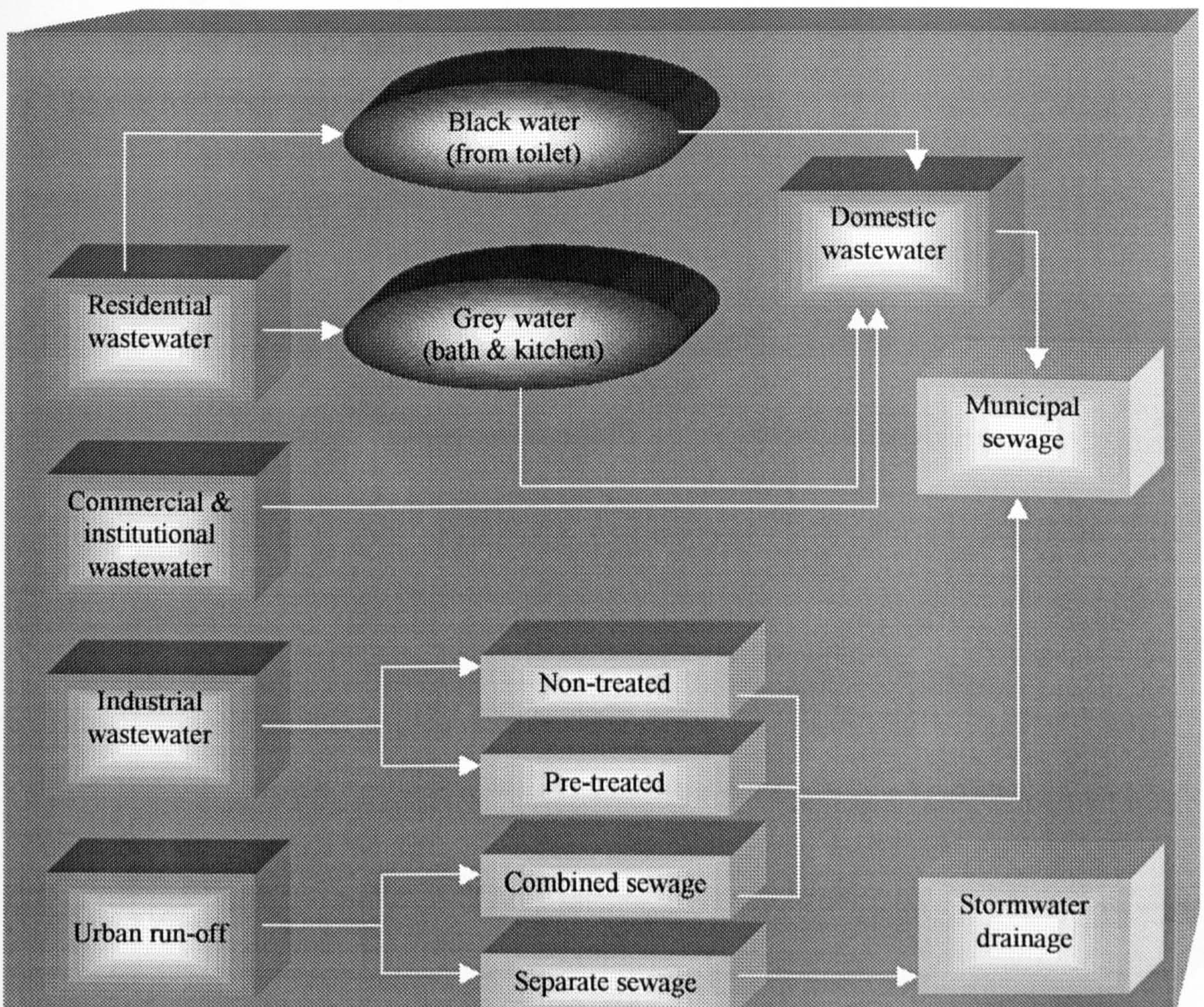


Figure A4.4. Origin and Flows of Wastewater in an Urban Environment (After Helmer and Hespanhol, 1997).

Pearce (1992); Dean and Lund (1981); al-Salum (1999); Porteous *et al.* (1993); Gillam and McCoy (1966) suggest the possibility of using the recycled water in sectors that do not require high quality water, such as irrigation, industry, and cooling. They indicate that not all domestic uses require high quality water either. Beekman (1998); Mahmoud and Sadeqi (1997) summarises the use of recycled water as follows (Figure A4.5):

- To mix with irrigation water in order to reutilise for irrigation of agricultural land.
- To release the recycled water into lakes and rivers.
- To use for industrial purposes such as cooling water.
- To clean roads, which is particularly important in arid areas.
- To use in parks and making artificial lakes.
- To produce fungi for use as animal feed.
- To recharge groundwater, to compensate for the loss due to overpumping and low levels of natural recharge.
- To use for urban non-potable uses such as fire fighting.

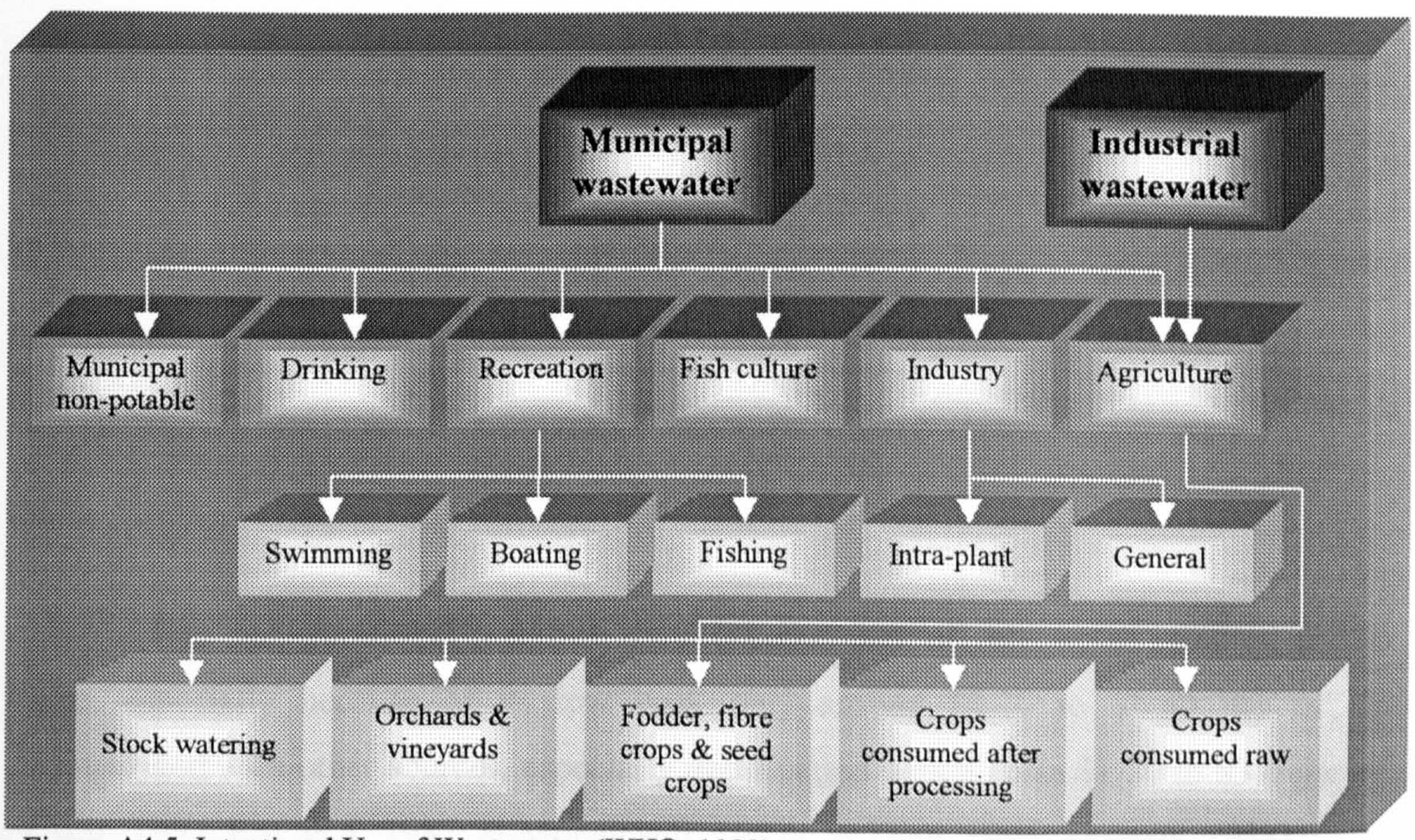


Figure A4.5. Intentional Use of Wastewater (WHO, 1989).

In arid country such as UAE, 62 Mm^3a^{-1} of recycled water are used for irrigation (Uqba, 1991; Arar, 1991; al-Mugran, 1992; Mahmoud and Sadeqi, 1997; al-Alawi and Abdulrazzak, 1994). The use of recycled water has not been exclusive to agriculture but has been extended to industrial and domestic use. This is not exclusive either to developing countries but also occurring in the developed nations. In some steel factories in Baltimore in the USA, around 680,000 m^3 of recycled water are used in the cooling processes of steel and slag (Abdulmaqsud, 1981; Dean and Lund, 1981). In a water-rich country such as Brazil, "automobile manufacturing and assembling plant in Belo Horizonte claims to be recycling 92% of the water utilised in its industrial processes" (Beekman, 1998).

al-Alawi and Abdulrazzak (1994); Ahmad (1989); al-Mugran (1992); al-Hajri (1995); Ali (1982); Abdulqafar (1999); Uqpa (1991); Cowan and Johnson (1985); Othman (1999) point to the Arabian Gulf as another area with scarce water and arid climate and where the authorities have been trying to use recycled water for irrigation (Table A4.1). Right now, recycled water is used in all Gulf countries for landscaping, parks, agricultural produce that is not eaten directly and animal feed. On the other hand, to use the treated sludge is also useful as a fertiliser. According to Agnew and Anderson (1992) "Recycled water will be an increasingly important source in the Middle East".

Table A4.1. Production and Use of Recycled Water in the Arabian Gulf Countries (Mahmoud and Sadeqi[a], 1997; Hussin, 2001).

Country	Production (m^3d^{-1})	Use (m^3d^{-1})	Purpose
KSA[a]	1,230,000	275,000	Industry and Agriculture
UAE[a]	300,000	170,000	Agriculture and Parks Irrigation
Kuwait[a]	300,000	180,000	Agriculture and Parks Irrigation
Bahrain[a]	150,000	60,000	Parks Irrigation
Qatar[b]	100,000-120,000	60,000	Agriculture and Parks Irrigation
Oman[a]	25,000	25,000	Agriculture and Parks Irrigation

This non-traditional resource must become part of any water strategy in this area, especially because of its low cost, only around \$0.20 to \$0.50 per m^3, in comparison with other sources, especially desalination which costs \$1.50 to \$3.0 per m^3 (Arar, 1997; ESCWA, 1987; al-Mohannadi, 1997a; al-Diab, 1994; Thomas, 1988).

Cooper (1991); Pescod and Alka (1985); WHO (1989); Harvy and Sadan (1994); Braverman (1994); Mahmoud and Sadeqi (1997) emphasise the importance of recycling as a source of water. But one of the obstacles to the use of this source is the fear of diseases that might spread in human settlements. The expansion in the use of recycled water for recharging groundwater, besides its direct use, also causes worry because of the nature of the chemicals it contains. Yet good treatment plants can produce high quality water, especially with improved technology (which still needs further research). Thus it will make it possible to produce recycled water that can be used in all sectors, even for drinking purposes, and will be considered an alternative non-traditional source of water. This research, as mentioned before, needs huge sums of money, which Braverman (1994) estimates at around $3 billion.

Abu Hggag (1981); Diamant (1985); Helmer and Hespanhol (1997) point to the difficulty of people, especially in Islamic countries, in accepting the use of recycled water for domestic uses, because they are suspicious of the treatment process. They agree with this perception of considering recycled water as contaminated and that the treatment process to increase its purity is complicated and costly. Hence they emphasise using this source only in industry and for agricultural products not eaten directly and to animal feed "provided that the impurities (*najassah*) are removed". This contrasts with the situation in some Western countries – it is, for instance, apocryphally stated that the water that Londoners drink has all been drunk several times before on it's way down the Thames (Eden *et al.*, 1977; Dean and Lund, 1981; Marriott, 1996).

APPENDIX FIVE:

WATER IMPORTATION

Water Importation

One way to gain sufficient amounts of water to meet human needs has been to import water from water rich areas to areas suffering shortages. In the beginning, the methods used were primitive and constituted a major constraint. The technical constraints are not now very significant and water can be moved between countries. The technological constraints have been replaced by political, economic and security concerns, adding another difficulty in utilising this method as a source of water. Gleick (1997); Mahmoud and Sadeqi (1997); Hadad (1994); ReVelle and ReVelle (1981); el-Mallakh (1985); Agnew and Anderson (1992) mention the numerous ways of transferring water, such through pipelines, aqueducts, tankers, floating bags and towing icebergs.

The transfer of water from one place to another, according to Lund and Israel (1995) and Beaumont (1993), expanded with the increase in the consumption of water and episodic dry periods that afflict some areas. They also indicate that this method takes many forms according to the desired aims. But they raise a very important point concerning the necessity of integrating the process of water transfer with the other traditional supplies of water, as well as the management of water demand in the country to which the water is transferred.

al-Abdulrazzak (1981); Beaumont (1993); Agnew and Anderson (1992) describe water import from Iraq to Kuwait. In 1908 there was a rush by owners of ships to transfer water from the Shatt al-Arab in the south of Iraq a distance of 96.5 km to Kuwait. These operations continued to expand and by 1932 there were 49 ships involved in transporting water (Plate A5.1). Water imports from Iraq reached a level of 80,000 $gald^{-1}$ in 1947. By 1951, these shipments stopped because Kuwait shifted its dependence to desalination. In mid 1964, due to the high cost of desalination, the Kuwaiti government was once more considering a policy of imports. An agreement between the governments of Kuwait and Iraq was reached with estimated cost at $99 million, enabling Kuwait to import an estimated 120,000 million $gald^{-1}$. The political conflict between the two countries halted this project (GCC, 1994).

Plate A5.1. In 1937, Water Being Brought into Kuwait from Iraq and Delivered to the Townspeople (Zahlan, 1989).

al-Faraj, 1999; Biswas *et al*, 1997; al-Qurashi, 2000 point to the transport of water from water rich countries to countries that experience increased demand and shortages in supply, in particular in the Arabian Peninsula. They consider it important, not only in terms of providing the needed water but also in encouraging co-operation among the different countries and creating an international network.

In this context it is essential to refer to one of the most important projects for water transfer, and one of the most expensive, that is the transfer of water from Turkey to most of the countries of Middle East. It is indicated by Berkoff (1994); Dabbagh *et al.* (1994); Luelmo (1996); Subhi (1994); Khalil (1998); Ramadan (2000) that Turkey was planning the building of two pipelines to transfer water to Syria, Jordan, Saudi Arabia, Kuwait, Bahrain, UAE, Qatar and Oman (Figure A5.1). The project was halted by Arab suspicions of Turkey, and the huge cost-about $20 billion (al-Alawi and Abdulrazzak, 1994). Political problems, especially between Syria and Turkey, were directly responsible for the failure of the project. This project, which was known as the Peace Pipelines, was supposed to transfer water from the Seyhon and Ceyhan rivers in southern Turkey, with a capacity of 1000 Mm^3 annually. Another smaller project was planned to transfer water from Turkey to Jordan (which is increasingly suffering shortages of water) but political problems have also influenced its implementation (Mukemer and Hijazi, 1996).

Figure A5.1. Water Transfer Schemes in the Middle East (After Biswas *et al.*, 1997).

Mukemer and Hijazi (1996); Gregory (1991); Ahmad (1991a) doubt the possibility of implementing projects such as the water transfer from Turkey to the Arab countries and they describe American support for the project as nothing but a way of increasing the strength of Turkey and increasing its influence in the face of other countries in Middle East such as Iraq and Iran, as well as giving American companies the opportunity to work in such a big project. Moreover there are suspicions on the part of the Arabs, especially Syria, that such a project will give Turkey a unique strategic position through which to exert pressure on the beneficiary countries according to its interests.

Marhon (1994); Schliephak (1992); Hadad (1994) point to the numerous projects for water transfer especially in the Middle East, such as the project of building pipelines from Baluchistan in south-west Pakistan through the Gulf of Oman to the UAE, the transfer of water from the Euphrates River in Iraq to Jordan and the project of transferring water from Iran to Kuwait. The governments of Kuwait and Iran are planning to build a pipeline through the Gulf to carry water from the Karun River in north-west Iran to east Kuwait. Estimates suggested 443 km long pipeline will provide Kuwait with a 760 Mm^3d^{-1} (Figure A5.2) (al-Mutairi, 2000; al-Qurashi, 2000; Awdah, 2001; Turki, 2001).

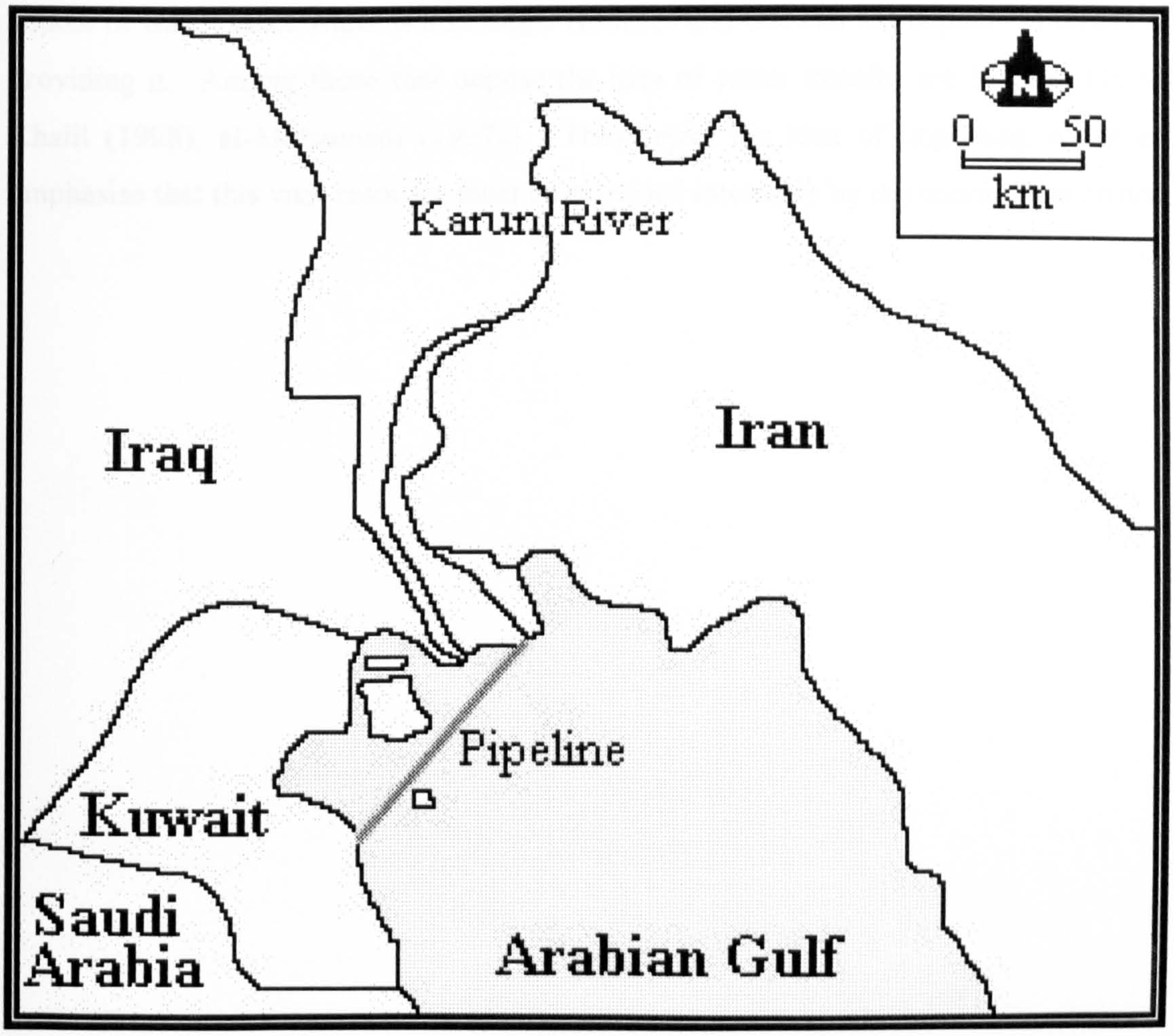


Figure A5.2. Water Transfer Project from Iran to Kuwait (After al-Mutairi, 2000).

Among other big projects that have recently been established is a water project in Libya. According to Allan (1994); Lee and Woodford (1994); Odone (1984); Abu al-Fatih (1997); Salem (1992), the Libyan government's aim of developing the agricultural sector was the reason for this very expensive project (annual cost of over $500 million). It transferred fossil groundwater reserves from the Sahara Desert in the south of Libya, previously utilised only by local people.

Among the many interesting water transfer projects is the towing of icebergs to warm areas and thawing them. This idea, as indicated by Gray (1994); Williams *et al.* (1995); al-Faisal (1982); Allaby (1996); Balba (1986) is become one of most widely studied for the transfer of water at present. It is based on utilising the major source of freshwater on earth, which is a clean source and does not need a lot of energy to thaw, but there are some difficulties in the transfer due to the size of the icebergs and the danger of moving them to far away places. According to Hult (1982), the cost of a pilot scheme to bring icebergs to the USA west coast in the 1980s was $0.2 per m^3.

In summary it can be said that water transfer is doubted as a viable alternative source of water, since water is a strategic resource and one can not depend on others for providing it. Among those that oppose the idea of water transfer are Marhon (1994); Khalil (1998); al-Mohannadi (1997a). They reject the idea of importing water and emphasise that this vital resource must be provided internally by the country concerned.

APPENDIX SIX:

RAINMAKING METHODS

Rain-making Methods

If in some countries, like the USA and Russia, attempts are made to disperse clouds in order to prevent rainfall during special celebrations. In arid countries where rainfall is scarce and clouds disperse by themselves, human thoughts have developed in the opposite way; that is to create the conditions where it is possible to cause rainfall. Some of these experiments in dry places such as the UAE and Australia have proved successful. It is indicated (Mussa, 1993; Deming, 1975; Williams *et al.*, 1995; Mather, 1984) that rain-making has become a fact in order to control rainfall. It is possible now to induce silver iodide smoke on land and carry it to the clouds through updraft (Figure A6.1). This takes place usually in high areas. Alternatively it can be spread on clouds by planes or rockets. The first trials in rain-making took place in 1946 in different parts of the world and achieved some success in stimulating artificial rainfall. Rain-making might be beneficial in regions where clouds form regularly, since in most cases clouds move toward the sea where rainfall occurs and is thus wasted in salty waters. Deming (1975) mentions one of the disadvantages of this method is that it deprives the surrounding areas of rainfall, since clouds would have moved towards them. In this, context some Egyptian scientists have complained recently about some neighbouring north African countries, because they resort to rain-making and hence deprive Egypt of rainfall.

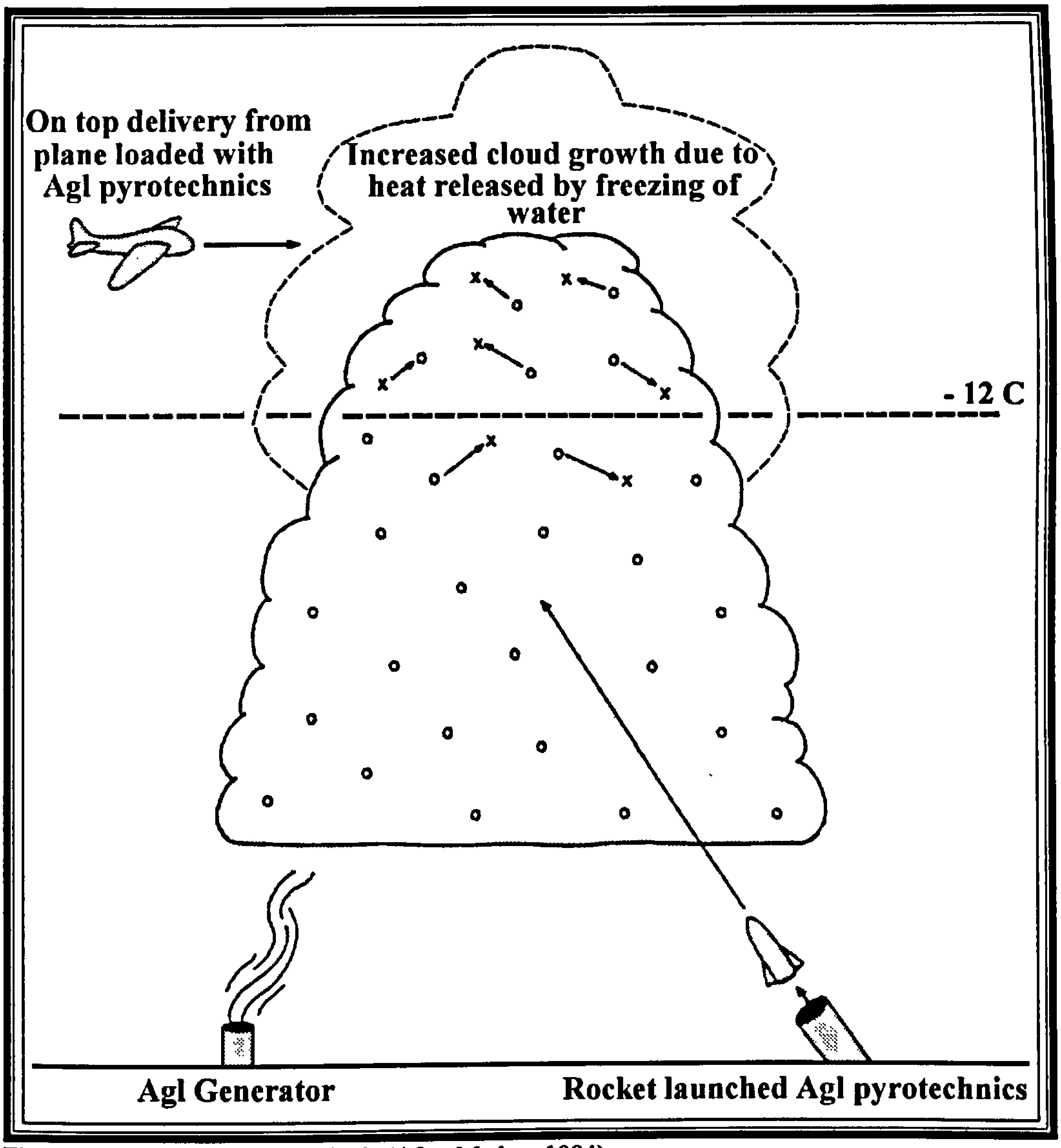


Figure A6.1. Rain-making Methods (After Mather, 1984).

It is emphasised (Silverman, 1986; Benian, 1994; Gass *et al.*, 1974; BBC2, 1998; Agenw and Anderson, 1992), that rain-making is considered a kind of water transfer, since it opens water storage in the atmosphere. But this process is effective only in areas where clouds form and when the temperature of the upper layer of the cloud is less than 10^0 C. Experiments showed that the spread of the silver iodide smoke on clouds at an average of 1kg of AgI per hour and in appropriate circumstances might produce 250 x 10^3 m^3 of rain. Thus, this method is considered one of the non-traditional ways of providing water through the use of modern technology. But this still that requires the presence of the appropriate climatic circumstances, which is not after the case in arid regions, since this technology does not makes clouds but only helps to induce rain from clouds that already exist.

APPENDIX SEVEN:

WATER DEMAND

Appendix Seven:

Water Demand

A7.1. Introduction:

Historically, water has been used by man in many of his activities. The usage of water at the present time has expanded massively. One of the most difficult tasks for any water system or industry is to control demand (for example Kandiah, 1999).

Demand is divided by Mather (1984); Sewell and Bower (1968); Biswas (1978) into two types: offsite use and onsite use. The former includes domestic, irrigation and industrial uses while the later includes navigation, hydropower creation, fishing and wildlife habitat. Since the focus of this study is on freshwater for onsite use in the State of Qatar, the discussion here will take account of the first type only. Figure A7.1 shows the world uses of water.

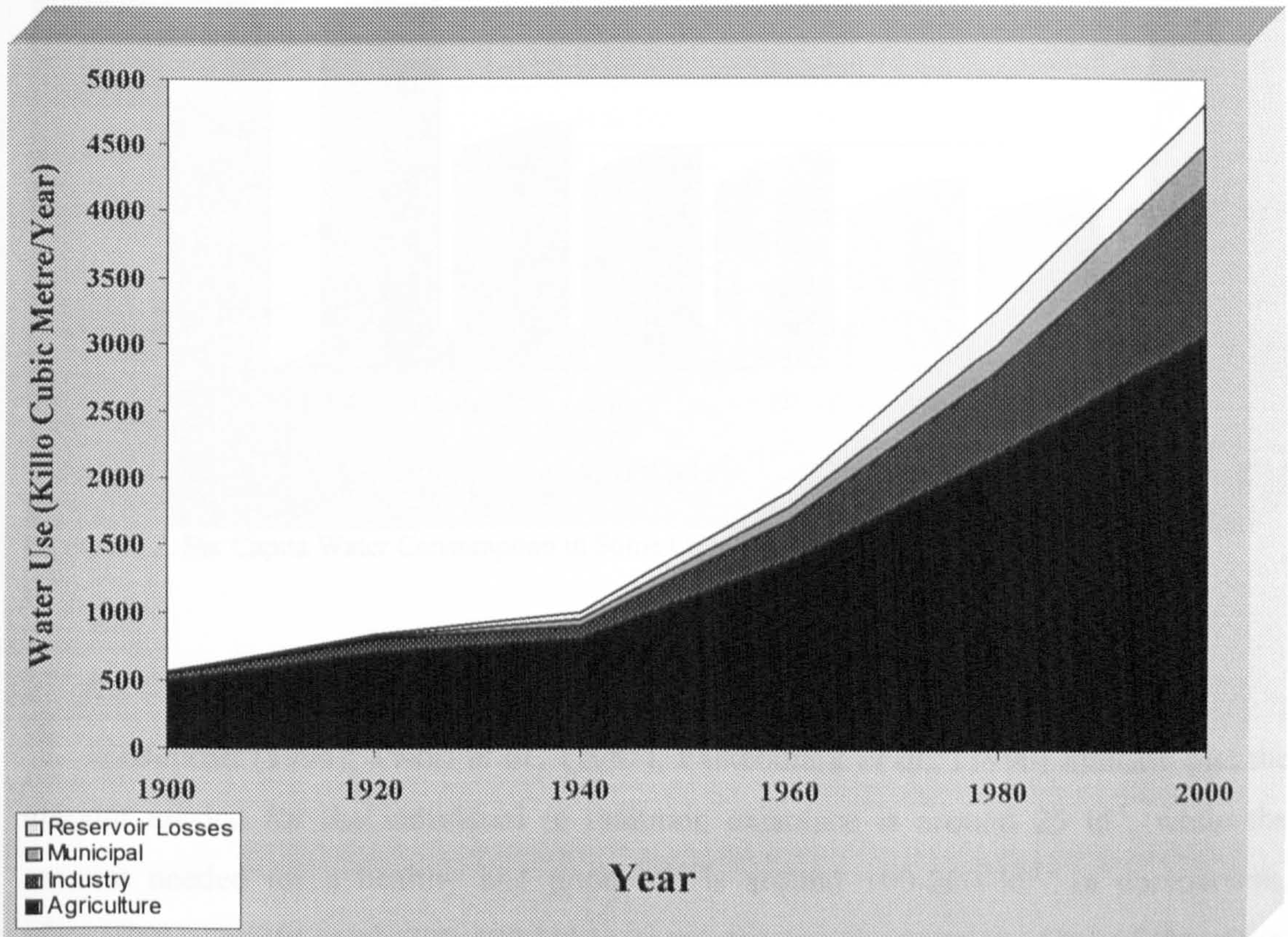


Figure A7.1. Estimated Annual World Water Use by Sector (After Kandiah, 1999).

A7.2. Domestic Demand:

Municipal use refers to household use of water for drinking, washing and cleaning and the use of water in government buildings and the private sector (such as hotels, hospitals and commercial centres). Household use of water in developing societies can be as high as 155 ld^{-1}, with the biggest share for personal hygiene, while drinking water does not exceed a few litres a day. Naturally these percentages differ from one region to another, according to the culture, climate and the standard of living. In Oman, which is an arid area, individual consumption does not exceed about 20 ld^{-1} on average, while in developed countries such as USA individual consumption reaches 568 ld^{-1} (Figure A7.2) (Clarke, 1993; Porteous *et al.*, 1993; al-Yahiawi, 1998; Hellawell, 1986; Bear, 1996; Beekman, 1998). Generally, the global per-capita demand for water is rising as the result of a number of factors.

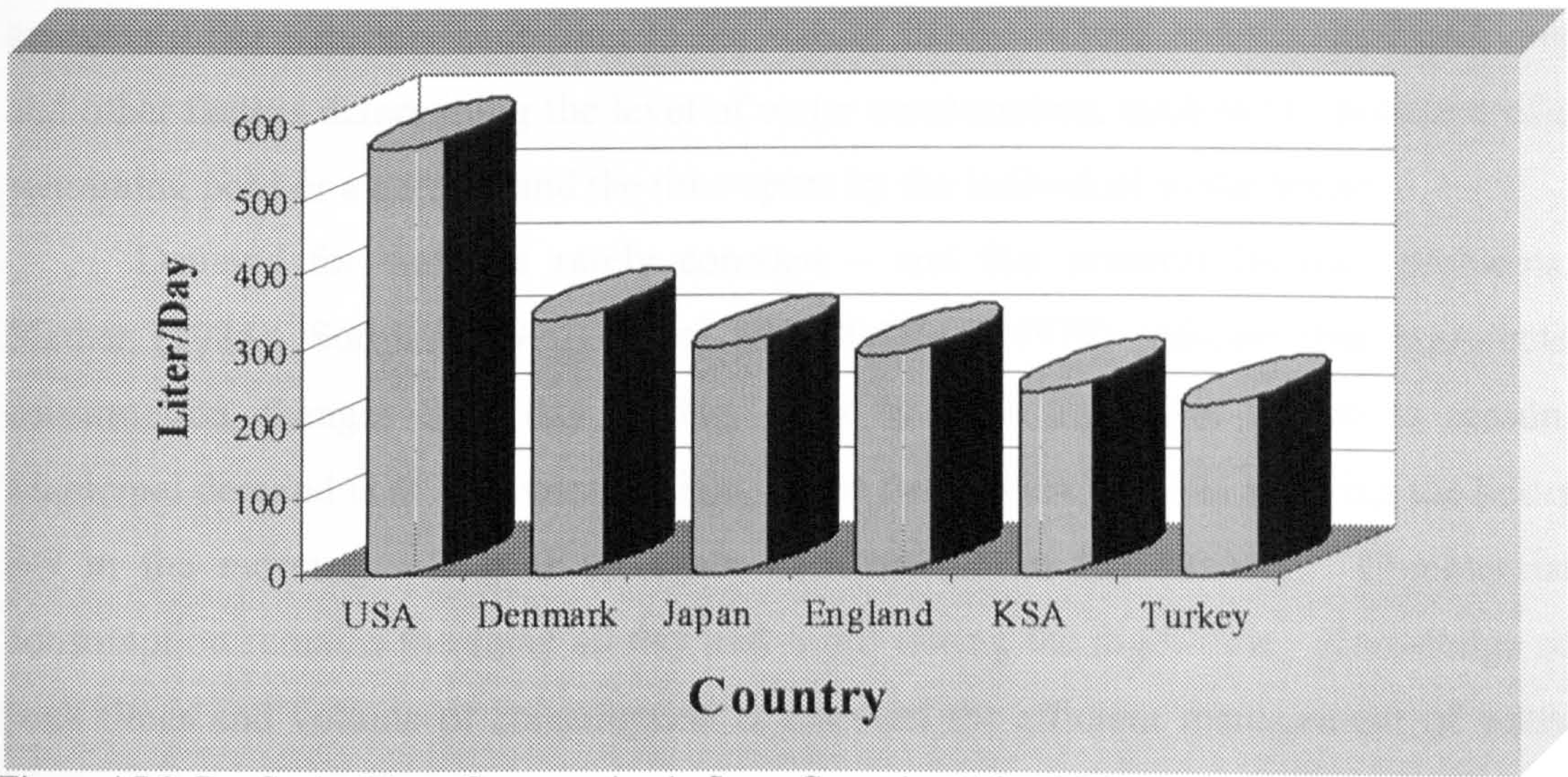


Figure A7.2. Per Capita Water Consumption in Some Countries (After Mukemer and Hijazi, 1996).

Berkoff (1994); Twort *et al.*, (1985); Falkenmark *et al.*, (1990) indicate that the amount needed for the individual to maintain existence is around 25 ld^{-1}, while the amount needed for a healthy and good life is around 100-200 ld^{-1}. In comparison, consumption might reach 300-400 ld^{-1} in some developed countries. One of the major problems for developing countries (apart from population driven expansion in demand) is the aspiration of their people to a developed world lifestyle - including rapidly rising demand because of the profligate use of water.

It is emphasised (OECD, 1989; Fittschen and Nimcznowicz, 1997; Tebbutt, 1992; Leopold, 1974; Shadi, 1999) that the largest part of domestic consumption is used in flushing toilets: around 20%. On average, an amount of 19 to 27 litres is used each time a valve-type tap is opened. In countries such as the USA, the consumption of water for bathing increases significantly and it is in the order of 40 ld^{-1}. For that reason, companies that manufacture bathing equipment are working towards finding ways that might help conserve water, such as mixing the water with pressurised air. Washing machines and dishwashers have also contributed significantly to the increase of domestic water consumption and as the number of these devices in society rise there is a consequent escalation of demand.

It is indicated (Gray, 1994; Linsley and Franzini, 1972) that in some developing countries, daily household consumption is divided for the individual as follows: 50 ld^{-1} for flushing toilets, 45 ld^{-1} for washing and bathing, 14 ld^{-1} for washing clothes, 14 ld^{-1} for dish washing, 8 ld^{-1} for outside use and 4 ld^{-1} only for cooking and drinking. These amounts differ naturally according to the size of the household and standard of living and other factors determining the level of water consumption, such as the presence of a swimming pool or a garden, and the time spent by the individual in the house.

Demand for water is rarely constant – and this presents its own problems. Mather (1984); Sormail (1990); Steel and McGhee (1979) indicate that household consumption changes from day to day, week to week and from season to season. Municipal demand is at its lowest at night, while the highest demand is during the hours 8-9 in the morning. It goes up again between 6-8 in the evening. Commercial consumption remains the same all day and drops during the night time. Knowledge of peak times and volume of consumption is essential for efficient management of water consumption.

A7.3. Industrial Demand:

There is a strong relationship between industrial development and water abundance since water is an essential factor in the expansion of industry. It is emphasised by Sharaf (1997); Williams *et al.*(1995); Kandiah (1999); Allaby (1996);

Jones (1997) that industry is the second largest consumer of water, with about 760 km^3 (23% of the total world consumption). In Figure A7.3 an indication is given of the scale of industrial consumption of water.

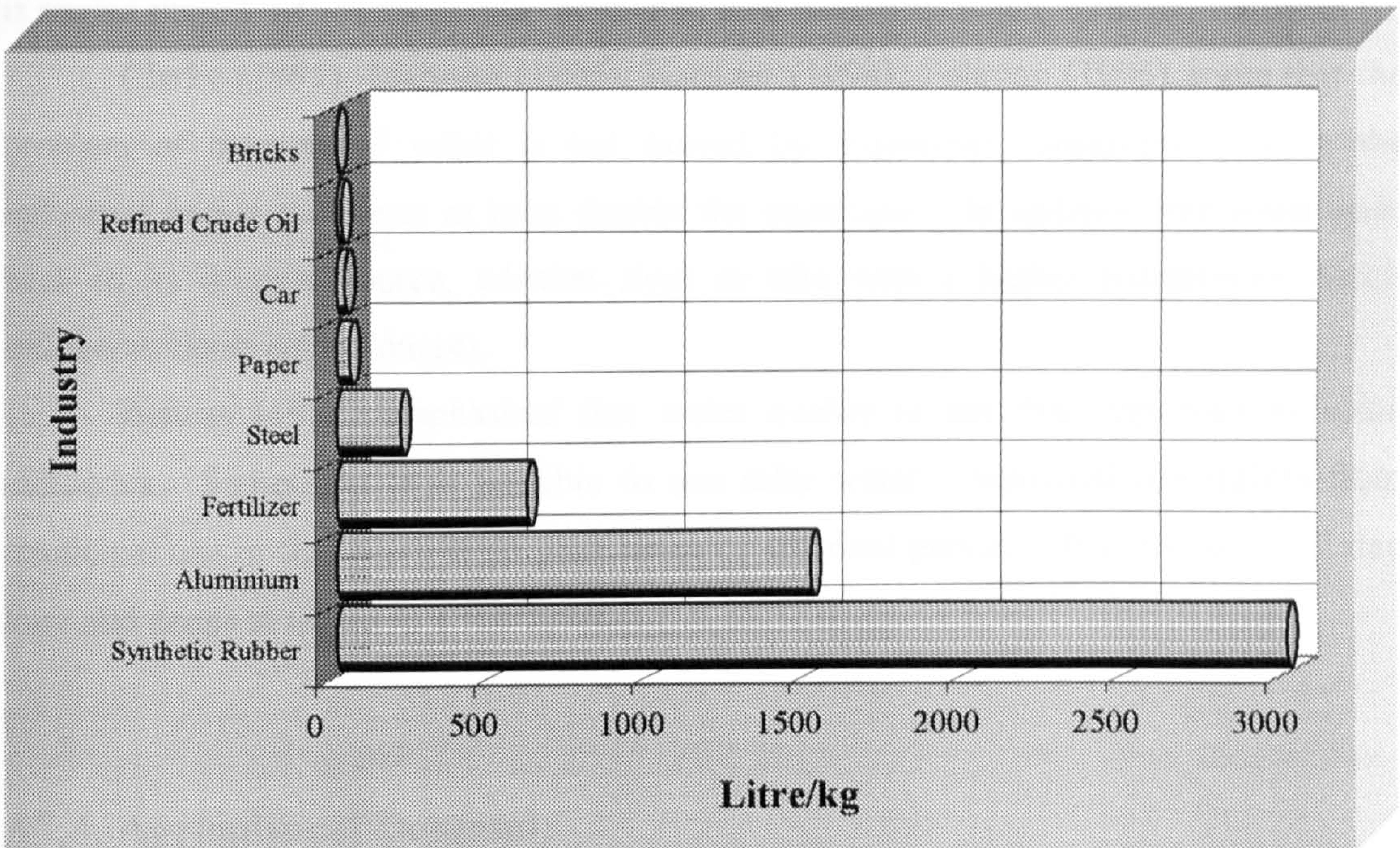


Figure A7.3. Water Requirements for some Industries (Williams *et al.*, 1995).

According to Mukemer and Hijazi (1996) industrial needs for water divide into three groups. The first group needs less than 10,000 gallons for each ton produced. Near the top of the items in this group is the slaughter and cleaning of chickens, since for each ton around 7,389 gallons of water is needed. The second group needs between 10,000 to 100,000 $galt^{-1}$. Aluminium is at the top of the list since it needs 98,300 $galt^{-1}$ produced, followed by steel, which needs 62,600 $galt^{-1}$. The third group consumes the most, more than 100,000 $galt^{-1}$. The manufacturing of cellulose string is at the top of the list; it needs 462,200 $galt^{-1}$ followed by non-cellulose strings, which needs 202,100 $galt^{1}$.

According to Linsley and Franzini (1972); Biswas (1978); Taylor and Denner (1985); Franks (1983); Calmon and Kinkgsbury (1966); Leopold and Davis (1971); Squires (1985) water in the industrial sector is used for a variety of purposes such as processing, boiler water, cleaning, drinking, cooling etc. Cooling in particular consumes huge amounts of water, accounting between 60% to 80% of water used in industry. A few industries have most of the industrial consumption. These include chemical production, primary metal, petroleum refinery, paper products and food processing.

Mather (1984) points to the increase in recent years in the reuse of water in order to conserve the huge amount utilised by the industrial sector. In some industries, water is reused three times or more. In the oil and coal industries water is reused six times.

Clarke (1993); Malyska (1995); Karliner (1994); Polevoy (1996) argue that the problem of overuse of water is not caused by municipal consumption, since the industrial sector consumes at least double the municipal. In addition this water goes back to its original source, whether river or lake with a higher temperature which influences these environments.

Biswas (1978) emphasises that water quality is not that important in some industries. Sometimes it is possible to use salty water. Industrial use differs from municipal use in that there is no peak times or seasonal periods. It is the same all day long and drops at nights to a low level.

A7.4. Agricultural Demand:

It is indicated (Biswas, 1967; White, 1977; Clarke, 1993; Pereira, 1973; Olivier, 1972; Leopold and Davis, 1971; al-Tarabulusi, 1999) that Man's first activity was gathering and hunting and he moved from place to place according to the availability of water and food. When Man needed more predictable food to sustain higher population densities he began cultivating small areas of land and thought for the first time about storing water. Hence came the idea of dams and reservoirs, which have been known since the ancient Egyptian civilisation 5,000 years ago and in many other countries such as India. In the Arab world, people used the summits of inactive volcanoes to store water for irrigation and excavated deep wells (Williams *et al.*, 1995).

Mather (1984); James and Lee (1971); al-Thani (1991) conclude that irrigation methods have been developed over the years and date as far back as the Egyptian and the Mesopotamian civilisations. According to Hansen *et al.* (1980); Stansfield (1997) irrigation has several agricultural purposes. Some of these are:

- To water plants and protect them during dry periods.
- To provide a climatic environment that helps plants to grow.
- To reduce disease.
- To reduce the effect of frost on plants.
- To remove the salts in the soil.
- To make the soil more cultivable.

The increase in world population, especially in the twentieth century has made agriculture a major consumer of water. It is emphasised (Arthur, 1994; Liebaert, 1997; Leopold, 1974; Cantor, 1970; Allaby, 1996; Dean and Lund, 1981; Kandiah, 1999; Sharaf, 1997; Jones, 1997) that agricultural consumption of water far exceeds all other sectors (about 3300 km^3 or 70% of the total global water usage) and is progressively on the increase year after year. Table A7.1 shows the areas of agricultural land depending on irrigation.

Table A7.1. Irrigation Land in Some Countries (Mather, 1984).

Country	Cultivated Land (1000 ha)	Irrigation Land	
		1000 ha	Percentage
China and Taiwan	111,167	76,500	69
India	164,610	38,969	24
USA	192,318	21,489	11
Pakistan	21,700	12,400	57
Former USSR	232,609	11,500	5
Indonesia	18,000	6,800	38
Iran	16,727	5,251	31
Mexico	23,817	4,200	18
Iraq	10,163	4,000	39
Italy	14,409	3,500	29
Thailand	11,200	3,170	28
Vietnam	5,083	3,040	60
Afghanistan	7,980	2,900	31
Egypt	2,852	2,852	100
Sudan	7,000	2,520	25

According to Agnew and Anderson (1992); Kandiah (1999) Crops need a lot water during the growing period. For one ton of vegetation, around 1,000 m^3 of water is needed in arid areas, where there is no rain. Clarke (1993) gave an example, assuming there is a village of 1,000 inhabitants, 2,500 cattle, 500 sheep and goats, the water consumption of this village would equal the amount needed to irrigate a quarter hectare twice a month

According to Abramovitz *et al.* (1996); Hazlewood and Livinqstone (1982); Linsley and Franzini (1972); Franks (1983), agricultural uses of water are considered a major reason for water loss, since half the amount used in the sector is lost and is not utilised by vegetation. Although a large part of this returns to rivers and underground, its quality is reduced because it is polluted with chemicals, salts and organic material. Despite this disadvantage, irrigation water is a source of security for farmers, especially during dry periods. Irrigation has become the major use of water for agriculture in many developing countries. In Egypt, for instance more than 98% of water used is in the agricultural sector. Egyptians do not consume individually more than 10 m^3a^{-1}, while agriculture consumption equals 950 m^3 per person a year (amongst others al-Saqar, 1999; Abdulwahab, 1999a). The same happens in China and India, where the agricultural sector consumes 90% of the total available water. There is a danger in using groundwater for irrigation, since it is not always renewable and needs a long time to recharge. This explains the dryness suffered by some wells and the salinity caused by increased pumping (Abramovitz *et al.* 1996).

According to Williams *et al.* (1995); Beaumont (1993); Carruthers and Clark (1981), irrigation covers 15% of cultivable land in the world, especially where it is not possible to cultivate without irrigation such as in Saudi Arabia and Egypt, where rain is scare and can not be depended upon. Irrigation is widely used in Asia for rice fields, which need soaking with water. In areas where rain is seasonal, water is stored and then used during dry periods.

Figure A7.4 shows the cost of food production in terms of water needed.

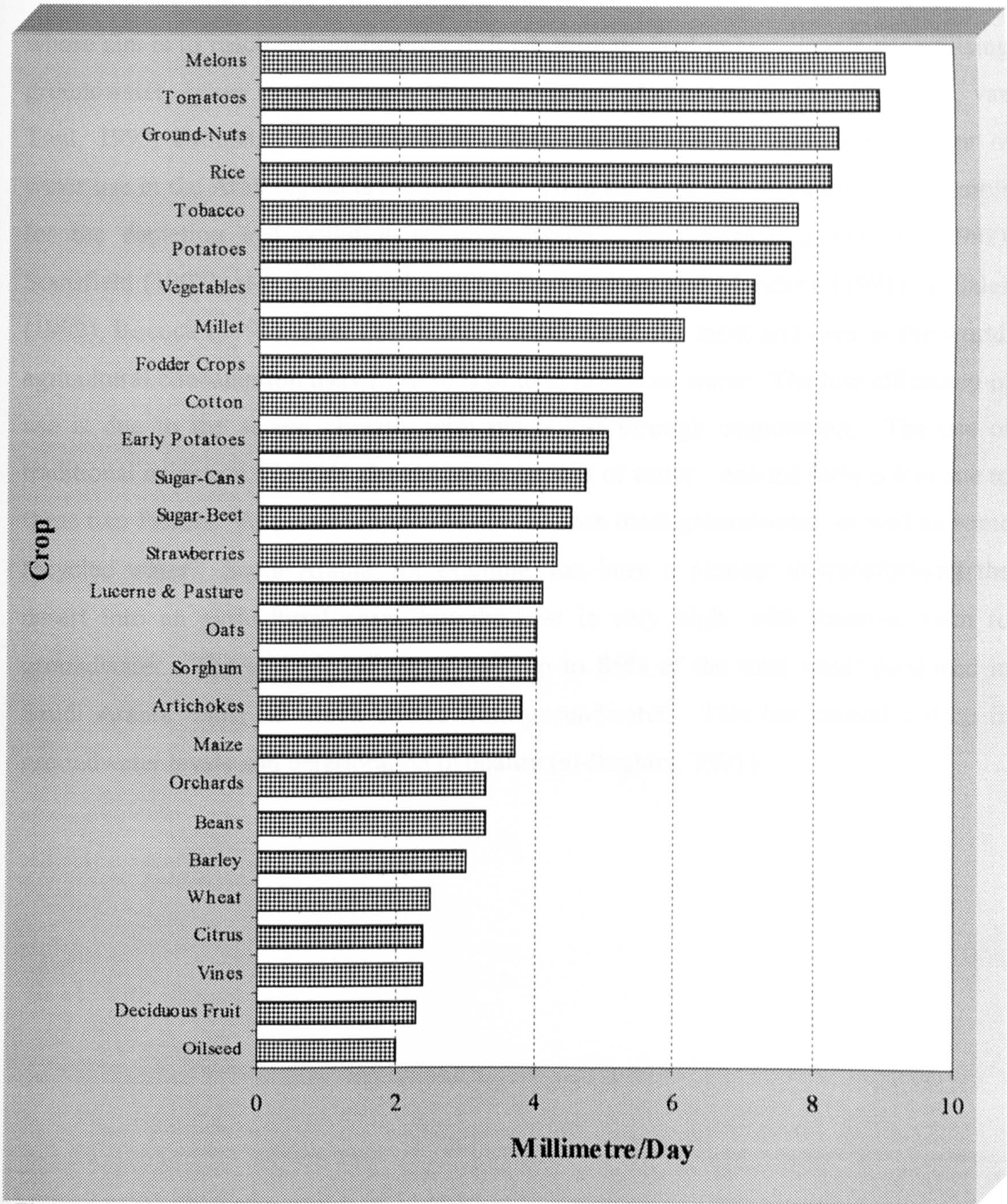


Figure A7.4. The Average Water Requirement for Some Food Plants (Carruthers and Clark, 1981).

Beaumont (1994); Gray (1994); Chilton *et al.* (1995); Hotes and Pearson (1977); Sayed (2000) argue that the inappropriate use of irrigation may cause harm to the soil and vegetation since the evaporation of water will leave the soil saturated with salts, making it unsuitable for cultivation except after washing the salt out, which by itself puts pressure on the water resource.

On the other hand, some countries located within the arid and semi-arid regions, whose aim is to reach self-sufficiency in food, through land improvements and utilising groundwater, cause massive harm to groundwater. According to (Young, 1997; van Tuijl, 1993; Brooks, 1993; Beaumont, 1994), the share of the agricultural sector of water use in the Arab region is around 87%. Here the agricultural sector is responsible for the depletion and pollution of groundwater. For instance al-Mugran (1992); Stansfield (1997); al-Sulaimi *et al.* (1996); Raveendram and Mandany (1991); al-Saleh (1992); Bocock (1996) show that in the Arabian Gulf, the most arid area in the world, agricultural consumption uses 75%-80% of total produced water. The low efficiency of use is due to the severe climate, with much lost through evaporation. The use of traditional irrigation methods also causes great loss of water. Around 50% is lost due to these two factors. At present, agriculture consumes most groundwater, as well as some recycled water. Saudi Arabia, for example, has been a pioneer in transforming the desert into an agricultural oasis, but the cost is very high, with massive harm to groundwater. The agricultural sector uses up to 85% of the total water produced in Saudi Arabia, most of which comes from groundwater. This has caused a drop in groundwater levels and deterioration in quality (al-Ibrahim, 1991).

APPENDIX EIGHT:

OLD PEOPLE SURVEY: FORM AND DATA

Appendix Eight:

Old People Survey: Form and Data

A8.1. Old People Survey Form:

I- Personal Particulars

1. Nationality Group:

Citizen	Non-citizen
5	0

2. Gender Group:

Male	Female
4	1

3. Education Group:

Very Little	Elementary	High School	Higher Education
4	1	0	0

4. Age Group:

65-69	70-74	75-80	80-84	85-89
1	1	0	2	1

5. Residence Group:

Doha	Al-Wakrah	Al-Khor	Al-Thakirah
2	1	1	1

II- The Water Resources and Distribution Methods

1. What is the source of the water you consume before 1950s:

Source	Frequency	Percentage
Fresh Groundwater	5	100
Brackish Groundwater	5	100
Seawater	5	100
Rainfall Gathering	5	100
Water Importation	3	60

2. How did freshwater reach you:

Water Distribution	Frequency	Percentage
By women	3	60
By al-Kandri (Water Carrier)	2	40
By ships (consumed by oil workers only)	3	60

III- Water Management

1. How did you store the freshwater:

Storage Method	Frequency	Percentage
Room with capacities of 4-9 gallons	1	20
Room with capacities of 10-20 gallons	3	60
Room with capacities of 30-40 gallons	1	20

2. How was water consumed:

Demand	Frequency	Percentage
Household	5	100
Household and agriculture	1	20
Household, agriculture and light industries	1	20

3. How was water managed:

Water Management	Frequency	Percentage
By people until 1940s	3	60
By people until 1960s	2	40

III- Opinions and Recommendations

1. How all these styles changed in the period that followed oil exploitation?.

Opinion	Frequency	Percentage
The availability of huge amount of funds affected on Government polices and as well as people behaviour toward water extravagantly	4	80
Different life needs different style	1	20

2. What is your recommendation to make control on current water waste?

Recommendation	Frequency	Percentage
Raise the public awareness by using advertising campaigns, laws and symbol tariff	4	80
increase investment in water production with import of modern technology	2	20
Media programmes about water management in prior to the oil production	3	60

A8.2. Old People Survey Data:

A8.2.1. Introduction:

The oil era in Qatar witnessed a major change in the management of water in all aspects: production, distribution, storage and demand. The transition period and after in the 1940s and 1950s was a very short period, during which major changes took place. There are no references or real studies on the era prior to oil discovery or the transition period for water management. Hence, the researcher resorted to undertaking interviews with five individuals who were contemporary to the pre-oil era. These interviews focused on the methods of water management prior to the 1940s as well as during the transition period (1940s and 1950s), which marked the beginning of the construction of the modern State.

Opinions were also sought on the present water management policy and its comparison with the old management policy. It is worth noting that the collected information through the interviews was very similar and this is because people shared similar environments. The majority of them were living in coastal cities and villages in similar social and cultural conditions. In addition, economic activities were monotonous and restricted to hunting and pearl diving and sometimes trade. As a result, their management of water was similar.

A8.2.2. Water Resources:

According to the information collected in the interviews, water resources can be divided into five types that differed in importance and uses as follows:

A8.2.2.1. Fresh Groundwater:

The interviewees unanimously agreed that the fresh groundwater was the most important and vital source in pre-oil period. This source was usually found a few kilometres into the interior. Most settlements were located near the coast, where groundwater usually got mixed with seawater, and hence was not suitable for consumption because of its high salinity. Wells used to be dug to about 10 m deep in interior lowland to reach freshwater by simple available methods such as pickaxes

(Plates A8.1 and A8.2). The well then was named after the area or the person who dug it. Water was available to everyone free, since the family or the person who dug the well acknowledges that it is public property in accordance with Islamic law. According to one interviewee, "there was a model co-operation among the people; the well will be dug by primitive means and collectively. People knew they had to depend on themselves collectively to manage their affairs in the absence of a real central authority". Most of these wells still exist but most of them are not utilised.

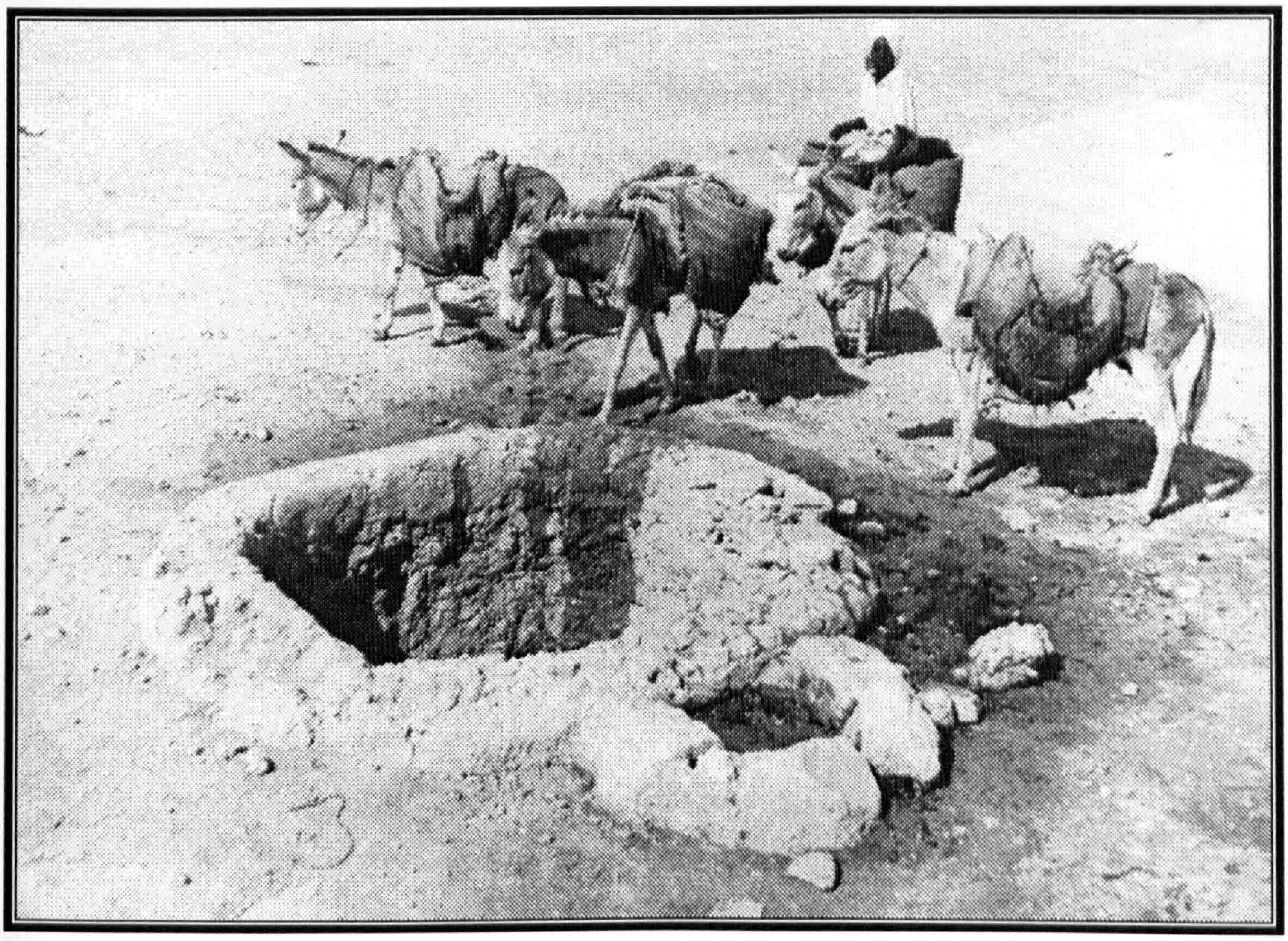


Plate A8.1. Water Production and Distribution Equipments Before 1950s (MFA, 1999).

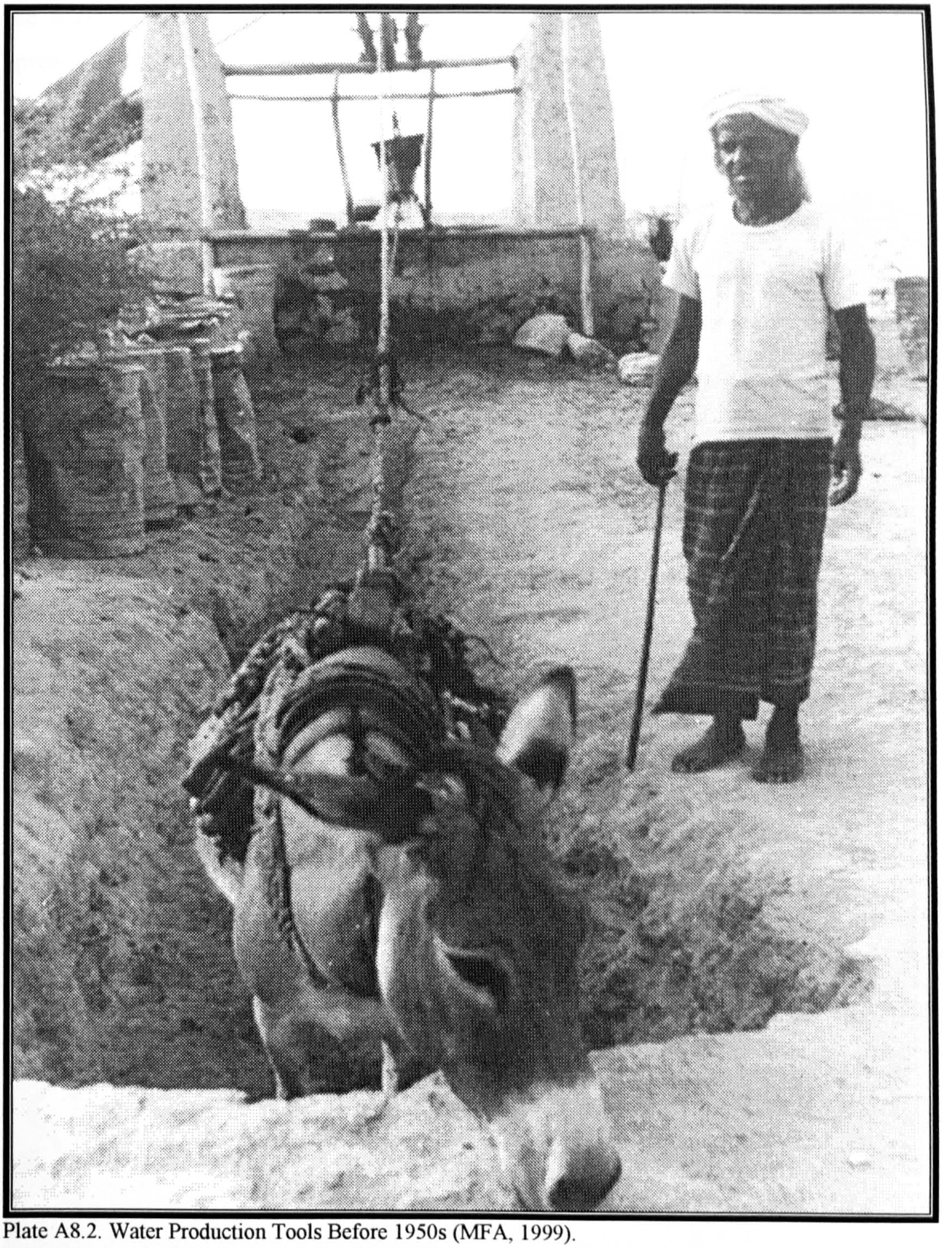


Plate A8.2. Water Production Tools Before 1950s (MFA, 1999).

A8.2.2.2. Brackish Groundwater:

This source comes second in importance. As mentioned before, settlements were near coastal areas, where groundwater was salty and not suitable for drinking. It was utilised, however, for personal and material washing, because these wells were near the settlements. Access to these wells was very easy and hence they became wide spread. 4 out of 5 of the interviewees confirm that each family had a well of that sort (Plate A8.3), while the rest used to have access to the village well. These wells were also dug collectively and were free and available to everyone, as was the case with the freshwater wells.

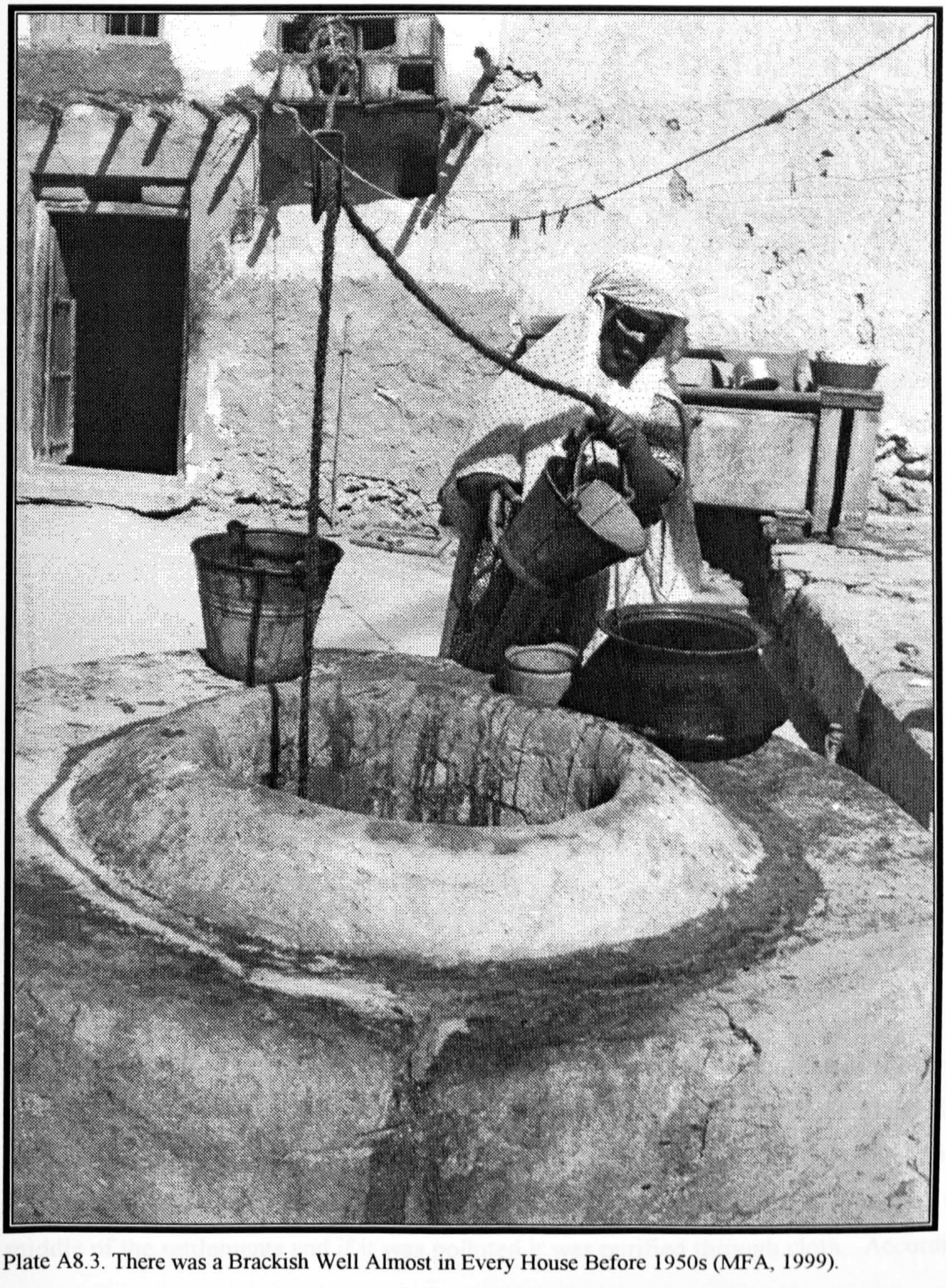


Plate A8.3. There was a Brackish Well Almost in Every House Before 1950s (MFA, 1999).

A8.2.2.3. Seawater:

The interviewees confirmed that seawater was used for some purposes such as bathing and washing clothes and dishes, especially as most houses at that time were overlooking the sea (Plate A8.4) and just a few metres away. Therefore, there was no need for water transport. According to one interviewee "I preferred to bathe every day in seawater especially during the very hot summer months".

Plate A8.4. Seawater was Used for Washing (MFA, 1999).

A8.2.2.4. Rainfall Gathering:

Although rainfall was limited and varied from season to season, the interviewees confirm that rainfall was gathered in low-lying areas and valleys by simple tools. The lack of widespread construction at that time facilitated this, since it was only undertaken in low-lying untouched areas. Hence, rainfall collected in the form of pools in the middle of the settlements and if it was polluted it was purified through cloth. According to one interviewee "sometimes a kilo of worms is collected this way from the water". This water would be stored in special places and would not be consumed except for special purposes, such as making coffee that was considered extremely important. Another interviewee says that "the water was very fresh and exceeded in its quality groundwater, hence there were caution in collecting, storing and consuming it".

A8.2.2.5. Water Importation:

This source, which was mentioned by 3 out of 5 of the interviewees, was used at the start of the oil era or during the early transition period. In Qatar, during the period of oil exploration in the mid 1930s, when pearl diving was dwindling because of low prices, most of the able men began working for the oil company in the mid west of the country where adequate amounts of fresh groundwater was not available. Hence, water was brought from the State of Bahrain by ships to Zekreet and distributed by pipeline to that area (Plate A8.5). This stopped when deep wells were dug by using modern techniques at the end of the 1940s.

Plate A8.5. Disembarkation of Imported Water at Zekreet Port (al-Othman, 1981).

On the other hand, the summer months (May, June, July and August) used to witness a collective migration of men to the sea for pearl diving. These men, while at sea, used to get their required water by buying it from people living in coastal cities. Some men took the selling of water as a livelihood, especially people from the northern part of the Arabian Gulf (Iran). A similar thing used to happen with those men trading with Asia, especially India. According to a woman interviewee "during the pearl diving season, strange men used to come to us to buy water and therefore we used to bring the same amounts that we would usually have during the normal season when men are not at sea so as to benefit from selling the water to these ships".

A8.2.3. Water Distribution:

According to the interviewees, distribution of water took three forms that varied in importance and degree of dependency.

A8.2.3.1. Women:

3 out of 5 of the interviewees confirm that women had most responsibility for providing freshwater (Plate A8.6). Usually, they would go in groups for three or four hours to bring the water from nearby wells. They used usually to bring the water on donkeys, with an average of 3-4 gallons (0.013-0.018 m^3) per trip. Sometimes young boys accompanied them.

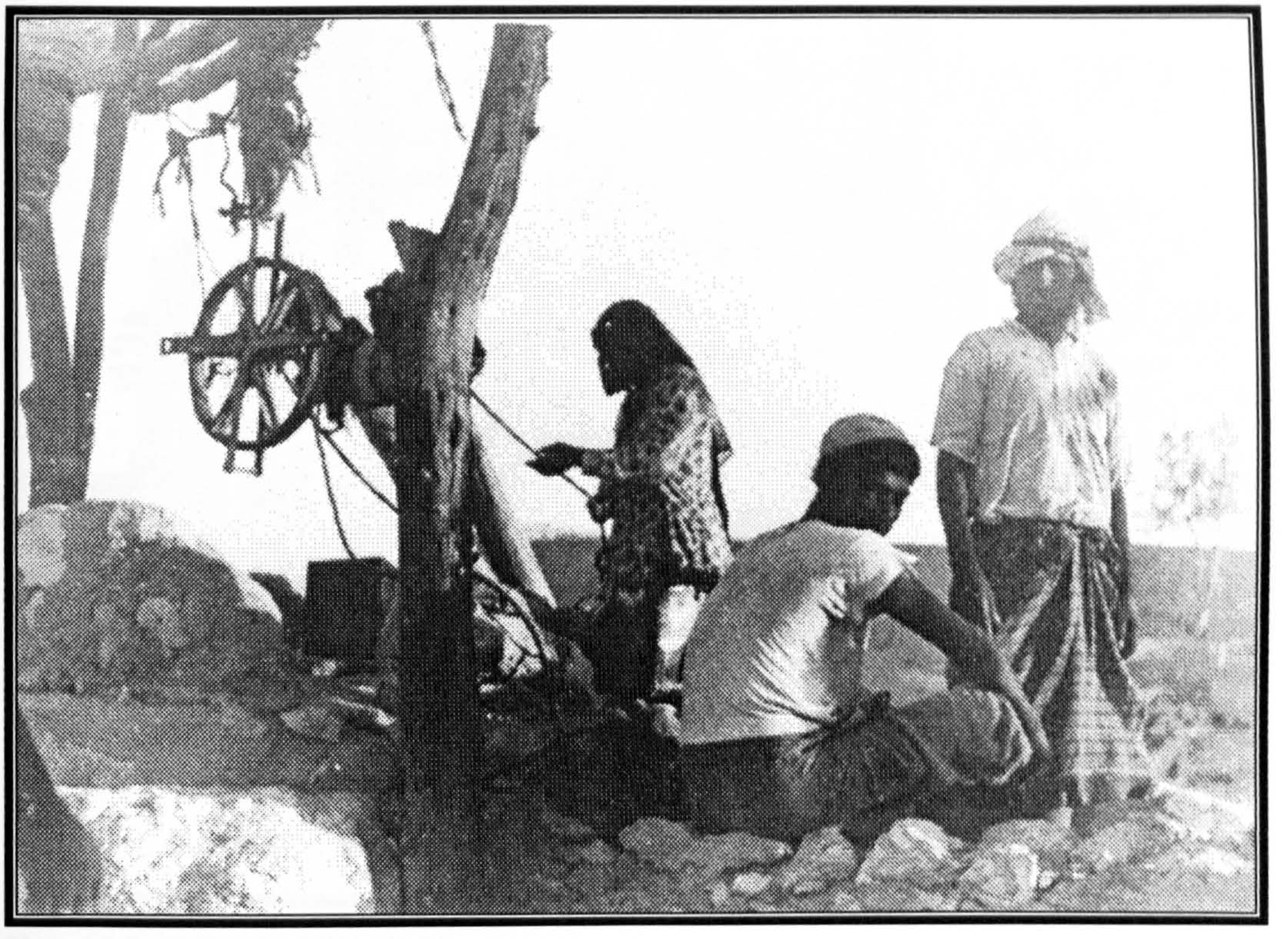


Plate A8.6. Women Played an Important Part in Water Production and Distribution (MFA, 1999).

A8.2.3.2. Al-Kandri (Water Carrier):

This is a name given to the person who carries the water on his shoulders for a fee (Plate A8.7). 2 out of 5 of the interviewees confirm that this was their method of getting the water. It was possible for people, such as traders, who were able to afford paying *Al-Kandri*. Also, families where women were unable to make the harsh trips used *al-Kandri* to get their freshwater.

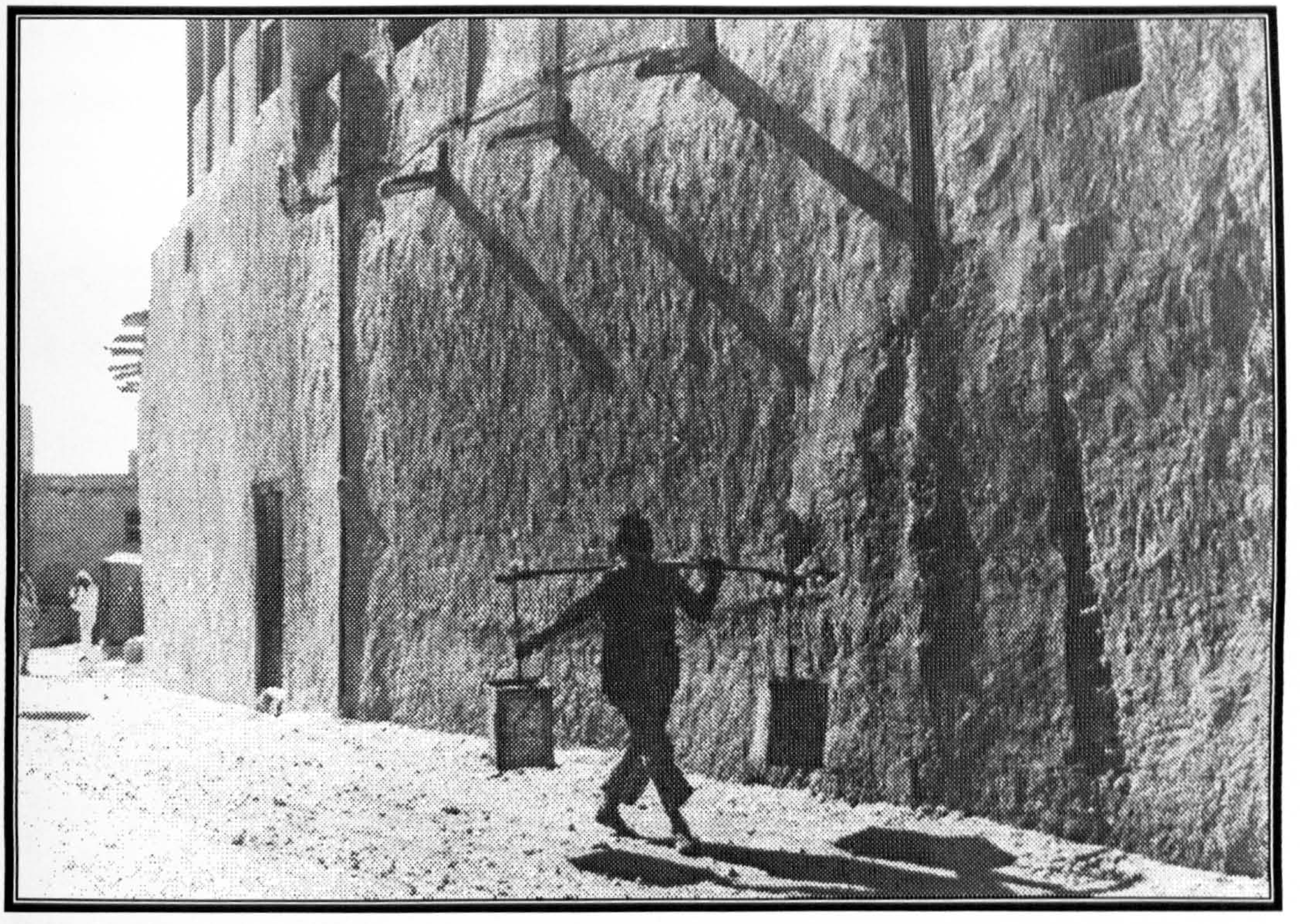


Plate A8.7. *Al-Kandri* (MFA, 1999).

A8.2.3.3. Ships:

This method was only used during the oil exploration period, as mentioned before (Section A8.2.2.5). Ships were used to carry water from Bahrain in regular trips, amounting sometimes to seven trips a day. It can be said that this was the start of the shift, from the traditional methods of people managing the provision of their water, to a more organised method depending on central authority.

A8.2.4. Water Storage:

The interviewees confirmed unanimously that they used to have a special room in the house for water storage, while they varied in their opinion about the size of the room, with quoted storage capacities of 5-40 gallons (0.022-0.18 m^3) of water. They also indicated that perfumes were added to pots to make water more palatable for drinking. Water used to be kept in pots made of clay, especially in summer to keep it cold (Plate A8.8). During the transition period, water used to be stored in metal tanks outside the house and these still exists in some areas.

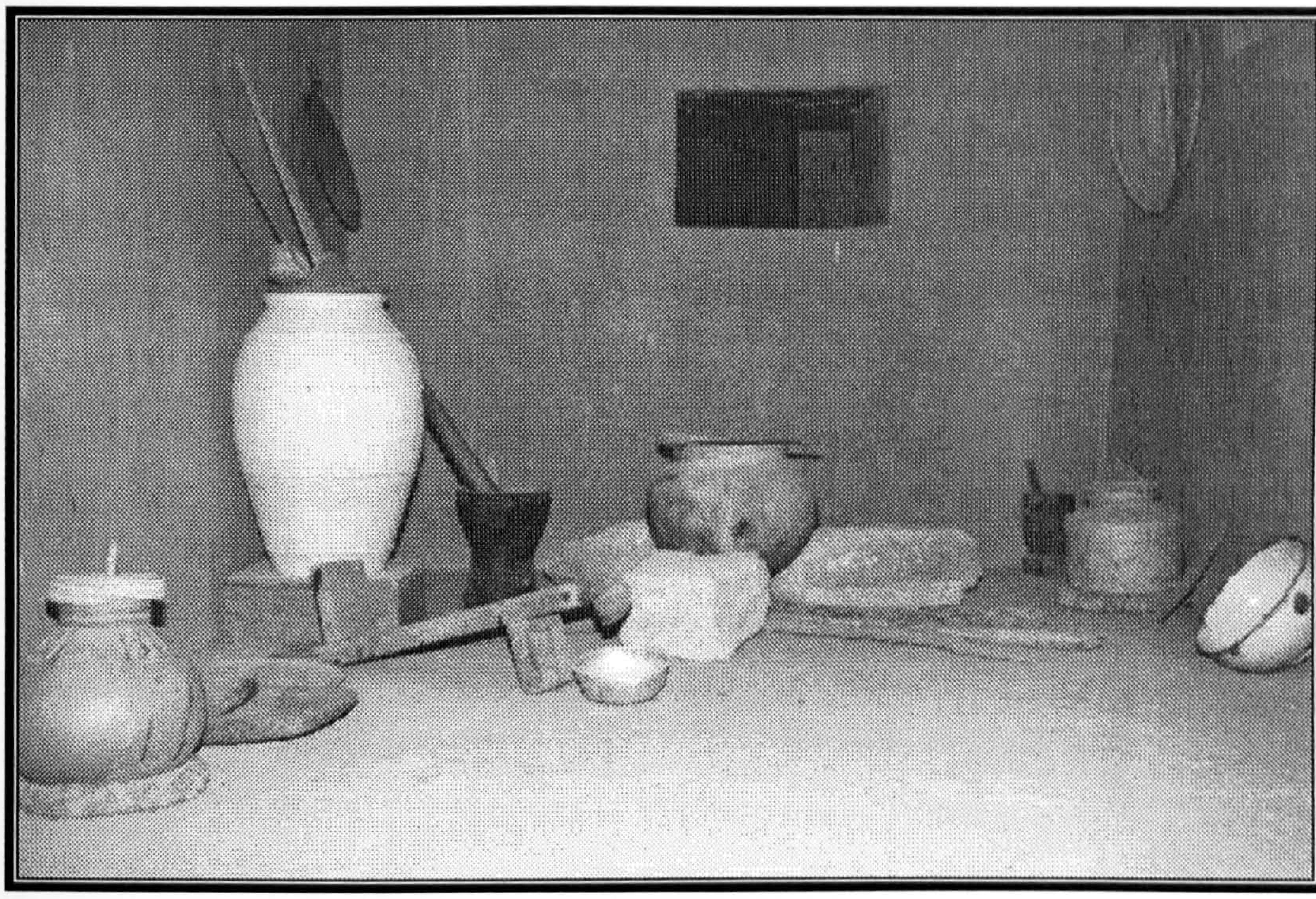


Plate A8.8. Clay Pot for Water Storage (AGSFC, 1999).

A8.2.5. Water Demand:

The Domestic sector was the main consumer of water, since economic activities were limited and most activities did not need much water, except for the agricultural sector.

A8.2.5.1. Household Demand:

The concern of most people was focused on providing water for different household purposes. Fresh groundwater was brought from areas surrounding settlements so it could be consumed for drinking and cooking and sometimes to water domestic animals. Great attention was given to this water, where it was stored in clay pots. According to one interviewee "we used to conserve each drop of water because it was not easy to squander what you get with difficulty". Brackish groundwater was used for bathing and washing and seawater was used for similar purposes.

A8.2.5.2. Agriculture Demand:

Agriculture was extremely limited then, and the number of farms was limited. They were owned by the wealthy. Thus, water consumption in this sector was small. According to one interviewee "we were introduced to most of fruits and vegetables after the 1950s. We depended almost completely on the sea to secure our food".

A8.2.5.3. Industrial Demand:

Some of the interviewees indicated that some light manufacturing existed at that time such as building the local craft used in the pearling, the making of fishing instruments and construction equipment. Yet industry was extremely limited and its consumption of water was very small. Among the industrial activities that consumed water, was construction, where water and mud were mixed together. Thus, limited economic activities made water demand (unlike the present day situation) small and exclusive to the household sector. People were more aware of the arid nature of their environment and were more cautious about water consumption or the expansion in fields that needed water.

A8.2.6. Water Management:

The interviewees unanimously agreed that water management was completely in the hands of the people and central or organised management did not exist. The inhabitants in their areas used to manage the provision and transport of water and no regulations existed to control or develop water resources. Government supervision started only after the 1940s in some areas, according to 3 out of 5 of the interviewees. The Government tried to levy fees for the service, but the people refused. According to one interviewee "how was it possible to pay water fees when very few of us benefited from the oil income, while those who had access to this income were exempted from paying the fees". Public opposition to paying fees continued. The Government tried to reduce the fees but still the people refused to pay. In the end the Government ignored the matter, especially with the increase in income from oil production during 1970s.

On the other hand, 2 out of 5 of the interviewees (those living outside Doha) claim that Government supervision started only after the mid 1960s and that they were buying water during the transition period from individuals who took it upon themselves to transport and distribute the water which they got free, for a fee. According to one interviewee "the Government ignored the matter completely, since it did not want to carry the financial burden of those living far from the capital. Government involvement only started after many complaints and demands by the people of these areas".

A8.2.7. The Opinions of Old People:

The commercial production of oil in 1949 and the sharp rise in its price during the 1970s and early 1980s is considered by 4 out of 5 of the interviewees as a major influence on Government policy as well as on people's behaviour. The availability of huge amounts of funds made the Government apparatus believe that nothing is beyond its means. For instance, oil wealth can buy the latest technology for desalination of water, extract deep groundwater and turn the desert into green land. The same attitude was adopted by the population, who believed they could get anything cheaply, especially that the generations that experienced the oil boom did not live in the conditions of the pre-oil era. According to one interviewee "if my wife or my daughter had to travel long distances to bring water I would not allow any body in my family to waste a single drop of it".

The opinions of the old people can be summarised as follows: the present water policy has not achieved its objectives, because the Government is providing water without attempting to control consumption levels in both the domestic and agricultural sectors. Also, the consumer is not suffering to get the amounts of water he desires, consequently he wastes it easily. The Government and individuals are both responsible for the current water issue. The old people support levying fees on water, since incomes have risen substantially in comparison to the 1940s or 1950s and the service of providing water had improved also, but they insist on the fees being equal among all citizens, while taking into consideration income and consumption levels.

1 out of 5 of the interviewees believe that Government policy is adequate, since the concerned authorities have tried to find alternative sources to water to compensate for the limited amounts of groundwater. For them consumption levels are a natural consequence of the rise in the standards of living and the openness of the society to the rest of the world, and such an increase is a common feature among all societies in today's world. From among the interviewees, 3 out of 5 own farms that have between 1 to 6 wells and they confirm that these farms are recreational rather than commercial.

The interviewees assert that the welfare society is on its way out, with the reduction of oil prices and the limited possibility of it going back to the level it reached in the 1970s. They expect the Government will face difficulty in providing water by desalination; because of its high cost the citizens will have to adjust to more stringent policies. Naturally they do not believe things will go back to what they used to be in the past where people had the responsibility of providing they own water without the control and interference of the central Government. Thus, they do not believe that privatisation is a possible alternative and they assert that the service must remain in the hands of the Government, with popular participation in formulating the overall water policy.

A8.2.8. Recommendations:

The interviewees assert the need to raise the awareness of the public about the importance of water through a variety of means, such as advertising campaigns, legalisation and levying fees. 4 out of 5 of them believe there is a failing in these aspects on the part of the Government and that the real cost of providing the water is unknown, unlike in the pre-oil era. One believe that the Government is trying but without success because of the absence of the principle of punishment through strict laws and or levying fees. There is unanimous agreement that fees must not be high and must come gradually and be imposed on everyone.

2 out of 5 call for increased investment in water production and import of modern technology since there are areas that still lack the same level of service as in big cities. 3 out of 5 assert the need for more media programmes and leaflets about the management of water prior to the oil boom so the citizens can appreciate what they have today. Such information must become part of the education in all different levels.

A8.2.9. Overall Conclusion:

In the pre-oil era the management of water was the full responsibility of the population. Settlements used to carry out that responsibility in a variety of ways. Most notably there was a high level of co-operation and selflessness. The person who searched and dug the well used to know that it was public property and that everyone has the right to benefit from it. What is most admired in people of that period is their understanding and appreciation of their very harsh environment, despite their little formal education. Water policy could be described as being based on investing in every resource that was available, from fresh and brackish groundwater, seawater and rainfall as well as conserving it by limiting consumption. Therefore, their approach to water management was sustainable.

The sea became the source of livelihood of the people since they realised that the land is not a viable resource considering the limited amounts of water. Thus one can say the success of man at that time depended on his understanding of his environment and not burdening it with more than it could carry. Some studies indicate that the appreciation of the past is the key to understanding the present (for instance Riad, 1992; al-Hajri, 1997), but that does not appear to be completely true of the situation of water management in Qatar.

Major changes have taken place in the past few decades. Water management shifted from people to the central Government. Water sources are now restricted to two: desalination and groundwater (Section 6.2) while in the past fresh and brackish groundwater were the main sources, besides secondary sources such as rainfall. In the past, the household sector was the main consumer: while nowadays there are many consuming sectors with the agricultural sector taking first place and the household sector coming second. New sectors have emerged, such as government, industry and commerce (Section 6.3).

What is most important is the change in the perception of the local environment. As mentioned before, man had greater understanding of his environment, despite the spread of education and environmental awareness at present. The water policy appears to be short-term, concerning the environmental balance. Take, for an example, the agricultural policy, which led to the depletion of groundwater and an imbalance in the natural equilibrium (Sections 7.3.2.2 and 7.3.2.3). Extraction of water far exceeded the natural recharge of groundwater. The people in the past tried to avoid such a situation.

Thus, the most important conclusion is that it is essential to understand one's environment and its development without causing much damage to it; in other words, adopting a water policy that suits the natural conditions of the area.

APPENDIX NINE:

WATER CHEMICALS PARAMETERS: SOURCES, PROBLEMS AND STANDARD

Appendix Nine:

Water Chemicals Parameters: Sources, Problems and Standard

A9.1. Introduction:

The aim of this appendix is to discuss sources, problems and standard of 11 water chemical parameters. Recently, the awareness of people concerning the quality of water they consume has been enhanced with the increasing awareness of public health matters (amongst others Bartram and Ballance, 1996; Chapman, 1996; Polevoy, 1996; Spray, 1997). The media has also played a major role in highlighting the importance of environmental pollution control including water quality (Newson, 1995). There are many sources of polluted water such as human and industrial waste (Figure A9.1) (for instance ReVelle and ReVelle, 1981; Falkenmark, 1993).

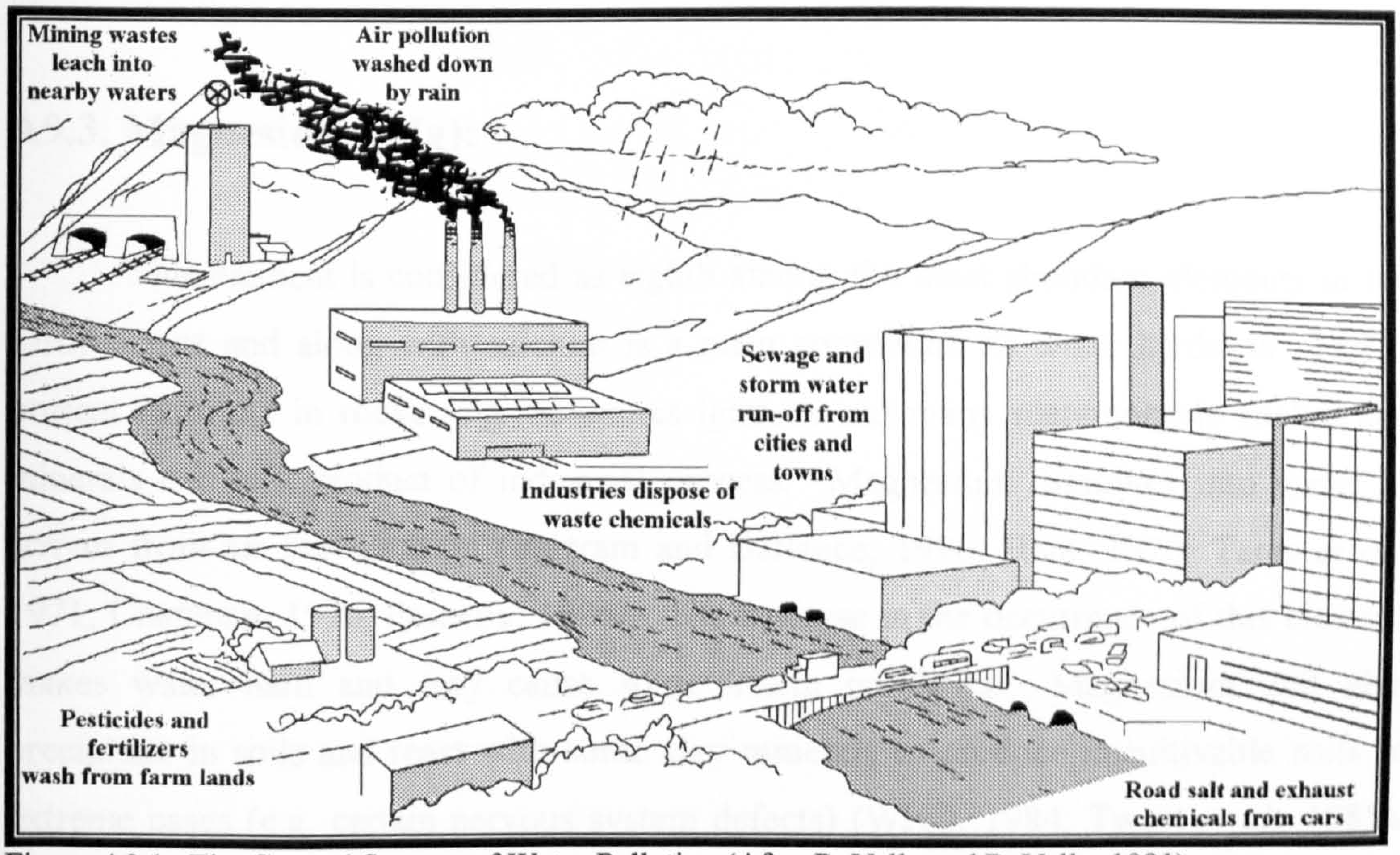


Figure A9.1. The General Sources of Water Pollution (After ReVelle and ReVelle, 1981).

A9.2. pH:

pH is an expression of the hydrogen ion concentration in water and can be related to the alkaline or acidic nature of the water. Its range in natural water is between 4 and 9. pH is neutral when the pH is 7. If pH is higher than 7 then the water is considered alkaline. On the other hand, if it is less than 7 then the water is considered acidic. The most important sources of pH problems are entry of strongly acidic water and acid industrial waste (for instance Abu Samur and Khatib, 1999; Droste, 1997; Black, 1996; Chapman, 1996). Highly acid or alkaline water, other than making the water less suitable for consumption, causes corrosion in the distribution network and household supplies. Moreover, corrosion in the water network hinders smooth flow (for instance Gray, 1994; WHO, 1984; Goodman, 1980). The WHO suggests desirable levels of pH between 7.0 and 8.5 and the maximum permissible range between 6.5 and 9.2 (for instance Tebbutt, 1992; Chapman, 1996; Schulz and Okun, 1992). The EC has set the drinking level at between 6.5 to 8.5 (Gray, 1994; De Zuane, 1997). For industry levels are between 3.0 and 11.7, and for irrigation recommended levels are between 4.5 and 9.0. High pH is limiting to some plants, especially Ericales, while acidity is limiting to most plants and fish below pH 4.5 (Train, 1979).

A9.3. Magnesium (Mg):

This element is considered as eighth among the most abundant elements in the earth's crust and along with calcium is a main contributor to water hardness. Mg is present naturally in rocks (e.g. dolomites igneous and many metamorphic rocks) and minerals and is a product of industrial process. Magnesium dissolves into water or arrives from air precipitation (Bartram and Ballance, 1996; Hem, 1978; Taras *et al.*, 1971; Chapman, 1996; Polevoy, 1996). The increase in the occurrence of this element makes water hard and may cause some health problems. Magnesium will also precipitate in soils and react with some clay minerals to produce uncultivable soils in extreme cases (e.g. certain nervous system defects) (WHO, 1984; Twort *et al.*, 1985). WHO has limited the highest desirable level of this element to 50 mgl^{-1} and the maximum permissible level to 150 mgl^{-1} (for instance Masschelein, 1992a; Schulz and Okun, 1992; Tebbutt, 1992), while the EC at 30 mgl^{-1} as a guide level and 50 mgl^{-1} as maximum (Gray, 1994; De Zuane, 1997). For industry levels are between 0.01 mgl^{-1} (boilers) and 25 mgl^{-1} (petroleum) (WMB, 2001), while for irrigation recommended level is 20 mgl^{-1} (Zajic, 1971).

A9.4. Iron (Fe):

This element is present in rocks and soils and is considered as the fourth most abundant element by weight, ranking next aluminium in abundance, in the earth's crust. In spite of its abundance in nature, iron is found in small concentrations in water bodies because its low solubility. The most important iron pollution sources are industrial wastes (e.g. steel industry), mine drainage waters, and commercial laundries. Iron dissolves into water mostly as a sulphate (for instance Bartram and Ballance, 1996; Train, 1979; Eichenberger and Chen, 1982; WHO, 1984). It causes many health problems (e.g. haemochromatosis) and gives water an undesirable colour and taste (for instance Twort *et al.*, 1985; Steel and McGhee, 1979; Gray, 1994). Iron oxides are stable in oxidising conditions, as in Qatari soil. Iron is only a problem in reducing low pH environments, where it can be mobilised. According to the WHO, the highest acceptable occurrence of this element is 0.3 mgl^{-1} and the maximum permissible level is 1.0 mgl^{-1} (for instance Chapman, 1996; WHO, 1984; Smethurst, 1988; Schulz and Okun, 1992; Tebbutt, 1992). For the EC this is reduced to 0.05 mgl^{-1} and must not exceed 0.20 mgl^{-1} under any circumstances (Gray, 1994; De Zuane, 1997). For industry levels is 0.5 mgl^{-1} (Zajic, 1971), while for irrigation maximum level is 5.0 mgl^{-1} (FAO, 1981; WMB, 2001).

A9.5. Conductivity:

Conductivity is a measure of the concentration of soluble salts and ion measured by the ability of water to conduct an electric current (for instance Judy and Wilkinson, 1980; Bartram and Ballance, 1996; Hem, 1982). Salts reach water through many routes including their dissolution from rocks and soil and leaching to surface or groundwater. Seawater may mix with groundwater near coastal areas. Wind is a carrier of salts from surface water such as seas, and rain and could cause precipitation of salts around coastal areas. Moreover, evaporation increases the concentration of salts in soil, especially during irrigation (for instance Walton, 1969; Train, 1979; Abu Samur and Khatib, 1999). Table A9.1 shows the levels of salts permitted for all types of water consumption. For instance the level permitted for drinking water is between 500 and 750 micro-siemen/centimetre (μS/cm) while a few plants can bear a level of 8,000 μS/cm (Judy and Wilkinson, 1980).

Table A9.1. Recommended Levels of Salt for Various Uses (Judy and Wilkinson[1], 1980; Train[2], 1979).

Water Uses	Dissolved Solutes Concentration (μS/cm)
Pure Water[2]	50-1500
Brackish Water	1,500-25,000
Seawater	25,000-50,000
Brine	>50,000
Drinking Water[1]	500-750
Drinking Water (Maximum)	3,000
Animals[2]	
Excellent	<1,000
Very satisfactory	1,000-2,999
Satisfactory	3,000-4,999
Can be used with reasonable safely	5,000-6,999
Unfit for poultry and probably for swine	7,000-10,000
Risks	>10,000
Industry[2]	
Textile	150
Pulp and Paper	1,080
Chemicals	2,500
Petroleum	3,500
Primary Metals	1,500
Copper Mining	2,100
Boiler Make-up	35,000
Agriculture[1]	
No Problems	<750
Limited Production (Sensitive Crops)	750-1,500
Limited Production (Many Crops)	1,500-3,500
Salt Tolerant Crops Only	3,500-6,500
Limited Production (Salt Tolerant Crops)	6,500-8,000

According to the WHO, water conductivity for human water consumption should be around 500 μS/cm and no more than 1,500 μS/cm (Schulz and Okun, 1992; Tebbutt, 1992), while EC levels are 400 μS/cm (Gray, 1994; De Zuane, 1997).

A9.6. Sodium (Na):

This element is widespread and considered as the sixth most abundant element on earth. Sodium represents about 26 gkg^{-1} of the earth's crust and is concentrated in high levels in seawater and in brackish groundwater. It is less concentrated in freshwater (Hem, 1978; Taras *et al.*, 1971; WHO, 1984). It is mixed with freshwater through its dissolution in rocks and soil and the mixing of seawater with freshwater. The most important sources of sodium pollution are seawater, industry (e.g. paper, glass, soap and chemical), treatment of water and de-icing roads (for instance Bartram and Ballance, 1996; Chapman, 1996; Dean and Lund, 1981). High sodium concentration causes many health problems (e.g. increased incidence of high blood pressure and some cardiac failures). It may give the water an undesirable taste and makes it unsuitable for consumption. Moreover, the concentration of sodium in soil through irrigation reduces the fertility of land (for instance Cowan and Johnson, 1985; Goodman, 1980; WHO, 1984; Taras *et al.*, 1971). The WHO limited the desirable concentration of sodium in drinking water at 75 mgl^{-1} and should not exceed 200 mgl^{-1} (for instance WHO, 1984; Masschelein, 1992a; Chapman, 1996; Schulz and Okun, 1992). At the EC the desirable level should not exceed 20 mgl^{-1} with a maximum level of 150 mgl^{-1} (Gray, 1994; De Zuane, 1997). For industry maximum level is 50 mgl^{-1} while for irrigation maximum recommended level is 10 mgl^{-1} (Zajic, 1971).

A9.7. Calcium (Ca):

This element is considered the fifth most abundant element in the earth crust. Ca is widely found in common minerals and rocks (e.g. limestone, gypsum) and in soil. Through dissolution it reaches water. The concentration level of calcium differs according to the type of rocks. It is found in quantities not exceeding 10 mgl^{-1} in granite or siliceous sand and reaches 30-100 mgl^{-1} in limestone. Waters associated with gypsiferous shale may reach several hundred mgl^{-1} (Taras *et al.*, 1971; Chapman, 1996; Hem, 1978; Twort *et al.*, 1985). Some of the effects of calcium include some health problems such as various type of cancer, anencephaly, certain nervous system defects and prenatal mortality. It tends to precipitate as carbonate or sulphate in harmful scales when water is boiled and may precipitate in pipe networks and block them. Its use is recommended in the water distribution network because it prevents corrosion. Moreover, it makes the water palatable (Bartram and Ballance, 1996; WHO, 1984; Taras *et al.*, 1971). The highest desirable level for drinking water according to the WHO is 50 mgl^{-1} and it must not exceed 200 mgl^{-1} (Schulz and Okun, 1992; Tebbutt, 1992; Smethurst, 1988), while for the EC the desirable level is set at 100 mgl^{-1} (Gray, 1994; De Zuane, 1997). For irrigation maximum recommended level is 40 mgl^{-1} (Zajic, 1971), while for industry levels are between 0.01 mgl^{-1} (boilers) and 420 mgl^{-1} (cooling) (WMB, 2001).

A9.8. Potassium (K):

This element is the seventh most abundant element and is found in all sedimentary and igneous rocks. Potassium is also found in salty and brackish water. Its level might reach 400 mgl^{-1} in saline brine while in freshwater it does not exceed 20 mgl^{-1} (Bartram and Ballance, 1996; Hem, 1978; Taras *et al.*, 1971). Potassium might reach water through solution, especially from the soil due to fertilisers. Other most important sources of potassium are industrial wastes, sewage effluents and concentrated farmyard manures. The high concentration of potassium might give rise to some physical upsets and is a nutrient for algae and plants higher in water (Twort *et al.*, 1985; Chapman, 1996; Goodman, 1980). According to the WHO the acceptable level of the presence of this element for drinking water is 12 mgl^{-1} (Masschelein, 1992a), while for the EC the desirable level is set at 10 mgl^{-1} and maximum is 12 mgl^{-1} (Gray, 1994; De Zuane, 1997). On the other hand, there are no values given for industry and agriculture.

A9.9. Nitrate (NO_3):

This element is widely found in rocks, soils, water, plant and animal debris and is considered the most highly oxidized phase in the nitrogen cycle. The fertilisers that have been used in agriculture on a wide scale in recent years in order to increase the quality of land and its fertility are largely responsible for the presence of this element. Other sources of nitrate are natural deposits, animal waste, domestic and industrial wastewaters which leach into water bodies (Porteous *et al.*, 1993; Chapman, 1996;

Hem, 1978; Gray, 1994; WHO, 1984; Train, 1979). Nitrate is present in many types of vegetables, and milk but has no known adverse health consequence. When it becomes, however, nitrite it has adverse health effects especially causing methaemoglobinaemia (blue baby syndrome). Haemoglobin unites with nitrite in the red blood cells and forms methaemoglobin, which causes problems in the uptake of oxygen, and hence reduces the percentage of oxygen in the lungs (for instance Steel and McGhee, 1979; Mason, 1981; Dean and Lund, 1981; Cowan and Johnson, 1985). The acceptable level of nitrate according to the WHO is 45 mgl^{-1} (Chapman, 1996; Schulz and Okun, 1992; Tebbutt, 1992), while the EC has set the desirable limit at 25 mgl^{-1} and the maximum at 50 mgl^{-1} (Gray, 1994; De Zuane, 1997). On the other hand, there are no values given for industry and agriculture.

A9.10. Chloride (Cl):

This element is present in all water sources and is widely spread in the form of salts; NaCl, KCl and $CACl^2$. Hence, it is concentrated in seas and oceans. In the lithosphere, it constitutes around 0.05% of total volume. The average human body (70 kg) carries around 81.7g of chloride. The ways in which it reaches water are varied; most important among them is industrial waste, oil fields, sewage water and irrigation water as well as from the mixing of groundwater with seawater. Chloride is used during water treatment to kill bacteria in water (WHO, 1984; Bartram and Ballance, 1996; Chapman, 1996; Twort *et al.*, 1985). The increase of the presence of this element in water may cause some health problems such as delicate kidney tissue damaged at an early age. Moreover, high concentration of Cl gives water an undesirable taste. Consequently it becomes unsuitable for consumption and also has effects on metallic pipes and agricultural plants (Linsley and Franzini, 1972; Goodman, 1980; Twort *et al.*, 1985; Bartram and Ballance, 1996). According to the WHO the highest desirable level of this element is 200 mgl^{-1} and it must not exceed 600 mgl^{-1} (for instance Smethurst, 1988; Chapman, 1996), while the desirable level in the EC is 25 mgl^{-1} (Gray, 1994; De Zuane, 1997). For industry levels are between 20-250 mgl^{-1} and for irrigation recommended level is 100 mgl^{-1} (Zajic, 1971).

A9.11. Sulphate (SO_4):

Sulphate is widely present in igneous and sedimentary rocks and leaches into water through oxidation of sulphides to sulphates. Its concentration varies from a few milligrams to thousands per litre of water. In addition to natural routes described above, domestic sewage and treated water used in industry and agriculture and its waste contributes to this process (Chapman, 1996; Hem 1978; Bartram and Ballance, 1996; Twort *et al.*, 1985). A link exists between the concentration of sulphate in water and many health problems such as catharsis, dehydration, and gastrointestinal irritation. Moreover, it causes corrosion of metals in water distribution systems. With high calcium levels, high sulphate levels may lead to problems caused by the precipitation of gypsum in agricultural soils (WHO, 1984; Goodman, 1980). According to the WHO the acceptable level for the presence of this element in drinking water is 200 mgl^{-1}, and it should not exceed 400 mgl^{-1} (Schulz and Okun, 1992; Bartram and Ballance, 1996; Chapman, 1996). In contrast, the EC sets the desirable level at 25 mgl^{-1} and the maximum level at 250 mgl^{-1} (Gray, 1994). For industry levels are between 100-250 mgl^{-1} while for irrigation recommended level is 190 mgl^{-1} (Zajic, 1971).

A9.12. Phosphate (PO_4):

Phosphate is found in common rocks and minerals, both in igneous rock and marine sediments. It is also found in soil, especially where fertilisers have been used. The most important sources of phosphate pollution are fertiliser as well as wastewater, especially from the industrial sector and storm run-off (Mason, 1981; Porteous *et al.*, 1993; Train, 1979; Hem, 1978). Under normal circumstances, the concentration of phosphate in freshwater does not exceed 0.1 mgl^{-1}. High concentrations of PO_4 stimulate algae productivity and the spread of fungi in water (eutrophication). This leads to problems such as anoxia and the mobilisation of heavy metals in the water (Goodman, 1980; Steel and McGhee, 1979; Train, 1979). The acceptable level of this element for drinking in the EC is 2.0 mgl^{-1} (Train, 1979; Tebbutt, 1992; Goodman, 1980). On the other hand, there are no values given for industry and agriculture.

APPENDIX TEN:

WATER QUALITY TESTS AND DATA

Appendix Ten:

Water Quality Test

A10.1. pH Test:

Table A10.1. pH Test Process.

Instrument	Jenway 3010 pH Meter
Temperature	18° C
Buffer	At 7 every 10 samples
Slope	At 4 every 10 samples
Time	5 minutes
Unit	pH Unit

Table A10.2. pH Tests Result (Drinking water indicated in bold).

No.	Value	No.	Value	No.	Value	No.	Value	No.	Value	No.	Value
1	**7.9**	10	**8.22**	19	7.90	28	8.20	37	8.32	46	8.10
2	8.0	11	**7.61**	20	**8.06**	29	8.10	38	8.25	47	**7.81**
3	**8.0**	12	7.40	21	8.01	30	8.26	39	8.0	48	6.46
4	8.2	13	**7.41**	22	8.06	31	8.30	40	7.80	49	**7.81**
5	**8.1**	14	7.50	23	**8.10**	32	**7.73**	41	7.91	50	7.71
6	**8.3**	15	7.64	24	8.05	33	**8.21**	42	**8.24**	51	7.98
7	7.9	16	7.53	25	8.0	34	8.40	43	**8.10**	52	**8.10**
8	**8.03**	17	7.29	26	8.05	35	8.26	44	7.61	53	**8.05**
9	**8.18**	18	8.12	27	**7.89**	36	8.25	45	7.74		

A10.2. Conductivity:

Table A10.3. Conductivity Test Process.

Instrument	Jenway 4010 Conductivity Meter
Temperature	18° C
Time	2 minutes
Unit	Micro-siemen/centimetre (μS/cm)

Table A10.4. Conductivity Tests Result (μS/cm) (Drinking water indicated in bold).

No.	Value	No.	Value	No.	Value	No.	Value	No.	Value	No.	Value
1	**728**	10	**326**	19	3,090	28	4,650	37	8,630	46	4,150
2	1,190	11	**307**	20	**397**	29	2,790	38	4,730	47	**575**
3	**3,700**	12	5,510	21	4,140	30	5,370	39	3,090	48	04.9
4	4,170	13	**345**	22	3,870	31	12,720	40	3,740	49	**570**
5	**1,810**	14	9,640	23	**446**	32	**566**	41	5,090	50	7,710
6	**1,221**	15	13,700	24	6,500	33	**371**	42	**290**	51	11,300
7	608	16	9,750	25	4,030	34	5,130	43	**351**	52	**312**
8	**1,555**	17	5,160	26	6,680	35	2,540	44	21,300	53	**310**
9	**1,496**	18	5,110	27	**668**	36	5,130	45	13,270		

A10.3. Chloride (Cl), Sulphate (SO_4), Nitrate (NO_3) and Phosphate (PO_4):

Table A10.5. Cl, SO_4, NO_3 and PO_4 Test Process.

Method	High Performance Ion Chromatography
Instrument	Dionex System 2010i
Column (Separator)	Star-Ion A3000 Anion Peek P/N OOD-4090-EO-BV
Detection System	Conductivity
Eluent	$NaHCO_3$ (sodium hydro carbonate) = 0.2856g Na_2Co_3 (sodium carbonate) = 0.3816g In 2 litres of distilled water
Standards	100ppm of NO_3 = 0.1371g of Sodium Nitrate ($NaNO_3$) SO_4 = 0.3356g of Sodium Sulphate (Na_2SO_4) CI = 0.1648g of Sodium Chloride (NaCI) PO_4 = 0.1495 of di Sodium Hydrogen (Na_2HPO_4) In a litre of water
Unit	PPM (mg/l)

Table A10.6. Cl, SO_4, NO_3 and PO_4 Standards Results (1ppm).

Peak#	Area %	RT	Area	BC
1	46.255	2.21	465,451 (CI)	01
2	10.657	4.23	107,235 (NO)	01
3	43.088	9.64	433,580 (SO)	01

Table A10.7. Cl, SO_4, NO_3 and PO_4 Standards Results (5ppm).

Peak#	Area %	RT	Area	BC
1	31.586	2.23	1,905,657 (CI)	01
2	12.781	4.21	771,109 (NO)	01
3	6.115	7.94	368,934 (PO)	02
4	49.518	9.61	2,987,484 (SO)	03

Table A10.8. Cl, SO_4, NO_3 and PO_4 Standards Results (10ppm).

Peak#	Area %	RT	Area	BC
1	31.19	2.24	3,816,289 (CI)	01
2	15.035	4.21	1,839,656 (NO)	02
3	5.151	7.89	630,301 (PO)	02
4	48.407	9.62	5,922,936 (SO)	03

Table A10.9. Chloride Tests Result (mg/l) (Drinking water indicated in bold).

No.	Value	No.	Value	No.	Value	No.	Value	No.	Value	No.	Value
1	**115.0**	10	**70.0**	19	670.0	28	940.0	37	2,700.0	46	800.0
2	160.0	11	**50.0**	20	**125.0**	29	530.0	38	780.0	47	**152.5**
3	**1,800.0**	12	1,000.0	21	900.0	30	1,400.0	39	300.0	48	0.2
4	2,500.0	13	**75.0**	22	4,300.0	31	5,000.0	40	450.0	49	**165.0**
5	**270.0**	14	2,800.0	23	**120.0**	32	**230.0**	41	1,220.0	50	2,500.0
6	**250.0**	15	2,800.0	24	4,000.0	33	**105.0**	42	**60.0**	51	5,200.0
7	160.0	16	12,000.0	25	790.0	34	1,600.0	43	**82.5**	52	**65.0**
8	**330.0**	17	2,400.0	26	1,340.0	35	790.0	44	10,600.0	53	**70.0**
9	**320.0**	18	5,400.0	27	**135.0**	36	8,300.0	45	4,200.0		

Table A10.10. Phosphate Tests Result (mg/l) (Drinking water indicated in bold).

No.	Value	No.	Value	No.	Value	No.	Value	No.	Value	No.	Value
1	**0.0**	10	**0.0**	19	0.0	28	0.0	37	0.0	46	0.0
2	0.0	11	**0.0**	20	**0.0**	29	0.0	38	0.0	47	**0.0**
3	**0.0**	12	0.0	21	0.0	30	0.0	39	0.0	48	0.0
4	0.0	13	**0.0**	22	0.0	31	0.0	40	0.0	49	**0.0**
5	**0.0**	14	0.0	23	**0.0**	32	**0.0**	41	0.0	50	0.0
6	**0.0**	15	0.0	24	0.0	33	**0.0**	42	**0.0**	51	0.0
7	0.0	16	0.0	25	0.0	34	0.0	43	**0.0**	52	**0.0**
8	**0.0**	17	0.0	26	0.0	35	0.0	44	0.0	53	**0.0**
9	**0.0**	18	0.0	27	**0.0**	36	0.0	45	0.0		

Table A10.11. Nitrate Tests Result (mg/l) (Drinking water indicated in bold).

No.	Value	No.	Value	No.	Value	No.	Value	No.	Value	No.	Value
1	**2.7**	10	**0.0**	19	40.0	28	50.0	37	23.2	46	5.3
2	16.0	11	**0.0**	20	**0.0**	29	23.6	38	11.4	47	**0.0**
3	**0.6**	12	4.8	21	4.0	30	23.6	39	5.5	48	0.0
4	57.6	13	**0.0**	22	22.8	31	23.6	40	7.9	49	**0.0**
5	**50.0**	14	9.1	23	**0.0**	32	**0.5**	41	720.0	50	16.0
6	**5.7**	15	70.0	24	5.7	33	**0.0**	42	**0.0**	51	5.5
7	11.6	16	100.0	25	5.7	34	0.0	43	**0.0**	52	**0.0**
8	**5.7**	17	1,000.0	26	30.0	35	5.9	44	0.0	53	**0.0**
9	**5.8**	18	33.6	27	**0.0**	36	10.8	45	34.8		

Table A10.12. Sulphate Tests Result (mg/l) (Drinking water indicated in bold).

No.	Value	No.	Value	No.	Value	No.	Value	No.	Value	No.	Value
1	**40.0**	10	**0.7**	19	80.0	28	740.0	37	1,000.0	46	1,340.0
2	100.0	11	**1.8**	20	**8.3**	29	270.0	38	540.0	47	**6.1**
3	**800.0**	12	700.0	21	800.0	30	520.0	39	330.0	48	0.0
4	1,000.0	13	**5.2**	22	7,000.0	31	600.0	40	710.0	49	**6.9**
5	**100.0**	14	5,100.0	23	**50.0**	32	**30.0**	41	800.0	50	620.0
6	**600.0**	15	600.0	24	800.0	33	**2.8**	42	**3.1**	51	9,800.0
7	60.0	16	2,000.0	25	400.0	34	560.0	43	**5.0**	52	**3.6**
8	**100.0**	17	1,000.0	26	780.0	35	520.0	44	5,200.0	53	**2.6**
9	**100.0**	18	2,000.0	27	**50.0**	36	800.0	45	1,300.0		

A10.4. Sodium (Na):

Table A10.13. Sodium Test Process.

Instrument	AAnalyst 100 Atomic Absorption Spectrometer
Wavelength	330.3 nm
Signal	AA
Integration Time	5.0 seconds
Calibration Type	Non-linear
Expansion	1.00
Print Calib	Yes (Medium)
Read Delay	5 Seconds
Firmware Ver	1.10
Slit	0.7 H
Lamp Current	7 mA
Replicates	3
Technique	Flame (Hold)
Energy	34
Print Peaks	No (Small)
Standards	1: 25.0 2: 50.0 3: 100.0
Unit	PPM (mg/l)

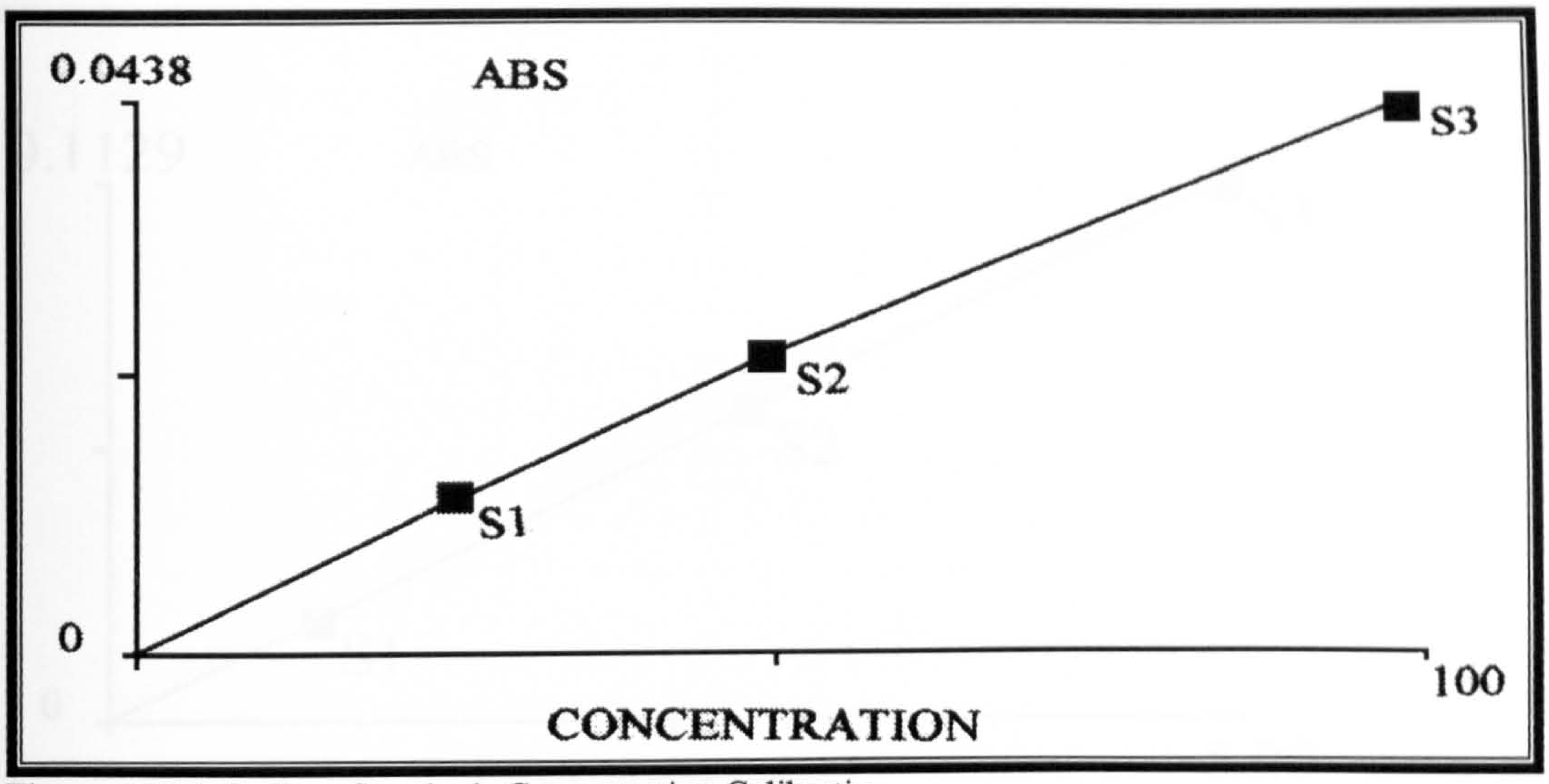


Figure A10.1. Sodium Standards Concentration Calibration.

Table A10.14. Sodium Tests Result (mg/l) (Drinking water indicated in bold).

No.	Value	No.	Value	No.	Value	No.	Value	No.	Value	No.	Value
1	**172.0**	10	**170.0**	19	692.5	28	847.5	37	1,315.0	46	662.5
2	225.0	11	**105.0**	20	**232.5**	29	500.0	38	662.5	47	**330.0**
3	**522.5**	12	767.5	21	685.0	30	1,022.5	39	525.0	48	252.5
4	610.0	13	**232.5**	22	577.5	31	2,265.0	40	635.0	49	**435.0**
5	**302.5**	14	1,935.0	23	**292.5**	32	**472.5**	41	652.5	50	1,250.0
6	**177.5**	15	2,415.0	24	1,237.5	33	**370.0**	42	**440.0**	51	1,905.0
7	212.5	16	1,687.5	25	732.5	34	932.5	43	**285.0**	52	**322.5**
8	**287.5**	17	1,055.0	26	1,147.5	35	555.0	44	2,140.0	53	**352.5**
9	**295.0**	18	817.5	27	**290.0**	36	721.5	45	2,515.0		

A10.5. Calcium (Ca):

Table A10.15. Calcium Test Process.

Instrument	AAnalyst 100 Atomic Absorption Spectrometer
Wavelength	422.7 nm
Signal	AA
Integration Time	5.0 seconds
Calibration Type	Non-linear
Expansion	1.00
Print Calib	Yes (Medium)
Read Delay	5 Seconds
Firmware Ver	1.10
Slit	2.0 H
Lamp Current	7 mA
Replicates	3
Technique	Flame (Hold)
Energy	63
Print Peaks	No (Small)
Standards	1: 1.00 2: 3.00 3: 5.00
Unit	PPM (mg/l)

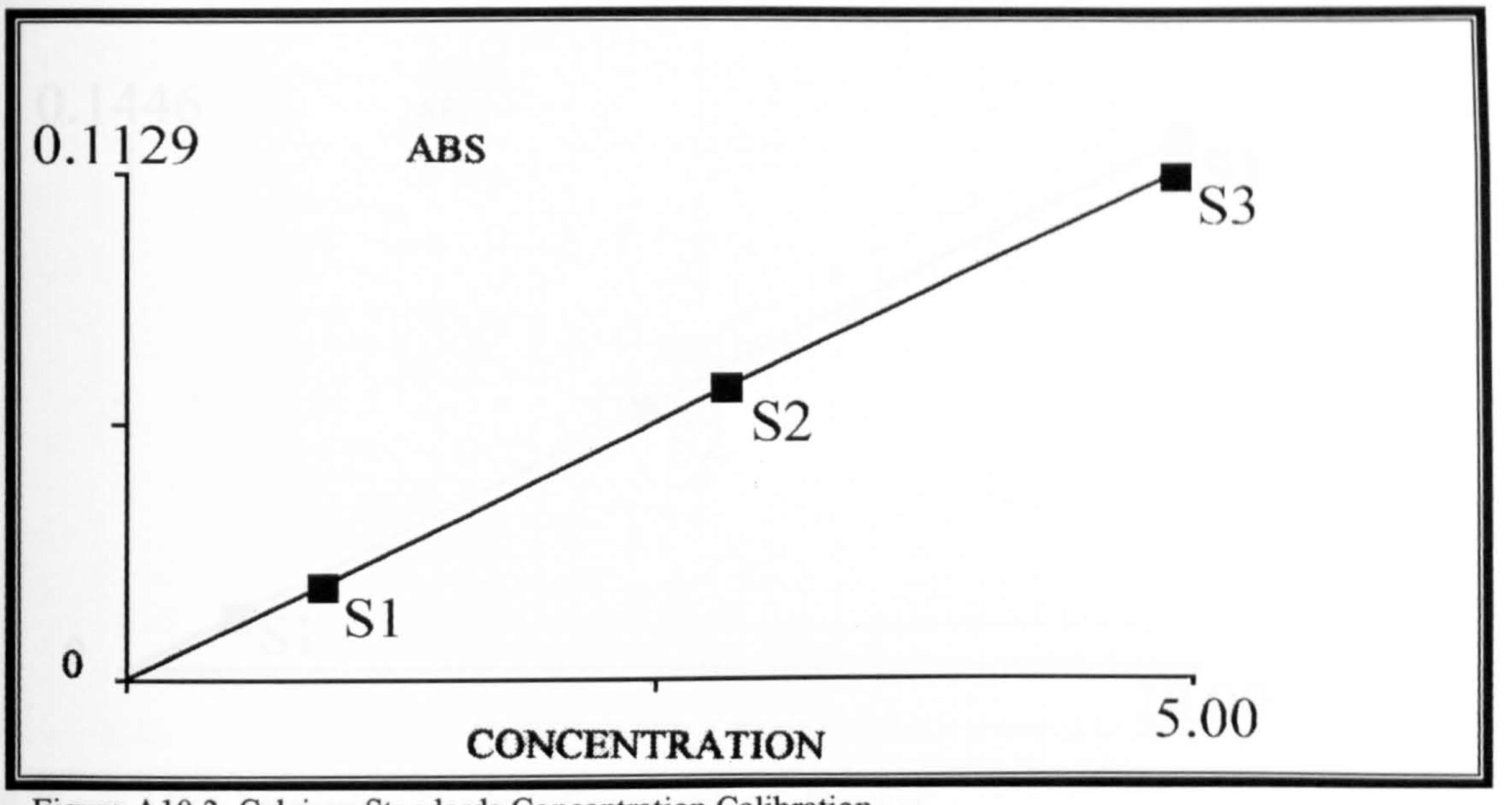


Figure A10.2. Calcium Standards Concentration Calibration.

Table A10.16. Calcium Tests Result (mg/l) (Drinking water indicated in bold).

No.	Value	No.	Value	No.	Value	No.	Value	No.	Value	No.	Value
1	**67.5**	10	**37.5**	19	200.0	28	247.5	37	470.0	46	465.0
2	85.0	11	**42.5**	20	**92.5**	29	227.5	38	447.5	47	**167.5**
3	**157.5**	12	337.5	21	322.5	30	280.0	39	332.5	48	142.5
4	190.0	13	**57.5**	22	365.0	31	445.0	40	402.5	49	**145.0**
5	**115.0**	14	310.0	23	**102.5**	32	**120.0**	41	490.0	50	455.0
6	**77.5**	15	432.5	24	252.5	33	**120.0**	42	**142.5**	51	492.5
7	70.0	16	285.0	25	232.5	34	260.0	43	**152.5**	52	**152.5**
8	**82.5**	17	272.5	26	360.0	35	235.0	44	650.0	53	**147.5**
9	**87.5**	18	315.0	27	**117.5**	36	442.5	45	472.5		

A10.6. Magnesium (Mg):

Table A10.17. Magnesium Test Process.

Instrument	AAnalyst 100 Atomic Absorption Spectrometer
Wavelength	202.6 nm
Signal	AA
Integration Time	5.0 seconds
Calibration Type	Non-linear
Expansion	1.00
Print Calib	Yes (Medium)
Read Delay	5 Seconds
Firmware Ver	1.10
Slit	2.0 H
Lamp Current	7 mA
Replicates	3
Technique	Flame (Hold)
Energy	52
Print Peaks	No (Small)
Standards	1: 1.00 2: 5.00 3: 10.00
Unit	PPM (mg/l)

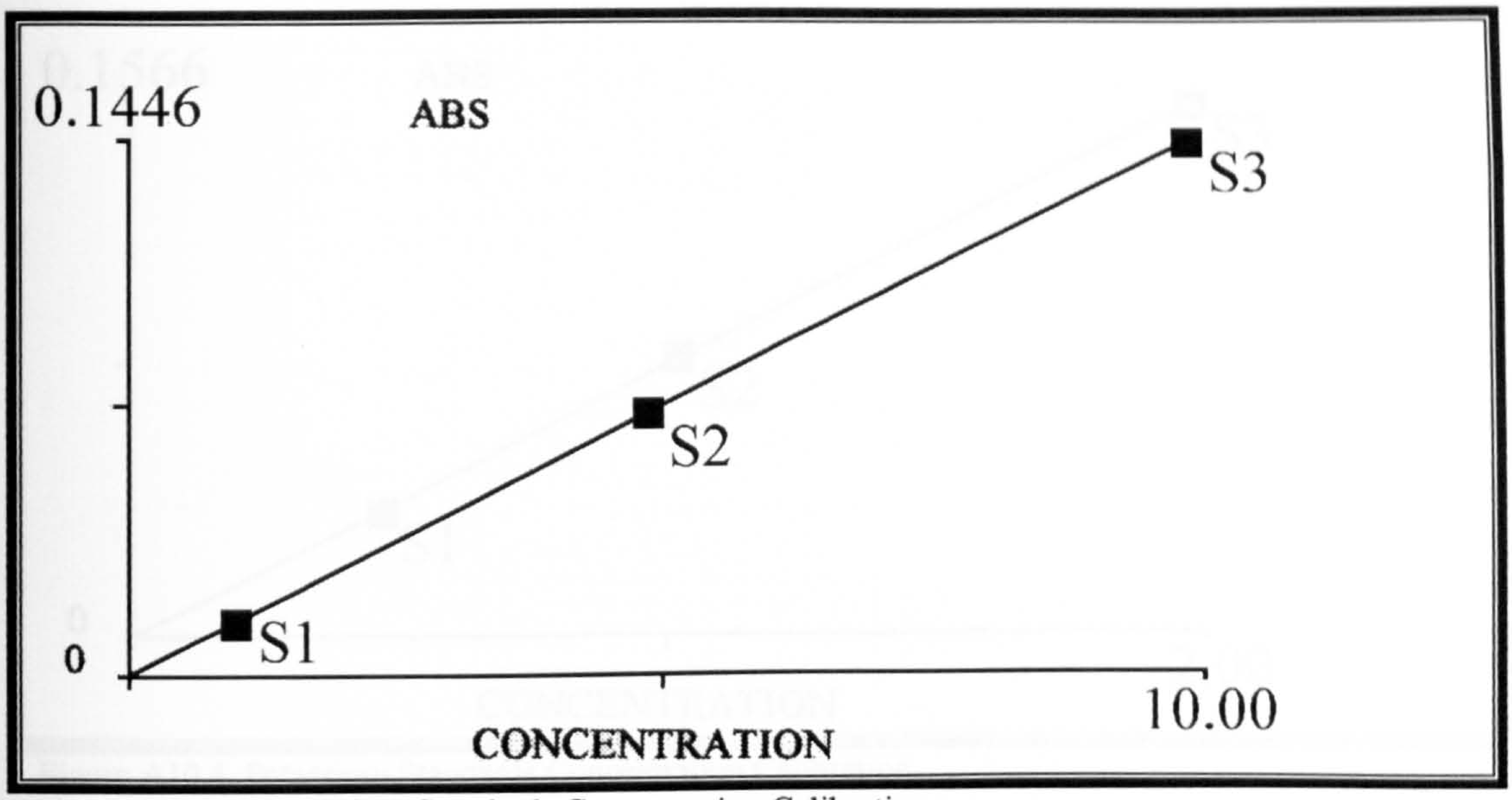


Figure A10.3. Magnesium Standards Concentration Calibration.

Table A10.18. Magnesium Tests Result (mg/l) (Drinking water indicated in bold).

No.	Value	No.	Value	No.	Value	No.	Value	No.	Value	No.	Value
1	**29.4**	10	**14.0**	19	72.5	28	119.5	37	322.0	46	168.25
2	50.7	11	**11.9**	20	**13.9**	29	98.5	38	239.0	47	**41.74**
3	**92.4**	12	179.5	21	178.5	30	112.0	39	140.0	48	22.75
4	163.0	13	**13.8**	22	166.5	31	322.0	40	187.75	49	**30.5**
5	**62.7**	14	178.0	23	**28.25**	32	**30.25**	41	205.0	50	225.75
6	**44.5**	15	279.5	24	123.5	33	**25.25**	42	**32.5**	51	304.5
7	44.7	16	170.0	25	103.25	34	114.5	43	**30.5**	52	**32.75**
8	**51.8**	17	108.1	26	164.0	35	93.5	44	489.0	53	**24.75**
9	**51.8**	18	170.0	27	**31.25**	36	207.0	45	332.5		

A10.7. Potassium (K):

Table A10.19. Potassium Test Process.

Instrument	AAnalyst 100 Atomic Absorption Spectrometer
Wavelength	766.5 nm
Signal	AA
Integration Time	5.0 seconds
Calibration Type	Non-linear
Expansion	1.00
Print Calib	Yes (Medium)
Read Delay	5 Seconds
Firmware Ver	1.10
Slit	0.7 H
Lamp Current	8 mA
Replicates	3
Technique	Flame (Hold)
Energy	52
Print Peaks	No (Small)
Standards	1: 0.50 2: 1.00 3: 2.00
Unit	PPM (mg/l)

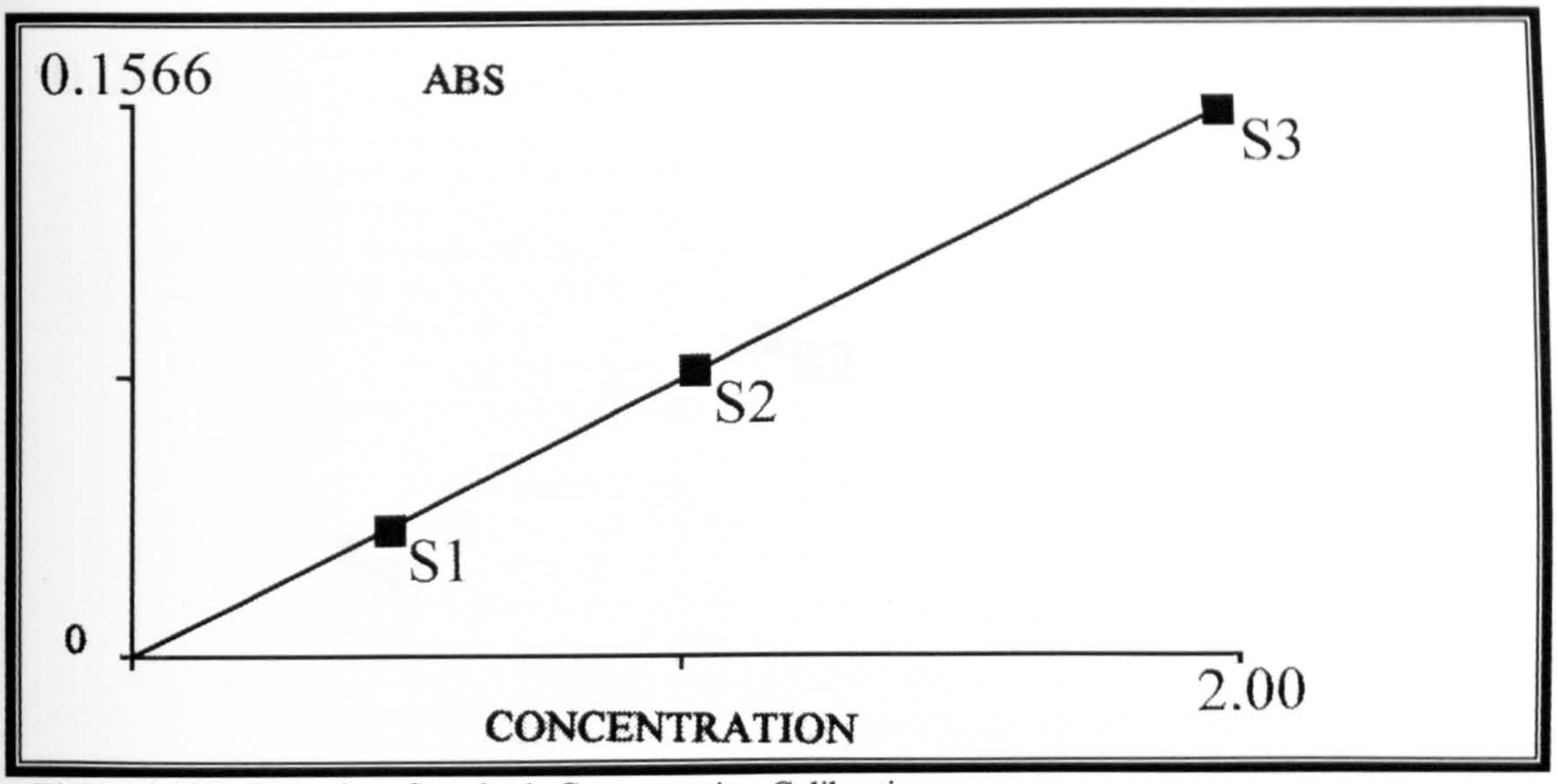


Figure A10.4. Potassium Standards Concentration Calibration.

Table A10.20. Potassium Tests Result (mg/l) (Drinking water indicated in bold).

No.	Value	No.	Value	No.	Value	No.	Value	No.	Value	No.	Value
1	**10.5**	10	**2.75**	19	34.0	28	73.0	37	60.0	46	42.0
2	23.5	11	**2.0**	20	**3.0**	29	49.0	38	50.0	47	**40.5**
3	**62.0**	12	80.5	21	53.25	30	51.75	39	41.75	48	5.25
4	48.25	13	**7.0**	22	40.25	31	153.0	40	65.0	49	**1.0**
5	**29.0**	14	106.0	23	**4.0**	32	**8.25**	41	56.5	50	108.5
6	**38.0**	15	132.0	24	91.0	33	**1.75**	42	**5.5**	51	116.0
7	23.75	16	120.0	25	77.0	34	70.5	43	**3.5**	52	**4.0**
8	**28.0**	17	58.0	26	98.0	35	64.0	44	186.0	53	**1.0**
9	**27.25**	18	73.0	27	**25.5**	36	59.0	45	121.0		

A10.8. Iron (Fe):

Table A10.21. Iron Test Process.

Instrument	AAnalyst 100 Atomic Absorption Spectrometer
Wavelength	248.3 nm
Signal	AA
Integration Time	5.0 seconds
Calibration Type	Non-linear
Expansion	1.00
Print Calib	Yes (Medium)
Read Delay	5 Seconds
Firmware Ver	1.10
Slit	2.0 H
Lamp Current	10 mA
Replicates	3
Technique	Flame (Hold)
Energy	70
Print Peaks	No (Small)
Standards	1: 1.00 2: 3.00 3: 5.00
Unit	PPM (mg/l)

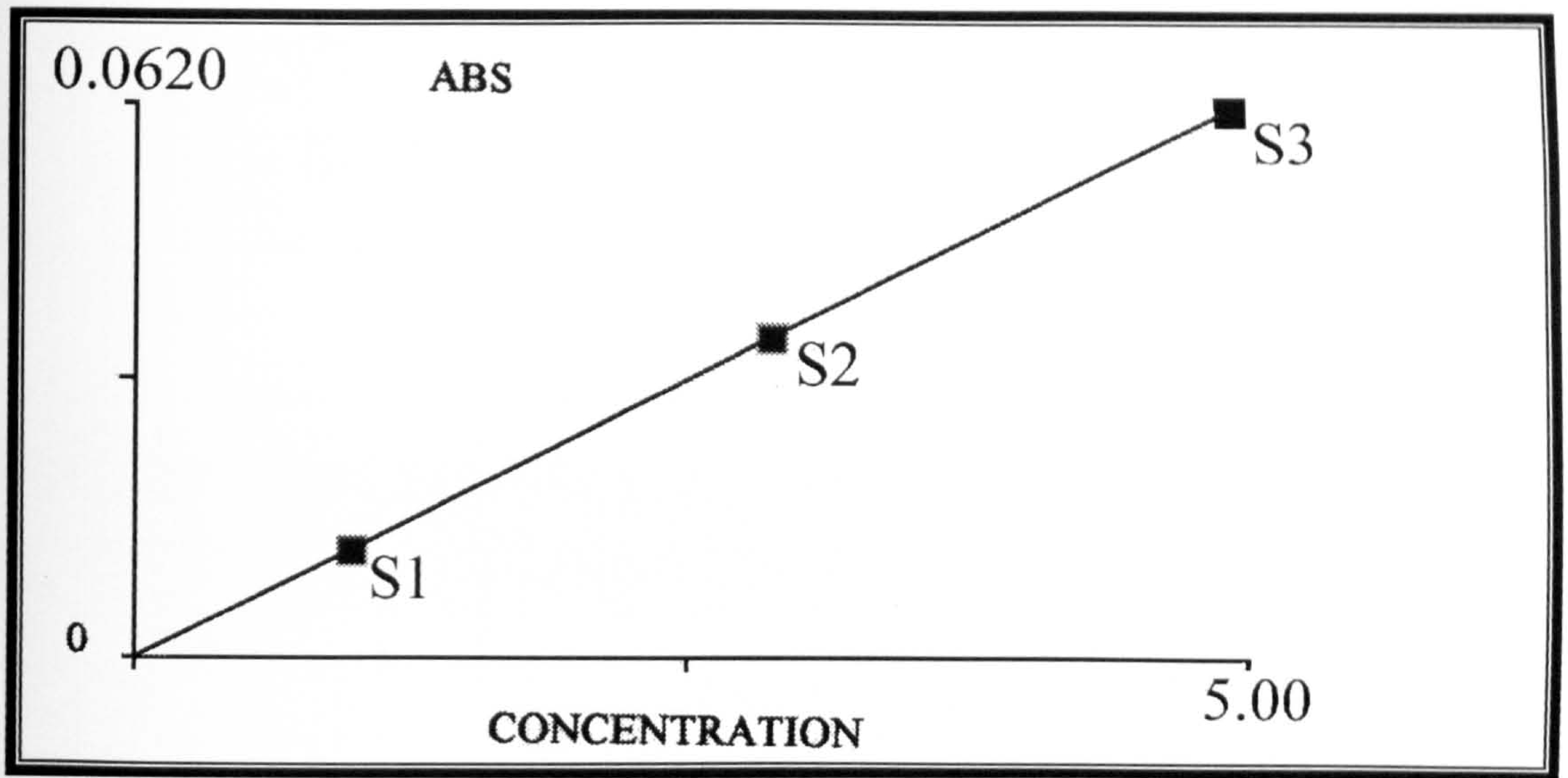


Figure A10.5. Iron Standards Concentration Calibration.

Table A10.22. Iron Tests Result (mg/l) (Drinking water indicated in bold).

No.	Value	No.	Value	No.	Value	No.	Value	No.	Value	No.	Value
1	**0.40**	10	**0.63**	19	0.71	28	0.80	37	0.89	46	0.85
2	0.46	11	**0.62**	20	**0.72**	29	0.78	38	0.84	47	**0.87**
3	**0.49**	12	0.70	21	0.76	30	0.83	39	0.84	48	0.84
4	0.52	13	**0.67**	22	0.76	31	0.87	40	0.83	49	**0.86**
5	**0.53**	14	0.75	23	**0.70**	32	**0.80**	41	0.84	50	0.94
6	**0.53**	15	0.74	24	0.77	33	**0.79**	42	**0.84**	51	0.98
7	0.56	16	0.67	25	0.79	34	0.81	43	**0.86**	52	**0.91**
8	**0.59**	17	0.71	26	0.77	35	0.81	44	0.97	53	**0.90**
9	**0.60**	18	0.71	27	**0.75**	36	0.85	45	0.89		

APPENDIX ELEVEN:

BOTTLED DRINKING WATER MARKET IN QATAR

Appendix Eleven:

Bottled Drinking Water Market in Qatar

Table A11.1.Chemical Constituents of Some Major Bottled Drinking Water in Qatari Market (Survey, 2000).

Country & Trade Name	pH	T.D.S.	HCO_3	SO_4	Cl	NO_3	Ca	Mg	K	Na	F	Fe	SiO_2
Qatar													
Al-Wajba	7.3	---	66.0	53.0	28.0	0.0	26.0	12.0	10.0	20.0	0.70	---	---
Rayyan	7.8	---	55.0	39.0	20.0	0.0	10.0	12.0	6.2	9.0	0.70	---	---
Arwa	8.2	190	76.0	22.0	58.0	0.0	20.0	9.6	1.0	26.0	0.05	---	---
Sterling	7.8	175	58.0	20.0	38.0	0.0	20.0	9.5	1.0	14.0	0.05	---	---
UAE													
Dibba	8.1	0.21	85.4	38.0	51.0	3.5	4.4	30.6	2.0	20.25	---	---	---
Zulal	8.2	120	42.0	---	40.0	---	12.0	1.7	---	24.0	---	0.01	---
Al-Ain	8.0	150	75.5	16.5	22.0	0.0	9.0	18	1.30	16.5	0.7	0.0	---
Al-Shallal	8.2	175	58.0	20.0	38.0	3.5	4.5	18.0	1.0	14.0	0.02	---	---
Masafi	8.2	175	58.0	20.0	38.0	3.5	4.5	18.0	1.0	14.0	0.02	---	---
Kadra	7.2	155	56.0	45.0	44.0	---	9.0	20.0	1.0	24.0	---	---	7.0
Mumtaz	8.1	---	85.4	38.0	51.0	3.5	4.4	30.6	2.0	20.25	---	---	---
Al-Rawabi	8.2	175	58.0	20.0	38.0	3.5	4.5	18.0	1.0	14.0	0.02	---	---
Gulfa	7.7	120	21.0	13.0	52.0	1.7	4.8	6.7	1.1	14.0	0.5	---	---
KSA													
Taiba	7.2	105	24.0	7.0	27.0	2.2	1.6	1.5	1.0	30.0	0.8	0.01	---
Honey	7.3	165	44.0	27.0	29.0	3.52	8.8	3.4	1.6	30.8	0.65	---	---
Hilwa	7.4	210	120.0	47.4	32.0	0.0	28.5	11.9	13.4	23.7	0.8	0.0	---
Safa	7.2	150	57.0	27.0	30.0	3.0	20.0	5.0	3.0	20.0	0.7	0.0	---
Al-Qassim	7.0	110	20.0	35.0	10.0	2.0	10.0	4.0	0.3	10.0	0.7	0.02	---
Nissah	7.3	200	90.0	50.0	25.0	12.0	40.0	9.0	2.0	20.0	0.7	---	---
Al-Rawiah	7.2	125	40.0	6.0	40.0	4.0	2.5	1.0	2.0	38.0	0.75	---	---
Hana	7.4	130	36.0	42.0	29.0	6.5	12.0	2.1	0.6	34.0	0.75	---	---
Hada	7.15	109	30.5	19.0	20.5	5.0	12.6	4.5	1.1	13.0	0.7	0.0	---
Bahrain													
Tylos	7.1	92	24.0	45.0	28.0	4.4	1.0	0.24	1.5	20.0	0.73	0.01	---
Nada	7.2	144	40.0	8.0	57.0	5.0	2.4	1.5	---	55.0	0.7	0.03	1.6
Aqua	7.1	92	24.0	<5.0	26.0	4.4	1.0	0.24	1.5	26.0	0.73	0.01	---
Salsabil	7.2	140	35.0	10.0	52.9	2.4	5.2	2.2	2.0	33	0.6	0.01	---
Oman													
Tanuf	7.8	480	21.0	4.2	3.0	0.8	5.2	2.0	0.16	2.1	---	---	---
El-J. El-Akhdar	7.0	470	2.2	0.44	0.28	0.05	0.5	0.21	0.02	0.19	---	---	---
Iran													
Sepidan	7.9	290	171.0	6.0	8.0	6.0	55.0	4.0	0.4	2.0	0.5	0.04	---
France													
Evian	---	---	357	10.0	4.5	3.8	78.0	24.0	1.0	5.0	---	---	---
Volvic	7.0	109	65.3	6.9	8.4	6.3	9.9	6.1	5.7	9.4	---	---	30.0

(--- No value given).

Table A11.2. Chemical, Symbol and Unit of Measurement (Gray, 1996).

Chemical	Symbol	Unit of Measurement
pH	pH	pH unit
Total Dissolved Solids	T.D.S.	Mgl^{-1}
Bicarbonate	HCO_3	mgl^{-1}
Sulfate	SO^-_4	mgl^{-1}
Chloride	Cl^-	mgl^{-1}
Nitrate	NO^-_3	mgl^{-1}
Calcium	Ca^{++}	mgl^{-1}
Magnesium	Mg^{++}	mgl^{-1}
Potassium	K^+	mgl^{-1}
Sodium	Na^+	mgl^{-1}
Fluoride	F^-	mgl^{-1}
Iron	Fe^{++}	mgl^{-1}
Silica	SiO_2	mgl^{-1}

APPENDIX TWELVE:

STAKEHOLDERS INTERVIEWS

Appendix Twelve:

Stakeholders Interviews: Form and Data

A12.1. Preliminary Analysis of Interviews with Stakeholders with Water Resources Experience

Number and Field of Experience Stakeholders.

Code	No. Interviewed	Field of Experience
A	5	Water Management
B	3	Water Engineering
C	2	Geology
D	1	Chemistry
E	1	Desalination
F	1	Physical Geography
G	1	Irrigation Engineering

1- In your opinion, is there a water problem in Qatar ?.

Code	No. Respondents	%	Opinions
5A-3B-2C-1E-1F-1G	13	93	There is a real problem
1D	1	7	There is no real problem in recent days, but will be in future

2- What is the best method to stop groundwater deterioration ?.

Code	No. Respondents	%	Opinion
4A-2B-1E	7	50	More groundwater laws and regulations
1B-1F-1G	3	21.5	Depend on desalination and import water
1A-2C	3	21.5	New comprehensive water policy is needed
1D	1	7	More water wells should be recharged

3- To what extent is the dependence on desalination or importing water from abroad useful ?.

Code	No. Respondents	%	Opinions
2A-3B-1C-1G	7	50	Both
2A-1E	3	21.5	Depends on desalination
1A-1C-1F	3	21.5	That depends on political and economical circumstances
1D	1	7	Don't know

4- What is your opinion with regard to the public and official interest in the issue of water scarcity ?.

Code	No. Respondents	%	Opinions
3A-1B-2C-1D-1E-1F	9	65	Both are very weak
1A-1B	2	14	Both are interested
1G	1	7	Only cultured class is interested
1B	1	7	Official are interested not the public
1A	1	7	Don't know

5- To what extent can we expand the use and exploitation of recycled water ?.

Code	No. Respondents	%	Opinions
4A-1B-2C-1F	8	57.5	There is a considerable possibility to use it for irrigation
1A-1B-1D	3	21.5	There is an economical barrier
1E	1	7	That depends on the kind of technology
1G	1	7	It is unhealthy
1B	1	7	Don't know

6- What is your opinion with regard to the quality of the domestic water consumed ?.

Code	No. Respondents	%	Opinions
3A-1B-2C-1D	7	50	Acceptable quality
1A-2B-1F	4	29	Good quality
1A-1E	2	14	Don't know
1G	1	7	Very bad

7- What are your suggestions for the development and improvement of the current water distribution network ?.

Code	No. Respondents	%	Opinions
4A-1B-2C	7	50	It is need more development and conservation
1B-1E-1G	3	22	Establish new water network
1A-1D	2	14	Don't know
1B-1F	2	14	It's acceptable now

8- To what extent have the previous water studies and research projects been successful in creating solutions to the water problems ?.

Code	No. Respondents	%	Opinions
3A-1D-1G	5	36	There are not useful because most of these studies were done by foreign organisations
1A-1B-2C	4	28.5	There were not applicable to water administration
1A-1B-1E-1F	4	28.5	Don't know
1B	1	7	Some studies were a bit useful

9- What is the extent of the current co-operation among the Arabian Gulf countries in the field of an integrated exploitation of the joined common groundwater aquifers ?.

Code	No. Respondents	%	Opinions
4A-2B	6	43	No co-operation is available
1A-1C-1D-1F-1G	5	36	Co-operation is very weak
1C-1E	2	14	Don't know
1B	1	7	Co-operation is available

10- From your own perspective, what are your suggestions (recommendations) to secure water in the future ?.

Code	Recommendations	The Importance of Recommendation			
		I	II	III	IV
2A-3B-2E	Establish new advanced desalination plants	7	---	---	---
1A-2B-1C	Raise people's interest	2	1	1	---
1A-1C-1D-1G	Enact more groundwater Laws	1	2	1	---
2A-1C	A new comprehensive water policy is needed	3	---	---	---
1A-1B-1G	A new water tariff policy is needed	---	1	1	1
2B	An expansion in recycled water uses is needed	1	---	1	---
1A-1C	Increase groundwater well recharge	---	---	1	1
1G	Use advanced irrigation technology	---	---	---	1

A12.2. Preliminary Analysis of Interviews with Stakeholders with Environmental Experience:

Number and Field of Experience of Stakeholders.

Code	No. Interviewed	Field of Experience
A	4	Environment
B	2	Geology
C	1	Agriculture
D	1	Water Quality
E	1	Water Resources Management
F	1	Physical Geography
G	1	Agricultural and Development Geography

1- From your own perspective, does the current water policy implemented in Qatar suit the environmental circumstances ?.

Code	No. Respondents	%	Opinions
1A-1D-1C-1E-1F-1G	6	55	There isn't a clear policy, which has led to some water resources problems (e.g. groundwater pollution and depletion)
2A-1B	3	27	Policy is unacceptable because its centred on one source only (e.g. desalination) and others are not used
1A	1	9	Don't know
1B	1	9	There is an acceptable water policy

2- What are the most serious environmental problems caused by the depletion of groundwater ?.

Code	No. Respondents	%	Opinions
2A-2B-1C-1E-1F-1G	8	73	The most serious problems are groundwater and soil salinisation
2A-1D	3	27	Groundwater pollution and depletion

3- What are the possible solutions to control the depletion of groundwater ?.

Code	No. Respondents	%	Opinions
1C-1D-1F-1G	4	37	Use of more advance irrigation technology and enforcement of groundwater laws and regulation
1A-2B	3	27	Expand recycled water uses, specially for irrigation and groundwater aquifer recharge
1A-1E	2	18	Use it for domestic purposes only
1A	1	9	Establish new comprehensive water policy
1A	1	9	Don't know

4- What are the main freshwater pollution sources in Qatar ?.

Code	No. Respondents	%	Opinions
4A-1D-1E-1F	7	64	Oil industry, urban waste burial, and haphazard building
2B	2	18	Industrial pollution
1C	1	9	Urban waste burial, and use of recycled water for irrigation
1G	1	9	Oil industry, and expanding use of agricultural chemicals

5- What are the most important side effects of the desalination process ?.

Code	No. Respondents	%	Opinions
3A-2B-1D-1E-1G	8	73	Increase of seawater temperature, salinity, and desalination chemical pollution
1C-1F	2	18	Increase of seawater temperature
1A	1	9	The desalination process pollution

6- From an environmental perspective, is it possible to import water from abroad ?.

Code	No. Respondents	%	Opinions
1B-1C-1D-1E-1F	5	45	It is impossible due to high economic cost
3A-1B	4	37	It is possible from the environmental side
1A	1	9	This issue needs more studies
1G	1	9	It is possible if its costs less than brackish or seawater desalination

7- What are the best methods to control the rise in the level of groundwater under the cities ?.

Code	No. Respondents	%	Opinions
2A-1B-1C-1E-1F-1G	7	64	Establish underground drainage and use this water for irrigation or pump it directly to the sea
1A-1D	2	18	Digging many close wells then pump it to the sea
1A	1	9	Don't know
1B	1	9	This issue needs more studies

8- What is the possibility of expanding the use of recycled water ?.

Code	No. Respondents	%	Opinions
4A	4	37	Yes, it is possible but we should develop the current water network before we expand the uses of recycled water
1B-1E-1G	3	27	It is better to use it for irrigation only
1B-1C	2	18	It is impossible to use recycled water for any purpose and we should to pump it to the sea directly after treatment process
1D-1F	2	18	It is possible to use it for some irrigation and industrial purposes

9- What is the degree of environmental awareness among individuals in society?.

Code	No. Respondents	%	Opinions
2A-2B-1E-1F-1G	7	64	Non-existent or very weak
2A-1D	3	27	There is some environmental awareness but its needs more calculated guidance
1C	1	9	It is existent in scientific organisations only

10- What are the best possible solutions, from an environmental perspective, to secure water resources in the future ?.

Code	Recommendations	The Important of recommendation				
		I	II	III	IV	V
2A-2B-1C-1D-1G	Use more clean and economical energy	4	1	2	---	---
2A-1B-1E-1G	Establish advanced sewage treatment plants	2	1	2	---	---
1C-1E-1F-1G	Enforcement of groundwater laws and regulations	2	1	1	---	---
2A	Improve water resources management policy	2	---	---	---	---
1A-1B	New water resources development (e.g. rainfall gathering)	1	---	---	1	---
1A-1C	Encourage scientific studies	1	---	---	1	---
1A	Water distribution network development	---	1	---	---	---
1C	A new water tariffs policy	---	1	---	---	---
1A	Groundwater pollution control	---	---	---	---	1

A12.3. Preliminary Analysis of Interviews with Stakeholders with Technology Experience:

Number and Field of Experience of Stakeholders.

Code	Interviewed	Fields of Experience
A	4	Water Engineering
B	3	Environmental Engineering
C	2	Mechanical Engineering
D	1	Desalination

1- To what extent is the water technology currently used appropriate to the local environmental conditions (circumstances) ?.

Code	No. Respondents	%	Opinions
2A-2C	4	40	The technology is unsuitable but there is no choice
1A-1B-1D	3	30	We should use more economical technology
2B	2	20	We should use advance technology
1A	1	10	The technology is suitable

2- Is there a necessity for establishing this technology locally ?.

Code	No. Respondents	%	Opinions
3A-3B-1D	7	70	It is necessary
1A-1C	2	20	It is necessary but there are some difficulties
1C	1	10	It is unnecessary

3- What are the most important effects of modern technology on water consumption ?.

Code	No. Respondents	%	Opinions
4A-3B-1C	8	80	It causes an excess of water consumption
1C	1	10	It causes a decrease water consumption but it is very expensive
1D	1	10	Don't know

4- What is your opinion about the technology of desalination currently used ?.

Code	No. Respondents	%	Opinions
3A-2B-1C	6	60	It is all right but very expensive
1A-1D	2	20	It is old and needs renewal
1C	1	10	It is all right now
1B	1	10	Don't know

5- What is the possibility of expanding the use of recycled water ?.

Code	No. Respondents	%	Opinions
3A-3B-1C	7	70	There is a considerable possibility
1A-1C-1D	3	30	There is economical barrier

6- Do you think it is possible to expand the use of modern irrigation technology ?.

Code	*No. Respondents*	*%*	*Opinions*
2A-2B-2C-1D	7	70	It necessary
1A-1B	2	20	It is necessary but should to be under the government direction
1A	1	10	Don't know

7- What are the most important technological methods that can be used to stop the waste of water resources ?.

Code	No. Respondents	%	Opinions
3A-2B-1C	6	60	New methods in water distribution network and more conservation
1C-1D	2	20	Water reuse and raise public interest
1A	1	10	Develop water distribution network and raise public interest
1B	1	10	New water tariffs policy

8- What is the possibility of importing water from abroad ?.

Code	No. Respondents	%	Opinions
3A-2B-2C-1D	8	80	It is possible but depends on political and economical circumstances
1A	1	10	For security purposes it is preferable to use importer water for irrigation only
1B	1	10	It is needs more studies

9- In your opinion, to what extent is the local manpower available ?.

Code	No. Respondents	%	Opinions
3A-1B-1D	5	50	Manpower is very rare
1B-2C	3	30	Manpower exists, but need more training
1A-1B	2	20	Don't know

10- From your perspective, what are the most important technological methods that can be used to provide water resources in the future ?.

Code	Recommendations	The Importance of Recommendation			
		I	II	III	IV
3A-1B-1C-1D	Use more economical technology	6	---	---	---
1A-2B-1C	Raise public interest	2	2	---	---
1A-2B-1C	Use a more efficiently water distribution network	1	2	1	---
2A	Extend recycled water uses	1	---	1	---
1A-1C	New water tariffs policy	---	1	1	---
2B	Develop non-traditional water resources "e.g. rain-making"	---	1	1	---
1A	Brackish groundwater desalination	---	1	---	---
1A	More groundwater wells recharge	---	---	---	1

A12.4. Preliminary Analysis of Interviews with Stakeholders with Economic Experience:

Number and Field of Experience of Stakeholders.

Code	No. Interviewed	Fields of Experience
A	4	Economists
B	2	Water Resources Management
C	1	Economic Geography

1- What are the main economic reasons that led to the high level of water consumption?.

Code	No. Respondents	%	Opinions
3A-1B	4	57.5	Increased standard of life for the people during the oil period
1B-1C	2	28.5	High incomes and water free or nearly free
1A	1	14	Economic development and a great diffusion of urbanisation

2- In your opinion, what are the most important methods that can be used to control this high level of consumption ?.

Code	No. Respondents	%	Opinions
3A	3	43	More water laws, tariffs, and new water management methods
1A-1C	2	28.5	New water tariffs policy
2B	2	28.5	Raise public interest and new water tariffs policy

3- From your perspective, to what extent is the application of water tariff consumption charges useful ?.

Code	No. Respondents	%	Opinions
3A-1C	4	57	Very useful
1A-2B	3	43	Very useful if its comes into force in all seriousness

4- Has the current water tariff achieved its aims ?.

Code	No. Respondents	%	Opinions
3A-2B-1C	6	86	It is not significant
1A	1	14	Don't know

5- From an economic perspective, is it possible to expand the desalination process ?.

Code	No. Respondents	%	Opinions
4A-1B-1C	6	86	Yes, by using more economical and advanced technology
1B	1	14	Yes, because there is no choice

6- Is it possible to import water from abroad ?.

Code	No. Respondents	%	Opinions
3A-1C	4	57.5	Yes, but there are economical and political difficulties
2B	2	28.5	No, due to economical and political barriers
1A	1	14	It is possible

7- In your opinion, which is better: importing water from abroad or stopping the agricultural expansion ?.

Code	No. Respondents	%	Opinions
3A-1B	4	57.5	Stop agricultural expansion
1A-1B	2	28.5	It is better to use advanced irrigation technology
1C	1	14	Import water if its less costly than desalination

8- What is the possibility of privatising the water sector in Qatar ?.

Code	No. Respondents	%	Opinions
4A-1C	5	58	It is partly possible
1B	1	14	It is not possible due to the high economical cost
1B	1	14	It is difficult in recent times

9- To what extent do the current prevailing economic conditions affect the water sector?.

Code	No. Respondents	%	Opinions
4A-1B-1C	6	86	They have negative effect because the government will reduce its support
1B	1	14	Maybe will have a positive affect due to foreign workers reversing their immigration

10- From your own perspective, what are the most important and possible methods that can be used to secure water resources in the future ?.

Code	Recommendations	The Importance of Recommendation I	II	III
1A-2B-1C	Depends on economical advanced desalination technology	4	---	---
3A	New water tariffs policy	2	1	---
1A-1B-1C	Support the scientific water research	---	3	---
3A	Raise public interest	---	1	2
1A	Stop agricultural expansion	1	---	---
1A	Import water	---	1	---
1B	More groundwater laws and regulations	---	1	---
1B	Expansion of uses of recycled water	---	---	1

A12.5. Preliminary Analysis of Interviews with Stakeholders with Decision-making and Legislation Experience:

Number and Field of Experience of Stakeholder.

Code	No. Interviewed	Field
A	6	Water Resources Management
B	3	Law
C	2	General Management
D	1	Political Geography

1- What is your opinion with regard to the current water policy ?.

Code	No. Respondents	%	Opinions
3A-3B-1D	7	58	There is not a clear and real water policy
3A-2C	5	42	There is an intellectual policy but it needs more development

2- Do you think we have a sufficient quantity of local expertise in the field of decision-making ?.

Code	No. Respondents	%	Opinions
5A-3B-1C	9	75	There are sufficient but without experience and training
1A-1C-1D	3	25	Very rear especially in some fields like technical experience of water management

3- What is the possibility of co-operation with the neighbouring countries in the water sector ?.

Code	No. Respondents	%	Opinions
3A-1B-2C-1D	7	58	There is a large opportunity
3A-2B	5	42	There is opportunity, but there is no real co-operation

4- Do you think the people's participation in decision-making is useful ?.

Code	No. Respondents	%	Opinions
5A-3B-1C-1D	10	84	It is very important
1A	1	8	Yes, but only the cultured class should be involved
1C	1	8	Not in decision-making, but in some parts of water management such as raising public awareness

5- What is your suggestion for developing decision-making ?.

Code	Recommendations	The Importance of recommendation		
		I	II	III
3A-1B-1D	Developing capabilities of the local labour	3	2	---
2A	Establish a high national water council	2	---	---
1A-1B	Establish committees to study water problems	2	---	---
1A-1C	Establish a bank of water data	2	---	---
2B	Establish local water councils	1	1	---
1A-1D	Enforcement of long term water policy	1	1	---
1A-1C	Use of modern administrative methods	1	1	---
1B-1C	Give people a chance to participate in water management	---	1	1
1C	Encourage scientific water research	---	1	---

6- Do we have a sufficient number of water laws ?.

Code	No. Respondents	%	Opinions
4A-2B-1C-1D	8	66	The exciting laws need more development and renewal
2A	2	17	Yes, we have enough water laws
1B-1C	2	17	No, we have not enough water laws

7- What are the issues that haven't been covered yet by water laws or regulations ?.

Code	No. Respondents	%	Opinions
1A-2C-1D	4	33	Designation of level of water consumption and water tariffs policy
3A	3	25	Water resources conservation
2A	2	17	There are none
2B	2	17	Groundwater conservation
1B	1	8	Groundwater pollution and depletion

8- How can law be used as a means for consumption control ?.

Code	No. Respondents	%	Opinions
2A-3B-1C	6	50	Enforcement of the laws into force in all seriousness
2A	2	16.6	Designation of special officials to enforcement the laws
1A-1C	2	16.6	Designate a level of water consumption
1A-1D	2	16.6	At first, raise the public's interest in water

9- How can equity be achieved while regulations are being implemented?.

Code	No. Respondents	%	Opinions
6A-3B-1C-1D	11	92	Application of water laws on all people without exceptions
1C	1	8	Demarcation of areas of water uses and priority

10- What are your suggestions for activating the role of law in water management ?.

Code	Recommendations	The Importance of Recommendation		
		I	II	III
5A-2B-1C-1D	Application of water laws on all people without exceptions	6	3	---
2A-2B-1C	Continuously development and renewal of water laws	3	2	---
1A-2B-1D	Raise public awareness about water laws	2	1	1
2A-1C	Give the censors more responsibility and power	1	2	---
2A	Exclude any conflict of water laws and regulations	---	1	1
1A-1B	Establish new a comprehensive water management policy	---	1	1
1C	Follow other countries water management experiences and practices	---	1	---

A12.6. Preliminary Analysis of Interviews with Stockholders with Water Administration*:*

Number and Field of Experience of Stakeholders.

Code	No. Interviewed	Field
A	7	Water Resources Management
B	2	General Management

1- Do you think that we have enough water administrators ?.

Code	No. Respondents	%	Opinions
5A	5	55.5	Yes, there is enough water administrators
2A-2B	4	44.5	No, there is necessity to have more water administrators

2- What is the extent of co-ordination between these administrators ?.

Code	No. Respondents	%	Opinions
4A-2B	6	67	Non-existent
3A	3	33	There is some co-ordination

3- Is there a collaboration between the local water administrators and the regional and international ones ?.

Code	No. Respondents	%	Opinions
5A-2B	7	78	Non-existent
2A	2	22	There are some collaboration within a very limited area

4- What is the extent of local labour available ?.

Code	No. Respondents	%	Opinions
4A	4	44.5	Yes, it is available, but in high positions only
2A-1B	3	33.5	There is some labour but without technique
1A-1B	2	22	local labour is rare

5- What is your opinion towards the participation of individuals in society in the water management ?.

Code	No. Respondents	%	Opinions
4A-2B	6	67	It became very important in recent time
2A	2	22	It is very important but only after raising people's water awareness
1A	1	11	To give opinions only not to make decision

6- What are the efforts of water administrators in the field of guidance and education to raise people interest ?.

Code	No. Respondents	%	Opinions
6A-2B	8	89	It is probably below the average
1A	1	11	It is almost satisfactory but without results

7- To what extent are water administrators independent ?.

Code	No. Respondents	%	Opinions
5A-1B	6	67	There are not
1A-1B	2	22	There is negative independence usually leading to conflicts between water administrators
1A	1	11	There is a kind of independence

8- What is the extent of the government's interest in water administration ?.

Code	No. Respondents	%	Opinions
4A-2B	6	67	Unsatisfactory and it is needs more development
3A	3	33	There is some interest

9- What is your opinion towards the privatisation of the water sector ?.

Code	No. Respondents	%	Opinions
4A-1B	5	56	It is possible but should to be under government direction
2A-1B	3	33	It is important to improve the public water services
1A	1	11	It is possible for the industrial sector only

10- In your opinion, what are the most important methods for developing water management ?.

Code	Recommendations	The Importance of Recommendations			
		I	II	III	IV
5A-2B	Improve the technique of the administrative officials	4	---	3	---
3A-2B	Establish a high water council	2	1	1	1
3A-2B	Establish a new water policy	1	2	2	---
3A-1B	Give water administrators more authority	1	3	---	---
1A	Train the local officials abroad	1	---	---	---
1A	Arrange periodic meetings about water experiences	--	1	---	---
1A	Take the local environmental conditions into consideration before establishing any water project	---	1	---	---
1A	Enforce the useful scientific studies	---	---	---	1

A12.7. Preliminary Analysis of Interviews with Islamic Religious Scholars:

Number and Field of Scholars.

Code	No. Interviewed	Field of Scholars
A	4	Islamic Law (Shari'a)
B	2	Qur'an Sciences
C	1	Islamic Economy

1- What is the religious opinion of the current waste of water resources ?.

Code	No. Scholars	%	Opinions
4A-2B-1C	7	100	It is forbidden, not in water but in every thing, according to many verses in the holy Qur'an such as "....And eat and drink and not cross the limit. Undoubtedly, the persons crossing the limit are not liked by him" and "No doubt, the extravagant are the brothers of the Devils. And the devil is very ungrateful to his lord".

2- How can religion be used as a means for consumption control ?.

Code	No. Scholars	%	Opinions
4A-2B-1C	7	100	Appropriate use of public communication tools, such as mosques, mass media, and schools to give the Islamic religious opinion of the waste of water.

3- From the religious perspective, what is the possibility of privatising the water sector ?.

Code	No. Scholars	%	Opinions
3A-1B-1C	5	71.5	It is impossible. According to the Prophet Mohammed "....Mankind are co-owners in three things: Water, Fire, and Pasture".
1A-1B	2	28.5	It is partly possible, with the government direction and invigoration.

4- From the religious perspective, what is the possibility of using of recycled water for bathing purposes for example ?.

Code	No. Scholars	%	Opinions
4A-1B-1C	6	86	It is possible if you can produce high quality water; or preferably use it only for irrigation.
1B	1	14	It is impossible because it is still impure.

5- From your perspective, what are the most important methods that can be adopted to change the consumption behaviour patterns of the individual?.

Code	No. Scholars	%	Opinions
4A-2B-1C	7	100	Use religion dictation and regulations very much, every where, such as mosques, mass media to change people behaviour from wastefulness to conservation.

A12.8. Preliminary Analysis of Interviews with Stakeholders with Social Experience:

Number and Field of Experience of Stakeholders.

Code	No. Interviewed	Field of Experience
A	5	Sociology
B	2	Human Geography

1- What are the most important social circumstances that lead to changes in the consumption behaviour of individuals in society?.

Code	No. Respondents	%	Opinions
4A-1B	5	72	Improvement of the standard of living during the oil period
1A	1	14	A jump in oil prices and opening of these societies to other civilisations
1B	1	14	Economical, cultural, and social development

2- How can these patterns of behaviour be improved ?.

Code	No. Respondents	%	Opinions
3A-2B	5	72	More efforts to raise public water awareness
1A	1	14	Enact new water laws and regulations beside raising the interest of the public's water
1A	1	14	Reappraisal of social education

3- Do you think that people in Qatar have special consumption behaviour patterns ?.

Code	No. Respondents	%	Opinions
4A-2B	6	86	Yes, there is special consumption behaviour keeping up appearances which is characteristic, due to high incomes
1A	1	14	No, there is not special consumption behaviour because it is a human disposition

4- What do you think of the current methods used to influence the consumption behaviours of individuals in society ?.

Code	No. Respondents	%	Opinions
3A-2B	5	86	There is not enough effort and it needs more development
2A	2	14	It is non-existent

5- What is your opinion of the participation of individuals in water management ?.

Code	No. Respondents	%	Opinions
4A-2B	6	86	Yes, it is a very important step
1A	1	14	Yes, especially if its synchronises with a water privatisation policy

6- Do you think that the termination and disappearance of the welfare society alone can lead to a change in these behaviour patterns ?.

Code	No. Respondents	%	Opinions
3A-1B	4	57.5	Yes, This will help to change some consumption behaviour
1A-1B	2	28.5	No, that will not happen
1A	1	14	Maybe, and that will lead to a reduction of the government responsibilities

7- How can we make society feel of the importance of water ?.

Code	No. Respondents	%	Opinions
3A-1B	4	57.5	There should be more concern about water education and training to raise public interest
1A-1B	2	28.5	It is necessary to raise public water awareness
1A	1	14	The government should create water crises to make people feel the importance of water

8- What is your opinion towards the currently used methods of establishing sufficient awareness of the importance of water?.

Code	No. Respondents	%	Opinions
4A-2B	6	71.5	they are non-existent
1A	1	28.5	There are enough tools without employing it

9- What are the bodies or institutions you deem necessary for participation in the establishment of general popular awareness ?.

Code	No. Respondents	%	Opinions
3A-2B	5	72	The most important are mosques and education institutions
2A	2	28	The most important bodies are mosques and other religious institutions, women's associations, and the mass media

10- From your perspective, what are the most important methods that can be adopted to change the consumption behaviour patterns of individuals ?.

Code	Recommendations	The Importance of Recommendation			
		I	II	III	IV
3A-2B	New comprehensive water control policy	3	2	---	---
3A-2B	Establish water courses in different education institutions	---	2	3	---
2A	Create spontaneous public sanctions	2	---	---	---
2A	Use the mass media to create engaging water programmes to raise public water awareness	1	---	1	---
1A	More local regional conferences to raise public water awareness	1	---	---	---
1A	Change social priorities	---	1	---	---
1A	Talk about the possibility of water sector privatisation to make people feel the importance of water	---	---	---	1

APPENDIX THIRTEEN:

DOMESTIC HYDROLOGY MEASUREMENTS SURVEY

Appendix Thirteen:

Domestic Hydrology Measurements Survey

Personal Particulars

Please place a tick in the appropriate box and in on the dotted lines:

1. Nationality: ☐ Citizen ☐ Non-citizen – Nationality: {......................}
2. Gender ☐ Male ☐ Female
3. Education: ☐ Very Little ☐ Elementary ☐ High School ☐ Higher Education
4. Age Group: ☐ Under 20 ☐ 20-29 ☐ 30-39 ☐ 40-49 ☐ 50 and over
5. Income Group: ☐ Under 5,000 ☐ 5,000-9,999 ☐10,000-14,999 ☐ Over 15,000
6. Occupation: { .... }
7. Number of family members: { ......}

Example

Use	Number of Times	Timing			Period		Time of Day								
		D	W	M	m	H									
Shower	1	√			15		6								
Cooking	1	√			10	1	14								
Cars Washing	1		√		20	0	17								
Garden Irrigation	2		√		30	1	7								

Please indicate your water consumption for deferent uses.

Use	Number of Times	Timing			Period		Time of Day								
		D	W	M	m	H									
Drinking															
Shower															
Personal Washing															
Toilet															
Cooking															
Dish Washing															
Clothes Washing															
Floor Washing															
Car Washing															
Garden Irrigation															
Others (Please indicate) --------------------------------- ---------------------------------															

D: Daily - W: Weekly - M: Monthly - m: Minute - H: Hour.

APPENDIX FOURTEEN:

PUBLIC QUESTIONNAIRE: FORM AND DATA

Appendix Fourteen:

Public Questionnaire: Form and Data

A14.1. Questionnaire Form:

QATAR UNIVERSITY

بسم الله الرحمن الرحيم

Department of Geography

Faculty of Humanities and Social Sciences

Dear Sir / Madam;

This survey forms an essential part of research I am currently undertaking for the degree of Ph.D. in Environment Management from the University of Huddersfield, under the support of the University of Qatar.

The main aim of my study is to design a comprehensive water management system in Qatar. In particular, this research assumes that there are a many social factors which should to considered before any water resources management is established. Your participation in this questionnaire will help to assess comprehensive water management.

Information obtained by this questionnaire will be treated with strict anonymity and confidentiality.

Thank you in anticipation of your help.

Hassan al-Mohannadi
University of Huddersfield
Geographical Sciences Section, School of Applied Science
Huddersfield HD1 3DH, UK
and
University of Qatar
Department of Geography
Doha - Qatar

<u>Please place a tick in the appropriate box and in on the dotted lines:</u>

I- Personal Particulars

1. Nationality: ☐ Citizen ☐ Non-citizen – Nationality: {............................}
2. Gender: ☐ Male ☐ Female
3. Education: ☐ Very Little ☐ Elementary
☐ High School ☐ Higher Education
4. Age Group: ☐ Under 20 ☐ 20-29 ☐ 30-39
☐ 40-49 ☐ 50-59 ☐ 60 and over
5. Income Group: ☐ Under 5,000 ☐ 5,000-9,999
☐ 10,000-14,999 ☐ Over 15,000
6. Occupation: { .... }

II- The Service

1. What is the source of the water you consume:
☐ Groundwater ☐ Desalination ☐ Unknown
2. How does this water reach you:
☐ Tankers ☐ Network
3. Do you use this water for drinking:
☐ Yes ☐ No
4. If you answered No to question 3, why you don't use it for drinking (<u>Please give reasons</u>):
....
....
5. If your water is sometimes disconnected, how much does this inconvenience you:
☐ Never disconnected ☐ No problem ☐ Slight inconvenience
☐ Moderate inconvenience ☐ Great inconvenience
6. Please indicate the level of efficiency of your supplies:
☐ Very efficient ☐ Efficient ☐ Tolerable
☐ Inefficient ☐ Very inefficient ☐ No opinion
7. Why do you think this is (<u>Please indicate the reasons</u>):
....
....

III. Water Laws

1. Do you think there are enough water laws in Qatar:
☐ Yes ☐ No ☐ Don't know

2. Which of the following water issues covered by current laws (<u>Please indicate how important you think these factors are</u>):

	Strongly Covered	Covered	Uncovered	Strongly Uncovered	Don't Know
Water resources conservation	☐	☐	☐	☐	☐
Consumption control	☐	☐	☐	☐	☐
Administration specialisation	☐	☐	☐	☐	☐
Water conflict	☐	☐	☐	☐	☐
Consumers responsibility and duty	☐	☐	☐	☐	☐
Water quality	☐	☐	☐	☐	☐
Other (Please indicate):					
....	☐	☐	☐	☐	☐

3. If laws controlling your use of water were made, what would make you obey them (<u>Please indicate</u> <u>how important you think these factors are</u>):

	Very Important	Important	Not Important	Not at all	Don't Know
Laws will apply to all people	☐	☐	☐	☐	☐
Laws will be applied by a strong authority	☐	☐	☐	☐	☐
Laws will be in harmony with local circumstances	☐	☐	☐	☐	☐
Laws will be publicised	☐	☐	☐	☐	☐
Offenders will be strictly punished	☐	☐	☐	☐	☐
Other (Please indicate):	☐	☐	☐	☐	☐

IV- Water Issues

1. Do you think the water which you consume is healthy:

☐ Very healthy ☐ Healthy ☐ Tolerable
☐ Unhealthy ☐ Very unhealthy ☐ Don't know

2. For which of these purposes would you agree that we can use recycled water (<u>Please indicate whether you agree or disagree with the following statements</u>):

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Don't Know
A. In all sectors, even household:	☐	☐	☐	☐	☐	☐
B. In all sectors, excepting household:	☐	☐	☐	☐	☐	☐
C. Industrial sector:	☐	☐	☐	☐	☐	☐
D. Agricultural sector:	☐	☐	☐	☐	☐	☐
E. Crops not for human consumption:	☐	☐	☐	☐	☐	☐
F. Public garden irrigation:	☐	☐	☐	☐	☐	☐
G. Groundwater recharge:	☐	☐	☐	☐	☐	☐
H. No uses:	☐	☐	☐	☐	☐	☐
I. Others (Please indicate):	☐	☐	☐	☐	☐	☐

3. From which country would you feel that we could import water (<u>Please indicate your preference</u>):

	Strong Preference	Preference	Dislike	Strong Dislike	Don't Know
Turkey	☐	☐	☐	☐	☐
Iran	☐	☐	☐	☐	☐
Pakistan	☐	☐	☐	☐	☐
Japan	☐	☐	☐	☐	☐
Malaysia	☐	☐	☐	☐	☐
None	☐	☐	☐	☐	☐
Others (Please indicate):	☐	☐	☐	☐	☐

V- Consumption

1. Please indicate your estimated level of water consumption in gallon per day:

☐ 10 - 39.9 ☐ 40 - 69.9 ☐ 70 - 99.9
☐ 100 - 129.9 ☐ 130 - 160 ☐ Don't know

2. How you describe your self as water consumer:

☐ Extravagant ☐ Liberal ☐ Neutral
☐ Sparing ☐ Very sparing ☐ Don't know

3. What are the most important reasons for this pattern of behaviour (Please indicate how important you think they are):

	Very Important	Important	Not Important	Not at all	Don't Know
Water availability	☐	☐	☐	☐	☐
Absence of strict laws	☐	☐	☐	☐	☐
Tariff	☐	☐	☐	☐	☐
Concern about water problem	☐	☐	☐	☐	☐
Standard of living	☐	☐	☐	☐	☐
Convention	☐	☐	☐	☐	☐
Education	☐	☐	☐	☐	☐
Religion	☐	☐	☐	☐	☐
Family attitude	☐	☐	☐	☐	☐
Awareness efforts	☐	☐	☐	☐	☐
Others (Please indicate)	☐	☐	☐	☐	☐

4. Which of these purposes do you think consume the most water in your house:

	Most Use	Frequent	Little Use	No Use	Don't Know
Drinking	☐	☐	☐	☐	☐
Cooking	☐	☐	☐	☐	☐
Clothes washing	☐	☐	☐	☐	☐
Car washing	☐	☐	☐	☐	☐
Floor washing	☐	☐	☐	☐	☐
Dishes washing	☐	☐	☐	☐	☐
Garden irrigation	☐	☐	☐	☐	☐
Personal washing	☐	☐	☐	☐	☐
Toilet uses	☐	☐	☐	☐	☐
Shower	☐	☐	☐	☐	☐
Others (Please indicate):	☐	☐	☐	☐	☐

5. Can you lower your water consumption:

☐ Yes (Go to next question 6) ☐ No

6. For which of these purposes can you most easily decrease your consumption:

	Most Easily	Easily	Slight Easily	Difficulty	Great Difficulty	Don't Know
Drinking	☐	☐	☐	☐	☐	☐
Cooking	☐	☐	☐	☐	☐	☐
Clothes washing	☐	☐	☐	☐	☐	☐
Car washing	☐	☐	☐	☐	☐	☐
Floor washing	☐	☐	☐	☐	☐	☐
Dishes washing	☐	☐	☐	☐	☐	☐
Garden irrigation	☐	☐	☐	☐	☐	☐
Personal washing	☐	☐	☐	☐	☐	☐
Toilet uses	☐	☐	☐	☐	☐	☐
Shower	☐	☐	☐	☐	☐	☐
Others (Please indicate):	☐	☐	☐	☐	☐	☐

VI. Water Tariff

1. Are you paying a water tariff: □ Yes (Go to next questions 2 and 3) □ No (Go to question 3).

2. Do you think the water tariff you pay has any influence on your water consumption levels:
□ Very strong influence □ Strong influence □ Weak influence
□ No influence □ Don't know

3. In what form and purposes do you feel the water tariff should be (<u>Please indicate whether you agree or disagree with the following statements</u>):

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Don't Know
A. Less than the current amount:	□	□	□	□	□	□
B. Identical with production cost:	□	□	□	□	□	□
C. To improve water services:	□	□	□	□	□	□
D. Enforced on all society individuals:	□	□	□	□	□	□
E. Dependent on family circumstances:	□	□	□	□	□	□
F. Dependent on level of water consumption:	□	□	□	□	□	□
G. To improve water quality:	□	□	□	□	□	□
H. Others (Please indicate)	□	□	□	□	□	□

4. Would you following make you more willing to pay the water tariff (<u>Please indicate whether you agree or disagree with the following statements</u>):

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Don't Know
A. Tariffs should pay for water production costs:	□	□	□	□	□	□
B. Tariffs should pay for improved water services and quality:	□	□	□	□	□	□
C. Tariffs should be enforced on all individuals in society:	□	□	□	□	□	□
D. Tariffs should reflect levels of family circumstances:	□	□	□	□	□	□
E. Tariffs should reflect levels of water consumption:	□	□	□	□	□	□
F. Others (Please indicate):	□	□	□	□	□	□

VII. Public Relations

1. Do you think there is enough efforts to make society aware of the importance of water:
□ Yes □ No □ Maybe □ Don't know

2. Please indicate which factors have influence your water consumption:

	To Economise Strongly	To Economise	No Influence	To Increase Consumption	To Increase Consumption Strongly	Don't Know
Religious maxims	☐	☐	☐	☐	☐	☐
Family education	☐	☐	☐	☐	☐	☐
School	☐	☐	☐	☐	☐	☐
Clubs and organisation	☐	☐	☐	☐	☐	☐
Friends	☐	☐	☐	☐	☐	☐
Television	☐	☐	☐	☐	☐	☐
Radio	☐	☐	☐	☐	☐	☐
Newspapers	☐	☐	☐	☐	☐	☐
Laws	☐	☐	☐	☐	☐	☐
Tariffs	☐	☐	☐	☐	☐	☐
Conferences	☐	☐	☐	☐	☐	☐
Water disconnected	☐	☐	☐	☐	☐	☐
Prospectus and reports	☐	☐	☐	☐	☐	☐
Others (Please indicate):						
....	☐	☐	☐	☐	☐	☐

3. What methods do you think are the most important for the creation of water awareness: (<u>Please indicate how important you think they are</u>):

	Very Important	Important	Not Important	Not at all	Don't Know
Religious organisations	☐	☐	☐	☐	☐
Family education	☐	☐	☐	☐	☐
School	☐	☐	☐	☐	☐
Television	☐	☐	☐	☐	☐
Radio	☐	☐	☐	☐	☐
Newspapers	☐	☐	☐	☐	☐
Friends	☐	☐	☐	☐	☐
Clubs and Associations	☐	☐	☐	☐	☐
Conferences	☐	☐	☐	☐	☐
Public Participation	☐	☐	☐	☐	☐
Tariffs	☐	☐	☐	☐	☐
Laws	☐	☐	☐	☐	☐
Prospectus and reports	☐	☐	☐	☐	☐
Water disconnected	☐	☐	☐	☐	☐
Others (Please indicate):					
....	☐	☐	☐	☐	☐

VIII. Water Administration

1. Would you like to participate in water management:

☐ Yes (Go to next questions 2 and 3) ☐ No (Go to question 4) ☐ Don't know

2. If your answered yes to question 1, why? (Please indicate whether you agree with these factors):

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Don't Know
A. Improve water services:	☐	☐	☐	☐	☐	☐
B. Raise water awareness:	☐	☐	☐	☐	☐	☐
C. Represent local interests:	☐	☐	☐	☐	☐	☐
D. Improve water administration:	☐	☐	☐	☐	☐	☐
E. Curiosity:	☐	☐	☐	☐	☐	☐
G. Cultured class only:	☐	☐	☐	☐	☐	☐
F. Other (Please indicate):	☐	☐	☐	☐	☐	☐

3. In which form would you like to be this participation (Please indicate whether you agree or disagree with the following statements):

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Don't Know
A. Knowledge of plans:	☐	☐	☐	☐	☐	☐
B. Participation by the local municipal corporation	☐	☐	☐	☐	☐	☐
C. Participation by representatives elected for the purpose:	☐	☐	☐	☐	☐	☐
D. Personally giving recommendations and suggestions:	☐	☐	☐	☐	☐	☐
E. Personal participation in management policy design:	☐	☐	☐	☐	☐	☐
F. Personal involvement in direct direction:	☐	☐	☐	☐	☐	☐
G. Other (Please indicate):	☐	☐	☐	☐	☐	☐

4. If your answered no to question 3, why? (Please indicate whether you agree with these factors):

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Don't Know
A. The current policy is good:	☐	☐	☐	☐	☐	☐
B. The Administration works correctly:	☐	☐	☐	☐	☐	☐
C. I don't care about water issues:	☐	☐	☐	☐	☐	☐
D. It's difficult to happen:	☐	☐	☐	☐	☐	☐
E. This will lead to abominable services:	☐	☐	☐	☐	☐	☐
G. There is no personal advantage:	☐	☐	☐	☐	☐	☐
G. I have not water experience:	☐	☐	☐	☐	☐	☐
F. Other (Please indicate):	☐	☐	☐	☐	☐	☐

5. If there is opportunity for you to make a decision in water management, what is the first decision you will take (<u>Please state</u>):

....

....

....

IX. Privatisation

1. Do you advocate water sector privatisation:

☐ Yes (Go to next question 2) ☐ Yes but partly(Go to next question 2)

☐ No (Go to question 3) ☐ Don't know

2. What do you think are the benefits of water sector privatisation for you (<u>Please indicate how beneficial you think these factors are</u>):

	Very Beneficial	Beneficial	Neutral	Damaging	Very Damaging	Don't Know
A. Improve water services:	☐	☐	☐	☐	☐	☐
B. Public participation:	☐	☐	☐	☐	☐	☐
C. Increase of water awareness:	☐	☐	☐	☐	☐	☐
D. Decrease of water consumption:	☐	☐	☐	☐	☐	☐
E. New water resources development:	☐	☐	☐	☐	☐	☐
F. Reduce government burdens:	☐	☐	☐	☐	☐	☐
G. Better administration:	☐	☐	☐	☐	☐	☐
H. Economic growth:	☐	☐	☐	☐	☐	☐
F. Other (Please indicate):	☐	☐	☐	☐	☐	☐

3. What do you think are the problem of water sector privatisation for you (<u>Please indicate how difficult you think these factors are</u>):

	Strongly Impossible	Impossible	Natural	Possible	Strongly Possible	Don't Know
A. Increase of water tariffs:	☐	☐	☐	☐	☐	☐
B. A clash with religious regulations:	☐	☐	☐	☐	☐	☐
C. Leads to monopoly:	☐	☐	☐	☐	☐	☐
D. Leads to abominable services:	☐	☐	☐	☐	☐	☐
E. Loss of jobs :	☐	☐	☐	☐	☐	☐
F. Water resources depletion:	☐	☐	☐	☐	☐	☐
G. Effect on the national security :	☐	☐	☐	☐	☐	☐
H. Leads to conflicts :	☐	☐	☐	☐	☐	☐
F. Other (Please indicate):	☐	☐	☐	☐	☐	☐

X- Knowledge of Water Issues

1. Do you know in which month is the Global Water Day:

☐ January ☐ February ☐ March

☐ April ☐ May ☐ Don't know

2. What are the available water resources in Qatar (<u>Tick as many boxes as you like</u>):

☐ Groundwater ☐ Surface ☐ Importer

☐ Desalination ☐ Recycling ☐ Don't know

3. What the ministry do you think is responsible for water production and domestic distribution:

☐ Ministry of Energy, Industry, Electricity, and Water (Changed to the Qatar General Electricity and Water Corporation in April 2000)

☐ Ministry of Water ☐ Ministry of Electricity and Water ☐ Don't know

4. How many desalination plants exist in Qatar:

☐ 1-2 ☐ 3-4 ☐ 5-6

☐ 7-8 ☐ 9-10 ☐ Don't know

5. How many potable groundwater fields produce for domestic purposes in Qatar:

☐ 1-2 ☐ 3-4 ☐ 5-6

☐ 7-8 ☐ 9-10 ☐ Don't know

6. How much does one cubic meter of desalination production cost (QR):

☐ 3-4 ☐ 4-5 ☐ 5-6

☐ 6-7 ☐ 7-8 ☐ Don't know

7. How much does one cubic meter of potable groundwater production cost (QR):

☐ 1-2 ☐ 2-3 ☐ 3-4

☐ 4-5 ☐ 5-6 ☐ Don't know

8. Do you know how much the non-citizen pays for every one cubic meter of water (QR):

☐ 0 ☐ 1-3 ☐ 3-5

☐ 5-7 ☐ 7-9 ☐ Don't know

9. Do you know how many million cubic meters were produced in 1997 by desalination:

☐ 10-30 ☐ 50-70 ☐ 90-110

☐ 130-150 ☐ 170-190 ☐ Don't know

10. About which water issue was the 1988/1 law:

☐ Consumption ☐ Resources conservation ☐ Groundwater

☐ Desalination ☐ Tariffs ☐ Don't know

11. The Prophet said: Excess in the use of water is forbidden, even if you have the resources of a:

☐ Well ☐ River ☐ Pool

☐ Spring ☐ Lake ☐ Don't know

XI. Overall Comments

<u>Please give any comments you have on the water resources management in the State of Qatar:</u>

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With my compliments

Hassan al-Mohannadi

See CD-ROM for:

A14.2. Public Data and Opinion.

A14.3. Data Exploration by Groups.

A14.4. Data Exploration: Reasons for Behaviour Patterns.

APPENDIX FIFTEEN:

ABBREVIATION AND ACRONYMS

Abbreviation and Acronyms*

A

a^{-1}: Per annum.
AD: Anno Domini (year of Jesus birth).
AgI: Silver iodide.
a.m.: Ante meridiem (before noon).

B

bar: A unit of pressure. 1 bar = 10^5 newtons per square metre.
barrel: 1 barrel = 35 imperial gallons (approximately).
= 42 US gallons.
= 159 litres (approximately).
b^{-1}: Per barrel.
bd^{-1}: Barrel per day = 50-50 tonnes per annum according to the specific gravity of the crude oil.
BC: Before Christ.
bf^3: Billion cubic feet = Adjusted equal gas of one thousand British unit/cubic foot. Does not include gas rich with Ethane.
bm^3: Billion cubic metres.

C

°C: Zero Celsius (Centigrade) = 32° Fahrenheit (F)
= 273 Kelvin (K)

$^{\circ}C = 5/9(^{\circ}F-32)$
$^{\circ}F = 9/5(^{\circ}C+32)$
$K = ^{\circ}C + 273$

Condition	Celsius (°C)	Fahrenheit (°F)	Kelvin (K)
Absolute zero	-273.16°	-459.69°	0
Freezing point of water	0°	32°	273
Boiling point of water	100°	212°	373

Ca: Calcium.
Cb Cloud: Cumulonimbus.
Cl: Chloride.

D

$: Dollar (United States of America) = 100 Cents. Exchange rate: $ 1 = QR 3.64.

E

EC: The European Community.
ESCWA: The Economic and Social Commission for Western Asia.

*The Abbreviation and Acronyms are from different sources, including Nelson and Nelson (1973); Moore (1979); Twort *et al.* (1985); Gabler *et al.* (1994); Makins *et al.* (1998); Merrett (1997).

F

f³: 1 cubic foot = 0.02832 cubic meters (m^3).
FAO: Food and Agricultural Organisation of the United Nations.
Fe: Iron.

G

g: 1 gram = 0.0353 ounce (oz).
Mg: Mega =1,000 kilograms (kg)

gal:	1 British Imperial Gallon	= 4.546 litres
		= 10 pounds
	1 United States Gallon	= 3.784 litres
		= 231 cubic inches

gal⁻¹: Per gallon.
gald⁻¹: Gallon per day.
galt⁻¹: Gallon per ton.
GCC: The Gulf Co-operation Council (Qatar, Kuwait, Bahrain, Saudi Arabia, United Arab Emirates and Oman).
gkg⁻¹: Gram per kilogram.
GNP: Gross National Product: the total value of the goods produced and the services provided in a country in one year.

H

ha: 1 hectare = 10,000 square metres
= 2.471 acres.
= 10 dunum.
hPa: Hectopascal a unit of atmospheric pressure and vapour pressure measurement.

K

kg: 1 kilogram	= 1,000 grams (m)
	= 2.2046 pounds (lbs).
KJ: Kilo joule	= 1,000 joules (J).
km: 1 kilometre	= 0.6214 mile.
km²: 1 square kilometre	= 0.386 square mile.

km³: Kilo cubic metre.
Knot: A unit of speed equal to one nautical mile per hour.
KSA: The Kingdom of Saudi Arabia.
KV: Kilovolt = 1,000 volts (V).
kwh⁻¹: Kilo watt per hour.

L

l⁻¹: Per litre = 0.21997 gallon.
= 1,000 cubic centimetres (cm^3).
l/cap/day: Litre per capita per day.
ld⁻¹: Litre per day.

M

m: 1 meter = 39.37 inch (in)
= 3.280 feet (ft)

= 1.0936 yards (yd)
m^3 : 1 cubic meter = 219.97 gallon (g)
= 1,000 Cubic litre (l^3).
MEIEW: Ministry of Energy, Industry, Electricity and Water.
Metric ton: Metric ton = 2,204.6 lb.
= 1,000 kg.
= 7.3 barrels (approximately).
MEW: Ministry of Electricity and Water.
Mg: Magnesium.
mgl^{-1}: 1 milligram per litre = 1 gram per cubic meter
= 1 ppm
1,000 mgl^{-1} = 1 gram/litre
m^3d^{-1}: Cubic meters per day.
mi^3: cubic miles.
$migd^{-1}$: Million imperial gallons per day.
µS/cm: Micro-siemen/centimetres.
Millimetre: 1 mm rainfall per km^2 = 1,000 cubic metre (m^3)
= 0.220 million gallon
mig: Million imperial gallons.
Mm^3 : Million cubic meter.
MMAA: Ministry of Municipal Affairs and Agriculture.
mmd^{-1}: Millimetre per day.
ma^{-1}: metre per annum.
mma^{-1}: Millimetre per annum.
MSF (desalination): Multi Stage Flash.
MW: 1 megawatt = 1,000,000 watts (W).

N

Na: Sodium
NGOs: Non-government Organisations.
NO_3: Nitrate.

P

P: Potassium.
Per capita GNP: Annual gross national product (GNP) of a country divided by its total population.
pH: A measure of acidity or alkalinity in water. >7, indicating alkaline state; if <7, indicating acid state.
p.m.: Post meridiem (after noon).
PO_4: Phosphate.
PPF: Public/Private Finance.
ppm: Parts per million. Unit of measurement typically used to define low concentrations of chemical elements and compounds. Parts per million = 1 milligram per litres (mgl^{-1}).

Q

QEWC: Qatar Electricity and Water Company.
QGEWC: Qatar General Electricity and Water Corporation.
QGPC: Qatar General Petroleum Corporation.

QR: Qatar Riyal = 100 Dirhams. Exchange rate: QR3.64 = $1.

R

RAA: Ras Abu Abboud Desalination Plant.
RAF: Ras Abu Funtas Desalination Plant.
RO (desalination): Reverse Osmosis.

S

SO_4: Sulphate.

T

tf^3: Trillion cubic feet
Ton: 1 ton = 1,016.046 909 kilograms (kg)
= 2,240 Pounds (bls)
TSE: Treated Sewage Effluent.

U

UAE: The United Arab Emirates.
UK: The United Kingdom.
UN: The United Nations.
UNDP: The United Nations Development Programme.
USA: The United States of America.
USSR: The Union of Soviet Socialist Republics.

W

WHO: World Health Organisation.

APPENDIX SIXTEEN:

GLOSSARY

Glossary*

A

Agenda 21: A blueprint for sustainable development into the 21st Century. Its basis was agreed during the "Earth Summit" at Rio in 1992, and signed by 179 Heads of State and Government.

Amir: The ruler of the State of Qatar.

Anencephaly: It is a maldevelopment of the brain skull which occurs in the first weeks of pregnancy. The upper part of the brain and the overlying skull cap are absent although the lower part of the brain and the base of the skull do develop to some extent.

Aquifer: A layer of rock, which holds water and allows water to percolate through it.

Arid: Dry, parched climate and the average annual rainfall is less than 250 mm with very high evaporation rates.

B

Blank flange: A solid disc used to dead a companion flange and close a pipeline.

Borehole: A deep, narrow hole, especially one drilled into the earth to monitor or exploit water.

Brackish water: Slightly salty water, which usually contains 1,500 to 25,000 ppm of salt.

C

Chemical: Concentrations of certain substance and compounds in water.

Climate: The average weather conditions of a place or region throughout the seasons.

Conductivity: Specific electrical conductance measures the ability of a substance to conduct an electric current.

D

Dam: An engineered barrier constructed to hold back water and raise its level, forming a reservoir or preventing flooding.

Demand management: Policies to reduce the Quantity of water that users choose to consume.

Depletion: The progressive withdrawal of water from surface or groundwater reservoirs at a rate greater than that replenishment.

Depression: Low-lying land.

Desalination: The removal of dissolved salts from brackish, saline or seawater from 3.5% to 0.05% or less.

Desert: A widespread sandy plain, with an arid climate and largely waterless, treeless and uncultivated.

Desertification: Conversion of rangeland, rain-fed cropland, or irrigated cropland to

* The glossary is from different sources, including Nelson & Nelson (1973); Moore (1979); Twort *et al.* (1985); Gray (1994); Gabler *et al.* (1994); Makins *et al.* (1998); Merrett (1997); Miller (1992).

desertlike land, with a drop in agricultural productivity of 10% or more. It is usually caused by a combination of overgrazing, soil erosion, prolonged drought, and climate change.

Domestic Hydrological Measurements: The amount and time of water consumed per capita for different proposes.

Drip irrigation: Using small tubes or pipes to deliver small amounts of irrigation water to the roots of plants.

Dug well: A well put down by manual labour; only picks and shovels are used.

E

Economy: System of production, distribution, and consumption of economic goods.

Element: Chemical, such as iron (Fe), whose distinctly different atoms serve as the basic building of all matter. There are 92 naturally occurring elements. Another 15 have been made in laboratories. Two or more elements combine to form compounds that make up most of the world's matter.

Energy: Capacity to do work by performing mechanical, physical, chemical, or electrical tasks or to cause a heat transfer between two objects at different temperatures.

Environment: All external conditions and factors, living and nonliving (chemicals and energy), that affect an organism or other specified system.

Evaporation: The transformation of water into a vapour.

F

Fertiliser: Natural or chemical substance, such as manure, added to soil to increase its productivity.

Formation: A series of rocks of a particular structure or shape.

Fossil groundwater: *A deep aquifer formed in prehistoric times and no longer* receiving a significant recharge.

G

Gaia hypothesis: The idea is that we may have discovered a living being bigger, more ancient, and more complex than anything from our wildest dream.

Groundwater: Water found within the soil as well as in the loose rock and bedrock below.

Groundwater discharge: Discharge of water from zone of saturation into bodies of surface water or upon the land.

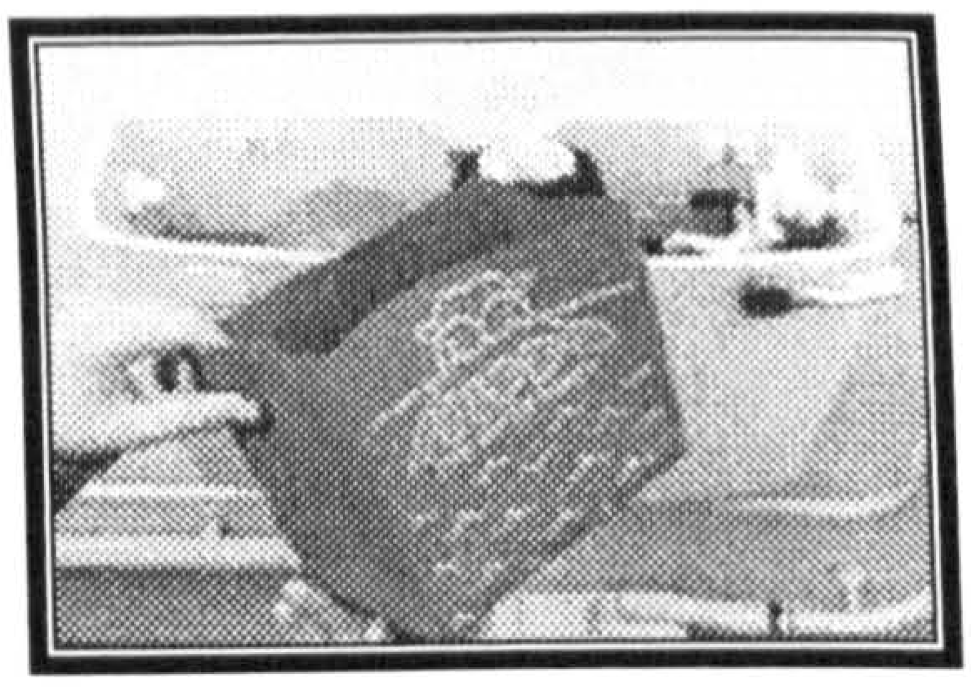
Groundwater over-pumping: The excess of groundwater abstraction over long-term recharge.

Groundwater recharge: The recharge or replenishment of water in the zone of saturation.

H

Haemochromatosis: It is an inherited disease in which the body takes in from food more iron that needs.

Hippo Bag: It happily sits in the water underneath the large cistern float. When the toilet is flushed, the water confined within the hippo is the volume saved. It will save on average 3 litres of water every time a toilet is flushed.



Holistic: The view that a whole is greater than the sum of its part.

Hydrology: The science encompassing the behaviour of water as it occurs in the atmosphere, on the surface of the ground, and underground.

I

Immigration: Migration of people out of one country or area to take up permanent residence in another country or area.

Infiltration: The slow movement of water through, or into, the pores or interstices of a soil or other mass.

Irrigation: Spraying or causing water to flow over arable land for farming and to benefit crops.

M

Management: The technique or practice of managing or controlling.

Mesa: Table-like upland, which falls away steeply on all sides; the word in Spanish means table.

N

Natural gas: Underground deposits of gases consisting of 50% to 90% by weight methane gas (CH_4) and small amounts of heavier gaseous hydrocarbon compounds such as Propane (C_3H_8) and Butane (C_4H_{10}).

Natural recharge: Neutral replenishment of an aquifer by precipitation, which percolates downward through soil and rock.

O

Oil: Gooey liquid consisting mostly of hydrocarbon compounds and small amounts of compounds containing oxygen, sulphur and nitrogen. Extracted from underground accumulations, it is sent to oil refineries, where it is converted into heating oil, diesel fuel, gasoline, tar and other materials.

Overdraft: Applied to a well from which the water pumped out exceeds the rate of replenishment from the outcropping parts of the aquifer; such practices lead to the eventual depletion of the resource.

Over-pumping: See Overdraft.

P

Policy: A choice of action based upon desired and actual system behaviour.

Population: Group of individual organisms of the same species living within a particular area.

R

Recharge well: An inverted well which conducts surface water into an aquifer at shallow or moderate depth.

Recycling: Treating effluent water so that it can be used again.

Resource: Anything obtained from the living and nonliving environment to meet human needs and wants.

Reuse: To use a product over and over again in the same form

Runoff: Freshwater from precipitation and melting ice that flows on the earth's surface into nearby streams, lakes, wetlands and reservoir.

S

Sabkha: An Arabic term applied to an inland or coastal saline flat.

Safe yield: The economic yield of a well.

Salinity: Amount of various salts dissolved in a given volume of water.

Sea: A continuous body of salt water.

Sewage: The discharge from sanitary appliances attached to domestic, industrial, or other buildings. It flows down a drain connected to a public sewer or sometimes to a septic tank.

Shallow groundwater: Near surface groundwater.

Solar energy: Electromagnetic energy produced by the Sun.

Strategy: The art of planning an activity.

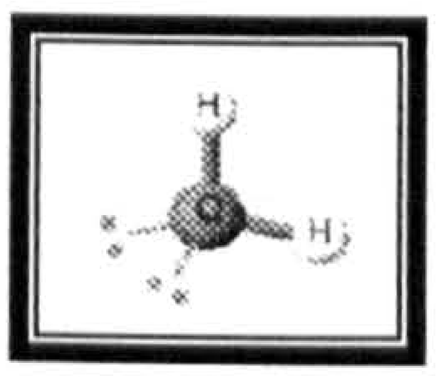
Surface water: General term for any water body, which is found flowing or standing on the surface such as rivers or lakes.

T

Technology: Creation of new products and processes that are supposed to improve our survival, comfort and quality of life.

W

Water: H_2O chemically pure water consists of hydrogen and oxygen combined in the ratio of about eight parts of oxygen to one part of hydrogen.



Water balance: An accounting of the inflow to, outflow from, and storage in, a hydrologic unit, such as a drainage basin, aquifer, soil zone, lake, reservoir, or irrigation project.

Water consumption: The amount of water consumed in a specified area.

Water demand: A Schedule of the total quantity of water required for a specific purpose such as household, industry and agriculture.

Water harvesting: Collecting and storing water from areas, which have been specially treated to increase the runoff.

Water management: Water development for drinking water supply, irrigation, flood control etc.

Water pollution: Any physical or chemical change in surface water or groundwater that can harm living organisms or make water until for certain uses.

Water quality: The relative ability of the water to satisfy a particular need.

Water resources: Traditional water resources such as rainfall, surface water, groundwater or non-traditional such as desalination.

Water supply: The conserving, pumping, treatment and piping of water, usually by a public authority to consumers.

Water table: The surface of the groundwater, or the surface below which the pores of a rock are saturated with water.

Water tariff: A charge made by a water authority for supply and use of water.

Water treatment: The mechanical, chemical and biological processes that raise the quality of freshwater and wastewater.

Well: An Underground source of water which has been rendered accessible by the drilling or digging of a hole from ground level to the water table.

Withdrawal: The water removed from the ground or diverted from a stream or lake for use.

Y

Yield, Aquifer: The maximum rate at which an aquifer can be pumped without reducing the hydraulic head to an unacceptable level.

Yield, Well: The maximum rate a well can be pumped without lowering the water level in it.