Development of a Sustainable Water Management Strategy in the Alwahat area of Libya

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Copyright Statement

Abstract

Groundwater in the Alwahat region of Libya is a non-renewable resource, and is the only source of water for agricultural land in the region. The aim of this research is to explore the contemporary performance of the groundwater sector in Libya and to develop a strategy for providing a sustainable groundwater resource to achieve a social, economic and environmentally-sustainable water future. Perceptions about groundwater sustainability are elicited from 769 local stakeholders. This analysis is conducted using a triangulated mixed-methods design, to interpret the collected information. Conflicts of opinion among the stakeholders are exposed, highlighting controversies concerning their levels of satisfaction with water supplies, their awareness of water sustainability issues, their understanding of recent changes in groundwater quality and the environmental impact of water use, and future solutions to prevent water misuse.

In addition to this, there is an examination of what officials report as the extensive misuse of water due to the installation of pumps, and some of the farmers abstracting drinking water from the network for irrigations well as digging deeper into the ground and sinking more wells, which abstracts excessive amounts of water and lowers the groundwater level. The known reasons of groundwater contamination discussed in this study include oil operations, increased salinity in water soil infiltration, and crop fertilization which is established by reliable sources; however no contemporary quantitative or qualitative monitoring data is available. The majority of the farmers, domestic users, and officials agree that the environment around Alwahat is adversely affected by oil company activities.

Education, training, and guidance are encouraged by all the stakeholders as a solution to prevent water misuse. In effect, farmers resort to changing their crop types and the metering of wells to conserve water; but, the government officials disagree. The hydrologist's solution

is to stop the expansion of the farms. Penalties for excessive water were introduced, but increasing the price of water was not popular among domestic consumers.

The findings make the following recommendations: (a) Stakeholders should adopt the principles of the Dublin statement, recognizing a holistic approach to sustainable water, linking local, social and economic issues with ecosystem protection; (b) The Libyan Government should develop a sustainable water strategy with long-term ambitions; (c) Further efforts from water legislators to clarify regulations and their implementation; (d) Long-term quantitative and qualitative monitoring of local groundwater resources, and the formulation and use of integrated models to support future water management. (e) A pricing structure to be implemented, using a water tariff system for domestic, agricultural, and industrial users.

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Chapter 1: Introduction

1.1 Background of the study

Water covers two thirds of the earth's surface, but 97 per cent of it is unfit for human use. Of the remaining three per cent, two thirds are locked up in glaciers and snow, which leaves only 1% available for human consumption (Serageldin, 1995). This residual amount should be enough to satisfy the needs of all water consumers in the world, but this is not the case (Omer, 2002). The reasons for this are related to temporal and geographical variation in rainfall. Human misconduct and waste of available water resources have complicated matters further. Little can be done to overcome the first barrier, however with suitable and sensible water management we can rectify the second obstacle through the development and adoption of sustainable water management strategies.

Sustainable water strategies and their utilisation are of concern because of their socio-economic impact on society. Sustainable development reconciles society's developmental objectives with its environmental limits over the long term. It works to balance the real conflicts between economy and environment and between the present and the future (National Academy Press, 1999). The strategy specifically identifies water as an example of a non-renewable resource, which "should be used in ways that do not endanger the resource or cause serious damage or pollution" (Benoit & Comeau, 2005).

The region of interest for the current project lies in a geographical area which shares its climate with that which prevails in most of the desert section north of the African continent. The Mediterranean Basin, by virtue of its' geographical location and physical setting, does not receive adequate precipitation in most of its surface area. The demand for water is relatively high due to the warm climate prevailing during much of the year. Demand also keeps increasing with time as a result of the high growth rate of the population. Since the surface water resources of many arid countries are limited, and the management of these sources is still incomplete, there is a growing need to fulfil some part of the demand from groundwater resources. Experience has shown that groundwater abstraction requires certain precautions to be undertaken in order to safeguard the quality of the abstracted water. Furthermore, the quality of the water also needs to be considered besides the quantity of available water deterioration of water quality is often slow. Therefore it is often undiscovered until sometime has elapsed (Shiklomanov, 1993).

The available water sources throughout the world are becoming depleted and this problem is aggravated by the rate at which populations are increasing, especially in developing countries (Algharíani, 2003). In addition to the threat of increasing population, water resources are endangered by diminishing water quality caused by pollution, reduced quantity caused by over-exploitation and the increase in water demand for agricultural use (Engleman & Leory, 1993).

Libya experiences scarcity of water due to its arid location (Pastel *et al.*, 1996). Population growth and rising income, coupled with rapid urbanization, assure the continued steep increase in the demand for water for irrigation, industrial and municipal uses (Shaffer *et al.*, 2004). In many parts of the region, demand for water is placing considerable pressure on existing supplies, stimulating mounting interest in finding new sources of water. Usually, developing these sources requires large investment in dams, canals and other infrastructures, resulting in relatively high per-unit costs (Edmunds & Droubi, 1997, p.503–581). The expected rises in costs of new sources of water suggest that strategies and technologies to encourage more efficient use of existing supplies need to be adopted. The conditions for achieving increased efficiency, while not well understood, are necessary steps towards developing water management strategies offering an alternative to the development of new water resources. Investigations and reviews of the water resources situation and management practices in Alwahat, Libya by hydro-geologists (Dorman, 2009) led to the conclusion that significant weaknesses and problems exist in its water management policies and strategies. As a major producer of dates in Libya, Alwahat is totally dependent on irrigation for the development of its agriculture. Groundwater deterioration occurs in various forms, namely, pollution and excessive drawdown. Due to the low travel velocity of groundwater from the south region to the north towards Alwahat, depletion may not be detected immediately and when detected, rehabilitation may either be impossible or very costly (Abdu el Gelil, 1996).

Therefore, monitoring is one essential activity in the process of groundwater protection. Monitoring of groundwater should be carried out by utilising in a strategy of integrated systems rather than simple networks (Salem, 1991). Important tools in this process are databases, geographic information systems, and numerical models. There is evidence that the groundwater table in Alwahat is declining at rates such that the economic life of the region's principal aquifer could be seriously threatened. It has been noted that there is "limited opportunity of extending the life time of the water transport system beyond 50 years" (Ghamim & Mohamed, 1999).

As the entire region's economy depends on irrigated agriculture, this situation poses a threat to living in the area (Dorman, 2009). In Alwahat, the current pattern of water usage does not fully reflect the shift from water abundance to scarcity. Government policies fail to take into consideration issues surrounding excessive water usage. Furthermore, farmers are also ignorant of the issue of water scarcity (Pallas & Omer, 1999). Therefore, there is a need for the establishment of sustainable water management strategies that need in the Alwahat region of Libya.

1.1.1 Research Focus

The current research explores the dimensions of the emerging water scarcity in Alwahat by examining water sustainability and the institutional factors influencing present patterns of water use. Water use in Libya is considered in terms of sustainability factors, that is, the economic, social and environmental impact of stakeholders. The aim of this research is to explore the contemporary performance of the groundwater sector in Libya and to develop a strategy for providing a sustainable groundwater resource to achieve a social, economic and environmentally-sustainable water future. This research demonstrates the potential value of water management strategies to contribute towards the sustainability of groundwater supplies in Alwahat, Libya.

Expected rises in the costs of new sources of water suggest that policies and technologies to encourage more efficient use of already developed supplies need to be put in place. The conditions for achieving increased efficiency are not well understood, however, investigation of the conditions is a necessary step toward developing efficiency as an important policy alternative to new development. Investigations and reviews of the water resources situation and of management practices in Alwahat, Libya by Dorman (2009), led to the conclusion that significant weaknesses and problems exist in its water management policies and strategies.

Considering this scarcity, the Great Manmade River Project (GMMR), brings water from large aquifers under the Sahara to coastal cities (Kuwairi, 2004). The GMMR indicates the serious commitment on the part of Libya to overcome water scarcity through the construction of a vast network of pipes, wells and pumping stations which transfer water from Libya's main underground fossil aquifers in its remote, arid south, to the coastal urban concentration (Wheid *et al.,* 2006). “However there are likely to be a number of challenges as a result of this being such a large, trans-boundary aquifer” (Gill, 2011).

Since the aquifer is a “common-pool resource” -i.e. where no single country owns the resource- those countries that share this resource have no motivation to use water efficiently and conserve it for the future (Alghariani, 1999). Thus mere self-interest of individual countries could lead to overexploiting the resources. Where the shared aquifers are non-renewable, or when the renewal rate is much less than that of withdrawal, the increasing drain on this resource will eventually lead to the depletion of the aquifer and water quality deterioration (Alghraiani, 1997).

Over the coming years, there are expected to be a number of factors that lead to a growing demand for water (Gill, 2011). The following statement by Gill concisely summarises the main issues surrounding water management in North Africa, of which Alwahat is a part:

> An increase in population, rising temperatures, increasing saltwater intrusion in coastal aquifers, and food insecurity could all lead to growing demand for fresh-water for drinking and irrigation. (Gill, 2011).

Later in this thesis, these issues are identified within the study area and potential solutions are proposed. The sustainability of this valuable water resource depends on the peaceful cooperation of the countries involved and their formulating strategic and managerial guidelines (Alghraiani, 1997).

1.1.1 Justification for the Research

The rationale for this research project is rooted in the growing awareness of increasing demand for freshwater, while fossil groundwater supply is limited. Fossil groundwater supplies were created during ancient climatic conditions and are not renewable under current conditions. Edmunds & White (1979, p.215–241) have said that fossil water must be used responsibly because, “This is a legacy from the past and one has to use it with great care in order to safeguard it for future generations.” The water-supply situation has become more critical with the rapidly-increasing population and low rainfall. Consequently, soon after the discovery of fresh groundwater in the desert of southern Libya, the government implemented the Great Manmade River Project to sustain the economy. The G M MR P transfers groundwater by pumping it from aquifers in the southern desert region, where it is transferred in huge concrete pipes under gravitational effects to the regions of northern coastal area. Libya subsidises the project financially for agricultural development (70 per cent) as well as domestic (27 per cent) and industrial use (3 per cent). Therefore, this is a complex problem due to the combination of water scarcity, non-renewable water and lack of awareness by the stakeholders. The objective of this study is to investigate the barriers to sustainable water management in the region in order to provide a strategy which contributes to safe water for the future.

The agricultural sector's need for water is greater than the amount available for use. The Libyan Authority began to design and install the hydraulic infrastructure needed to withdraw and transport this fossil water to various demand sites along the coast where most of the population lives. This water is used to meet the demands of irrigation use in order to sustain the self sufficiency of the country in regards to its food supply (Salem, 1996). Rapid development of agricultural activity and expansion of irrigated areas has led to more depletion of water resources, since most of the country's groundwater resources are non-renewable. The supply-driven approach to water management has led to an inability to deliver a substantial degree of water sustainability at the national Libyan level (Salem, 2007). Despite the strenuous efforts made by the country, it still faces serious water deficits, owing to ever--increasing water demands which are well and beyond the available supply of water. After what was mentioned above, we can recognise the current problems in Libya's water resource management, and aims to address this issue by assessing the sustainability of its water resources and by proposing water management strategies.

Previous studies have reviewed the water situation and management practices among the different stakeholders in Libya, and have identified that significant problems exist in water management policies and strategies for implementing these policies. These problems include:

- Levels of groundwater have fallen, making it difficult and costly to abstract (Custodio, 1992).
- The continuing shortage of rainwater and over-exploitation of groundwater in Libya (Zidan, 2007).
- Limited public awareness of water issues as well as a lack of public participation in decision-making in water sectors and social fabric (Salem, 1996).
- Deficiency in legislation and institutional coordination (OSS, 2007).
- Water level decline in a number of areas that seriously threatens the continuation of farming for the future as well as sea water intrusion which undermines the groundwater water quality (Alsadik *et al.*, 2002).
- Continuing saline intrusion due to excessive groundwater abstraction (Salem, 2007).
- Limited development of wastewater re-use technology (Salem, 2007).
- Oil companies contributing to pollution of the aquifer system by dumping oil waste. (Ayesha, 1999).

These interrelated problems will all have an impact on the water situation in Libya that will be visible in the near future. This study therefore aims to investigate these problems before it is too late to act. Further justification for this research is to draw attention to these problems as well as propose strategies that can maintain the water sustainability for future generations. The following chapter (which comprises the literature review) includes more in-depth discussion of these factors and identifies challenges that threaten the existence of water, which is a limited and non-renewable resource.

1.2 Research Aim

The broad aim of this research is to explore the contemporary performance of the groundwater sector in Libya and to develop a strategy for providing a sustainable groundwater resource to achieve an economically, socially and environmentally sustainable water future. This aim is described in more detail in the following sections, which outline the research questions and their objectives, as well as the research design along with the proposed contribution to the knowledge base.

1.2.1 Research Questions

Given the variety of problems identified in the previous section, a set of focused research questions guide the current study. The research questions are based on the identification of stakeholders (i.e. those people and organisations that have some influence upon and in Libya's water management strategy) as follows:

Q1. What do the stakeholders use water for and how much is used for different purposes?

Q2. Are the stakeholders satisfied with their current water supply situation?

Q3.Are the stakeholders aware of any issues associated with water sustainability?

Q4. Has there been a decline in the level of available groundwater?

Q5. Has the water quality deteriorated?

Q6. What is the environmental impact of water use?

Q7. What is the issue associated with the disposal/re-cycling of wastewater (sewage)?

Q8. Do the stakeholders have any solutions to prevent misuse of water?

1.2.2 Objectives

The objectives of this research are:

(1) To identify the current water supply and demand in Alwahat, Libya.

(2) To identify who are the main users of water in the Alwahat area of Libya and assess the effect of this water usage upon the groundwater level.

(3) To collect information from multiple sources to address the eight research questions.

(4) To determine how the triangulated information might be applied in practice to contribute towards the development of a sustainable water management strategy in the Alwahat study area.

1.2.3 **Proposed contribution to knowledge**

This study aims to make a contribution to knowledge in the following ways:

1. To contribute to the understanding of the development of sustainable water practice in Libya by presenting an empirical and analytical study. This in turn will expand the literature in relation to water usage and development in semi-arid countries.

2. To raise awareness of the importance of demand management, and provide a better understanding of how sustainable water development can be managed effectively, through realising and promoting the importance of a systematic approach and supporting of related demand management.

3. To consider strategies for sustainable water management in order to alleviate water shortage and abate water pollution.

Thesis Structure

The thesis is divided into six chapters, and its structure is illustrated in Figure 1. Following the figure is a brief summary of the contents of each chapter.

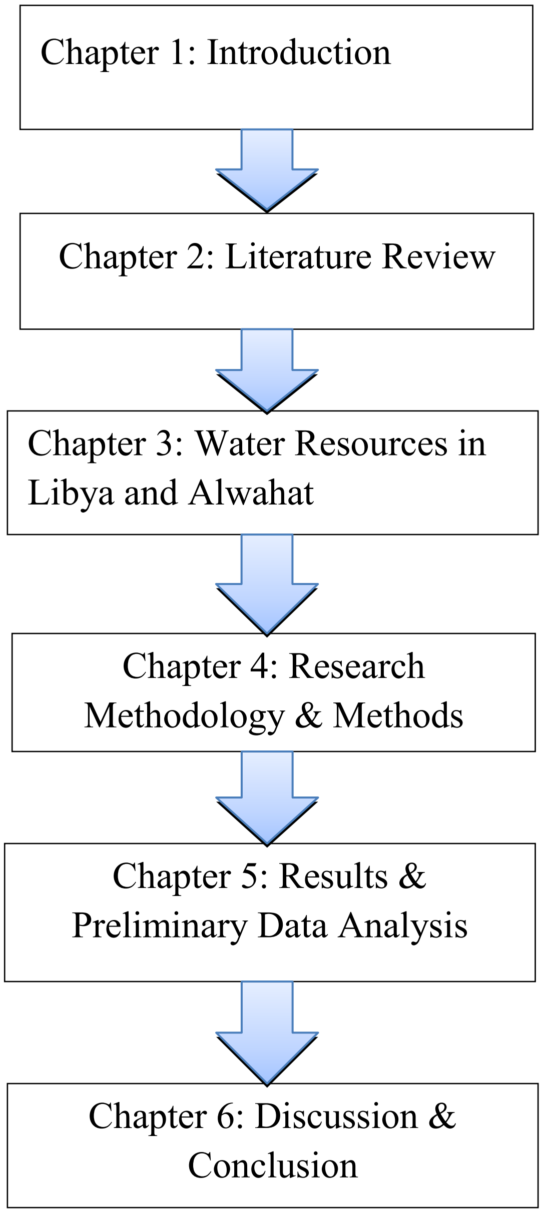

Figure 1: Thesis structure.

The present chapter outlines the justification and importance of the research to develop a sustainable water management strategy in Libya. It also outlines the research aim, objectives, research methodology, contribution to knowledge and the thesis structure.

Chapter 2 comprises the literature review, which highlights that water scarcity is closely associated with geographical, seasonal and inter-annual variability factors. Thus it is imperative to manage and sustain the available water resources properly through all existing means, such as constructing dams, educating the population to use water efficiently and establishing organised government policies to maximize water availability. This chapter discusses the problems of unbalanced water allocation that can be overcome through efficient water management. This is then also classified into three main categories (functional, comprehensive, and integrated). There are studies that challenge the behaviour and changes of the stakeholders through legislative, operational, and informal arrangements. Another important theme of the literature review is the land use planning and management. These studies guide the policy makers to evaluate a strategy to match water withdrawal demand and ecological water demand by analysing inter-basin water transfer.

Chapter 3 includes the water resource situation in Libya and in particular the focus is the Alwahat study area. The study investigates the current water state in Libya, in terms of the available groundwater, surface water and the Great Man Made River project. Included in this chapter are also reviews of the current stakeholders (municipal and farms water use and oil companies) and their methods of managing the water in the region and the issues related to the geological and hydrological study of Alwahat, and the impacts the stakeholders have on the water in the region .

Chapter 4 deals with the research design and the methodology, and discusses the procedures used to conduct the research. It includes issues centred on the reliability and validity of the result with ethical considerations. There is also discussion on the data collection methods, sampling procedures-which include questionnaires and interviews, a water diary and focus group outlines the significance of the study.

Chapter 5 deals with the results and preliminary data analysis, and presents the stakeholder analysis strategy which aims to analyse both the quantitative and qualitative data. The results of this study are presented systematically in an eight section table related to the eight research questions, to provide a visual analysis to compare and contrast the stakeholders' views.

Finally, Chapter 6 includes a discussion of the results and an evaluation of the research methods and findings. The evaluation includes a discussion of the limitations of the research methods, provides a concise description of the results as well as their implications for the field, and presents potential strategies for implementing the proposed policies.

Chapter 2: Literature Review

2.1 Introduction

Water scarcity is the result of growing human demands on limited water resources. Water scarcity on a regional scale has the potential for conflicts at different levels (Fisher, 1995). Three sources of conflict are easily identified: 1) problems due to water availability and conflict between its uses by competing sectors, 2) conflicts because of trends of land use development and 3) problems arising due to impacts on environmental and ecological levels. Water scarcity is one of the current dangers threatening the development of today's human communities. It has led decision-makers to seek alternative advanced and optimum measures for the efficient use of the limited quantity of water (UN/WWAP, 2003). It is therefore imperative to develop better and more precise strategies for water resources management to meet the day-to-day demands of the stakeholder.

Rapid population growth and industrialisation have placed pressures on increasingly scarce water resources. Currently, more than 470 million people in Africa, Asia, and the Middle East live in water-stressed conditions, and this number is expected to increase to more than three billion by the year 2026. A good example of this fact is the tension over water reserves in all the major river basins of Africa due to rapid population growth. Lack of sufficient water is a crucial barrier to food self-sufficiency for many countries as reported by the Environment and Energy Study Institute (EESI, 1999).

The United Nations Environment Programme (1999) has identified that Water scarcity entails increasing competition between different sectors of users and as a result, has a great economic impact. The mounting competition between water users and water sectors is manifested in many complex trends. For instance, urban and agricultural sectors have undergone great changes in recent decades with the adoption of demand management measures. This strenuous interaction between different water sectors, water users, and the resulting changes in regional water resource management has yielded a range of options that are intended to reliably stretch the supplies of available water to meet the required needs of the stakeholders (Kite, 2001). The stewards of water resources have made planning for water supply and demand easier by involving structural, operational, and economical resolutions, initiatives, and solutions to improve water supply and demand management in a holistic manner.

2.2 Water Availability

Among the planet's valuable resources, and despite its relative abundance, water cannot be considered as a limitless resource. Given the cumulative influences of growing population with associated contemporary consumer lifestyles, human destruction of natural habitats, rising environmental pollution, intensive and unsustainable use of land, and the consequences arising from climate change, some form of management is necessary for the future. The factors mentioned above, linked with water availability variations, both temporally and spatially, i.e. seasonal and annual variability, and geographical distribution, along with the fact of water being of a non-renewable and limited nature, have meant that water available for human use is becoming more scarce over time (Rijsberman & Mohammed, 2003; United Nations, 2003). This has had a significant impact on water use patterns and the activity of human populations.

2.2.1 Limits of water availability

The limits associated with the availability of water have been discussed on various levels. Indeed, the vital importance attached to water, as well as its limited nature is the basis of one of the water management principles expressed in the Dublin Statement (ICWE, 1992): “Freshwater is a finite and vulnerable resource, essential to sustain life, development, and the environment”. This principle highlights that the limitation and vulnerability associated with water encourages an approach that is holistic. This necessitates that protection of the ecosystem is linked to economic and social measures that are adopted broadly to span the groundwater aquifer or the area in question. Such an approach has required innovative strategies to cope with water availability; but limits imposed by biophysical factors were an obstacle to implementing such strategies, and so water resources scarcity remains an unresolved issue (Hunt, 2004). The availability of water is also restricted given the need for quality (Fry, 2005), where poor quality water is unusable. Therefore, implementing water pollution prevention measures are the first choice to protect such a precious resource. In this context, pesticides and fertilizers used in agriculture should not be overused as pesticides could pollute water sources through runoff from fields (Selborne, 2000, p.11). Therefore, the water industry should take account of the existing local socio-economic conditions and supply availability, along with local ecosystems, where water in quality and quantity must be protected, and decision making benefit from participation of local communities (Selborne, 2000, p.14). On the level of domestic dwellings, water use must be guided by best practice, building sufficient awareness, and fostering positive attitudes aimed at achieving reductions in water consumption, and minimal pollution, if at all.

2.2.2 Geographical variability

The availability of water varies quite significantly across the world, from country to country, and from one region to another. This variation dictates the diversity in flora and fauna, and food availability across these areas, as well as the potential for human settlement. Other factors underlying water availability are the inhabitants’ culture, water demand and supply patterns, the biophysical nature, and local geography. These factors are also reasonably time-variant, and may develop and change over different periods of an area, which again contributes to the evolving dynamic of water availability, consumption and its influence on human habitation (Hassan, 2004). The adoption of technology to solve the problems of water supply, e.g. drilling deep well boreholes and diverting water courses, over the course of the previous century, has meant that human population could settle more or less anywhere, without being affected by water resource variability in the geographical area. Hence, urban areas have developed, and crops have been cultivated in dry and semi-dry areas. Yet, the existence of technology has not made human settlements immune to the variability in water availability, especially over long periods of time, which crucially dictates that, crucially, local area conditions have to be considered in solving water-related issues.

2.2.3 Seasonal variability

As was mentioned previously, the variation in the availability of water is also linked to time, where water supply and also demand do vary over the course of a year. This variation is the result of multiple influences, like the water supply network design and human consumption (anthropogenic factors) and seasonal variations in climate (natural phenomena). Hence, water management considers such variations to prepare for times when water supply is reduced in the face of unchanged or higher demand at particular times in a year.

2.2.4 Inter-annual variability and climate change

The issue of water availability is not only one that varies annually, but also from year to year and over the longer term. Anthropogenic factors, such as changing population size and lifestyle, and including economic development along with natural factors, i.e. climate change, pose a challenge for long term planning associated with water security, as consequences are far-reaching. This impacts directly on the feasibility of urban settlements and protection of ecosystems, where measures for protection and conservation of varying and finite water sources must be taken to prevent pollution or excessive use.

This represents the basis on which the ethical approach to water management is founded. Otherwise, water management would not be governed by any rules or ethics, resulting with disastrous effect. For example, in the presence of abundant water, water distribution need not be on the basis of ensuring fairness; however, this scenario is not reflected in reality across the world, or in time due to climate change. Water as a common-pool resource is, typically, not subject to the clear boundaries imposed politically or administratively, and remains a shared resource on which the many, (i.e. people, species, ecosystems, etc.), depend upon for their survival. Since the basic question is one of survival, water management must effectively ensure fair distribution to all, in terms of quantity as well as quality, to include users upstream and downstream of a water flow. In this light, water management is no longer a local issue, but may extend beyond national jurisdictions, and is inclusive of all species and ecosystems. This particular context is highlighted in the report by the UN World Water Development body, entitled “Water for People, Water for Life” (United Nations, 2003a), where water is identified as being shared both by users and by use. The former relates to political and administrative entities (state, national or international), while the latter relates to diverse uses each requiring a share (urban use, energy purposes, environmental). Therefore, water must be managed to enable fair sharing between users as well as between boundaries.

2.2.5 Distribution between users

The vital importance of water to life, and hence shared by many, means that regardless of its origin, underground or on the surface, it may be termed, a “common-pool resource” (Ostrom *et al.*, 1999, p.278). This term describes those resources, man-made or natural, which regardless of who holds the rights to their ownership, cannot be denied to others, actual or potential; indeed, on the basis of the “subtractability” concept, one party may actually exhaust this resource single-handedly. Such common-pool resources may be renewable or non-renewable (Ostrom *et al.*, 1999, p.279). This is applicable to water, which is considered a common-pool resource that one community or more shares for their common good. The common good principle is defined as “the social conditions that allow people to reach their full potential” (Priscoli *et al.*, 2004, p.16). Indeed, this principle is inclusive of access to water, as a key element in enabling humans to realise their full potential and exercise their dignity. Therefore, in the context of the common good, water must be exempt from control by market forces, and allocated according to environmental needs (Hillman, 2004). This is founded on the idea of sharing for the community’s common good, whether local or not, and applicable to all species. These concepts, i.e. water as a common-pool resource and the principle of common good, form the proper foundation for the management of water use; but these very same two principles also hold the potential for conflict. Therefore, theorists, such as Ostrom and others, proposed rules governing access, rights, and responsibilities to ensure equitable and appropriate use, minimising negative outcomes, and facilitating maintenance and improvement of the common-pool resource (Ostrom *et al.*, 1999, p.279) to avoid the well-known “tragedy of the commons” (Hardin, 1968,p.1243–1248). Management of any common-pool resource requires restricted access and the presence of sufficient incentives, and with the formulation supervision and enforcement of appropriate rules and consequent punishment for misuse. Moreover, access to the common-pool resource must be regulated in terms of quantity and time under a formal regime of monitoring (Ostrom *et al.* 1999).

The participation of stakeholders is enhanced by granting a degree of autonomy, in terms of defining suitable rules by them, but always under the provision that the long-term sustainability of the resource must have priority to maximise benefits and minimise losses. In addition, the resource must be properly understood in terms of the different users’ interests and the effect of the interaction of these interests as well as the functioning of the resource system itself (Ostrom *et al.* 1999). This results in decisions being made locally on an informed basis, which supports the effective management of the common-pool resource. The overriding principle governing any decision-making framework relating to a common-pool resource is fairness, which ensures the absence of conflict even in times of resource scarcity. The practice of justice, in consequential and procedural forms, is key to assuring amicable rather than conflictive relationships over the sharing of water. The process of deciding the individual shares must be fair, and be seen to be fair by all parties involved for solutions to be equitable, especially in light of the fact that it is common for shares to be unequal (Stone 2002). Among all common-pool resources, water occupies a distinct place, which complicates the process of assigning ownership titles. This is because water is: 1. A basic necessity to maintain life (humans and the environment have priority); 2. a flowing resource, and so ownership rights are very likely shared, and unlikely to be assigned to one entity or individual (hence, interaction exists between upstream and downstream); 3. an issue at the local level, and is traded locally from rivers or man-made distribution networks; 4.variable in nature, with no possible manner of guaranteeing certainty in the matter of transferable rights without great cost and considerable difficulty (Shen, 2003). This imposes conditions on water management regimes, where these need to be designed to be decentralised, fair, based on cooperation, and adaptable.

2.2.6 Distribution across boundaries

The common-pool resource nature of water is a complicating factor in the relations of different entities across jurisdictions, whether political or administrative, and national or international, where typically water courses go beyond such boundaries (United Nations 2003a). This necessitates a high degree of cooperation in the management of water on a trans-national and possibly trans-regional basis to prevent a conflict over the shared surface or groundwater resource (Selborne 2000; Batz 2001), and in maintaining a healthy river environment (Postel and Richter 2003, p.6). Cooperation and preventing conflict in managing the shared water resource requires effective and timely flow of information among all stakeholders (Selborne, 2000). The attitude of upstream parties is especially important as they hold the privileged position of influencing those downstream, where pursuing their own agenda means conflicts will inevitably arise, concerning pollution, fisheries, etc. Guidance on how to negotiate issues between states over trans-boundary water resources is provided by the 1966 Helsinki Rules on the Uses of the Waters of International Rivers (International Law Association). These rules are founded on the principles that use by the individual parties is both equitable and reasonable. Basin states each hold the right to a share within their national boundary of an equitable and reasonable share in beneficial uses of international drainage basin waters (Article IV of International Water Law, in: ILA, 1967).

In practice, the terms, ‘equitable’, ‘reasonable’, and ‘beneficial use’ can only be defined on individual cases, bearing in mind various unique factors. Additionally, the Helsinki Rules and International Water Law do not explicitly take into account the well-being of the environment or future uses and users of that resource. Successfully achieving in the two tests of equity and reasonability, and ensuring sustainability on questions of trans-boundary waters requires institutions that are holistic and flexible, and capable of responding to the inevitable variations associated with the water resource, whether hydrological or socio-economic, as well as related to the values held by societies, and changes in political regimes (United Nations, 2003a, p.25).

2.3 Water Management

While in principle the total freshwater of the world could be enough for human needs, the natural allocation of the world’s freshwater is unbalanced. Thus, water management is needed to resolve this problem. Water resources management can be classified into three main categories: 1) functional, 2) comprehensive, and 3) integrated. *Functional water* management focuses on a single purpose and tries to identify the "best course of action" to meet the single management objective (Mulder *et al.*, 1979; Grigg, 1996; Thompson, 1999). In *comprehensive water* management, a wide range of water uses is incorporated into different management strategies. It is developed and embraced due to the belief or recognition of the fact that more than one management objective should and can be attained from the same water management project (Mulder *et al.*, 1979; Thompson, 1999). *Integrated water* management states that there are relationships between water users (Grigg, 1996; Thompson, 1999), and that, therefore, one water use can impact another. Integrated management considers the social, economic, and environmental impacts of these interrelationships. Which of these approaches is considered the most holistic is at issue.

There are many studies that have been conducted to address a holistic perspective of water management. Liu (1993) discusses the development of water management and the description of the concept of system complexity. Liu addresses the complexity issue in water management by developing an intelligent system named Delft Intelligent Supporting System in Water Management (DISSWAM). The system has two levels: the first level can answer the question regarding what the water management style does to the manager, and the second level is a modelling level that can answer questions on the roles of information flow and mathematical modelling.

Larson (2006) studies several aspects of water allocation and management issues in relation to agricultural practices. Larson considers issues such as comparison of behaviour replies of stakeholders to changeable policy methods and comparison of the effectiveness of marketing based on managing and sharing resources. This study demonstrates that some of the issues shaped by the legislative, operational, and informal arrangements are apt to change. Both formal and informal arrangements are being investigated by Larson, using various methodologies such as experimental economics, agent-based modelling and qualitative assessment techniques.

Mendelsohn and Bennett (1997) focus on two serious questions in water management: The first question is the allocation of water across users, and the second is the assessment of proposed water projects in light of available information about global warming. They focus on studying the sensitivity of benefits of alternative water allocation schemes, and they discuss whether there might be significant impacts on the expected values of other water allocation schemes if global warming shifts mean annual water supplies decline. The first part of their study focuses on how well alternative schemes perform if the distribution of flow changes, whereas the second part investigates the effect of a gradually-changing distribution of flows. Based on their research results, they conclude that most project analyses will be unaffected by global warming. The major response by water managers to climate change may simply be to closely monitor runoff and incorporate flexible rules to adapt their behaviour to environmental changes.

Arnell and Delaney (2006) study the way that water supply companies in England and Wales adapt to climate change. They find that public water supply in England and Wales is offered by private sector companies subject to environmental and economic rules. Their study results show that no specific actions were necessary to deal with future climate change.

The recent economic and political developments in Central Asia needed a new system of analyzing water management. McKinney and Cai (1996) focus on developing a new system of water management based on multi-objective optimization and water balance principles that can be used to evaluate the efficiency and sustainability of water use in the region. Their study results show that the model could be useful as a decision-making tool for water distribution planning that will be sustainable and helpful to local specialists.

Kiwan, Dorrah, and Huhmy (1994) investigate the problem of multi-objective optimization between hydropower generation and irrigation releases. Their results show that several trade-off curves for hydropower and irrigation uses could be developed and solved using the model.

2.3.1 Land Use Planning and Management

Commonly, the purpose of land use planning is to develop the “physical dimensions” of the study area; however, it should also take into account social and environmental concerns. To produce a reasonable unity between the environment and land use activities, one has to account for the underlying complexities that are associated with an optimum strategy (Loewe, 1979). Thus, the major objective of successful land use planning is to benefit both the public and the environment simultaneously (Leung, 1989).

Cai *et al.* (2004) state that the Yellow River Basin in China has water management problems due to land use changes and population growth. This basin is important to China in terms of food production, natural resources management, and socioeconomic development. This study was conducted to evaluate a strategy to match water withdrawal demand and ecological water demand in the Yellow River Basin by analysing inter-basin water transfer. Based on the results of this study, water use efficiency of the basin was increased, thus guaranteeing extra water availability through inter-basin water transfers for the next 25 years.

Wang (2001) addresses the relationships between land uses and river-water quality in the Little Miami River Watershed, Ohio. The needs of different federal and state agencies are integrated within a Geographic Information System (GIS). For this purpose, four different kinds of data are gathered which include water chemistry data using traditional sources of information, biological data in order to asses water quality, the data specific to pollution, and data on the discharge into the water from industrial facilities. The results show that water quality did not degrade significantly below the outfall of water treatment plants. Although significantly lower water quality is found in urban areas or close to the point of pollution sources, the author shows the importance of integrating water quality management and land use planning. Wang (2001) supports the idea that planners and policy makers should bring stakeholders together to alleviate the occurrence of pollution and to plan for a sustainable future.

Nehme and Simoes (1999) attempt to develop a mathematical tool for agricultural planning based on a professional system of land evaluation. This study includes two dimensions: the ecological dimension, which reflects the limitations and potentials for sustainable use of natural resources, and the economic dimension, which expresses the growth of the communities of the region. This information system has the potential to help decision-making and could be a powerful tool for land use planning and environmental management.

Each of the aforementioned examples shows the way in which environmental issues have been factors in the planning and legislative processes. Different land uses reflect different aspects of the environment; when one addresses the environment, land use and other activities are implicitly taken into account. Many other studies have adopted the same approach and they have shown that water supply can be successfully linked with land use planning systems (e.g. Lund, Jenkins, and Kalman, 1998; Shih and ReVelle, 1994; Wilchfort and Lund, 1997; Willis and Yeh, 1987).

2.3.2 Approaches to Water Management and Land Use Planning

There are two groups of researchers and managers who discuss the coordinated approach to water management and land use planning. The first group does not see resources (such as water) as a problem for growth, and they say that development is not dependant on water supply since a new infrastructure (i.e., a pipeline) can always be built (Villiers, 2000).The second group concludes that there is a relationship between growth and the capacity of the environment. In other words, growth should be limited by the capacity of the environment to provide services to a given area (Jacobs, 1993). In the second group, the assumption is made that each geographic area must have only the amount of development that can match the availability of services or resources. The two groups define a new understanding for the relationship between development and water resources, which lead them to develop specific characteristics of both integrated and sustainable management (Jacobs, 1993).

Child and Armour (1995) suggest that the integrated water resources management approach should attempt to incorporate multiple purposes and multiple means of achieving them and the blending of multiple sectors. The integrated water management approach tries to satisfy water demand and environmental concerns by balancing the water demands of all parties at the watershed scales and at the same time minimize the negative effects to the ecology of the watershed. In summary, the main goal for integrated management is to establish a balance between different resources and users. It is a strategy to coordinate the goals, interests, and shared goals of multiple stakeholders to narrow the gap between them and to find common ground in management practices (Margerum, 1999).

Rossi, Quay, and LaBiance (2005) present a GIS model that is helpful in developing a strategic water supply and water infrastructure master plan for Phoenix, Arizona, by testing the potential impacts of extra land use scenarios on water supply and water infrastructure needs. They use the GIS model to develop additional growth, populating, and employment estimates for each scenario from which the water demand and the locations for alternative structures could be projected.

Davis (2003) is interested in developing models that could be used in water resource planning in the state of California. The work focuses on developing a water-demand forecasting model. The author proposes a systematic methodology for forecasting municipal and industrial water demand throughout the state based on the analysis of available data. This study concludes that a water demand forecasting methodology should be a function of three primary criteria: planning objectives, available data, and available resources.

Jenkins, Lund and Howitt (2005) argue that the high population growth and the increase of competition for water to meet environment needs in California are producing severe strains on the current water resources and their management. They study the maximum water demands as the amount users would take if water were priced at its current level. Their work develops reasonable economic loss functions for urban water supply studies. The results also show that by using these economic loss functions, the estimated average annual cost to end-users of urban water scarcity in California in the year 2020 for operations, allocations, and infrastructure would be $1.6 billion per year.

Soler and Planes (1999) study the effect of price policy on water demand in the industrial, domestic, and residential sectors of Spain. They demonstrate that using policies based on economic concepts of demand elasticity to price variation only, without taking into account the consistency of this elasticity, will cause inefficiency in controlling the demand.

Lund (1995) focuses on developing a mathematical program to estimate the willingness –to-pay by water customers for enhancement in water supply reliability. The author develops a two-stage linear programming variant. The result from this study shows that the model could estimate the willingness-to-pay for improving the reliability of different classes of customers and help in evaluating different water conservation programs for different customer classes.

Jenkins, Lund, and Howitt (2005) study the engineering economic model for integrating urban water supply reliability analysis with water shortage management options (such as dry year option) and spot market water transfers, water reuse, and long-and short-term water conservation. Their studies link supply to probabilistic shortage management optimization. They use a probability plotting position formula. Their results show that jointly managing supply capacity and operating rule decisions with shortage management decisions may produce major economic savings.

Alcubilla and Lund (2006) apply two-stage linear programming to approximate the willingness-to-pay of individual groups of households for changes in water supply reliability and the price of water. The study has a simple analytical treatment of long- and short-term conservation options in the context of the probability distribution of water sharing levels and varying prices of water. In this study, the authors focus on modelling the costs of implementing long and short term conservation measures and calculating the water demand curves for conservation measures. Their results represent household variability using the Monte Carlo method and estimate the aggregate willingness to pay for water supply reliability.

Renwick, Green, and McCorkle (1999) study the potential of price policy as a residential water resources management tool. They formulate an econometric model for residential demand that explicitly incorporates other demand-side management policy methods, endogenous block pricing, schedules, and a Fourier series to capture the effects of seasonability and climate on residential demand. Their results estimate that price is a moderately effective method in reducing residential demand within the observed range of prices. Additionally, they suggest results that point to alternative demand-side management policy method that may reduce the residential water usage.

Lund and Israel (1995) study water transfer as a common component of many regional water systems and increasingly measured for meeting the growing water demand. They studied many economic forms of water transfer available to water managers and used these forms in the engineering of water resources systems. Their results show that water obtained by transfer could serve a multiplicity of operational, environmental, and economic purposes. In general, the multiple forms of water transfers and their flexibility, joined with legal, third party, and technical issues in implementing transfers, make water transfer one of the more promising methods of water resources management.

The earlier discussion, related to previous studies, indicates that work already completed in managing water resources in scarce conditions is scattered across different themes, and is somewhat incomplete and inconsistent. Also, these previous studies do not often consider land-use change and the corresponding implication on water allocation and the incumbent economic considerations in allocating scarce water resources.

The conventional approach to water management, which primarily consists of supplying water for a variety of human endeavours, has proved to be inadequate for the long-term sustainability of our water resources (Figueres, Tortajada, and Rockstrom, 2003). The World Water Commission declared in 2000 that due to rising global population, water consumption and water mismanagement, there will be a lack of water resources to meet all the industrial, domestic and agricultural global water requirements by 2020 (Figueres *et al.*, 2003).

Since 1930, the world's population and water consumption have increased three- and six-fold respectively (Gleick, 2000). Population growth has had a significant influence on accelerating the rate of depletion of natural resources, including water, worldwide (De Souza, Williams, and Meyerson, 2003; Mazur, 1998). Water consumption is expected to rise significantly following population growth (WWAP, 2003). A rise in population is expected to require greater agricultural and industrial outputs, urbanization and increased access to water (WWAP, 2003). It is expected that water requirements will increase significantly if major social change with respect to population growth and water consumption do not occur (Mazur, 1998; Population Reference Bureau, 2003; WWAP, 2003).

Water mismanagement refers to inefficient use of water, water pollution, inaccurate water pricing, and disparities in access to safe drinking water among other concerns. Inefficient water use is a major problem in agriculture and industry (Cai, McKinney, &Rosegrant, 2003; Postel, 2001). Qadir, Boers, Shubert, Ghafoor and Murtaza (2003) estimate that only 13 to 18% of water supplied for irrigation is taken up by transpiration. The rest is lost in storage, conveyance, evaporation, runoff and drainage (Postel, 2001; Qadir *et al.*, 2003). Furthermore, water subsidies and inaccurate water pricing that do not reflect the cost of water supply and distribution perpetuate the inefficient use of water resources by both agriculture and industry (Johnson, Revenga, and Echeverria, 2001). Degraded and polluted wastewater returned to aquatic environments accelerates the growing scarcity of clean and safe water resources (De Villiers, 2000). For example, the WWAP (2003) estimate that 6,000 people die of infectious diseases related to poor water quality every day, 1.1 billion people suffer a lack of sufficient drinking water, and 2.4 billion lack access to proper sanitation of waste. Disparities in access to water resources in many developing nations are largely due to water mismanagement by central governments (Basu and Main, 2001; Robinson, 2002). In summary, population growth, water consumption patterns and conventional water management practices are key factors that require change to avoid further water quality and quantity degradation. Alternatives are necessary for redirecting water management towards sustainability.

2.3.3 Sustainable Water Management

In response to inadequacies in conventional water management practices, and due to the need to sustain ecosystems for present and future generations, sustainable water management (SWM) has become the desired means of managing water (Gleick, 2000; Jaffe and Al-Jayyousi, 2002; Loucks, 2000; Tortajada, 2003; WWAP, 2003). The key considerations of SWM are:

- Water quality and quantity should not be degraded or reduced over the long term;
- Present and future basic human water needs should be met; and
- Ecosystem integrity and biodiversity should be maintained (Gleick, 2000; Loucks, 2000; Pykh and Pykh, 2003; Tortajada, 2003; WWAP, 2003).

The move of SWM from theory to practice has proved to be difficult; a lack of political will, legal and institutional frameworks, stakeholder involvement and a long-term vision for water resources are but a few obstacles to its implementation (Abu-Zeid, 1998; Matondo, 2002; Petit, 2003; Tortajada, 2003). SWM concepts tend to be subjective in nature, leading to multiple interpretations that are an impediment to its thorough application (Tortajada, 2001; 2003).

Despite these challenges, researchers continue to develop practical approaches for the application of SWM (Rockstrom, 2003; Simonovic, 2002; 2003; Tortajada, 2003; WWAP, 2003). To ensure the long-term and sustained use of water resources, it is imperative to:

- live within the watershed’s renewable freshwater potential and capacity for waste assimilation,
- reduce water consumption, while meeting basic human water requirements and
- Maintain a resilient and biodiversity ecosystem.

A discussion of the importance of these three key considerations in sustaining water resources follows.

The *Brundtland Report* (WCED 1987) and Agenda 21 from the United Nations Conference on Environment and Development (UNCED Earth Summit), in Rio de Janeiro, 1992, popularized and lent international legitimacy to the concept of sustainable development. The *Brundtland Report* defined sustainable development as human development that "meets the needs of the present generation without compromising the ability of future generations to meet their own needs" (WCED 1987, p.8). Agenda 21 recognized humanity's dependence on the natural environment and thus the necessity to protect it for current and future generations (United Nations 1993). Agenda 21, followed by various other international conventions and agreements, strengthened the commitment to sustainable development and recognized that water and other natural resources must be managed for the benefit of future generations.

Inter-generational equity is important for the shift from short-term thinking to long-term planning. The concept expands moral awareness from individuals and populations currently living on this planet to those who will live after us. Sustainability extends moral consideration to the future. To do so means recognizing ecological interdependence (Langhelle 2000) and protecting ecosystems in a functional manner so that future generations can benefit from them and lead healthy lives. Although not the direct intent, ecosystems also benefit from this protection. While the shift towards intergenerational equity is the most dramatic contribution of sustainability discussion, social justice (or intra-generational equity) is an implicit contribution. Hillman (2004, p.28) suggests the "nexus between sustainable development and environmental justice is not surprising, given that the origins of the environmental justice movement lie in an articulation of the lines between economic, social and environmental disadvantage, the 'triple bottom line' of sustainability". The sustainability discussion contributes the idea of balance between social, economic, and environmental values. Sustainability considers three primary systems: "interacting, interconnected, and overlapping", each with its "own value-laden imperative" (Paehlke 2004, p.44). The ecological imperative is to maintain functional ecosystems. The economic imperative is to ensure adequate and equitable material standards for all people living. The social imperative is to ensure adequate social structures for sustaining the values the people wish to live by. Sustainable development is an attempt to reconcile these three different imperatives.

Although sustainable development has provoked much debate, the term sustainability can move away from explicit reference to development and away from the "imaginative" reconciliation effort that Dryzek (1997, p.14) suggests of sustainable development as it "attempts to dissolve conflicts between environmental and economic values that energize discourses of problem-solving and limits". Robinson *et al.* (1990, p.39) define sustainability as "the persistence over an apparently indefinite future of certain necessary and desired characteristics of the socio-political system and its natural environment".

So in closing, it can be seen that sustainability need not include economic growth, but may merely imply the indefinite continuance of desired characteristics. The concept of sustainability does not assume that "stability is natural and humanly achievable"; instead it assumes that change is natural and questions stability. Seeking sustainability requires the assumption of change rather than the search for an end condition. Mitchell and Shrubsole (1994, p.51) argue that sustainable development is not just an end; it represents "an ethic and a process, or a means to an end". They suggest that sustainable development embodies the following aspects: meeting basic needs; maintaining ecological integrity and diversity; merging environment and economics in decision making; keeping options open for future generations; reducing injustice; and increasing self-determination. To achieve sustainable water use, each of these aspects of sustainability should be considered. Each of these aspects incorporates the idea of equity. Fundamental to sustainability is the attempt to reconcile intraand intergenerational equity (Langhelle, 2000). Thus equity and sustainability are mutually reinforcing.

2.3.4 Water Quality and Quantity

The well-being of humans, economic progress, and the sustainability of ecosystems is vitally dependent on the quality and quantity of water (World Water Assessment Programme WWAP, 2003; Pykh and Pykh, 2003). It can be appreciated that the quality of water is a key determinant of the health of the human organism, and also of the polluted or otherwise state of the environment (WWAP, 2003). It is typically the case that water taken for human use is then returned as effluent or wastewater, which requires treatment before release back into the environment (Gosh, 2002; Machiwa, 2003). Water treatment is an energy-intensive undertaking, requiring dedicated infrastructure and specialised equipment (Cheng, 2002; Oates, Shanahan, and Polz, 2003; Greiter, Novalin, Wendland, Kulbe, and Fischer, 2004). Hence, it is an indirect contributor to pollution, arising from power generation plants that supply the energy, which affects the environment, including the sources of water (Sinyak, 1994; Hurtak, 1996; Mukherjee, Melanen, Ekqvist, and Verta, 2000; Tsur and Zemel, 2000; Cosmi *et al.*, 2003). Indeed, good water quality may most effectively be achieved by simply ensuring that natural ecosystems are able to cope with the level of pollutants in wastewater (Davies and Mazumder, 2003).

In the same context, maintaining long-term viability of freshwater supply is most effectively achieved by only taking the amount that can naturally be replenished by the water resource environment. The consequences of failing to do that are serious, and may include desertification, or aquifers emptying completely (Villarroya and Aldwell, 1998; De Villiers, 2000; Lal, 2000; Sophocleous, 2000; Custodio, 2002). Indeed, the amount of water taken from an aquifer should be less than its capacity to replenish so as to be assured of effective long-term sustainability of supply (Sophocleous, 2000).

2.3.5 Present and Future Human Water Needs

The essential elements for assuring survival of the human species may be summarised in water, air, food, shelter and reproduction (Boyle, 2002; Melloul and Collin, 2006). Water needs and consumption levels vary with climate and lifestyle (Gleick, 1996). According to WWAP (2003), one person requires 20 to 50 litres of water daily. Yet, for simple survival, this amount reduces to 1.8–5.0 litres per day (Gleick, 1996), and rises to 6–15 litres per day to maintain hygiene (washing the body to avoid contracting skin disease), and then again to 6–15 litres per day to account for sanitation (WWAP, 2003). Water needs related to cooking have been estimated at 10 litres per day minimum (Gleick, 1996). These water consumption figures for the single individual may be reduced by adopting simple measures, such as preparation of food in large quantity, and utilising dry or chemical toilets (Gleick, 1996; CzemielBerndtsson and Hyvonen, 2002; Mara, 2003). The daily nutritional needs of a single individual are estimated to lie between 2000 to 3500 kcal (Gleick, 1996; Wallace, 2000). In the agricultural sector, the cultivation of crops requires allocation of water for irrigation, of which amounts vary widely based on, for example, crop types, approaches to irrigation, soil types, and prevailing climate (Postel, 2001; Qadir *et al.*, 2003). In this respect, innovative irrigation measures are available, which help reduce water consumption (Wallace, 2000; Postel, 2001). In animal rearing, water consumption varies by type of animal raised, and in the view of some, dietary change in favour of a more vegetarian menu will also help to reduce water needs (Renault and Wallender, 2000; Wallace, 2000). While adopting the various measures may reduce water consumption levels, for the purpose of this research, the water consumption figures presented in Table 1which reflect present day trends, are used.

Table 1: Water requirement amounts for meeting basic human needs (Gleick, 1996, 1998; Wallace, 2000; WWAP, 2003).

Basic human needs	**Water requirement (litres per person per day)**
Basic water consumption for survival	2 – 5
Basic sanitation	8 – 20
Bathing or showering	6 – 15
Cooking	4 – 10
Total Basic Water Requirements	**20 – 50**
Basic human needs	**Food and equivalent water requirement.**
Basic nutritional needs	2000 – 3500 kcal/day[a]
Equivalent in water	2000 – 17500 lpd[b]

Notes: [a] 2000 kcal/day represents a caloric intake for an area with a very poor food security and 3500 kcal/day represents a caloric intake with a very high food security (Wallace, 2000).

[b] 1000 litres are required to produce 1000 plant-based kcal and 5000 litres are required to produce 1000 animal-based kcal (Wallace, 2000; WWAP, 2003).

2.3.6 Economic Impact of Water Management

Historically, poverty reduction via water provision has been viewed solely through the prism of health and hygiene and thus the need to provide the poor and marginalized with access to water supply and eventually sanitation became a priority in the effort to halt the spread of disease and hunger. So although it is a regrettable fact that in many places the poor are more prone to become sick and the sick are more likely to become poor, this can be avoided by taking the step of water provision not only from the perspective of health and hygiene, but also through that of improving livelihood. Water resources management is key to the improvement of livelihoods, creating the enabling environment for communities to manage and thus be responsible for the resources on which they depend. . The most poor and marginalized communities are those who often do not have a voice in decision-making processes and do not often receive adequate and equitable services from their colleagues who possess a healthier quality of life. Perhaps the improvement of livelihood is a complex issue to tackle and it is for this reason that it is a relatively new course of action followed by international development aid agencies. This agenda requires a more holistic approach to water, requiring all sectors at all levels to be involved in the planning and development of water resources infrastructure, which includes sanitation, and to manage water in such a fashion as to promote socio-economic development.

The benefits of effective water resources management are many. Perhaps the most important is the sustainability that an improved livelihood implies. Better education, income generation, reduced vulnerability to disaster, disease and conflict, and cooperation among neighbours are all factors that build the platform for an empowered community. Without adequate access to water, efforts to retaining the bare minimum of survival leave no time to configure how the situation can be improved as a whole. Without water resources management, adequate access to water cannot be sustained, leaving a trail of failed water initiatives and broken spirits. Therefore effective water resources management must be inherent in all poverty reduction strategies if they are to succeed.

2.4 Poverty Reduction and Sustainability

Many development experts are advocating the improvement of water resource management as a key step towards poverty reduction. Similarly, many governments in both developing and industrialised nations alike acknowledge the importance of water to all aspects of improving likelihoods. With regard to water, the Millennium Declaration (MGDs, 2005) realizes the need for "sustainable water management strategies at the regional, national and local levels, which promote both equitable access and adequate supplies," though perhaps it is a detriment to its stated goals that increased access to and protection of water resources in itself is not one of the goals, but rather a subset of other goals. It is believed that as a result of this, water and sanitation aid does not amount to the level that it should. However, a strong case can be made that water plays a key cross-cutting role, either directly or indirectly, in achieving each of the following eight Millennium Development Goals which are discussed in more detail in the following section.

2.4.1 Millennium Development Goals

Goal 1: Eradicate extreme poverty and hunger

The target for this goal is to "Halve, between 1990 and 2015, the proportion of people whose income is less than $1 a day" and to halve the number of people suffering from extreme hunger. Water availability is necessary for both agricultural and livestock activity, and leads to both economic generation and increased food production. Improved water quality leads directly to an improved fishing industry. Improving access to water through infrastructure investments also leads directly to local and regional development.

Indirectly, ensuring ecosystem integrity also ensures that water will naturally flow to its proper destinations and will retain its portability – to reach areas of food production without needing manipulation and to free people from water-related illnesses, thereby allowing them to increase their production. Water resources protection is also a contributor to disaster prevention, because areas prone to droughts and floods are plagued by impediments to production and development.

Goal 2: Achieve Universal Education

It has been shown repeatedly that improved nutrition leads to a child's improved ability to learn. Improved access to water improves health and allows children time to go to school. Lack of sanitation facilities in schools is an especially strong impediment to attendance, specifically for girls upon the age of adolescence. Indirectly, a more educated community is more likely to know to manage their resources and more empowered to make their voices heard at the decision-making level.

Goal 3: Promote Gender Equality and Empower women

Because it is often found that women in developing countries are burdened with the duty to fetch water, it follows that reducing the amount of time that goes into task will create the enabling environment for more education and income generation. Improving access to water creates this enabling environment.

Goal 4: Reduce child mortality

The target for goal four is to reduce by 2/3 the under-five mortality rate. Water-borne illness is a major cause of childhood deaths. It thereby follows that improving quality and quantity of available water will directly contribute to reaching the target for goal four. It also follows that better nutrition reduces susceptibility to disease.

Goal 5: Improve maternal health

Improved quality and quantity of water leads to improved hygiene and health which, in turn, can directly contribute to a decreased maternal mortality rate.

Goal 6: Combat HIV/AIDS, malaria and other epidemics

Poor water management can lead to instances of stagnant, polluted water, which serves as ideal breeding grounds for disease-carrying insects. Additionally, improved health and nutrition reduces vulnerability to disease and increases the ability to become more informed about disease prevention.

Goal 7: Ensure Environmental Sustainability

As water is essential to ensuring environmental sustainability, Goal 7 is the most directly related to water. Water management determines the allocation of resources, the quality of resources and likewise the integrity of the ecosystem. In urban areas, where residents are often at quite a distance to natural ecosystems, responsible water management is critical because the wastewaters resulting from high population densities pose a serious threat to ecosystems as a whole. The way in which water resources are used can directly promote the health or seriously harm an ecosystem. The ways in which proper water management is tied to the environment are indeed numerous; environmental sustainability does not exist without adequate quality and quantity of water resources.

Goal 8: Develop a global partnership for development

Improving livelihood includes the ability to generate a sustainable income. In today's global market, the ability to export goods (other than oil) can make a considerable contribution to GDP. As an example, effective water management can utilize the resources as a means for increasing agricultural productions, as well as productivity from individuals. Effective water management also can be used as the lever for cross-border cooperation as riparian countries are forced to work together to benefit from shared resources.

Despite the worldwide recognition of water as a means to reduce human suffering, each year, every day even, the number of deaths relating to declining water supply and quality is far greater than that of disasters. Environmental sustainability is also becoming a major concern as the side-effects of global warming on the earth's water resources become ever-more evident. Thus increasing awareness has been brought to water conservation and water use efficiency, with the aim of withdrawing water at a lower rate than it can be replenished, in effect reserving the current trends that exist today.

Effective water management is now recognized as key to achieving the MDGs for water. Encompassing all aspects of the betterment of livelihoods, it is understood that water cannot only be viewed through the prism of health; rather, it must also be viewed through the prism of improved livelihoods. Preventing water-borne illness alone will not lead to poverty reduction. Water provision must also be accompanied by a functioning mechanism to manage the infrastructure that delivers water to the most effective locations, which implies that some training and consultation at the local level would be needed. Disseminating knowledge of best practices and lessons learned, perhaps through study visits and multi-border cooperation, would be necessary as well. Without these elements, an effective, functioning water resources management plan cannot be executed.

In the following sections, a discussion of four key areas of water resources management in need of urgent improvement and implementation is made, i.e., sanitation, gender mainstreaming, trans-boundary management and integrated water resources management.

2.4.2 Sustainable Sanitation

Sanitation is an issue that relates to the economic sustainability of a society. Therefore, it makes sense to consider the issue in relation to the development of a sustainable water resource management policy. Statistics gathered from the World Health Organization (WHO) show that an estimated 2.6 billion people lack access to improved sanitation, 75 % of whom are living in Asia and 18 % in Africa. It is also estimated that approximately 6,000 people die every day from diseases related to inadequate sanitation and hygiene, (World Health Organization and UNICEF, 2006). Unfortunately, these numbers may be even higher when taking into consideration the likelihood of underreporting.

As an impediment to development, lack of access to safe sanitation is a major contributor. Apart from the health perspective, sanitation also has major social implications. It is estimated that in Pakistan, more than 50% of girls stop going to school between the age of seven to eight because there are no sanitation facilities for them to use. This sort of occurrence is not unique to Pakistan. If a large number of children are denied access to education, there is little chance that society as a whole will be able to overcome poverty. This is very reflective of how approaches to sanitation provision must not only be made through the health prism, but also through a socio-economic prism.

It is important to define what is meant by improved sanitation here. Previous estimates of people's access to sanitation took into consideration all means of excreta removal, termed basic sanitation, which included even unsanitary, unsafe methods of disposal. As the purpose of surveys of this kind is to estimate the needs as to reduce health-related impacts, it is important to present a more accurate view of the people lacking access to sanitary, healthy ways of removing excreta, which became generally defined by the WHO as the following: connection to a public sewer, connection to a septic system, pour-flush latrine, simple pit latrine, and ventilated improved pit latrine.

It is also important to note that although the issue of sanitation has made considerable progress in gaining attention in the past few years after previously facing much ignorance, it is still lacking recognition in many governments, and this is reflected in their relative policies and allocated budgets. The benefits of bringing the various delegates from different countries together for gatherings like the Commission on Sustainable Development is that they are able to come to agreement and bring issues like sanitation to the surface. However, as is reflected in the WHO/UNICEF 2000 assessment on meeting MDG target, globally sanitation receives less than a third of the funding for that of water supply. This is very reflective of the large gap between commitments and actual implementation.

It is thus that sanitation remains an issue that needs to be addressed urgently. People are dying by the day and population growth and rapid urbanization will only expedite the process. The current cycle is that rural dwellers are fleeing to the cities to escape meagre conditions, which in part are caused by disease and poverty, which in turn are partly a result of a lack of sanitation infrastructure. This rapid, unmitigated growth of unplanned settlements and stresses on municipal infrastructure threatens to reach a level that will be both technically and politically difficult to mend in years to come.

The question is whether the developing world can provide sanitation services utilising the strength of their developed counterparts while at the same time avoiding the mishaps that have occurred. As mentioned above, the current gap in funding between water supply and sanitation is evidence that corrective measures, as a whole, have not yet been pursued. However, as the outcomes of both the Millennium Task Force on Water and Sanitation and the Commission on Sustainable Development specify, the need to put sanitation as the top priority in poverty-reduction strategies is great, and it is hoped that a change in attitude will soon be brought about.

The most ideal move towards a more sustainable sanitation management program in developing countries would be for governments to establish policies that strictly regulate the environmental outputs of waste management schemes and to ensure access to improved sanitation as a public right, as is more coherently recognised within the realm of water supply. However, as many countries have historically lacked the political will to put the environment and, more specifically, sanitation, at the top of the agenda, there is little likelihood of this happening any time soon.

Thus, a decentralised approach to sanitation service provision may currently be the most realistic choice for developing countries to tackle health and hygiene, as their governments are often lacking the political will and institutional capacity to oversee the sector as a public commodity. Taking this bottom-up approach to sanitation could have the potential for scaling-up and influencing governmental policy in the long-term, but for the short term at least there is the urgent need for more responsible practices in sanitation management.

As is the case with most developing nations, monetary resources are often lacking, and so each project should be approached with much consideration to sustainability if the limited resources are to be used effectively. This is a reason why the costly treatment plants and infrastructure with which most industrialized nations manage their wastes may not be the most appropriate option for their developing counterparts. Developing nations often do not have the infrastructure to treat and properly store wastes, and if they do achieve such infrastructure, political instability or economic decline could reduce their financial and technical capacity to maintain them for the long-term. Apart from chances of failure, many widely-used methods of waste management are not environmentally sustainable. In a way, most of Africa and Asia can count this as a unique opportunity to build nation-wide sanitation systems from scratch, and so this is a chance for them to do it right.

Innovation, not only as a technology but, rather, in the current mindset of wastewater management, is thus a necessity, for not only do sanitation and responsible hygiene practices need to be brought down to the household level, but communities as a whole need to mobilize in order to collectively and responsibly manage their waste for the sake of their environmental health. This issue is particularly critical in crowded slums, where wastes can accumulate rather quickly in places where children play and adults work. Thus, given the current situation, an important factor for success is to manage wastes at the community level to safeguard environmental sustainability.

2.4.3 Ecological Sanitation

While there is no perfect sanitation solution that can be adapted by all countries of different origins, there are some common criteria that should be met. It would be ideal to devise a system of excreta removal that is maintainable, affordable, technically feasible, culturally acceptable and sustainable. One such method of excreta management, applicable to both urban and rural environments, utilises waste as a resource rather than as an unsightly, removable item. Termed *ecological sanitation*, this process has a number of benefits to society in addition to being an effective method of full-containment of pathogenic matter.

The process of ecological sanitation varies, but its main components are the separation of urine and faecal matter, the storage and production of compost and fertiliser and thereafter the return of end products to the soil. Ecological sanitation, when applied properly, addresses numerous environmental and societal concerns, including ecosystem health, food security, income generation potential, water scarcity, water pollution and rapid urban growth. Besides the aforementioned benefits, ecological sanitation encompasses all aspects of sustainability as it manages excreta removal from the health perspective while returning vital nutrients to the soil, which is from the environmental perspective. These vital nutrients, such as phosphorus, are being mined for the production of fertiliser at a pace that cannot be sustained.

Ecological sanitation reduces vulnerability to disease and environmental degradation because it hygienically handles excreta and replaces vital nutrients in the soil. Additionally, contrary to the more generic methods of excreta removal, it avoids the discharge of polluted effluents into natural waterways and requires no water. Products from ecological sanitation can be used for agricultural production, leaving farmers less dependent on fertilizers, which reduces their financial and environmental burdens. Even for urban dwellers, for whom there may be no use for agricultural products, ecological sanitation can serve as a source of extra income made from marketable end products and jobs will be created to construct the required infrastructure. Thus this income generation provides further testament to the sustainability of this process. Some hurdles to implementation do exist. For one, gaining cultural acceptance can be a rather difficult manner. Similar to the AIDS pandemic which to this day is well known issue that even some developed countries like Japan are only recently openly addressing, the handling of faecal material can tend to have a negative cultural response, while in other cultures, like that of the farmers of China, utilizing the nutrients of excreta has been a common practice for centuries. As the scaling up of ecological sanitation cannot happen without support from cohesive communities, awareness, acceptance and educational campaigns are a necessity for implementation to occur. A successful scaling-up of responsible ecological sanitation could in turn have the effect of decreased vulnerability to disease and cost-effectiveness, giving sanitation some momentum in the political arena. This scaling-up has a potential to overcome the other major hurdle: lack of political will. Until sanitation is truly accepted as a priority by governments, municipal budgets on public spending will be reflective of this and financing will have to be mobilized through other mechanisms.

2.4.4 Climate Change and Water Resources

As global temperatures rise, the hydrologic cycle changes. Changes in hydrology have implications for precipitation, runoff, and the intensity and frequency of floods and droughts "especially at the basin and watershed levels…" (Frederick and Major, 1997 p. 21). Climate-related sea level rise also impacts water resources through groundwater intrusion of salt water, wetlands migration, and storm surges. "Increasing temperatures mean that a smaller proportion of precipitation may fall as snow. In areas where snowfall currently is marginal, snow may cease to occur — with consequent, very significant, implications […] for hydrological regimes." (IPCC, 2001, p.197). According to the Intergovernmental Panel on Climate Change (IPCC), rising ocean, lake and river temperatures, decreasing seasonal snow and glacial area in northern latitudes, increased runoff and rising seas have already been observed (IPCC, 2007). Recent reports confirm that increases in seasonal precipitation in the northern latitudes, more frequent extreme weather events, and seasonal drought can be expected in coming years: "Anthropogenic warming and sea level rise would continue for centuries due to the timescales associated with climate processes and feedbacks, even if greenhouse gas concentrations were to be stabilised." (IPCC, 2007, p.12). Further, "Of the more than 29,000 observational data series, from 75 studies, that show significant change in many physical and biological systems, more than 89% are consistent with the direction of change expected as a response to warming." (IPCC, 2007 p.3). Despite uncertainties in predicting exact local hydrologic affects, observed changes in hydrology coupled with increased certainty in the future direction of climate change can form a basis for adapting to future conditions (IPCC, 2007).

Water resources are an integral component of human systems. Potential impacts of climate change may have effects that range beyond weather extremes mentioned above. "Changes in hydrological regimes have the potential to alter health risks….waterborne diseases and water-related insect vector diseases are more sensitive to changes in hydrological patterns." (e.g., Patz *et al.*, 1998; Checkley *et al.*, 2000).

> Floods have associated health problems, and climate change also has the potential to alter contamination of water supplies (through changes in flow pathways that lead to increased leaching of pollutants and through reduced flows that lead to increased concentrations)and contamination of shellfish and fish. (IPCC, 2001, p.225)

One reason local water managers may be unaware of the impacts of climate change on water resources is a result of imprecise data. Researchers obtain information about the impacts of climate change on water resources by combining General Climate Models (GCMs) with hydrologic models. One difficulty in this effort is the differences in scale between GCMs that measure climate over vast areas and long time periods and hydrologic models that require more frequent measurements in areas spanning only a few kilometres. GCMs are limited in the numbers of systems and locations they include and are designed to measure global temperature, which is less variable than regional temperature (IPCC, 2007). Scientists have made advances in methods for downscaling GCMs to meet hydrologic model requirements. However, the reliability of their results is affected by difficulties in correlating data and observable phenomena in a complex and dynamic system (IPCC, 2001). This challenge limits the degree of certainty in predicting local impacts of climate change on water resources. Since municipal agents depend on reliable data to manage water resources, a lack of precise data due to limitations of predictive models may reduce the likelihood that municipal agents will respond to climate change in the near term. Sustainable water management relies on a network of infrastructure designed to balance the needs of both human development and ecological health now and into the future.

As previously noted, climate change poses a challenge to local water management because the extent and timing of its affects are uncertain. Nonetheless, municipal agents are charged with managing local water resources into the future and are thus responsible for mitigating the effects of climate change. In the following section, the research and theories of Adaptive Management in the context of water scarcity in Libya are explored and examined from different perspectives.

2.5 Summary

The literature review highlights that water scarcity is closely associated with geographical variability, seasonal variability and inter-annual variability. Water availability mostly depends on particular geographical locations and weather condition. Thus it is imperative to manage and sustain properly the available water resources through all the available means like constructing dams, educating the population to use water properly and make proper government policies to maximise the water availability. On the other hand, integrated water management states that there are relationships between water users and that, therefore, one water use can impact another. So integrated management considers the social, economic and environmental impacts of these relationships (Grigg, 1996). In this direction, Larson (2006) has focused on the behaviour changes of the stakeholders through legislative, operational, and informal arrangements.

Another important theme of the review of the literature is the land use planning and management. In this direction, the study of Cai, McKinney & Resegrant (2003) can guide the policy makers evaluate a strategy to match water withdrawal demand and ecological water demand in the Yellow River Basin by analysing inter-basin water transfer. Based on the results of this study, water use efficiency of the basin was increased, thus guaranteeing extra water availability through inter-basin water transfers for the next twenty-five years.

Water sustainability requires a multi-dimensional approach which should cover seasonal planning, aims at behavioural changes of the stakeholders and the proper land use planning. People's behaviour can be changed through education while land use planning should include dam-building, water storage and regulating the available water usage.

Chapter 3: Background to Libya's water Resources

3.1 Introduction

As discussed in the introduction chapter of this thesis, the main aim of this research is to explore the contemporary performance of the groundwater sector in Libya and to develop a strategy for providing a sustainable groundwater resource in order to achieve a socially, economical and environmentally sustainable future. Whereas the previous chapter explored global issues of water sustainability, the present chapter deals specifically with these issues in the context of the study area, which is the Alwahat region of Libya. For this purpose, this chapter explores classical and contemporary literature on the sustainability of water with the aim of providing a foundation for answering the research questions that are outlined in Chapter 1. The aim of this chapter is to collect and evaluate all available data relevant to this project's research focus. By doing this evaluation, we will be able to identify gaps in current knowledge and identify where new contributions to knowledge can be made.

3.1.1 Location and climate

The following sections provide insight into the problems of water scarcity in Libya. Libya is situated in the north coast of Africa (Figure 2), and covers an area of 1,769,000 km^2 (Alghariani, 1997). It has a long coastline on the Mediterranean Sea with a length of 1,730 km (Loucks, 2004), except for a narrow strip in Northern Tripolitania and a wider coastal strip in northern Cyrenaica. Libya is the fourth largest country of the African continent covering a surface area of more than 1.5 million km^2 while occupying the North part of it (Alghariani, 1997). Annual precipitation is scarce and unreliable in most parts of the country. 99% of the country is either arid or semi-arid land with annual rainfall averaging less than 50 mm. The availability of surface water is extremely limited – there are no flowing rivers and no lakes throughout the whole country. The surface water provided less than 3% of the water supply in 1977 (Salem, 1991). Underground water is the basic, if not the sole, source of water upon which the country depends to meet its present and future water supply needs.

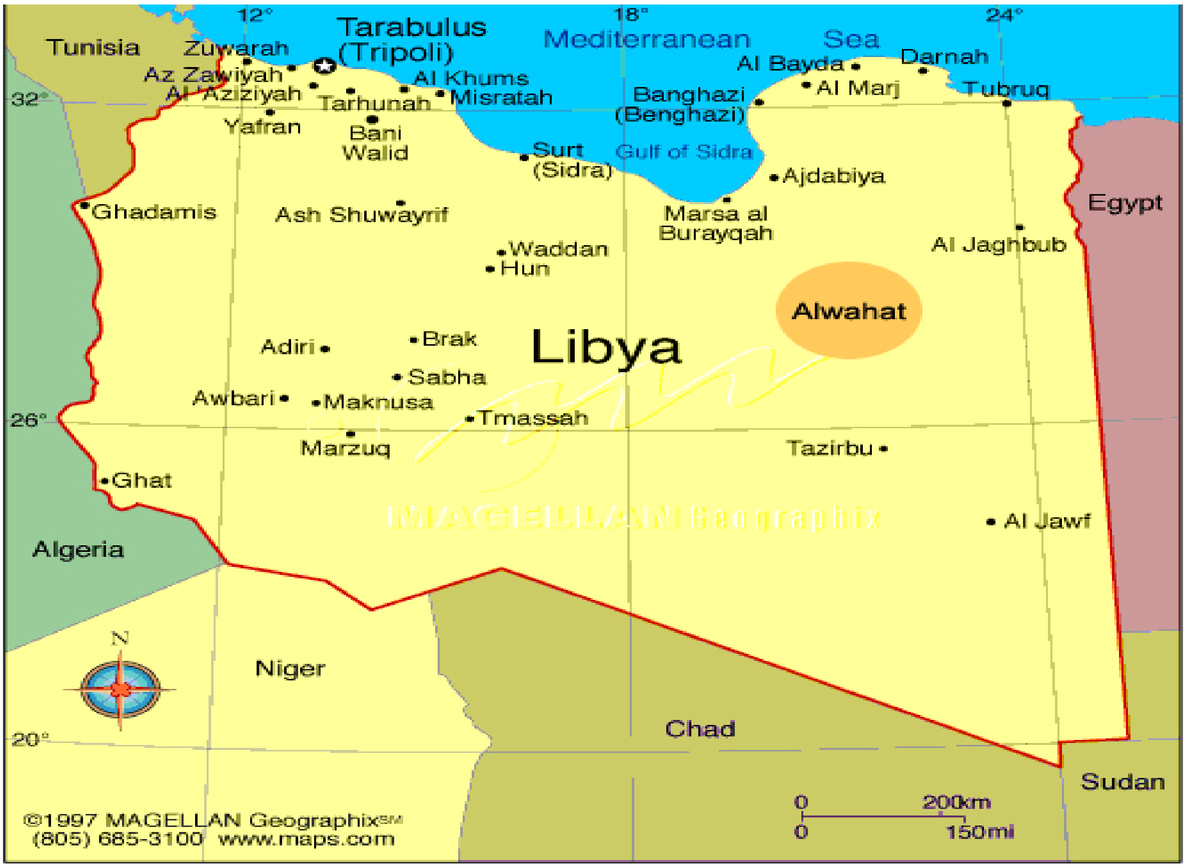

Figure 2. Map of Libya (source: http://www.ewpnet.com/libya/river.htm)

Libya experiences scarcity of water due to its arid nature of its location (Salem, 1991). Population growth and rising income, coupled with rapid urbanization, assure continued steep increase in demand for water for irrigation, industrial and municipal uses (Skran, 2008). In many parts of the region there is a rise in demand for water which is already pressing hard against existing supplies, stimulating mounting interest in finding new sources of water. Usually developing these sources requires large investment in dams, canals and other infrastructures, resulting in relatively high per unit costs (Edmunds, 1998). The expected rises in costs of new sources of water suggest that policies and technologies to encourage more efficient use of already developed supplies need to be put in place.

The conditions for achieving increased efficiency are not well understood, however, investigation of the conditions is a necessary step towards developing efficiency as an important policy alternative to new developments. Investigations and reviews of water resources situation and management practices in Alwahat Libya by the Hydrologist, Dorman (Dorman, 2009), led to the conclusion that significant weaknesses and problems exist in water management policies and strategies.

Libya shares international boundaries with Egypt and Sudan in the East, Chad and Niger in the South, Algeria and Tunisia in the West. To the North, Libya borders the Mediterranean Sea, where the Libyan coast extends for more than 2000 km, most of which is dominated by desert (CIA, 2002) (Figure 2). Libya shares large groundwater basins with neighbouring countries; of which Nubian Sandstone basin is of great importance because of the largest quantities and quality of water (which is non-renewable) and agricultural development relies heavily on this groundwater aquifer (Salem, 1991).

The Libyan climate is affected by the Mediterranean Sea to the North and the Sahara desert to the south, resulting in sudden weather transitions. . There are three different climatic segments that can be noticed:

- The Mediterranean Coastal strip; these areas undergo dry summers and relatively wet winters.
- The Jabal Nafusah and Jabal Akhdar highlands; these areas experience a plateau climate with higher rainfall and low winter temperatures, as well as snowfalls on the hills.
- Moving towards the interior South, pre-desert and desert climatic conditions are found; this results in high temperatures and large daily thermal amplitudes.

- Rain is rare and irregular and diminishes progressively while coming down to zero in the South.

The average annual rainfall situation varies from region to region according to the geographic position and the topography. Average rainfall in Jabal Akhdar is the maximum (600mm/year), whereas in Al-Jghbob and Marada in the South it is being calculated as minimum (Pallas, 1980; Alghraiani, 1993; Salem, 1991). Rainfall occurs from October to March, but great variability is observed every year. For example, the total rainfall at Benghazi in 1980 was 158 mm, whereas in 1981 it was 469 mm (Benina Meteorological Report, 2002).

January is the month of lowest temperature; whereas the temperature gradually increases from February until August when the country's highest temperatures are recorded. . The temperature also varies region to region. In the coastal region, the average monthly temperature is between 23°C and 25°C, while in the semi-desert regions, the average monthly temperature is between 25°C and 28°C, whereas, the maximum temperature in the desert regions may exceed up to 30°C (Benina Meteorological Report, 2002). The annual humidity at the coast is between 70 and 80 per cent. The high temperatures experienced in the coastal area decrease with altitude in the hills. In the summer, coastal temperatures near sea level can exceed 43°C, but in the winter these can fall to freezing point (Pallas, 1980; Salem, 1996; Alghraiani, 1993).

Prevailing winds are north-easterly in northwest Libya and north-westerly in the rest of the country. In the spring and autumn, strong southerly winds, locally known as "Gibli," blow from the desert, filling the air with sand and dust, which in turn raises the temperature up to approximately 50°C. These strong winds are a major erosion factor in the desert, transporting sand from one place to another.

3.1.2 Population distribution

Libyan population is estimated about 1.56 million in 1964,while according to 2005 census this figure increased to 6.7 million (Pallas & Omer,1999) . In 1973 the western coastal area Gefara and Misrata registered a population of 2.25 million out of which 551,477 of the population is in Tripoli. The eastern coastal area is second in terms of population concentration with 585,648 inhabitants of which 282,192 are in Benghazi. This means that 75 per cent of the population is concentrated over 1.5% of the total area. Table 2 shows the predicted population growth until 2025.

Year	1995	2000	2005	2010	2015	2020	2025
Population (10^6)	4.8	5.7	6.7	7.8	9.0	10.3	11.7

Table 2: Population Growth basted on adjusted rate of growth included non-Libyan population.

Source: Salem, 1991.

This table is showing a predicted regular growth in population. The data in Table 3 is gathered from another source and it confirms the growth in population in Libya, but shows a reduced population growth in recent years. This decline is attributed to a lack of jobs for young people, and also because the age at which people are getting married is becoming later. Another possible factor is emigration from Libya to its neighbouring countries in addition to people emigrating to Libya from other countries.

Period	Growth rate (%)
1956-64	3.9
1964-73	4.1
1973-84	4.2
1984-91*	4.9
1991-2011*	1.5

Table 3: Population statistics for Libya, 1956–2011.

*This information is given by NTC, during an interview on Jan, 2011
http:/www.youtube.com/watch?v=lwTGKmLERhI

3.2 Water resources in Libya

3.2.1 Surface water

Rainfall occurs in the northern Tripoli region (Jable Nafusah and Jafara plain) and the northern Binghazi region(Al Jable Akhdar), these two areas being the only ones where the average yearly rainfall exceeds the minimum value (250–300mm) which is considered necessary to sustain rain fed agriculture (Elfeet and Baird, 2007). The average rainfall in Libya shows an extreme variability in terms of the time of year and location (Omer, 2002).

There is a small amount of surface runoff water that reaches the sea, and it is considered that most of the runoff water is either evaporated or infiltrated in the valley beds for replenishing the underlying aquifers. The total mean annual runoff water calculated or measured at the entrance of the valley is roughly estimated at 200 million m^3 per year (Zidan, 2007). There are also more than 450 springs, some are of continuous discharge while others are seasonal. Table 4 summaries the surface water resources in the five water basins of Libya.

Basin	**Run off (Mm^3/y)**	**Spring (Mm^3/y)**	**Total (Mm^3/y)**	**Recoverable Quantity (Mm^3/y)**
Gefara	87	0	87	52
Hamada	30	74	104	48
Jabal	80	110	190	92
Akhdar	0	0	0	0
Murzuk	0	0	0	0
Kufra and Sarir	0	0	0	0
Total	**197**	**184**	**381**	**192**

Table 4: Surface water in Libya (source: Salem, 1991).

3.2.2 Groundwater in Libya

Libya depends heavily on groundwater which accounts for more than 97% of water use (Omer, 2007). The demand for water has more than doubled between 1977 and 1994, thus, intensifying pressure on this finite resource (Alghraiani, 2003). Libya has five principal regions with substantial water resources, which are: Jifarah Plain and Jabal Nafusah region; the Middle zone; Al Jabal Al Akhdar region; Fezzan region and Kufrah and Assarir region (Pallas, 1980; Jones, 1996) (Figure 3).

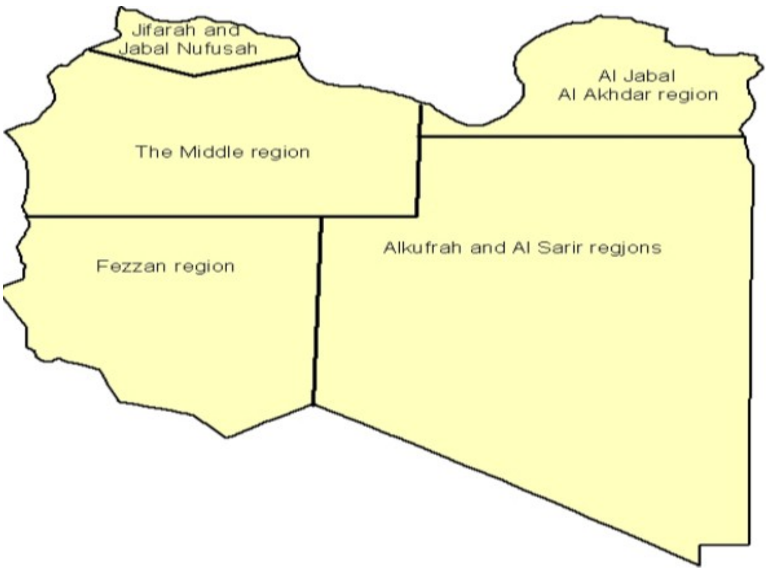

Figure 3: Groundwater basin regions in Libya.

This region constitutes a transition between Jifarah Plain in the west, Al Jabal Al Akhdar and Fezzan and Alharuj Aswad in the south. The region is characterised by Tertiary Quaternary formations containing shallow aquifers especially along the coast. The depth of these reservoirs ranges between 30 and 100 m (Salem, 2007). There are also deep reservoirs present in the late Cretaceous formations, with depths ranging from 100 to 800 m from the soil surface along with Cretaceous aquifers ranging in depth from 70 to 250m from the soil surface. The current water use is around 400 million m^3/yr. (Alghariani, 1997).

Pallas (1980) described and illustrated cross sections of the main features of the geology and hydrogeology of Libya as follows:

1. South of latitude 29°N, an important development of Palaeozoic and Mesozoic continental sandstones enabled water to be stored safely during the long periods of the late Quaternary when the climate turned extremely arid.

2. From the 29^{th} to 32^{nd} parallel, in the central and eastern zone, the Tertiary deposits form the main groundwater reservoirs, which is more than 1000m thick but contains an significant proportion of evaporates which have deteriorated its quality.

3. In the western zone, north of latitude 29º, the main groundwater reservoir is composed of lower Mesozoic sandstones, but in correspondence with Jable Nafusah, the present recharge from rainfall is superimposed on several perched groundwater systems in the Cretaceous formation over the main water body .Along the coast and mostly around Tripoli, Palaeo-Quaternary deposits from another important groundwater system are well replenished every year by rainfall.

4. In the eastern zone, north of lat 32°, the geology is dominated by the anticlinorium of Al Jable al Akhder. The main groundwater system in the Eocene limestone follows the geological structure with a radial flow around the core of the jabal.

In addition to these main features, it is worth mentioning some areas of persistent uplift conditions which are lacking a substantial accumulation of sediments. These include the Tibisti and Jable al Awaynat where almost no groundwater exists (Figure 2). In the next chapter more focus will be placed on the Sirte basin of the Libya Desert- which relates to the Alwahat study-, by reviewing the Geological and Hydrological data of the basin and surrounding area to understand the structural and the stratigraphic aspects of the Alwahat region.

3.2.3 Unconventional water resources

There are a number of desalination plants of different size that were built near large municipal centres and industrial complexes. Table 5 gives the location and capacity of existing plants In addition to this, a number of small size units with capacities of existing plants also exist. There are also a number of small size units with capacities from 100 to 6000

m^3/day that are used for desalination and treatment of seawater and brackish water (Salem, 2007).

Location	Capacity (m^3/day)	Location	Capacity (m^3/day)
Zanzur	22,500	Ajedabia	35,000**
Tajura	11,000	Susa	13,500
Suq el Khamis	42,000	Ras Lanuf	33,000
Zliten	18,000*	Bomba	30,000
Sirte	18,000	New Zliten	30,000
N. Benghazi	48,000	Misurata	8,500
Derma	9,200	Steel Authority	33,000
Tobruk	24,000	(Misurata)	18,000
Ben Jawad	5,900	Zawara	

Table 5: Desalination plants.

*Replaced by a new plan with a capacity of 10.00 M3/day. **Presently out of order (Source: Salem, 2007).

3.2.4 The Groundwater Resources of the Man Made River Project (GMRP)

Libya was considered as a dry region. Limited water resources and the growth in population, caused higher demand for water (Alghariani, 1997). In the 1950s, during the oil search in the south of Libya, a large amount of freshwater aquifers were discovered (Salem, 1996), which became a starting point for the state leadership to develop some type of systematic plan to use these natural resources. This large amount of the groundwater was estimated to exceed the amount 35,000km³ (Jijsber *et al.,* 1999).

In view of this water scarcity, the Great Manmade River Project (GMMR) (Figure 4), started to bring water from large aquifers under the Sahara to coastal cities (CIA Factbook, 2009). The GMMR indicates the serious need for Libya to overcome water scarcity through the construction of a vast network of pipes, wells and pumping stations, supplying water from Libya's main underground fossil aquifers in its remote, arid south, to the coastal urban concentration (Middle East Economy: Scarcity Amid Plenty, 2008). This project has been divided into five phases, out of which two phases (Tazerbo to Benghazi, and Hassounta to Jefara) have been completed and which supply freshwater quantities of 3.5 million m^3/day and 2 million m^3/day respectively (Middle East Economy: Scarcity Amid Plenty, 2008).

By the 1980s, Libya started one of the largest civil engineering projects in the world (Jijsber *at el*, 1997). The idea of the project was to carry the groundwater from more than 1300 wells, with each well being more than 500m deep, transported through large diameter pipelines for thousands of kilometres to the areas short of water usually in the North region (Salem, 1991). The GMRP will supply a total of 6.500.000m^3/day of freshwater when fully completed (Salem, 1991), and construction is planned in five phases (Figure 4).

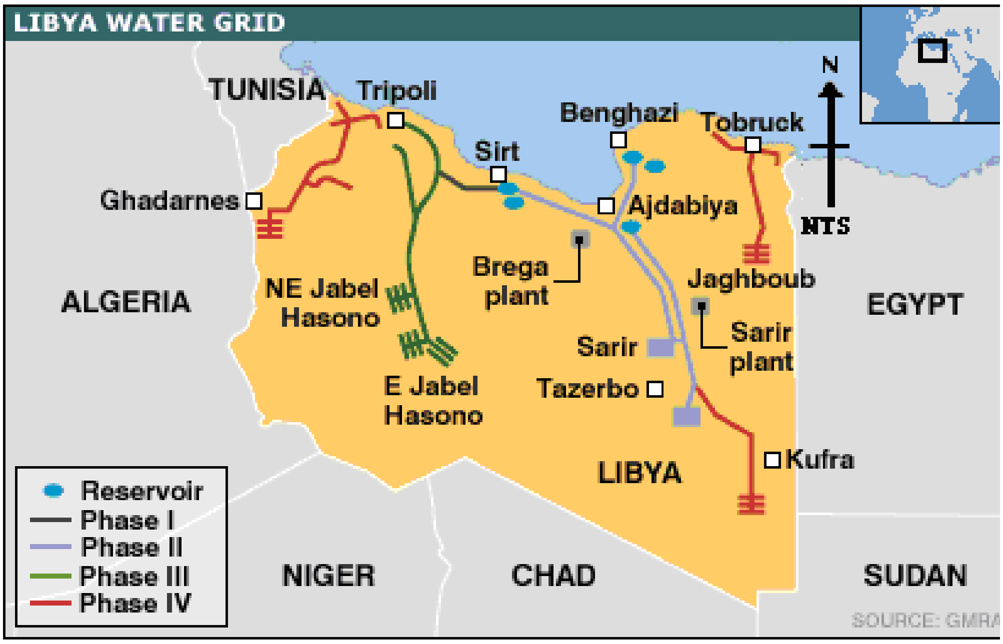

Figure 4 : The phases of the project Source: www.gmmra.org

3.2.4.1 Phases of the Project

The first phase is to Benghazi, the second largest city of Libya. The plan started in 1990 and was completed in 1994. A total of 2.000.000 m ^{3}/day (Hallag, 1991) is transported to Benghazi via the GMRP. Two well fields are designated to provide 1Mm^3/day each. The first is located in Sarir area and consists of 126 production wells, 450 m in depth, and functioning in 3 rows, with a distance of 10 km between the rows, and the distance between each well is 1.3 km, with the static level from 60 to 90 m.b.g.l (metres below ground level). TDS ranges from 560 to 1640 mg/l. (Salem, 1991).

The second well field is located in Tazerbo area, between Kufra and Sarir basin, with 108 produced wells topping the palaeozoic aquifer. The depth of the wells ranges from 500m to 800m, with static level between 7 and 24 m.b.g.l. TDC is lower than the Sarir well field.

The second phase of the project was in the Libyan capital of Tripoli and was completed in the year 2000. It provides 2.5Mm³/day, from more than 500 wells topping the Combor Ordovicib aquifer in the northeastern part of Muzuk Basin. The wells vary in depth from 400 to 800m and their static water level is expected to be between 80 and 175 m.b.g.l. The design of the water wells could not be constructed according to the row system due to the rough topography of the area. For this reason, the wells distribution will be controlled to a greater extent by the shape and direction of local valleys (Salem, 1991).The phase three functions to increase the water flow in phase one, which provide 1.6Mm³ located in south of Kufra , while Phase 4 will provide 1,000,000m³ per day of water through a pipeline to Tobruk. Phase 4 will join Phases 1 and 2, and install two power stations to pump the 1,000,000m³/day of water.

3.2.5 Deficit of water supplies and Agricultural use

The GMMRP was planned to use for Agricultural purposes, about 85% of the water consumption for agriculture. According to the assumptions made about water productivity in agriculture, the total water requirement to support basic food self-sufficiency and to meet the domestic and industrial water demand was the amount previously listed (Salem,1991).

Agriculture is responsible for 85% of the water consumption and irrigation agricultures are expanding in the north as well in the oases and along valleys. At present it is estimated, (Salem, 1996), between 350.00 and 400.00 h are under irrigation and their water requirement is less than 10.000m³/h/y depending on the location, type of crop and irrigation method. Table 6 below shows the yearly extracted groundwater for irrigation in each water zone.

Area	Year		
	1978	**1984**	**1995**
Gefara	435	500	965
Hamada	173.1	241.2	360
Jabal Akhdar	79.5	150.5	469
Kufra and Sarir	216.5	535	535
Murzuk	372.5	551	751
Total	**1276.6**	**1977.7**	**3080**

Table 6: Extracted groundwater for irrigation in Mm³/y

To evaluate the water resources available for use in Libya, it is necessary to include and analyse the non-renewable groundwater resources contaminated in the southern half of the country by allowing an acceptable rate of water level decline without exposing the aquifer to serious deterioration in quality. According to Salem, calculation volume of the non-renewable groundwater could be safely used within a reasonable time scale. The volume of water that is available for use at acceptable rates of delectation is estimated at about 4000 m³/y, which is expected to change in time as a result of improvement in the state of knowledge on the aquifer. The imbalance between supply and demand is expected to grow much wider in the future, especially for the north basin. Table 7 below shows the projected water balance.

Source	Gefara Plain	Jabal Akhdar	Hamada	Kufra and Sarir	Murzuk	**Total**
Groundwater	200	200	230	563	771	**1964**
Surface water	52	92	48	-	-	**192**
Unconventional Sources	27.5	45.5	50.5			**123.5**
Total	279.5	337.5	328.5	563	771	**2279.5**

Table 7: Total supply in Mm^3/y (Salem, 1991)

About 2.2 million ha estimated (1.2% of the total area), the cultivable area in Libya, national investment brief, with 18 million ha for annual crops and 0.3 million ha permanent crops; in addition to 13.3 ha for permanent pastures (NIB, 2008).

In the past Libya relied heavily on rainfall, which is less than 100mm/year in the whole of the country during the winter (Wheida & Verhoeven, 2006). Today, great variability is observed in rainfall, so the amount of water available for agriculture is highly unreliable (Wheida & Verhoeven, 2006). The highest rainfall occurs in the northern Tripoli region and in the north of Benghazi (NIB, 2008). In 1998, approximately 400million $m^3$of water was withdrawn for agriculture, municipal and industrial purposes (Wheida & Verhoeven, 2006). 85% of the total water withdrawal is used for agriculture, 11.5% is used for municipal and 3.5% in industrial use.

Irrigation potential has been at 75,000 ha, however the development of this potential would have relied mainly on fossil water (NIB, 2008). Considering renewable water resources, it is estimated that the maximum of 40,000 ha could be irrigated in the coastal area. The total water managed area is approximately 470,000 ha, all equipped for full or partial control irrigation (NIB, 2008). Sprinkle irrigation is used for most of the area due to the sandy soil prevailing in most areas of Libya. The cost of installing sprinkler irrigation equipment on a farm amounts to about US$10,000/ha. It was estimated that of the total area of 470,000 ha, 316,000 ha was actually irrigated in the year 2000 (NIB, 2008). About 99% is irrigated using groundwater, while the remaining 1% is irrigated by treated wastewater and surface water. Private irrigation farming, mostly on 1–5 ha plots (NIB, 2008), is concentrated in traditional development area (Jifara plain, Jable Al Akhdar, and Murzuq and Sirir Basin) with the actual irrigation area of about 257,000 ha in 2000 (NIB, 2008). The large state farms are located mainly in the southern area, where new irrigation schemes have been set up based on highly productive deep well water divided into small plots and cultivated by small scale farmers. Only 2 per cent of the irrigated land is estimated to be equipped with some form of drainage because of lack of experience in the concept of drainage and the high cost of drainage insulation (NIB, 2008).

The NIB claims that Libya made serious efforts to address its water deficit problem through the implementation of the transfer water project (the GMMRP). This project is expected to transport approximately 6.5 million cubic meter of water per day, corresponding to about seven times the annual renewable water resources, which demonstrates that such rates of withdrawal are unsustainable due to fast depleting the water resources availability. There is also moreover the huge financial commitment in laying the pipeline to transfer the water over such the long distance. The NIB statement argues that

> Up till now, Libya has done little to moderate demand for water, particularly in the agriculture sector which consumes the vast bulk of available water; in fact, management measures that previously existed, such as regulation of well development, support to efficient irrigation and controlled cropping patterns, have weakened with the decentralization of regulation and support function. (NIB, 2008, p.5).

The fast -rising municipal and industrial water demand is placing a massive burden on allocation to irrigated agriculture. This is especially the case in the Jifarah plain near Tripoli, where the domestic water demand in year 2025 is projected to grow to 2 million m^3/day .i.e., almost one third the amount of the planned water transport through the water transfer project. Irrigation agriculture plays an important role in the country's food security but it clearly cannot be expected to meet the bulk of Libyan long term food demand. Therefore, key policy decisions need to be taken to allow economic and social development to proceed within the constraints of the country's natural resources.

3.3 Characteristics of the Study Area, Alwahat

3.3.1 Introduction

The Alwahat "Oasis" area is one of the most essential economic areas of Libya. Its importance stems from two facts; firstly, it is one of the main oil-producing regions of the country, and secondly, its climatic features make it a potentially important agricultural region. Both oil production and agriculture require large amounts of water. Water is required for injection into petroleum reservoirs in order to enhance the recovery of oil. In addition to these two uses, water is also required for domestic use by the inhabitants of the area. Hence the water supply in Alwahat must be adequate for three purposes: irrigation, industrial operations (secondary recovery of oil from the petroleum reservoirs) and domestic need. Since precipitation in the Alwahat region is insufficient for agriculture, irrigation is necessary, all of which comes from groundwater resources. To explore the current performance of the groundwater sectors (stakeholders), this chapter identifies the issues that have significant impact on water sustainability in order to develop a strategy for providing a sustainable groundwater resource in Alwahat, Libya. The chapter presents an overview of water resources in the study area of Alwahat. It also describes in more detail the water situation among the stakeholders (farming, domestic and industrial). In addition, it examines the current stakeholder impact on water sustainability by identifying the critical issues that could make for a future of sustainable water.

3.3.2 Historical development

Alwahat is located in the north-eastern part of the Sahara Desert (Central Cyrenaica), about 400 km south of Benghazi, on the desert route to Kufra. There are several settlement clusters within Alwahat, the largest of which are Jalo, Awjala and Jkherrah (Figure 5).

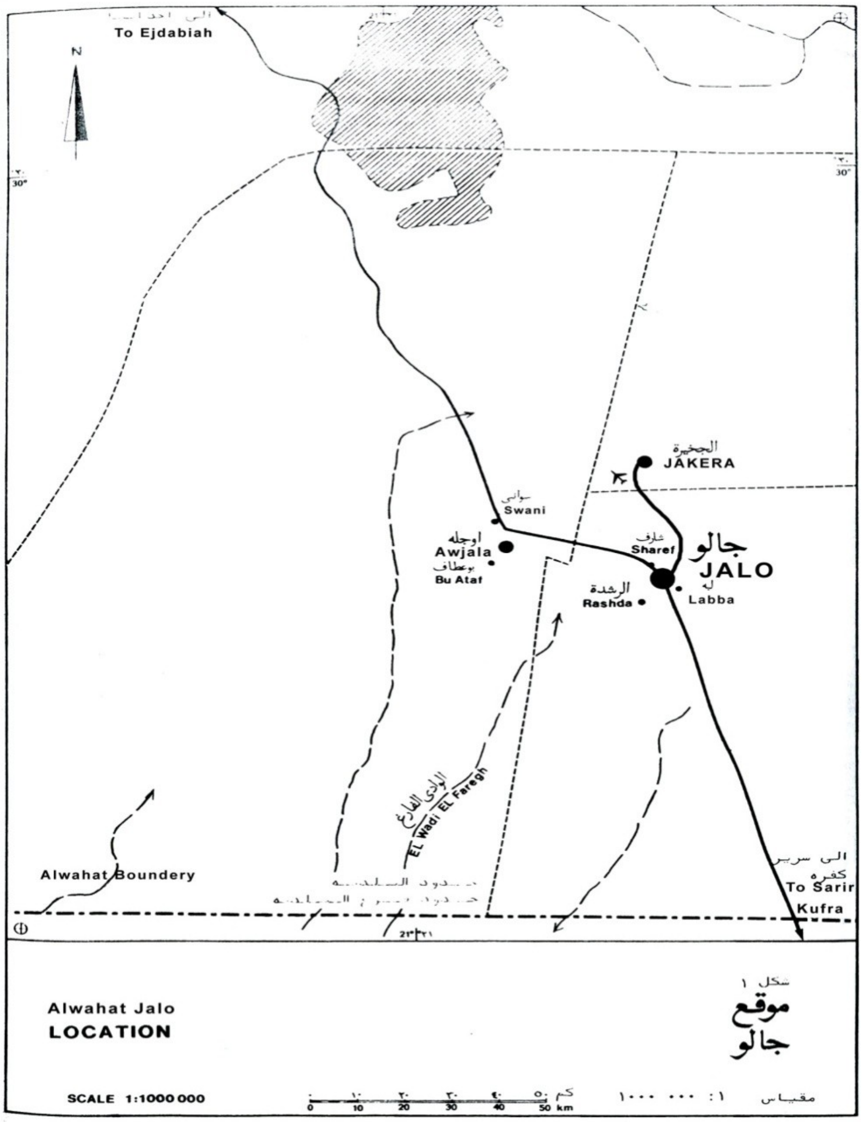

Figure 5: Location map of Alwahat area. (Source: Al Alwanie, 2007)

Cultivation in the Alwahat area has been practised since its earliest recorded history, in the migrations of coastal tribes to gather dates in the area, as recorded by Herodotus 2500 years ago (Husanin, 1922). Traditional caravan trading routes from the Mediterranean coast to

Kufra, and from Maradah to Jarabub, intersect in the area where shallow wells provide convenient watering places (Figure 6).

Figure 6: Buttafal Jalo water well. Source: http://saharasafaris.org/hassaneinbey/ngs06.htm

Hutton (1819, pp.161–162) states that, “There are three towns in the territory of Augila; the town properly so called, Mojabra (now Jalo), and Meledila. The two latter are near each other, Mojabra being on the south, and Meledila on the north of our road, at rather more than half of the way to Augila.” The total size of the administrative area is 47000 km². The Jalo Oasis is the largest and most important oases of Alwahat.The first census of the Jalo area, carried out in 1964, shows that the total population was 5700 (Jalo Baladiya, 1964), based on un-graduated data. The population in Alwahat from an analysis of the situation in 1978, with an average family size of 4.8 people, is shown in Table 8:

Area	No. of families	Males	Females	Total
Jalo	1313	2810	2821	5631
Awjala	608	1848	1785	3633
Jakara	368	908	892	1800
Total	2289	5566	5498	11064

Table 8: Population of Alwahat, Libya, in 1978.

The first modern census of Alwahat, carried out in 2006, shows that the population was 23,000 for the Alwahat area with a total of 5,727 family members, with an average of 7 people per household. The same statistics for its constituent areas are as follows: Jalo 3,234, Awjala 1,563 and Jakara 930 (Office for National Statistics, 2009).

The current climate of Alwahat is typical of inland desert, with generally hot temperatures, very little precipitation, and low relative humidity. The average temperature over the past 50 years is 23.2˚C in August, with an average maximum of 37˚C in July. The highest recorded temperature was 48˚C in June, 1961, while the lowest recorded was −2.8˚C in January, 1954 (Meteorological Station, 2009).

Precipitation (rain) is extremely rare in the region. Meteorological Data indicates an average annual perception of 1.25 cm. The maximum recorded rainfall was 5.55 cm in 1960, while the minimum annual rainfall was a trace amount recorded in 1965. Humidity is also relatively low, ranging from 34% in May 2000 and 1955 to a high of 96% in December 1975.The average relative humidity is 44.1%.

Winds are predominantly from north and North West. These northerly winds account for 85% of wind and have speeds of less than 7 m/s. The south winds, locally known as the “Ghibli”, blow during the late spring and early summer. Although they are less frequent than the northerly winds, their high speeds produce large amount of blowing dust and sand which inconvenience the local inhabitants and disrupt transportation and other activity. However, farms are largely protected from the wind by fences and plantations.

3.3.3 Previous investigations into water resources in the Alwahat region

Since 1970 the Alwahat area has received considerable attention from petroleum companies and geologists. However, their efforts were limited to the lower geologic section where huge amounts of oil have been discovered. Oil drilling programs paid little attention to the first 300m of the litho-logy section, the portion of greatest interest to hydrogeology. Limited sampling, logging and analyses were performed above a depth 200 m. It is for this reason, along with the lack of any significant water resources investigations, the hydrology of Alwahat region was virtually unknown until the early 1970s (Alkaseh, 1979, p.6).

During the 1960s, water resource investigation in the study area was to a large extent quite limited (Agrar and Hydrotechnik of Libya Ltd., 1966). In their study, Agrar and Hydrotechnik present the first hydrological, geological and static maps of the water level in Alwahat area. A generalised description of the geology, hydrology and hydro- geochemistry of Central Cyrenaica was presented by Wright and Edmunds (1982). The Institute of Geological Sciences (I.G.S.) of Great Britain (1971–1973) conducted an extensive hydro-geological survey covering the Alwahat region. The data was collected from the records of oil companies and an exploratory drilling program was conducted. I.G.S. reported the existences of two aquifer systems, the Post Middle Miocene (PMM), and the single aquifer with moderate salinity water, and middle and lower Miocene and Oligocene multi-aquifer system containing mainly saline water. From the calculated data and assumed hydraulic parameters of the PMM aquifer, I.G.S developed three exploitation schemes that corresponded to the different proposed future uses of the aquifer. It is important to report here that I.G.S. considered the occurrence of minor upward leakage from lower aquifer system (Alkaseh, 1979), which indicated, for the first time, the different layers of aquifers. This identification of different layers was helpful in making strategies by different stakeholders.

Groupementd`EtudeFrancais en Libya (GEFLI, 1976–1978) conducted a water resources study for long-term exploitation. Based upon three month pumping tests and two exploration production wells (Jl-p and JM-p), GEFLI concluded that the lower aquifer system in the vicinity of Awjala is unusable because of it is poor quality water. GEFLI also calculated water-level decline after 50 years of pumping at 800 litres/second or 25 million cubic meters (MCM) per year. In addition, based upon a reinterpretation of I.G.S short-term pumping tests, GEFLI concluded that most trans-missives values were 50 % higher than those given by I.G.S.

The General Water Authority, the official government office for water resources in Libya, prepared the drilling specifications and supervised the drilling operations of twelve water wells for the Jalo-Agedabia water supply as well as the farmers' wells (Alkaseh, 1976). The authority presented several reports designed to stop the oil companies from using groundwater for secondary recovery of oil.

After examination of all previous material, see it is clear that the initial work and exploration in the area focused on the petroleum operations in the study area, and neglected the status of water, as well as not taking into account the socio-economic and environmental issues in the long term. Moreover, there is no comprehensive, up-to-date research available in the Alwahat area, though there are some old documents available; yet these documents do not fulfil the needs of water resources strategy planning. Therefore more of this kind of research is needed to fill this gap in knowledge of the topic.

3.3.4 Soils and Vegetation

Soils of Alwahat exhibit typical desert characteristics: low moisture content, coarse texture and lack of chemical weathering. Vulnerability to wind erosion is a constant problem according to, Secretariat of Utilities (SFU, 1977), however, given protection from wind and careful irrigation, the Alwahat soils have been productive enough to support limited settlement over the centuries. Adaptation to the climate and traditional water management techniques have been essential factors in the survival of Alwahat life (Shraf, 1971). About 10% of the study area, mainly in the oases, is covered by vegetation while the remainder is desolate sand plains (Alkaseh, 1979). Plants known locally as "belbal" and "rebian" are the only grasses that grow in the desert after the scarce rain seasons. Around the Alwahat region and nearby depressions, palm trees provide the dominant vegetative cover; but with the decline of groundwater level, this has caused serious damage to the old palm trees. These trees cannot rely on deep groundwater supplies for their nourishment while the, and shallow groundwater is no longer available in Alwahat.

3.3.5 Alwahat's Regional Hydrogeology

The Calancio province is notable for its variable water quality due to the variable lithology, continental sand and clays to the south and carbonates and local marine evaporates to the north. Large amounts of both fresh and saline connate groundwater are found in the province aquifer complex (I.G.S., 1971). The origin of this water is related to one or more pluvial intervals (during the Pleistocene era) when moisture was more abundant. Because these waters are non-renewable, resources their development is possible only by groundwater mining. As a result the permissive mining concept must be applied for the development of this arid area where water is a most precious resource. The permissive mining concept is defined by the American Society of Civil Engineers as: "The maximum volume of water in storage in a particular source that can economically and legally be extracted and utilized for beneficial purpose without bringing about some undesirable results" (A.S.C.E., 1961).

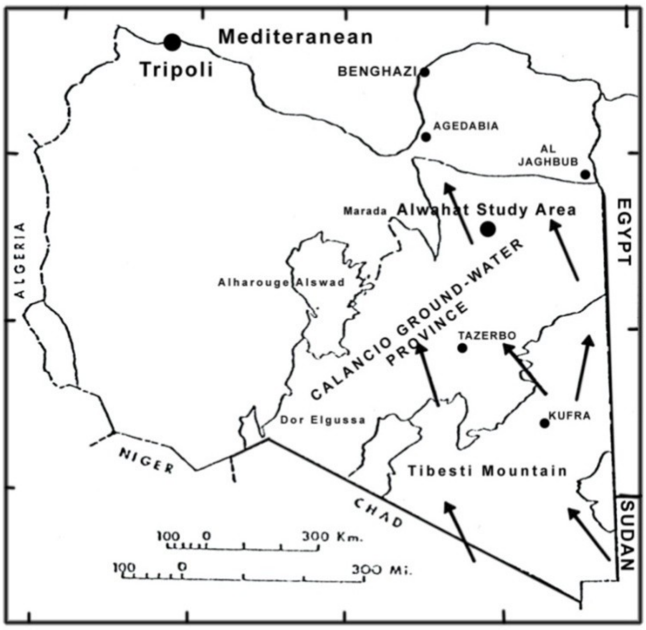

Figure 7: Index Map of the Calancio groundwater province (arrows indicate groundwater flow direction).

Both agriculture and industry compete for groundwater. Among the undesirable results of these activities is that on one hand there appears the rapid depletion of resources due to excessive pumping. On the other hand, the cost of production is also increased. Agricultural production and settlement projects such as the South Sarir Production Project (SSPP), the North Sarir Production Project (Figure 7), the Tazerbo Projects, and the Jalo/Awjala Settlement Production Project, have been established in the southern and central parts of the province. The new Alwahat farms project, which consists of four settlement projects, was established in 1999. Oil companies are using a large amount of water from these aquifers for the secondary recovery of petroleum (Dorman, 2009). Hydrogeological investigations have been conducted for the agricultural projects but the mutual effects of industrial and agricultural projects have not yet been considered. Such a study is necessary to explore the contemporary performance of groundwater sectors in Libya and to develop a strategy for providing a sustainable groundwater resource to achieve a financially, socially and environmentally sustainable water future.

3.3.5.1 Recharge

The Calancio province is Located in the south Sahara Desert where there is practically no precipitation. Groundwater flow to the province is possible only from the south where the underlying Nubian aquifer (Cretaceous and older) is located. It is important to note that the probable recharge from the Nubian aquifer is small compared to the huge amount of water stored in the aquifer system of the province or the existing and proposed abstractions for industrial and agricultural projects.

3.3.5.2 Discharge

Groundwater flow in the Calancio province is to the north where natural discharge occurs in the Sabkat (swamps) of Quanin and Karkorah which are located southeast and southwest of Agedabia City. No study has yet been conducted to determine the amount of the outflow from these sabkats and the hydro-geologic effect on the Calanicio aquifers. Water from the shallow aquifer is discharged by evapo-transpiration and pumped out for local agriculture in the Alwahat area. The Sarir agriculture projects were established in 1974 and 1976 to irrigate an area of 50,000 hectares which has a daily water of 2.9×10^3 l/sec (2.5 MCM/day). The projects incorporate 200 wells designed to pump 72 l/sec, and were completed in 1977. The average depth of each well is 300 metres. The Tazerbo project is the southern part of the area (Figure 7). It should be noted here that an exploratory drilling program is being conducted by the Agricultural Development Council, but the objective of the program is not clear and the drilling specifications were poorly prepared (Alkaseh 1979). The Jalo and Awjala project is not the only settlement projects province. This project requires about 900 l/sec (28 Mm^3/yr.) for the irrigation of 300 farms of 7 hectares each. The Alwahat farms project, which has four big farms around the area, will contribute to the water level since no study has been made to evaluate the water situation after this farm project.

3.3.6 Geology of the Alwahat Region

The Alwahat region lies in the southern part of the Sirte basin of Libya Desert (Table 9). It is therefore necessary to review the regional geology of the basin and the surrounding area to understand the structural and the stratigraphic aspects of the study area. The two major tectonic elements of Libya are the Saharan-African Shield to the south and the Mediterranean Shield to the north. Several plaetectonic formations have been occurring throughout geologic time, for example Caledonian and Hercynianorogenies in Paleozoic time, caused the formation of the present structure of Libya. This basement rock becomes deeper as one moves to the north as a result of the wedging phenomenon resulting from the sea-landmass relation. Two major sets of faults trending southeast-northeast were recognized in the central part of Libya (Klitzsch, 1971). The southern set extends from the southern part of the AlharougeAlaswd Mountain to the central part of the Tibesti Mountains at the Libya-Chad border. The northern set extends from the Socan Oasis on the west to the Marada Oasis on the east.

Extensive lava flows known, as the Alharoug Alaswad Mountain Outcrop, form a hydrogeological boundary between the Calancio groundwater province and those of the western part of Libya. The geological development of the area was controlled by the land mass of the Saharan African Shield and its relation to the Mediterranean Sea on one side and the orogenic movement on the other side. During the Precambrian time, fluctuations continued between the highland to the south and the sea to the north and, as a result, alternating marine and continental deposition took place. A summary of the lithology is given in Table 9.

Table 9: Lithological Section of the Sirte Basin.

Age	Approx. thickness	Formation Name	Lithology
Post Middle Miocene	150	Calanscio	Predominantly Sandstone, with thin limestone and clay beds.
Middle and lower Miocene	300	Marada	Variable lithology, ranging from marine limestone to continental sand with evaporates,clays, calcareous, and shales
Oligocene	300	Diba	Fine to coarse sandstone with same clay and calcareous fine glauconitic matrix.
		Arida	Soft Gary shale overlying fine glauconitic sandstone.
Eocene	1000	Aujla	An upper limestone overlying a sandstone with interlarded clays.
		Jalo	White to light gray limestone cemented with interebedded calcitutite and abundant mummulities.
		Gir	Light to dark dolomite with alternating beds of hard dense microcrystalline anhydrite.
Palaeocene	800	Khier	Thin shale alternating with calcilutite and calcarenite.
		Harash	White calcilutite alternating with shale.
		Zelten	Mainly limestone with inter-bedded shale.
		Halifa	An upper argillaceous limestone and lower dark shale.
		Dahra	White to light graycalcarenite and calcilutite with interebedded dolomitic and dark shale.
		Beda	Tan brown calarenite alternating with dolomite and calcilutite.
Cretaceous	300	Kalsh	Light to dark to graycacilutite.
		Rakb	Argillaceous limestone often grads into shall.
		Naragh	Sandstone with some dolomite

Along with younger rock, the Miocene sequence is very important to hydrology of the Sirte basin. A detailed study of the Miocene sequence and it is relationship to the underlying rock is a prerequisite for understanding the hydro-geological boundaries of the aquifer system in the Alwahat area, but regrettably, groundwater investigation has not been carried out until very recently. These studies, in contrast to the oil investigations, have been conducted since 1957. In their investigations and data collection programs, oil companies have shown minimum interest in the first 300 meters of sediments, which contain most of the usable groundwater in the Alwahat area. This lack of interest and consequent poor sampling in this interval (for example, incomplete lithology and geophysical logging) makes it difficult to use this data in a hydro-geologic study.

Desio (1935) was the first to describe the Miocene sequence. The distribution of the Miocene sequence of Marada formation is a heterogeneous sequence of both continental and marine deposited. Conant and Coundrzi (1964) report that the Miocene Sea retreated to the north, leaving the Alwahat region a shallower marine environment than that of the Oligocene.

The Marada formation was named by Desio (1935) for the entire Miocene sequence in the basin. Because the Miocene sequence is not exposed at Jalo, the study of this sequence in the study area was not carried out until the I.G.S was asked to conduct a hydro-geological investigation in the Alwahat area. Using oil companies' data, I.G.S concluded that the deposits were controlled mainly by sea level fluctuations during the time of deposition (Institute of Geological Sciences, 1973). They also found that the same depositional environment in the Marada area was predominant in the entire basin in clouding Jalo area.

The Marada formation was first described by Desio (1935) and includes the lower and the Middle Miocene rock exposed to the north of the Marada oases. It is the uppermost formation the oil companies recognised and described in the Sirte Basin Lithological Sequence. This formation extends over the entire basin, at the surface at Marada and subsurface elsewhere. At its bottom, the Marada formation dis-conformably overlies the Oligocene sequence. The upper boundary of the formation lies in an unconformity which explains the absence of the upper Miocene sequence in the whole basin.

According to Selley, (1966), the Marada formation is characterised by a very complex geometry and composition. Selley describes the Marada as consisting of a large number of variable rock types, randomly inter-bedded, and varying laterally over very short distances. Selley concludes that these variations are due to simultaneous near-shore deposits of marine accumulation from the sea to the north and the Sahara Shield to the south. On the basin of environment, lithology, geometry, structure, and fossil content, Selley (1966) subdivides the Marada into five sedimentary faces. Arranged in a north-south direction, these faces are detrial limestone of an offshore bar deposit environment, gypsiferous shale of a lagoonal environment, sand and shale of a inertidal environment, shale of a fluviatile environment, and sandy limestone calcareous sandstone of estuarine channels which cut through the other four faces. From his study of the formation, Selley concludes that the Marada formation was deposited under variable conditions which resulted in the complex geometry, and variable lithological composition of the formation. These variations are reported in both the vertical and lateral direction which indicates the change of the environment of deposition in both time and the distance from the sea.

These variations were also reported by Benfield (1972) during his studies of the post-Eocene sequence in the Jalo area. He recognized a marked similarity between the Miocene sedimentary faces change in Jalo and those of the Marada area described by Selley (1966). The only difference he finds is related to the direction of the Miocene shoreline which extends northwest-southeast in Jalo and north-south in Marada. The existence of similar sedimentary environment was confirmed by the drilling conducted by the African Drilling Company for the I.G.S study and the JM-P and JL-P wells drilled by the Egyptian drilling company (Regwa) for G.E.F.L.I.'s study in Jalo,.

The Middle Miocene Sediment in the Sirte basin is not well defined. Its definition remains one of the most important problems in the geology of the basin. For some geologists, both the Middle and lower Miocene are collectively termed the 'Marada Formation' (Desio, 1935), but it is necessary to note that Selley (1966) uses the term 'Marada Formation' for the lower Miocene sequence. Selley describes the upper limestone beds as equivalent to the Marmarica formation of the Middle Miocene age. Barr and Weegar (1972) use the Marada formation to describe all the sequences of the Miocene sediments. They suggest a lower Miocene age for the lower beds, as proposed by Savage (1972), and uncertain age for the upper units.

Benfield (1972) adopted the term 'Marada Formation' as it is described by Desio (1935) and Barr and Weegar (1972) for the whole sequences of the upper limit of Marada Sequence. Benfield reports the existence of a lower unit of the post-Miocene sediment. This unit was given the name of Aklash Formation (I.G.S interim report, 1973) and is described as a thinly-developed formation, consisting mainly of clay sandstone, sand, and inter-bedded clays. I.G.S reports various faces ranging from sand to fossiliferous limestone. This sequence was described as having a different lithology from the rest of the Marada Formation. However, it is difficult to see how these differences could be found in a similar lithological sequence. This sequence of the Aklash and the lower Marada units might represent a slight change to a shallower water environment, as indicated by the increase of the continental deposits, but both lithological units still have a heterogeneous sequence. In summary, it seems unreasonable to use this sequence as a hydrogeological boundary on the regional scale.

By 1974, I.G.S reported a major change with regard to the age of the proposed Aklash Formation. A paleontological examination of the core samples indicated a middle Miocene age for this formation. Their findings led to the remapping of the base middle Miocene sediment to the top of Marada formation which includes the previously known Aklash Formation. In its final report, I.G.S reported that no major changes have been found in the base of the PPM (parts per million), except to the north of latitude 29 degrees. In this respect, it is unnecessary to change the aquifer boundary based upon these findings because these boundaries were based upon the lithology characteristics of the formation and is not on its age.

3.3.6.1 Post-Middle Miocene

All rock components overlying the Miocene sediments are referred to as Post-Middle Miocene (PMM) sediments. This name was given because of the uncertainty regarding the age of the information and the lack of fauna in the sediment. The PMM sediment outcrop can be found all over the central part of the Sirte basin. This outcrop is usually covered by a vast blanket of pebbly grains known as Sarir (pebble). The Sarir grains vary in colour from white to black to red with a reddish-brown colour predominant over the whole area. The mineralogical composition of the Sarir is mainly of quartz and feldspar. Some black ferromagnesian grains are also present. The grain shapes range from flaky discs to rounded and sub-rounded grains with well-developed sphericity as result of wind saltation. The PMM sequence underlying the Sarir is composed mainly of unconsolidated sand with some sandstone, clays and limestone beds. It is believed that a continental environment was dominant during this time with shallow lakes in which evaporates were deposited. Clay beds with irregular trends have been observed in both the surface and subsurface. These outcrops are observed just south of Jalo, the northeastern area of an oil company’s camp along the roads to Kufra, and in same wastes south of Awjala.

In the subsurface, the clay is observed in almost every hole drilled in the area of more than 30 meters depth. In Jalo clay beds are present in most shallow wells drilled for local irrigation. Sand and sandstone, which predominate in the post Miocene sediment, vary in grain size from fine sands to pebbles in some cases. The sandstone is also reported to have a clay matrix.

3.3.6.2 Basal contact between PMM and lower Miocene in the Jalo area

The basal contact between the post-Middle Miocene and the lower units is a very important factor in the hydrological study. Understanding the lithological characters of Middle Miocene sediment and its effectiveness as an impermeable boundary between the upper and lower aquifer units is requisite for any hydro-geological classification of the aquifer system. In this regard, three factors will be considered: (1) the effect of the Miocene unconformities on the relationship between the upper and lower parts of the aquifer system, (2) the possibility of finding similar faces to those found in Marada by Selley (1966), and (3) the later and vertical extend of clay beds of the Miocene sequence and its effectiveness as a regional basal hydrogeological boundary for the Post Middle Miocene sequence.

The Sirte basin was subjected to sedimentation from both the sea to the north and the Saharan African Shield to the south. As a result, an alternating sequence of marine and continental sediment was deposited throughout the basin. Sediments grading from open sea limestone to clay and shallow marine evaporates to terrestrial sediments (mainly sandstone) have been reported in the Miocene sequence. Selley (1966) reports that the mixed rock units of the Marada Formation make it very difficult to trace or correlate any single bed from long distance. During the Post-Middle Miocene time, the same general trend of previous Miocene environment prevailed except that the sea retreated to the north leaving a predominantly continental environment in which more sand, sandstone, and fewer marine sediment were deposited.

Two unconformities were reported in the Miocene sequence. The first is reported to exist between the Middle Miocene sequence and the Post-Middle Miocene and explains the absence of the late Miocene sediment from the whole Sirte basin (Barr and Weegar, 1972).The second is reported by I.G.S (1973). This sequence is between the top of Marada Formation and the Aklash Formation in the Miocene Sequence .The presence of these two unconformities in the heterogeneous lithology of Jalo Miocene sequence will bring several faces in contact along the unconformity surface (Krumbeing and Sloss, 1963). This would bring highly permeable beds into contact with each other and would have important implications for the hydrologic boundaries of the aquifer system.

As outlined earlier, the Marada Formation has a complex geometry and composition. These complex variations, both laterally and vertically, were recognized by Selley (1966) at Marada and by Benfield (1972) at Jalo. The similarities in both lithology and geometric variations imply the existence of similar sedimentary faces at the Jalo and Marada areas, where a mixed sequence of limestone, sandstones, clays, and evaporates were reported by Selley (1966). He also reported the existence of estuarine channels in the Marada area. These channels were formed during Miocene time when many rivers were in existence in the whole basin. These mixed sedimentary faces and estuarine channels could exist in depositional conditions similar to those in the Marada area that existed in the Jalo area. The existence of estuarine Miocene channels is supported by the existing geomorphological features such as the subsurface Sahabi Channel to the northeast of Jalo, the Awjala Valley, and the Catmir Valley. These existence channels in Jalo area were previously unknown because of the absence of hydro-geological investigation until recently.

I .G.S. (1973) reported the existence of a clay layer in Miocene sequences which varied in thickness from 3 to 50 meters. They consider this layer as a basal boundary for the upper part of the aquifer. The lateral extent of this clay bed is uncertain. However, the institute drew a geologic cross section to trace the lateral extent of the clay bed in the lower units of PPM. From the study of the cross section and the available data, Alkaseh (1979) reports that many clay beds existed in many wells. These clay beds are similar to each other and vary in number over short distances from one well to another. The clay content in the aquifer system also increases as one moves north. These facts lead to the conclusion that theses clay beds have a limited lateral extent and therefore cannot be used as a regional basal boundary. This research has tried to highlight the two top aquifers (the Post Middle Miocene (Calanscio) and the Middle and Lower Miocene (Marada) aquifers), because they are very important hydrological aspects, as all freshwater comes from these aquifers. Recently, these layers have started to suffer from over-demand by farmers, citizens and oil companies without their realizing it, which has led to a decline in quality and increased salinity of the water.

3.3.7 Water Resources in the Alwahat region

Water in the Alwahat area is the reason for its existence, despite its location in the heart of the desert. It is the fountain of life, inasmuch as the discovery of water that made the people of ancient times concentrate in this desert area, struggling to make it a habitable location by cultivating the land and taking advantage of the crops, especially the palm tree dates. Sharif states that:

> Alwahat draws its water from layers near the surface in the range between 2.5–3.5 m. The water area available in this layer is present, but it tends to salinity. In some wells the salinity may rise to a level that makes the water undrinkable. The chlorine level is never less than 1.5 grams per litre, and has more than 3 grams in same wells. As has been previous stated, citizens have

> access to freshwater from the Abu Tiffel well for drinking and sometimes for cooking and making tea, due to its high price. (Sharif, 1971, p.256. Translated from Arabic).

This quotation provides evidence of the salination of water resources in the region, which shows that at least part of the problems with water availability lies in natural causes and not just human causes. The quotation also shows that a water tariff imposed in the seventies improved the awareness of these issues in the community and as a result people were more careful with using water. Although groundwater is the only source of freshwater in the Alwahat area and the main source of water is Abu Tiffel 35 km south of Jalo, where two wells were drilled in 1976 (SOMSL, 1978), yet today stakeholders are still unaware of the importance of groundwater in the Alwahat Area. This raises the question as to how to make the stakeholders realize the value of water without implementing water pricing.

3.3.7.1 Domestic water in the Alwahat region

Alwahat is facing increasingly difficult problems with water resources management (Figure 8 and Figure 9). The photos were taken in different years in the Alwahat residential area during the study. The photos indicate urban water overflow during opening hours. The water sector allows two intermediate times per week where the water supply is available. This allows Alwahat residents to fill the water tank, which is shown in Figure 8. Figure 9 shows the street near the farms and the freshwater on the street. Also Figure 10 shows one of the main Alwahat residential streets and a similar waste of water.

Figure 8: Evidence of urban water waste in Alwahat, 2008 (photo by the author).

Figure 9: Evidence of urban water waste in Alwahat, 2009 (photo by the author).

Figure 10 shows misuse of water in the centre of Alwahat (Jalo), near the official government buildings. Figure 11 illustrates the main Alwahat residential districts which lead to Awjala and Jakera. It shows freshwater misused by householders during the day time.

Figure 10: Evidence of urban water waste in Alwahat, 2010 (photo by the author).

Figure 11: Evidence of urban water waste in Alwahat, 2010 (photo by the author).

To overcome these problems, a new ethic of sustainable development is required. This should not only reinforce the established principles and technologies but also extend to integrated water resources management which includes water supply and wastewater management.

Alwahat has been dramatically changed by the discovery of oil in the area (Alalwanie, 2007), i.e., the modern house now has an average of 3–5 toilets (Drman, 2009) whereas before the average house previously may have only had two toilets. Without planning to reduce the everyday water consumption, this high standard of living has a very bad impact on water sustainability. Moreover, in Alwahat there is no metering system to measure domestic water usage, which would otherwise help to apply a tariff. Sadly the water is free of charge, and as a result the stakeholders do not value water, especially in Alwahat's situation with a severe lack of water.

The present water extraction and aquifer sites in Alwahat are located 35 km east of Jalo. They consist of 16 production wells drilled between 1975 and 1990 (GWA, 2008). Recent information (GWA, 2008) indicates that fourteen wells have been abandoned by the General Water Authority because of unreliability of the water supply. Two wells are fully working at depths between 120–160m, with productivity of 25 l/s (90 m^3/hr) for each well. Water is collected into two storage tanks of 600 m^3. In the study area the GWA faces challenges due to the age of abstraction equipment and the size of the network pipeline which carries water between the three oases: Jalo, Awjala and Jakera.

Water sources from the Great Man Made River Project (GMMRP) have been used since 1993. At that time, the GWA proposed for the Alwahat area (Jalo, Awjalah and Jakera) to get its supply from the GMMRP. Since then, this resource has become hugely important for the region (GWA, 2008), The water supply from the GMMRP transfer project to Jalo, Jakera and the Alnafora oil company averages 10,500 m^3/day. Water supply from the transfer project to Awjala is 2,500 m^3/day, but the GWA still applies for more water from the transfer projects such as the GMMRP. The GWA argue that the amount of water estimated for the region should be 14,365 m^3/day instead of current 10,500 m^3/day sourced from GMMRP for Jalo and Jakera and Alnafora Oil Company and also for Awjala to be estimated at 5,420 m^3/day instead of 2,500 m^3/day. In responding to this argument, the GWA in Libya explain that the water supply network has insufficient capacity. The total renewable water resources in Libya are usually estimated at 600×10^6 m^3/yr. This means that 87% of the present groundwater use is coming from non-renewable resources.

According to a recent study, groundwater resources in Alwahat are divided into two general types, one being local groundwater which represents 45% of all available water. The second source is groundwater deriving from the GMMRP wells which represent 55% of all available water for use. This represents a serious problem for the future, given that 50% of the water coming from these sources is brought in by pipework that is quite old and unreliable and is desperately in need of being replaced with an entirely new network of pipes (Alskran, 2012).

If something systematic is not done for the future, there will be great problems to come with not only available water, but even the quality of the water delivered to stakeholders. Some of these problems have already materialised due to leakage in the pipe network. These leaks have led to water waste that can be seen in pictures included in Appendix 8.16.

3.3.7.2 Water and Agriculture in Alwahat

As the world population increases, demand for food production increases. This implies that farmers require more water to meet rising production needs. In agriculture, as in industry, there are numerous locations where real problems exist (Overman, 1976). The cultivatable area of Libya is estimated at about 2.2 million ha (1.2% of the total area), with 1.8 million ha for annual crops and 0.3 million ha for permanent crops in addition to 13.3 million ha of permanent pastures. Agriculture contributes approximately 9% of GDP and provides employment for about 5% of the total economically active population (Overman, 1976).

In the Alwahat area of Jalo and Awjala, a state project was implemented in the early ‘80s, consisting of 101 farms of 6ha each. Water was to be supplied by a well field located a few kilometres south where water was found of better quality in the post Middle Miocene aquifer. 33 wells in 3 parallel rows of 11 wells were drilled from 1977 to 1981 but only one row was connected to the irrigation network of the farms. Now only 4 out of the 11 wells are in operating conditions and each well has a capacity of approximately 50 l/s. In view of the insufficient amount of water available for irrigation, the farmers drilled their own wells at depths ranging from 60 to 100m but supplying water of poor quality (2.5 to 5 g/l TDS) to be mixed with the better quality water from the deep wells. Information gathered from the agricultural engineers working in Jalo suggests that most of the 600 ha originally planned are now under irrigation, mostly with shallow well water (EIA, 2005).

Private irrigation has rapidly developed in Jalo and Awjala based on shallow drilled wells each with a capacity ranging from 4 to 7 l/s but with poor quality water. Nevertheless, the private irrigation area is now estimated at 3500 ha approximately 2000 ha in Jalo, 1000 ha in Awjala and 500 ha in Jekara. The main crops grown with the brackish water are date palms and tomatoes. The average yearly water abstraction is estimated to be 60–80 million m^3/yr (Pallas and Omer, 1999).

Figure 12: Evidence of drought on urban farms in Alwahat (photo by the author, 2010).

Figure 13: Evidence of drought on urban farms in Alwahat (photo by the author, 2002).

3.3.7.3 Water and the oil industry in Alwahat

The oil industry uses a great deal of water in its drilling and refining operations, and this has an effect on the availability of water for other users, such as farmers and domestic users. Libya's onshore oil production is located mainly in three geological trends of the Sirte Basin (see the map of the oil locations in Figure 14). There are several areas of Libya that contain active oil operations: (1) There is the western fairway, which includes several large oil fields (Samah, Beida, Raguba, Dahra-Hofra, and Bahi); (2) the north of the country, which contains the Defa-Waha and Nasser fields, as well as the Hateiba gas field (3); an eastern trend, which has several fields, containing approximately 80 % of Libya’s proven oil reserves and accounts for 90 % of production (EIA, 2005).

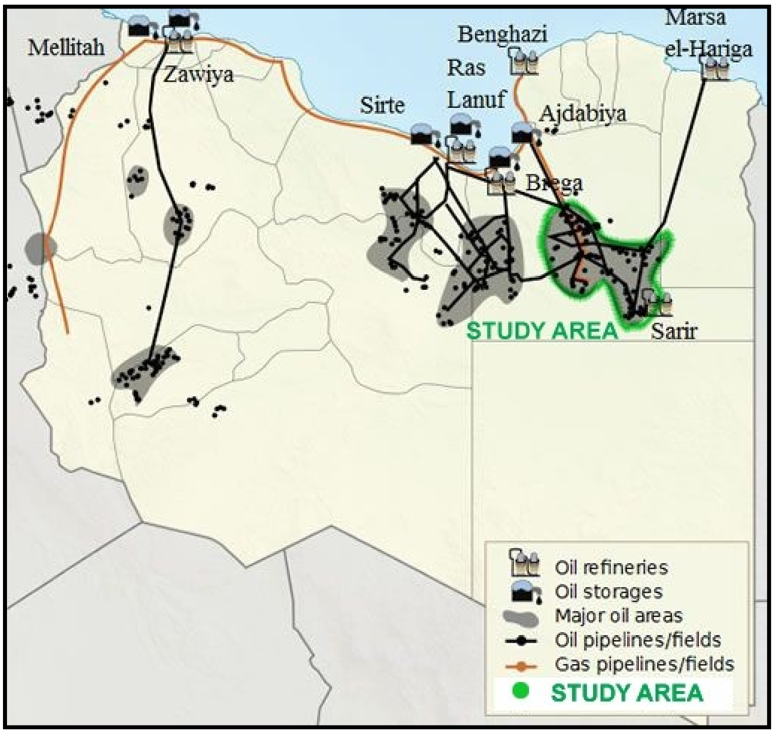

Figure 14: Oil companies located in the Alwahat study area.

Oil was discovered in the Jalo basin in 1961. This gave rise to a distribution of production fields and pipelines across Alwahat (Figure 14). As described in the introduction, Alwahat has a considerable importance in the network of transport located in the centre of Libya’s major oilfields cluster. Despite this, the oil industry has minimal impact on the local domestic economy and maximum environmental impact. This is due to the fact that the oil companies are self-sufficient in technological services and local manpower are only required in the fields of transport and construction. The upstream petroleum industry provides essential petroleum products. The use of petroleum products is a major contributor to the present standard of living. The activities of finding and producing petroleum, however, can have an impact on the environment, from the release of waste into the environment in unsafe concentrations. This waste includes hydrocarbons, solids contaminated with hydrocarbon, water contaminated with a variety of dissolved and suspended solids, and a wide variety of chemicals (Joint & Forum, 1997).

Figure 15: Untreated produced water in the Alwahat region. Source: (Dorman, 2012).

Some of this waste has significant adverse effects on the environment. One of these problems is called ‘produced water’, which can be defined as: “Mainly salty water trapped in the reservoir rock and brought up along with oil or gas during production” (ODOGO, 2008). Figure 15 shows an image of water produced from oil activities, indicating the large volumes of water involved. This massive volume of produced water from an oil well can be more than

10 times the volume of oil produced (Stephenson, 1992). In desert arid regions, where freshwater is scarce and costly, it may be economically viable to reuse the massive amount of produced water for agricultural and domestic purposes. Through the concentration of oil samples of water accompanying the two different areas of studies, Ayesha (1999) shows clearly where the results were higher than international safety standards (Figure 16 and Figure 17).

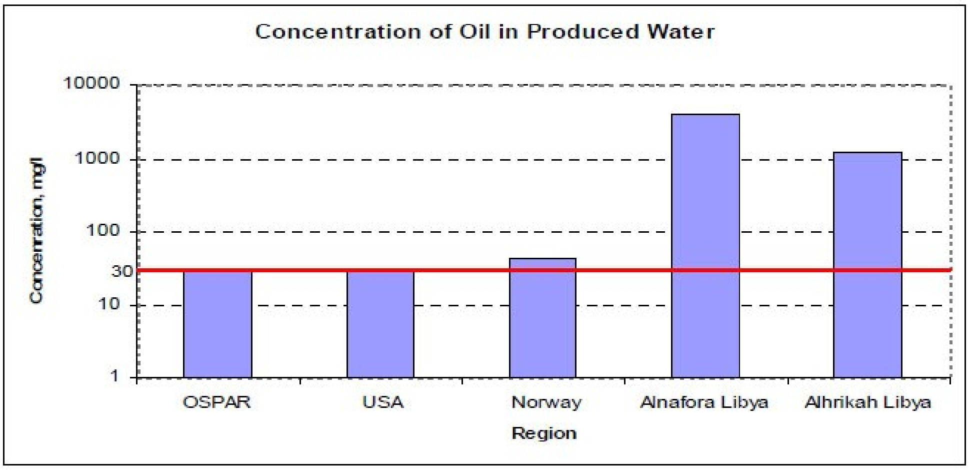

Figure 16: Allowable concentration of oil in produced water. (Source: Ayesha, 1990)

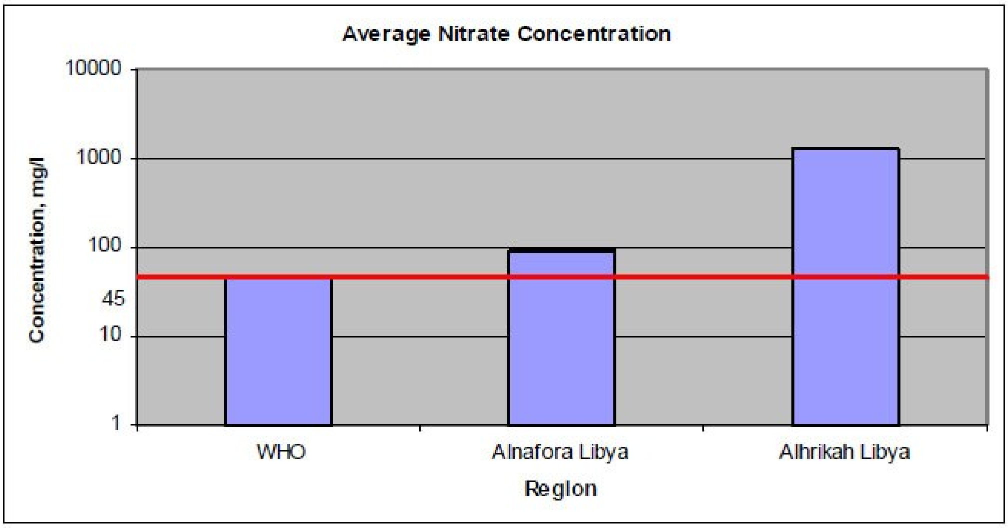

Figure 17: Average Nitrate Concentration in produced water. (Source: Ayesha, 1990)

In addition to these problems, Alwahat population also suffers from environmental pollution from the extraction of oil and gas from fields around the area. The consequence is that the health of humans and animals is put at risk. More alarmingly, the increase of hydrogen sulphide in the air presents a significant hazard for human health, especially in children and pregnant women in the area. Anecdotal evidence, and personal experience in the region, show that this pollution is likely responsible for the increased proportion of miscarriages and reduced fertility in the local population (Ballal, 2006).

3.3.7.4 Sewerage in Alwahat

Sanitation water is one of the most commonly used sources of water after treatment in developing countries and those countries use that water for agriculture or industry purposes. In the Alwahat region, there are seven public housing areas (525 households in total) connected to seven communal septic tanks. The rest of the region (around 5000 households) has no collection system other than individual septic tanks or cesspits which are emptied by the water sector periodically. Individuals managing their wastewater, which can be from black water (water from toilet), or grey water (from laundry or bath), collect all this water in septic tanks. This system has been used since the mid-1960s, and provided Alwahat with essential public facilities as mentioned by the Secretariat of Utilities (SU, 1979).

Figure 18: Septic tanks where the householders discharge wastewater in Alwahat (photo by the author 2010)

The house wastewater enters the septic tanks through the house discharge sewer pipe (Figure 18). This tank is built from concrete and the cover is made of iron. The size of the tank depends on the family size and the householders' preference. The bottom of the tanks is not closed; it has contact to the ground surface to allow the effluent discharge into the ground aquifer. At first, the ground aquifer absorbs the wastewater from the septic tank, but after years of use the tank fills up with sludge which contains cooking fats, oil, soap, scum and liquid. This provides a good environment for bacterial action increase in the sludge layer (Thomes, 2006). Usually the septic tank is located near to where the individuals collect their drinking water. Drinking water is often stored in a different water storage tank with a similar construction design (Figure 19). The difference is that it is isolated from the bottom with concrete which prevents the water from escaping. However, sometimes there is contamination from the septic tanks sited nearby which contain the sewage water. When this does take place, the householder will clean the freshwater tank and reuse or abandon and rebuild a new tank (Saleh, 2010).

Figure 19: Underground water tank in Alwahat area used to collect drinking water which comes from a municipal water pipe line network (photo by the author, 2010).

If the ground aquifer cannot absorb the sewage water which contains the grey and black water, the householder will call for the pump and empty the septic tanks within one week or a month, depending on how fast the ground can absorb the water. When the householder starts pumping, it indicates that the ground aquifer is saturated with water and will not absorb any more of the wastewater, which increases the risk of contaminating the drinking water from the septic tanks.

In Alwahat there is problem with a lack of tracks for drainage vehicles to collect the sewage water (Saleh, 2010). Often, wastewater from the septic tanks is discharged without treatment directly to the ground surface, close to farming and residential areas (Figure 20). Human effluent on the ground surface can be a source of dangerous water-borne diseases and can

Figure 20: Evidence of unregulated discharge of sewage from septic tanks to the ground surface. Approximately 1 km from the residential area of Alwahat. The wall in background of this photo is a farm boundary (photo by the author, 2010).

produce offensive odours (Scherer, 2006). The effluent should be delivered to a properly designed and constructed drain field or lagoon for treatment. Despite the fact there is no perfect solution that can be adapted by all countries of different origins, there are some common criteria that should be met. It would be ideal to devise a system of excreta removal that is maintainable, affordable, technically feasible, culturally acceptable and sustainable. One such method of excreta management, applicable to both urban and rural environments, the most ideal move towards a more sustainable sanitation management program in developing countries would be for governments to establish policies that strictly regulate the environmental outputs of waste management schemes and to ensure access to improved sanitation as a public right, as is more coherently accepted within the realm of water supply.

Salem (2010) conducted a study on collecting a water well sample from different areas of Alwahat for chemical and physical analysis. The results show a high amount of chemical components in the water and also they show that the closer the water wells are to the Alwahat area the higher the nitrate level, and the wells located further from centre of the Alwahat area are in lower nitrate level. Salem concludes that this is due to sewage water intrusion into the groundwater. Nevertheless, there are three reasons to doubt that the contamination is *only* due to sewage: Firstly, it is possible that nitrates could be naturally present in the soil. Secondly, nitrate contamination could come from farming, either through chemical use (fertilisers) or via the irrigation process; nitrates could be washed from already contaminated and treated soil, especially through over-watering. Finally, there is the possibility of contamination through waste dumping by oil companies, such as dumping of 'produced water' (Ayesha, 1999). Sustaining water quantity requires living within the freshwater renewable potential of the environment. Failure to do so can result in serious environmental impacts such as aquifer depletion, desertification and overall damage to the environment. Figure 21 shows evidence of damage to the environment from unsustainable water management practices.

Figure 21: Evidence of regular discharge of untreated sewage water which suggest that it has damaged the trees, land and the local environment (photo by the author, 2010).

Alwahat has traditionally been supplied with water from either dug or shallow-drilled wells. Nowadays, however, these wells are used much less frequently as water sources, and are instead being used as dumping sites for wastewater. The problem with this practice is that increases the risk of local freshwater contamination (Figure 22), with the potential to also affect the region's aquifer which, as the principle water source for the region, has potentially greater consequences.

Figure 22: Unused old dug wells in Alwahat area, not used because of drying up or high salinity.

3.3.7.5 Hydro-geochemistry of Alwahat

In Alwahat groundwater is used for domestic, industrial and agricultural purposes. The quality is the most important factor in limiting the use of the aquifer. The existing water chemistry and related data for groundwater in the study area were compiled from several sources (Alkaseh, 1979), including: The Agrar and Hydrotechnik of Libya, Ltd. (1966) investigation program in the Jalo area, the I.G.S. (1973) in the Jalo area, G.E.F.L.I.'s (1978) investigates in the vicinity between Jalo and Awjala. These organizations used different standard methods for analysis and determined only those constituents needed for their purpose; however, the major cations and anions in the samples(Na^+, K^+, Mg^+, Ca^{2+}, Cl^-, HCO_3^-, and SO_2^{4-}) were generally determined.

The Agrar Hydrotechnik Sampling Program was limited to the main public water supply wells and about 10 oil companies' water wells surrounding the Alwahat area. The I.G.S. conducted a sample program in addition to collecting the available water quality data from oil company files. Their water sample analyses included the determination of the major chemical constituents (cations and anions), finding some trace elements such as strontium and fluoride, except for two samples from closely-spaced water wells in the Jalo oasis, two samples from Awjala location, and one sample from the Gatmier water well. The institute ignored the quality of shallow aquifers which were heavily relied upon by individuals for drinking and farming purposes (Alkaseh, 1979). The Institute also compiled water data analyses from different oil companies. This water data was oriented mainly to the corrosion and encrustation properties of water.

G.E.F.L.I conducted drilling and a long-duration pumping test program on their sampled site. Irregular sampling for the shallow water wells within the Alwahat area was carried out by the department of water resources. The analyses of these samples were found to have a high percentage of error and inaccuracies in the sulphate determinations (Alkaseh 1979, p.48).

By1979, an additional water quality sampling program was conducted by Alkaseh (1979) in the study area of Alwahat, finding a variation of water quality in the Alwahat area. Since the study area is located in the transition zone between the freshwater body of Kufra and Sarir to the south and saline discharging swamps to north, the hydro-geochemistry is an important consideration in groundwater development. Lateral variation in Alwahat in groundwater is now quite apparent. These variations are controlled by the distances the water has travelled from the sources, by the lithology, and also by evapo-transpiration. The general trend of Alwahat groundwater chemistry indicates a directed increase in total dissolved solids (TDS) as one move to the North. The heterogeneous lithology has a marked influence on the water quality of the area; also the lithological variation breaks the general water quality trend at 40 km south of Alwahat.

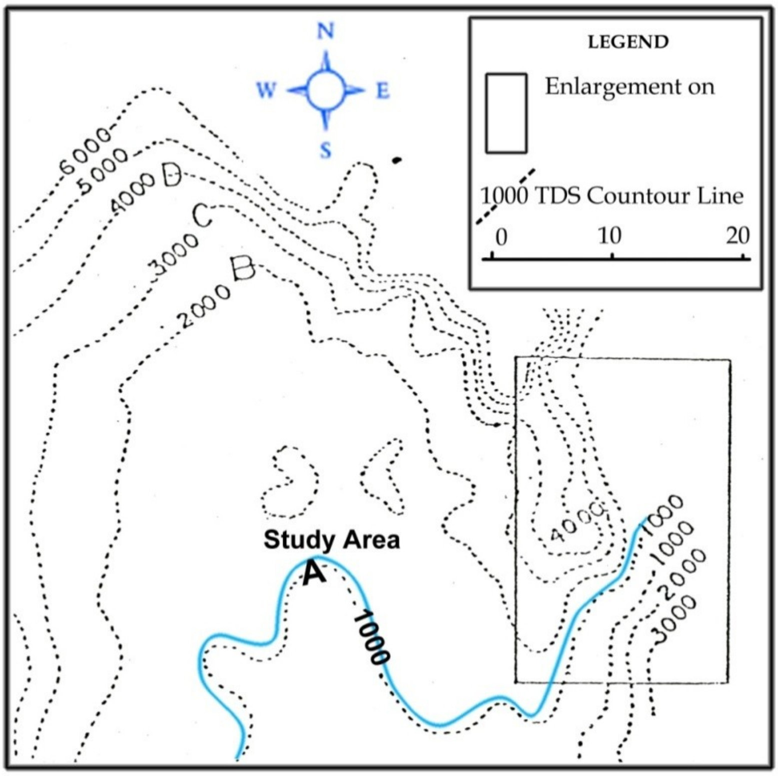

Figure 23 Total Mineralization of Groundwater in the Jalo Aquifer System
(image modified, after I.G.S., 1973)

Evapo-transpiration plays an important role in the deterioration of water quality around the Alwahat area and the nearby depression where the water level is close to the land surface (Alkaseh, 1979). The water deteriorates sharply along a north eastern–southeastern boundary passing through the area of Jalo and Awjala where TDS values as high as 10,000 ppm were reported. This abrupt deterioration in the water quality coincides with the increase of the marine faces, which include limestone and highly soluble evaporates (Selley, 1967).

Quality variation with respect to time is not apparent in the freshwater in Alwahat Labe, known as the I.G.S area. This area was sampled during the investigation program in 1972, and some of these wells were re-sampled during the G.E.F.L.I (1977) program and by Alkaseh (1979). The TDS were found by GEFLI to vary from 1,850 to 1,950 ppm for JL-p, and from 1300 to 1400 ppm for JC-p, whereas the IGS reported TDS values of 1,910 to 1,350ppm (respectively) for these wells. It would appear from these measurements that significant change in water quality is occurring in the wells, by comparing to the water quality variation in TDS re-sampled by Salem (2010), for the same JL-p and JD-p show the variation of TDS from 4,200 to 3,308 ppm. This study also shows that the Gatmer and Butafal shallow water wells (located in the Alwahat area) have lower TDS values than other parts of the study area. The nitrate (NO_3) level ranges from 10.0 to 44 ppm with an average TDS of 356.4 to 158 ppm calculated from various samples from different wells, this value is considerably higher than that recommended by the U.S. Public Health Service (U.S.P.H.S.). There is a need for a regular sampling program to check nitrate and fluoride variation with time, and different laboratories should be used for analyses. In summary, Salem (2010) is a reliable source of data on the types and quantities of water contamination, but we can be less certain about the sources of that contamination.

3.3.7.6 Groundwater Level in Alwahat

During the 1930s, in some parts of the Alwahat area, the water table interacted with the land surfaces where it loses water via evaporation. Today the static water level is deep enough to prevent direct evaporation from storage. Agrar and Hydrotechnik of Libya, Ltd. (1966) was the first to measure the water levels and draw a simple water level map for the Alwahat area. This map shows only a small number of oil companies and public water wells in the region. Wright (1977) published a water table contour map of post-Eocene sequence of the Alwahat and Sarir areas. This map shows a general hydraulic gradient from south to north with a regional flow direction to the north. On this map, Wright did not distinguish between the upper and lower aquifer layers.

The IGS measured the water level of about 100 wells drilled by the oil companies. These wells were used for water supply and drilling operation (Alkaseh, 1977, p.42). The IGS presented a piezometric map for the Alwahat area which included heads for both the PMM aquifer and the Middle and Lower Miocene and Oligocene Aquifer. Alkaseh tried unsuccessfully to measure the static levels in those wells drilled by oil companies. His lack of success can be attributed to several reasons, which include difficulties in locating the well, destruction of some wells, and the existence of a thick oil layer on the top of water surface in same wells. Dug wells were the only existing wells in Alwahat, with large diameters about 2 m. Static water levels for twelve dug wells in Alwahat area location of Jalo and Awjala were measured, and each well was measured two to four times over three years. The results of these measurements are presented in Table 10.

Area	Number of wells	Average Annual Decline cm/ft
Jalo/Elserrif	5	19.3 cm/0.65ft
Jalo/El labbah	15	35.3cm/1.15ft
Jalo/Rashdah	3	36.78cm/1.20
Jalo (Average)		33.50cm/1.10
Ojala/Elswani	5	25.69cm/0.84
Ojla/Abuattaf	7	37.0cm/1.28ft
Ojala/(Average)		28.8cm/1.04ft
Alwahat Average	(1975,1978)	319.3mm/1.04ft

Table 10: Rate of water level decline of Alwahat (Jalo/Awjala) shallow aquifer between 1975 and 1978 by Alkaseh.

The obvious water level decline of all measured wells is due to an increased withdrawal of water from the aquifer. The increasing withdrawals are attributed to local pumping for irrigation or large amounts of water used by oil companies for their injection programs. It should be noted that the limited available data are not enough to forecast which of these factors is most responsible for the decline. However, the water level in the wells did not show signs of seasonal recovery, which may indicate a regional decline of water levels in the area (cone of pressure) due to withdrawals for secondary recovery operations (Dorman, 2010). Dug wells used to be the most popular way to abstract ground for drinking and irrigation water. This is mainly not available today with a general decline in the static water level, which leads to use the drilled well system (Figure 24) that bore very deep in the ground to reach water (Alalwany, 2007).

Figure 24: The commonly-used drilling water wells in Alwahat area (photo by the author, 2010).

In summary, a large amount of freshwater is being pumped from the aquifer, mainly from the lower part. However, the shallow aquifer is being used extensively by some oil companies and farms. Sophocleous (2000) argues that to be sustainable, water withdrawals from aquifers must be considerably less than their recharge to avoid negative environmental impact. These withdrawals have an adverse effect on the general water balance in the area and special implications for the non-irrigation palm trees in the area.

Chapter 4: Research design and Methodology

4.1 Introduction

This chapter outlines how the research was carried out. It discusses the strategy that directed the research and the empirical methods by which the data were collected. It also presents how the data was collected and the steps that were taken to improve the validity of the research findings, and it presents the ethical considerations made during the investigation. The methodology used in this study adopts a multi method approach (quantitative and qualitative) conducted through questionnaires and interviews to present a comprehensive exploration of current water supply situation in Libya.

4.2 Research Design

The design of any study begins with a selection of a topic and a research methodology. The previous sections introduced the topic of this research. The researcher's next responsibility is exploring, describing, explaining, and interpreting the topic through an appropriate methodology (Marshall and Rossman, 1995). There are many research designs or approaches that could be used when conducting research but the nature of the research questions and objectives imply a specific type of research design to be followed. Yin (2003) suggests that 'what' questions are best answered using surveys, while 'how' questions are often appropriate for case studies. However, a survey is predominantly a quantitative strategy, while a case study falls within the category of qualitative methods. In this project the research questions do not fit exclusively into either qualitative or quantitative methods. So it is due to the aforementioned statements that the *mixed methods* approach is used for this study.

In this study, the intention is to conduct a stakeholder analysis which incorporates a triangulated mixed methods research design. Eight groups of stakeholders are identified as having a stake or interest in the development of sustainable water management in the Alwahat study area in Libya. The eight groups are agricultural water users, domestic water users, younger working women, government heads of agriculture, water Company and sanitation officials, hydrologists, environment agency officials and oil companies. The interests of all stakeholders are assumed to have equal priority. The study focuses on the perceptions of the eight stakeholders, and it addresses eight issues that are associated with sustainable water management in the Alwahat region. The objective is to collect this data using two quantitative methods (questionnaires and a water diary) and two qualitative methods (semi-structured interviews and focus groups). A comprehensive review of literature is conducted and questionnaires are used to collect data for the study (Chapter 3 provides more detail).

After the researcher decided upon the research questions and objectives, criticism and issues relating to sustainable water management performance, he found that the multi-methods approach (triangulation) is an appropriate and flexible way to conduct this research. Since the nature and main objective of this study is to explore and investigate the water supply and development strategy, the investigation uses a questionnaire and semi-structured interviews to fulfil this objective. The rationale behind the choice is justified in the following sections.

4.3 The mixed methods approach

'Mixed methods' is a relatively young research approach which embraces the strengths of traditional research paradigms. It is a type of research design in which qualitative and quantitative approaches are used in types of questions, research methods, data collection and analysis procedures, and/or inferences (Creswell *et al.*, 2003). In mixed methods research, qualitative and quantitative data collection and analysis techniques could be used either in parallel or in sequential phases. The ability to use different methods that have complementary strengths and non-overlapping weaknesses is perhaps the greatest advantage of mixed methods research (Johnson and Turner, 2003). Green and Caracelli (1997) are of the opinion that due to the complex nature of most social phenomena, different kinds of methods are necessary to help researchers get the best understanding and to make inferences of such complexity. They argue further that most social phenomenon cannot be fully understood using either purely quantitative or qualitative techniques, and therefore a variety of data sources and analysis are needed to completely understand such complex multifaceted phenomenon. Gabble (1994) recommends the use of mixed methods in PhD research when time and resources permit. A mixed methods approach provides more perspective on the phenomenon being studied and is gaining wide acceptance in organisational and academic research (Easterby-Smith, 2002).

4.4 Research methodology

The methodology dictates that it is necessary to first establish the water situation in Libya in general and the study area in particular. It does this using a detailed investigation of published and unpublished literature, personal research using archival and historical sources and interviews with key personnel in the water sector. Having established the current water supply situation, the next stage is to estimate the water demand. This is achieved through questionnaires, semi-structured interview techniques employed to identify perspectives of three stakeholder groups who play significant roles in water usage and management and whose involvement is crucial to successful investigation of water sustainability in the study area. The outline of this project's methodological approach is as follows:

1. Collect available hydrological and hydro geological information about Libya in general and the study area in particular. Special attention will be placed on data concerning water resources, supply, demand and balance in order to understand the reasons behind the water deficit nationally and in the study area.

2. Categorise the main users of water in the Alwahat area and identify their usage of groundwater.

3. Design two different questionnaires and conduct surveys of the stakeholders (water users and irrigation water users), and interviews with water professionals to gather information and investigate water sustainability in the area of the study.

4. Conceive and prepare schedules for semi-structured interviews with individuals selected from each of the above mentioned groups, plus oil companies and women, as they play a critical role in the contribution to water sustainability. The interviews are focused on topics related to different components of sustainable water management that emerged as being especially important or controversial in the questionnaire survey.

5. Because some interesting unexpected issues emerged from the interviews, it is considered necessary to examine these as well; this is carried out by direct observation and focus group discussions.

6. Information collected using the water diary to measure water use over time.

There are many important and complex social, behavioural, and organizational factors which need to be explored and explained in detail through other data collection methods such as interviews. Therefore, combining interviews and questionnaires in this study helps in generating deeper insights and better understanding to reveal further facts about the research dimensions. Also, it helps in understanding the facts underpinning the questionnaire answers and identifies many other important themes and facts related to the investigation of sustainable water and development at the study area. In addition, applying qualitative and quantitative methods was very important because of the difficulty in quantifying all aspects and development outcomes, which are mostly subjective in nature and require a long time to emerge. In the study, the main data methods used are both face-to-face semi-structured interviews and self-administrated questionnaires. These data collection methods work in a complementary way rather than in competition with each other. The chosen methods are outlined in the following sections.

4.5 Data Collection methods

The main data collection methods used in the study are interviews, questionnaires, focus group discussions, and a behavioural pattern study. Other supplementary methods include direct observation, which is used to collect data on each of the supplementary research questions. The choice of methods used for each supplementary question was based primarily on the type of data sought and the types of respondents involved. These generalised approaches use the following methods and techniques, detailed in the following sections:

4.5.1 Questionnaires

A questionnaire is considered to be one of the most common and widely used data collection methods. It is used in order to obtain the required data from a relatively large number of respondents in an economical way. Sekaran (2003, p.263) defines a questionnaire as: "A reformulated written set of questions to which respondents record their answers, usually within rather closely defined alternatives". The questionnaire is an efficient data collection method when the researcher knows exactly what data are required to answer the research questions and what kind of data the study is likely to produce. It allows the collection of data from a large sample prior to quantitative analysis. Questionnaires could be used with other data collection methods such as interviews. This study uses self-completed personally-administered questionnaires, which are also called delivery and collection questionnaires (drop-in, pick-up).

The purpose of these questionnaires is to collect data that enables the researcher to answer the research questions of this study.

After identifying the main water users in Alwahat (agricultural water users, domestic water users, and oil companies), the researcher planned to design one set of questionnaires which could address all of the 3 stakeholders, but the problem with this approach was that there was no direct relation between these 3 because of the different issues and interests between them. Therefore 3 different questionnaires were designed, each one related to a particular group of stakeholders. In the end, the questionnaire intended for the oil companies could not be carried out because they would not allow their employees to undertake the process due to time consumption. (It is, of course, possible that these companies were simply reluctant to divulge such information.) So, instead of a questionnaire, interviews were conducted with representatives from the oil companies (see the following section for details).

4.5.1.1 Stage 1: Developing Questionnaires

For the development of the research instrument, it is vital to commence its design with reference to the aim of the study (Hoxely, 2008). During the time of the literature review on the issues of water sustainability related to Alwahat, the researcher decided to develop two sets of questionnaires for each group; agricultural water user and domestic water user, in order to cover all the sustainable water management issues. The design of these questionnaires took some ideas from similar studies by Al-Shagsi (2004) on water demand management, and Addo (2005) on improving water services to the urban poor. During the development of the questionnaires, some alterations were made to these original designs in order to adapt them to the study area of Alwahat, Libya. For example, questions that related to expert farms in Oman were removed because they were not relevant to the study area. Two sets of questionnaires were designed to collect information from the agricultural and domestic water users. The eight main issues that we aim to clarify through this method are:

- Water use
- Awareness of water sustainability
- Groundwater depletion issue
- Legislation reform and implementation
- Issue of the water quality
- Education and training
- Environmental issues
- Solutions Provided by Stakeholders

The Agriculture questionnaire consists of 21 questions, and these questions are divided into 6 categories (see Appendix 2, for an example of the questionnaire). The first issue is awareness. To avoid unnecessary water use, farmers were asked whether they were aware of water sustainability. This information was generated through Q1, Q2 and Q3 which focused on awareness of water use. The second issue is the depletion of groundwater which may concern the number of wells and the well depth. Information about number of the wells in each farm is generated from Q4, Q7, Q8 and Q9. These questions in particular dealt with year by year analysis of water level decrease and extension of the water well each year by agriculture users taking part in the questionnaire. The third issue is water quality, which consists of Q9. This dealt mainly with the personal experience of users regarding the taste quality of their water over time. Water quality is one of main issues that will require a solution that will guarantee long term results. This was first by ascertained by assessing the water quality. The fourth issue is legislation reform and implementation, which consists of Q6, Q10, Q11, Q12, Q13 and Q14. Legislation is crucial to encourage sustainable water use in order to reduce water scarcity. Farmers were given a set of questions related to legislation reform and implementation. The fifth issue is education and training, which consists of Q5, Q15, Q16, Q17, Q19, and Q20. This is another target area which can help to solve the water problem. Finally, the issue related to environmental problems is covered in Q18.

The pilot study showed that the approximate time needed to complete the questionnaires is about 20–25 minutes. Participants were given one week minimum to complete the questionnaire. In some cases, where the participants had poor reading and writing ability, the questionnaires were completed in the presence of the researcher with his assistance.

The domestic water user's questionnaire consists of 17 questions. The questions are divided into 6 categories of issues (see Appendix 4 for an example questionnaire). The first issue is awareness of water use. Understanding of water sustainability terms could differ from one user to another, therefore five interpretations of terms have been extracted from users in Q2, also Q1, Q3, Q6, Q7 are related to the awareness of water use issue. The second issue is the education and training of water users. If users are educated and receive the basic training it will then be easier to achieve higher water use efficiency. Based on this idea, a set of questions need to be answered in order for the future strategy to be established. These questions are Q9 and Q10. The third is the sanitation issue, covered in questions Q11, Q12, Q13 and Q14. The fourth issue is legislation reform and implementation, in Q4, Q5, Q15 and Q16. Fifth is the environmental issue, which is covered by Q17.

4.5.1.2 Stage 2: Questionnaire Translation

After the approval of questionnaire design by the research committee and acceptance by the director of the studies, it was important to translate them from English into Arabic, because this is the main language of the target area population. Keeping in mind the importance of this stage, the Arabic translated version was distributed to the following to get feedback and check the accuracy of the translation and the format of the questionnaire design:

- A specialist in statistical analysis from Leeds University
- A hydrologist
- Water officer
- Environmental officer
- Agricultural officer
- Oil company manager (who would have the same knowledge as the representatives that were interviewed previously)
- Expert Arabic–English translator

Following advice from these specialists, four questions were rewritten in order to ensure that the questions were likely to be understood by the participants. For example, the usual translation of the word 'sustainability' could not be used for fear of it being misunderstood, so in this case a simpler and more recognisable phrase was used instead.

4.5.1.3 Stage3: Pilot Study

After the feedback and revision, it was necessary to pre-test the questionnaires to ensure that the collected data would be valid and reliable. The research conducted the pilot using two groups (agricultural and domestic water users), and each group were distributed 10 questionnaires. They were asked about the questions and wrote their notes on separate pieces of paper attached to the questionnaires. The aim of this was to ensure the clarity of the questions, to avoid ambiguity, and to determine the time required to complete the task.

4.5.2 Population of the Study Area

In statistics, the full set of cases from which a sample is collected is called the *population*. For the questionnaires, the population is separated into two groups: agricultural water users and domestic water users. According to the 2005 agriculture census (AM, 2009), there are 5783 farms in the Alwahat study area, 3139 of which are in full production. Since 2005 the number of farms has increased, but there is a lack of up-to-date information on the exact amount of the increase. Due to this, the research uses a population including the total number of the farms in Alwahat area, which has presumably increased since these records were made. The number of householders in the study area is calculated from the national census that was carried out in 2009. It shows the total number of the householders in Alwahat to be 5727 (GFR, 1994).

4.5.2.1 Sampling Stage

Instead of testing the whole population, these questionnaires are directed to only a sample. Statistical research such as this need to consider the following issues in probability sampling (Saunders *et al.*, 2003 p.153):

- Identify a suitable sample frame based on your research questions or objectives
- Decided on a suitable sample size
- Select the most appropriate sampling technique and select the sample
- Check that the sample is representative of the population

It is important to consider all these aspects in order to draw a representative sample from the population of study (Hunt and Tyrrell, 2001). This study uses a form of probability sampling called stratified random sampling, in which a proportional sample is selected. As pointed out before, Alwahat consists of three parts **(**Jalo, Jakera and Awjala). There is no numbering for houses and farms in the study area, so this research uses a *stratified sampling frame* which is divided into non-overlapping groups, i.e. geographical areas in the South, East and West.

4.5.2.1.1 Agricultural Sampling

Before the questionnaires were administered, several meetings were held with the interview participants to discuss the best way to proceed with the questionnaires. Based on the total population of farms at 5783, the sample size we used was 357. This figure is derived from the sampling size table in Saunders *et al.* (2003, p.156), which recommends for a 5% margin of error and 95% level of certainty.

The first step was to use the number of the farms from the three sample areas. The population size for each area is: Jalo 2891, Awjala 1890, and Jakera 1002 (total = 5783). To find the sample size for each area, we calculate as follows:

Area sample size = area population / total population × total sample size.

Jalo farm sample size = 2891 / 5783 × 357 = **178**

Awjala farm sample size = 1890 / 5783 × 357 = **116**

Jakera farm sample size = 1002 / 5783 × 357 = **62**

4.5.2.1.2 Domestic Sampling

The procedure for the domestic water users' questionnaire was very similar to the previous method. Again, there is no house numbering, so the research again applied a randomised numbering system to select the final sample. The total number of households is 5727 (domestic water users) in the Alwahat area, and the breakdown for each of the areas is: Jalo 3234, Awjala 1563, and Jakera 930 households. Sample sizes for these areas were calculated as follows:

Jalo household sample size = 3234 / 5727 × 357 = **201**

Awjala household sample size = 1563 / 5727 × 357 = **97**

Jakera household sample size =930 / 5727 × 357 = **58**

4.5.2.2 Fieldwork (Questionnaire administration)

Given that the households and farms in the study area do not have house numbers, to decide which households and farms to sample the study gave randomised numbers to the farms, and then selected a sample by picking numbers at random.

The researcher personally delivered and collected the questionnaires with help of a former university colleague. It was explained to the participants how to complete the questionnaires, and they were also told of the significance of this work and its aim. With the questionnaire was supplied a personal letter from the researcher, with contact details provided, in case the participants needed support in completing the questionnaires. There was also a section where the participants could comment and provide feedback about the questionnaires. Most of the participants agreed that they were comprehensive questionnaires.

4.5.2.3 Questionnaire Response Rates

Since the study area is comparatively large and the sample size is quite high, the administration of the questionnaires took a fairly long time, and was carried out between 25/8/2010 and 6/11/2010.

The questionnaires that were addressed to the farmers consisted of 17 questions. A total of 400 agricultural questionnaires were distributed in study area, and 367 questionnaires were returned. 17 of these were excluded because they were incomplete. This leaves the study with 350 sets of agricultural data. The domestic questionnaires consisted of 21 questions. From a total of 400 questionnaires distributed in the study area, 366 were returned and 9 were excluded due to incomplete responses. This leaves the study with 357 sets of data on domestic water users.

4.5.2.4 Preparation for data analysis of the questionnaires

After the completion and collection of the questionnaires the next stages are as follows:

- Coding of questionnaires by given number to each answer of a question, to identify from other questionnaires.
- Coding each question and answer. For example “Yes” was given 1 and “No” was given 0. In the case of multiple-choice questions, the answers were numbered sequentially.
- A database for each type of question was created and entered using Microsoft Excel software.
- SPSS statistical analysis software was used to analyse the data collected

Chapter 5 explains the data analysis procedure in greater detail.

4.5.3 Interviews

The purpose of employing interviews as a method to collect data are as follows: The literature review on the Alwahat study area identified that there is a lack of current and accurate data relating to water management in the region. For that reason, the idea is to conduct interviews with the stakeholders in the Alwahat area, to classify the main users of water in the region. Furthermore, the interviews aim to highlight the critical issues which can be barriers to building a sustainable water management strategy in Alwahat. In brief, the barriers that need to be scaled would include formulating and evaluating comprehensive studies on the water situation in the region, establishing principles and technology for water supply, water supply and waste management, a metering system to measure domestic water usage, applying an affordable tariff to the usage and new legislation to regulate all of these matters and systematize the workings of all the stakeholders so that they are working in tandem with one another and not against each other.

In this study, interviews are used to gather first-hand data on the water supply situation in the research area of Alwahat. The interviews are semi-structured, thus giving interviewees the freedom to express themselves in their own words, while at the same time ensuring that all the relevant issues of concern to the study are adequately covered. The semi-structured interview process aimed at achieving an insight into the region's water-related problems, their water use practices, attitudes and beliefs about paying for improved water services. The semi-structured nature of the interviews also allows the moderator to investigate further other interesting issues that come up. Gillham (2000) explains that it is the opportunity to narrate their experience in a less structured form that brings in the elements of new discoveries and understanding in research. These two elements of new discoveries and understanding are, to a large extent, the primary essence of an exploratory study, thus making the use of interviews an essential part of any exploratory research. In the context of consumer behaviour studies, Mariampolski (2001,p.163) notes that interviews serve as means for gathering an authentic understanding of consumers' values, their thinking, and their experiences.

The interviews generate qualitative data in sufficient depth to provide a detailed understanding of relevant consumer perceived issues concerning the provision and use of water services. The insight gained, together with some of the issues that came up during the interview phase of the research are incorporated into the subsequent data collection phases of the research.

4.5.3.1 Selection of respondents for interviews

In this research the semi-structured interviews are conducted with selected stakeholder officials. The selection procedure for the interviewees was not a probability sampling technique but a purposive sample. The sample size was not very large, so by interviewing all the eight officials available, it allows for a more thorough exploration of the evidence required to justify the current issues within water stakeholders in the region.

4.5.3.2 Preparation for the interview

After the identification of issues that can be a barrier to sustainable water management, these issues need to be explored in depth. The aim is to select the available eight stakeholder officials for in-depth interviews (2 from oil companies, 1 hydrologist, 1 from the Environment Agency, 2 Water and sanitation officials, and 4 government heads of Agriculture). The research is exploratory, using open-ended questions, which allows interviewees to formulate their responses according to their ideas, opinions and values (Patton, 1980). Before the semi-structured interviews took place, the researcher gained authority to conduct the interviews with the interviewees, and the interviews were arranged to take place in their workplace. As preparation for the interviews, information concerning water usage in the region is categorised as follows: current use of water, satisfaction with water supplies, awareness of water supply and sustainable issues, perception of groundwater and deterioration in water quality, the environmental impact of water use, and the stakeholder's suggested solutions.

4.5.3.3 Conducting the interview

Interviews form one part of the triangulation methodology, in addition to the focus group discussion, questionnaires and the water diary. All the interviews were conducted at the interviewees' offices. The researcher explained to each interviewee the research aims, and justified the importance of this work in terms of how it can help to sustain water in the area of Alwahat and help to provide a strategy for Libya. The researcher also explained the importance of them answering without any response bias, and asked them to answer what they feel to be true. The researcher gained permission to record the interviews, which generally lasted for around one and a half hours.

4.5.4 Focus Group

The aim of the focus group discussion is to seek further understanding of some of the issues that came up during the interviews and questionnaire survey. It also provides the opportunity to clarify understanding of the water supply problems and water user behaviour within the research communities in the area of the study. The use of focus group discussion at the later stage of data collection helps in making better interpretation of information obtained from the methods used in previous phases of the data collection exercise. The focus group discussion therefore helps enhance the interpretative validity of research.

4.5.5 Behavioural Pattern Study: The Water Diary

4.5.5.1 Rationale for the Water Diary

One of the objectives of the study is to estimate the water consumption for personal activity and household activities in Alwahat, Libya and to compare it with the average general usage in the country, as reported by (Alsakran, 2012). Since very little research has been done in this specific study area, especially about Libya, so the water authorities try to predict the average water use based on the international standard estimation, which has little to do with the study region.

In order to answer this problem, a water diary was specially designed to collect information about water consumption of the households inside the study area of Alwahat. The water diary table form was distributed for filling in and was later collected. The first idea was to include all the family members into the diary table but that strategy did not work, as the majority of the people do not like to fill in the water diary table. It seems that they don't want to do it or they start but do not complete it at all. Then the design of the water diary was slightly changed to ask for volunteers who really want to complete the table. Secondly, the design of the diary was changed to cover the whole week, rather than just one day. This idea of studying the whole week was initiated because the householders are not doing every water consumption activity every day, for example using washing machines or having a shower. A third change was to make separate gender categories (female and male). The reason to add this feature is that some household activity might be related to one gender only.

4.5.5.2 Empirical Measurement for the Water Diary

Based on the semi-structured interviews with the top water sector managers, the average water consumption per day per person is 300 litres. Alsakran (2007) and the local authority stated a need for more water in the Alwahat area. Also, we find in the literature review estimated water consumption for basic requirements of 20–50 litres/person/day (Gleick, 1996). Because this data is not necessarily reliable for the current state of affairs in the area of study, it was decided to inform our measurements by making our own calibration for the estimates of water usage. The following sections detail these calculations for each water-using activity.

4.5.5.2.1 Calibration

Drinking Water: Most of the people use glasses for drinking water. This is a common practice in the study area that people were using glass for the purpose of drinking, so glass has been taken as a unit of measurement. A glass is, on average, equal to 0.25 litres of water.

Washing hands and face: The Muslim community living in the area of study need to wash their hands and face (called *WUDU*) for the sake of prayers, five times a day. Prayer is performed at the local Mosque and water usage at the mosque can be calculated. The time consumed per *wudu* was calculated by using a stop watch. The water flow from the tap per second has been multiplied with the total time consumed per person per *wudu* . When this practice has been done throughout the day, the final consumed water per *wudu* was 7 litres. What this meant was that the stop watch was started around the time of the bucket being filled and wudu being done and not the tap being opened as the tap opened did not in and of itself represent the water usage. Random Assessment was also done with some selected people, and the average consumption of water remained around 7 litres per *wudu* . This study was done using 7 individuals over seven periods of time. The selection was not based on random sampling but was specific to people at the site. In comparison, out of seven individuals over seven periods of time, the lowest amount of time used was 47 seconds for a *wudu* which used one litre of water while an individual in a two minute period used 1.25 litres. Upon examination of the duration, it can be observed that water consumption increased over certain periods when there was an increase of fluoride in the water.

Shower: Although the installation of meter devices for water reading at the houses is very important in finding out the accurate consumption of water, yet it was not available in the area of Alwahat. Therefore, the procedure conducted with those willing to contribute was to use a stop watch and water bucket to estimate the amount of water consumed. Firstly, the water was calculated by noting the time on a stopwatch and the estimated consumed water in litres was calculated. Secondly the total amount of water in the upper reserve tank of the property was calculated and then asked the volunteer for shower. The difference was calculated to confirm the exact amount of water consumed in a shower. The procedure was repeated and an average of total water consumed has been entered in the table for the sake of accuracy. In a simplified fashion, the volunteer would turn on the reserve tank upstairs to prepare for a shower, but the fluoride had to run out before the shower was ready. This time was also included in the calculation. Then when the shower was ready, the time for the shower itself was also added into the equation as the preparation and the shower itself were both one action. The average water consumed in a shower was 5litres/min. There were 25 people involved in this study, of whom 15 were women and 10 were men. Comparison was drawn between the duration and the consumption of the two groups. The lowest duration of time in the shower was 6.5 minutes and the highest was 18 minutes. When discussing the men, the shortest duration of time in the shower was 6.3 minutes with a usage of 35L of water while at the highest duration, the men took 8 minutes with a usage of 48L of water. In examination of the data on the women, the minimum time in the shower was 8.5 minutes with a usage of 43L of water while the maximum was 18 minutes in the shower with a usage of 80L of water.

Bath: The estimated amount of the water consumed in taking a bath in a bathtub depends on the size of the bathtub and water filled into it for a normal bath. In the area of study, normally 75 to 90 litres of water were used for single bath. Surprisingly most people did not like using the bathtub, due to the hygiene reasons. Another reason for not using bathtub was the style of living as people preferred to live in a joint family system.

Toilet: Flapper flush system was used for flushing toilets in the area of study. This has a tank for the water storage from 14 to 17 litres of water. There were also some flushing systems which were called Bash. These were installed in some of the newly-constructed houses, as these were exported from Turkey as it was in fashion, but they consume more water.

Domestic Washing Up: This would include washing things in the sink, such as the washing of dishes, cups, bottles and so forth. The same idea of using the stop watch and water bucket to estimate the amount of water consumed in using a running tap and this procedure has been conducted with women, as it was only women who worked in the kitchen. Firstly, the water was calculated by noting the time on a stopwatch and the estimated consumed water in litres was calculated. Secondly the total amount of water in the upper reserve tank of the property was calculated and then asked the volunteer to wash under the running tap. The difference was calculated to confirm the exact amount of water consumed in running tap. The procedure was repeated and an average of total water consumed has been entered in the table for the sake of accuracy. The average water consumed was 25 litres per wash. It is important to keep in mind that this consumption corresponds to the family size mentioned in our study previously and also the fact that the washing was done under a fully running tap.

Dishwasher: Dishwashers are not very popular in the study area, but some dishwashers were available on a small scale, as some vendors were trying to import them, without taking care of the amount of water consumed by these types of machines. Normal dishwashers consume 60 to 80 litres per load. Fortunately the dishwashers were not in use there in the study area.

Washing Machine: Most people use a washing machine for washing their clothes. These are big because of large families. There will be increased consumption with washing machines as often the washing machines will have a capacity of 20 litres and use maximum water consumption without any economy or water conservation setting. Thus keeping this in mind, the average consumption of water per load is 80 litres.

Cleaning the house: Normally houses are cleaned twice a day due to the weather conditions. An average wash consists of 2 buckets and uses 15 litres of water. This statistic was found by examining the women in the normal cleaning activities when they took clean water, put the soap in and then used this to clean the floor. After this, the soapy water would be poured out and clean water would be poured in for the rinsing of the areas in the house required.

Food preparation: Water is also consumed in cooking and usually a family has three meals per day. Average consumption of water in food preparation is 5 litres per meal. This was done by visual observation and estimated based upon the water used in the cooking and preparation in things like washing certain foods and other things on the stove.

Activity	Estimated amount of water used
Drinking water	0.25 l per glass
Washing Hand and face	7 l per wash
Having a shower	6–12 l per min = estimated 10 l per min
Having bath	Between 75–90 l per bath
Flushing toilet	15 l per flush
Washing up	25 l per wash under running opening tap
Dishwasher	60–80 l/ per load
Washing machine	80 l/ per load
Clean house	15 l per clean
Food preparation	5l/per meal

Table 11: Estimates of water used in household and personal activities.

4.5.5.3 Stage 1: Design and trial of the initial water diary table

The idea of the water diary is to estimate water use for householders in Alwahat. The initial design for the water diary table recorded activities over 1 day, but this had the problem of not covering every activity, so it was expanded to record a whole week. This diary was distributed to about 20 householders during the pilot study. Some of the water diary tables were not fully completed as householders had no time to fill it in completely. Furthermore some household activities were not practiced in just one day. Due to these reasons the water diary was redesigned to cover all house activities and personal usage.

The water sector in the study area proposed that the average water consumption used by a single person as 300 litres/day. Water information was collected during the day, firstly in public areas (these public areas have been included as domestic as well for the people use these areas just as much as their home and would in fact consider this an extension of their family or domestic life), for example the Masjed (the place where Muslim people use to go to pray; they use to water to wash hand and face and feet about 5 times a day, using an open running tap between 2 in to 5 min for this activity), and secondly the information was collected many times about the usage of water by householders in Alwahat. Finally the average usage of the water for both personal activity and house activity was calculated.

4.5.5.4 Stage 2: The re-design of the water diary table

The water diary table has been re-designed in a more comprehensive way, to cover the whole week and the total number of activities. It has included all house activities a weekly/24 hr, the personal activity such as drinking water, having shower, washing hands and face, and flushing the toilet. It also covered the house activity like food preparation, washing machine, and clean house, and so forth. The final design recorded activities over 18 hours – the time during which most people are awake and active. Given the possibility that some activities occur at night, if this research was repeated in future, it should include 24 hours.

4.5.5.5 Stage 3: Distribution of the water diary

The water diary was distributed to all places at the research area which was about 400 water diary tables. Later on about 60 water table diaries were returned, of which 40 water table diaries were complete and have therefore been used for this research.

4.5.5.6 Stage 4: Collection and Analysis

This involved the collection and analysis of the data received in water table diaries and the entering of the date into the computer program (Excel file) for the specification of data into further categories such as gender and the like as well as calculation of the water used in an 18 hr/day/week and summing-up of the total per person consumption. In the following section, we look at each activity in turn, summarizing the results in a graph, before compiling all the weekly data at the end.

4.6 Validity and Reliability

Gorman and Clayton (1997, p.57) define reliability as "the extent to which a measurement procedure yields the same answer however and wherever it is carried out" and validity as "the extent to which a piece of research gives the correct answers". These two criteria (reliability and validity) are deeply rooted in the quantitative tradition and less so with qualitative research. Denzin and Lincoln (1994) note that the notions of reliability and validity, however, represent key questions that must be answered one way or the other in any piece of research, and so cannot be disregarded. It is certain that the level of reliability or validity of a piece of research has repercussions on the credibility of the findings and conclusions and thus needs to be considered throughout the research process.

With quantitative methods, validity is concerned with whether or not the method truly measures that which in intended to measure or how truthful the result are in reality. Two types of validity refer to whether or not what is identifying here internal validity and external validity: internal validity refers to whether or not what is identified as the ‘causes’ or ‘stimuli’ actually produced what have been interpreted as ‘effect’ or ‘responses’. External validity, on the other hand, generally refer to the extent to which any research findings can be generalised or extrapolated beyond the immediate research sample or setting in which the research took place (Bryman, 2001).

4.6.1 Reliability/Dependability

Reliability is also known as dependability in the literature and it illustrates the level to which the method is stable and consistent with measuring the concept to allow repeating the same research using the same method, sample and data collection produced so as to obtain the same results of those previous study (Sekaran, 2003). Reliability is concerned with the question of whether the results of a study are repeatable (Bryman, 2001).

4.6.2 Significance of the Study

It has been said that:

> Research can be considered as a voyage of discovery and whether anything is discovered or not the essential feature is that it should make an original (increment) contribution to knowledge (Fellows & Liu, 1997, p4).

This study makes a contribution to knowledge in the following ways:

1. It contributes to the understanding of the development of sustainable water practice in Libya by presenting an empirical and analytical study which will expand the literature in relation to water usage and development in semi-arid countries.
2. It introduces a strategy for sustainable water management and it is expected that such efforts will alleviate water shortages and abate water pollution.

3. It raises awareness of the importance of demand management, and gives a better understanding of how sustainable water development could be effectively managed.

4.6.3 Ethical considerations:

Ethical considerations are important for a researcher who deals with real people in real world situations (Bassey, 1999). Bell (1999) also emphasises that a researcher must be aware of, and be guided by, ethical protocols throughout the research process, and that common sense and courtesy are invaluable in establishing good research practice. Due to the sensitivity of the research data and possibly the findings, ethical standards are adhered to in order to safeguard the identity of respondents. That is, the respondents' identities are kept anonymous and information respondents give is only be used for the purpose of the research. Published material resulting from the research would be done such that it will not reveal the identities of respondents (Oppenheim, 1992).

The ethical deliberation subjects were considered by the researcher during the research process and design and data collection and analysis, the following ethical issues were addressed by the research and approved by Nottingham Trent University:

a) Permitting free choice
   Allowing the participant during the research the free of choice and also of withdrawing from the study at any time without penalty was guaranteed.
b) Confidentiality and Anonymity

All the collected data remains confidential and anonymous by acquiring knowledgeable permission from participants after fully informing them of the purpose and aim of the study. Anticipated uses of the data, identity of researcher, the respondents' role in the research, degree of anonymity and confidentiality, the methods to be employed and the anticipated length of questionnaires and interviews were clearly explained. Also, all participants were assured that after transcribing was completed and checked for accuracy, duplicates would be made and the originals would be attested. If the participant requested a copy of the findings when the research is done, the researcher assured them that he would send a copy.

4.7 Analysis Methods (Stakeholder Analysis)

The analytical strategy used in this study is a stakeholder analysis. A stakeholder is an organisation or person with a vested interest in the development of a social or environmental policy or program, and whose participation and support are crucial to achieve its success (Sharma & Starik, 2004). Stakeholders may include national government officials, governmental or non-governmental organisations, non-profit organisations, commercial/for-profit organizations and consumers/users including the general public (Mitchell *et al.*, 1997; Savage *et al.*, 1991). Stakeholder analysis involves collecting, classifying, and interpreting information from specified stakeholders (Babou, 2008; Sharma & Starik, 2004). In this study, eight groups of people are identified as having a stake or interest in the development of sustainable water management in the Alwahat study area in Libya. The eight groups are: Agricultural Water Users (350 farmers); Domestic Water Users (397 members of the general public); Younger Working Women (7 women from the Social Care Department; Older Housewives (5 female senior citizens aged from 70 to 81); Government Heads of Agriculture (Four Head Officers); Water Company & Sanitation Officials (Two Head Officers); the Hydrologists and Environment Agency (one Hydrologist and one Environment Agency Head Officer) and Oil Companies (two oil company executives). The interests of all stakeholders are assumed to have equal priority. The reason for this is that there is a direct relationship between all of them, namely water, its scarcity and availability over time. Further to this, what affects what group will necessarily affect another group, i.e. if oil companies are forced to use more aggressive water extraction methods to obtain water for their projects, this will in turn deprive farmers of water for their crops and householders for their basic domestic needs.

The relationship between all of these groups therefore has to be considered equally and the resource that they all share, i.e. water has to be thought out in a careful manner for the future.

The stakeholder analysis incorporated a triangulated mixed methods research design. The perceptions of the eight stakeholders concerning eight issues associated with sustainable water management in Alwahat were collected using two quantitative methods (questionnaires and water diary) and two qualitative methods (semi-structured interviews and focus groups) . The stakeholder matrix, defining the cross-classification of the eight groups of stakeholders by the eight issues, creating 64 cells, is presented in

Table 12 below.

Table 12: Stakeholder matrix for identifying which issues are investigated by which methods.

Issues	Stakeholders								
	1.Agricultural Water Users	2.Domestic Water Users		3. Older House-wives	4. Younger working women	5. Government Heads of Agriculture	6.Water & Sanitation Officials	7.Hydrologists & Environment Agency	8.Oil Companies
	N = 350	N = 357	N = 40	N = 5	N = 7	N = 4	N = 2	N = 2	N = 2
	Farmer Questionnaire	Domestic Water User Questionnaire	Water Diary	Focus Group	Focus Group	Semi-structured interviews	Semi-structured Interviews	Semi-structured Interviews	Semi-structured Interviews
1. Stakeholder's current use of water	X	X		X	X	X		X	X
2. Stakeholder's perceived level of satisfaction with water supplies	X	X	X	X	X	X			
3. Stakeholder's awareness of water supply and sustainability issues	X	X	X	X	X	X	X	X	X
4. Stakeholder's perceptions of groundwater issues	X	X				X	X	X	X
5. Stakeholder's perceptions of the deterioration in water quality	X	X	X	X	X	X	X	X	X
6. Stakeholder's perceptions of the environmental impact of water use	X	X	X	X	X	X	X	X	X
7. Stakeholder's perceptions of issues associated with the disposal and/or re-use of wastewater	X	X	X	X	X	X	X	X	X
8. Stakeholder's suggested solutions to prevent misuse of water	X	X	X	X	X	X	X	X	X

×The collected information from the stakeholder put into the cells (regardless of whether the data were qualitative (i.e. focus group and interviews) or quantitative (water diary and questionnaires).

4.7.1 Population of the Stakeholder Matrix

Different analytical strategies are used to analyse the responses of the stakeholders and populate the stakeholder matrix with appropriate information, depending upon whether the data were quantitative or qualitative (Creswell, 2009).The following sections explain how the research deals with the quantitative and qualitative data.

4.7.1.1 Quantitative Data Analysis

The quantitative data analysis was performed with SPSS using the methods described by Field (2009). The information collected using the questionnaire items consisted mainly of categorical variables, which were either nominal dichotomous responses which did not represent a rank order (e.g. “Yes” or “No”) or ordinal responses, representing a rank order measured on a 5 point Likert type scale (e.g., 1 = “Very Dissatisfied”; 2 = “Dissatisfied”; 3= “Unsure”; 4 = “Satisfied”; 5 = “Very satisfied”). Due to the fact that the variables were nominal and ordinal, it was not justified to use parametric descriptive statistics (e.g., mean and standard deviation) to summarize the responses.

The information collected using the water diary was entirely quantitative. The measurements of water use over time in units of litres/person/hour or litres/person/day were found to be approximately normally distributed, as illustrated by the bell-shaped histogram constructed to summarize the daily use of drinking water by the domestic users (Figure 25). It was therefore justified to estimate the mean rates of use of water as measures of central tendency.

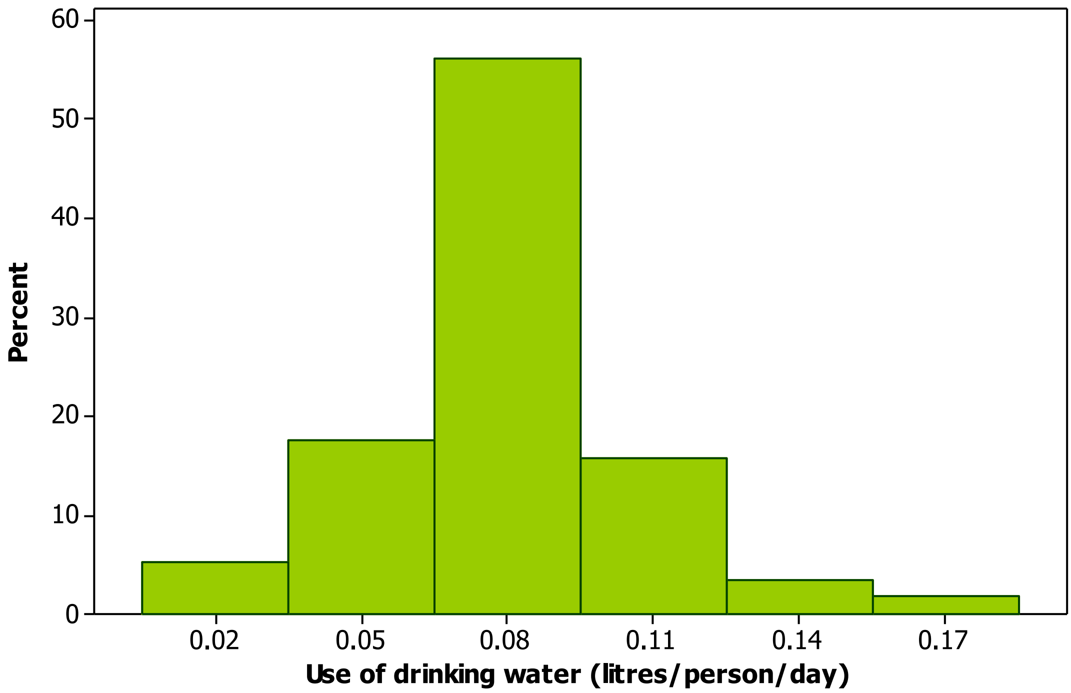

Figure 25: Normal distribution of water use by domestic users for drinking purposes.

4.7.1.2 Qualitative Data Analysis

Many researchers using qualitative research methodologies have been criticized for not describing in sufficient detail how they interpreted the narrative or verbal information they collected (Bernard, 2000; Babbie, 2009; Creswell, 2009). For example, some researchers may, consciously or unconsciously, give preference to the voices of certain interviewees in preference to others, or exclude certain views that are directly opposed to their own. It is common for researchers to interject their own assertions, or present their own personal value judgements, without exact qualification of the evidence, based upon the manifest or latent meaning of what was said by the respondents. Some researchers may imply cause and effect relationships, based on limited evidence, which contradict the principles of qualitative research methodologies. Consequently, it is often difficult to determine the validity and reliability of the conclusions drawn by many researchers using an interpretive approach, as they may be corrupted by subjective observer bias (i.e., the personal intuitions, attitudes, and opinions of the researcher). Consequently, to highlight the integrity of the researcher, the interpretive methods used to analyse the information obtained from the semi-structured interviews and focus groups in this study are described.

The analytical strategy used to interpret the qualitative data was content analysis, which is currently in widespread use by qualitative researchers in social science (Creswell, 2009). The essential feature of the content analysis was that a direct link was established between the eight research questions and the qualitative information collected from each stakeholder. Content analysis was applied to interpret the written transcripts of the interview or focus group responses and classify units of the transcripts into eight pre-determined themes. The eight themes corresponded to the eight issues listed in the stakeholder matrix and the eight research questions (i.e., 1. Use; 2.Satisfaction; 3. Awareness; 4. Groundwater; 5. Water quality; 6. Environment; 7. Waste-water; and 8. Solutions).

The units of the content analysis were the individual sentences actually spoken by each stakeholder. These sentences were recorded verbatim, and were entered into the content analysis in full. The responses were not summarized, slanted, or distorted, and subjective interpretations of their manifest or latent meanings were avoided. This strategy ensures that the responses of all the stakeholders are included, and all are given equal priority.

The eight research questions and their corresponding themes were identified prior to the content analysis. Consequently a top-down or *a priori* approach (i.e., identifying the units of analysis which corresponded to predefined themes) was applied to classify the recorded sentences.

There was a natural dichotomy of sub-themes within each theme, based on the stakeholder groupings. A bottom-up or *a priori* approach (i.e., identifying completely new themes after reviewing all the units of the analysis) was not used.

Each unit of the content analysis was prefixed with the name of one of the eight themes it corresponded to (i.e., Use, Satisfaction; Awareness; Groundwater, Water quality, Environment, Waste-water, or Solutions. An alphanumeric code was added to the theme name to identify the stakeholder who provided the unit of analysis (GHA1, GHA2, GHA3, and GHA4 = Government Heads of Agriculture Sector; DOW1 and DOW2 = Water & Sanitation Officials; H1 = Hydrologist; EA1 = Environment Agency; OC1 and OC2 = Oil Companies, DWU = Domestic Water Users; OW = Older housewives, YW = Younger working women). The sub-themes within each theme were then categorized. A table (Table 13) containing a list of the stakeholders in the rows and their responses in the columns was subsequently compiled for each theme and its associated sub-themes.

4.7.2 Integration of Qualitative and Quantitative Data

Brannen (2005) and Bryman (2007) criticised many researchers for not integrating effectively the quantitative and qualitative information that they collected in mixed methods studies. For example, the results based on quantitative and qualitative methodologies are frequently not presented in conjunction, but in parallel (e.g., in different tables and figures) and are discussed separately. It is common for quantitative data collected using questionnaires and qualitative data collected at interviews or focus-groups to be presented and interpreted as if they were disconnected entities. Many researchers give one type of data more priority than another type. A dichotomy has developed between researchers who prefer quantitative data and those who prefer qualitative data. Very often, qualitative and quantitative data are used to answer different research questions, and to make different inferences. Bryman suggested that the widespread lack of integration of qualitative and quantitative data is hindering the development of mixed methods research, and that the traditional barriers which polarise quantitative and qualitative methodologies must be broken down. The triangulated design or mixed model research applied in this study, however, was consistent with the view that quantitative and qualitative data should be integrated across all parts of an investigation in order to answer common research questions, and that no clear distinction should be made between the interpretation of numbers and words. This study supported the pragmatic paradigm that quantitative and qualitative methodologies are complementary and not in direct opposition to each other (Creswell, 2009; Greene *et al.*, 1989; Onwuegbuzie & Teddlie, 2003). Consequently, all of the quantitative and qualitative data collected from different sources in this study were integrated and tabulated. The categorical responses to the questionnaires, in the form of frequency distributions (counts and percentages) and the qualitative responses to the interviews, in the form of the units of the content analysis (sentences), were compiled and deliberately juxtaposed in tables under common headings. For those who may prefer to visually interpret the categorical responses to the questionnaire items, rather than to extract the quantitative data from the tables, the frequency distributions are also presented in the form of pie charts and histograms (see Appendix). These figures are not referred to directly in the text, since the presentation and interpretation of quantitative and qualitative data in separate figures and tables is not considered to be conducive to the development of mixed methods research.

4.7.3 Triangulation

Triangulation involved comparing and contrasting the information derived from different stakeholders and methods located in each row of the stakeholder matrix corresponding to each of the eight themes. The integration and tabulation of both quantitative and qualitative information relating to a specified theme or sub-theme facilitated this process. The use of triangulation aimed to overcome the weaknesses and biases which might arise from the use of only one source of information (Creswell, 2009).It involved identifying and interpreting commonalities or convergences (i.e., consistent agreements among stakeholder) and discrepancies (i.e., consistent conflicts of opinion among stakeholders). By using different sources to address the same research questions, the hope was that they would produce similar answers. If several sources provided consistent responses, then the information is more likely to be credible and reliable than if it came from only one source (Saunders *et al.*, 2003)

Triangulation, however, could potentially provide inconsistent conclusions, because different sources of information concerning the same phenomenon do not always prove to be equivalent. For example, (a) all stakeholders may not necessarily agree about the issues associated with water management in Alwahat, due to their different levels of knowledge and vested interests; and (b) the respondents' information may not be valid or reliable due to response bias, including misconceptions, misrepresentations, and possibly even deliberate falsification (Bernard, 2000). The perceptions of individuals collected using questionnaires, interviews, focus groups, and diaries are subjective realities, and are not necessarily exactly the same as what the respondents actually believe or do in reality (Willis, 1998). For example, some of the responses could be contaminated by acquiescence response bias, which is the cultural communication style of some people to provide agreeable, affirmative, or positive responses to research methods irrespective of what they really believe to be the true answer (Smith, 2004).Acquiescent response bias has been found to be particularly prevalent among Arab cultures (Baron-Epi *et al.*, 2010).

Another problem which may have slightly biased the content analysis was that the semi-structured interviews and focus groups were conducted in Arabic, but the stakeholders' responses were translated from Arabic into English before the content analysis was performed. Different patterns of thought and linguistic devices are known to give rise to communicative as well as textual problems in the translation of Arabic to English (Shiyab, 2006).An English translation can only approximate certain patterns of thought and linguistic devices that are indigenous to Arabic. There is a possibility, therefore, that the

English translations may not have accounted for all the potentialities of meaning or conveyed the totality of the messages embedded in the Arabic responses of the stakeholders.

4.7.4 Reflexivity

The use of interpretivism within the context of a qualitative analytical strategy implied that the researcher must be reflexive (Holland, 1999). Reflexivity meant that it was necessary for me, as a stakeholder with an interest in water management in Libya, to be aware of, and to reflect personally upon, what role I played in constructing knowledge, and to explain how and why I came to certain conclusions. The reliability and validity of the stakeholder analysis depended on my own integrity to observe and record information consistently and accurately, and so it was essential to be self-critical and implement a protocol that avoided observer bias. For the purposes of this study, as far as possible, I tried to interpret the responses of the stakeholders without observer bias, so that my own personal viewpoint did not corrupt the analysis. I tried to use a non-judgmental orientation and refrain from using distorted personal value judgments. I did not attempt to give preference to the voices of certain stakeholders, nor did I exclude any responses that were directly opposed to my own personal views. The role that I tried to play in the construction of knowledge and the drawing conclusions for the purposes of this study was that of an objective, unbiased, and impartial researcher.

4.8 Summary

We began with a discussion of different methods or approaches that can be used to guide the research process. These were the quantitative method, qualitative method, and multi-method (triangulation). Therefore, the appropriate research design and method multi-method (triangulation) settings undertaken to conduct the current study have been explained and justified. The development of the methods for each group has been described. In addition, this chapter has outlined the procedures followed in collecting data with consideration given to maximising reliability and validity and ethical issues relevant to the research were also discussed.

Chapter 5: Results and Preliminary Analysis

5.1 Introduction

The findings of this study are presented systematically in eight sections, with 21 tables. Each table includes the information elicited from every stakeholder who provided relevant information, classified with respect to a specific theme or sub-theme. The structure of the results tables and their contents is summarised in Table 13:

Table 13: Summary of results tables.

Section	Research Question	Theme	Sub-theme	Table
1	What do the stakeholders use water for, and how much is used?	Use	Agriculture	Table 14
			Oil production	Table 15
			Domestic use	Table 16
2	Are the stakeholders satisfied with their current water supply?	Satisfaction	Agricultural users	Table 20
			Domestic users and suppliers	Table 21
3	Are the stakeholders aware of any issues associated with water sustainability?	Awareness	Understanding of the term	Table 22
			General awareness	Table 23
			Water use on farms	Table 24
			Water use in houses/properties	Table 25
4	Has groundwater level declined?	Groundwater	Groundwater	Table 26
5	Has the water quality deteriorated?	Water quality	Water quality	Table 27
6	What is the environmental impact of water use?	Environment	General perceptions	Table 28
			Oil companies	Table 29
7	What issues are associated with wastewater (sewage)?	Waste-water	Contamination by sewage	Table 30
			Recycling	Table 31
8	Do the stakeholders have any solutions to prevent misuse of water?	Solutions	Farms	Table 32
			Houses/properties	Table 33
			Legislation for farmers	Table 34
			Legislation for domestic users	Table 35
			Education for farmers	Table 36
			Education for domestic users	Table 37

5.2 Theme 1: Use

5.2.1 Analysis of Questionnaire and Interview Data

This section addresses the question, *What do the stakeholders use water for, and how much is used for different purposes?* The stakeholders' responses are presented in Table 14 (with respect to farms), Table 15 (with respect to oil companies) and Table 16 (with respect to domestic consumers).

The majority (214, 61.1%) of the 350 agricultural water users claimed to have only one well on their farm, whilst less than 15% reported 3 or more wells. Over half (191, 54.6%) claimed that the depth of water in their wells was 40–70 m, and less than one third (105, 30.0%) reported shallower wells. The majority (217, 62.0%) reported that they extended the depths of their wells by 1 to 3 m per year. Over half of the farmers (179, 51.1%) used the modern drip irrigation system, whilst less than half (146, 41.7%) used both the modern and the traditional flooding systems. The Government Heads of Agriculture confirmed that the drip irrigation system, which is reputed to be more efficient than traditional system, was in use by the majority of farmers. The hydrologist speculated that the volume of water used for irrigating one farm field was about 180 m^3 /hour or 4.32 x 10^3 m^3 / day. One Government Head of Agriculture complained the farmers may take up to 300 litres/ day to help the growth of one tree, whereas 60 litres/day was considered to be sufficient (Table 14).

The Oil Companies reported that the water used in oil production operations was either stored in an open reservoir, or treated and re-used on the ground. The amount of water used by the oil companies were not disclosed (Table 15).

The water diary (Table 16) indicated that 40 domestic users consumed an average of about 286 litres/person/day in their properties/houses. The highest average consumption of water was for flushing toilets (64.9 litres/person/day); showering (64.8 litres/person/day) and washing dishes by hand (58.3 litres/person/day). The young working women perceived that they consumed much more water today than older generations of women (Table 16).

Table 14: Use of water for agricultural purposes.

Stake-holders	Item	Responses	Frequency	%
Agricultural Water Users	How many wells are located on your farm?	1 2 3 4 5 or more	214 84 26 20 6	61.1 24.0 7.4 5.7 1.7
	What is the depth of the water in your wells (m)?	5-30 40-70 80-110 > 110	105 191 41 13	30.0 54.6 11.7 3.7
	How much do you extend the depth of your well every year (m)?	0 1 2 3 > 3 m	73 140 45 32 60	20.9 40.0 12.9 9.1 17.1
	What type of irrigation techniques to you use?	Traditional flooding Modern drip irrigation Both	25 179 146	7.1 51.1 41.7
Government Heads of Agriculture	What type of irrigation technique do you use?	GHA1:Recently many of the farmers in Alwahat started used drip irrigation, in which water is added in the form of drops directly below the plants. This system reduces water loss so conserves water. GHA2:Most farmers use the drip irrigation with an average irrigation efficiency of 75%. It is very appropriate for sandy desert land. Some farmers still use traditional flood irrigation with drip irrigation . GHA3:Most of farmers in Alwahat use the drip irrigation system because it is easy to irrigate large areas without much effort, and it stops water from being wasted. GHA4:In last 10 years the drip irrigation system is widely used in Alwahat area. This is the highest in terms of irrigation efficiency. It also increases the efficiency of fertilizer, and prevents leaching and transfer of fertilizers into the groundwater.		
Hydrologists & Environment Agency	Are you aware of any problems associated with water sustainability?	H1: In Alsahaby there is a long narrow area (about 10 km long and 2 km wide) with about 350 farm fields. Each farm field consumes about 180 m^3 per hour or about 4.32 x 10^3 m^3 per day. The consumption by about 350 farm fields is therefore about 151.2 x 10^3 m^3 / day. The Government plans to expand the farm fields in Alwahat to grow palm, olive, and fruit trees. This may increase the consumption of water to about 604. 8 x 10^3 m^3 / day.		

Government Heads of Agriculture		GHA1: The more water a farmer uses, the more he think it helps the plants grow, especially palm trees will grow quicker and faster. It is estimated that 60 litres per day is enough for one palm tree; however, the farmers may take about 300 litres per day to help the growth of one tree.

Table 15: Use of water for oil production.

Stake-holders	Item	Responses
Government Heads of Agriculture	What actions are being taken to solve the problem of producing large amount of contaminated water?	OC1: Through our operations during oil production, we keep the water that is generated in an open reservoir. OC2: We separate out the oil, gas, and chemical components and then reuse the water in the ground.

Table 16: Use of water for domestic purposes.

Stakeholders	Item	Responses
Young Working Women	What is the relationship between the levels of water consumption and the age difference of water consumers?	YW1: The older generation didn't have the easy availability of water as today. The older generation had basic lifestyles. They didn't have as many household chores, or use so much water. YW2: After we have drunk a cup of water, we feel the need to wash the cup thoroughly with soap before reusing it, whereas the older generation didn't do that, they simply gave the cup a quick water splash to re-use the cup. It is a difference in attitude towards cleaning and water consumption. When the open the tap, we automatically turn it up to full water pressure. YW3: The types of houses have changed, nowadays houses are bigger in size, with more rooms, so water consumption is higher.
Domestic Water Users (Water Diary)	**Use**	**Average consumption**
	Drinking water	0.25 litres/glass. 1.52 litres/person/day
	Washing hands and face	7 litres/wash. 35.8 litres/person/day.
	Having a shower	6–12 litres /min. 64.8 litres/person/day.
	Having bath	75-90 litres/ bath
	Flushing toilet	15 litres/flush. 64.9 litres/person/day.
	Washing dishes by hand	25 litres/wash. 58.3 litres/person/day.
	Dishwasher	60-80 litres/ load
	Washing machine	80 litres/load. 39.7 litres/person/day
	Clean house	15 litres/clean. 12.5 litres/person/day.
	Food preparation	5litres/meal. 9.1 litres/person/day.
	Total	**296 litres/person/day**

5.2.2 Analysis of Water Diary Data

This section presents a detailed analysis of the data gathered via the water diary (behavioural pattern study). This data has already been shown to provide a method of calibration for estimating amounts of water used in daily domestic activities, but by looking at the data in more detail, we may reveal interesting patterns of behaviour that could be used to inform a sustainable water management strategy in the region. In the following analysis, data was recorded daily over a 24-hour period from 06:00 to 24:00 for a total of one week.

In order to achieve informative results from the underlying data, two statistical approaches will be followed: exploratory and inferential statistics. For the exploratory analysis box-plots were used, an example is presented in (Figure 26) which is used to discover the basic features of data-set. Since the underlying data-set do not belong to the normal distribution, then it is not correct to apply parametric approaches. A solution to this circumstance is to use non-parametric methods. In this study, three non-parametric tests will be applied. The researcher used Wilcoxon rank-sum test, Mann-Whitney test and Kruskal-Wallis one-way analysis of variance by ranks.

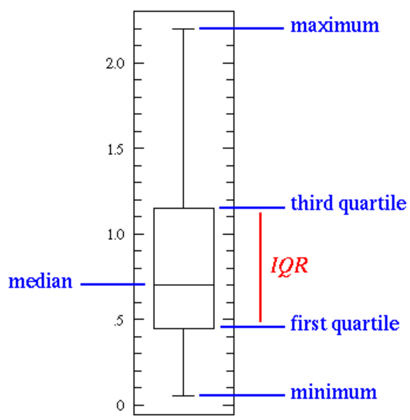

Figure 26. Example of a box plot

The graphs and other illustrations provided are based upon median averages between the maximum and minimum of water usage. These factors, along with the fact that all activity is included under one heading, i.e. washing the dishes includes the turning on of the tap and the running of the water and the turning off the tap, should be kept in mind by the reader when examining all graphs and illustrations. This method of estimated averages and including the median was done to ensure that the most reliable and objective measurements were taken for this study.

Furthermore, the statistics listed above can be further divided into twenty four hour periods to show interesting variables and details in water usage for women, men and so forth. There will be three methods utilised in analysing the water data over a twenty four hour period.

Wilcoxon rank-sum test is a non-parametric statistical test which is used for testing whether a sample median of observations is a larger median or a particular median. In other words, the aim is to determine whether the level of water consumption in Libya, particularly in Alwahat area, is statistically different from some countries of interest.

Mann-Whitney will be performed on ranked data for two groups and the hypothesis evaluated is whether or not the median differences in each water activity can be attributed to gender.

Kruskal–Wallis one-way analysis of variance by ranks is another non-parametric approach for testing whether median samples for a number of independent groups belong to the same distribution. Therefore, the null hypothesis is that the populations of underlying samples have the same median. When the Kruskal-Wallis test leads to significant results, then at least one of the groups is statistically different from the other. If the test result becomes significant, the test cannot spot where the differences occur or how many differences in detail occur.

5.2.3 Water Activities during a 24 hour period

5.2.3.1 Drinking Water

In terms of using water for drinking, it is clear from, Figure 27, that the average amounts of water were different as time progressed from morning to afternoon. It was noted that the underlying households use more water between 12:00–13:00pm than during other hours, which is the most popular time for lunch. Moreover, at this time of the day temperature is very high in arid desert regions such as Alwahat, which increases the need for drinking water. Notice that the consumption between 14:00–17:00pm is lower than 18:00–22:00pm. The statistical test based on Kruskal Wallis ANOVA was found to be 77.670, with *p*-value <.001, indicating highly significant differences in drinking water during the 24 hour period.

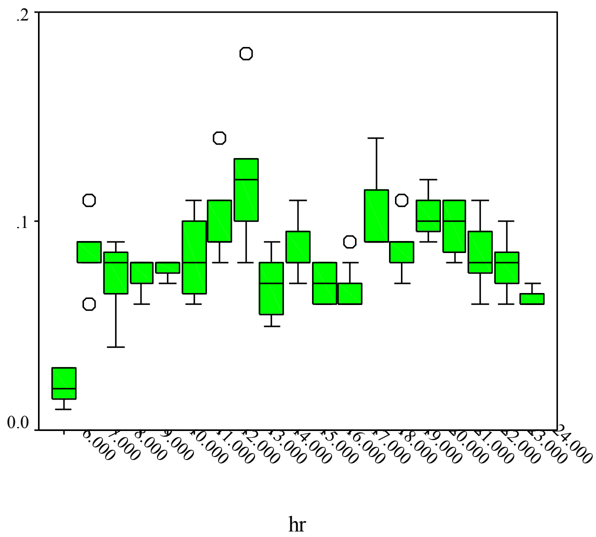

Figure 27. Average daily drinking water consumption (l/person/hour).

5.2.3.2 Washing of hands and face under running tap (ablution)

Regarding the washing of the hand and face, people seemed to use more water at 6:00am, 13:00pm, 15:00pm and 20:00pm. This activity reached the lowest amount between 8:00–11:00am. By using the Kruskal Wallis test, which was 113.659, with *p*-value <.001, the differences in the amount of average water used for the hand and face was very highly significant due to the time, as this is the time for many of the participants to prepare themselves for their prayers (Figure 28).

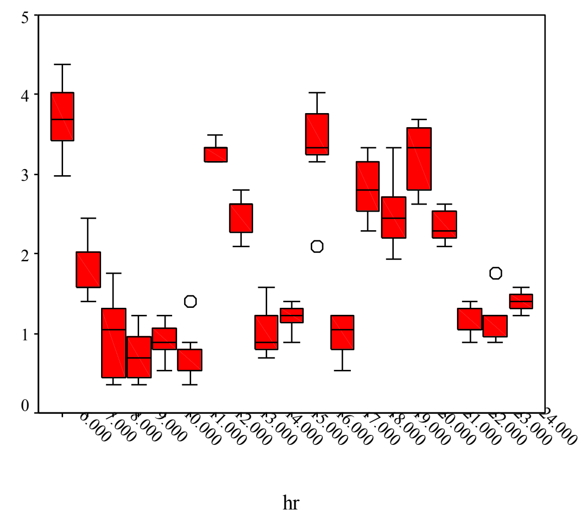

Figure 28. Average daily water consumption for washing hands and face (l/person/hour).

5.2.3.3 Shower

The shower activities commenced between 7:00–8:00am, which is the time where most households are preparing to go to work, as shown in Figure 29 but thereafter water usage consistently declined. This variation in shower activity was confirmed by the Kruskal Wallis test, which was 70.611 and p-value <.001. Overall, most of the households reported having a shower twice per day.

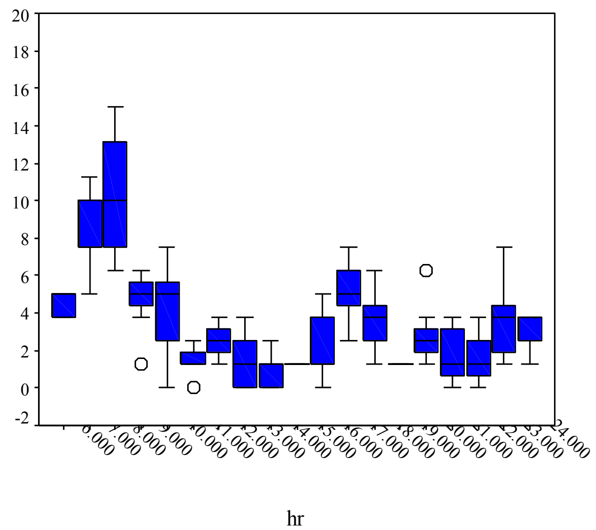

Figure 29: Box-plot for the average water consumption for a shower during 24 hours (l/person/hr)

5.2.3.4 Toilet flushing

It is clear from, Figure 30 that the highest amount of average water usage occurred at 7:00am, 12:00am and 20:00pm. For the rest of time, it was not possible to observe a particular trend in this activity. Based on the Kruskal Wallis test, which was 86.613 and *p*-value <.001, it was concluded that there was a very high significant difference in flushing activity during the day.

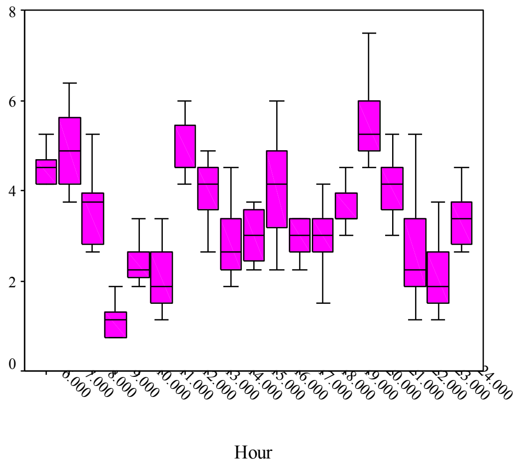

Figure 30: Box-plot for the average toilet flush during 24 hours.

5.2.3.5 Washing dishes by hand under running tap

The amount of water used an average when washing dishes by hand under a running tap was noted to be much higher at 13:00pm, this is when most of householders wash the lunch dishes. Overall there are 3 peaks which correspond to the 3 daily meals (breakfast, lunch, and dinner) Figure 31. The difference in this activity was very highly significant as chi-square =105.067 and *p*-value <.001.

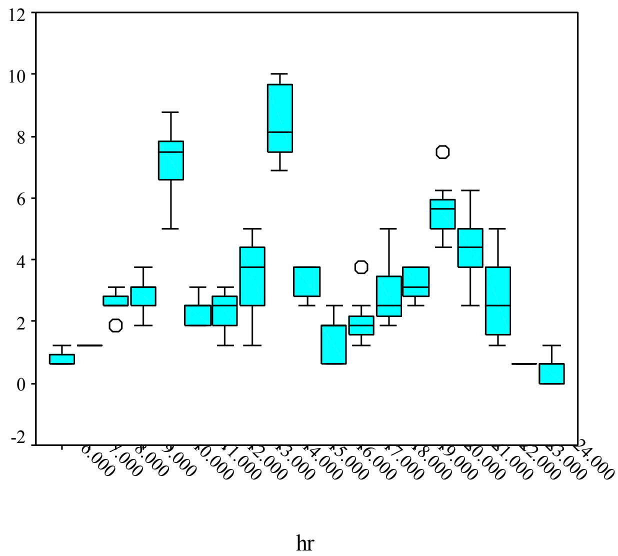

Figure 31: Box-plot for the average consumption for washing dishes by hand under a running tap over 24 hours (l/person/hr).

5.2.3.6 Machine Washing Clothes

Water consumption for machine washing clothes on average was very high at 10:00am, and then the difference in average water usage seemed to slow after that period of time because the women during these other time periods are engaged with other household activities, for example cooking. The Kruskal Wallis was found to be a very highly significant where chi-square =96.795 with *p*-value <.001 as indicated in Figure 32.

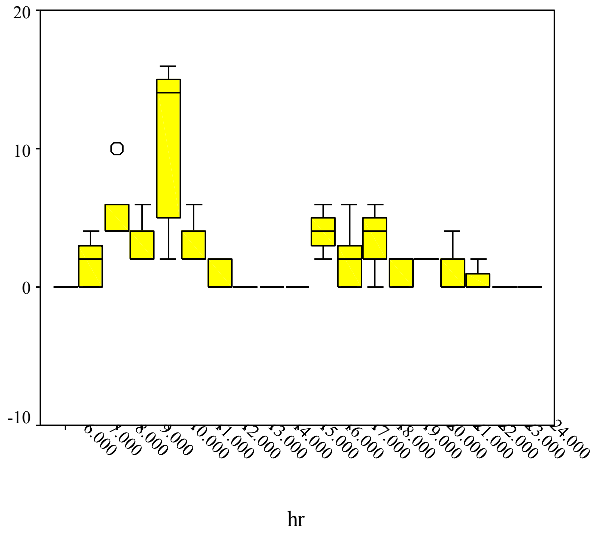

Figure 32 : Box-plot for the average washing machine during 24 hours (l/person/hr).

5.2.3.7 Cleaning the house

The average water usage for cleaning the house was at its highest between 9:00-11:00 when the house cleaning activity started (Figure 33). This is the time when the women started housework after breakfast time, and this led to a very highly significant difference in this activity as shown the Kruskal Wallis test which was 96.792 with *p*-value <.001.

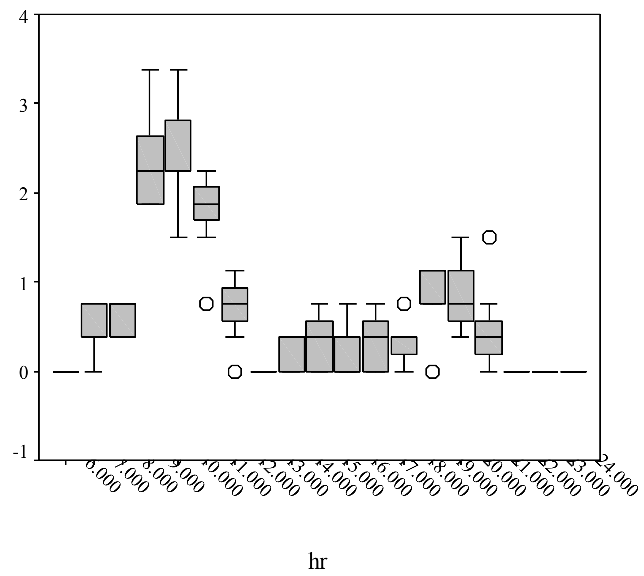

Figure 33. Average daily water consumption for cleaning the house (l/person/hr).

5.2.3.8 Food preparation (cooking)

Tests found that water used for food preparation during 24 hours had a statistically higher difference, where chi-square =109.86 with p-value<.001. This is presented in Figure 34.

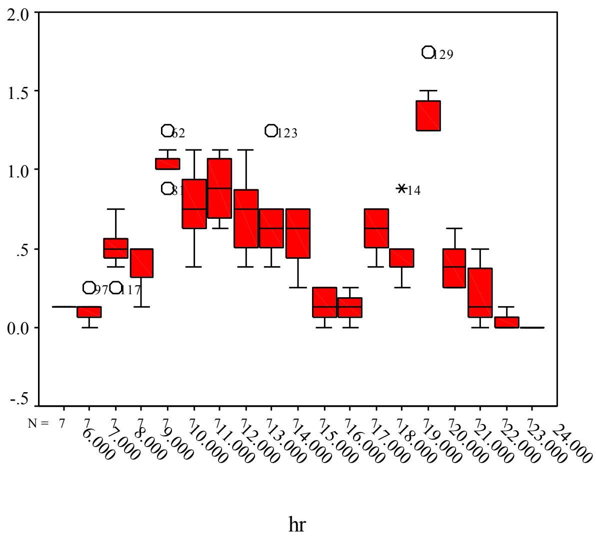

Figure 34: Box-plot for the average water use for food preparation over 24 hours (l/person/hr).

5.2.4 Average water consumption for all activities

Generally, the average water usage peaked at 8:00am and 13:00pm for all the activities as given by Figure 35 and Figure 36. By comparing the water activities, the highest average can be attributed to WC flushing and shower activity, respectively. The water used by WC flushing and shower activity reached 10.360/l/person/day and 5.570.l/person/day. The lowest average was reported for drinking water and cleaning the house. The Kruskal Wallis test showed that there was a very highly significant difference (p-value <.001) in using water between the underlying activates (Table 17).

Table 17. ANOVA results for water activities using Kruskal Wallis test.

	Drinking /per glass	W Hand & Face/lit/min	Shower/l/min	WC flushing/per/flush	W by Hand/lit/min	W Machine/per/load	Clean House/lit/min
Mean	.081	1.884	3.412	3.417	3.068	2.090	.633
Median	.800	1.400	2.860	3.380	2.770	1.140	.320
Minimum	.020	.700	.890	1.130	.450	.000	.000
Maximum	.120	3.700	10.360	5.570	8.480	10.290	2.460
Chi-square	71.551						
P-value	<.001						

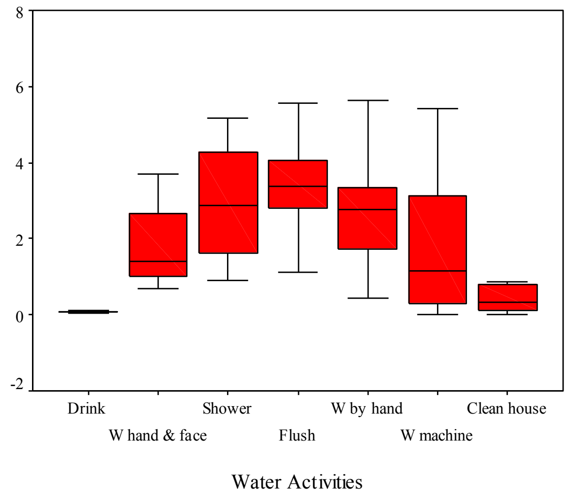

Figure 35. Box-plot detailing the average water consumption (l/person/day).

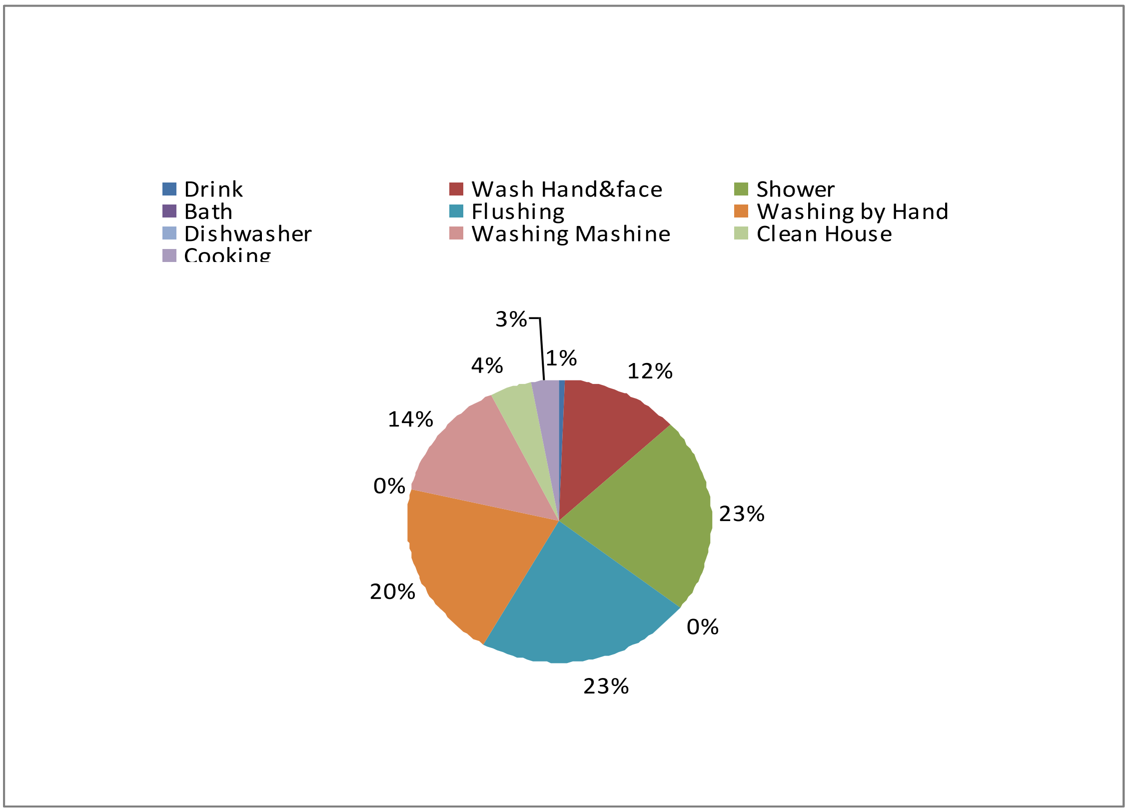

Figure 36: Pie chart showing the breakdown of indoor water usage for typical house in Libya.

A comparison of water usage between developed and developing countries are highlighted in Figure 37. Average water usage is between 200 to 300 litres per person, per day in most countries in Europe, and up to 575liter/p/day in the USA. In contrast, average use in countries such as Mozambique is less than 10 litres/person/day, while each person in the UK uses 150 litres of water a day. The water usage comes from cooking, cleaning, washing and WC flushing, and this amount has been rising by 1% a year, since 1930 (Water Wise, 2009).For example British people use more than 50 litres of water a day for flushing toilets, and that is more than 10 times the total water available to people without access to improved water sources, which is the case in much of rural sub-Saharan African countries.

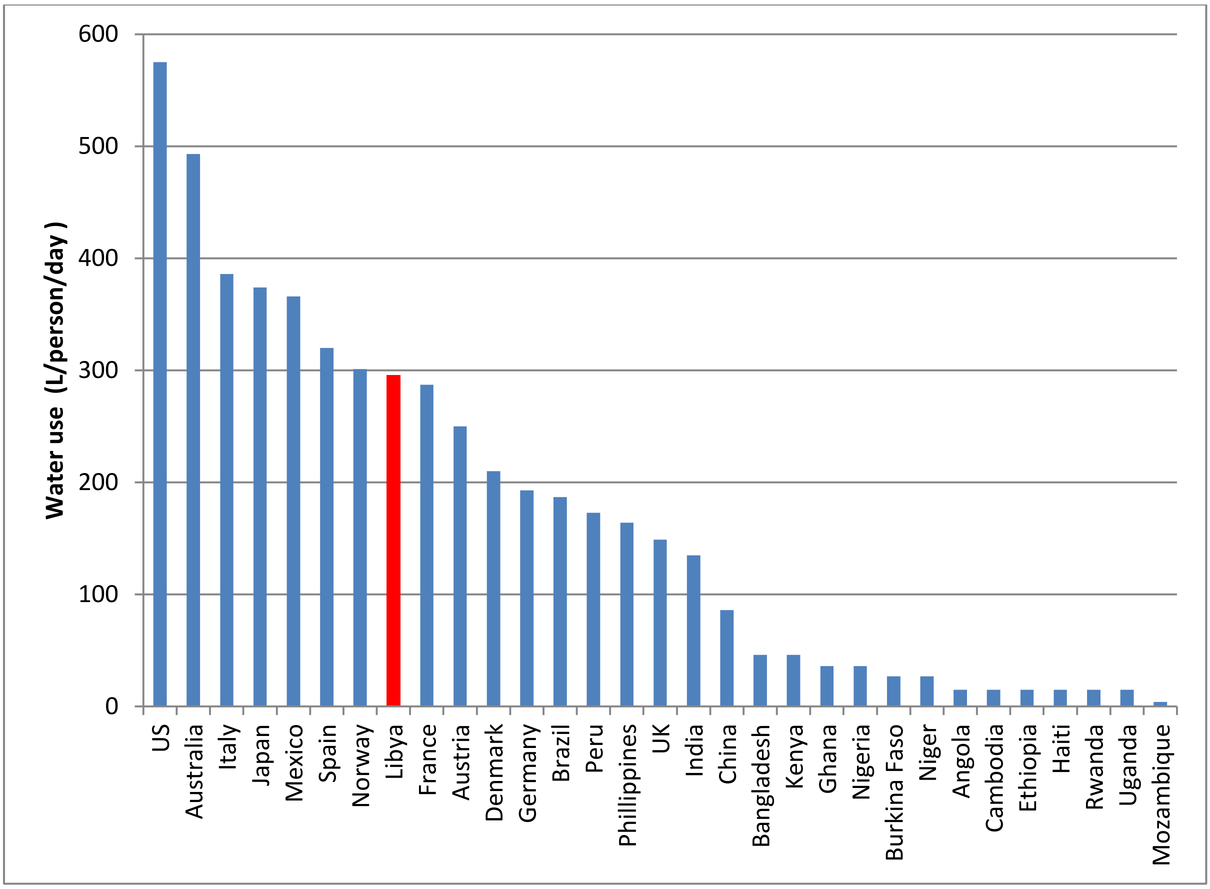

Figure 37: Comparison of average water usage internationally.

(Libya data developed in the current research). Source: http://www.data360.org/pub_dp.aspx

Libya is an arid country which consists mostly of desert, however, the average water usage in 296 l/p/day which is similar to the average consumption in France. The high usage and mismanagement of non-renewable water resources is not sustainable in a country without substantial rain or a moderate climate such as in the case of the United Kingdom which has smaller consumption rates but is still able to replenish its resources quite readily through rainfall. Libya, on the other hand, with a rising population and greater demands for water, cannot continue on the same path that it is currently on and there needs to be a solution to this water management versus supply management issue. Awareness of this issue is absolutely necessary for a sustainable water management system that will serve the needs of the people of Libya.

5.2.5 Water Consumption Based on Gender

To examine the effect of gender on water activities, Figure 38 and Table 18 indicates males seemed to drink more water than females, this difference was significant, using the Mann-Whitney test which was 111 with p-value=.043.

When considering the topic of washing the hands and face under a running tap, the male usage was lower than female usage, this difference was significant, p-value<.001, using the Mann-Whitney test which was 4. For the rest of activities, no significant difference was detected by the Mann-Whitney test. Figure 39 illustrates the daily water consumption patterns for all the activities measured, in litres per person per hour.

Table 18. Descriptive statistics and Mann Whitney tests results for water consumption in terms of gender (lit/person/day).

		Drink/l/p/day	W face & hand l/p/day	Shower l/p/day	W.C Flushing l/p/day	W by Hand/ l/p/day
Male	Mean	.0947	2.076	4.366	3.054	.288
	Median	.090	1.920	2.750	2.800	000
	Minimum	.010	.380	000	.660	.000
	Maximum	.170	4.4560	15.930	5.270	1.100
Female	Mean	.073	1.791	2.953	3.592	4.406
	Median	.080	1.410	2.380	3.410	3.840
	Minimum	.030	.560	1.060	1.350	.660
	Maximum	.100	3.410	8.470	6.030	12.170
Mann-Whiney		111.000	149.500	165.000	143.000	4.000
p-value		.043	.370	.665	.284	<.001

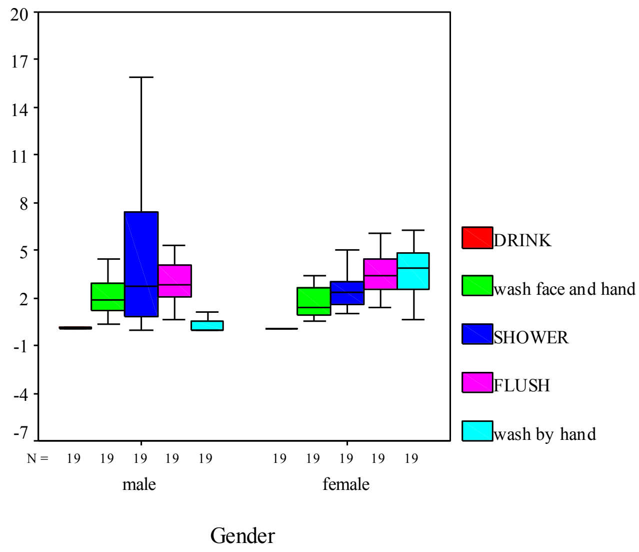

Figure 38: Box-plot for average water consumption in terms of gender (l/person/day).

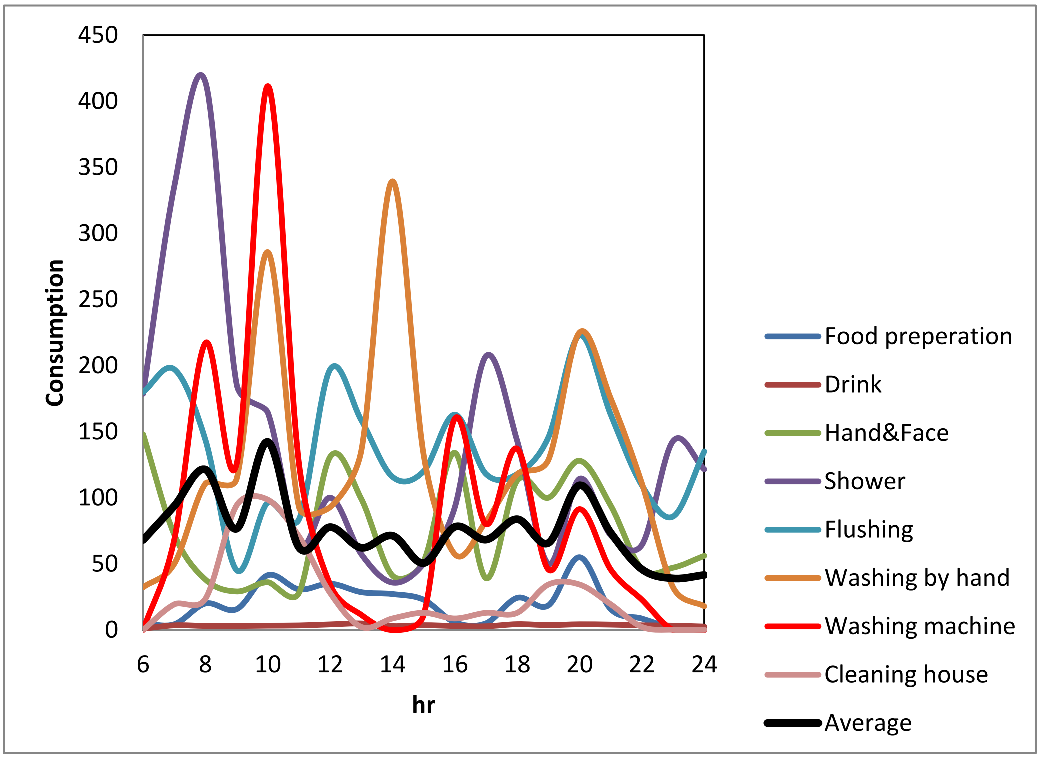

Figure 39: Average consumption of water (l/p/day).

5.2.6 Comparison with other Countries

In this section, the researcher compared the average water (median) used by Libyans in the Alwahat area with 30 other countries around the world. The data is organised in Table 19 from highest to lowest according to the amount of water determined by the government of each country. The Wilcoxon test was conducted in order to test whether the average water used in Alwahat was statistically higher than the countries of interest, such as the USA and UK. Based on Table 19 the resulting median water usage in Alwahat was 296.768liters/person/day which is statistically smaller than the usage in the US, Australia, Italy, Japan, Mexico, Spain, Norway and France. On the other hand, the resulting median water usage was statistically higher than Austria, Denmark, Germany, Brazil, UK, China and the rest of the countries presented in Table 19.

Table 19. The results for the Wilcoxon test for comparing the median of Libya with other countries.

Country	Mean	p-value
Libya	296.768	
US	575	0.993
Australia	493	0.993
Italy	386	0.993
Japan	374	0.993
Mexico	366	0.993
Spain	320	0.993
Norway	301	0.993
France	287	0.466
Libya	286	0.466
Austria	250	.011
Denmark	210	.011
Germany	193	.011
Brazil	187	.011
Peru	173	.011
Philippines	164	.011
UK	149	.011
India	135	.011
China	86	.011
Bangladesh	46	.011
Kenya	46	.011
Ghana	36	.011
Nigeria	36	.011
Burkina Faso	27	.011
Niger	27	.011
Angola	15	.011
Cambodia	15	.011
Ethiopia	15	.011
Haiti	15	.011
Rwanda	15	.011
Uganda	15	.011
Mozambique	4	.011

5.2.7 Summary

The water diary data was used to calculate the Libyan average water consumption, and the water usage for micro components which included personal and household activities. With respect to showering and toilet WC flushing activities, these are the highest consumed of water, which contribute to about 64 l/p/day, to the total water usage. The a daily activity of washing the hands and face and using the washing machine the average water usage is similar with an average approximately of 39l/p/day. This is slightly lower in comparison to the average of water that is used for washing by hand, and dish washing under a running tap which are about 58.03 l/p/day. An average of around 12 l/p/day was the consumption of cleaning the house and the food preparation. The water dairy study did not show water consumption for activities such as having a bath and the use of dishwashers. This because women from this area do not use baths, as culturally they consider it unclean. Similarly when an extended family lives together in one house, they cannot use the bathroom for bathing for extended periods of time. In relation to dishwasher use, families prefer to clean the dishes after a meal rather than storing the dishes and doing it in one go in a dishwasher.

5.3 Theme Two: Satisfaction

This section addresses the question *Are the stakeholders satisfied with their current water supply situation?* The perceptions of the stakeholders are presented in Table 20 (with respect to agricultural users) and Table 21 (with respect to domestic users and suppliers).

Over half of the 350 Agricultural Water Users (199, 56.8%) claimed that they were satisfied or very satisfied with the current water supply situation for agricultural purposes. In contrast, the Government Heads of Agriculture were not satisfied, complaining that the farmers used excessive amounts of water, and one (GHA3) perceived that the farmers did not know very much about the current water situation (Table 20).

The majority (228, 63.9%) of the 357 Domestic Water Users perceived that they were not satisfied with the water services provided by the suppliers. About a half of the domestic consumers claimed that they were dissatisfied or very dissatisfied with the time water is available (195, 54.6%); with the water quality (173, 48.4%) and with taking a part in decision making (159, 44.5%). A smaller proportion (132, 37.0%) was dissatisfied or very dissatisfied with the price of water. The comments of the five older housewives, however, indicated that they are more satisfied with the water supply situation today than about half a century ago, when obtaining water was much more difficult (Table 21).

Younger women stated that they felt that the idea for water consumption conservation would not work out for the future as people might result to using pumping equipment to extract large amounts of water and this would be unfair distribution.

The two Water & Sanitation officials generally expressed satisfaction with the current water supply situation, with respect to the time water was available, the water quality, and the price of water; however they were both dissatisfied with their level of involvement in making decisions about water management (Table 21).

Table 20: Agricultural users' satisfaction with their current water supply situation.

Stake-holders	**Item**	**Responses**	**Frequency**	**%**
Agricultural Water Users	Are you satisfied with your current water supply situation in your farm?	No reply Very dissatisfied Dissatisfied Neutral Satisfied Very satisfied	1 31 83 36 165 34	0.3 8.9 23.7 10.3 47.1 9.7
Government Heads of Agriculture	Are you satisfied with your current water supply situation in Alwahat?	GHA1: I am not happy with the situation. Before, they could get water easily from the top aquifer about 1 to 5 m deep, but they now drill to a deeper level from 30m up to 200m. This has caused excessive water use. GHA2: The situation is unsatisfactory. There is excessive use of water due to agricultural projects built by the Government, and through the use of modern techniques to abstract excessive water from the aquifer. GHA3: The water situation in Alwahat is becoming more unsatisfactory due to the increasing number of farms. The farmers still do not know very much about the water situation. For example, the drip system was introduced to reduce the consumption of water; however, the farmers tended to open the network all day for 24 hours.		

Table 21: Domestic users' and suppliers' satisfaction with their current water supply situation.

Stake-holders	Item	Responses	Frequency	%
Domestic Water Users	Are you satisfied with the water services provided by the suppliers?	No Yes	228 129	63.9 36.1
	Satisfaction with water price	No reply Very dissatisfied Dissatisfied Unsure Satisfied Very satisfied	2 30 102 110 103 10	0.6 8.4 28.6 30.8 28.9 2.8
	Satisfaction with time water is available	No reply Very dissatisfied Dissatisfied Unsure Satisfied Very satisfied	2 46 149 39 110 11	.6 12.9 41.7 10.9 30.8 3.1
	Satisfaction with water quality	No reply Very dissatisfied Dissatisfied Unsure Satisfied Very satisfied	2 39 134 60 112 10	.6 10.9 37.5 16.8 31.4 2.8
	Satisfaction with taking a part in decision making	No reply Very dissatisfied Dissatisfied Unsure Satisfied Very satisfied	2 40 119 127 62 7	.6 11.2 33.3 35.6 17.4 2.0
Older Housewives	What do you feel is the trend of water consumption of women today?	OW1: Today the situation is better, women can clean clothes, dishes and the house easier than before because there is water. Before the situation was very difficult. OW2: Women before were very careful with using water, because she had to suffer to get it, especially when the weather was very hot. We used to fill one water pitcher, and all the members of the family had to drink from that one pitcher. Today thank God, women are in a better situation to get amount of water they need and everything is available. OW3: Women are now in a better situation compared to previous times, thank God, but in terms of excessive use she is worse than women of previous generations. OW4: Before women were more careful about using the water, and we used to value the water as an important element, but today women don't have		

		a sense of awareness at all. OW5: Now life is better in terms of water, its easily available, and that makes living life easy and healthier, but there is the issue of excessive use.		
Water and Sanitation Officials	Are you satisfied with the services provided by the water suppliers?	DOW1: I am 65% satisfied with the service we provide for local residents DOW2: I am positive about the water supply service provided by the suppliers		
	In relation to your water supply, rate your level of satisfaction.	Time water supplies are available Water quality Involvement in management decisions Price of water	DOW1 Satisfied Satisfied Dissatisfied Satisfied	DOW2 Satisfied Satisfied Dissatisfied Satisfied

5.4 Theme Three: Awareness

This section addresses the question, *Are the stakeholders aware of any issues associated with water sustainability?* The perceptions of the stakeholders are presented in Table 22 (with respect to understanding of the term sustainability); Table 23 (with respect to general awareness of the issues); Table 24 (with respect to farms); and Table 25 (with respect to houses/properties).

Over two thirds of the Domestic Water Users (252, 70.6%) perceived that sustainability meant that water is available, every time you need it, for a long time. The two Water & Sanitation officials, the Hydrologist, and the Environment Agency Officer, on the other hand, perceived sustainability of water to be essentially a management problem, involving many different issues, to ensure that enough water is available for everyone in the 21st century and beyond (Table 22).

The majority of the Domestic Water Users (298, 83.5%) and the Agricultural Water Users (279, 79.7%) claimed that they were aware of the problems associated with water sustainability in the Alwahat area. Lack of awareness of the misuse of water (133, 37.3%)

and excessive use of water (142, 39.8%) were the most frequent problems reported by the Domestic Water Users. They cited misuse of water in the street and houses (143, 40%) and too much water used by farmers and the oil companies (90, 25.2%) as the main causes of excessive use of water. All five of the Younger Working Women expressed concern about the current water situation.YW5 commented that "The problem is that even the people in charge of the water supply aren’t bothered about this issue", contradicting the serious concerns expressed by the two Water & Sanitation officials, the Hydrologist, and the Environment Agency Officer.

The Hydrologist, Environment Agency official, and Government Heads of Agriculture pointed towards the rapid growth of the population in the Alwahat area following the discovery of oil as the root cause of the problems associated with water sustainability. Population growth in the last twenty years led to an increasing amount of water extracted from the aquifer to supply domestic consumers and irrigate more farm fields, lowering the groundwater level, and reducing the availability of water (Table 23).

The majority of the Agricultural Water Consumers (191, 54.6%) perceived that they used water efficiently (Table 8). The cheap cost of water, the easiness of drilling a well, the food market competition, or other reasons, were cited by only 43 (12.3%) or less of the farmers as reasons for not using water efficiently. Only a few farmers (17, 4.9%) claimed that they were not at all aware of the increasing number of farms, or not at all aware of groundwater scarcity due to excessive pumping (11, 3.1%), or not at all aware of the increasing number of water wells (14, 4.0%) or not at all aware of the amount of fertilisation used on crops (7, 2.0%). Over a half of the farmers claimed that they were moderately or extremely aware of all these issues; however, such a high level of awareness was not consistent with the views of three Government Heads of Agriculture, who commented “The farmers just keep drilling more wells and using the water to irrigate crops without thinking about how much water is available and how much water is needed to survive" (GHA2);"We really need to do something to stop this irresponsible behaviour" (GHA2); Most of the farmers...do not care about issues of sustaining the limited water we have" (GHA3) and "We need to change the attitudes of farmers to use water in a responsible way (GH4).All the Government Heads of Agriculture were concerned about the increasing number of farms, excessive water consumption, the lowering of the water table, and the need for a policy to manage water abstraction by farmers. They were, however, aware of the barriers to implementing such a policy. GHA1 complained that "We have no power to control abstraction from the wells" and GHA2 predicted that "To implement this policy will be very difficult, but we have to try first, and then we can see the feedback" (Table 24).

Table 22: The stakeholders' understanding of the term sustainability.

<table>
<tr><th>Stake-holders</th><th>Item</th><th>Responses</th><th>Frequency</th><th>%</th></tr>
<tr><td rowspan="5">Domestic Water Users</td><td rowspan="6">What do you understand by the term sustainability?</td><td>Safe and healthy water</td><td>24</td><td>6.7%</td></tr>
<tr><td>Water is available every time you need it</td><td>150</td><td>42.0%</td></tr>
<tr><td>Water is continuously available</td><td>102</td><td>28.6%</td></tr>
<tr><td>Water is scarce, so we have to save it</td><td>42</td><td>11.8%</td></tr>
<tr><td>We must reduce water consumption</td><td>32</td><td>9.0%</td></tr>
<tr><td>Water & Sanitation officials</td><td colspan="3">DOW1: It is easy to define water sustainability in physical terms such as the annual rate of water withdrawn should be equal or close to the annual rate of consumption; however, the definition of non-renewable groundwater sustainability is complex and difficult. It presents a challenge for the management of water, and needs careful and in-depth studies covering many social, economic and political issues.
DOW2: We must work hard to achieve sustainability in water. The amount of water we have is limited, so we need to optimise and maintain our use of water</td></tr>
</table>

Hydrologists & Environment Agency		EA1: Water is an essential element for life. Without water we cannot live. We need to develop a water management strategy and apply it. We must save our water for people in the future by managing it in a responsible way and not wasting it. H1: Our groundwater resources are non-renewable, so if we lose them we cannot get them back. Sustainability means we must manage our water resources properly so that they are saved for a long time. Enough water is available in the Alwahat area for 100 years if it is managed in a very responsible way.

Table 23: Stakeholders' general awareness of the issues of water supply and sustainability.

Stake-holders	Item	Responses	Frequency	%
Domestic Water Users	Are you aware of the issues of water sustainability in the Alwahat area?	No reply Not at all Slightly Somewhat Moderately Extremely	40 19 16 50 116 116	11.2 5.3 4.5 14.0 32.5 32.5
		Water is misused in the street Water is misused in the house There is an excessive use of water in farms There is excessive use of water for spraying There is lack of awareness of the misuse of water	104 39 60 14 133	29.1 10.9 16.8 3.9 37.3
		The quantity and quality of water is not good enough Lack of maintenance of the water supply network The groundwater is not renewed and is threatened by drought Too much water is by farmers and oil companies There is excessive use of water	73 46 70 90 142	20.4% 12.9% 19.6% 25.2% 39.8%
Agricultural Water Users		No Yes	71 279	20.3 79.7

Younger Working Women	If we continue our behaviour in this way, how do you feel this will affect our existence 10 years from now?	YW1: Indeed, the water is not going to be enough for the next generation. YW2: We will have a problem, and several other problems. YW3: Even The Man-Made River project is not going to sustain the water supply for more than 15 years. YW4: In this time, water is in decline. For the coming future, the water will be in further decline. YW5: The problem is that even the people in charge of the water supply aren't bothered about this issue. YW6: There is no awareness to save water.
Hydrologists & Environment Agency	Are you aware of the problems associated with water sustainability in Alwahat area?	H1: An increasing amount of water is extracted from the aquifer in Alwahat for the following reasons: (a) Water is needed for increasing domestic consumers and farm irrigation; (b) In the last 20 years the population of domestic consumers and the number of farms have increased, lowering the groundwater level and reducing the availability of water; (c) Farmers and domestic water users are using advanced technology (e.g. high power water pumps) to abstract more water from the aquifer; (d) A large amount of water is used by the oil companies. EA: The population in Alwahat has dramatically increased in the last 20 years. It is one of the most important economic areas of Libya. It is a rapidly developing area and very important for oil production and the farms which provide food for the whole of Libya. The amount of water in Alwahat is not enough using the old water sources. New sources of water are required to support the increasing demand from the population.

Government Heads of Agriculture		GHA1:There is a good availability of cheap water. The bad impacts only appear after the water has dropped down, because of the increasing number of water wells in the farms. There is no distinction between the water used in the urban areas and in the farming areas. GHA2: When oil was discovered in Alwahat, the wealth of people increased and they could afford to invest in more efficient machinery to extract the deeper groundwater. The excessive pumping of water from the aquifer, and the increase in the number of non-Libyan farmer workers, has a negative effect on water sustainability. GHA3: The problem is that the big farms have so many wells. Government farmers employ many workers and pump unlimited amounts of water 24 hours a day. GHA4:The number of people working in Alwahat is dramatically increasing, and is not tightly controlled, leading to an increased demand for water. The food market competition, the increase in the employment of non-Libyan workers on the farms, and the lack of restriction to drill water wells, has increased the consumption of water. The groundwater is the only source of freshwater in Alwahat. Many new farms have been developed by the Government in Alwahat area, and the number of wells have increased. There are numerous locations where problems of water sustainability exist. The consumption of water exceeds the rate of replacement, resulting in a progressive lowering of the water table. The prolonged existence and practical use of the aquifer is endangered

Table 24 Stakeholders awareness of the issues associated with efficient use of water on farms

Stake-holder	Item	Response	Frequency	%
Agricultural Water Users	Do you consider you use water efficiently?	No Yes	159 191	45.4 54.6
	Do not use water efficiently because it is cheap	No Yes	307 43	87.7 12.3
	Do not use water efficiently because it is easy to drill a water well	No Yes	307 43	87.7 12.3
	Do not use water efficiently because of food market competition	No Yes	308 42	88.0 12.0
	Do not use water efficiently because of other reasons	No Yes	311 39	88.9 11.1
	Aware of increasing number of farms	No reply Not at all Slightly Somewhat Moderately Extremely	70 17 18 62 107 76	20.0 4.9 5.1 17.7 30.6 21.7
	Aware of groundwater scarcity due to excessive pumping	No reply Not at all Slightly	70 11 12	20.0 3.1 3.4

		Somewhat Moderately Extremely	71 111 75	20.3 31.7 21.4
Agricultural Water Users	Aware of amount of fertilization used on crops	No reply Not at all Slightly Somewhat Moderately Extremely	70 7 16 81 102 74	20.0 2.0 4.6 23.1 29.1 21.1
Government Heads of Agriculture	Do you consider farmers in Alwahat use water efficiently State the reasons?	GHA1:Water is very difficult to manage in Alwahat for various reasons. The location is a harsh desert environment, and much water is required for irrigation. We have no power to control abstraction from the wells. We are just a small department and we have to take orders from the Government in Tripoli. What worries me is the increasing number of farms in Alwahat without any planned strategy to address the problems of water sustainability. We do not know how the water situation will be managed in the future. GHA2:We are not quite sure about the impact of the farmer activity in Alwahat. They just keep drilling more wells and using the water to irrigate crops without thinking about how much water is available and how much water is needed to survive. There is a necessity to develop more knowledge and understanding of water sustainability. I think the quantity of water we use in our farms on a daily basis is too much. The water is not managed a sustainable way. We really need to do something to stop this irresponsible behaviour. To implement this policy will be very difficult but we have to try first and then we can see the feedback. GHA3: There is an increasing number of farms in Alwahat with employees who work hard to produce food for a competitive market. This causes an increase in the number of the water wells, affecting the groundwater security due to excessive pumping. All these factors are deleterious to sustainability. The quantity of the water used in farms in Alwahat must be controlled to ensure sustainability. Our water resources are non-renewable and the only water we have is from the aquifer. This means that if we lose it we can't get it back. Most of the farmers do not consider this, and do not care about issues of sustaining the limited water we have. GHA4: In general, I am aware of the issue of sustaining water in Alwahat. We need to change the attitudes of farmers to use water in a responsible way. The groundwater is the only source of freshwater in Alwahat. Government irrigation has rapidly developed in Alwahat area and there are numerous locations where real problems of water sustainability exist. The consumption of water exceeds the rate of replacement, resulting in a progressive lowering of the water table. The prolonged existence and practical use of the aquifer is endangered.		

The most frequently cited reason for the problems associated with water sustainability in properties/houses, endorsed by a half of the Domestic Water Consumers (178, 49.9%) was poor services from the water supply companies (Table 25). The majority (319, 89.4%) also expressed awareness of water misuse. Surprisingly, most (302, 84.6%) approved of such misuse. Five of the Younger Working Women agreed that their water consumption was excessive, mainly because it was available. Their reasons included “I think using two buckets of water for cleaning is better than using one “(YW1); “When I was connected to the government water supply network, it was very easy to become lazy about thinking of my water consumption” (YW2); “We live in a big joint family, so the consumption is high” (YW4); and “When I clean the house, I don’t think about my water consumption (YW6). Only one of the Younger Working Women (YW5) who lived in a suburban area, where the water supply was less frequent, and sometimes had to be purchased from trucks, complained about the shortage of water. All of the Older Housewives complained that the younger people today use excessive amounts of water, whereas many years ago, when water was not so freely available, it was used more responsibly. In those days, the women had to travel a long way to fetch water from a well in clay water pitchers. The Hydrologist and Officials from the Environment Agency and added further reasons why some people currently misused drinking water including throwing it out into the streets, the installation of water pumps to improve their supply, and farmers taking drinking water from the network for irrigation. The Younger Working Women generally agreed that the technology currently used to abstract and deliver water to houses was having a negative effect on sustainability. In contrast, the Water & Sanitation Officials complained about the technology, describing serious problems with the old water distribution network, including a shortage of wells and pumps, corrosion and broken valves, maintenance issues due to a lack of mapping of the water pipes, miss-matched pressure of water, and lack of water for some properties.

Table 25: Stakeholders' awareness of efficient use of water in houses/properties.

Stake-holders	Item	Frequency	Frequency	%
Domestic Water Users	Are you aware of the problems associated with water sustainability?	Opening times and availability are inadequate There is no education for users about water issues Water storage in houses is not controlled There is a lack of awareness of the possibilities Poor services from the water supply companies	63 36 26 47 178	17.6 10.1 7.3 13.2 49.9
	Are you aware of water misused by other properties?	No Yes	38 319	10.6 89.4
	Do you approve of water misuse by other properties?	No Yes	55 302	15.4 84.6
Younger Working Women	How do you describe the water consumption in the household? Why do you use water in the pattern that you do?	YW1: We do misuse a lot of water, just because it is available. YW2: Yes I agree, we do misuse water, and the evidence is water puddles that can be seen in our streets. YW3: Because the water is always there, and our consumption is high. YW5: (Suburb resident) Because of the high water consumption in the bigger towns, we suffer the shortage of water in the suburban areas. The water is supplied once a week, and sometimes it takes as long as two weeks to get water. Because of the shortage we have to buy water from trucks, delivered to paying customers) and paying for water becomes very expensive. YW6: I am from the middle area, so our water supply is on weekly basis, but our water consumption is still high.		
Younger Working Women	Why is there a high consumption of water?	YW1: It's a feeling of the house not being clean enough if we wipe rather than thoroughly washing with good amounts of water. When I clean I think using two buckets of water for cleaning is better than using one. YW2: When we used to buy the water from water tanks, it was so expensive for family life, that I am very careful about water usage when it comes to household use and cleaning. Then when I was connected to the government water supply network, it was very easy to become lazy about thinking of my water consumption. When we used to buy the water, we knew the value of it. YW3: Two years ago, the water problems appear in the area where I live. There is one water tank that comes to the area, and then there the additional problems of overbooking water tanks, and transporting water at times in difficult travelling circumstances, and subsequently the price of water went higher. YW4: We live in a big joint family, so the consumption is going		

		to be higher. YW5: In some suburb areas, we try to bring water from the town, for cooking and drinking, and we have to rely on working water wells for cleaning and other household chores. Those people who don't have access to water wells suffer the most from the shortage of water wells. YW6: The problem is not with the availability of the water, the problem is there is no sense of responsibility with the water supply. When I clean the house, I don't think about my water consumption, in comparison to my mother who uses the water far more carefully and responsibly. I don't think about the water supply drying up or cutting off, however the only time I do become a little more responsible is in the presence of my mother.
Older Housewives	How do you compare water usage to your time and to the age we live in now?	OW1: Today women in general are wealthier. The water is available and water consumption is very high. Women open a tap on full pressure even to wash a spoon or a cup. Women today are very spoilt. OW2: The majority of women use too much water, when they are washing, even watering the plants. The consumption is excessively high especially during weddings and funerals. Today women don't have to suffer to get access to free flowing water, in comparison to us, and so that gives her no awareness or responsibility. OW3:I always remind my daughters and son-in-laws to avoid the excessive spillage of water, because water is very important to us and we can't survive without it. Allah and Prophet Mohammed's advice has always been to preserve our natural resources for everyday use. However, many women don't value water, they use too much. OW4: The water is available today and easy to access, but there is high misuse of water. Before, one bucket was enough to wash all the dishes; however, today the availability of water has meant that women have no awareness of saving water. OW5: There is water of good quality, and available in a generous quantity. Before we didn't have the same availability of water as we have today, and today women don't treat water with responsibility or importance
Older Housewives	How was water made accessible in your times on an average of 50 years ago?	OW1: We used to gather as a group of women by bringing water from a water well (Sidi Ali). This well was located in an area called Ashraf, and before sunrise we had to fetch the water in clay water pitchers. On our journeys we used to talk to each other and play games, and when we get there we helped each other to fill our containers, and then we returned back to the house after a long journey only to finish off the rest of the day domestic chores. The men were also very tired to get water to do farming for the agriculture lands to cultivate food, using a system called "jabadah" (the traditional way of equally sharing water resources) OW2: The women in the area lived in very harsh conditions, and were responsible for everything inside the property. Life was

		very difficult and for survival women brought water from far distances for the property using heavy water pitchers, using their head to balance it. When they got back home they used to have to do the rest of the domestic chores before ending the day. I myself have been one of those women, and I used to have to help my mother to bring water to the house before sunset and sometimes early morning. OW3: During those times I used to go with my mother to bring water from wells to provide water to the village, which was drilled in the area by the community. This provided water to the community for drinking and cooking. Today the situation is very different, and water is easily available. OW4: The women used to go together every morning as a group to wherever the water wells were to collect the water. There were several times when the water level in the wells used to drop after being used, that either we had to wait for water level in the wells to rise again, or share whatever we had collected with the person behind us in the queue so that they could have some water to take back with them. This water used to be used for drinking and cooking. OW5: There were salt water wells located in the village or town, that could only be used for cleaning and washing, and the drinking and cooking water wells were located in faraway locations.
Younger Working Women	Do you feel that technology is contributing to water sustainability in a negative way?	YW1: Yes, there are side effects to technology; mainly it depends on how technology is used. YW2: The technology makes life easier, but it is expensive, and causes excessive use of water. YW3: Too much technological developments mean it causes a lot more complications. YW4: Technology has great impact on water sustainability in a negative way. Before we collected water in buckets, now we have all sorts of equipment that uses an excessive amount of water. YW5: In present days water resources are few, and in the future there is going to be even fewer water resources, because there is a lot more technology and more need to use up more water than before.
Hydrologists & Environment Agency	Identify any problems of water sustainability that you are aware of	EA1: We can see in our streets how the water is misused by large amounts of water thrown out of the doors. Houses at the tops of hills cannot get water because the water pressure is not strong. The people install water pumps to improve their water supply, and this leads to an unfair distribution. Some farmers take drinking water from the network and use it for irrigation, so there is not enough water for the houses. The water company officials have problems implementing the regulations because they cannot get right of entry. H1: The service delivered by the water suppliers in Alwahat is a problem. Some people are provided with adequate amount of water and some people are not.

Water & Sanitation Officials	Identify any problems of Water Sustainability that you are aware of	DOW1: The corporate side of water supply companies is corrupt, and that causes further technical problems with water supplies. There are some people are using drinking water for the wrong purposes, for example using if for irrigation farms or throwing it out in the streets. DOW1: The carrier for the water line to the main pumping station performs poorly. The line was constructed in the 1970s, and is suffering from corrosion in most its parts, as well as broken air valves. Rather than building a new network, we go out and do maintenance on the same old networks. There is a geographical problem with the locations of the water pipes. There is no record showing the maps of the old pipes and the new pipes in the network. As a result the maintenance of the network is an obstacle. That causes technical problems like miss-matched pressure of water, and a lack of water for some properties. DOW2: There is a shortage of wells and submersible pumps. The use of water by the residents is inefficient. It is difficult to solve all existing problem in one ago with the lack of information about our network not mapping, the difficult of leak detection and repair, and water users' behaviour with water. The large amount of water used in houses and activities like washing clothes and toilet flushing has direct impact in water sustainability

5.5 Theme Four: Groundwater

This section addresses the question, *Has there been a decline in the level of the groundwater?* The general perceptions of the stakeholders about this issue are presented in Table 10. Over half (186, 53.1%) of the Agricultural Water Users claimed that they were moderately or extremely aware of groundwater scarcity due to excessive pumping. Only a few farmers (23, 6.5%) declared that they were not at all or slightly aware. In comparison, only about one fifth of the Domestic Water Users (70, 19.6%) believed that groundwater was not being renewed, and was threatened by drought. The Hydrologist and Environment Agency Officials expressed very serious concerns about the lowering of the groundwater level, associated with the increasing population in the Alwahat area, including the use of powerful pumps to abstract increasingly more water from the same aquifer. The Hydrologist explained that the water resources in Alwahat consist of groundwater linked to an aquifer which is a part of the

Sirte River Basin. The water is about 10 m to 200 m below the surface. The water is the reason why people moved into the Alwahat area, even though the land is not good. All the people abstract water from same aquifer. The groundwater supply is supplemented by Great Man Made River Project to carry the water from the river into the desert. The Hydrologist calculated that the level of groundwater had declined in the last 10 years, and confirmed that most farmers were aware of this problem, increasing the depths of their wells by up to 3 m or more per year. The Hydrologist estimated the approximate drawdown to be 1.3 m per/year, based on a very simple regional model. This was considered to be excessive, and will become a more serious problem in time. The Government Heads of Agriculture provided further evidence to confirm that the farmers were drilling increasingly more wells, and were abstracting increasingly more water, which was correlated with a lowering of the groundwater level. Two of them (GHA3 and GHA4) expressed concern that the drilling of wells by farmers was not regulated or controlled (Table 26).

Table 26: Stakeholders' perceptions about the level of the groundwater.

Stake-holders	**Item**	**Responses**	**Frequency**	**%**
Agricultural Water Users	Aware of groundwater scarcity due to excessive pumping	No reply Not at all Slightly Somewhat Moderately Extremely	70 11 12 71 111 75	20.0 3.1 3.4 20.3 31.7 21.4
Domestic Water Users	Identify problems which you are aware of:	The groundwater is not renewed and is threatened by drought	70	19.6
Hydrologists & Environment Agency	What do you think about the level of groundwater and the increasing number farms in Alwahat?	EA1: Historically the water level in the aquifer was recharged by a river. Recently the groundwater level has started to drop by over 1 m in some places. It might be due to the growing number of farmers. EA1: When the level of groundwater drops the famers have less water to irrigate their crops.		

	How would that impact in water sustainability?	
	Are you aware of any problems associated with groundwater levels?	H1: Historically the water resources in Alwahat consist of groundwater linked to an aquifer which is a part of the Sirte River Basin. The water is about 10 m to 200 m below the surface. The water is the reason why people moved into the Alwahat area, even though the land is not good. All the people abstract water from same aquifer. The groundwater supply is supplemented by Great Man Made River Project to carry the water from the river into the desert. H1: Before the discovery of oil in Alwahat, the people were very poor and did not have enough money to drill new water wells. After the oil was discovered people had more money to buy pumps that increased the quantity of groundwater abstracted. Water wells are now drilled using 60–100 horse-power pumps that can abstract about 180 m^3 per hour.
Hydrologists & Environment Agency	Are you aware of any problems associated with groundwater levels?	H1: The level of groundwater has declined in the last 10 years. Most farmers know that groundwater is declining year by year. The farmers are extending the depths of the wells by 3 m or more per year. Without the exact hydrology parameters we cannot predict exactly how much is the rate of drawdown of groundwater. I estimate the approximate drawdown is 1.3 m per/year, based on a very simple regional model of our local aquifer. This is a very high drawdown for one region. An annual drop of 1.0 cm in any area would be alarming, so 1.3m is very large. After 10 years the drawdown will be 13 m from the Sirte Basin reservoirs, so in time, the lowering of the groundwater level will become a more serious problem.
Government Heads of Agriculture	Are you aware of any problems associated with groundwater levels?	GHA1: The problem is caused because the farms are aligned very close to each other. The groundwater we use for farming exists in the top layer of the aquifer. When many water wells were drilled in a small area the groundwater levels fell very quickly. There are certain areas where the groundwater has dropped alarmingly; however, in other areas the water level has maintained itself. In general, the groundwater level in the first aquifer layers is 12 to 13 m, and in others it is 60 m. GHA2: The farmers do not follow scientific methods in drilling water wells. They do not try to solve the problem. They just drill more wells and now they abstract excessive amounts of water which lowers the groundwater level. GHA3: There is no legislation to deal with the number of wells that the farmers drill. Farmers can afford to drill many water wells in their farms which has led to the lowering of the water table. GHA4: More legislation is needed to regulate the farmers, because there is clear evidence of an increase in the number of

		water wells and a lowering of the groundwater level.

5.6 Theme Five: Water Quality

This section addresses the question, *Has the water quality deteriorated?* The general perceptions of the stakeholders about this issue are presented in Table 27.

The farmers provided conflicting reports about their water quality. Less than a half of the Agricultural Water Users (151, 43.1%) claimed that their water quality was "Average", whereas about one third (132, 32.9%) considered that their water quality was "Extremely poor" or "Below average". Less than one quarter (82, 23.4%) reported that their water quality was "Above average" or "Excellent". In comparison, three of the Government Heads of Agriculture agreed that the water quality on the farms was "Average" (Table 27).

The Hydrologist and one of the Oil Company executives reported that oil operations were having a negative effect on the quality of the groundwater. One of the Government Heads of Agriculture (GHA4) claimed that the water quality was poorest near where the oil companies are located. It was suggest that chemical monitoring of the groundwater showed evidence of contamination. One explanation was that the water generated during oil production was dumped on the ground and intruded into the aquifer. One of the Oil Company executives confirmed the need to establish methods to treat the water before it can be reused.

The Hydrologist was also concerned that the water quality was declining due to the soil which was washed into the groundwater during well drilling. One of the Government Heads of Agriculture reported an additional problem of water quality changes caused by fertilization of crops. Chemicals were apparently transferred from the soil to the water, so that the water became salty. The water in the first aquifer layer is currently believed to be salted, so the farmers are spending a lot of money drilling down to the second layer reaching 300 m deep, to obtain cleaner water (Table 27). The chemical monitoring data for the groundwater was not published, therefore none of the information provided at the interviews concerning the deterioration of the water quality could be confirmed for the purposes of this study.

Table 27: Stakeholders' perceptions of water quality.

Stakeholders	**Question**	**Responses**	**Frequency**	**%**
Agricultural Water Users	How would you describe the water quality abstracted this year compared to 10 years ago?	No reply	2	.6
		Extremely poor	27	10.6
		Below average	78	22.3
		Average	151	43.1
		Above average	53	15.1
		Excellent	29	8.3
Government Heads of Agriculture		GHA1: The water quality is average. It depends on the depth of the water wells. The deeper you go the better the quality of the water. GHA2: I would say average GHA2:Average GHA4: The water quality is poorest near where the oil companies are located		
Hydrologists & Environment Agency	Identify any problems of water sustainability that you are aware of	H1: The groundwater is polluted by the oil companies. For example, water wells were drilled in the irrigation farm settlements about 5 km from the oil company installations. When the water quality was tested it showed evidence of contamination. One explanation is that the water generated during oil production is dumped on the ground and intrudes into the aquifer. Also, the water quality is deteriorating because more soil is washed into the water when new water wells are drilled.		
Government Heads of Agriculture		GHA1: When we use fertilisers for crops, the quality of the water changes. Chemicals are transferred from the soil to the water, so that the water becomes salty. The water in the first aquifer layer is salted, so the farmers are now drilling down to the second layer reaching 300 m deep. This process can cost up to £5,000		
Oil Companies	What actions are being taken to solve the problem of contaminated water?	OC2: Oil operations are having a negative effect on the quality of the groundwater. Some of the side effects are immediately revealed but others take a long time to be discovered. We have to establish technical methods to treat the water before it can be reused inside the aquifer.		

5.7 Theme Six: Environment

This section addresses the question, *What is the environmental impact of water use?* The stakeholders' perceptions on this general issue are presented in Table 28. The stakeholders' perceptions of the environmental impact of water use by oil companies are presented in Table 29.

The majority of the Agricultural Water Users (294, 84.0%) claimed that the natural environment in Alwahat had been adversely affected by water abstraction. A similar proportion of the Domestic Water Users (291, 81.5%) perceived that the natural environment in the Alwahat area had deteriorated during the last 10 years. The most important contributor to the deterioration in the natural environment was considered by all of the stakeholders to be the oil companies. About one quarter (90, 24.7%) of the farmers believed that the deterioration caused by the oil companies was "Moderate" whilst about one half (173, 49.4%) considered it to be "Extreme". About one fifth (68, 19.0%) of the Domestic Water Users perceived that the deterioration caused by the oil companies was "Moderate" whilst over one half (202, 56.6%) considered it to be "Extreme". In comparison, less than 20% of the respondents believed that deterioration by municipal users, private householders, or farms was "Extreme" (Table 28).

Both of the Water & Sanitation officials thought that the environment had deteriorated extremely during the last 10 years, and the main sources of this deterioration was the oil companies and waste which result from production processes, especially water associated with oil (Table 29).The Environment Agency official pointed out the major problem was that oil production is associated with large water volumes with undesirable quality and high salinity in open reservoirs on the ground. Although the Environment Agency had requested the oil companies to reuse this water, and they promised to solve the problem, up until now, nothing had happened. The open water reservoirs provide a breeding ground for insects which may be harmful to human health, and increase the high humidity which comes during hot weather. It was reported that some oil companies follow the Environment Agency protocols at the international level, but some companies not. For example, not all of them manage their wastewater and garbage properly. The Hydrologist confirmed that the oil companies around Alwahat use large quantities of freshwater from the aquifer. This water becomes polluted during the oil production process, and cannot be reused, so it is retained in open reservoirs that cause a lot of environmental problems. Sometimes the polluted water is discarded on the land.

The comments of all four of the Government Heads of Agriculture about the impact of the oil companies were consistent with those of the other stakeholders. They all reported that the main sources which pose a threat to the environment in the Alwahat area were the oil companies and the operations resulting from oil production.GHA3 and GHA4 added the unregulated use of fertilisers in agriculture, associated with contamination of the groundwater. It was generally agreed that the polluters must pay the remedial costs to clean up the impact of the environmental deterioration that they are directly responsible for.

Despite the high level of criticism from the other stakeholders, both of the Oil Company executives asserted that they had policies to implement environment protection and reduce the impact of their activities on the natural environment. One company worked hard towards having ISO accreditation, and confirmed that they cooperated with the Environment Agency. Both companies undertook environmental risk assessments, monitoring the environment before and after using different locations for oil operations. Nevertheless, it was reported that there are still a lot of weaknesses. There are plans in the future for one company to treat the contaminated water and re-inject it into the boreholes. The other company reported that there are new systems being tested and planned to separate out the oil, gas, and chemical components and then reuse the water in the ground (Table 29).

Table 28: Stakeholders' general perceptions about the environmental impact of water use on the environment

(This information is defined based upon details obtained from questions put to the municipal, private householders, farmers and oil company sectors. Their replies and the ratios associated with them are included below. The details included are five in number on the scale, which are the following: 0 no reply; 1 no deterioration; 2 slight deterioration; 3 somewhat deteriorated; 4 moderately deteriorated; and 5 extremely deteriorated)

Stake-holders	Item	Responses	Frequency	%
Agricultural Water Users	Do you think the natural environment in Alwahat has been adversely affected by water abstraction?	No	56	16.0
		Yes	294	84.0
	Deterioration caused by municipal users	No reply	56	16.0
		None	13	3.7
		Slight	38	10.9
		Somewhat	75	21.4
		Moderate	98	28.0
		Extreme	70	20.0
	Deterioration caused by private householders	No reply	56	16.0
		None	19	5.4
		Slight	49	14.0
		Somewhat	78	22.3
		Moderate	93	26.6
		Extreme	55	15.7
	Deterioration caused by farms	No reply	56	16.0
		None	25	7.1
		Slight	44	12.6
		Somewhat	54	15.4
		Moderate	115	32.9
		Extreme	56	16.0
	Deterioration caused by oil companies	No reply	56	16.0
		None	7	2.0
		Slight	5	1.4
		Somewhat	19	5.4
		Moderate	90	25.7
		Extreme	173	49.4
Domestic Water Users	Do you think the natural environment in the Alwahat area has deteriorated during the last 10 years?	No reply	1	.3
		No	65	18.2
		Yes	291	81.5

	Deterioration caused by municipal users	No reply None Slight Somewhat Moderate Extreme	65 18 68 59 97 50	18.2 5.0 19.0 16.5 27.2 14.0
	Deterioration caused by private householders	No reply None Slight Somewhat Moderate Extreme	65 25 74 61 95 37	18.2 7.0 20.7 17.1 26.6 10.4
	Deterioration caused by farms	No reply None Slight Somewhat Moderate Extreme	65 28 58 52 116 38	18.2 7.8 16.2 14.6 32.5 10.6
	Deterioration caused by oil companies	No reply None Slight Somewhat Moderate Extreme	66 6 3 12 68 202	18.5 1.7 .8 3.4 19.0 56.6

Table 29: Stakeholders' perceptions of the environmental impact of water use by oil companies.

Stake-holders	**Item**	**Responses**
Water & Sanitation Officials	How much do you think the natural environment in Alwahat has deteriorated during the last 10 years?	DOW1: I think that the environment has deteriorated extremely during the last 10 years. The main source of this deterioration is the oil companies and waste which result from production processes, especially water associated with oil. I do not think farmers have significant impact on the environment, as much as municipal water users. DOW2: I think there has been deleterious changes in our environment during the last 10 years. The production processes of oil companies extremely deteriorate our environment. In my opinion, the farmers do not pollute the environment. Most pollution is caused by sewage water and motor vehicles.
Hydrologists & Environment Agency	To what extent do your Agency implement and apply the environment regulation on oil companies	EA1: The major problem with the oil companies is that oil production produces large water volumes with undesirable quality and high salinity in open reservoirs on the ground. We have requested the oil companies to reuse this water, and they promise to solve the problem, but up until now, nothing has happened. The area is suffering from the insects coming from the open water reservoirs which

		surround Alwahat. Also, they increase the high humidity which comes during hot weather.
	How far do the oil companies follow the environmental protection protocols of the Environment Agency?	EA1: The environment agency legislation was published in 1982. It covers all environment protection protocols. Some oil companies follow the protocols in a very good way at the international level, but some companies not. For example, they do not manage their wastewater and garbage properly.
	Are you aware of any problems associated with water sustainability?	H1: The oil companies around Alwahat use large quantities of freshwater from the aquifer. They do not keep it safe and clean for the next generation. This water is polluted and cannot be reused so it is retained in open reservoirs that cause a lot of environmental problems. Sometimes the polluted water is discarded on the land.
Government Heads of Agriculture	Do you things the natural environment in Alwahat has been adversely affected by water abstraction?	GHA1: The main sources which pose a threat to the environment in the Alwahat area the oil companies and the operations resulting from oil production. We ignore the negative impact of the oil companies on the environment in Alwahat. GHA2: Oil companies are the main source of environmental pollution. They abstract and produce large quantities of polluted water. GHA3: Our environment has changed for the worse, and responsibility come from oil companies, the unregulated use of fertilizers in agriculture. GHA4: The worst environment change in the Alwahat is caused by the oil companies. Wastewater contaminated with oil is stored in reservoirs in the region. Air and water pollution has an impact on agricultural produce, even the colour of leaves. The increasing water salinity on the farms is counterproductive.
Government Heads of Agriculture	Should water polluters pay the remedial coasts?	GHA1: They must pay the remedial costs, especial the problem we suffer from in this region of the reservoirs of water associated with the oil production process. GHA2: The polluter must pay the costs to clean up water pollution, especially the oil companies which surround the Alwahat area. It is essential to implement strict laws, because large quantities of water abstracted from the ground are polluted during the processes of oil production. GHA3: I agree with this it`s the only way to reduce and provident our groundwater from pollution. GHA4: I agree that water polluters should pay remedial costs. Both oil production and agriculture demand large amounts of water. After use, this water becomes polluted with oil and salt. We have to implement strict polices to reduce water pollution.

Oil Companies	To what extent does your company implement environment regulations?	OC1: We have highly qualified engineers in the company to implement environment protection and reduce the impact of our activities on the environment. We provide our employees with training in the environment risks of the oil production process. Our company works hard towards having ISO accreditation. OC2: We have an environment management system, and it follows the Department of Loss Prevention and Environment Department regulations. Our duty is to check and monitor all our locations by doing detailed reports about the environment situation. We don't have the ISO accreditation.
	Do you cooperate with environmental services in the region?	OC1: There is cooperation with the Environment Agency.
	Does your company undertake environmental risk assessments?	OC1: We do observational monitoring of the environment before and after we use different locations for the company's operations. Our company has done complete environmental risk assessment studies. OC2: Our company does not start any activities without detailed environmental assessments. I think the strategy of our company is very good, which is to eliminate the environmental risks, but still there are a lot of weaknesses.
	What actions are being taken to solve the problem of producing large amount of contaminated water?	OC1: Through our operations during oil production, we keep the water that is generated in an open reservoir. We have done studies in water operations and have solutions to this problem. There are plans in the future to treat this water. There are clear strategies from the start with cooperation with private companies to deal with the efficiency of the water separators, and treat the produced water. I believe we can use the generated water and re-inject it into the boreholes. OC2: The best way is to separate out the oil, gas, and chemical components and then reuse the water in the ground. We always try keep the oil separator working efficiently and clean. We use expert knowledge and highly technical equipment and make contracts with professional companies to dispose of the water. We have a system to dispose of the water in a safe way. There are new systems being tested and planned.

5.8 Theme Seven: Waste-Water

This section addresses the question, *What are the issues associated with the disposal or re-cycling of wastewater (sewage).* The stakeholders' perceptions about the contamination of water by sewage are presented in Table 30.Their concerns about the re-cycling of wastewater (sewage) are presented in Table 31.

The majority (296, 82.9%) of the Domestic Water Users were aware of water contamination problems from sewage (wastewater) within their property. Their different ways of dealing with this problem included abandoning the old water system, and building a new one (128, 35.9%); calling the water supplier (111, 31.1%); or cleaning the system and using it again (42, 11.8%).Four of the young working women recommended that the sewage reserves should be located far away from the drinking water reserves. One suggested that the current way of storing water and sewage should be completely reformed. The two Water & Sanitation officials were aware of these problems. One complained that there is no water treatment system in the area, so we are negative at solving this issue. The other confirmed that there is currently no mechanism to solve these problems, and studies are needed to develop the solution (Table 30).

The Domestic Water Consumers were divided with respect to the reuse of water. About a half (168, 47.0%) believed it was unacceptable, or totally unacceptable, whereas over one third (136, 38.1%) considered it to be acceptable or perfectly acceptable (Table 31). The majority of the Older Housewives (3, 60%) and Younger Working Women (5, 83.3%) did not accept the concept of recycled water. The Water & Sanitation officials commented that no serious plan exists to treat and re-use wastewater. The Environmental Agency official agreed that it was a good idea to re-use wastewater, and had requested to the department of the city planning to introduce and build a treatment station to collect and treat wastewater for re-use as a fertilizer; however, nothing had happened so far (Table 31).

The plan to use old private water wells for sewage disposal was totally unacceptable or unacceptable to the majority (282, 79%) of the Domestic Water Users. The Water & Sanitation Officials and the Hydrologist similarly agreed that the use of old private wells for sewage disposal was unacceptable because of the risk that groundwater may become contaminated by sewage.

About a half (165, 46.2%) of the Domestic Water Users were ignorant of the concept of using sewage water treatment for agricultural crop irrigation in Alwahat, and less than one fifth (61, 17.1%) considered it to be very expensive. One of the Water & Sanitation Officials (DOW1) confirmed that is very expensive, and must conform to strict standards. The other (DOW2) was against the concept, and suggested that there are other more important problems that must be solved first, such as reducing water losses, and maintenance of the water network. The Hydrologist disagreed with the concept, and suggested that contamination of groundwater is possible if a large quantity of wastewater (sewage) is dumped onto the land as a fertiliser, due to the high permeability of the sandy soil in the Alwahat area (Table 31).

Table 30: Stakeholders' perceptions about the contamination of water in houses/properties by sewage.

Stake-holder	**Item**	**Responses**	**Frequency**	**%**
Domestic Water Users	Are you aware of water contamination problems from sewage (wastewater) within your property?	No reply No Yes	1 59 296	.3 16.5 82.9
	How you do deal with this problem if it happens? Do nothing	No Yes	342 15	95.8 4.2
	Call water supplier	No Yes	246 111	68.9 31.1
	Abandon and build new one	No Yes	229 128	64.1 35.9

	Clean and use again	No Reply No Yes	1 314 42	.3 88.0 11.8
Younger working women	What do you know about water sanitation and water storage?	YW3: The sewage reserve should be located far away from the water reserves, because there have been incidents where the water and sewage reserves leaking into each other, which creates so many health risks. YW4: They should build water and sewage reserves outside and away from residential property or land. YW5: They should be kept apart. YW6: The way of storing water and sewage should be completely reformed; the current system is outdated for modern living. YW7: Some people try to build the sewage reserve away from their properties, because they are afraid of leakage.		
Water & Sanitation Officials	Are you aware of the water contamination problems from sewage (wastewater) in Alwahat properties?	DOW1. I am aware of this problem. There is no water treatment system in the area, so we are negative at solving this issue. In my opinion the reason why we are unable to reuse wastewater is because Alwahat is located in the middle of the desert with high permeability and high temperatures, and the soil very quickly absorbs the water. DOW2. I understands the risks resulting from contamination with sewage. There is no mechanism to solve these problems because they are complex. We need studies to develop the solution.		

Table 31: Stakeholders' perceptions of sewage water recycling.

Stake-holders	Item	Responses	Frequency	%
Domestic Water Users	How acceptable is the reuse of water?	Totally unacceptable Unacceptable Neutral Acceptable Perfectly acceptable	83 85 53 61 75	23.2 23.8 14.8 17.1 21.0
Older Housewives	How will you accept the idea of using re-cycled water?	OW1.I don't have any issues with recycled water OW2.I don't feel it's a good idea to use recycled water. OW3.I don't have a problem with recycled water OW4.I don't accept the concept of recycled water. OW5.I don't feel it's a good idea to have recycled water.		
Younger Working Women	If we provide recycled water, will you be happy to use it?	YW1: I don't want to use recycled water when there is pure water available. YW2: Yes, it's a great idea if it saves water. YW3: No, I don't like to use it. It would taste contaminated, even if it is safe. YW4: No, I won't accept it. YW5: No. YW6: No, I don't like it.		
Water & Sanitation	How acceptable is the treatment and re-use of wastewater ?	DOW1.This strategy only exist on paper. The project was planned in the seventies, but there is no serious plan to implement them.		

Officials		DOW2. Treatment and re-use of water are now at a very basic stage of development		
Hydrologists & Environment Agency	Are there any plans to re-use wastewater in the Alwahat area?	EA1. We have made a request to the department of the city planning to introduce and build a treatment station to collect and treat the wastewater for re-use as a fertilizer. This has still not yet happened. I really think it is a good idea to re-use this water better then lose it		
Domestic Water Users	Do you accept the use of old private water wells for sewage disposal?	No reply	2	.6
		Totally unacceptable	174	48.7
		Unacceptable	108	30.3
		Neutral	45	12.6
		Acceptable	15	4.2
		Perfectly acceptable	13	3.6
Water & Sanitation Officials		DOW1. This behaviour is completely unacceptable, because it could led to contamination of groundwater. DOW2. This is not acceptable, because of it is risk to groundwater .		
Hydrologist & Environment Agency		H1. Groundwater may become contaminated by sewage.		
Domestic Water Users	What do you consider the reasons for not using wastewater for agricultural crop irrigation in Alwahat?	No reply	1	.3
		Do not know	3	.8
		Ignorance of concept	165	46.2
		Very expensive	61	17.1
		Treatment is not important	30	8.4
		Other reasons	97	27.2
Water & Sanitation Officials		DOW1. It is very expensive, and must conform to strict standards. DOW2.There are fundamental problem that must be solved first, such as reducing water losses, and maintenance of the water network H1. Contamination of groundwater is possible if a large quantity of wastewater (sewage) is dumped on the ground, due to the high permeability of the soil in the Alwahat area.		

5.9 Theme Eight: Solutions

This section addresses the question *Do the stakeholders have any solutions to prevent misuse of water?* The stakeholders perceived solutions are presented in Table 32 (general solutions respect to farms); Table 33 (general solutions with respect to houses/properties); Table 34 (legislation to prevent misuse of water by farmers); Table 35 (legislation to prevent misuse of water by domestic consumers); Table 36 (education/training issues concerning sustainable use of water on farms); and Table 37 (education/training issues concerning sustainable use of water in houses/properties).

5.9.1 General Solutions with respect to Farms

Most of the farmers were generally acquiescent about the regulation of agriculture to ensure sustainability of water. Over three quarters of (292, 83.4%) of the Agricultural Water Users agreed that they should only be allowed to extract water if they can prove that they are going to use it in an efficient way, and 74.6%agreed that the amount of water taken from their wells should be limited to ensure the sustainability of the supply. Over half (191, 54.6%) would consider changing the type of crop they grew to conserve water.

The Environment Agency Official agreed that it was a good idea to introduce crop types that do not take too much water. Three of the four Government Heads of Agriculture, however, indicated barriers to changing the types of crops, specifically (a) We inherited the crop types that we grow in the desert from our ancestors, and it is not easy to change existing crops in order to sustain the water; (b) Changes in crop type are not easy to introduce, because new crops may not give the same profit as the old crops, and if the harvest is not good, then the farmers will not cultivate the same crops again; and (c) Changing crops requires more agricultural knowledge and experience. Most farmers cannot afford to experiment with new crops in case of failure of the harvest of the new crop. In contrast, one of them (GHA4) was very keen to make changes in crops types in order to reduce water consumption, and suggested that we need to demonstrate that new crops are good and the food market competition will profit the farmers (Table 32).

One of the Government Heads of Agriculture (GHA1) suggested that one way to solve the problem was to encourage the farmers to cooperate and reduce the amount of water they used as a whole. This would produce less harvest and reduce the amount of food going to waste from over production. All four of the Government Heads of Agriculture agreed that the metering of water would be difficult to implement in practice on farms because (a) There are a large number of wells, and the farmers consume very large amounts of water, so it would be difficult to monitor and regulate the huge amount of water used; (b) The farmers believe that water is a gift from God and should not be charged. The Environment Agency Official suggested that one solution would be to penalize farmers for using drinking water to irrigate their farms by connecting their pipes to the municipal drinking water system. The Hydrologist commented that the Great Man Made River Project is not a solution, because it has a life expectancy. The Hydrologist's solution to the problem of excessive use of water by farmers was to stop the expansion of the large farm settlements proposed by the government in the Alwahat area (Table 32).

Table 32: Stakeholders' solutions to help prevent the misuse of water with respect to farms.

(The definition of the statements below was based upon discussions and interviews about long term solutions to agricultural water sustainability issues with the stakeholders in which answers were provided to the following questions. The answers were given by the stakeholders in their own words and were the implementation of what ideas had been brought out of the questionnaire.)

Stakeholders	**Item**	**Responses**	**Frequency**	**%**
Agricultural Water Users	Should farmers only be allowed to extract water if they can prove that they are going to use it in an efficient way?	No Yes	58 592	16.6 83.4
	Do you agree the amount of water taken from your wells should be limited to ensure the sustainability of the supply?	No reply No Yes	1 88 261	.3 25.1 74.6

	Would you consider changing the type of crop you grow to save water?	No reply No Yes	1 158 191	.3 45.1 54.6
Hydrologists & Environment	What do you think about changing the type of crops grown to save water?	EA1: In Alwahat the farmer must irrigate crops because there is no rainwater like in the north of Libya. It is a good idea to introduce crop types that do not take too much water.		
Government Heads of Agriculture	Would you consider change the changing type of your crop grows to save water?	GHA1: Some crops such as tomatoes and palm trees consume too much water. It is difficult to change the types of crops, because we inherited these from our ancestors. It is not easy to change crops in order to sustain the water. GHA2: Changes in crop type cannot be easy to introduced Alwahat. The new crops may not give the same profit the old crop. If the harvest is not good then the farmers will not cultivate it again. GHA3: I do not think the existing crops need to be changed because they are appropriate to the nature of desert region. Changing crops requires more knowledge and experience. Most farmers cannot afford to experiment with new crops in case of failure of the harvest of the new crop. GHA4: I am very keen to make changes in our crops types in order to reduce our water consumption. We need to show farmers that the new crops are good and because the food market competition will profit the farmers.		
Government Heads of Agriculture	Can you suggest any solution to help prevent the misuse of water?	GHA1: I think a way to solve the problem is to encourage the farmers to cooperate and reduce the amount of water they use as a whole. This will produce less harvest and will reduce the amount of food going to waste from over production. GHA1: The amount of water taken from the wells for agricultural produce is excessive. I think this is something that needs to be reduced and controlled, not allowing the farmer to use the water, unless they prove they use it in controlled amounts.		
Government Heads of Agriculture	Would you accept metering of water from wells?	GHA1: Metering is very difficult to implement, because farmers consume very large amounts of water. They also believe water is a gift from God and should not be charged. GHA2: It is not easy to apply metering because a large number of wells and large amount of water are used for cultivation. GHA3: Metering cannot be applied in desert area like Alwahat. When the weather is very hot, and the plants need large amount of water, it is difficult to regulate. GHA4: Metering is a good idea, but it cannot be applied, due to the very large number of wells and the large volumes of water needed to be abstracted for agriculture.		

Hydrologists & Environment Agency	Can you suggest any solution to help prevent the misuse of water?	EA1: Farmers should be penalized for using drinking water to irrigate their farms by connecting their pipes to the municipal drinking water system. H1: Some people might say we have the Great Man Made River Project. I answer to them this project has a life expectancy. H1:We have to stop all the large farm settlements proposed by the government and stop the injection of freshwater into reservoirs used to enhance recovery of oil

5.9.2 General Solutions with respect to Houses/Properties

The most frequently suggested solution by the Domestic Water Users to help misuse of water in houses/properties (Table 33) was the installation of meters (139, 38.9%) followed by education and guidance about how to save water (128, 30.6%) and legislation and penalties for excessive use (62, 17.4%). Increasing the price of water was not popular (21,5.9%). All five of the Older Housewives considered that it would be a good idea to introduce a water tariff, because it would make people more responsible in their use of water, and that will reduce water consumption; however, they were concerned whether people could afford it, especially for larger families. Only one of the Younger Working Women agreed that they should pay for the water, then perhaps they might learn to save it too.

Two of the Older Housewives and two of the Younger working women suggested that they should be made more aware of the maintenance of taps and pipes to avoid water leakages. Two women suggested that the water network distribution should be more effective, for example, they should have salt water when the drinking water supply is cut for technical reasons, or that they should use salt water for cleaning purposes and only use drinking water for drinking and health related reasons. Two women suggested that water should be released only for certain hours a day, and people should store water during that period of time, this will encourage people to be more conscious about the water supply; however one believed this was not a good idea, because if water is available for certain hours a day, then people will resort to using pumps to extract larger quantities of water.

Two of the Older Housewives suggested that people should conserve water by preventing its misuse, e.g., by avoiding the use of drinking water for gardening and external domestic cleaning, and by doing everything they can in order to save water and spread awareness about conserving it. Similarly, the Environment Agency Official suggested that domestic users should learn how better to conserve water. For example, when people fill the water tank in their house they must close the top, and not let water over-spill outside their properties. The Environment Agency Official proposed that the water companies must observe misuse of water and prevent it from happening. The department of planning should also organise the maps of the street and house locations in order to plan a new water network and sewage pipelines, not just for now, but for the next fifty years (Table 33).

Table 33: Stakeholders' solutions to help prevent the misuse of water with respect to houses/properties.

Stake-holders	Item	Responses	Frequency	%
Domestic Water Users	Can you suggest any solutions to help prevent the misuse of water?	Installation of water meters in houses Guidance about how to save water Education of people Legislation & penalties for excessive use of water Increasing price of water	139 56 72 62 21	38.9 10.4 20.2 17.4 5.9
Older Housewives	What do you think is the best ways to save water and make people realize the value of water?	OW1: We should have water meters to monitor the amount of water used, and the price of it, just like the electric meters that have been installed. OW2:The best way is to introduce a tariff for using water, similar to buying bottled water OW3: Women should be made more aware of water taps and the maintenance of them to avoid any water leakages. In my experience I feel that water wastage happens more because of tap or pipe leakages. I hope water meters are installed in properties to reduce the high water consumption. OW4: I think it is difficult to solve this problem because there are different levels of consumption of every individual in a property. As a society we		

		have to try everything we can in order to save water and spread awareness about conserving it. OW5: We have to ensure maintenance of a property eternally and internally to avoid any leakages of water taps and pipes. We should avoid using drinking water for gardening and external domestic cleaning.
	Do you think if we introduce a water tariff and price, do you think people will reduce their water consumption?	OW1: Yes, we will be more careful about how much we use and that will reduce water consumption. But I don't have any idea about water pricing and how that will work. OW2: Yes it's an active way to make women feel more careful about water, because high consumption will mean paying a higher price and that can become unaffordable. OW3: Yes it's a very effective way especially if the price is very high. For example when you top-up your telephone credits, when you need it you'll buy it, the same principal applies here. OW4: I think it's a good idea to have a water tariff s people become more responsible with their consumption, however I am worried for the rates that people will have to end up paying and whether they will even be able to afford it, if the tariffs were set on high values. OW5: We are a joint family, so we have a bigger number of people living at the property, so our consumption is naturally higher. It is a good idea to have a price on the water, but I'm worried that they may increase the tariff or the price for larger families, and it may become unaffordable.
Young Working Women	Has the high water consumption got anything to do with the timings of the water supply?	YW1: When we get the water, we clean, we wash, we garden, everything that has to do with water. If there is water available, then we use it. If not then we store it. YW2: If water is released for certain hours a day, and people store water during that period of time, this will encourage people to be more conscious about the water supply and prevent the health risks of water storage. YW3: I don't think this idea will work out for our region. If water is available for certain hours a day, then people will resort to using pumps to extract large quantities of water on a daily basis, and that is unfair distribution. YW4: If free flowing water is available, then people are not being responsible for its use. YW6: Look at our houses when water is not available, and how difficult it becomes to live.
	Can you suggest any solution to help prevent the misuse of water?	YW1: Reform the water network distribution to become more effective. YW2: They provide salt water when drinking water supply is cut for technical reason. YW3: They should use salt water for cleaning purposes and only use drinking water for drinking and health related reasons. YW4: If we pay for the water, then perhaps we might learn to save it too. Reform the mechanism of the water system, for example the water municipal should reduce the quantity of the water supply, for example, by using this method, provide a meter reading, then calculate an average, then any additional use of that amount of water should be sold on tariff. YW5: The idea of water reduction should be done slowly, and that will begin to encourage the attitude towards valuing water availability.

Hydrologists & Environment Agency	Can you suggest any solution to help prevent the misuse of water?	EA1: When they fill the water tank in their house they must close the top, and not let water over-spill outside their properties. The water companies must observe such behaviour and prevent it from happening EA1: The department of planning should organise the maps of the street and house locations in order to plan a new water network and sewage pipelines, not just for now, but for the next fifty years.

5.9.3 Legislation to Prevent Misuse of Water by Farmers

Less than one third of the Agricultural Water Users were aware of the current irrigation policy (113, 32.3%) and only about one quarter (90, 25.7%) considered that the current policy is adequately enforced. One of the Government Heads of Agriculture (GHA2) confirmed that the farmers were not aware of the current irrigation policy, stating, "We know that the majority of farmer are not educated and they maintain their wells without knowledge of legislation" and "Most farmers do not know about the existing legislation. They all agreed that current agricultural policies and legislation are not adequately enforced (Table 34).

The majority of the Agricultural Water Users (282, 80.6%) agreed there is a need for legislative reform. This was not consistent with the views of three of the Government Heads of Agriculture, who asserted that there is no need to reform the existing legislation, but there is a need to implemented and make it more active. There was a general agreement that the current legislation is not enforced. The number of wells drilled, the amount of water abstracted, and the use of fertilizers are not currently regulated. Two of the Government Heads of Agriculture commented that the legislation is not specifically appropriate for Alwahat due to the different environmental conditions compared to other regions of Libya.

About three quarters of the farmers (261, 74.2) accepted that their use of water should be regulated and over a half (203, 58.0%) would accept water meters. This was not consistent with the views of the Governments Heads of Agriculture, who, believed that metering on farms would be difficult to implement in practice, since restrictions on water would reduce agricultural production, and the farmers would not accept it; however, relatively few farmers claimed that they would not accept metering because of the cost (65, 18.6%) or due to their large farm (22, 6.3%) many wells (22, 6.3%) or quantity of water abstracted (37, 10.6%). One of the Government Heads of Agriculture (GHA3) commented that is would also be difficult to apply a law that farmers should prove they are using water in an efficient way (Table 34).

Table 34: Stakeholders' perceptions about legislation to prevent misuse of water by farmers

Stake-holders	**Item**	**Responses**	**Frequency**	**%**
Agricultural Water Users	Do you think there is a need for legislative reform to ensure the sustainability of water supply in Alwahat?	No Yes	68 282	19.4 80.6
	Are you aware of the current irrigation policy?	No Yes	237 113	67.7 32.3
	Do you consider the current irrigation policy is adequately enforced?	No Yes	260 90	74.3 25.7
	Do you accept the use of the water in farms should be regulated?	No Yes	89 261	25.4 74.6
	Should water polluters pay the remedial costs?	No Yes	43 306	12.3 87.4
	Would you accept the metering of water from your wells?	No Yes	147 203	42.0 58.0
	Not accept metering because of cost	No Yes	285 65	81.4 18.6
	Not accept metering because of large farm	No Yes	328 22	93.7 6.3
	Not accept metering because of many wells	No Yes	328 22	93.7 6.3
	Not accept metering because of quantity of water abstracted	No Yes	313 37	89.4 10.6
Stakeholders	**Item**	**Responses**		

Government Heads of Agriculture	Do you think the existing water regulations are adequate?	GHA1: There is no article in the legislation about the number of water wells on a farm, and because of this reason a wealthy farmer can drill many wells. There is no legislation to deal with the increasing numbers of wells. I think they should evaluate the numbers of water wells being built; however, the strategy of the government demands an increase in the number of water wells. The policy is “let's plant in the desert wherever there is a possibility of plantation”. GHA1: The farming legislation control the use of electronically timed droplet water supplies is good. Using the droplet system ensures a reduction in the amount of water consumed. In addition it reduces the amount of physical labour required by the farmers to build water channels and other harvesting chores. There is no legislation, however, about controlling the traditional system of water supply.
	Should farmers only be allowed to extract water if they can approve that they are going to use it in an efficient way?	GHA1: This is difficult to apply in practice, because the concern is to get profit from agricultural production, and this can only be achieved if there is no restriction on water. GHA2: This is possible if the existing legislation is active and implemented, but it is very difficult in practice, because the farmers believe that they have a right to extract as much water as they want. GHA3: The farmer does not pay for water they consume. The only cost they incur is for the running of pumps, fuel and maintenance. It is very hard to apply a law that farmers should prove they are using water in an efficient way. It is possible that the farmers will not give the correct information. GHA4: It is very good idea but I think the farmers will disagree.
	Do you think there is need for legislative reform to ensure the sustainability of water in Alwahat?	GHA1: We don't need to reform the existing legislation, we need to be implemented and make it active. GHA2: There is a lack of mechanisms to implement the legislation. Most farmers do not know about the existing legislation. It is not flexible and does not cover the conservation or depletion of groundwater. The legislation does not distinguish between one area of Libya to another. What is suitable for Tripoli area is not appropriate for Alwahat due to the different conditions. GHA3: I don’t think we need to reform the legislation but we need to implement it. GHA4: The legislation is not appropriate for all areas in Libya. For example, when there is no adequate rain water in some areas, they do not allow the farmer to cultivate certain types of crops. All of the legislation is not suitable for the Alwahat area.
Government Heads of Agriculture	What do you think about the current irrigation policy and	GHA1: No irrigation policy is enforced. The patrols come sometimes when there is a problem. GHA2: We know that the majority of farmers are not educated and they maintain their wells without knowledge of legislation; however, they have awareness of the importance

	how is acceptable enforced? And what do you think about farmers being be regulated?	of water, for example, they understand that insufficient water means a threat to the productivity of farms. GHA3: There are no laws and regulations used for irrigation. The farmers can drill any number of wells according to their financial ability. GHA4: The way of life in Alwahat depends mainly on agriculture; however, the harvests of crops are not so good as before. The use of fertilizers, as well as over-exploitation of the soil, has led to this problem. There are no laws governing the quantities of fertilizer used or the amount of water abstracted. It is difficult to implement laws to regulate farmers.

5.9.4 Legislation to Prevent Misuse of Water by Domestic Users

Over three quarters (282, 79.0%) of the Domestic Water Users perceived that the current water regulations are inadequate, and there is a need for legislative reform to ensure sustainable water supplies in Alwahat (269, 75.4%).These opinions were not consistent with those of the Water and Sanitation Officials, who asserted that there is no need to reform the existing legislation, but there is a need to implement and make it more active. The same views were endorsed by the Hydrologist and Environment Agency Official (Table 35).

Over three quarters (284, 79.6%) of the Domestic Water Users perceived that there should be controls that limit their misuse of water and that the water supplier should enforce the installation of water meters in properties to conserve water (269, 75.4%).Three (50%) of the Younger Working Women agreed with the idea of using water meters; however, they expressed reservations, suggesting that metering should take into consideration the number of people in the family, especially the number of children. One of the Younger Working Women disagreed, and suggested that the water supply should not be monitored, regardless of how much water is used. The Environment Agency Official commented that the price is an element that lets water users feel the value of their consumption, and those misuse water should be charged. The Water and Sanitation Officials agreed that water meter systems, or a pay-as-you-go slot system should be introduced, and a tariff should be charged on how much water is used in excess of a set limit. The Hydrologist, however, completely disagreed. He stated that “A water tariff and water meter installation inside the properties is unreasonable. The State tried to introduce water meters in Alwahat in the 1980s. That plan was dropped. The project needs very good servicing and the people in the Alwahat area do not want it”. Four of the Young Working Women agreed that it is a good idea for women to be included in decision making processes concerning their use of water. One of them pointed out that “It makes us feel powerless and unworthy to be not part of what we are paying for. We need to be a part of it, and when we are a part of it, we’ll follow it”. The Environment Agency Official also agreed that taking part in the design of the protocols will make the users more responsible about water issues; however, one of the Young Working Women believed that this cannot happen, and another considered that their community and society was not so concerned about legislation (Table 35).

Table 35: Stakeholders perceptions about legislation to prevent misuse of water by domestic users

Stakeholders	Item	Responses	Frequency	%
Domestic Water Users	Do you think there is a need for legislative reform to ensure sustainable water supplies in Alwahat	No Yes	88 269	24.6 75.4
	Do you think the existing water regulations are adequate?	No Yes	282 75	79.0 21.0
	Do you consider there should be controls which limit the misuse of water by users?	No Yes	73 284	20.4 79.6
	Do you agree the water supplier should enforce the installation of water meters in properties in the Alwahat area to conserve water?	No Yes	88 269	24.6 75.4
Younger Working Women	How do we implement the law to people?	YW1: If we use meters to put the price on water, the people will begin to care. YW2: I do agree with the idea of a water meter. YW3: If I have a meter I will think twice about the amount of water I am using. YW4: The important part for me is water supply, and I am		

		not bothered about the implementation of the law. I don't think that our water supply should be monitored, regardless of how much water we use. YW5: The government needs to reform the entire regulations of water supply. YW6: If you want to implement the water meter regulation, the government should also take into consideration the number of people living in a property.
	What difference will the number of people in a property make to the water meter regulation?	YW2: They should take into consideration the number of people in the family before they implement a water meter-reading device. At the moment the census counts the number of adults to be listed, however it does not count the number of children residing in the property, they should update their census book. YW3: We don't have to calculate an estimate of water usage per person, but we should also add estimate of water use by children in a household to estimate an average price of water, because adults and children use water differently
Younger Working Women	Should women be a part of the decision making process about the consumption of water?	YW1: It is a good idea to be included in making a decision. YW2: When the regulation comes from the water sector, the only thing that we can do is follow that regulation. It makes us feel powerless and unworthy to be not part of what we are paying for. We need to be a part of it, and when we are a part of it, we'll follow it. YW3: I want to say, this cannot happen. We know that for every one who follows the legislation there are ten who don't. You can never make everyone happy. YW4: Our community and our society don't want to know about legislation. YW5: It helps people to understand the importance, and by making people a part of the issue, they will respect it and understand it better. YW6: When legislation comes from high state order, annoys the entire community. Even if people are on the side of the decision, an authoritative decision backfires.
Water & Sanitation Officials	Do you think there is a need for legislative reform to ensure water supplies sustainability in Alwahat?	DOW1: The regulations are not adequate, because they are not complied with, resulting in the instability of the water supply. We don't need to reform the legislation; however we need to implement what the current legislation holds. DOW2: The law exists on the shelves but no regulations are applied on the ground. I do not think it is important to re-draft the law. We want the current law activated and applied
Hydrologists & Environment Agency	Do you think the existing water regulations are adequate? Should there be legalisation reform?	EA1: I don't think we need legalisation reform because legislation is already available, We need to implement the legislation, and make it more active. H1: The legalisation is available but we need activate and implement it.

	Do you think users should be involved in the design of water management regulations?	EA1: That is one of the important elements we should consider because it will make the users more responsible about water issues. If they take part in the design of the protocols, then they do not need to be educated simply because took part in the process.
Water & Sanitation Officials	Can you suggest any solution to help prevent the misuse of water?	DOW1:To solve this problem we need to introduce water meter systems, like in other countries, to control consumption. We need to detect and repair leaks in the network. DOW2: The only way to control the misuse of water is to introduce water meter systems or a pay-as-you-go slot system. A tariff should be charged on how much water is used in excess of a set limit
Hydrologists & Environment Agency	Can you suggest any solution to help prevent the misuse of water?	EA1: The price is an element that lets water users feel the value of their consumption, Those who misuse water should be charged. Domestic water users should be penalized for misusing water in the house and in the street. H1: A water tariff and water meter installation inside the properties is unreasonable The state tried to introduce water meters in Alwahat in the 1980s. That plan was dropped. The project needs very good servicing and the people in the Alwahat area do not want it.

5.9.5 Education/Training with respect to Sustainable Water Use on Farms

The majority (280, 80.0%) of the Agricultural Water Users considered that they did not have enough training in water use/management. Nearly all of the farmers (297, 84.9%) agreed that they should become more involved in water management issues. All of the Government Heads of Agriculture confirmed that this was a good idea, including the participation of farmers in the drafting of resolutions to improve their awareness of the problems and find solutions. One of the Government Heads of Agriculture pointed out that this policy must be applied in practice, and not just on paper (Table 36).

Other people (147, 42.0%) the TV (105, 30.0%) and experience (59, 16.9%) were reported by the farmers to be the main sources of information that they had available to make them more aware of water issues in Alwahat. The Hydrologist and Environment Agency Official suggested that farmers should be better educated about how they should consume water in a responsible way. The Government Heads of Agriculture agreed, but pointed out that the formal education of farmers about water management is currently limited, confirming the responses of a high proportion of farmers (280, 80.0%) who perceived that they did not have enough training in water use/management.

The Government Heads of Agriculture commented that there are a few leaflets and other materials available in the Farmers' Association, but there are insufficient funds, and a lack of coordination between the agricultural departments in Libya to organize special training courses for farmers. One of the Government Heads of Agriculture perceived that there is a "lack of seriousness of the farmers to attend such courses", contradicting the responses of the majority of farmers (297, 84.9%) who perceived they wanted to be more involved in water management issues (Table 36).

Table 36: Stakeholders' perceptions about education/training with respect to sustainable use by farmers.

Stake-holders	Item	Responses	Frequency	%
Agricultural Water Users	How did you become aware of water issues in Alwahat?	Radio TV Newspapers Experience Other people	27 105 12 59 147	7.7 30.0 3.4 16.9 42.0
	Do you consider you have had enough training in water use/ management?	No Yes	280 70	80.0 20.0
	Do you think farmers should be involved in water management issues?	No Yes	53 297	15.1 84.9

Government Heads of Agriculture	Do you think farmers should be involved in water management issues?	GHA1: I think the idea is good; however, all the decisions we apply come from Tripoli. GHA2: The participation of the farmers in decision-making will contribute towards their awareness of the problems and how to overcome them. GHA3: Farmers should participate in the drafting of resolutions to improve awareness of the problems and find solutions. GHA4: It is good idea to apply in practice, but not just exist on paper.
Hydrologists & Environment Agency	Can you suggest a solution?	EA1: Farmers should be educated about how they should use water in a responsible way by applying the knowledge of water management used in other countries H1: The farmers should learn a proper strategy leading them to more responsible consumption of water. They must learn that that their future depends upon the continued availability of water.
Government Heads of Agriculture	Do you do provide training to farmers on how to use water and maintain its sustainability?	GHA1: There are a few leaflets and other materials available in the Farmers' Association. In this aspect, we are very remiss. This is due to the lack of sufficient funds for training courses, and also the lack of seriousness of the farmers to attend such courses. GHA2: There are no training courses for farmers, mainly because of the lack of coordination between the agricultural departments in Libya. GHA3: There are no courses for farmers, we must have some because it helps increases awareness about the importance and methods of water conservation. GHA4: It is necessary to give farmers training to understand methods of sustaining the water.

5.9.6 Education/Training with respect to Sustainable Water Use by Domestic Users

The majority of the Domestic Water Users (208, 58.3%) were not aware of any guidance or publicity relating to sustainability of water. Over three quarters (281, 78.7%) believed that the water suppliers should train, demonstrate, and educate consumers to use water in a sustainable manner. There was a general consensus of opinion among nearly all of the other stakeholders that education of water users is very important (Table 37).

All but one of the Young Working Women perceived that educating the people will be an effective solution. The Environment Agency Official suggested that we need to educate water users, make them realize the important of water, and that we have a water shortage problem. The Hydrologist suggested that education is one of the very important elements to sustain water in Alwahat. Water users need to learn the truth about the water situation. They need to understand the challenges we are faced with and what the future holds for this area. One of the Water and Sanitation Officials commented that education is vital so that people learn to use water wisely.

There was a conflict of opinion about how the proposed education about water management should be implemented. Three of the Younger Working Women suggested the Government was responsible. Two suggested education should be done via the media (newspapers, leaflets, and TV). One suggested that education starts at home. Women in the household should start by educating children and other family members. One suggested kindergarten is the place to start educating children about water use, whereas another considered that the local water municipal was responsible. One of the Water and Sanitation Officials (DOW1) suggested that education should start at school by incorporating water management into the curriculum. The other (DOW2) was less certain about the value of education via the media. He complained that "when we have circulated information about water sustainability we have never had much response from people or seen a change in their ways of using water". He perceived that women play a key role in economic and social development, and their participation in the development process should be enhanced. Training programs, awareness campaigns and panel discussions should be intensified at the local level to help people overcome their traditional perceptions that limit the role of women in the development and management of water resources. Training programs should be promoted to help rural women identify the best methods of water resource management and rationalize their consumption and disposal of wastewater. These suggestions appeared to be generally consistent with the views of most of the Young Working Women, who expressed concern about the need for more education (Table 37).

Table 37: Stakeholders' perceptions about education/training with respect to sustainable use of water by domestic users

Stake-holder	Item	Responses	Frequency	%
Domestic Water Users	Are you aware of any guidance or publicity relating to water users in relation to sustainability?	No Yes	208 149	58.3 41.7
	Do you consider water suppliers should train, demonstrate, and educate water users in using water in a sustainable manner?	No Yes	76 281	21.3 78.7
Younger Working Women	What is the best way to reduce water consumption in households?	YW1: Educate people from the government through the media, especially to educate women YW3: The government should take more action to educate people. YW4: The government should make people aware of the long-term availability of water as water levels are dropping with time. YW5: The people must know the consequences of high water consumption, and why it is important to change our attitudes and patterns of using water. YW6:The important issue in all of this is to educate the people and the problem will reduce.		
	How and who do you educate?	YW1: We should educate the people, especially children from kindergarten about water, and when they get older their attitudes are going to be more sympathetic towards water consumption. This change won't happen overnight, it will take up to a generation for things to really change. YW2: Education is the best solution to save water. Educating people through the media (newspapers) will help to bring about a change in attitude. YW3: Education starts at home. Women in the household should start by educating children and other family members to bring about realistic and positive changes. Use the media, television, and leaflets to spread information about new technologies and equipment to bring about awareness of water consumption.		

		YW4: The local water municipal should be responsible to educate and increase awareness about water allocation and consumption YW5: I don't feel educating the people is a solution that will be effective.
Hydrologists & Environment Agency	Can you suggest a solution?	EA1: We need to focus on educating water users regarding the law, so that the law will benefit the people and the country. We need to educate water users, make them realise the important of water, and that we have a water shortage problem. We have to make people more aware of the problem. H1: Education is one of the very important elements to sustain water in Alwahat. Water users need to learn the truth about the water situation. They need to understand the challenges we are faced with and what the future holds for this area.
Water & Sanitation Officials	Are you aware of any guidance or publicity relating to water users in relation to sustainability?	DOW1: Education is vital so that people learnt to use water wisely. Education should start at School by incorporating water management into the curriculum. DOW2: There is not much advertising or information for people about the value of water and ways to save it. Even when we have circulated information about water sustainability we have never had much response from people or seen a change in their ways of using water.
	Do you consider water suppliers should train, demonstrate, and educate water users to use water in a sustainable manner?	DOW1: Education is an important element to convince people to use water responsibly. Due to the lack of highly qualified and capable personnel in water management it is difficult to train water users. DOW2: Women play a key role in economic and social development in Libya, and their participation in the development process should be enhanced. Women should be involved in decision-making relating to water resource management. Training programs, awareness campaigns and panel discussions should be intensified at the local level to help people overcome their traditional perceptions that limit the role of women in the development and management of water resources. Training programs should be promoted to help rural women identify the best methods of water resource management and rationalize their consumption and disposal of wastewater

5.10Summary

The discussion of the results focuses upon the third objective of this study, specifically to determine how the triangulated information might be applied in practice to contribute towards the development of a sustainable water management strategy in the Alwahat study area. A detailed summary of the results is presented in the following chapter.

Chapter 6: Discussion of Results

6.1 Introduction

The findings of this study are discussed systematically in six sections (a) A summary of the results, addressing the research questions, based only on the perceptions of the stakeholders; (b) A consideration of the methodological limitations, focusing on the potential sources of response bias; (c) An interpretation of the perceptions of the stakeholders, in the context of information from the literature; (d) Recommendations for action, describing how the findings of this study could potentially be applied in practice to develop a strategy for providing a sustainable groundwater resource in the Alwahat region, in order to achieve an economic, socially and environmentally sustainable water future; (e) Recommendations for further research; and (f) Conclusions.

6.2 Summary of the results

The responses of the stakeholders are summarized with respect to the eight research questions:

1. What do the stakeholders use water for and how much is used for different purposes?

The majority of the farmers claimed to have one or more wells for the purpose of irrigating their land, containing an average depth of water of 40–70 m. The depth of most of the wells was extended by about 1 to 3 m per year. The majority of the farmers used the modern drip irrigation system, which was confirmed by the government heads of agriculture. The hydrologist speculated that the volume of water used for irrigating one farm field was about $4.32 \times 10^3\ m^3$ / day. The oil companies reported that the water used in oil production operations was either stored in an open reservoir, or treated and re-used on the ground. The amount of water used by the oil companies was not disclosed. Domestic consumers reported they used an average of about 286 litres/person/day in their properties/houses. The young women perceived that they consumed more water today than older generations of women

2. Are the stakeholders satisfied with their current water supply situation?

Conflicts of opinion were exposed concerning the current water supply situation. Most of the farmers claimed that they were satisfied with the current situation. In contrast, the government heads of agriculture were not satisfied, complaining that the farmers used excessive amounts of water. The majority of the domestic water users perceived they were not satisfied with the services provided by water suppliers, including the time water is available, the water quality, taking a part in decision making, and the price. In contrast, the water & sanitation officials generally expressed satisfaction with the current water supply situation, with respect to the time water was available, the water quality, and the price; however they were dissatisfied with their level of involvement in making decisions about water management.

3. Are the stakeholders aware of any issues associated with water sustainability?

Conflicts of opinion were exposed concerning water sustainability. The majority of the farmers perceived that they used water efficiently, and were aware of the issues associated with water sustainability in the Alwahat area. Relatively few farmers claimed that they were not aware of the increasing number of farms, or groundwater scarcity due to excessive pumping, or the increasing number of wells, or the amount of fertilization used on crops. Such a high level of awareness was not consistent with the views of the government heads of agriculture. One perceived that the farmers did not know much about the current water situation. The government officials expressed concern about the increasing number of farms, excessive water consumption, the lowering of the water table, and the need for a policy to manage water use by farmers, despite barriers to implementing such a policy.

Most of the domestic water users perceived that sustainability meant that water is available, every time you need it, for a long time. The water and sanitation officials, the hydrologist, and the environment agency officer perceived sustainability to be essentially a management problem, involving many issues, to ensure that enough water is available for everyone in the 21st century and beyond. The majority of the domestic water users perceived that lack of awareness and excessive use of water were important issues. The most frequently cited reason for the problems associated with water sustainability in properties/houses, was poor services from the water supply companies. It was suggested that the people in charge of the water supply are not bothered about the issues, the negative opinions of the domestic water users contradicted the serious concerns expressed by the water and sanitation officials, the hydrologist, and the environment agency officer. Their concerns included misuse of drinking water, the installation of water pumps to improve supply, and farmers taking drinking water from the network for irrigation. Other issues included the old water distribution network, including a shortage of wells and pumps, corrosion and broken valves, maintenance issues due to a lack of mapping of the water pipes, miss-matched pressure of water, and lack of water for some properties.

4. Has there been a decline in the level of the groundwater?

Conflicts of opinion were exposed about the decline in the level of the groundwater in the Alwahat area. All the stakeholders except the domestic consumers pointed towards the rapid local growth of the population following the discovery of oil and/or the expansion of the farms, as the root cause of the problem. It was perceived that population growth in the last twenty years had led to an increasing amount of water extracted from the aquifer to supply domestic consumers and irrigate more farm fields, lowering the groundwater level, and reducing the availability of water. The government and water and sanitation officials expressed their concern about the lowering of the groundwater level, including the use of powerful pumps to abstract increasingly more water from the same aquifer. The hydrologist estimated the approximate drawdown of the local aquifer was 1.3 m per/year, which was considered to be excessive. The government heads of agriculture provided evidence to confirm that the farmers were drilling increasingly more wells, and abstracting increasingly more water, which was related to the lowering of the groundwater level. About half of the farmers claimed that they were aware of groundwater scarcity due to excessive pumping. In contrast, relatively few of the domestic water users expressed their concern about the decline in the groundwater level.

5. Has the water quality deteriorated?

Conflicting reports were received about changes in the quality of the groundwater. Less than a half of the farmers claimed that their water quality was “average” whereas all the government heads of agriculture agreed that the water quality on the farms was “average”. The hydrologist and one the government heads of agriculture claimed that oil operations were having a negative effect on the quality of the groundwater, mainly because the water generated during oil production was dumped on the ground and intruded into the aquifer. One of the oil company executives confirmed the need to establish improved methods to treat the water before it can be reused. Other sources of changes in water quality reported by the officials included the washing of soil into the groundwater during well drilling, and changes induced by fertilisation of crops. The water in the top aquifer layer is currently believed to be saline, possibly due to seawater incursion, so the farmers are drilling down to deeper layers to obtain cleaner water

6. What is the environmental impact of water use?

A conflict of opinion between the oil companies and the other stakeholders was exposed concerning the environmental impact of water use. The majority of the farmers, domestic users, and officials claimed that the natural environment in Alwahat had been adversely affected by water abstraction in the last 10 years. The most important contributor was perceived to be the oil companies. In comparison, relatively few respondents perceived that environmental deterioration was caused by municipal users, private householders, or farmers. It was confirmed that the oil companies around Alwahat use large quantities of freshwater from the aquifer. This water becomes polluted during the oil production process, and cannot be reused, so it is retained in open reservoirs that cause a lot of environmental problems. Sometimes the polluted water is discarded on the land. Although the Environment Agency has requested that the oil companies must solve this problem, up until now, nothing has happened. It was reported that some oil companies follow the Environment Agency protocols at the international level, but some companies do not. It was generally agreed that the oil companies must pay the remedial costs to clean up the impact of the environmental deterioration that they are directly responsible for. Despite the high level of criticism from the other stakeholders, the oil company executives asserted that they implemented strict policies to ensure environment protection and reduce the impact of their activities on the natural environment. The oil companies had plans to treat the contaminated water in the future before it is re-used on the land.

7. What are the issues associated with the disposal/re-cycling of wastewater/sewage?

The majority of the domestic users expressed concern about drinking water contamination from sewage/wastewater within their properties. The most frequent way of dealing with this was to build a new wastewater system. The water & sanitation officials were aware of the problem, and suggested that much more work is needed to provide a solution, including the construction of a new wastewater treatment plant.

Conflicts of opinion were exposed concerning the re-cycling of wastewater/sewage. About half of the domestic water consumers believed that re-cycling was unacceptable. The Environmental Agency official, in contrast, thought it was a good idea to re-use wastewater, and had requested to the department of the city planning to introduce and build a treatment station to collect and treat wastewater for re-use as a fertiliser; however, nothing has happened so far. The hydrologist suggested that contamination of groundwater is possible if a large quantity of wastewater is dumped onto the land as a fertiliser, due to the high permeability of the sandy soil in the Alwahat area. The plan to use old private water wells for sewage disposal was considered to be unacceptable to the majority of the stakeholders.

8. Do the stakeholders have any solutions to prevent misuse of water?

The stakeholders suggested many solutions to prevent misuse of water, including (a) general solutions with respect to farms; (b) general solutions with respect to houses/properties; (c) legislation to prevent misuse of water by farmers; (d) legislation to prevent misuse of water by domestic consumers; (e) education/training concerning sustainable use of water on farms and in houses/properties.

Conflicts of opinion were exposed with respect to general solutions for preventing the misuse of water on farms. Most farmers would consider changing the type of crop they grew to conserve water. Although the Environment Agency official believed it was a good idea to introduce crop types that do not take too much water, three of the four government heads of agriculture warned that there were barriers. Over three quarters of the farmers agreed that they should only be allowed to extract water if they can prove that they use it in an efficient way, and that the amount of water taken from their wells should be metered. The government heads of agriculture, however, suggested that the metering of water would be difficult to implement in practice. The environment agency official suggested that farmers should be penalized for extracting drinking water from the municipal supply to irrigate their farms, and the hydrologist's solution to was to stop the expansion of the large farm settlements proposed by the government in the Alwahat area.

Conflicts of opinion were also exposed with respect to general solutions for preventing the misuse of water in domestic properties. The main solutions agreed by the domestic consumers were the installation of meters, education and guidance, but penalties for excessive use and increasing the price were not popular. The Environment Agency official suggested that domestic users should learn how better to conserve water, those who use excessive water should be charged, and that a more effective water network should be installed. The water and sanitation officials agreed that a tariff should be charged on how much water is used in excess of a set limit. The hydrologist, however, disagreed, because a metering system needs servicing and the people in the Alwahat area do not want it. Four of the women and the Environment Agency official agreed that taking part in the design of protocols to conserve water will make the users more responsible.

The majority of the farmers and the domestic users agreed that the current regulations concerning the misuse of water are inadequate, and there is a need for legislative reform. This was not consistent with the views of the government heads of agriculture, the environment agency officer, the water and sanitation officials, and the hydrologist, all of whom who asserted that there is no need to reform the existing legislation, but there is an urgent need to make it more active.

Education was put forward as a possible solution to prevent misuse of water. The majority of the farmers considered that they did not have enough training in water use/management, and they wanted to be more involved. The government heads of agriculture, the environment agency officer, and the hydrologist agreed that education was a good idea, including the participation of farmers in the drafting of resolutions. The lack of funds and coordination between the agricultural departments in Libya to organise special training courses for farmers was considered to be a barrier. There was a general consensus of opinion among nearly all of other stakeholders that domestic water users should be trained to use water in a sustainable manner. There was, however, a conflict of opinion about how the proposed training should be implemented, and how domestic consumers could become personally involved in the development and management of water resources.

6.3 Methodological limitations

Before the perceptions of the stakeholders described above can be accurately interpreted, a reflexive critique of the methodology must first be performed, not to test the assumptions that justified the use of a stakeholder analysis in the first place, but to establish the limitations of the collected data (Johnson & Duberley, 2003).

The findings of this study were based mainly upon information elicited from 769 stakeholders (350 agricultural water users, 409 domestic water users, four government heads of agriculture, two water and sanitation officials, one hydrologist, one environment agency official, and two oil company executives).The perceptions of the stakeholders, who volunteered to take part in the study, may not be representative of the whole population of Libya (i.e., over 6 million people). The results of this study may therefore not exhibit external validity (i.e., they cannot necessarily be generalised so that they apply to the whole population). According to Creswell (2009) at least 10% of each demographic group in a target population should agree to participate in a survey for the findings to exhibit external validity. Consequently, the findings of this study may be biased towards the responses of the small proportion of the Libyan population who agreed to participate.

Other potential sources of response bias which posed a potential threat to the validity of the stakeholder analysis, discussed by Paulhus (1991) included: (a) Some respondents may naturally be very polite and respectful people, who prefer to avoid any type of argument or social risk-taking, so they consistently provided positive or agreeable responses which they think might gratify the researcher; (b) Some respondents may perceive themselves to be of lower educational and/or social status than the researcher, and so they deferred to his authority by endorsing what he believed to be true; (c) Some respondents may not have answered the questions according to their own individual perceptions, but responded with the collective perceptions of their own social group or culture; and (d) Some respondents may have provided very positive/agreeable responses, or very negative/disagreeable responses simply because it takes less time and effort than carefully weighing up all of the different possible options.

Response bias is known to vary culturally, and certain types of bias have been found to prevail specifically among Arabs (Baron-Epel *et al.*, 2010; Harzing, 2006; Lalwani & Shavitt, 2006; Smith, 2004). These include “extreme response bias” (a tendency to provide a reply which is either very positive, or very negative); “acquiescent response bias” (a tendency to provide agreeable or positive answers to all questions regardless of content or what is believed to be the “true” answer) and “socially desirable reporting” (a tendency to provide deceptive answers in order to maintain a good relationship with the researcher).Response bias among Arabs may be related to Hofstede’s (2001; 2009) dimensions, formulated to distinguish between different cultures. Hofstede’s cultural dimensions are open to criticism for stereotyping and failing to engage deeply with local contexts. Despite the fact that Arabs live in different countries, with diverse cultures, beliefs and a variety of religions, they are commonly classified as one cultural group (El-Farra, 1996). Hofstede's analysis indicates that power distance (i.e., a high level of inequality between people, acting as a barrier to upward mobility); uncertainty avoidance (i.e., an aversion to taking risks) and collectivism (i.e., a very strong loyalty towards family, friends, and cultural identity) are the predominant characteristics of Arabs. According to Harzing (2006), some respondents in Arab countries, such as Libya, which exhibit Hofstede's cultural dimensions of a high power distance, a high uncertainty avoidance, and strong collectivism, may attempt to avoid confrontations with interviewers, by generally providing positive or agreeable responses. According to Minkov (2009) Arab respondents are more likely to exhibit strong and polarized quality judgments (i.e., very good versus very bad) in their assessments of current domestic social issues as measured by the 2007 Pew Research Centre survey in 47 nations. Such broad generalizations may or may not apply to the results of this study. The extent to which response bias contaminated the results of the stakeholder analysis is unknown; however, it is possible that it may have accounted for some misleading responses.

Another source of bias which may have influenced the content analysis was that the semi-structured interviews and focus groups were conducted in Arabic, but the stakeholders' responses were translated from Arabic into English before the content analysis was performed. Different patterns of thought and linguistic devices are known to give rise to communicative as well as textual problems in the translation of Arabic to English (Shiyab, 2006; Mughazy, 2007).An English translation can only approximate certain patterns of thought and linguistic devices that are indigenous to Arabic. There is a possibility, therefore, that the English translations may not have accounted for all the potentialities of meaning or conveyed the totality of the messages embedded in the Arabic responses of the stakeholders.

6.4 Interpretation of the results

Until this section, the discussion of the results has focused almost entirely on the perceptions of the stakeholders. Now that the voices of the stakeholders have been heard, it is pertinent to interpret their perceptions with respect to the issues and contentions discussed in the literature, and also to interject my own reflective and reflexive opinions, specifically with respect to: (a) groundwater depletion; (b) misuse of water; (c) groundwater quality; (d) the activities of the oil companies; (e) the conflicts of interest between the stakeholders; (f) the education of the water users and (g) water use legislation and policy formulation.

6.4.1 Groundwater depletion

The main water resource in Libya is groundwater, which constitutes about 95% of the total amount available in the country, and 99% of the water pumped from groundwater is used for irrigation. In some regions of Libya, including Alwahat, which represent the best agricultural land, the groundwater is a non-renewable resource. The water withdrawn may exceed natural aquifer replenishment by more than 500% Pallas and Omer (1999) causing a significant annual decline in groundwater levels. The problem has been made worse by the shortage of rainfall experienced in Libya during recent years. Population growth and rising income, coupled with rapid urbanization, assure the continued steep increase in the demand for groundwater for irrigation, industrial and municipal uses (Asswad, 1995). For these reasons it has been asserted by several researchers in the last twenty years that groundwater depletion, and the associated shortage and misuse of freshwater, pose a serious and growing threat to sustainable development and the protection of the environment in Libya, particularly in regions such as Alwahat, where the economy depends on irrigated agriculture (Asswad, 1995; Custodio, 1992; Dorman, 2009; Zidan, 2007).The results of the stakeholder analysis carried out in this study confirm the validity of these assertions. Apart from the domestic consumers, whose interests focused mainly on the availability of water for consumption in their properties, all of stakeholders who participated in this study were more of less aware of the decline in groundwater levels in the Alwahat region in the last ten years. All of the available evidence therefore points towards a decline in the level of groundwater which requires remediation if it is not to become more serious in the future.

What this means in real terms can be gleaned from our study. The water in the aquifers leaving Alwahat level has been steadily declining due to excessive use an amounting to 319.3 mm (0.31930m) on average every year. (Alkaseh, 1975, 1978, p.99). However according to unpublished hydrologist measurements and examinations in this current period (Dorman, 2010), the water level has been dropping 1.3 m per year.

During this study, the farmers were asked how much they believe that they are extending their wells every year and 40% of them replied that they are extending them a total of one meter every year. This shows that the draw down has increased rapidly between the years 1975–2010. There has been no serious investigation into this drastic situation thus far. The time for such research is no longer viable in light of this information. What is now required is no longer research but immediate action to slow this current rate of drawdown before it becomes irreversible.

6.4.2 Misuse of water

It has been reported that private irrigation has rapidly developed in the Alwahat area, based on shallow drilled wells each with a capacity ranging from 4 to 7 litres/second. The average yearly water abstraction is estimated to be 60−80 million m^3/year (Pallas & Omer, 1999). The question of whether this amount represents a legitimate use or a misuse of water is debatable. Since the quantities of water extracted from the wells are not accurately monitored and recorded in the public domain, it is impossible to provide exact quantitative information about the consumption of water used by each individual farmer. Most of the farmers perceived that the increasing number of farms and excessive pumping was potentially responsible for groundwater scarcity. The main circumstantial evidence obtained in this study to suggest that the famers are misusing water is based on the perceptions of the government heads of agriculture, who may, or may not, be biased. Because of the small sample size in this project, more objective quantitative evidence may be required before any conclusions can be reached regarding whether or not the farmers in the Alwahat area can be accused of misusing water for agricultural purposes, and whether or not remedial action is necessary.

Data collected using the water diary indicated that the average consumption of water by domestic consumers in the Alwahat region during the period of this study was about 286 litres/person/day. This is nearly twice as much as that in the United Kingdom, where the average domestic water use was reported to be 147.4 litres/person/day (Water UK, 2009) and over twice that in Switzerland, where the average reported domestic water use was 110 litres/person/day (World Bank, 1997). Rosen & Vincent (1999) observed that the domestic water consumption in rural areas of Zimbabwe and Malawi were much lower than that recorded in this study, ranging from 1.4 to 48.2 litres/person/day. The WHO estimates that 20 litres/person/day is the absolute minimum amount of water needed to satisfy metabolic, hygienic, and domestic requirements (World Health Organization, 1996).Gleick (1998) suggested that 25 litres/person/day is sufficient water for personal consumption and sanitation, but another 25 litres/person/day is needed for bathing and food preparation, producing a total daily minimum requirement of 50 litres/person. On the basis of the available evidence, and taking into account that the demand for water is relatively high in Libya, due to the warm climate prevailing for most of the year, it is apparent that the domestic waters users in the Alwahat region are consuming water in excess of their minimum daily requirements, and substantially more than that reported elsewhere in Europe and Africa.

6.4.3 Groundwater quality

It has been suggested that increased salinity associated with seawater intrusion is the main cause of deterioration in the groundwater water quality in Libya, especially in the coastal regions (Alsadik *et al.*, 2002; Salem, 2007). Abadalla *et al.* (2010) recently confirmed that seawater intrusion, estimated using Cl^-/Br^- ratios, has moved inland from the Tripoli region, because of heavy exploitation by extreme pumping of the aquifers to meet the increasing water demand. The estimated concentrations of seawater intrusion ranged from 10 to 15%. In contrast, it was suggested by some of the stakeholders in this study that fertilizers and effluents from the oil industry percolating through the sandy soil were mainly responsible for deterioration of the water quality in the Alwahat region. The main problem facing this study is that groundwater quality data in Libya is regarded as confidential (due to reluctance on the part of private companies and government officials to share data), and much of the evidence is incomplete, so that it is impossible to provide a detailed chemical description of the aquifers. Without further research, it is not possible to determine exactly what caused the reported changes in salinity and/or other water quality parameters in the Alwahat area in the last ten years. Because the deterioration of groundwater quality is often a slow and gradual process as it cannot usually be identified properly until long term chemical monitoring data are available (Gleick, 1993). It is evident that more detailed chemical evidence is required before the source of groundwater contamination can be identified and remedial measures to improve the water quality in the Alwahat area can be justified.

6.4.4 Activities of oil companies

During the last twenty years, it has been reported that oil companies have exerted a deleterious impact on the natural environment in Libya, including the release of hydrocarbons, solids contaminated with hydrocarbons, and water contaminated with a variety of dissolved and suspended solids (Ayesha, 1999; Ballal, 2006; Joint E & P Forum/UNEP, 1997; Stephenson, 1992). A recent article in *The Telegraph* (31 Jan, 2011) reported that the most significant environmental issue in Libya at present time is contamination of soil and water from oil pits, storage facilities, refineries and the petrochemical and chemical plants associated with production and refining operations. The dumping of solid and liquid waste is a common practice, particularly in the remote areas of Libya, where most oil wells and production facilities are located. Evidence from these external sources is consistent with the perceptions of most of the stakeholders who participated in this study, that the most important contributors to environmental degradation in the Alwahat area include the oil companies.

6.4.5 Conflicts of interest

This study exposed the existence of many conflicts of opinion between the stakeholders involved in sustainable water management in the Alwahat region. Such conflicts about the use of water are common throughout the arid regions of the world (Fisher, 2002) where water may even provide a reason for declarations of war. For example, in the Israeli-Syrian negotiations, a major issue as to the return of the Golan is reported to be control of the water resources. In the Israeli-Palestinian negotiations, water appears to be a potential obstacle to a lasting peace agreement (Fisher & Huber-Lee, 2010). Conflict about the use of water is clearly not worth war in Libya, and rational collective thinking about water management is essential to ensure a sustainable future. All stakeholders with vested interests in water sustainability in Libya must ideally be aware that the management of water resources should provide an opportunity for cooperation rather than a source of conflict.

6.4.6 Education

It has been suggested that the people of Libya are not aware of water resource issues, the government does not take excessive water usage into account, and it is the government's responsibility to educate its people about water sustainability (Pallas & Omer, 1999). These suggestions are not consistent with the information elicited from the stakeholders in this study, most of whom perceived that they valued water, that they were aware of water resource issues, and that they would like to become more involved. The question of whose responsibility it is to educate the Libyan people about water sustainability is problematic, since conflicts of opinion were observed among the stakeholders. The results of this study point towards barriers to implementing appropriate educational schemes, associated with a lack of funds and poor coordination between the government and the stakeholders.

6.4.7 Legislation

It has been suggested that although Libya is among the few countries with modern water legislation, its policy on water management is largely ineffective because it is hardly enforced (Pallas & Omer, 1999). The responses of the stakeholders in this study confirmed that significant weaknesses and problems still exist in implementing water management policies and legislation in Libya. According to *The Telegraph* (31 January 2011) Libya is slowly acknowledging the need to regulate the environmental impact of its oil production. This is mainly due to the recent influx of foreign companies, which have a corporate responsibility to operate in an environmentally-conscious manner. Given the confusing regulatory situation in Libya, most foreign companies adhere to the environmental standards established by their own companies, which reflect North American/European legislation. In practical terms, the government of Libya's concern about the environmental impact of the oil industry appears to be marginal, and significant shortcomings in the regulatory framework and the legal system remain. *The Telegraph* article reported that poor enforcement of legislation and a lack of facilities to implement environmental remediation were the key issues, consistent with the views expressed by the stakeholders in this study.

6.5 Recommendations for action

Any recommendations for action with respect to promoting a sustainable water future in Libya must first take into account certain cultural considerations and barriers, reflected by many of the responses of the stakeholders in this study. Most Arab organizations, whether in the public or private sector, are managed with a top-down management style, and with a centralised rather than a distributed form, no matter what their utilised technology. The major specifications of the Arab management style includes (a) hierarchical power; (b) compliance to regulations and laws implemented by individual personalities; (c) instability and hesitance in decision making, and (d) paternalism and nepotism (Taleghani *et al.*, 2010). Innovative and creative management styles, as used in Europe and the United States (e.g., the devolution of power, so that leadership is decentralized, shared, and distributed horizontally amongst a team of collaborating stakeholders) is not common amongst Arab organizations for solving problems and breaking norms. Arab managers, in contrast, tend to score high on self-protective traits, including self-centredness, status-consciousness, face-saving, and reliance on formal procedures. Organisational problems are usually settled in terms of tribal and cultural values rather than by means of transformational management (House *et al.*, 2004).

The point in mentioning this is that by implementing privatisation measures, this will create departments that will be mutually responsible to agreements and guidelines set into place based upon mutual cooperation and agreement among themselves. This further undermines centralisation in which one person will be responsible for power in all of a sector. Rather, the outcome of privatisation will lead to every one of a given department knowing of the matters that require judgement and then coming to a mutual agreement on such matters that require treatment.

Therefore before we can change how we use and manage water as a non-renewable resource, we have to change how we manage each other and establish privatised institutions based upon mutual benefit, cooperation and shared responsibility.

The first recommendation is that all the stakeholders with vested interest in water supplies in Libya should adopt the principles of the Dublin statement (ICWE, 1992) which recognized that (a) sustainable water management involves a holistic approach, linking social and economic issues with ecosystem protection and (b) that management policies should not be applied universally, but should take the local contexts into account, and be applied across a whole catchment area or groundwater aquifer. Given the management styles described above, these principles may be foreign to the authorities controlling water resources in Libya.

The second recommendation for action is political. The Government of Libya needs to drive a sustainable water strategy with a long term ambition, for example, to halve domestic consumption to around 130 litres/capita/day by the year 2030. This strategy assumes that to effectively govern common-pool resources such as water supplies, outside authorities must devise, monitor, and enforce rules to limit the resource's use; specify amount and timing of use; establish formal monitoring arrangements; as well as establish punitive arrangements for non-conformance (Ostrom *et al.* 1999). This strategy is also based on the assumption that municipal water companies alone cannot deliver long term sustainable water services. They need support from, and partnerships with, regulators, policy makers, customers, and communities, all of which have an important role to play in a sustainable water industry, similar to the strategy currently implemented in the United Kingdom (Water UK, 2010).

The third recommendation concerns legislation. More concerted efforts by legislators in Libya, particularly with respect to clarifying regulations and enforcing them, will be necessary if Libya is to adequately safeguard its environment.

The fourth recommendation for action is scientific. The long term quantitative and qualitative monitoring of local groundwater resources and the formulation and use of integrated models to support water management decisions is necessary. This is consistent with Salem (1991) who suggested that the supply-driven approach to water management in Libya has demonstrated an inability to deliver a substantial degree of water sustainability at the national level. Twenty years later, this inability still prevails. Sixteen years ago Salem (1996) recommended that the monitoring of groundwater in Libya should be carried using an integrated systems approach. Sixteen years later, the hydrologist in Alwahat reported that only a simple local model is available to monitor and predict deleterious changes in the groundwater level. Clearly, there is considerable scope for improvement in Libya with respect to the scientific management of water resources using models based on empirical data.

My final recommendation concerns expenditure. It has been suggested that the Libyan people regard water as a shared resource which is free, and they do not value water because they do not pay for it (Pallas & Omer, 1999). The cost of implementing a strategy to ensure a sustainable water future in Libya must, however, come from somewhere, and the obvious recommendation is that the consumers should start to pay more for their water. Domestic consumers are, however, likely to suffer if the financial burden is passed mainly on to them. Straub (2009) pointed out that about 70% of households in the developing countries would face severe difficulties if the full cost of water reforms was recovered directly from domestic consumers. A pricing structure that differentially prices water tariffs between domestic, agricultural, and industrial users is recommended, with the industrial users paying the most, and the domestic users paying the least.

6.6 Contribution to Knowledge

This research has gone through different stakeholders, from oil companies as water users, the domestic water users, agriculture water users, to attempt to identify the main issues, and define the eight crucial issues related to the Alwahat area. A combination of mixed qualitative and quantitative methods were used which provided further opportunities to collect more data and develop perspectives in different contexts. Similar previous research focused on either the demand side or the supply side of water, which lacked organized actions for water sustainability, and urgency was needed to more clearly understand and address this issue as the water resource is non-renewable in Alwahat.

For the economic, social and environmentally sustainable water future it became more crucial to find solutions and rework strategies for the Alwahat area. The oil companies are the biggest consumers of water, and the most damaging industry to the natural environment currently in Libya. They are using more than their share of the aquifer, which in effect gives other users a shortage of water supply, and further these companies are dumping undrinkable water back into the environment, with little or no consideration to work with the water industry to treat the output water (please refer to pp. 316–317 in the study).

This research proposes actions with respect to promoting a sustainable water future in Libya. Firstly research of this kind needs to take into account certain cultural considerations and barriers. From analysing the responses from stakeholder as part of this study in the Alwahat area, the approaches to develop sustainable water management should be as following:

All stakeholders have interests in water supplies in Libya and they should adopt principles similar to the Dublin statement. This approach involves a holistic approach, linking the social and economic issues with ecosystem protection.

The Libyan Government should take appropriate political actions needed to drive a sustainable water strategy with long term ambition with regulators, policy makers, customers and communities, all of which have an important role to play in a sustainable water industry. With regards to the concerns of legislation in Libya, they need to be clarified, implemented and enforced assertively. There should be scientific actions and approaches to assess the long term quantitative and qualitative monitoring of local groundwater resources and the further formulation and use of integrated models to support water management decisions. Finally, there needs to be sufficient planning to introduce pricing as part of the strategy to ensure a sustainable water future in Libya.

6.7 Consideration of Libya's Current Political Climate

Since the change in government post Colonel Muammar Gaddafi's regime, the research has seen difficulty in obtaining specific data from oil companies. During Gaddafi's regime oil companies were reluctant to divulge in deeper details as oil companies were closely related and under the direct instruction of Colonel Muammar Gaddafi. Other stakeholders and other agriculture related departments provide information, however, that data was out of date. For example, studying the water sector data in the literature review, it was evident that some current documents were direct repeats and translations from Italian texts almost from forty years ago (as was directly witnessed by the writer during the research project). The officials in the water sector in Tripoli had clearly altered just the dates on those documents. In addition all council and government related documents for the Alwahat region were centralised and only accessible in the Libyan capital Tripoli, hundreds of miles away.

The Libyan government prioritized the water supply and management, without any awareness or regard for controlling and understanding the demand of water and its repercussions. There are expectations from the new transitional Libyan government to devise new policies and make them more transparent for effective implementation by the Libyan people. The government hence needs to revise the ineffective existing strategies in the current uncertain governing administration. With new policies and strategies in place on instruction of the government, there is optimism that oil companies in effect will begin to change their attitudes towards water sustainability and educating their staff and users with more open and up to date policies that come with strict and thorough implementation. This chain of maintaining water without consequence to the natural resources and balance, will then have direct impact on the water users of giving education, awareness and motivation to act on the policies for water sustainability and everyday use by the Libyan people. As said previously, the current state of Libya's water situation no longer allows us to wait. We must take direct and responsible action for the future of water sustainability and management for the Libyan population.

6.8 Potential for further research

I recommend that efforts should be made to launch a research project to formulate a mathematical model, for example MODFLOW or GPS which simulates the present physical and chemical state of the aquifer in Alwahat, and to predict its future behaviour in accordance with the planned development schemes for providing a sustainable water supply. This would involve monitoring extraction and the resulting drawdown. The outcomes of this research should support an evidence based management policy to regulate the use of the water supply and to secure its protection from over-exploitation and pollution by setting rules for waste disposal control and prevention of industrial contamination.

Also, further to this, I would recommend that the following methods should be put into place: (a) there needs to be a complete privatisation of the water industry into a sector managed by an overall body of mutually concerned committees; (b) the private sectors committees should be concerned with searching for and maintaining accurate stores of water for use by the Libyan people; (c) these committees and groups must be accountable among each other and subject to regulations and guidelines that have been agreed upon among all the parties involved; (d) the committees will have to invest in the infrastructure of Libya's water industry and subject to a complete overhaul in areas such as laying new pipes and creating a new and efficient pipe network and (e) there has to be a shared set of values and clear lines of cooperation and communication between the government and the private sector of water and its' committees.

6.9 Conclusion

After examination and consideration of all previous material, a number of matters need to be considered in the conclusion. The following solutions will be effective in the long term for sustainability of the non-renewable resource of water in the Alwahat region:

Bringing about a strategy of water management – not just in Alwahat but throughout the country – that holds people responsible for water usage and also controls waste and the disposal of water that is not fit for human consumption. The recycling, reuse and purification of such water is crucial for use in the future.

There are presently no regulations in place for the management of ground water and the waste from oil companies in the region. This will need to be solved if there is to be any positive movement towards a water management strategy.

Pollution from used water that comes from oil companies is something that can be seen with the naked eye and clearly in front of all residents. This needs to be met with regulations that hold these companies responsible, in fact the same regulations that they would be responsible for in their home countries in Europe and elsewhere.

There is a clear need for legislation that will govern the management of new wells and water systems in Libya for the future. This legislation will need to cater to the needs of the residents and also hold companies criminally responsible for dumping waste or poisoned water in areas where the residents might drink from that water or the domestic water supply might be poisoned.

In addition to this, leaks in the water system will need to be mended and sealed or have a new water system fitted when necessary to ensure that this non-renewable resource will not be wasted. In residential areas where water is supplied through the pipe network system, there needs to be a connection between the residential areas and their companies and transparency in their dealings in order for the users of the supply to be aware of who is in charge and responsible. In cases of complaints or questions about new legislation, the residents need to know whom to contact and to whom they are to express their concerns.

Money will also need to be managed in regards to the water industry in a three-part cooperation between the government, the oil companies and water companies and environmental agencies so that the matter is resolved by mutual consultation and not merely spending money without knowing how it will be used. All of these groups working together will accurately assess the money needed for future projects, how it can be efficiently used, proper legislation needed in order to implement the goals and what outcomes such activity may have on the environment.

There will need to be a change in attitude by the residents and oil companies towards pollution. There will need to be regulations put into place in which both the residents and oil company representatives will learn about water, its' use, conservation and safeguarding and the dangers that water pollution poses to everyone on a domestic and business level. This needs to be a plan that is implemented nationally to increase the awareness of people about this situation, especially in the case of the women in Alwahat who in the future will have to play a key role in implementing these plans.

Excessive use of non-renewable sources of groundwater from the aquifer in the Alwahat area has been reported, leading to a perceived lowering of the water table. Salinity and contamination of the water supply by oil companies is also perceived to be a potential problem. Despite conflicting reports to the contrary, and the possibility of response bias, most of the stakeholders appear to be aware of this critical situation and the need for a policy to prevent excessive consumption and control pollution would be welcomed. Conflicts of opinion were expressed however, as to how to provide a long term solution, particularly with respect to legislation and education. Recommendations for action are presented, including political, legislative, and scientific measures which may help to promote a sustainable water future.

Chapter 7: References

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Chapter 8: Appendices

8.1 Appendix 2: Questionnaire for Agricultural Water Users

Nottingham Trent University

School of Architecture, Design and the Built Environment

Development of a sustainable water management strategy in Alwahat Libya

Questionnaire Survey for irrigation Water Users (Farmer)

Name of Community area Jalo ☐ Awjala ☐ Jakera ☐

Date ☐

How many people do you employ on your farm? ☐

Q1. Do you consider you use water efficiently Yes ☐ NO ☐
If the answer is no identify the reasons why:

Cheap	
Easy to drill water well	
Food Market Competition	
Other	

Q2.Are you aware of the water issues in Alwahat? Yes ☐ No ☐
If yes rate each of the following:

Opinion	Not at all	Slightly	Somewhat	Moderately	Extremely

	aware	aware	aware	aware	aware
Issues					
Increasing number of farms					
Groundwater scarcity due to excessive pumping					
The amount of fertilization used on crops					
Increasing the number of water wells					

Q3.How did you become aware of these issues?

Radio	
TV	
Newspaper	
Other	

Q4. How many water wells are located on your farm?

1 well		2 wells		3 wells		More	

Q5.Are you satisfied with your current water supply situation on your farm?

Strongly Unsatisfied.	unsatisfied	Neutral	satisfied	Strongly satisfied

Q6.Do you agree the amount of water taken from your wells for irrigation should be limited to ensure the Sustainability of the supply? Yes ☐ No ☐

Q7. What is the depth of water in your well? ☐

Q8. How much do you extend the depth of your water well each year?

1m		2m		3m		More	

Q9. How would you describe the water quality abstracted this year compared to last 10 years ago?

Extremely Poor	Below Average	Average	Above the Average	Excellent

Q10. Should farmers only be allowed to extract water if they can prove they are going to use it efficiently ? Yes ☐ No ☐

Q11.Do you think there is a need for legislative reform to ensure the sustainability of water supplies in the Alwahat? Yes ☐ No ☐

Q12. Are you aware of the current irrigation policy**?** Yes ☐ No ☐

Q13. Do you consider this policy is adequately enforced

Yes ☐ No ☐

Q14.Do you accept the use of water on farms should be regulated?

Yes ☐ No ☐

Q15. Do you consider you have had enough training in water use/management ?

Yes ☐ No ☐

Q16. Do you think framers should be involved in water management issues?

Yes.☐.No.☐

Q17.Should water polluters pay the remedial costs**?**

Yes ☐ No ☐

Q18. Do you think the natural environment in Alwahat has been a adversely affected by water abstraction**?** Yes☐ No ☐

If yes how do you rate the amount of environmental damage caused by the following users:

Opinion group	Not at all deteriorated	Slightly deteriorated	Somewhat Deteriorated	Moderately Deteriorated	Extremely Deteriorated
Municipal					
Private householder					
Farms					

Oil companies					

Q19.Would you consider changing the type of crop you grow to save water?

Yes ☐ No ☐

Q20.What you type of irrigation technique do you use?

Traditional flooding system	
Modern System	
Both	

Q21.Would you accept the metering of water from your wells?

Yes. ☐ No. ☐

If no identify why (select one only?

Cost	
Large Farm	
Many Wells	
Quantity water abstracted	

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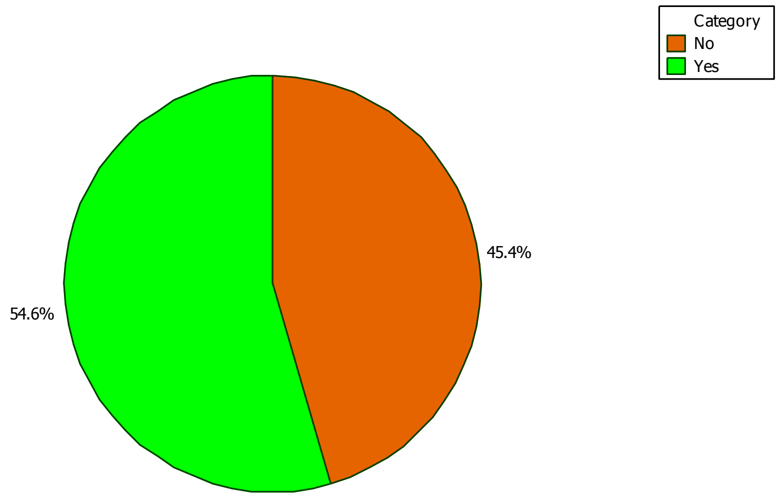
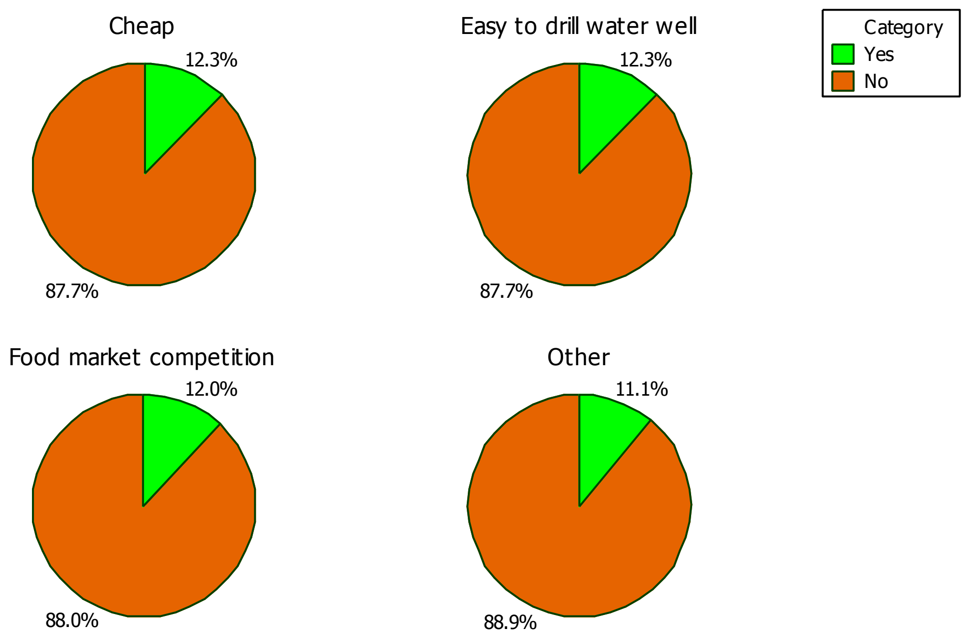
8.2 Appendix 3: Results of Questionnaire for Agricultural Water Users

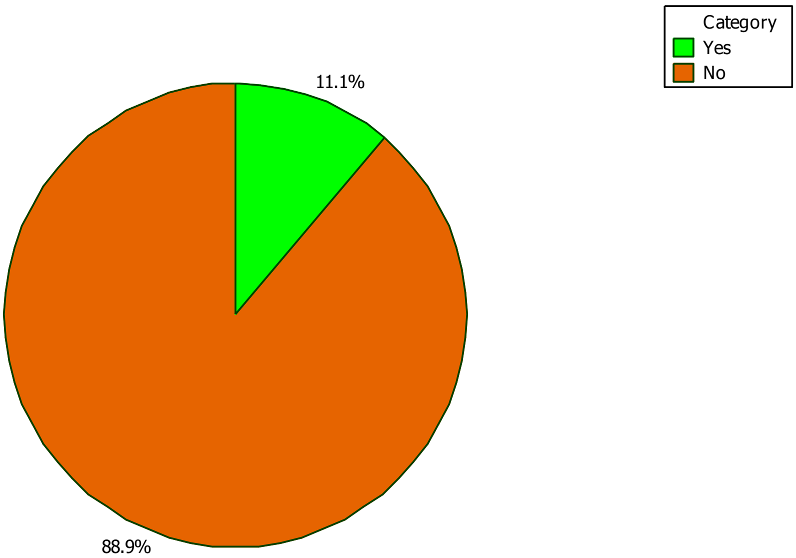
Q1. Do you consider you use water efficiently?

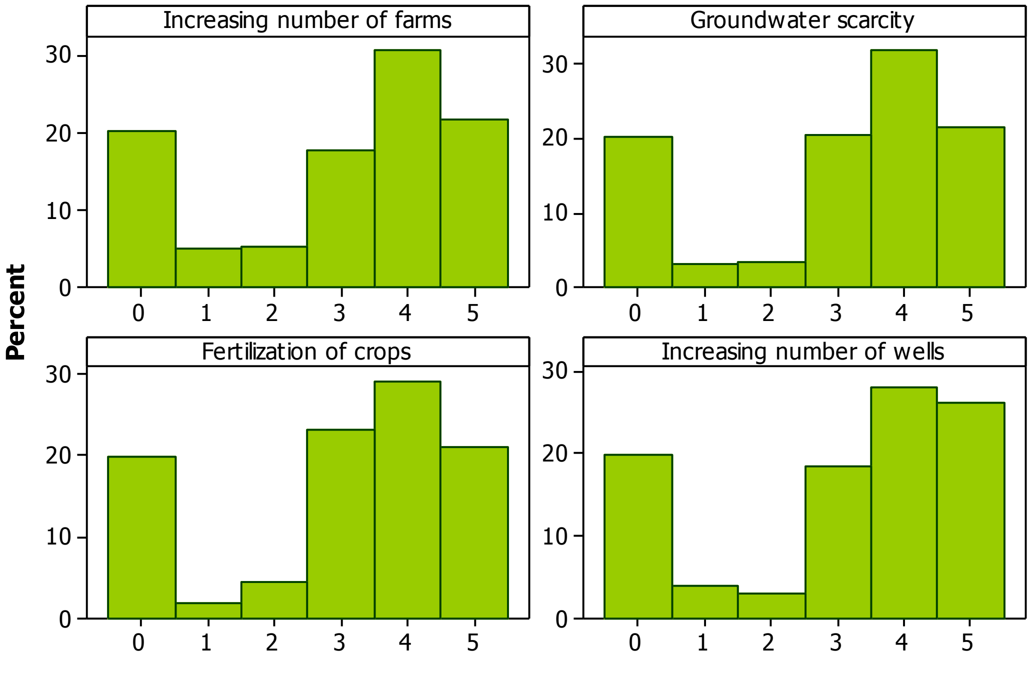


If the answer is no identify the reasons why:



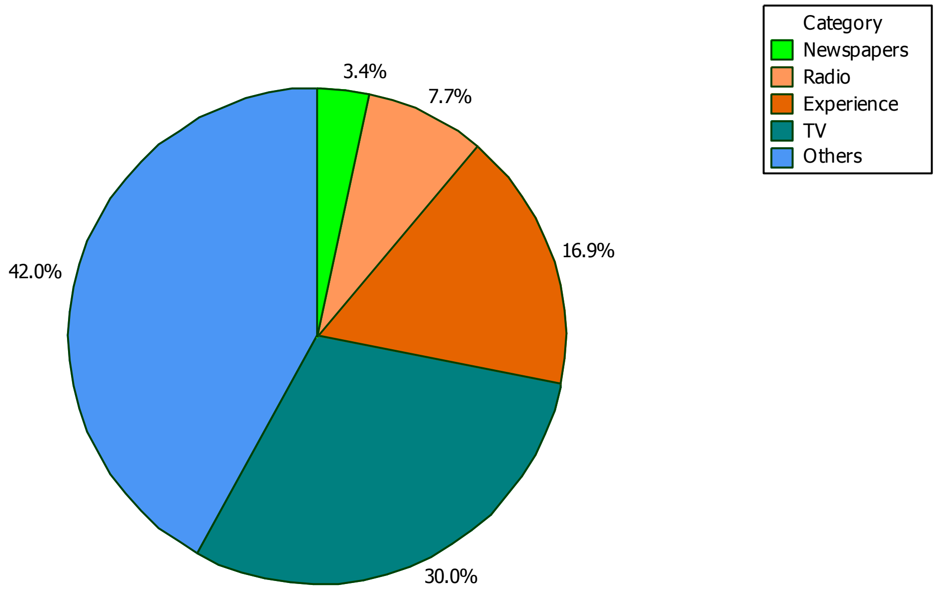
Q2.Are you aware of the water issues in Alwahat?



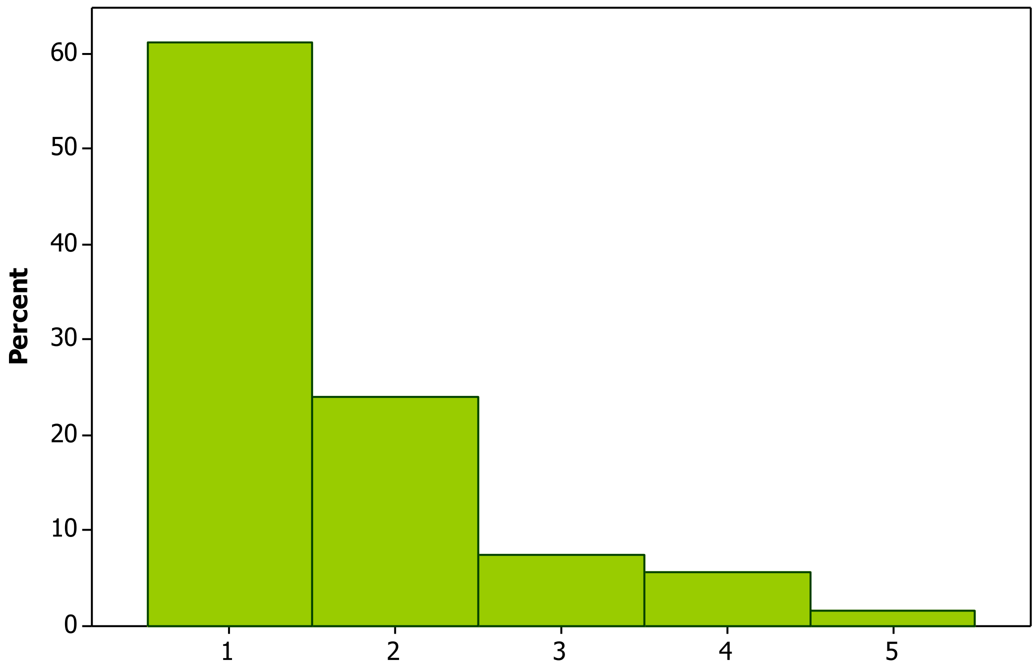


No reply	Not at all aware	Slightly aware	Somewhat aware	Moderately aware	Extremely aware
0	1	2	3	4	5

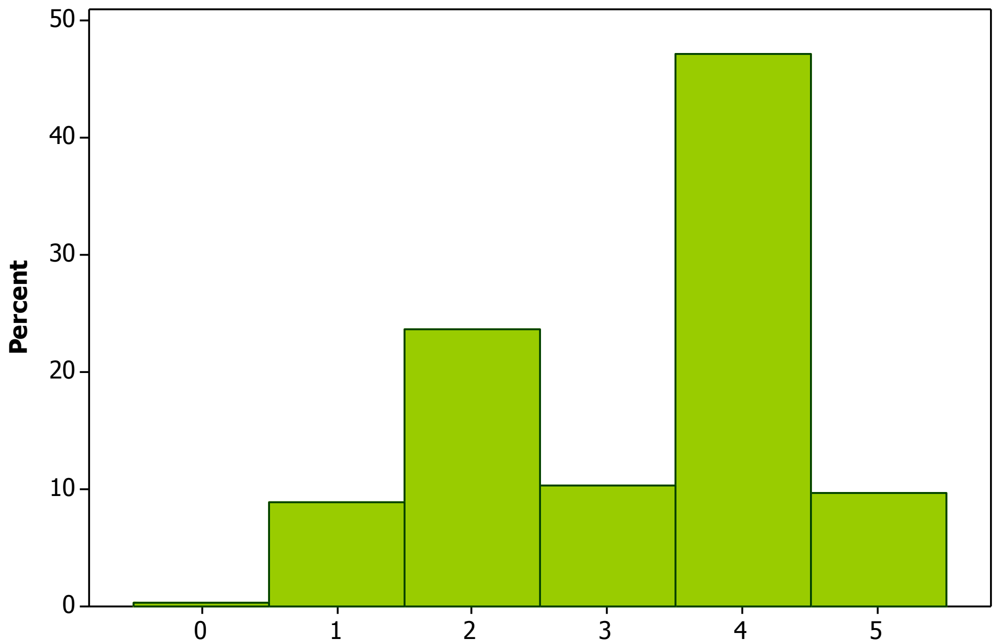
Q3. How did you become aware of these issues?



Q4. How many water wells are located on your farm?

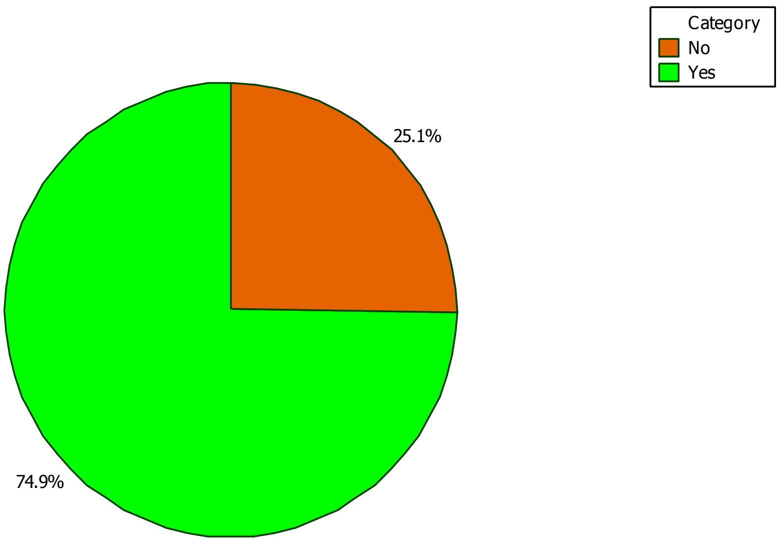


Q5.Are you satisfied with your current water supply situation on your farm?

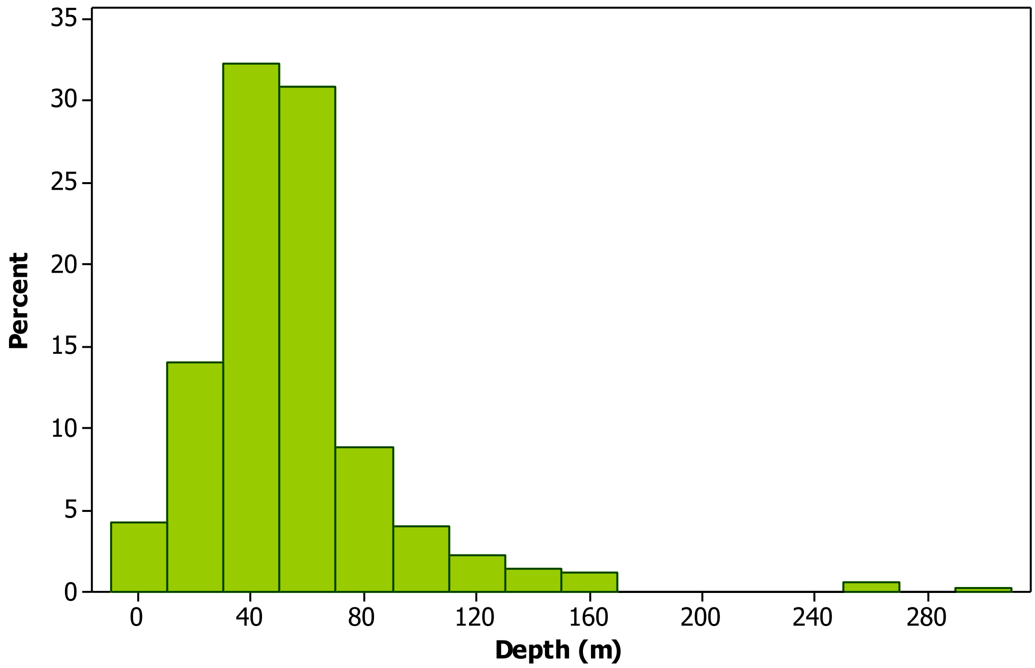


No reply	Strongly Unsatisfied.	unsatisfied	Neutral	satisfied	Strongly satisfied
0	1	2	3	4	5

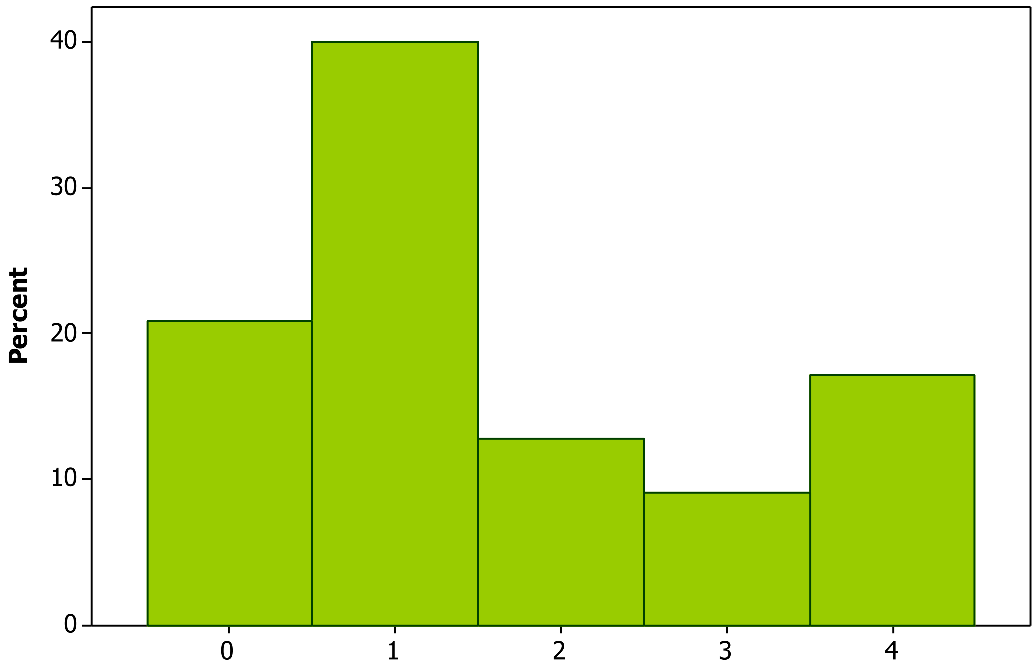
Q6.Do you agree the amount of water taken from your wells for irrigation should be limited to ensure the Sustainability of the supply?



Q7. What is the depth of water in your well?

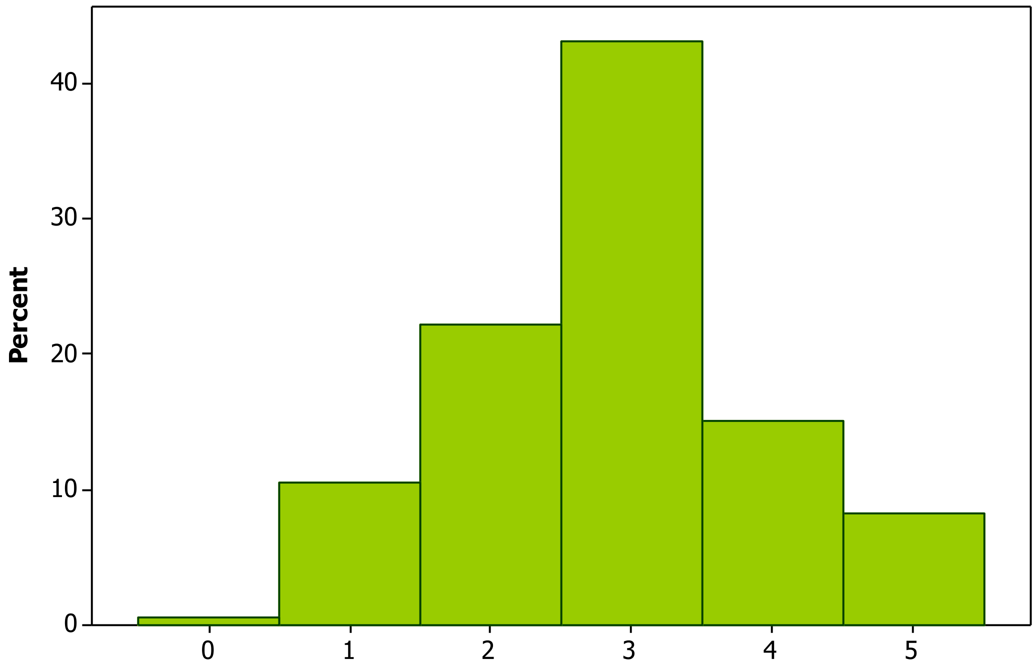


Q8. How much do you extend the depth of your water well each year?



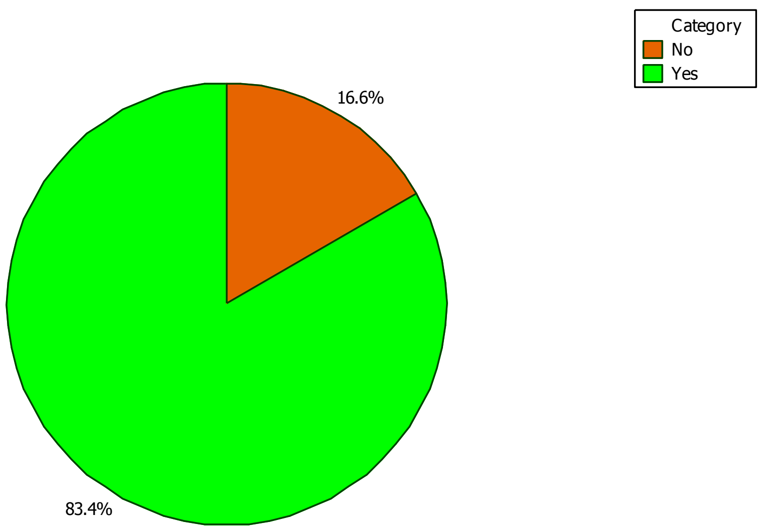
0	1	2	3	4
No reply	1m	2m	3m	> 3m

Q9. How would you describe the water quality abstracted this year compared to last 10 years ago?

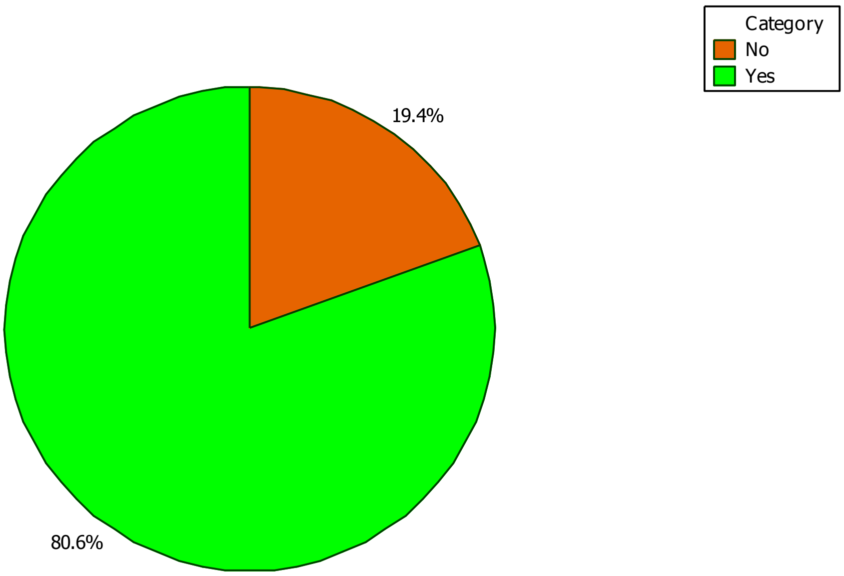


0	1	2	3	4	5
No reply	Extremely Poor	Below Average	Average	Above Average	Excellent

Q10. Should farmers only be allowed to extract water if they can prove they are going to use it efficiently ?......

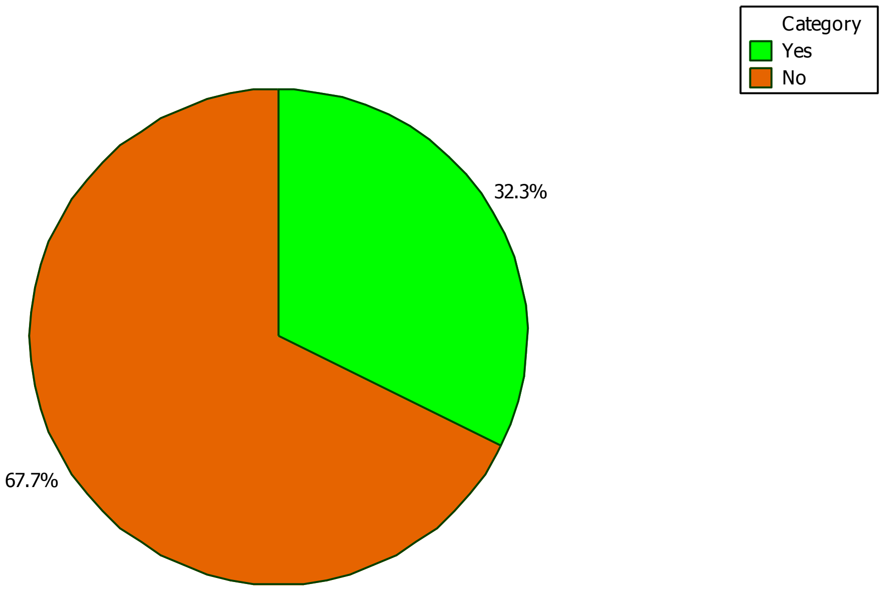


Q11.Do you think there is a need for legislative reform to ensure the sustainability of water supplies in the Alwahat?...

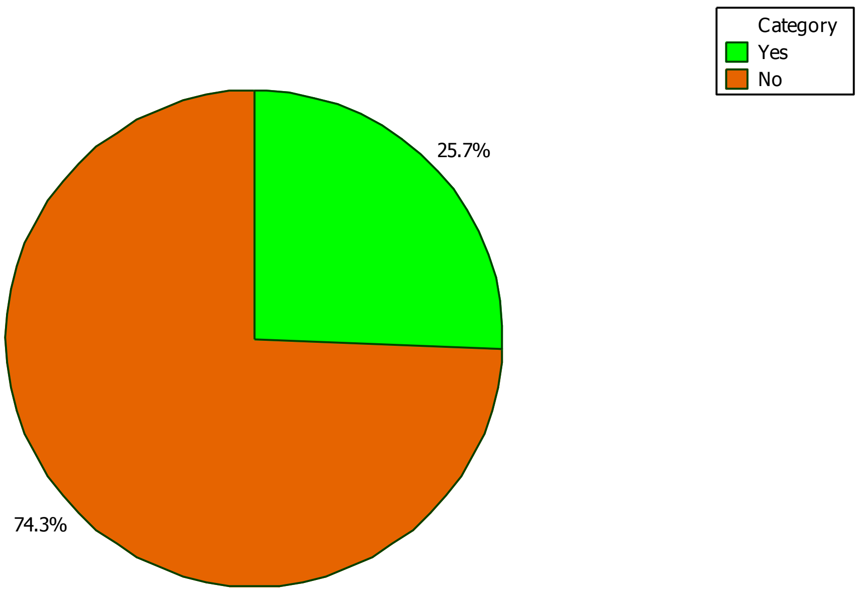


....

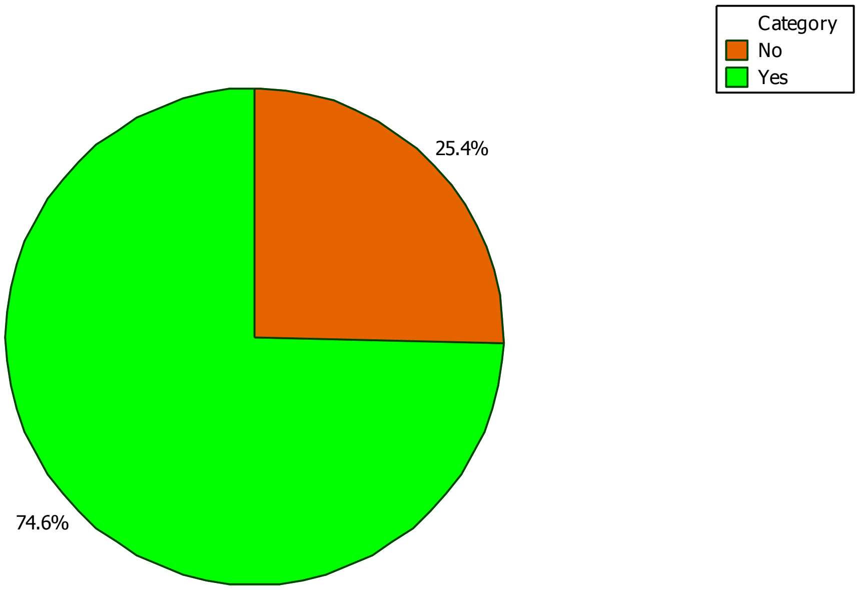
Q12. Are you aware of the current irrigation policy?



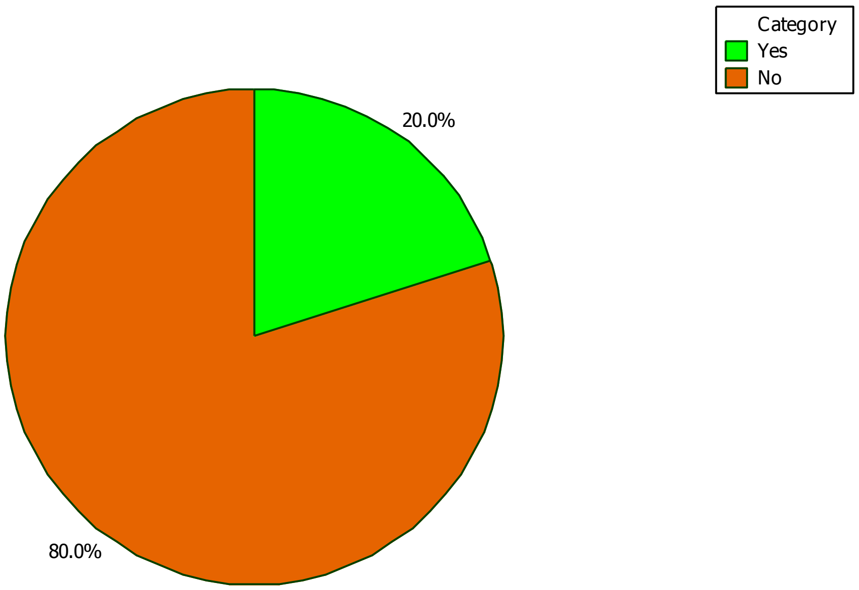
Q13. Do you consider this policy is adequately enforced



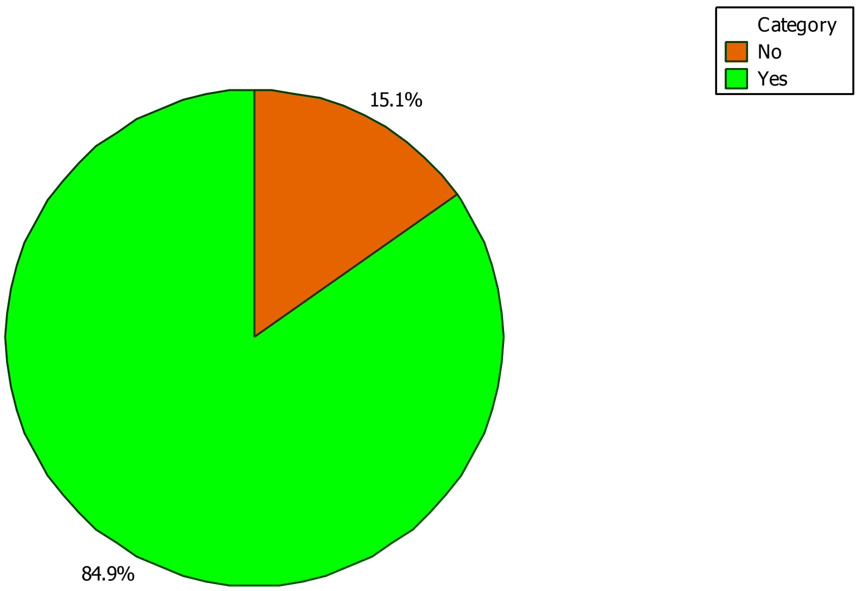
Q14.Do you accept the use of water on farms should be regulated?



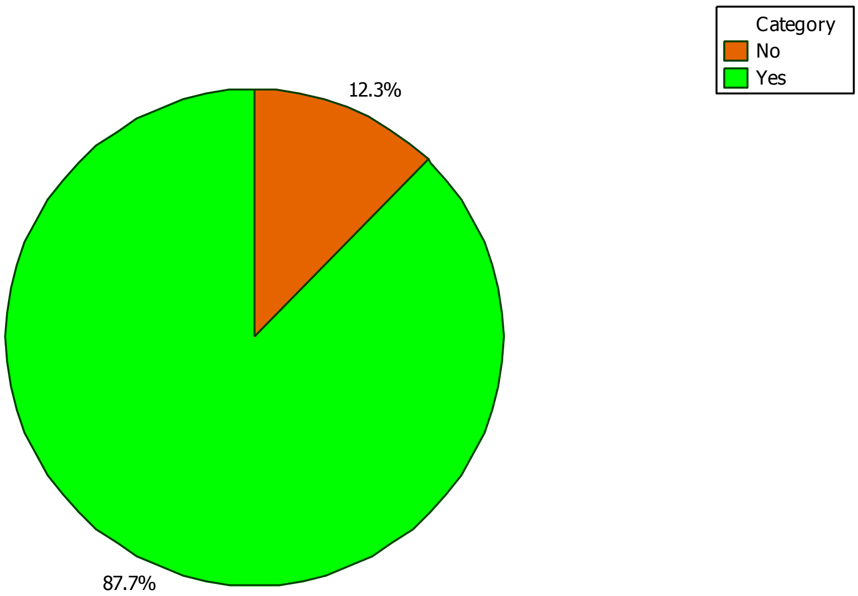
Q15. Do you consider you have had enough training in water use/management ?



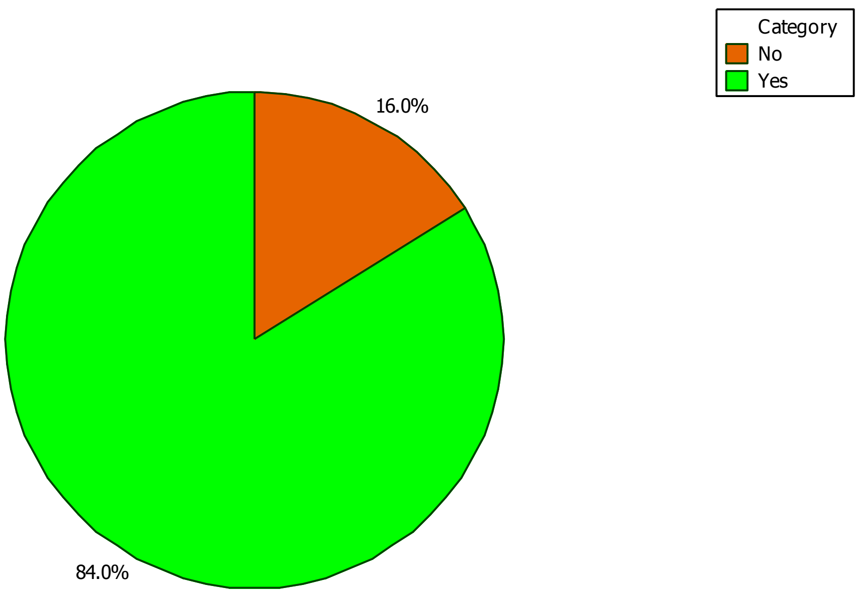
Q16. Do you think framers should be involved in water management issues?



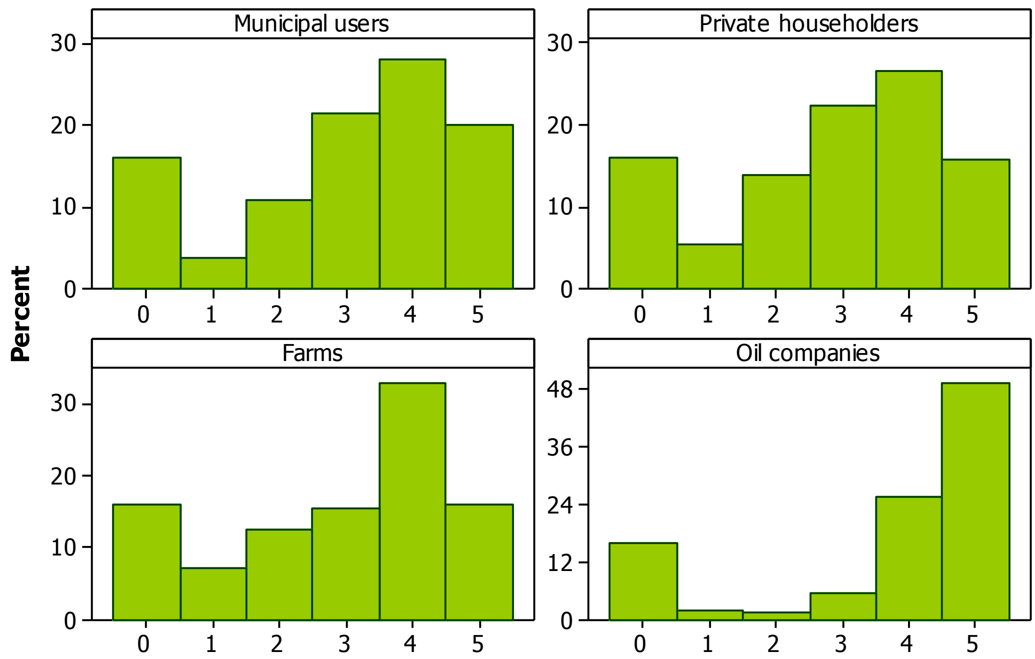
Q17.Should water polluters pay the remedial costs?



Q18. Do you think the natural environment in Alwahat has been a adversely affected by water abstraction?

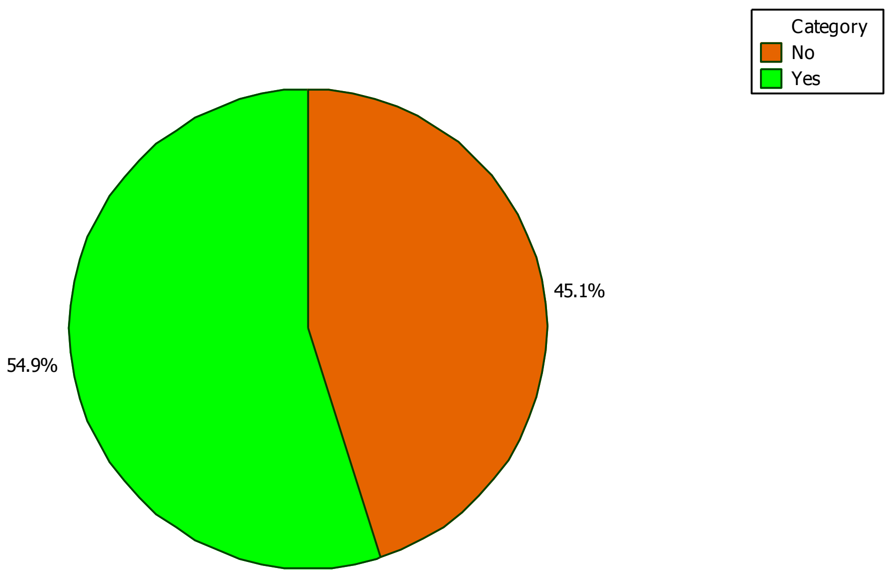


If yes, how do you rate the amount of environmental damage caused by the following users:

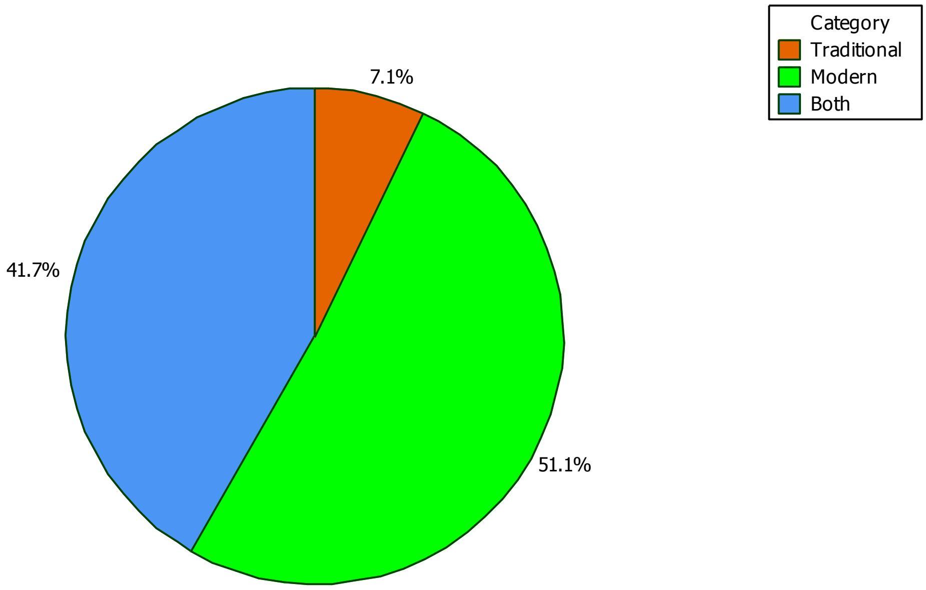


No reply	Not at all deteriorated	Slightly deteriorated	Somewhat Deteriorated	Moderately Deteriorated	Extremely Deteriorated
0	1	2	3	4	5

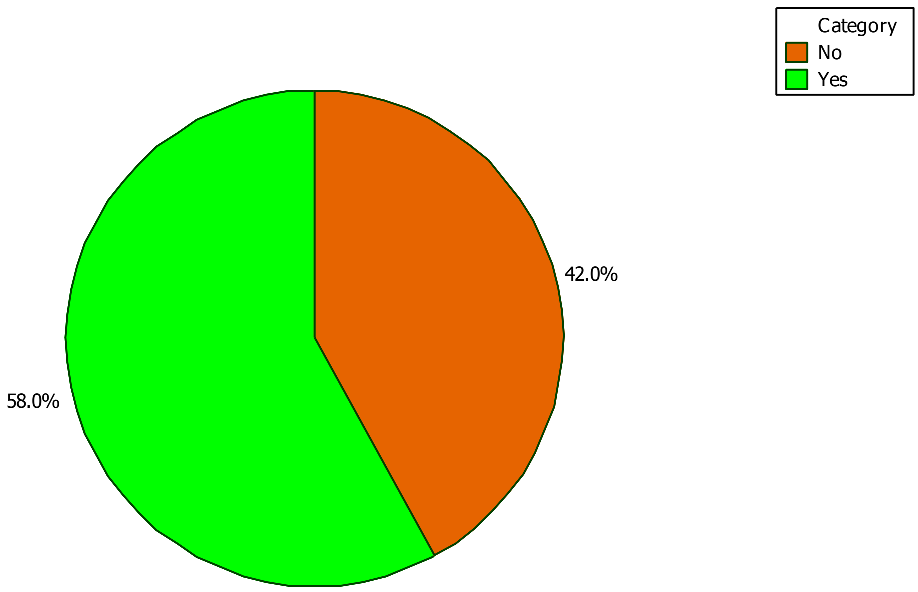
Q19. Would you consider changing the type of crop you grow to save water?



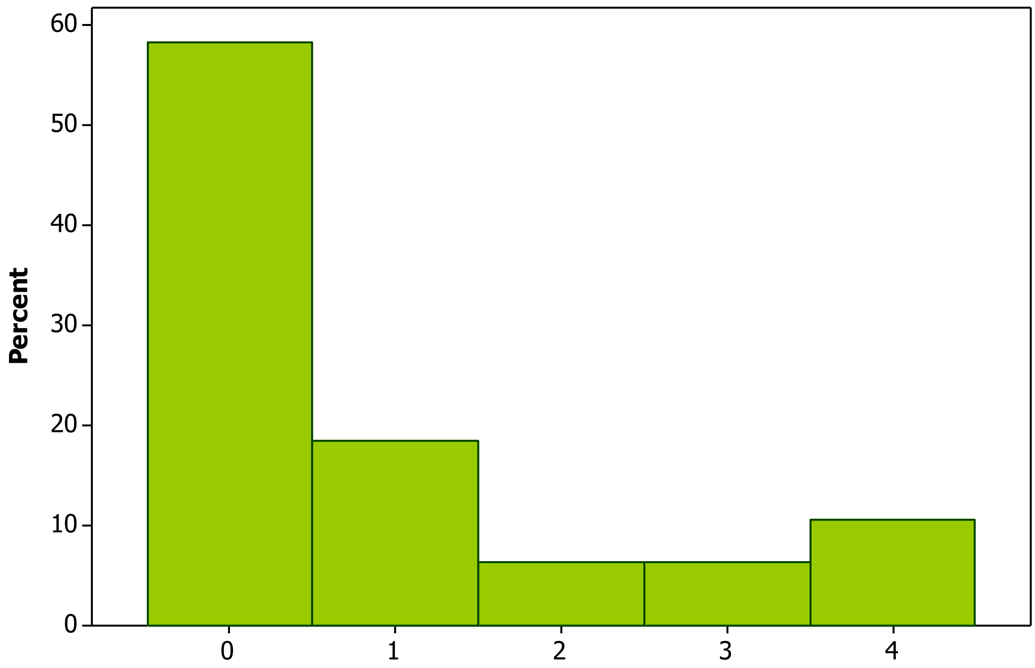
Q20. What you type of irrigation technique do you use?



Q21.Would you accept the metering of water from your wells?



If no identify why (select one only)?



No reply	0
Cost	1
Large Farm	2
Many Wells	3
Quantity of water abstracted	4

8.3 Appendix 4: Questionnaire for Domestic Water Users

Name of Community area Jalo ☐ Awjala ☐ Jakea ☐

A) Your education level

Primary level		Secondary Level		University Level	

B) Number in your family

2	4	6	7	more

Q1 .What do you understand by term **Sustainability**?

*Q2.*Are you aware of any problems associated with water sustainability in the Alwahatarea? *Yes.* ☐ *No* ☐

If yes

Rate your level of awareness

Not at all aware	Slightly aware	Somewhat aware	Moderately aware	Extremely aware

b) Identify the problems of which you are aware*?*

Q3 .Are you aware of any guidance or publicity relating to water users in relation to Sustainability? Yes. ☐ No ☐

Q4.Do you consider there should be controls which limit the misuse of water by users? Yes. ☐ No ☐

Q5. Do you agree the water supplier should enforce the installation of water meters in properties in Alwahat area to conserve water? Yes. ☐ No ☐

If yes which following considerations should be taken into account when identifying properties in which to install water meters

a. Family Size ☐

b. Family Income ☐

c. Size of the house ☐

d. garden Size ☐

Q6. Are you aware of water misuse by other property owners?

Yes ☐ No ☐

Q7. Do you approve of water misuse by other property owners?

If yes,

a) Identify the perceived of the misuse of water

Can you suggest any solutions to help prevent the misuse of water?

Q8. Are you satisfied with the water services provided by the suppliers?

Yes ☐ No ☐

If , no, identify deficiencies in the water services provided by the water suppliers?

Q9. Do you consider water suppliers should train, demonstrate, and educate water users in using water in a sustainable manner?

Yes ☐ .No. ☐

Q10. In relation to the water supply rate to your property. Assess your level of satisfaction.

Level of Satisfaction	Very dissatisfied	Dissatisfied	Unsure	Satisfied	Very Satisfied
Issues					
Length of time water supplies are available every week					
Water quality					
Yourinvolvement in local water management decisions					
Water price					

Sanitation issues

Q11. How acceptable is the reuse of water?

Totally Unacceptable	Unacceptable	Neutral	Acceptable	Perfectly Acceptable

Q12.Are you aware of water contamination problems from sewage (used water) within your property?

Yes☐.No☐

If yes how you do deal with this problem if it happens?

Do Nothing ☐

Call water supplier ☐

Abandon well and build new one ☐

Clean and use again ☐

Q13. Do you accept the use of old private water wells for sewage disposal?

Totally Unacceptable	Unacceptable	Neutral	Acceptable	Perfectly Acceptable

Q14.What do you consider the reasons for not using sewage for agricultural crop irrigation in Alwahat?

Which of the following reasons do you agree with?

Ignorance of concept to use sewage as a fertiliser ☐

Very expensive ☐

Not a priority ☐

Treatment not important ☐

Other (specify)

Q15. Do you think there is a need for legislative reform to ensure water supplies are sustainable in Alwahat?Yes ☐ No ☐

Q16. Do you think the existing water regulations are adequate Yes ☐ No ☐

Q17.Do you think the natural environment in the Alwahat area has deteriorated during the last 10 years? Yes ☐ No ☐

If the answer is yes rate the level of deterioration:

Opinion	No deterioration	Slight deterioration	Somewhat Deteriorated	Moderately Deteriorated	Extremely Deteriorated
group					
municipal					
Privet householder					
Farms					
Oil companies					

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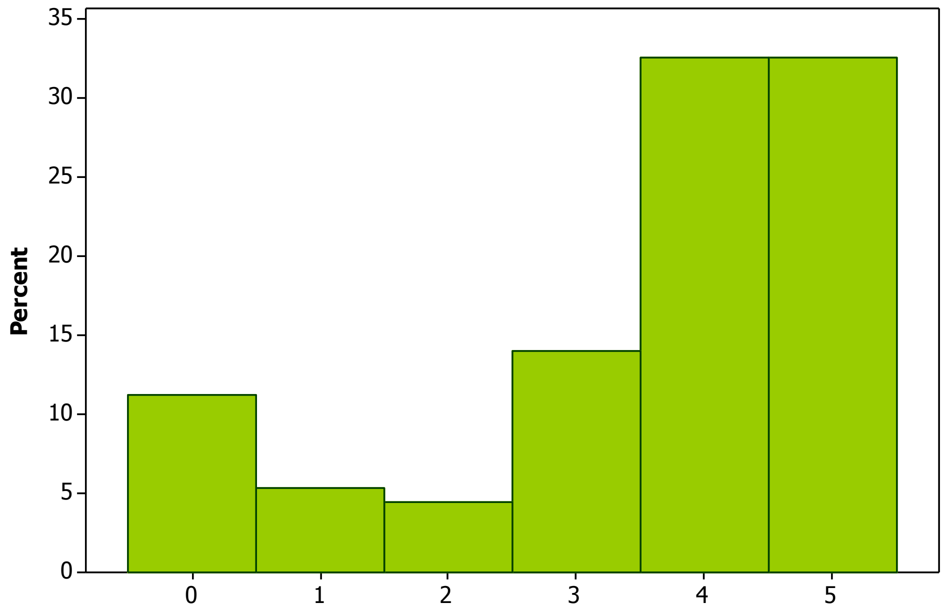
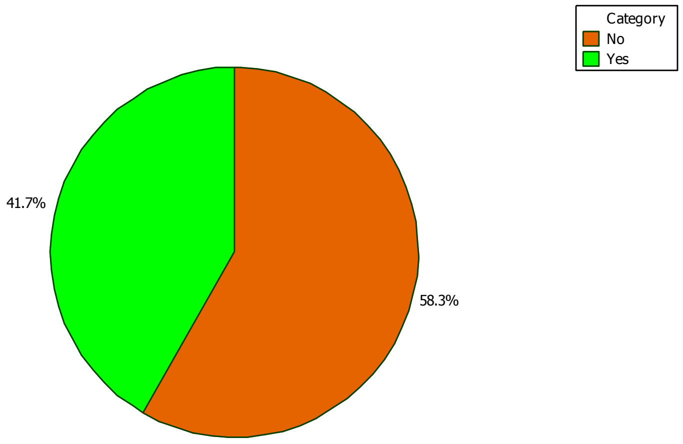
8.4 Appendix 5: Results of Questionnaire for Domestic Water Users

Q1. Rate your level of awareness of problems associated with water sustainability in the Alwahat area

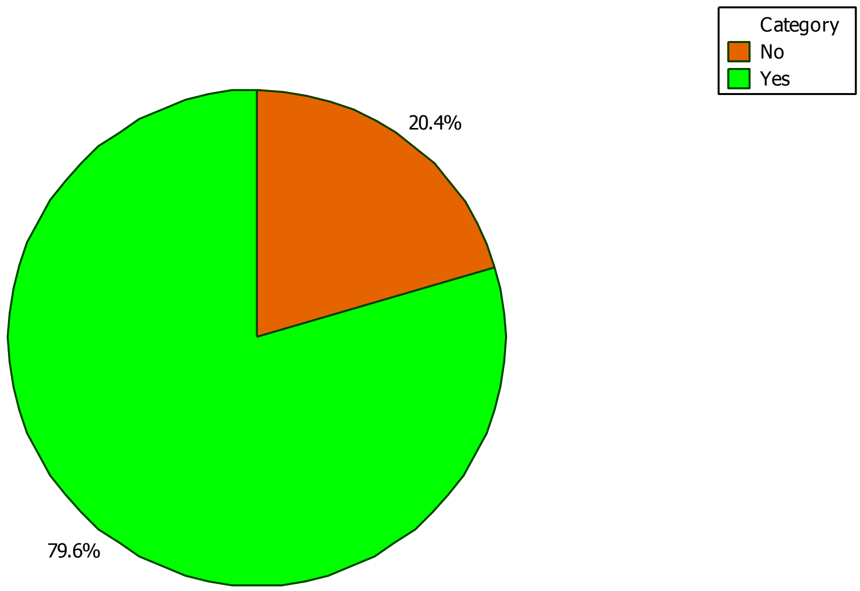


No reply	Not at all aware	Slightly aware	Somewhat aware	Moderately aware	Extremely aware
0	1	2	3	4	5

Q2 .Are you aware of any guidance or publicity relating to water users in relation to Sustainability?



Q3.Do you consider there should be controls which limit the misuse of water by users?



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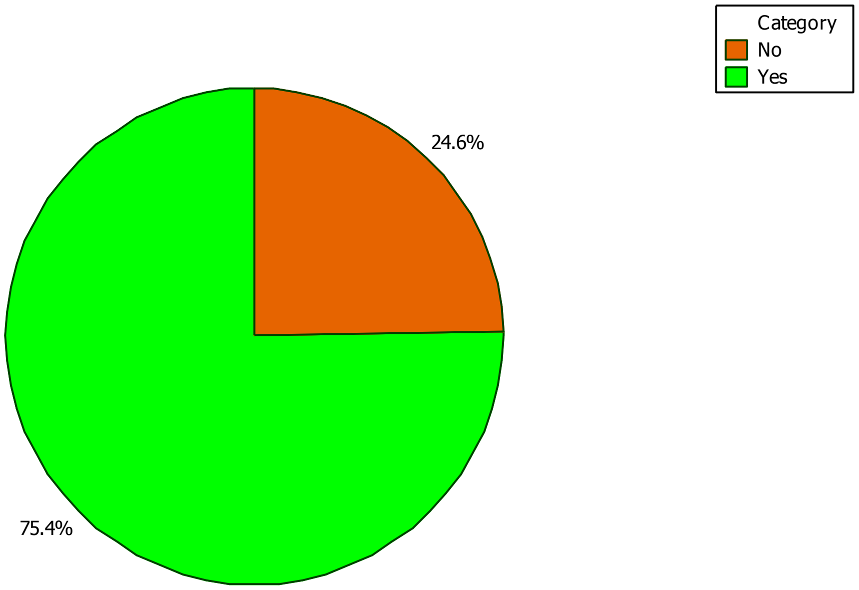
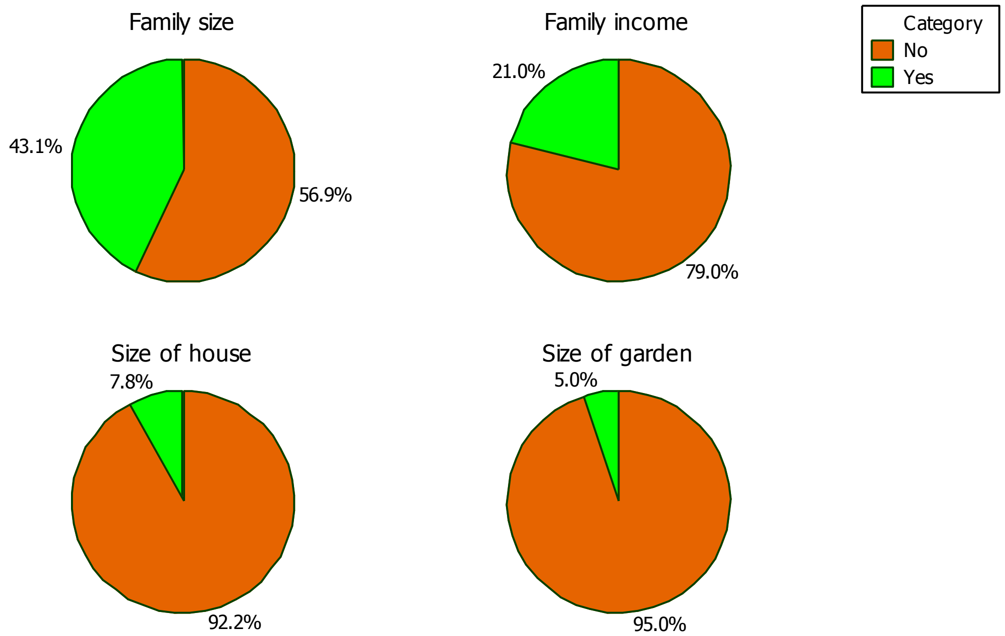
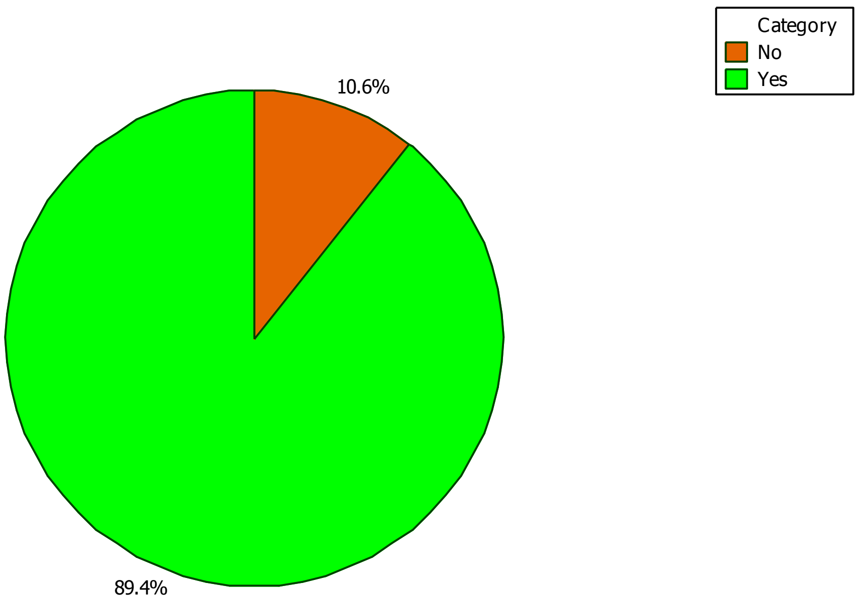
Q4. Do you agree the water supplier should enforce the installation of water meters in properties in Alwahat area to conserve water?



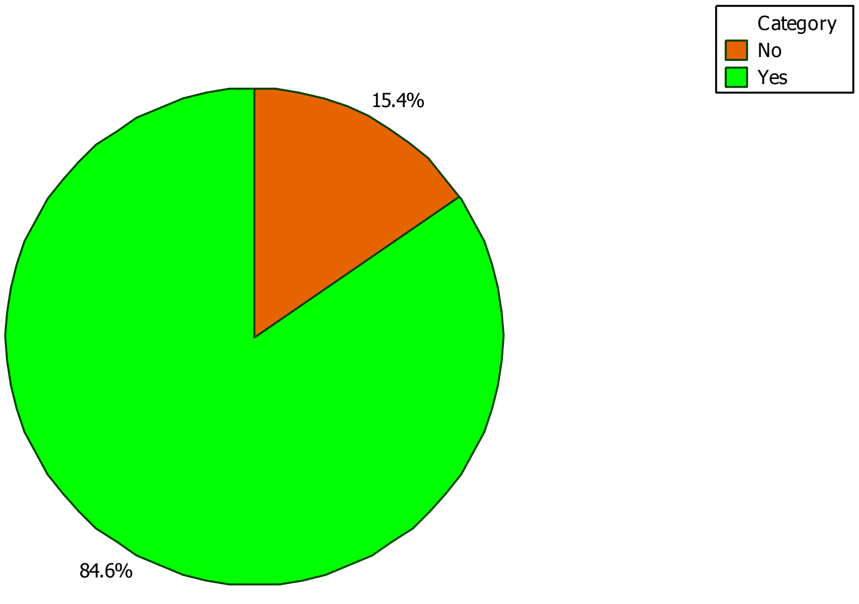
If yes, which of the following considerations should be taken into account when identifying properties in which to install water meters



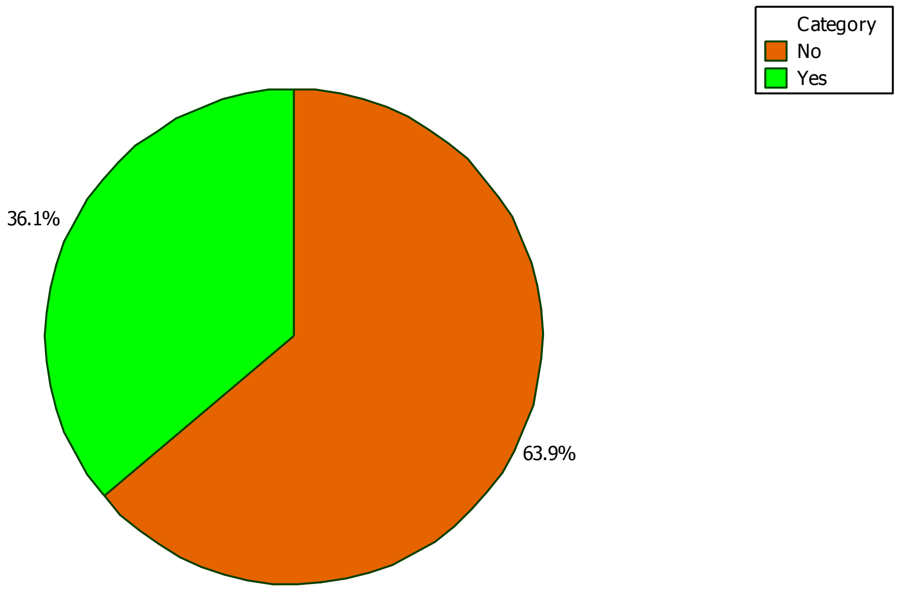
Q5. Are you aware of water misuse by other property owners?



Q6. Do you approve of water misuse by other property owners?

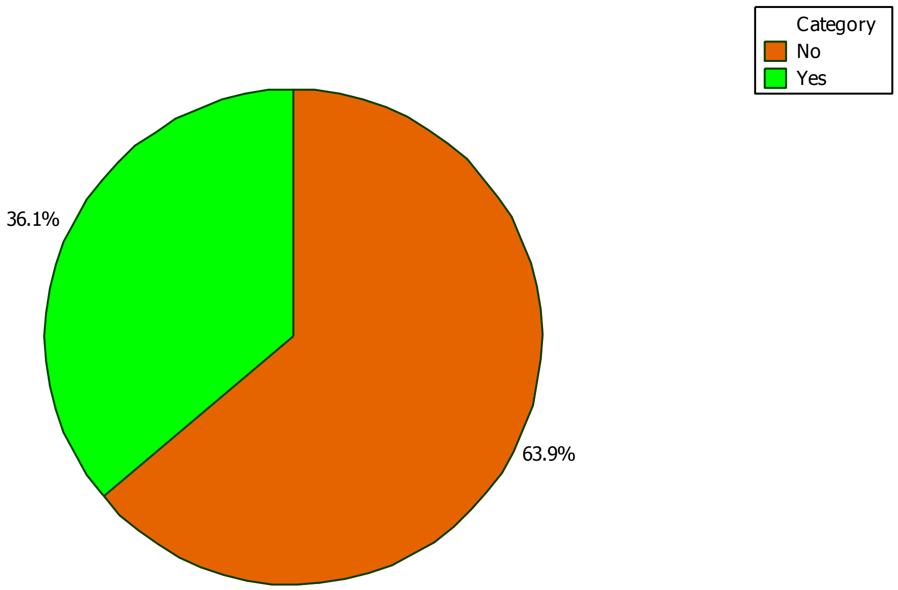


Q7. Are you satisfied with the water services provided by the suppliers?

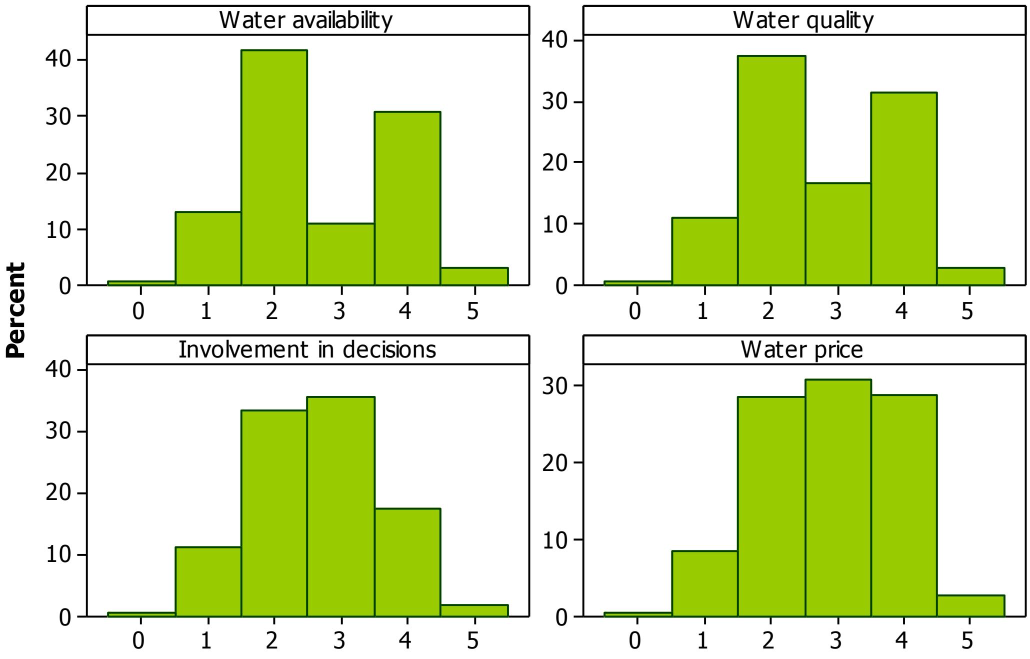


……

Q8. Do you consider water suppliers should train, demonstrate, and educate water users in using water in a sustainable manner?

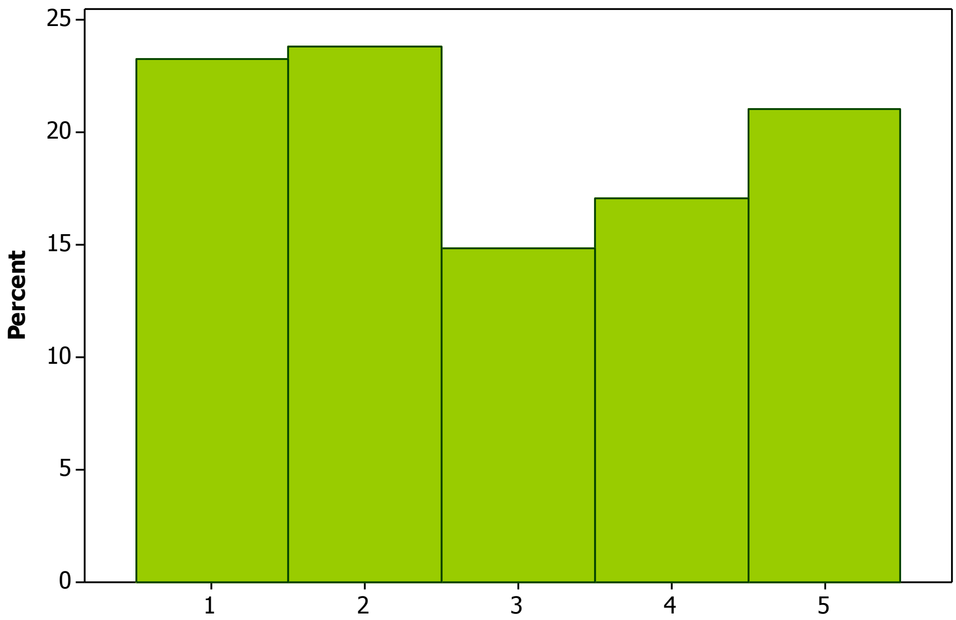


Q9. In relation to the water supply rate to your property. Assess your level of satisfaction.



No reply	Very dissatisfied	Dissatisfied	Unsure	Satisfied	Very Satisfied
0	1	2	3	4	5

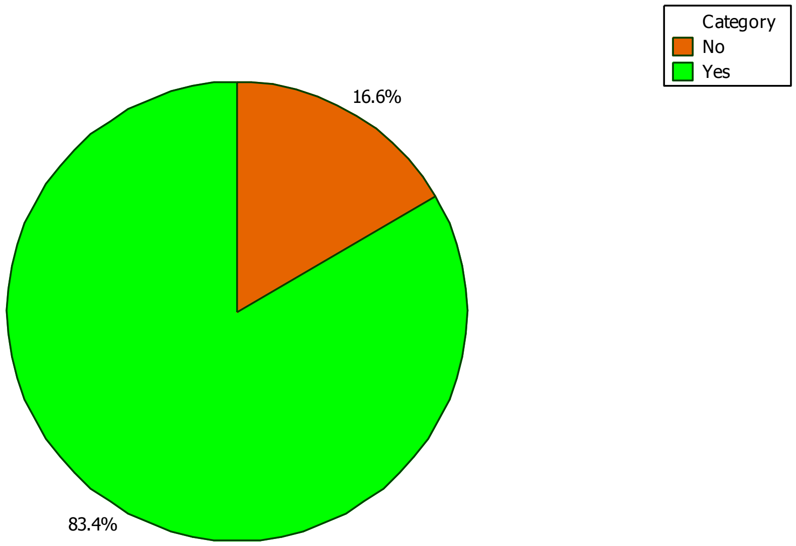
Q10. How acceptable is the reuse of water?



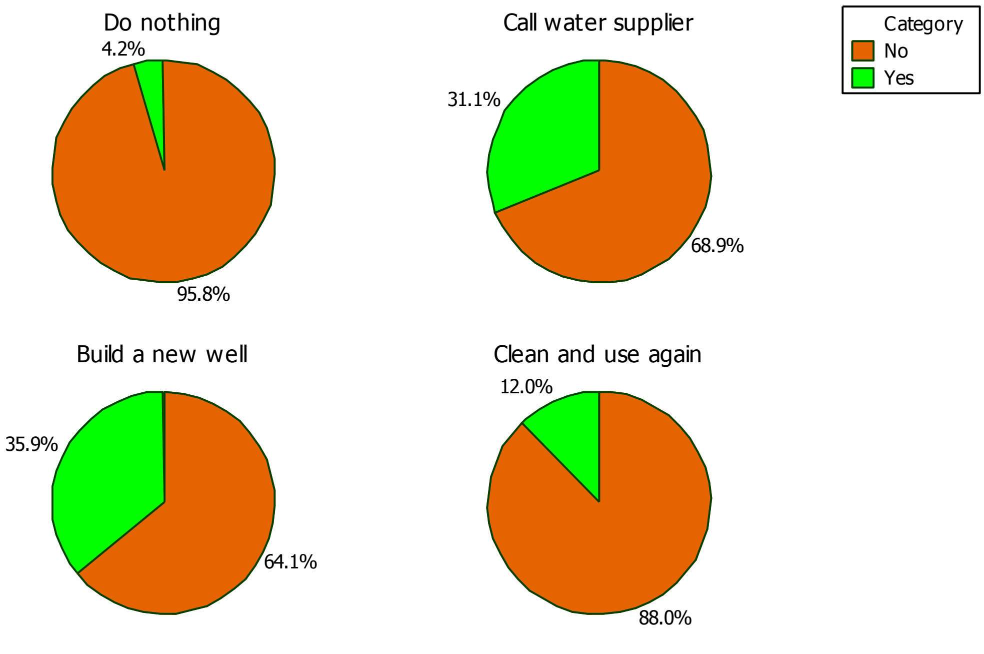
Totally	Unacceptable	Neutral	Acceptable	Perfectly

Unacceptable				Acceptable
1	2	3	4	5

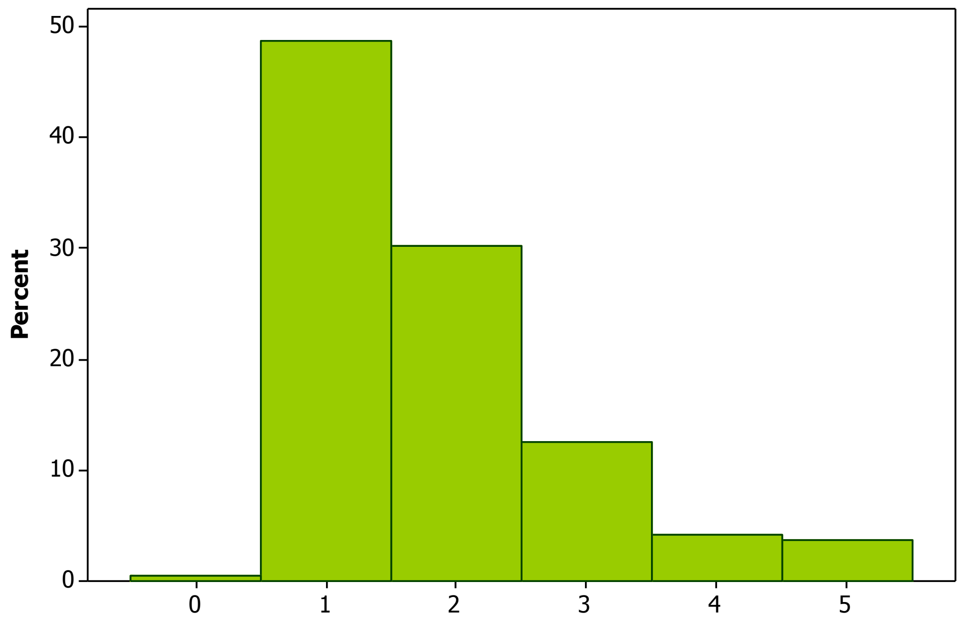
Q11.Are you aware of water contamination problems from sewage (used water) within your property?.



If yes, how you do deal with this problem if it happens?

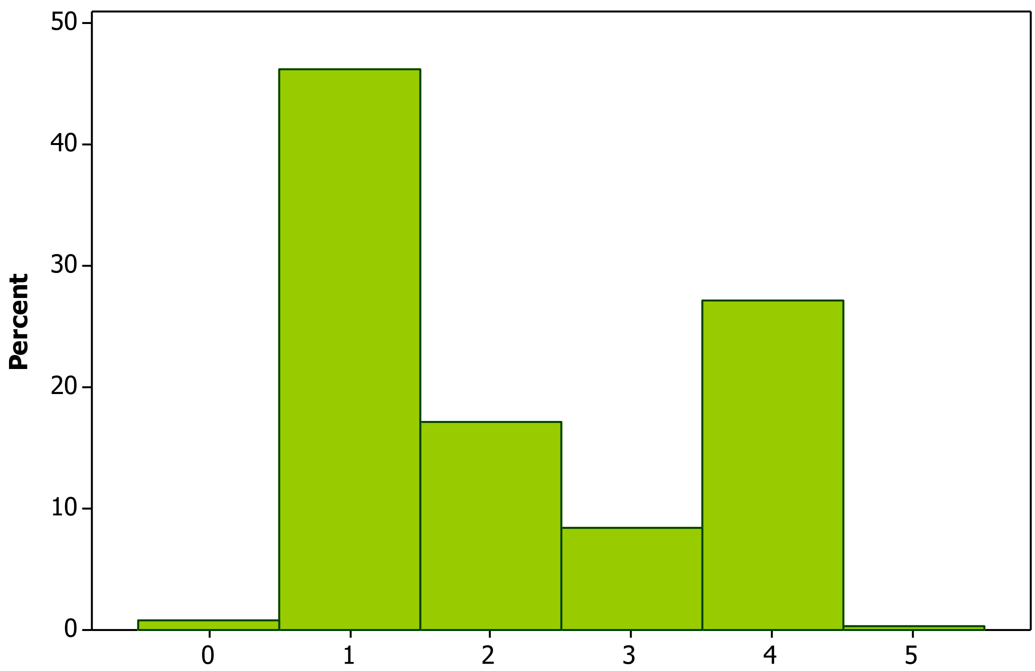


Q12. Do you accept the use of old private water wells for sewage disposal?



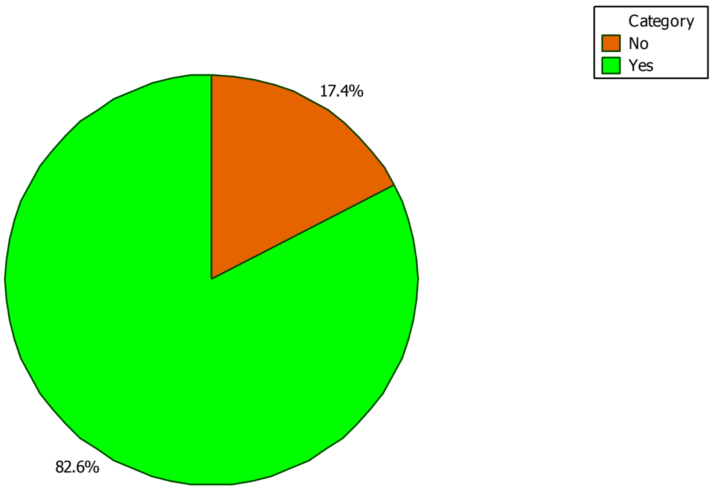
No reply	Totally Unacceptable	Unacceptable	Neutral	Acceptable	Perfectly Acceptable
0	1	2	3	4	5

Q13.What do you consider the reasons for not using sewage for agricultural crop irrigation in Alwahat?

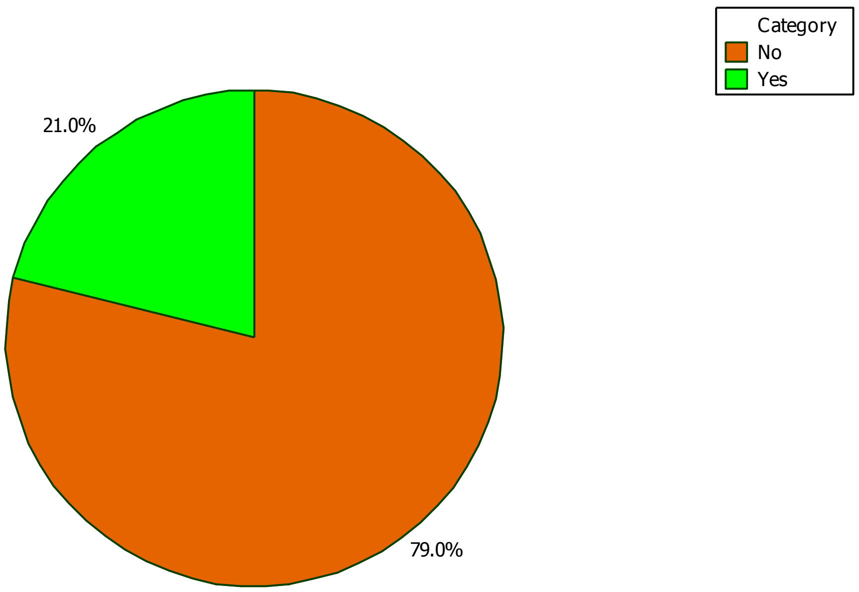


0 No reply
1 Ignorance of concept to use sewage as a fertiliser………
2 Very expensive…………………………………………
3 Not a priority ………………………………………....
4 Treatment not important ……………………………… .
5 Other

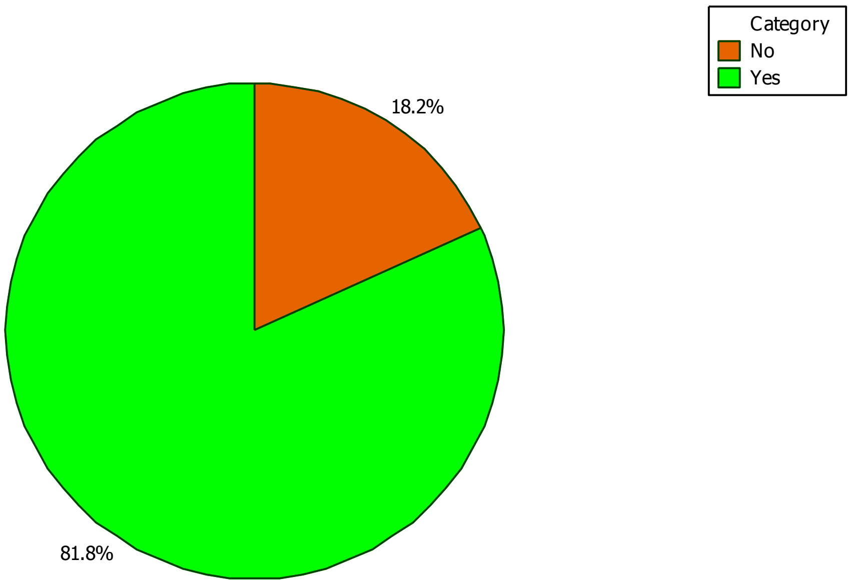
Q14 Do you think there is a need for legislative reform to ensure water supplies are sustainable in Alwahat?



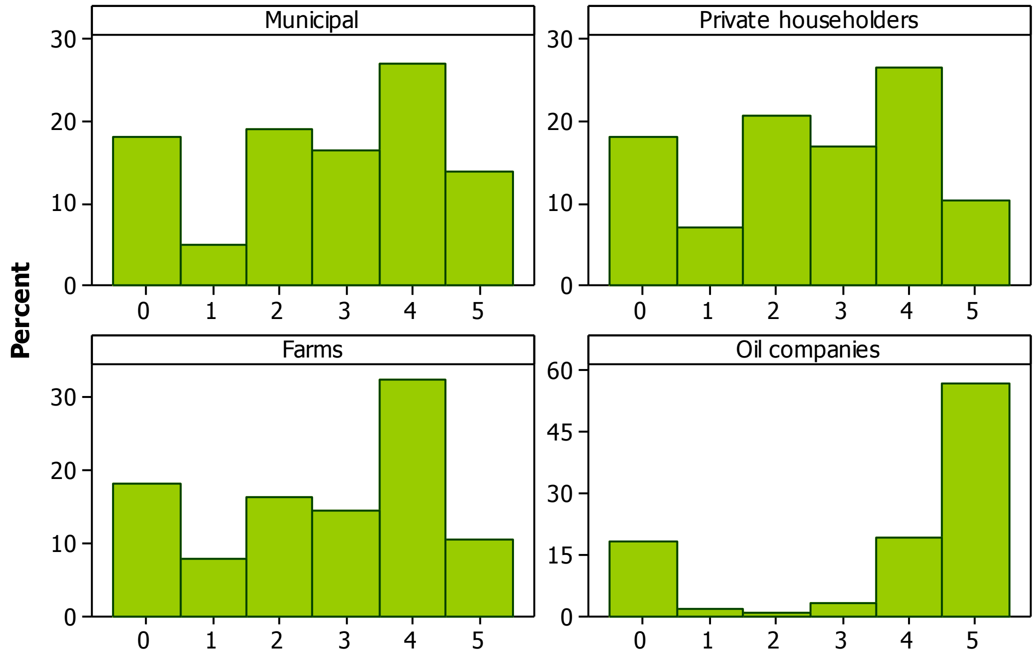
Q15. Do you think the existing water regulations are adequate?



Q16.Do you think the natural environment in the Alwahat area has deteriorated during the last 10 years?



If the answer is yes, rate the level of deterioration:



No reply	No deterioration	Slight deterioration	Somewhat Deteriorated	Moderately Deteriorated	Extremely Deteriorated
0	1	2	3	4	5

8.5 Appendix 6: Permission Form for Focus Group Interview

Focus Group Interview Permission Form

This focus group is part of a research degree that is currently undertaken at Alwahat study area .The research is exploring the border idea to identifywhy women behaviourstoward water usage is misused ,to gather idea to develop an understanding to further construct another questionnaires that is rigorous in understanding the issue and the questions of my research .

I would greatly appreciate your time to participate in this group discussion. The group meeting should only take 60 minutes / Hour. Your participation is very much appreciated and will allow us to focus on critical issues related towater sustainability in Alwahat.

The results will only be used for the research degree purposes and the participants' details will not be sold or passed on to the third parties. If you have any further questions regarding my research project and usage of material, Please don't hesitate to contact me on:

Email: shoab.alamin@ntu.ac.uk/ mgbery200@yahoo.com

Permission Statement

I have read and understood the information provided in this document. I agree to the recording of my opinion or writing statements or quotes and grant Shoab Alamin consent to use the interview material obtained for research project described above and in the research degree thesis.

Read and Agreed by

Researcher	Interviewee
Name:..	Name:...
Signature:...	Signature:...

8.6 Appendix 7: Transcript of Focus Group Discussion (elderly women)

Focus Group Discussion

Before starting the discussion:

1. Thank participants for turning up.
2. Inform them of the purpose of the focus group and why they were selected
3. Assure them that their identify will be kept confidential
4. Tell them the approximate time for discussion

Date: 09/12/2010

Participants: 5 older generation housewives

Brief: From the previous Focus group of younger working females, I wanted to make a comparison of the attitudes towards water consumption and sustainability was relative to age and generation. I did not go into as deep questions as I had run in my previous focus group rather I wanted to highlight the background of when patterns of water sustainability began to change.

QUESTION 1: How will you compare water usage to your time and to the age we live in now?

A1-P1: Today women in general are wealthier and prosperous, and the water is available each time for her to easily open the tap, because of that her water consumption is very high. When she opens the tap, she opens it on a full pressure even to wash a spoon or a cup. Women today are very spoilt about their consumption of resources including water.

A2-P2: Majority of the women they use too much water in their kitchens, when they wash up, even when they're watering the plants. The consumption gets to an excessively high rate especially during weddings and funerals. Today women don't have to suffer to get access to free flowing water, in comparison to us, and that gives her no awareness or responsibility towards water preservation.

A3-P3: I always remind my daughters and son-in-laws to avoid the excessive spillage of water, because water is very important to us and we can't survive without it. Allah and Prophet Mohammed's advice has always been to preserves our natural resources for everyday use.However, there is high number of women who don't value the water now that they have it, and they won't value it if they don't have it either. Even when they do domestic chores, they use too much water and that is not a good attitude.

A4-P4: The water is available today and easy to access, but high misuse of water. Before 1 bucket was enough to wash all the dishes, however, today the availability of water has meant that women today have no mental awareness of saving water and sing as minimal amount as possible.

A5-P5: There is water today, and it is of good quality, and available in a generous quantity. Before we didn't have the same availability of water as we have today, and today women don't treat water with responsibility or importance.

QUESTION 2: How was water made accessible in your times on an average of 50 years ago.

A6-P1: We used to gather as a group of women by bringing water from a water well (Sidi Ali). This well was located in an area called Ashraf, and before sunrise we had to fetch the water in clay water pitchers. On our journeys we used to talk to each other and play games, and when we get there we helped each other to fill our containers, and then we returned back to the house after a long journey only to finish off the rest of the day domestic chores. The men were also very tired to get water to do farming for the agriculture lands to cultivate food, using a system called “jabadah”. Jabadah is the way of equally sharing water resource during the days through the month from the water wells.

A7-P2: The women in the area lived in very harsh conditions, and she was the one responsible for everything inside the property. Life was very difficult and for survival women brought water from far distances for the property using heavy water pitchers, using their head to balance it. Then when they got back home they used to have to continue to do the rest of the domestic chores before ending the day. I myself have been one of those women, and I used to have to help my mother to bring water to the house before sunset and sometimes early morning.

A8-P3: During those times I used to go with my mum to bring water from wells to provide water to the village, which was drilled in the area by the community. This provided water to the community for drinking and cooking. Today the situation is very different, easy life and everything is easily attainable.

A9-P4: The women used to go together every morning as a group to wherever the water wells were to collect the water. There were several times when the water level in the wells used to drop after being used, that either we had to wait for water level in the wells to rise again, or share whatever we had collected with the person behind us in the queue so that they could have some water to take back with them. This water used to be used for drinking and cooking.

A10-P5: There were salt water wells located in the village or town, that could only be used for cleaning and washing, and the drinking and cooking water wells were located in faraway locations.

QUESTION 3: What do you feel is the trend of water consumption of women today.

A11-P1: Today the situation I better, women can clean clothes, dishes and the house easier than before because there is water. Before the situation was very difficult.

A12-P2: Women before were very careful with using water, because she had to suffer to get it, especially when the weather was very hot. We used to fill one water pitcher, and all the members of the family had to drink from that one pitcher. Today thank god, women are in a better situation to get amount of water they need and everything is available. However, I am not aware of the water consumption, and I don’t really treat water as an important enough of a priority to save it.

A13-P3: Women are now in a better situation compared to previous times, thank god, but in terms of excessive use she is worse than women of previous generations.

A14-P4 Before women were more careful about using the water, and we used to value the water as an important element, and today women don’t have a sense of awareness at all.

A15-P5: Now life is better in terms of water, its easily available, and that makes living life easy and healthier, but there is the issue of excessive use.

QUESTION 4: What do you think is the best ways to save water and make people realise the value of water?

A16-P1: With introducing water meters to calculate the amount of water used, and the price of it, just like the electric meters that have been installed.

A17-P2: The best way is to introduce a tariff for using water, similar to buying bottled water that has to be paid for.

A18-P3: Women should be made more aware of water taps and the maintenance of them to avoid any water leakages. In my experience I feel that water wastage happens more because of tap or pipe leakages. I hope to install water meters in properties to reduce the high water consumption.

A19-P4: I think it is difficult to solve this problem because there are different levels of consumption of every individual in a property. As a society we have to try everything we can in order to save water and spread awareness where possible about preserving it.

A20-P5: We have to ensure maintenance of a property eternally and internally to avoid any leakages of water taps and pipes. We should avoid using drinking for gardening and external domestic cleaning.

QUESTION 5:Do you think if we introduce a water tariff and price, do you think people will reduce their water consumption?

A21-P1: Yes indeed, we will be more careful about how much we use and that will reduce water consumption. But I don't have any idea about water pricing and how that will work.

A22-P2: Yes it's an active way to make women feel more careful about water, because high consumption will mean paying a higher price and that can become unaffordable.

A23-P3: Yes it's a very effective way especially if the price is very high. For example when you top-up your telephone credits, when you need it you'll buy it, the same principal applies here, when you want to drink water, you pay for it.

A24-P4: I think it's a good idea to have a water tariff s people become more responsible with their consumption, however I am worried for the rates that people will have to end up paying and whether they will even be able to afford it, if the tariffs were set on high values.

A25-P5: We are a joint family, so we have a bigger number of people living at the property, so our consumption is naturally higher. It is a good idea to have a price on the water, but I'm worried that they may increase the tariff or the price for larger families, and it may become unaffordable.

QUESTION 6: How will you accept the idea of using re-cycled water? What do you feel is the biggest and most important problem related to water consumption needs addressing immediately?

P1: The only problem is water puddles on the streets because there is no maintenance for broken pipes, and I feel that's the only problem. I don't have any issues with recycled water at all.

P2: The only problem is that the water well in our area is not clean or pure, and this causes kidney related problems for several people, and I don't feel it's a good idea to use recycled water for the same reason.

P3: I don't have a problem with recycled water, and I don't feel that there are any urgent issues related to water consumption that need solving straight away.

P4: There is no good water supply network, and the amount of water available is not enough especially when we need it out of timed water hours. I don'taccept the concept of recycled water.

P5: There needs to be more regulations and implementation of those regulations for water consumption. I don't feel it's a good idea to introduce recycled water.

8.7 Appendix 8: Transcript of Focus Group (young women)

Focus Group

Date: 04/2009

Participants: 7 female Social Care Work

Brief: Get a broader idea to identify why the female social workers behaviour towards water usage is misused. Gather ideas to develop an understanding to further construct another questionnaire that is rigorous in understanding the issues and questions of my research.

QUESTION 1: How will you describe the water consumption in the household? Why do you use water in the pattern that you do?

1. P1: We do misuse a lot of water.

SA: Why is that?

2. P1: Because it is available.
3. P2: Yes I agree, we do misuse water, and the evidence is water puddles that can be seen in our house and streets.
4. P3: Because the water is always there, and our consumption becomes high.
5. P4: If we pay for the water, then perhaps we might learn to save it too.
6. P5: (Suburb resident) Because of the high water consumption in the bigger towns, we suffer the shortage of water in our areas. The water comes once a week, and sometimes it takes as long as 2 weeks to get water, and because of that shortage we have to buy water from water tanks (water custom ordered on trucks, delivered to paying customers). And paying for water from water tanks becomes very expensive. Many water wells have dried up, and because of that our plantation has dies, and it's very difficult re-using water for crops (the drop on the water levels is evidence of this point).
7. P6: I am from the middle area, and our water supply is on weekly basis, and our water consumption is high.

QUESTION 2: Has the high water consumption got anything to do with the timings of the water supply?

8. P1: If there is water, we use it and we store it.
9. P2: If certain hours during the day, every day, they release the water supply, and people store water during that period of time, this will encourage people to be more conscious about the water supply and prevent health risks of large water storage.
10. P3: I don't think this idea will work out for our region, because if we open each week all day, and we store large qualities each week. To convert to certain hours on a daily basis, people will resort to using pumps to extract large qualities of water on a daily basis, and that is unfair distribution.

QUESTION 3: You agree that there is high consumption of water, and unnecessarily used, why do you think that is the case?

11. P1: It’s a physiological feeling of the house not being clean enough if we wipe rather than thoroughly washing it with good amount of water. When I clean I think using two buckets of water for cleaning is better than using one.
12. P2: In my experience, before when we used to buy the water from water tanks was so expensive for family life, that I am very careful about water usage when it comes to household use and cleaning. Then when I was connected to the government water supply network, it was very easy to become lazy about thinking of my water consumption. When we used to buy the water, we knew the value of it.
13. SA: Make the people feel the value of the consumption of the water.
14. P3: 2 years ago, the water problems appear in the area where I live. There is one water tank that comes to the area, and then there the additional problems of overbooking water tanks, and transporting water at times in difficult traveling circumstances, and subsequently the price of water went higher.
15. P4: We live in a big joint family, so the consumption is going to be higher.
16. P5: In some suburb areas, we try to bring water from the town, for cooking and drinking, and we have to rely on working water wells for cleaning and other household chores. Those people who don’t have access to water wells, suffer the most from the shortage of water wells.
17. P6: The problem is not with the availability of the water, the problem is there is no sense of responsibility with the water supply. When I clean the house, I don’t think about my water consumption, in comparison to my mother who uses the water far more carefully and responsibly. I don’t think about the water supply drying up of cutting off, however the only time I do become a little more responsible is in the presence of my mother.

QUESTION 4: What is the relationship between the levels of water consumption and the age difference of water consumers?

18. P1: Absolutely, the older generation didn’t have the easy availability of water as today. The older generation had basic lifestyles. They didn’t have as many household chores.
19. P2: After we have drunk a cup of water, we feel the need to wash the cup thoroughly with soap before reusing it, whereas the older generation didn’t do that, they simply gave the cup a quick water splash to re-use the cup. It is a difference in attitude towards cleaning and water consumption. When the open the tap, we automatically turnit up to full water pressure.
20. P3: The types of houses have also changed, nowadays houses are bigger in size, with more rooms, so the consumption is higher.

QUESTION 5: What is the best way to reduce water consumption is households.

21. P1: Educate people from the government through the media, especially to educate women about the importance of water.
22. P2: In terms of implementing of reformed regulations about water consumption, the government needs to take firm action against those who abuse the water supply.
23. P3: I disagree, not in terms of how the government threatens people, the government should take more action to raising awareness about this issue.
24. P4: The government should make people aware of the long-term availability of water as global water levels are dropping with time.
25. P5: Not to enforce the people, but show the people the consequences of high water consumption, and why it is important to change our attitudes and patterns of using water.
26. P6: There was old man in town who used to drive around residential areas, and if he noticed water puddles collected outside a house, he would knock the door, and he would get into argument with the residents about their excessive water consumption turning to waste. As result he would persuade people to cut down on their consumption, and as a result he

gather a lot of respect from locals, because he was educating people about being conscious about water use, and the consequences of waste.

QUESTION 6: In town areas, the water sector limit water supply to 12,000 cubic liters upon consumption estimation, and as an alternative supply water wells if required for additional use. The water supply comes from The Great Man Made River project. There are also issues of population increase, and as a result, the demand in water supply also increases, and now all water resources in residential areas are limited. And still people's attitudes towards water supply are irresponsible.

27. P1: We don't know of a problem, and we don't know where the water comes from.
28. P2: To educate people about water is by changing the regulations and timings of water supply.
29. P3: If a facility of free flowing water is available, there is going to be neglect towards the responsibility of its use.
30. P4: I don't feel educating the people is a solution that will be effective.
31. P5: Water is very important for human beings for living, we have to continue educating people, till the do understand the importance of saving water.
32. P6: Look at our houses when water is not available in our house, and how difficult it becomes to live.

QUESTION 7: How do we implement the law to people?

33. P1: If we put the price on water, the people will begin to care.
34. P2: I do agree with the idea of a water meter.
35. P3: Even when washing my hands, I will think twice about the amount of water I am using.
36. P4: The important part for me is water supply, and I am not bothered about the implementation of the law, and I don't think that our water supply should be scrutinised to have it cut of, regardless of how much water we use.
37. P5: The government needs to reform the entire regulations of water supply.
38. P6: If you want to implement the water meter regulation, the government should also take into consideration the number of people living in a property.

QUESTION 8: What difference will the number of people in a property make to the water meter regulation?

39. P1: Reform the water network distribution to become more effective.
40. P2: They should take into consideration the number of people in the family before they implement a water meter-reading device. At the moment the census book although counts the number of adults to be listed, however it does not count the number of children residing in the property, they should update their census book.
41. P3: We don't have to calculate an estimate of water usage per person, but we should also add estimate of water use by children in a household to estimate an average price of water, because adults and children use water differently.
42. P4: Reform the mechanism of the water system, for example the water municipal should reduce the quantity of the water supply, for example, by using this method, provide a meter reading, then calculate an average, then any additional use of that amount of water should be sold on tariff.
43. P5: The idea of water reduction should be done slowly, and that will begin to encourage the attitude towards valuing water availability.
44. P6: The important issue in all of this is to educate the people about the water issue, and the problem will begin to reduce.

QUESTION 9: How and who do you educate?

45. P1: We should educate the people, especially children from kindergarten about water, and when they get older their attitudes are going to be more sympathetic towards water consumption. This change won't happen overnight, it will take up to a generation for things to really change.
46. P2: To educate people through the media, newspaper will help towards bringing a change in attitude.
47. P3: Education starts at home, women in the household should start by educating children and other family members to bring about realistic and positive changes.
48. P4: The local water municipal should be responsible in bringing education and awareness about water allocation and consumption, and developing measures towards bring those practical changes.
49. P5: By strict measures is the only way that people will actively take notice, for example an electric company, when they restrict users with regulations and firm action if they misuse electricity, the same principal should be adopted here.

QUESTION 10:Issue of water sanitation and water storage.

50. P1: To store huge amounts of water for long time is unhealthy. The way that water is stored is really unhygienic as insects and clay travel into the water, when the water tank is uncovered for technical reasons.
51. P2: Many people get ill with kidney stones and other kidney related infections because of the water storage systems.
52. P3: The sewage reserve should be located far away from the water reserves, because there have been incidents where the water and sewage reserves leaking into each other, which creates so many health risks.
53. P4: They should build water and sewage reserves outside and away from residential property or land.
54. P5: They should be kept apart.
55. P6: In my theory, the way of storing water and sewage should be completely reformed; the current system is outdated for modern living.
56. P7: Some people try to build the sewage reserve away from their properties, because they are afraid of leakage.

QUESTION 11:If we have 1 day a week water supply, and we use up all the supply for that week, what do you think will happen if we had the opportunity to have water every day supplied during certain hours of the day?

57. P1: When we get the water, we clean, we wash, we garden, everything that has to do with water.
58. P2: They provide salt water when drinking water supply is cut for technical reason.
59. P3: They should use salt water for cleaning purposes and only use drinking water for drinking and health related reasons.
60. P4: Some people don't drink from the network-supplied water, as the corrosion from the metal pipes can be unhealthy, so they resort to buying bottled water for eating and drinking.

QUESTION 12:If the water sector provides equipment and technology for saving water in everyday use, would you be able to satisfy your water needs and be happy to change your attitudes towards water consumption?

61. P1: We are already used to using the old equipment and ways, I don't feel comfortable in changing my ways to adapt to using new technologies. I is a worthy idea for the next generation, maybe.

62. P2: Education is the best solution to save water.
63. P3: Use the media, television, leaflets to spread the information and education f new technologies and equipment to bring about awareness of water consumption.

QUESTION 13: When it comes to water consumption, should the people be a part of the decision making process?

64. P1: It is a good idea to be included in making a decision.
65. P2: When the regulation comes from the water sector, the only thing, that we are need for is to follow that regulation, and makes us feel powerless and unworthy to be not part of what we are paying for. We need to be a part of it, and when we are a part of it, we know it, and we'll follow it.
66. P3: I want to say, this cannot happen. We use it, so we know that one follows and 10 don't, so you can never make anyone happy.
67. P4: Our community and our society don't like to read.
68. P5: Through the television, show footage of people of how to apply new rules and regulations. It helps people to understand the importance, and by making people a part of the issue, they will respect it and understand it better.
69. P6: If the implementation comes from high state order, it will annoy the entire community, and even if you are on the side of the decision, an authoritative decision backfires.

QUESTION 14: If we provide recycled water, will you be happy to use it?

70. P1: I don't want to use recycled water when there is pure water available.
71. P2: Yea it's a great idea if it saves water.
72. P3: No, I don't like to use it, physiologically would taste contaminated, even if it is safe for everyday use.
73. P4: No, I won't accept it.
74. P5: No.
75. P6: No, I don't like it.

QUESTION 15: If we continue our behaviours in this way, how do you feel this will affect our existence 10 years from now?

76. P1: Indeed, the water is not going to be enough for the next generation.
77. P2: We will have a problem, and several other problems.
78. P3: Even The Man-Made River project is not going to sustain the water supply for more than 15 years.
79. P4: In this time, water is in decline. For the coming future, the water will be in further decline.
80. P5: The problem is that even the people in charge of the water supply aren't actually aware or bothered about this issue. They add more chlorine to the water unnecessarily and that doesn't make sense.
81. P1A6: There is no awareness to save water. Some people just use drinking pure water to farm.

QUESTION 16: Do you feel that technology is contributing to water sustainability in a negative way.

82. P1: Yes, there are side effects to technology; mainly it depends on how technology is used.
83. P2: The technology makes life easier, but it is expensive.
84. P3: Too much technological developments mean it causes a lot more complications.
85. P4: Technology developed today has great impact on water sustainability in a negative way. Before we watered our farming vegetables using buckets, now we have all sorts of equipment that in fact it uses an excessive amount of water.

86. P5: In present days water resources are few, and in the future there is going to be even fewer water resources, because there is a lot more newer technology and more needs and that uses up more water than before.

8.8 Appendix 9: Transcript of Interviews with Agricultural Officials

1. **Office of cooperation and guidance**
2. **Office of plant production**
3. **Office of planning and control**
4. **Director of Agriculture**

Initially, a little brief was given to the interviewees about the purpose of the interview and they were also informed about the selection criteria for this research. The approximate length of the interview was also mentioned to them.

A Guarantee was also given to them that their identity will be kept confidential. All necessary measures has been taken to make sure the environment remain encouraging for the interviews. It's also taken care of that the interviewee was comfortable with the using recording systems, but if they were not comfortable with the recording, then the research advance by taking notes.

Guiding questions for interview

1.Farmers' awareness of water sustainability

2. Groundwater depletion issues

3.The issue of water quality

4.Education and training

5.Environmental issues

6. Regulation and Reform

1 . What do you think about increase in the total number of employees and how will that effective the water in Alwahat?

RGHF1. I think the number of employees, get increased in Alwahat because most of the Libyan farmer no longer want to work in land and the problem is that those workers are not local, so they did not care about the water at all .

RGHF2. If you could compare during the last 10 years, the total number of farms in Alwahat area has increased a lotwith the availability of Mechanise and Money. Farmers stared to get the very good machine that abstracted the deeper groundwater aquifer. So this excessive pumping has abandoned the water availability. Secondly, the availability of foreigner farmer workers has also spoiled the situation.

RGHF3. Most of the private farmers have at least one employee and even a single employee's main focus is on getting as much water as he can for his form and that would be a big problem in term of the amount of water taken. On the other hand, the situation is even worst, as with the Government framers; the big ones, have many wells and they employed a large number of workers and pump unlimited amount of water, almost 24 hours a day without stopping for a single second.

RGHF4. I think the number of employees in Alwahat is dramatically increasing and it needed to be controlled. The reason behind this is that they are trying to capture the whole food market. Secondly there is no rule for water wells andit is easy to drill water wells.

2. Do you consider farmer in Alwahat using water Efficient? State the reasons?

RGHF1.we know the water is from the gad, it is very difficult to controlled for various reasons, first Alwahat area location in very harsh desert environment, and for the irrigation to much water required So no one has the right to control the abstraction from the wells Since there is not planned from the Government in Tripoli as we are just a small department and we use to get the order from them.

RGHF2. I think the quantity of water we use in our farm in a daily basis it is too much ,and really in unsustainably way ,and really need to do something to stop such behaviours, even know that to implement policy that would be very difficult but we have to try first and then we can see the feedback .

RGHF3. The quantity of the water are used in farms in Alwahat is has to be controlled because to sustainable the water is the availability base over time and that not exist in Alwahat since the our water resources non-renewable and the only water is available is from the ground aquifer that mean if we lose it we can’t get it back, and must of farms did not consider this facts, or they did not care and wears of this issues of sustainable the limited water we have.

RGHF4. As we know that the groundwater is the only sources of freshwater in Alwahat, it is usage exceed the rate of neutral replacement, which result in a progressive lowering of water table, this is creates a significant situation, which endanger the prolonged existence and practical use of aquifer, Government irrigation has rapidly developed in Alwahat area and there are numerous location where real problem exist.

3. What is the most important issues you aware of regarding to the water sustainability in Alwahat?

RGHF1. Actually, what is worries me in this respect of aware the increasing number of farms in Alwahat without any planned strategy to highlight the good side and the bad side and how that will affected the water situation in the future,

RGH2.I am aware of the issue that we are not quite sure about the impacted of all farmer activity in Alwahat so just we keep drilling water wells and using exciting water for our farms without deep thinking about How much water available and How much water we should use to survive, there in necessity to develop our area Build on knowledge.

RGHF3. It is logic think, the number of the farmer getting increasing and the will contributed to increasing the number of the water wells and the will affected the groundwater security due to excessive pumping with fact that employee can work hard to produce food and market, all this factors will contradicted to the water availability, that is what I am very aware of in big pictures.

RGHF4. In general, I am aware of the farmer awareness of the issue of existing water in Alwahat area, and how will change them attitudes by using water is unreasonable way.

4. Groundwater depletion issues and increasing of water wells in Alwahat

RGHF1.Regarding to an increasing the water wells number in Alwahat area, we know that the number is always increased, you can find some farmer have one water wells some more than one But what is we have to focus into is that the depth of the groundwater which farmer abstracted that allows increasing to and farmer extended their the depth of water by year.

RGHF2. Farmer pay no attention to about the to follow scientific methods in drilling water wells, increasing the depletion of the level of the water and the farmer when have such as problem they do not tried to solved but they going to drilled another wells and now the abstracted the very good water quality with excessive using this water which led to changing the water quality after time.

RGHF3.In term of increasing the number of water wells in the area, there is no legislation to deal with that first and second farmer can afford to drilled many water in their farms that which led to lowering the water table.

RGHF4.studies of the area in need of waste overdraft of water and place the agricultural schemes, that will help farmer and possible of applying the law, because there are clear evidenced of the groundwater increased and the number of water wells to.

5. Are you satisfied with your current water supply situation in Alwahat?

RGHF1.still water available in Alwahat but with more bad quality that most farmer used for irrigation them planted ,before you could get water easily from the top aquifer about 1 to 5 meters bout now there are different level from 30 up to 200 matters that caused by excessive water using and I am not the happy with the situation .

RGHF2.Waht is available in Alwahat current stylish excessive water using in farmer and agricultural projects build by the state, and the existence of modern techniques to abstracted water from aquiferall that led to poor quality of the waterand diminishin same area that is all unpleasant situation .

RGHF3.The water situation in Alwahat are becoming more problematic with increasing the farms and farms still do not know about the water situation, for example when we introduced the use of droplet system that was very good to reduce the amount of the but farmer attended to opened the network all day for 24hr which affected the quality of the plum dates produce which cause by Humidity in the farms.

RGHF4.The water situation really need highly consideration to changes our behaviours and attitude of how using water in farms ,in compered to past time even it was difficult to get water but the water always available ,since the oil was discovered in Libya the culture life changes the people started to get all the equipment which make the life much easily but that have very bad effect on water condition in Alwahat in terms of quality and quantity ,the big challenges we are facing now is to educated the farmer water user about how use water in suitable way before we loess what is excess .

5. How would you describe the water quality abstracted this year compered 10 year ago?

RGHF1.qulaity of the water is an average and also depended to the depth of your water wells the depth you go the good quality you got.

RGHF2.i would say an average

RGHF2.Average

RGHF4, Poor especially if your farmer located near where the oil companies located

6. Regulation and reform

6.1 Should farmers only be allowed to extract water if they can approve that they are going to use it in an efficient way?

RGHF1.This is difficult to apply, especially with the farmers, said the foremost concern is to get the profit from agricultural production and this can only be no restriction on water.

RGHF2.This is can be possible if the existing legislation active and implemented but, I think it is very hard because farmer might say the water right.

RGHF3.The farmer does not pay for water it consumes and the only coast incurred is the running costs of pumps fuel and maintenance and it is very hard to apply such this idea the reasons is that we did not know the how much water available and also farmer would not give a corrected information about them framer satiation.

RGHF4. It is very good idea but I think , the common of farmer will disagreed with the idea of implement such allowed of water abstracted .

7. Do you think there is need for legislative reform to ensure the sustainability of water in Alwahat?

RGHF1. I don't think we need to reform the existing legislation, what is really needed to implemented and make it active.

RGHF2.lack of a central planning and policy formulation and mechanism

RGHF2.Most of farmer did not know about existing legislation, it is not flexible and not covered all the conserving part for example issue related to the groundwater depleted and how we do then and sometime it is not distinguish between one area to another what can be suitable for Tripoli area, can't be appropriate to Alwahat area due to the different location.

RGHF3.I doesn't think we need to reform the legislation but we need to implement.

RGHF4.In Libyan the legislation sometime implements where there is problem presented for example, when there is no adequate rain water in same area, the do not allowed the farmer to cultivate sort of vegetable, and sometime this action not has any connection to Alwahat area.

8. What do you think about the current irrigation policy and how is acceptable enforced? And what do you think about farmer should be regulated?

RGHF1.To is honest, there is no legislation for farmer, but there are regulations and patrol come sometime when there is problem with same Farming produce.

RGHF2.We know that the majority of farmer are no educated .although, find they have awareness of the importance of water and maintain them without their knowledge of legislation, for example ,draw down of water means a threat to the productivity of farms .

RGHF3. Indeed, there are no laws and regulation used for agriculture, framer can drilled any number of wells they as much financial ability and at the present law have to be regulated.

RGHF4.Way of life in Alwahat depends mainly on agriculture, and that quantities of crops produced are not as good as was before. The use of fertilizers, as well as over-exploitation of the soil led to this problem, and there are no laws governing the methods of complex process of the quantities of fertilizer and amount of water used from the ground up, and I think, and despite the difficulty to be law to regulate agriculture.

9.Do you do provide necessary training to farmers on how to use water and maintain its sustainability?

RGHF1. In this aspect, we are very remiss, and due to the lack of sufficient funds for the work of training, and also lack of seriousness of farmer to attend such course.

RGHF2.Really on training course for farmers and the reasons is due to the lack of coordination between the agricultural departments in Libya.

RGHF3.There are no courses for farmers, we must have some because it helps increases awareness about the importance and methods of water conservation.

RGHF4. Do not give farmers` training to understand the good knowledge of all methods of agriculture and preserving the water. AS a result of these experiences they have gained in through their work as farmers.

10. Do you think farmers should be involved in water management issues?

RGH1.I think the idea is good but could be involved if there were decisions that could simply share the originally .Because the decisions come from agricultural management in Tripoli, we just applied.

RGH2.The participation of the farmers in decision-making contributes to their awareness of the problem and how to overcome them. In fact, this does not exist.

RGH3. Given to participate if the drafting of resolutions awareness of the problems, and how the premise of the solution in this group and help to increase awareness of the farm and find solution.

RGH4.It is good idea to apply to the ground and not just exist on paper.

11. Should water polluter pay the remedial coast?

RGHF1.They must pay the cost of remedial, especial the lakes of water associated with production process; we suffer from in the region.

RGHF2.Must pay these coats to clean up water pollution, especial oil companies which surrounding Alwahat area, and also implement of strict laws, because large quantities of water token from the ground and then polluted during the processes of oil produced

RGHF3.I agree with this it`s the only way to reduce and provident our groundwater from pollution.

RGHF4. The implementation of water polluter pay remedial ,I personally agree with that ,in Alwahat area, both oil production and agriculture demand large amount of water ,After using this water becomes contaminated with oil and salt and this has effects on the water in the regain and we have to put strict polices to reduce theses bad behaviours .

12. Do you things the natural environment in Alwahat has been a diversity affected by water abstraction?

RGHF1.The only sources which position a threat to environment in the Alwahat area the oil companies and the operations resulting from oil production, indeed we need to focus on the negative side too, because we look at oil and ignore the negative impacted of environment in Alwahat.

RGHF2.Yes, oil companies are the main source of environment pollution, as wells as use of large quantities of water and polluted.

RGHF3.Sure, our environment has changed for the worse, and responsibility come from oil companies, the unregulated use of fertilizers in agriculture.

RGHF4.there is doubt that the environment change in the Alwahat of the worst ,and contributed the oil companies ,with the obvious negligence in maintaining the area ,As consequent, wastewater contaminated with oil exist in the form of oil lakes in the region, increasing water salinity in the farms is counterproductive ,as well as pollution of air the impact of the agricultural produce, even the colour of leaves.

13. Would you consider change the changing type of your crop grows to save water?

RGHF1.As we know that some of crops that consume to much water such tomatoes and palm trees and is difficult to stop because we have grown with and inherited from ancestors ,and hard to change in order to maintain the water .

RGHF2.changes crop type cannot be easy to introduced Alwahat, if just prove that the new crops will be given same value for the old crop, there are always new plants enter by the farmers .if the result of planting is encouraging a good crop, farmers seem to grow like what happened to the cultivation of olives, potatoes, and if the Crop were not good the farmers will not cultivation again.

RGHF3.i do not think the existing crops does need change because they are appropriate to the nature of desert regain ,and change requires another kind of experience of the new type .and most of farmer can`t adventure their crops in case of failure of the quality of the new crop .

RGHF4. I am very keen to make changes in our crops types in order to reduce our water consumption, but need to show farmers that the news crops which you want to introduce are good and because the food marked computations make farmer more satisfy with certain types of cultivate.

14. What type of irrigation technique do you use?

RGHF1.Recentaly most of the farmers in Alwahat started used the drip irrigation, in this system of irrigation water added in the form of drops of water directly below the plants

Although it is expensive, most farmers in the region using at their farms, also reduced water loss and safer foe water.

RGHF2.Most farmer use the drip irrigation ,this is provides the water ,where the average irrigation efficiency of this system is 75% ,it is very appropriate for sandy desert land and also not need be resolved ,but same farmers still used the flood irrigation with drip irrigation .

RGHF3.Most of farmers in Alwahat today they used the drip irrigation system because the easy-irrigation agricultural areas without large effort, keep water from waste.

RGHF4.In last 10 years the drip irrigation system widely uses in Alwahat area for the following reasons. The provision of irrigation water due to lack of losses, which increases the efficiency of irrigation systems and is the highest in terms of efficiency also result in the organization and raising the efficiency of fertilizer added to increase the productivity and unit area of land with preservation of the environment to prevent laundering and delivery of fertilizers to groundwater

15. Would you accept metring of water from wells?

RGHF1.This is very difficult to implement, because farmers consume very large amounts of water in agriculture, also they believe a gift from God and should not be put upon tax.

RGHF2.It is not easy to apply this because a large number of wells and large amount of water the used for cultivation.

RGHF3. Cannot apply it in desert area like Alwahat and the weather is very hot, plants need large amount of water and can`t regulate.

RGHF4. Good idea, but can`t applied to the presence of large number of wells and large amounts of water withdrawn for agriculture.

8.9 Appendix 10: Transcript of Interview with Water and Sanitation Officials

Director of water operation and Maintenance
Director of Water and Sanitation

Awareness of water sustainability by the domestic water users.

Q 1. What do you understand by the term 'Sustainability'?

DOW1.In fact, represent a non-renewable groundwater management dilemma for decision makers in Libya .and difficult to apply the concept and principle of sustainable management of traditional groundwater. While easy to clearly define physicist for renewable groundwater sustainability and can be applied in practical such as the amount of water withdraw annually from these water equal or close to the rate of nutrition you receive annually, the definition of nan-renewable groundwater sustainability is a complex and difficult and presents a challenge for the management of these water, and need to be careful and in-depth studies covering many aspects of social, economic and even political.
DOW2.Sustainability it is Requirement of civilisation, we must work to archive sustainability in water, although the amount of water we have limited it to optimise and maintain, this is the concept of sustainability.

Q2.Are youAware of the problems associated with water sustainability?

DOW1.There are a lot of problem that need to be addressed in order to maintain the water example provided network ages and a lack of pumps based on water distribution, as well, and there are connections illegal in some areas in turn led to a deterioration of services provided by the company of water to the resident ,this range of problem which I concerns me .
DOW2. I am aware of the excessive misuse by the residents, and now they have started to ask to get 800 litres per day instead of 300 cubic litres, which is what we are providing now.

Q3. Identify the problems of which you are aware?

DOW1.Poor performance of the carrier for the water line to the main pumping station, the line was its construction in 1970s, this line suffering from corrosion in most its parts, as well as broken air valves which causes a large number of explosions that occur usually.

DOW1.Lack of water significantly ,shortage in the number of wells are now operating ,and a shortage of submersible pumps for wells ,and bad use of water by the resident .also, I am aware of the excessive misuse by the residents, and now they have started to ask to get 800 cubic litres instead of 300 cubic litres, which is what we are providing now.

Q 4. Are you aware of water misuse by other property owner?

If yes: Identify the perceived of the misuse of water?
DOW1.Yes ,it is very clear on the street ,
DOW2.Yes ,Look at our street you will find clear evidence of water misuse by people in Alwahat area.

Q5. Can you suggest any solution to help prevent the misuse of water?

DOW1.To solve this problem we need to introduce the water meter systems, like in other countries to control our consumption and more over leak detection and repair.
DOW2. The only way to control the misuse of water consumed is to introduce water meters system or the pay-as-you-go slot system. To put tariff on whatever is used beyond a set limit of water allocated to a household.
2.Education and training domestic water users

Q6. Are you aware of any guidance or publicity relating to water users in relating to Sustainability?

DOW1.Eduaction of water users is vital to satisfy water users to use water wisely and to achieve that community education should start at the school by incorporating into the school programs some topics about water conservation but that not available in Libya.
DOW2. In terms of educating people, there is not much advertising and information for the people about the value of water and ways to save it. Even when we have circulated information about water sustainability we have never had much response from people or seen a change in their ways of using water.

Q7. Are you satisfied with the water services provided by the suppliers?

DOW1. I am 65% satisfied with the service we provide for local residents. What I am not happy with is the systems of water supply operation and its maintenance. When we try to build a new water network, rather than building a building a new one, we go out and do maintenance on the same old networks. That causes technical problems like miss-matched pressure of water, and that causes lack of water for some properties. The corporate side of

water supply companies is corrupt, and that causes further technical problems with water supplies.
DOW2.I am positive about water supply service which provided ,while it is difficult to solve all existing problem in one ago with this lack of information about our pips not work mapping and difficult of leak detection and repair ,water users behaviour with water, this is just an example about existing barrier to sustain water .

Q8.Identafiy deficiencies in the water services which you provided ?

DOW1. There is geographical problems with the locations of water networks pips. There is no record show the mapsof difference between the old pips and the new ,as a result the maintenance is obstacle .Additional , not happy with the water supply networks, because it is very old , and how some people are using potable water for the wrong purposes, for example irrigation farms or misuse on street .
DOW2. Reduction in water losses and leak detection and repair ,also. Reduced the amount of used water in house and person activity like washing machines and toilet flash has direct impact in water sustainability

Q9. Do you consider water suppliers should train, demonstrated, and educate water users in using water in sustainable manner?

DOW1.Education of water users is important elements to convince water to use water perceptively, but with a lack of highly qualified and capable personnel in water management make difficult to train water users.
DOW2.If the domestic water users educated and receive the necessary training that help to achieve higher water use efficiency. To adopt a training program for demonstrating to educating users that need long term programs.

8.10 Appendix 11: Transcript of Interview with Hydrologist

Translation of semi-structured interview with hydrologist in the Alwahat area

Q1 . What do you understand by term Sustainability? Are you aware of any problems associated with water sustainability in the region?

HydrologistwaterSustainabilityis group of elements if we target them, we will be in safe our water for long time. The large amounts of both fresh and saline connate groundwater, these water resources are non-renewable ,what we lost it we cannot get it back.

Hydrologist :There are some significance elements has very bad effective on water sustainability in Alwahat areaTHAT WOULD BE THE BARRIER TO WATER Sustainability as following :
excessive water used from the aquifer in Alwahatcaused by the Farm reasons:

1. excessive water wells used for both domestic purposesand forming irrigation
2. last 10 years thenumber of farm settlementproject increasing by state countrythat will effective on groundwater level and availabilityof water.
3. the improving of standard of living which make farmer and water users can get all technology that take more water from the aquifer for example water pumps.
4. the large amount of water used in oil companies for injection wells and produce wells
5. the water rechargefrom the original water province

Hydrologist :In Alwahat the water is available and the recharge is there if we calculated in very good way that can be enough for 100 yr. .

Hydrologist :The barrier of water sustainability from the significant elements which has motioned for example the state planned to plants abut million plum trees without any careful study of the quantity of existing water in the area about ¼ million meter square that really effect on water sustainability. If we carry on such behaviour and attitudealarm bells should ring .to reduce this barrier we have to stop all big farmer settlement which proposal by the government and stop the injection freshwater for petroleum reservoirs in order to enhance recovery of oil
As result the water turned salty.

Me. Pleas identify the problem of which you aware?

Hydrologist :The water problem started from the $60^{th}$when the oilwere discovered in Libya and people standard of living are changedthey introduced the water pumps that can take a big amount of water in second , the water were located in aquifer with quality and verity the people started to use the water andby time the water has changes in quality and even the humidity level increasing from watering the carps to reached 70 to 80 % in Alwahat ,

Me .Can you suggest any solution to help prevent the misuse of water ?

Hydrologist :Education water users are one of very important element to sustain water in Awlwahat. To implement the education water users need to lesson about the water situation and what is the problem we are challenge, the remain question need to answering are *(what is the Futures of this Areaunder all the circumstances ?*

Educated water users tell them the truth about the water situations

Me. Do you think there is need for legislative reform to ensure water supplies sustainability in Alwahat?

Hydrologist :Legalisation reformthe water legalisation is available but we need to make it active and implement .

Me: Are you satisfied with water services provided by the suppliers ***?***

Hydrologist :The service provided by the water sectors in Alwahat they problem is the way to delivered the services for example in case ofdrinking water some people not get water as provide and some other got ,the realisation of that seen on the Awlwahat street during the water opening time.

Me: Do you accept the use of old privet water wells for sewage disposal? what the reasons for not using sewage water treatment for agriculture in Alwahat?

Hydrologist :Sewerage water issue people not aware of the issue just .Regarding to the sewerage water contamination problems, ther is individual cases and geological formation lithology, show that the Alwahat area has high filtrationcome from the sand, we have to be more care if this cases becoming more incidence that is related to the possibility of water contaminations inside the properties .In term of contamination of groundwater that is possible because of large quantity of sewerage water damped in an open area.

Me: Do you consider farmer in using water efficient ?if no, pleas state the reasons?

Hydrologist:The irrigation palm trees farms that proposed by the government in Alwahat area, which consists of4 different areaas Alsafan farm field, Alsahaby farm field, Alkufra rod farm field and Jalo Awjala farm field for example Alsahaby farm field has 350 farm and in each farm there are one water well with production of about 180 meter square in hours and in 24 hours is it 4320 meter squire in one day for one water well, that is a quantity of water abstracted for the aquifer, try to make out in 350 farms that well be about 1512000 meter squire per day for total Alsahaby and if adding the other 3 farms that will be about 6048000 meter squire in one day that just for ,Really tree to imagination as narrow area that cover just about 10 km long and 2 km wider it has about 350 water Wells that not logically ,the irrigation consumption might be low during the winter time but we know that the palm tree in first age need to watered every day and they planting a fruit and olive tree that need water 24 hr and might not living, this very high consumption is not responsible it is look like the want to deteriorated the which storage in this area .

Me: That is in for Government farm what about the privet farm which own by local people ?

Hydrologist: privet farm the effective not that much as the oil companies ,the main issues that always consider when we take to the farmer that the sense of worrier about the sustain the water and the future ,the majority of them would have a proper strategy led them to more wise using their consumption because they know that their future will remain by thewater availability .

Hydrologist :People in Alwahat they do not relay on farm today they most of the farmer make it as second choose for their income but for them it is look like a future support the idea of that come from if something happen in Libya like war or inspected issue they will go back to the farm and get food and water from it. Some people might say we have the Great Man Made River Project, I will answer to them this project has life expectancy .

Me: *Should farmers only be allowed to extract water if they can approve that they are going to use it in an efficient way?*

Hydrologist:it is very difficult to apply this to Alwahat since the water is look free , In terms ofselling water in Alwahat areathere is some cases but one as goods because the water price is cheap and the value of money that taken is about the track that carry the water and the employee who derived, some people might argue of the water price and said 10 LD that expensive, the water not expensive but the charge on the carrier of it.

Me: What do you thinks implementation of water tariff, and water device installation inside the properties?

Hydrologist:Regarding to water tariff and water device installation inside the properties: the people will see this idea it is unreasonable even though the water are very stencil element in the life, do you believethat the Libyan state try to introduced the water meter device in the area of Alwahat in 80th ,and they sent in All other 4 water sectors department in Libya to installed and that planned was stop because this projected needed a very will preparation and services and peoples so for that we want able to do it in Alwahat area **.**

Me: how would you describe the water quality abstracted this year compared to 10 year ago?

Hydrologist: I really more considered the issue of the water quality, we know that all oil companies they have them own water recourse, the most old oil companies which are located around Alwahat area they use a large quantities of water fresh which taken from the aquifer of Alwahat rather than keep it safe a clean for next generation, this kind of water when the used for recovery and injections oil services becoming more risk that water are taken for irrigation(the irrigation can evaporation or return to the aquifer) But what have used in oil companies production it is finishand hard to reuse them and always remain as an open reservoir land that cause a lot of environmental problem ,sometime the water not enough then they try stem the water to help recovering the oil and during thatwater loss all componentand discarded on the land.

Me: what do you think of Water availability in Alwahat ?

Hydrologist: Historical the water resources in Alwahat found as groundwater which is a part of Sarir Basin which implanted many projects for example like the great man mad river project to carry the water from desert,if we take a section in the contour map the most important information for Alwahat the information call Clanisoinformation that where water found and it is about started from 10 m to 200 m ,for the oil companies the drilled more this depth where the salt water and they take freshwater from Claniso and used and make it salty , Alwahat are of desert the reasons why people moved and lived her because there are two rezones one is the water and the second is the land even thoughthe land not that good but they used for them plant the land will be remain but the water if finished no one can live her .

Me: what do you think of groundwater depletion and increasing number of water wells in Alwahat?

Hydrologist: It is very clear that the level of groundwater declining in last 10 year and all farmers know and experimental that groundwater are decline year by year, without the hydrology parameter we cannot predicted how much is the drawdown exactly, but the farmer always asked about that but even the can feel that in them own water wells, for example when the farmer said that I have four water pipe in my wells as the total depth(one joint pip is 3 m and 4 joints it mean 12 m total water depth) and this year I extended one joints that mean he adding the total depth to be 15m to sum up that he extended his water wells depth more 3 m in one years and some they might adding more and 3 meter in year that is very big number what will be after 10 years? As I said before the answer for that in not easy to

predicted, then he told me a point that not publicly a published about how much the drawdown in Alwahat area annually?
And the answer was 1.3m per/year(not showing evidence)but he adding I am quite confident about this number ,I made a very sample module in term of regional because as hydrologist the local area cannot be accurate and will meaning less ,since our local Aquifer area joint with the main regional Aquifer so we cannot make it locally ,and I came up with that number and I am claim of it, and I things this is a high in term of regional area, one centimetre in any area would be alarming not 1.3 that isbig .after 10 years that would be 13 meter from the sierrt basin reservoirs that is noting comport it to local area but by the time it will be a problem .

Hydrologist: We have to know that the aquifer reservoirs are joints together and it is no matter if there is big drop down in water level in same area and other not but at the end the will effect by the time, and there is what the calling the con of pressures and that significant of high water usage that is show in the area .
The growing activity used water by the privet farmer and government statement irrigation projects around the area and oil companies' abstracted a large amount of water all activity taken water from same aquiferthat sure effectiveon water quality and quaintly in sort time as Alwahat and long-time As Libya

Me: Do you think the natural environment in Alwahat area has deteriorated during the last 10 years ?and by who?

Hydrologist: There is too much water used in Alwahat area in unwise way and there is example during the drilling of the water wells in the irrigation farms settlement about 5 km distanced from the oil companies and when they started to test the water pumps the water was showing evidence of contamination by oil and the one explanation for that this oil shows comes from the oil companies where they are dumping the produced water generated during the oil production and the produced water intrusion to the groundwater Aquifer .
Me: what do you think about thetechnical used to abstracted the water ?
Hydrologist: The technical that used to get the water in Libya and all Alwahat has been changed by the discovered of the oil and people living stranded transformed also ,before thepeople ability very poor as a result to get water wells that might coast money but after the oil discovered people stared to have the very good equipment that contributed in water as

quantities andthe government stared planned this large 4 farmers irrigation settlement in Alwahat targeting the very good water quality sometime the water wells reached a 200 m that was convenientbefore ,some privet farmer have to drilled production water will as the government doneand introduced a latest water pump with 60-100 hoarse pumps that will take about 180 m squire per house ,all the privetand Government irrigation will has bad impacted on the water because more water we take the more groundwater decaling and the more soil washed and the more water quality deteriorated.

8.11 Appendix 12: Transcript of Interview with Environment Official

Translation of the semi structured interview with the head of environment department sector (HEDS)
19/july/2009
The interview was contacted in his house after a request letter from the NTU agreeing to have that meeting.

I introduced myself and told him about the research and why highlighting the importance of the research.

ME. What do you understand about the term sustainability?

HEDS: He stared by welcoming me, and said (As we know Alwahat has a large quantity and quality of water compared to any other area in Libya, therefore we hadlarge of developmentin farmer and irrigation not in Jalo but in all southern of Libya from Alkofra to Alwahat Jalo , Awgal and jakra for example Alkffra farmer settlement and jalo Awjala and know Alsahaby and .all these settlement projects dependingon the large quantity of water found in siere and Tasrbo basin .So we should have sustain our water for next people by using it in management way and do not wasted .
2.As Alwahat locationof the water quality the southern towards the good water quality and quantities you find even the solid quality are good ,

Me: Attitude and behavioursof water users ?
HEDS :Regarding to Alwahat population figure show that population are increasing and the demand on water are too regarding to people attitude and behaviours with water for irrigation or drinking water for example for farmer they have to install the drop system network in all farms to save water rather than the old system which take a lot of water, for the water users the have to educated them about their water consumption and how the safe water especial when they full the water tank in their house they must closed the top not let it running outside the properties .water Authority have to observationlike this behavioursand prevent such as this action .

Me: During the interviews with Head of water and Sanitation Sector they pointed that the social fabric one of the rezones to implement the legislation in Alwahat .do you consider that is be one of the issues?

HEDS:I think that case would be in some irrigation farm when the farmer took a drinking water from the network and using it for plant and as we know there is different quality of water between the farmer one and the drinking, in such case water sectors have problem with implement the regulation about how they can get right of entry the farm (access promotion) and that very difficult to applied in Alwahat area,
We need to originate and implemented the law in way that stop those behaviours.

ME: Libya one of arid with little water what do you think about crops typeschange and if that possible to applied in Libya to save water in irrigation farm ?

HEDS: Fist of all in Alwahat the farmer must irrigated those crops because there is not rainwater like the north of the country and the irrigation take large quantity of water that is mean the farmer sectors should educated the farmer about how they should using water in sensible way by applying the very update knowledge of saving water in other countries have smaller problems. It is a good idea to introduce all types that not taken to much water but really farmer need to prove that then they will followed

ME: What do you think about the level of groundwater and increasing number of the farms in Alwahat and how would that impacted in water sustainability?

The water level in Alwahat was between 2mto 3m and 6 m that time in general the palms tree, fruit tree and olive tree they when they arrive at age of 3 year from that they don't needed to irrigated because he root will get water itself but when the level of water drop down farmer stated to irrigated them smaller as vegetables crops if you let them without irrigation for 6 month the will remain wood that clear proof ofthe groundwater drop down it might reason of grown farmers number,historically water recharge from the southern to the north for the Alwahat area and there is a place was a river it is about 40 km from jalo area and the water stared to drop tell becomingdesert ,recently in that place the watercan reach in depth of 1 meter .

Me: Identify the problem of water misused by other and what can you suggest the solution? Drinking water what is the reasons of excessive using water?

HEDS :Really we need educate water users and make they realise the important of the water and where we are is stage of water shortage problem .Water is the life essential element without it we cannot life, we need to develop a strategy and apply for it Really we have to make the people aware of the water problem generated, we can see in our street how the water is misused by the large water out the door and that might be a good environment for insects that can put peoples health at risk .anther remarkablewater problem for those residualhouse uphill they cannot get the water in righttime because water follow not strong. And sometime the stared install water pumps to get water and that led to unfair getting water. This is problem the people should have to feel about some needed from other to.
Me. Are you satisfied with the water services provided by the suppliers?

HEDS:I don't think the water which provided for Alwahat are enough becomes the using the anther old water wells locked 30km from the area to cover the all Alwahat ,I think with applying the strategy that save the water consumption that would cover all area for the this time but not for futurewith increasing the population that need to find new source of water to feed .if you compared the increasing of the population 20 year it is dramatically increased in Alwahat area (it is developing
Area and very important for oil produce and farms which feed all Libya area)

Me: (Water prices):What do you thinks implementation of water tariff, and water device installation inside the properties?

HEDS :That one of important element let water users feel the value of the consumption, I don't like to introduced water prices but I do like to see charge on those misused water and focus in education the users .regarding to social fabric the law have to be above all and we know the law will benefit the people and the country.

Me: what do you think of Water availability in Alwahat ?

Alwahat area is one of the most important economic area of Libya, becomes.

It is one of the major oil production .as known the down side of petroleum production, to what extend do your Agency implement and applying the environment regulation on oil companies in Alwahat as we heard thy implement ISO 1400 in some companies ?

Me: what do you think of groundwater depletion and increasing number of water wells in Alwahat?

HEDS :We consider the major problem with the oil companies which surrounded the area of Alwahat and the big problem we are facing is the produced water which are attributed. During the oil production and they left large water volumes of with undesirable quality and high saline in an opened reservoir in ground, regarding to this problem we have request to the oil companies operate around the area and the answering was they will reuse this water for injection inside the ground But up to know noting happing in the reality, as a result from this problem the area suffering from the insects come from this opening water reservoirs which around Alwahat. Also, increasing the humidity which comes from hot weather, Alwahat is golf of oil in middle of desert; they should have solved this problem.

Me: From my understanding that the Environment Agency they have them protocol , how far oil companies following those protocol?

HEDS:The environment agency legislation were published in 1982 in Libya .it cover all environment protection protocol and one of the objective it is the produced water generated during oil process, as a side we asking them in writing and they promises to solve this problem, as you know all the main head offices of all oil companies located in Tripoli, all the office hear in Alwahat will foreword our inquiry to them.

way in international level but some did not follows the protocol or example of the produce waterand oil companies sewerage and collection companies waist and garbage .

Me: In Alwahat area, the large water consumption by inhabitantand all this water goes to be sewerage water are there any planning to reused this water in Alwahat area?

HEDS :We have made a request to the department of the city planning in Alwahat to introduced and build treatment station to collected and treated this water and reused that would be useful as water and fertilise the respond was to have planning for it but the apply still yet taken place .and really thing that great idea to reused this water better then lost and might let to groundwater contaminate by sewerage.

Me: Do you think that important to make water users as part of the design maker in water management issues?

HEDS :That is one of the important element we should be considered because that will make the users more responsible about that water issues and they take part of design made that given he or she the consideration and value of protocol took a place and then you don't need to educated them about design simply they know it because they took part of make it.

Me. Do you think there is need for legislative reform to ensure water supplies sustainability in Alwahat?

HEDS :In terms of the oil companies inside them monitoring regulation of them waste
There are some oil companies follows the enlivenment regulation in them stranded but some companies not. So we can said some companies applied the protocol in very good

HEDS :I don't think we need the legalisation reform because it is readily available but to make it active and implement, for example the wastewater on the street if there are legalisation implement and by committee guard which that one of them work to stop people to do those action by the law we will never see water on the street or farm, legalisation have to be active and implement to safe water.
Regarding too far regulation on farm water and the water take from wells I don't have idea on which proposal those farmer settlement bias but I think the government must have study before development of the large produced farms which absolutely have effects on groundwater in Alwahat area .But I thing, they have to have study about the water situation in Alwahat to make sure that will enough for next people.

Me: what do you think of groundwater depletion and increasing number of water wells in Alwahat? This is Finally questions have covered all of the issues of water and farmer and wells, regulation and sewerage water and oil companies what do you want to adding

The rezones as we state at the beginning of the interviewees we want to collected reliable date that would help to design my questioners

HEDS: The department of planning to should have plan for the street and the house location not just for now but for next fifty year with planning the water system pipeline and sewages water pipes line system and commutation services system like TV cable and lighting all the construction and facility that would provident the unwanted communities out of the plan, if the inhabitant get all service they need it is impossible they build communities out of the government planning but with diminutive planning the area or implement planning that cannot be enough for existing inhabitant not even for future that result of an planned settlements .One more thing the water Thief I think this is a crime they should punish for it and waist as well to reduce the action even it is not large cases they should penalize all farmer try to use a drinking water for the irrigation farms by contacted the farmer pipes to the municipal drinking water system, and for those misused water on the street and house.

8.12 Appendix 13: Semi-Structured Interview with Oil Company

Interview with Arabian Gulf Oil Company – Head of Loss Prevention & Environment Department

02 October 2010

Face-to-Face interview.

Does your company have an Environment Management System?

Yes, we have an environment management system, and it follows the department of the Loss Prevention and Environment Department. Our duty is to check and monitor all our locations by doing detailed reports about the environment situations.

Is your company accredited to ISO 14000?

We don't have the ISO accreditation.

Is there a system in the company to monitor and reduce the large amount of produced water, in order to meet your own environmental standards?

Yes, we have water disposal system, and it disposes the water in a safe environmentally friendly way.

The inefficiencies caused from the age of the oil wells and the separation processes of oil, gas and water produces a greater amount of water. What actions are being taken to solve this problem? What are the future plans to take advantage of the large quantity of water being produced for example re-use for agriculture purposes?

There are systems being tested and planned, and with regards to the separator, we always try to change, the oil separator, keeping it working efficiently and clean.

Are companies cooperating with environmental services in the region and how effective are the processes of dealing with issues, in order to maintain and minimize damage to the environment? What are the strategies that can work to prevent and reduce harmful effects to the environment as a result of oil operations in the region?

In terms of strategies I think we have to use experimental knowledge and highly technical equipment to get rid of the water produced. We make contracts with professional companies to deal with the water produced.

Can you describe how your company is committed to continuing improvements of oil productions?

I think the strategy of our company is very good, from the planning stated, which is to eliminate the environmental risks, but still there are a lot of weaknesses to apply.

Does your company publicly report on progress and achievement of their environment protection related targets and objectives?

Sure, there are regular reports, they are very detailed to evaluate and assess the environment issues in the location.

What measures does the company believe would be a way for sustainability of water used in oil production, and how does it intend to take advantage of reusing consumed water?

The better way to reuse this water is first to separate the water from the oil and gas, and then filter the water from chemical components and then reuse it in the ground to avoid air filling up in the ground. Or we do use it in the company for other purposes.

Does your company undertake and meet its detailed environment oil pollution risk assessment, to commence any work on all construction sites?

Our company does not start any activities without deep studies about the environmental assessments.

It is well known that the amount of water that is produced in the process of oil production is in large quantities. Will that water affect the groundwater in the area of Alwhahat? What kind of major strategies can be implemented to protect and prevent risks of water pollution?

Of course, the produced water from oil operations has an effect on the groundwater negatively, however some of the side effects are immediately revealed and others take a long time to come out. For that we have to establish institutions to clean this water in very professional way and to reuse inside the aquifer.

8.13 Appendix 14: Conference Paper

Paper presented at WIT (Wessex Institute of Technology) conference, LaCoruña Spain,2010.

Investigating the sustainability of water management in Alwahat, Libya

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Abstract
Libya is known to suffer from water shortages due to its location indesert and semi-desert terrains.. The population is growing in Libya and because of the continuing reliance on groundwater supplies; a strain has been placed on this water resource. As a consequence, levels of undergroundwater are decreasing making it difficult and costly to abstract. The problem has been made worse by the shortage of rainfall experienced in Libya during recent years. The threat to water resources has brought into focus the urgent need for planned action to manage water resources effectively as it is widely acknowledged that water is a major limiting factor in the socio-economic development of the country with a rapidly expanding population. The paper collates data from various sources to provide an overview of water use in the case study area of Alwahat which demonstrates the need to develop a sustainable water management strategy.

Keywords: sustainability, water management, irrigation, produced water, water policy, water users.

Introduction

Water covers two thirds of the earth's surface, but 97% of it is unfit for human use. Of the remaining 3% two thirds are locked up in glaciers and snow. Approximately 1% is available for human consumption [1]. This residual amount should be enough to satisfy the needs of all water consumers in the world, but this is not the case [2]. The reasons for this are related the temporal and special variations in the availability of rainfall. . Our misconduct and waste of the available water resources has complicated matters further. Human beings could hardly do anything to overcome the first barrier. However, with suitable and sensible water management we can rectify the second. Sustainable water strategies and their utilisation are of concern because of the potential socio-economic impact on the whole society. *Sustainable development* reconciles society's developmental objectives with its environmental limits over the long term. It works to balance conflicts between economy and environment and between the present and the future [3]. The strategy proposed in this paper specifically identifies water as an example of a resource, which 'Should be used in ways that not endanger the resource or cause serious damage or pollution' [4].

The region of interest to this project is the Alwahat region in Libya, which lies within the Mediterranean Basin [Figure 1]. By virtue of its geographical location and physical setting, the region does not receive adequate precipitation over most of its surface area. The demand on water is relatively high due to the warm climate prevailing most of the year. Demand is also increasing with time as a result of the high growth rate of the population. Since the surface water resources of many countries are limited, and the management of these sources is still incomplete, there is a growing need to cover, at least a certain part of the demand from groundwater resources. Experience has shown that groundwater abstraction requires certain precautions to be undertaken in order to safeguard the quality of the abstracted water. One should always remember that the deterioration of water quality is often slow, therefore it cannot be discovered except after some time [5].The available water sources throughout the world are becoming depleted and this problem is aggravated by the rate at which populations are increasing especially in developing countries. In addition to increasing population, water resources are threatened by diminishing water quality caused by pollution, reduced quantity caused by overexploitation and the increase in water demand for agricultural use [6].

Figure 1: Map of Libya with Alwahat area highlighted. Source: www.maps.com

Libya experiences scarcity of water due to its arid location [7]. Population growth and rising income, coupled with rapid urbanization, assure the continued steep increase in the demand for water for irrigation, industrial and municipal uses [8]. In many parts of the region demand is placing considerable pressure on existing supplies, stimulating mounting interest in finding new sources of water. Usually developing these sources requires large investment in dams, canals and other infrastructures, resulting in relatively high per unit costs [9]. The expected rises in costs of new sources of water suggest that policies and technologies to encourage more efficient use of existing supplies need to be put in place. The conditions for achieving increased efficiency are not well understood but are a necessary step towards developing water management policies which are an alternative to the development of new water resources.

Investigations and reviews of the water resources situation and management practices in Alwahat Libya by hydro-geologists [10], led to the conclusion that significant weaknesses and problems exist in water management policies and strategy. Alwahat is a major producer of dates in Libya and is totally dependent on irrigation for the development of its agriculture. Groundwater deterioration occurs in various forms, namely, pollution and excessive drawdown. Due to the low travel velocity of groundwater from the south region to the north towards Alwahat, depletion may not be detected immediately; and when detected, rehabilitation may either be impossible or very costly [11]. Accordingly, monitoring is one essential activity in the process of groundwater protection. Monitoring of groundwater should be carried out in strategy of integrated systems rather than simple networks [12]. Important tools in this process are databases, geographic information systems, and numerical models.

At present there is evidence that the groundwater table is declining at rates such that the economic life of the regions principal aquifer could be seriously threatened with "*limited opportunity of extending the life time of the water transport system beyond 50 years*" [13]. As the entire region's economy depends on irrigated agriculture, this situation poses a threat to exist living in the area [10]. In Alwahat the current pattern of water usage does not fully reflect the shift from water abundance to scarcity. The Government polices fail to take into consideration for excessive usage; indeed, the farmers are ignorant of the water scarcity [14]. Current research study explores the dimensions of the emerging water scarcity in Alwahat; examines the economic, social and environment impact on water sustainability, and the institutional factors influencing present patterns of water use. It also discusses a range of policy options to encourage farmers and oil companies to adopt patterns of usage more appropriate to present and prospective conditions of water scarcity. The aim is to demonstrate the potential value of water management policies to contribute towards the sustainability of groundwater supplies in Alwahat, Libya.

Water Resources in the Alwahat region

Groundwater is the only source of freshwater in the Alwahat area. Its usage exceeds the rate of natural replacement, which results in a progressive lowering of the water table. This creates a situation, which puts in danger the prolonged existence and practical use of aquifers [15]. Moreover, lowering of the water table usually generates wider degradation of the environment and tertiary problems such as salt water intrusion [16]. Therefore, achieving stability between supply and demand is a necessary goal for the long term management of water resources in the Alwahat area. For Libya in general, and the study area in particular, most of groundwater monitoring network is focused on the control of large water development projects for agriculture or water transport. Groundwater abstraction from private farms, which corresponds to 47% of total present abstraction and abstraction is not currently monitored. Figure 2 shows the overall water balance projected for the year 2025. One reason for this increased shortfall is the increase in the standard of living and improvements in abstraction plants equipment [17].

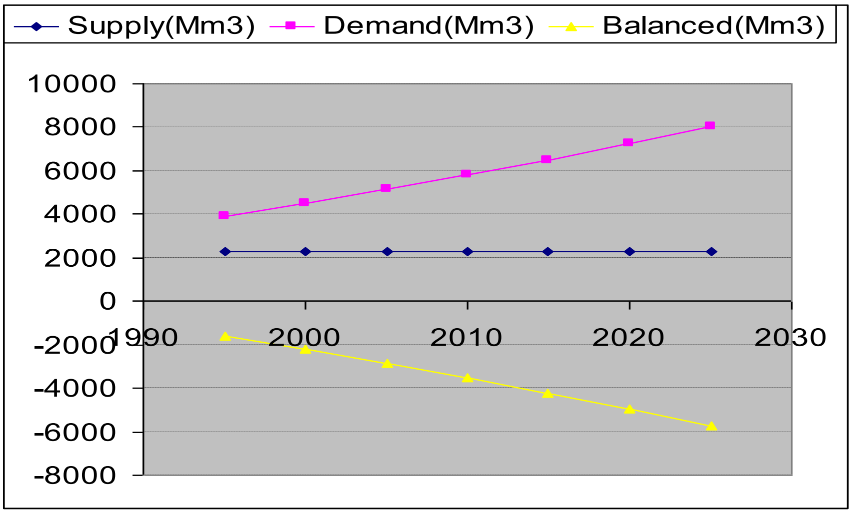

Figure 2: Projected water balance in Libya. ***Source*****: GWA 1999**

The quality of water varies across the area of study. Groundwater is of a good quality in the north-south aquifer, this is because the aquifer lies close to the sources of natural recharge from the Sirir Basin Aquifer. In the area of north Alwahat near the oil settlement where groundwater over-abstraction has been most severe, saline intrusion has occurred. In the Jakera area, north of Alwahat, the water quality is too poor even to grow salt-tolerant crops such as dates. In general the quality of water drawn from wells is deteriorating with time [10]. The total number of inhabitants of the oasis, according to census figures of 2006 is 31,537 comprising both non-Libyans and Libyans. Using a population growth projection of 37% by 2031, and a consumption rate of 350 litres per day per person, it is possible to estimate the consumption requirements of the population [18], which is shown in Figure 3.

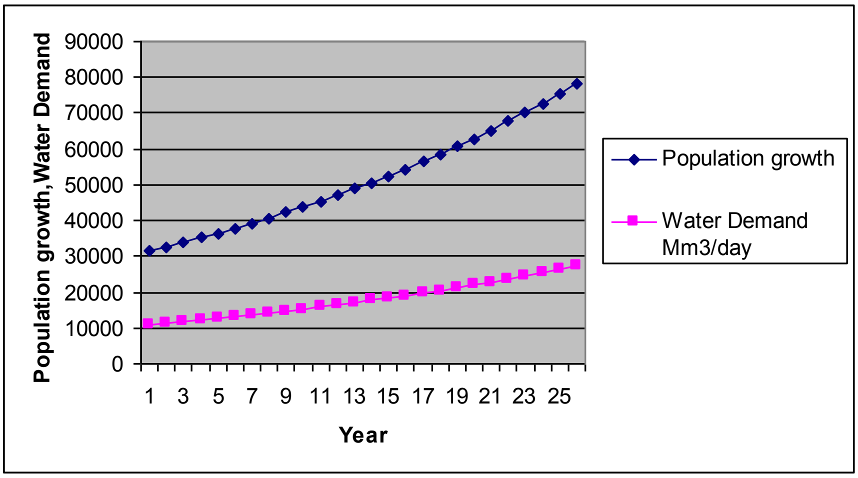

Figure 3: Projected increase in total water demand from 2006. *Source*: Alskran, 2007.

The realities of the water resources situation in Alwahat Libya represent a serious challenge to water resources management. In spite of the problems associated with water development, energy, domestic and industrial water supplies there is requirement that groundwater resources be used much more effectively than at present. The challenge for water users, planners, policymakers is how best to achieve such development to contribute effectively towards meeting social and economic goals, while maintaining water resources on a sustainable, high quality basis and avoiding serious degradation of the physical environment and unacceptable social disruption.

Domestic Water in Alwahat

Alwahat is facing increasingly difficult problems of water resources management [figure 4]. To overcome the problems, a new ethic of sustainable development is required. This should not only reinforce the established principles and technologies but also extend to integrated water resources management which includes water supply and wastewater management. The present water extraction and aquifer sites in Alwahat are located 35 km east of Jalo. It consists of 16 production wells drilled between 1975—1990 [19]. Recent information indicates that fourteen wells have been abandoned by the General Water Authority (GWA) because of unreliability of the water supply. Two wells are fully working from depths between 120—160m, with productivity of 25l/s, which equals 90 m^3/hr for each well. Water is collected in to two storage tanks of 600m^3. The GWA in the study area faces challenges due to age of abstraction equipment and the size of the network pipeline which carries water between the three oases: Jalo, Awjalah and Jakera. Water sources from the Great Man Mead River Project (GMMRP) have been used since 1993. At that time, the GWA proposed for the Alwahat area (Jalo, Awjalah and Jakera) to get its supply from the GMMRP. Since then, this resource has become hugely important for the region [19]. The water supply from the GMMRP transfer project to Jalo, Jakera and the Alnafora oil company averages 10,500m^3/day. Water supply from the transfer project to Awjalah is 2,500m^3/day, but the GWA still applies for more water from the transfer projects (GMMRP).

Figure 4: Evidence of urban water misuse in Alwahat (photos by the author, 2008).

The GWA argue that the amount of water estimated for the region should be 14,365 m^3/day instead of current 10,500 m^3/day sourced from (GMMRP) for Jalo and Jakera and Alnafora oil company. For Awjalah to be 5420m^3/day instead of 2500m^3/day. In responding to this argument the GWA in Libya explain that the capacity of the water supply network has insufficient capacity. The total renewable water resources in Libya are usually estimated at 600×10^6 m^3/yr. This means that 87% of the present groundwater use is coming from non-renewable resources

Water and Agriculture

As the world population increases, demand for food production increases. This implies that farmers require more water to meet rising production needs. In agriculture, as in industry, there are numerous locations where real problems exist [20]. The cultivatable area of Libya is estimated at about 2.2 million ha (1.2% of the total area), with 1.8 million ha for annual crops and 0.3 million ha for permanent crops in addition to 13.3 million ha of permanent pastures. Agriculture contributes approximately 9% of GDP and provides employment for about 5% of the total economically active population [20].

In the Alwahat area of Jalo and Awjalah, a state project was implemented in early 80s, consisting of 101 farms of 6ha each. Water was to be supplied by a well field located a few kilometres south where water was found of better quality in the post Middle Miocene aquifer. 33 wells in 3 parallel rows of 11 wells were drilled from 1977 to 1981 but only one row was connected to the irrigation network of the farms. Now only 4 out of the 11 wells are in operating conditions and each well has a capacity of approximately 50 l/s. In view of the insufficient amount of water available for irrigation, the farmers drilled their own wells at depths ranging from 60 to 100m but supplying water of poor quality (2.5 to 5 g/l TDS)to be mixed with the better quality water from the deep wells. Information gathered from the agricultural engineers working in Jalo suggests that most of the 600 ha originally planned are now under irrigation, mostly with shallow well water [21].

Private irrigation has rapidly developed in Jalo and Awjlah based on shallow drilled wells each with a capacity ranging from 4 to 7 l/s but with poor quality water. Nevertheless, the private irrigation area is now estimated at 3500 ha approximately 2000 ha in Jalo, 1000 ha in Awjlah and 500 ha in Jekara. The main crops grown with the brackish water are date palms and tomatoes. The average yearly water abstraction is estimated to be 60−80 million m^3/yr [14].

Water and the oil industry

Libya's onshore oil production is located mainly in three geological trends of the Sirte Basin: Firstly, the western fairway, which includes several large oil fields (Samah, Beida, Raguba, Dahra-Hofra, and Bahi); secondly, the north of the country, which contains the Defa-Waha and Nasser fields, as well as the Hateiba gas field; thirdly, an eastern trend, which has several fields, containing approximately 80 per cent of Libya’s proven oil reserves and accounts for 90 per cent of production [22].

Figure 5: Produced water in the Alwahat region. Source: Google Earth

Oil was discovered in the Jalo basin in 1961. This gave rise to a distribution of production fields and pipelines across Alwahat [23] [Figure 5]. As described in the introduction Alwahat has been a considerable importance in the network of transport located in the centre of Libya major oilfields cluster. Despite this, the oil industry has minimal impact on the local domestic economy and maximum environmental impact. This is due to the fact that the oil companies are self-sufficient in technological services and local manpower are only required in the fields of transport and construction. The upstream petroleum industry provides essential petroleum products. The use of petroleum products is a major contributor to the present standard of living. The activities of finding and producing petroleum, however, can have an impact on the environment, from the release of waste into the environment in unsafe concentrations. This waste includes hydrocarbons, solids contaminated with hydrocarbon, water contaminated with a variety of dissolved and suspended solids, and a wide variety of chemicals [24]. Some of this waste has significant adverse effects on the environment. One of these problems is called 'produced water', and can be defined as follows: "Mainly salty water trapped in the reservoir rock and brought up along with oil or gas during production" [25]. This massive volume of produced water from an oil well can be more than 10 time the volume of oil produced [26]. In desert arid regions, where freshwater is scarce and costly, it may be economically viable to reuse the massive amount of produced water for agricultural and domestic purposes. Ayesha [27] shows clearly through the concentration of oil samples of water accompanying the two different areas of studies, where the results were higher than international safety standards [Figures 6 and 7].

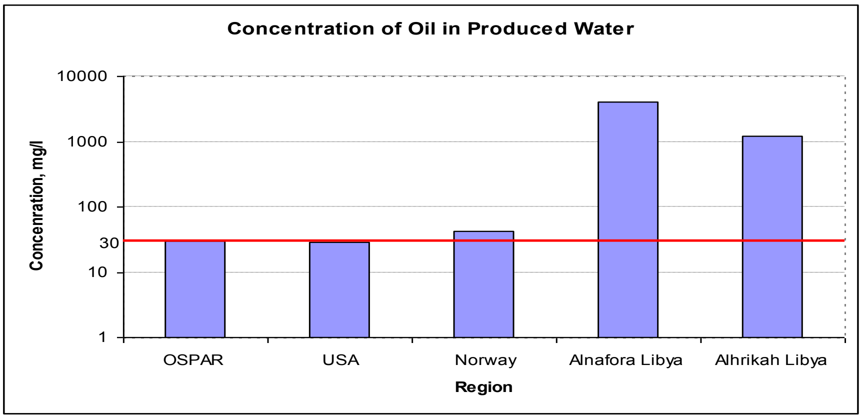

Figure 6: Allowable concentration of oil in produced water. (Source: Ayesha, 1990).

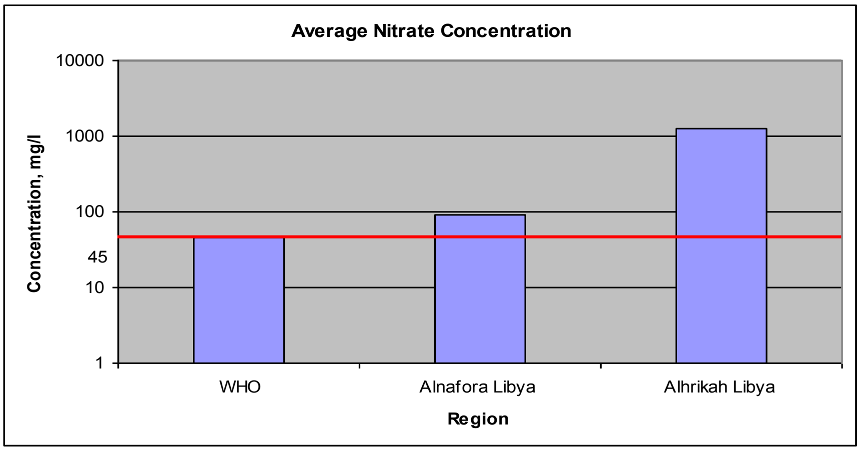

Figure 7: Average Nitrate Concentration in produced water. (Source: Ayesha, 1990)

In addition to these problems, Alwahat's population also suffers from environmental pollution from the extraction of oil and gas from fields around the area, the consequence is that the health of humans and animals is put at risk. More alarmingly, the increase of hydrogen sulphide in the air presents a significant hazard for human health, especially in children and pregnant women in the area. Anecdotal evidence, and personal experience in the region, shows that this pollution is likely responsible for the increased proportion of miscarriages and reduced fertility in the local population [28].

Discussion and Conclusions

Whilst Libya is among the few countries with modern water legislation, its policy on water management is largely ineffective because it is hardly enforced. The reasons for this are to be found in the social fabric of the country. Agricultural policy allows the planting of date palms too close to polluted water sources. This research project identifies the following barriers to sustainability:

Improper irrigation and drainage practice has resulted in substantial degradation of soil in Alwahat. The planned use of transport water(GMMRP) for irrigation in Alwahat where brackish aquifers exist at shallow depths may also result in water logging and Salinity problem if appropriate irrigation and drainage techniques are not applied.

Ignorance of the problem. People are not aware of the issues; this is partly the government's responsibility to educate its people.

Polluting oil companies, which need greater regulation.

Conflict of interest between stockholders in oil companies, government, water authorities, and the private sector.

Lack of communication and cooperation between water suppliers and users.

Lack of data and also no access to some data e.g. oil companies waste.

Attitude to water as a resource: people regard water as a shared resource which is free, and they don't value water because they do not pay for it. As a result, when water supply is increased, people waste more water in the area; when electricity began be charged, usage decreased.

Water abstraction either for local agricultural projects or for water transport (GMMRP) to the region will cause a significant water level decline in the aquifer, due to the non-renewability of the water resources. This will gradually induce the disappearance of natural vegetation which is vital in the area. In Alwahat as case of shared water resources system any strategy in the area may directly indirectly affect the other sectors, however national plan should be with investigation onthe long-term impact on strategies and regional policy should benefitfrom internationalexperiences and best practices.

Shortage and misuse of freshwater pose a serious and growing threat to sustainable development and protection of the environment. Problems related to sustainable water use are generally more serious in arid areas due to hydro-geological complexity of water systems in such areas. Therefore, water use policies should be based on these prevailing issues and driving forces. The policy should also consider all components of the environment. Transparency of the policy formulation process and general public approval are the key elements to achieve the necessary objectives.

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8.14 Appendix 15: Water Diary Table

Example of water diary (this shows just one day, but the actual diary included a whole week.)

Time / Activity	Saturday																		
	06:00	07:00	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	00:00
Personal Activity																			
Having Drink																			
Washing for prayer																			
Having a shower																			
Having a bath																			
Flushing the toilet																			
Washing the dishes																			
Using a dishwasher																			
Washing machine																			
Cleaning the house																			
Cooking food																			

8.15 Appendix 16: Photographic Evidence

These photographs represent part of the evidence gathered by the researcher over 4 years during visits to the Alwahat region. The images show various ways in which water is being wasted and the effects of water mis-management.

The first group of photos illustrates decline of vegetation as a result of groundwater depletion.

The second group shows water misuse and dumping of sewage.

The third group shows urban misuse of freshwater.