

Water Management in Jordan and its Impact on Water Scarcity

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ABSTRACT

Jordan is among the poorest countries in the world with respect to water resources. Water scarcity in Jordan is an alarming problem that can jeopardize the economy and the stability of the country. It is a multidimensional problem caused by many factors such as the fluctuation of annual precipitation rates, the rapid change in population caused by the refugee influx from neighbouring countries, and the economic situation of the country. The water scarcity problem is aggravated by limitations in water management. This research investigated the shortcomings of water management that contribute to water scarcity. It involves a literature review, a survey questionnaire and interviews. These methods aim to assess the current challenges that prompt water scarcity, understand the water management shortcomings and their causes, identify the existing government solutions for water scarcity, and propose a sustainable solution for this problem.

The research finds that water management in Jordan has several shortcomings such as the lack of monitoring and controlling water resources and preventing illegal drilling, the incapability of the government to reduce the non-revenue water as a result of aged water network and water theft, and illegal practices of the agricultural and industrial sectors. This research proposed a solution that aim to mitigate water scarcity in Jordan by enhancing several management practices. Moreover, the proposed solution calls for efficient managerial practices to be adopted by decision makers and the public. I argue that the proposed solutions are sustainable and cheaper than the existing government solutions that rely on searching for new water resources rather than improving water management.

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Last but not least, I would also like to acknowledge the second readers of this thesis Dr. Sonia Wesche and Dr. Paul Heintzman, I am gratefully indebted for their valuable comments on this thesis.

Dedication

I dedicate this thesis to the soul of my father Khaled Al Omari who always inspired me by his motivation and determination and to my mother who is my director in life. This dedication also goes to my family; my husband Nasser and my lovely kids Nathalie and Mohammed who provide me with their continuous support. Last, I would like to thank my very special influential friends who were beside me in my hard circumstances and helped me to look at the brighter side of my life.

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Chapter 1 Introduction

1.1 Water Management and Sustainability

This thesis investigates the impact of water management upon water scarcity in Jordan with reference to the experience of some other Middle-Eastern developing countries by responding to certain gaps in the existing literature (as discussed below). It seeks to identify current water management limitations that may be addressed on the basis of solutions or responses suggested by the research.

Water management can play an important role in water sustainability. It involves employing various practices and measures in order to reduce the unnecessary use of water and water loss. These measures should be applied to water use in the domestic, agricultural, and industrial sectors. Effective water management can lead to water conservation and hence reaching sustainability.

A major water management aspect should consider managing water in the agricultural sector. For instance, 50% of water consumption in Jordan is used by the agricultural sector. Therefore, I believe a good water management for the agricultural sector can participate greatly to water sustainability in Jordan. According to a report issued by SAI platform (SAI, 2010), reaching water sustainability in farming comprises applying a set of practices that include the use of water saving devices, reduce water pollution from pesticides, replace damaged water gutters and water pipelines, compare the crop returns (yields) against the volume of water applied, and keep records of water irrigation performance. In the domestic sector, water management practices can lead also to water sustainability. This can be achieved by maintaining water pipelines and water

meters, and monitor water theft. Water sustainability is directly related to water management, however applying good water management is constrained by several factors such as the economic situation of a country and the awareness of people.

Before looking at the water situation in Jordan, it is necessary to define some concepts that will be used. The term sustainability is used in many contexts; the broader meaning of sustainability refers to the management of resources in order to meet the needs of people who are living now as well as future generations (Loucks & Gladwell, 1999). This definition can be applied to all natural resources, including water. The second concept is water scarcity which also refers to water shortage; it is a situation in which the demand for water is higher than the availability of freshwater resources (Science Daily, 2019). According to Pereira et al (Pereira et al., 2009), water scarcity happens when the amount of water per capita in a region, or a country is less than 1000m³/year. The third concept is water stress; used here to refer to a situation where people lack sufficient access to potable water. The fourth concept is water poverty; it is defined as a situation where a nation or region cannot afford the cost of sustainable clean water to all people at all times (Feitelson & Chenoweth, 2002). The water poverty line is calculated using the Water Poverty Index (WPI) that uses a mathematical formula that depends on five factors: water sources, water access, capacity, water use, and the environment. Each one of the factors also has different parameters (Cho & Ogwang, 2014). Since water scarcity affects food security, it is also vital to define food security. According a report by the Food and Agriculture Organization (FAO, 2006), "Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life".

The last concept to be introduced here is water management which is the primary subject of this research. Water management is the planning, developing, distributing and optimum use of water resources under defined water policies and regulations. Water management includes the treatment of drinking water, industrial water, and wastewater, as well as management of irrigation (OMICS, 2014). Water management arrangements for sustainability in Jordan are the ultimate focus of the overall analysis.

There are 2.1 billion people around the world who do not have access to good quality water (World Health Organization, 2017). Even though water covers around 70% of the earth's surface, only 3% of earth's water is fresh water (EurekAlert, 2015). Considering these statistics and the enormous growth of the world's population especially in developing countries, the future demand for secure and safe quality water will increase, and the water share per capita in these countries will decrease, which results in water scarcity.

Water scarcity in some developing countries is becoming an alarming issue that could cause a water crisis in the next few decades. A water crisis can have an impact on human health, and economy. It can create poverty and hunger because farming and agriculture depend heavily on water. Since water scarcity represents a current problem situation, we can predict that current and future water sustainability in affected countries cannot be achieved unless those countries adopt and apply effective regulations regarding the use and consumption of freshwater and conservation of its sources.

1.2 Water Scarcity in Jordan

Jordan is a small country of 89,500 km² located about 80 km east of the Mediterranean Sea. With a population of around 9.5 million, including 2.5 million refugees (Jordan Times, 2019) Jordan is bounded by Palestine and Israel from the west, Iraq from the east, Syria from the north, and Saudi Arabia from the south (see Figure 1).

Jordan has an altitude between -400 m at the Dead Sea surface (lowest point on earth) and 1,750 m at Jebel Rum. It has three different bioclimatic zones. The first zone is Jordan valley, it is a narrow strip located in the western part of the country at the border between Jordan and Palestine; it is below mean sea level and characterized by warm winters and hot summers. Also, this zone is an agricultural area



Figure 1: Map of Jordan source (Altz-Stamm, 2012a)

that depends mainly on irrigation. The second zone is the western highlands which is located to the east of the Jordan Valley. Here annual precipitation is in the range of 300 to 600 mm. The third zone, called the "Badia", is located on the eastern and southern part of the country in the area between the Iraqi and Saudi Arabia borders. The Badia includes arid and semiarid areas where annual rainfall is below 200 mm (Al-Bakri et al., 2013).

The temperature in Jordan varies between below zero in the winter to more than 40 degrees centigrade during the summer season. The annual precipitation ranges from 50 mm in the Badia to 600 mm in the highlands. On average, 9% of Jordan's highlands receives above 200 mm of annual rainfall. Jordan is heavily dependent on rainwater for drinking, agriculture, and industry. This dependence puts the country in a critical situation since the amount of rain fluctuates from one year to another.

The water scarcity problem is aggravated as a result of high population growth caused by war refugees from Palestine, Iraq, Lebanon, and Syria. It is also affected by the depletion of groundwater reserves and climate change which can create future challenges for the country. Jordan is one of the developing countries that has water scarcity. It is a highly compelling case since it is considered the fourth driest country in the world (Al-Ansari et al., 2014a). The average share per capita of renewable water resources is 135 m³ per year (Hadadin, 2015). This amount is well below the water poverty index threshold, which is 500 m³ per person per year (Altz-Stamm, 2012b).

1.3 Research Motivation

Jordan is one of the poorest countries in the world in terms of water scarcity. Millions of people in Jordan are suffering every year from water shortage, especially when rainfall is below average. This is an alarming problem that can jeopardize the economy

and the stability of the country. The situation is aggravated by climatic conditions, geography, and the region's geopolitical environment (section 2.4.2). Therefore, my motivation to conduct this research is not just about water security; it is also about food security since the country relies on agriculture that depends heavily on rainfall. For instance, the production of crops and vegetables in Jordan fluctuates every year depending on the amount of rainfall, which affects the economy and the agriculture sector.

Moreover, the sharing of scarce water with neighbouring countries such as Israel could provoke a war over water. This research aims to encourage the government of Jordan to enhance its water management. The lack of water management regarding the agricultural sector and the non-revenue water (water that does not produce revenue such as the old network), has significant impact on water scarcity (section 2.5.5). Moreover, conducting this research can help in understanding the real nature and the extent of the problem in order to propose suitable solutions or recommendations (see chapter 5).

Finally, there is a lack of literature that discusses the impact of water management on water scarcity in Jordan. Therefore, this research can enhance the knowledge on this dimension.

1.4 Research Scope

Effective water management is required to achieve sustainability in countries with limited freshwater resources. In this context, water management is governed by water strategies, policies, and plans that are established by the government of Jordan including the Ministry of Water and Irrigation and the Ministry of Environment regarding the use of water and conservation of water resources. Indeed, water management can be influenced by political, environmental, and social factors. For instance, the Jordan River is not

equitably shared by Jordan and Israel. In 1953, Israel planned a project to divert the Jordan River water to the arid south by building a project known as the National Water Carrier. Jordan, Syria, Lebanon, and Egypt rejected this project. The United States led negotiations between Israel and these Arab countries in order to reach an agreement about their water share and to stop Israel from building the National Water Carrier (Johnston, 2014). However, these negotiations failed due to the rejection by Israel and the Arab countries of the US proposals. Israel succeeded in building the National Water Carrier and it became operational in 1964 (Haddadin, 2004).

Although this background context is extremely important, developments in the international setting fall outside the scope of this thesis. This research focuses on the internal management challenges that impact and hinder water sustainability in Jordan. This study focuses on water strategies and policies, water treaties, water tariffs and their impact on water consumption, and water allocation for agricultural, industrial, and domestic uses.

1.5 Research Problem

The main research question asks whether existing water management practices in Jordan contribute to water scarcity and influence water sustainability. In order to provide an answer to this primary research question, we expanded it into several secondary research questions that can provide insight into the existing water situation in Jordan. The following questions are investigated:

Question 1: What are the existing water strategies and policies in Jordan?

Question 2: What are the primary sources of water in Jordan?

Question 3: What are the factors that have an impact on water scarcity in Jordan?

Question 4: What are the shortcomings of existing water management?

Question 5: What are the existing government solutions for water scarcity?

Question 6: What are the proposed management solutions for mitigating water scarcity in Jordan?

1.6 Research Objectives and Contributions

Water scarcity in Jordan is an alarming problem that can jeopardize the economy and the stability of the country. This research examines this problem and seeks to identify preventive measures, regulations, and water policies that mitigate water scarcity. The research findings could help to inform influential audiences such as UN agencies, private sector representatives, donors, policymakers, and government officials about the severity of the problem and its effect on Jordan. The main purpose of this thesis is to initiate a proposal for achieving water sustainability by suggesting efficient managerial practices to be adopted by decision makers. This objective can be achieved by carrying out the following directions:

- Identifying the different water resources and water allocation policies among different sectors.
- Assessing the challenges that prompt water scarcity in Jordan, including the management factors that cause water scarcity.
- Realizing the shortcomings of current water management by identifying factors that lead to these shortcoming
- Identifying existing government solutions for mitigating water scarcity in Jordan.

- Examining other non-managerial factors that prevent water sustainability in Jordan; this allows the identification of alternative suggestions for achieving water sustainability.
- Proposing some sustainable solutions that can mitigate the water scarcity problem.

1.7 Research Methodology

This research was based on a set of methods that are intended to answer the research questions. I used the following methods:

- Systematic literature review: The review aimed to collect existing information about water resources and water allocation for domestic, agricultural, and industrial sectors. Moreover, the review aimed to study the water strategies and policies in Jordan. Finally, the review investigated the environmental, political, geographical, and social challenges that have an impact on water scarcity in Jordan (see Chapter 2).
- Semi-structured interviews and survey. The interviews were conducted with Jordanian officials and researchers who are familiar with the water situation in Jordan. The survey targets university students and homemakers to gain perspective for results in several cities and towns in Jordan including Amman, Zarqa, Jerash, Al Azraq, Al Mafraq, and Irbid. It was used to gain information about the domestic use of water. It also helped to fill a gap in the literature by measuring the level of public satisfaction concerning water quantity and quality (see chapter 3).

- **Data analysis:** The collected information from the literature review, the interviews, and the survey were analyzed to understand the water scarcity problem. The analysis included clarifying and categorizing the data based on its relevance to the research questions. In addition, Excel were used to perform the necessary calculations for water consumption, water quality and water services. The analyzed results are discussed to identify realistic solution that support water sustainability for existing and future generations.

1.8 Thesis Organization

The rest of the thesis consists of four chapters: Chapter 2 provides a literature review about the water situation in Jordan. It examines the water resources and water allocation for different sectors. Also, it discusses the main challenges that have impacts on water scarcity. Furthermore, it discusses the current management strategies, the role of government organizations and the private sector to overcome the water crisis and investigates the gaps related to water management. Chapter 3 describes the research methodology that includes the questionnaire and the interview sampling and design. Chapter 4 provides the results and identifies the potential water management problems. It also provides some promising solutions that can be induced from the analysis of the literature review, interviews, and the survey questionnaire and on their applicability, and cost-effectiveness. Chapter 5 provides a discussion of the results and concludes the thesis, including suggestions for future research.

Chapter 2 Literature Review

This chapter provides a literature review of the factors that are related to the water scarcity problem in Jordan. Mainly, it discusses the water management factors that contribute to water scarcity and hinder water sustainability in Jordan. The literature review will also discuss the issues that concern water scarcity in some other Middle Eastern countries. Moreover, the review helps to identify and to investigate the existing water management solutions that can lead to water sustainability. The effectiveness of these solutions are analyzed in terms of their applicability and execution. This review covers the following aspects which are related to the central research question:

- Water problem in Jordan.
- Water resources in Jordan.
- Water consumption in Jordan.
- Water strategies and policies in Jordan.
- Comparison between Jordan with other developing countries
- Shortcomings of existing water management.

2.1 Identifying the Water Problem in Jordan

The share of water per capita in Jordan is one of the lowest in the world; it was around 135 m³/capita/year in 2014 (Hadadin, 2015). Experts consider countries with 1,000 m³/capita/year to be water-poor countries (Jaber & Mohsen, 2001). The minimum amount of water per capita/year should be 500 m³, any value less than this amount indicates a water scarcity problem (Hadadin et al., 2010). The water scarcity problem in Jordan stems mainly from the climate and the geographical location of the country. The

geography of Jordan places it in three distinct climate zones (see Figure 2) which have low average rainfall (MWI, 2017b).

The first zone is a strip along the western part of Jordan called the Jordan Valley. This zone is an agricultural area that depends mainly on irrigation (Ammary, 2007). The second zone is the eastern Badia of Jordan which is located in the eastern and southern part of the country bordering Iraq and Saudi Arabia. It is a desert that comprises 90% of Jordan's area; The Badia includes arid and semi-arid areas where the annual rainfall is below 200 mm (Al-Bakri et al., 2013). The third zone is related to the highland plateau which delineates the Jordan Valley from the eastern Badia region. It has a Mediterranean climate; the average rainfall in this zone is 580 mm/year (Alkhaddar et al., 2005).

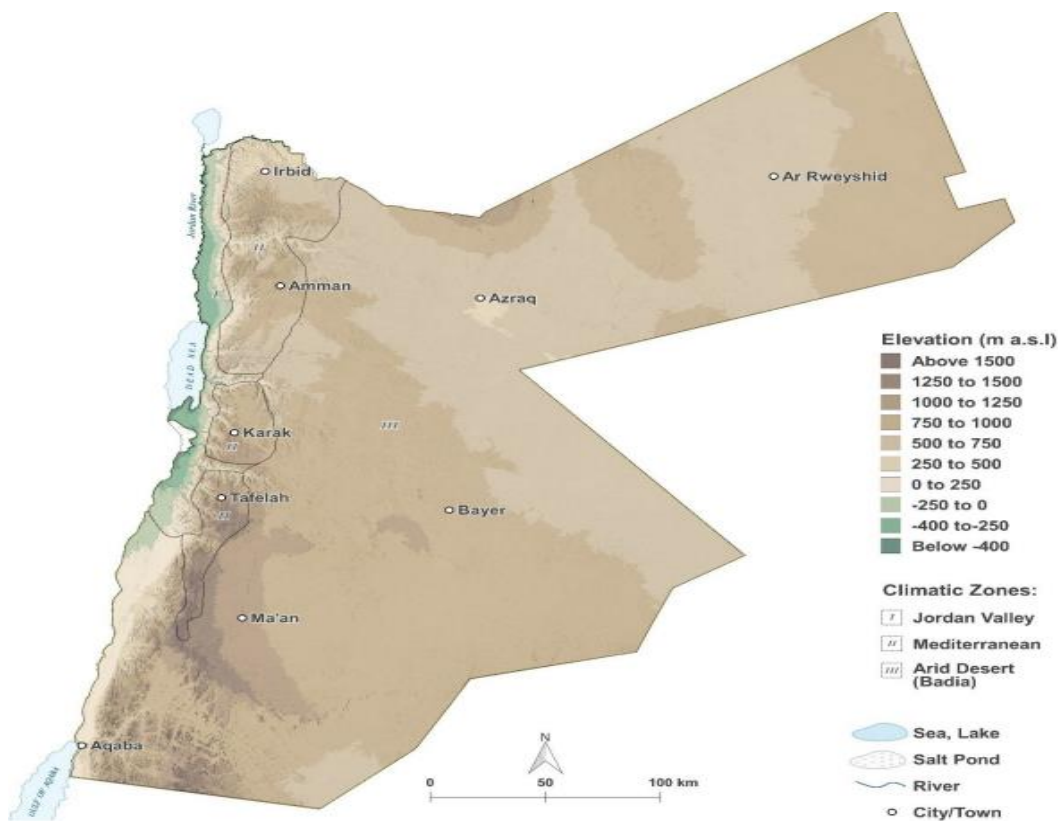


Figure 2: Elevations and climate zones in Jordan source (MWI, 2017b)

The arid climate in Jordan causes a high percentage of rainfall evaporation; only a small percentage is used to recharge groundwater and surface water. The annual precipitation ranges from 50 mm in the Badia to 600 mm in the highlands.

Beyond climate and geography the water scarcity problem is linked to other factors other than Jordan's climate and geography. There are environmental, political, social, and managerial factors that contribute to the problem. For instance, Jordan's water strategies and policies lack application as a result of uncontrolled factors such as the growth of Jordan's population. This growth has resulted from wars in the neighbouring countries of Jordan and the influx of refugees from these countries to Jordan. These considerations are discussed further below in Section 2.5

2.2 Water Resources in Jordan

The conventional water supply in Jordan comes from three primary resources; surface water, rainfall, and groundwater. In addition, Jordan develops some unconventional water resources such as treated wastewater. The agricultural and industrial sectors are using all water resources; however, only surface and ground waters are used for domestic purposes. Rainfall has a significant impact on recharging the surface water and groundwater supplies; however, a high percentage of rainfall evaporates and is therefore unavailable for recharge.

Surface water in Jordan comes mainly from the Jordan River and the Yarmouk River basin which accounts for 40% of the surface water in Jordan. However, the waters of the Jordan and Yarmouk rivers are not only used by Jordan; they are also shared with Syria and Israel. Surface water also comes from the discharge of groundwater by springs and the floodwater from rainfall. Jordan has twelve main dams that hold floodwater. The

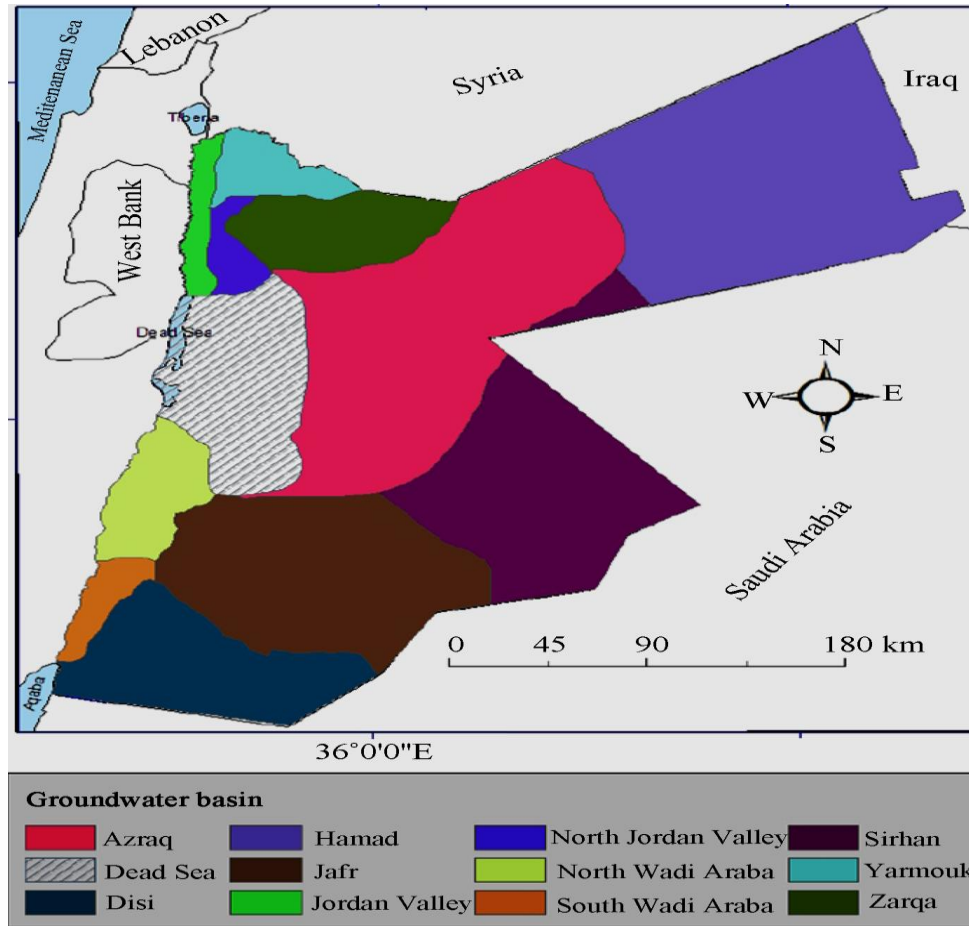


Figure 3: Groundwater Basins in Jordan, source (Al-Ansari et al., 2014b)

capacity of these dams is about 335.3 Million Cubic Meters (MCM), and their total inflow was 219.594 MCM in 2017 (MWI, 2017). Groundwater is the primary resource for drinking water in Jordan. Groundwater is generated from 12 basins that are comprised of several groundwater aquifer systems (see Figure 3).

The Dissi aquifer is the main nonrenewable groundwater resource in Jordan with a safe yield of 125 MCM/y for 50 years (Jaber & Mohsen, 2001). The total safe yield for these basins in 2017 was 418.5 MCM, and the total water abstraction from these basins was 641.06 MCM with a deficit of -223.37 MCM (see Table 1). There are approximately

3000 active wells monitored by the government of Jordan (MWI, 2017b). Groundwater in Jordan can be described to be in critical condition since most of the groundwater resources are overexploited (MWI, 2017b).

Treated wastewater is an un-conventional water source in Jordan. It is mainly used in agriculture and industrial sectors for irrigation and industrial uses. Treated wastewater is characterized by a low cost compared to other un-conventional water resources such as seawater desalination and is considered a significant component of the national water budget. Jordan is making good progress in this direction by constructing 34 high-quality wastewater plants at different locations in the country with a total capacity of 639,320 m³. The largest plant is Al-Samra Waste Stabilization Ponds; the outflow from this plant comprises about three-fourths of collected wastewater in Jordan (Ammary, 2007). In 2017, the treated wastewater from these plants was 163.68 MCM (MWI, 2017). It is

Table 1: Groundwater Basins in Jordan (MWI, 2017)

Groundwater Basin	Safe Yield (MCM)	Abstraction (MCM)	Deficit/surplus (MCM)
Dissi	125	141.58	-16.58
Amman-Zarqa	87.5	164.98	-77.48
Yarmouk	40	54.53	-14.53
Jordan Side Valley	15	45.64	-30.64
Azraq	24	69.66	-45.66
Jafer	27	35.53	-8.53
Jordan Valley	21	27.04	-6.04
Dead Sea	57	83.85	-26.85
Araba South	5.5	10.9	-5.4
Hammad	8	1.59	6.41
Sirhan	5	0	5
Araba North	3.5	6.56	-3.06
Total	418.5	641.06	-223.37

Table 2: Water consumption in Jordan (MWI,2017)

Sector	Surface Water	Groundwater	Treated Wastewater	Consumption per sector
Domestic	131.3	338.4	0	469.7
Agriculture	154.4	253.2	144.2	551.8
Industry	2.4	27.2	2.5	32.1
Total	288.1	618.8	146.7	1053.6

estimated that by the year 2020 wastewater treatment plants will produce around 245 MCM (Ammary, 2007).

2.3 Water Needs and Consumption in Jordan

Jordan's water need is shared by three main sectors; agricultural, municipal or domestic, and industrial. These sectors consume close to 1000 MCM per year. On the other hand, the fresh water supply is between 780-850 MCM per year (Altz-Stamm, 2012b). This level of supply results in a water deficit of approximately 225 MCM per year. The municipal sector is the largest consumer of surface and groundwater supplied by government, despite the low consumption per capita, which is about 135 m³/capita/year. In the year 2017, all three sectors were using 1053.6 MCM from the three water sources (see Table 2). The domestic water use was 469.7 MCM (44%); it comes mainly from surface water and groundwater supplies.

The agricultural sector is the most significant consumer of the overall water resources in the country because it has direct access to wells (legal and illegal) as well as re-used wastewater and conventional sources. The agriculture sector used 551.8 MCM in the year 2017 (MWI, 2017). Most of the lands irrigated by surface water are located in the Jordan Valley and the flat land along the banks of the perennial streams.

Water management in the area is the responsibility of Jordan Valley Authority (JVA) which is a regional governmental agency. The JVA drilled deep groundwater wells during the 1970s and 1980s (Molle et al., 2008) to allow larger areas to be irrigated in Wadi Araba and the northern part of the Jordan Valley. In general, the irrigation of the highlands depends mainly on groundwater resources (Roques, 2015).

Industrial sector water consumption is the lowest among the three sectors. It was only 32.1 MCM in 2017; 4% of the total water consumption (MWI, 2017a). The most substantial parts of this amount are consumed by phosphate mining (13.8 MCM), potash mining (9.6 MCM), and petroleum refining and the El-Hussein Thermal Station (5.1 MCM). It is difficult to verify the accuracy of these figures which include only industrial water users who obtain their water from private wells and major water users connected to the public network. Almost all industries in Jordan suffer from water shortage, which has led them to recycle their wastewater wherever and whenever possible. The treated wastewater is only used for agricultural and industrial purposes; however, all sectors are also using surface water and groundwater (see Table 2).

2.4 Water Strategies and Policies

Jordan's government has adopted several water strategies and associated operational programs that focus on the economic, social and environmental dimensions of water policy in order to mitigate the water scarcity problem. In 1998, Jordan adopted the first water strategy, "Jordan Water Strategy and Policies" (MWI, 2004). The strategy is supplemented with four water policies related to groundwater management, irrigation water, wastewater management, and water utilities. The policies have significant emphasis on the role of the private sector in balancing between water supply and demand

(Mohsen, 2007). In 2008, Jordan adopted the second water strategy, “Water for Life”, for the years 2008-2022 (MWI, 2009). The strategy focuses on the Dissi water conveyance and the Red-Dead Canal. The Red-Dead Canal will be connecting the Red Sea to the Dead Sea by pipelines that brings a large supply of desalinated water produced by the Red Sea water to compensate the decrease in the water level of the Dead Sea. In addition, the desalinated water can provide Jordan with clean drinking water and generate electricity. The Dissi project is already completed and the Red-Dead canal should be operational by 2022. Also, the strategy emphasizes that the non-revenue water (NRW) would not exceed 25%, however, there is no indication in the policy about the tools for achieving this percentage. Finally, it states the importance of defining cost-effective tariffs and introducing a new Water Law, Water Regulatory body and a Water Council (MWI, 2009).

In 2016 Jordan adopted the “National Water Strategy” for the years 2016-2025 (MWI, 2016). The strategy builds on the recently developed sector policies and emphasizes several issues such as the implementation of the approved action plan for reducing water losses, the development of strategic projects such as a Nuclear Power plan, and the Red–Dead conveyance. Also, it focusses on the increased demand for water as a result of the Syrian refugee influx, the exploitation of groundwater resources, and the adoption of the new technologies and techniques for wastewater reuse.

Although these strategies call for useful actions in order to achieve water sustainability, many experts believe that government water policies fail to meet the increasing demand for water as a result of population growth. These policies are very limited in many aspects such as regulating highland groundwater abstraction, raising

tariffs and correcting distorted incentives, and reducing non-revenue water use (Al-Jayyousi, 1995; Molle, 2008; Rajsekhar & Gorelick, 2017; Yorke, 2013). These aspects are explained in section 2.5.5.

2.5 Factors that Impact Water Scarcity in Jordan

As discussed in Section 2.1, Jordan is considered among the poorest countries in terms of water resources. Many factors influence water scarcity in Jordan; some of these are human made, others are natural as human intervention is limited. The factors that impact water scarcity in Jordan can be grouped into the following categories:

- Natural factors (geographical location, climate)
- Environmental factors (pollution, climate change)
- Demographic factors (Natural growth rate, immigration)
- Political factors (international treaties, local legislation)
- Management factors (economy, awareness, non-revenue water, infrastructure, technical and maintenance, illegal wells, water recharge).

A discussion for these factors is provided below.

2.5.1 Natural Factors

Natural factors refer to those that human intervention has no or limited control over; these include geographical location, topography, climate, evaporation, and average rainfall. Section 2.1 pointed out that Jordan's geographical location and topography results in three climate zones characterized by an arid or semi-arid climate. As a result, the average annual rainfall is low; 80% of the country is receiving a rainfall of less than 100 mm/year (Awawdeh et al., 2014) and the average annual precipitation is around

300mm/year (Hadadin & Tarawneh, 2007). Although Jordan is building several dams to preserve the maximum amount of rainfall, 93.5% of the rainfall amount evaporates as a result of the high temperatures during summertime. Moreover, 90% of Jordan's area is a desert (Al-Bakri et al., 2013) with an arid climate in which the temperature in winter is between 2-9 C° and rises during summer to more than 40 C° (Awawdeh et al., 2014).

2.5.2 Environmental Factors

Environmental factors such as pollution and climate change play a significant role in the exploitation of the amount and quality of rainfall and surface water in most countries of the world (Balbus et al., 2013). The impact of climate change on the water scarcity problem in Jordan can be seen from the statistics on rainfall and evaporation. For instance, the reported rainfall in Jordan in 2017 was 8165 MCM, but only 362 MCM (4%) recharged the groundwater (Mohsen, 2007), while 7636 MCM evaporated (93.5%), and 167 MCM flooded into rivers and dams (MWI, 2017). Moreover, the country is expected to suffer a decrease in rainfall by 30% by 2100 and increase in the annual temperature by 4.5 C°, especially with the absence of international climate change policy action (Rajsekhar & Gorelick, 2017). This decrease will reduce water availability and increase water demand. Also, the impact of climate change on water availability has been reported by many studies. According to a study that simulates the effect of climate change on rainfall and drought in Jordan between the years 2011 and 2100 the country will suffer a decrease in rainfall of 30% by 2100 and the annual temperature will increase by 4.5 C°. The study also shows that multiple drought-type occurrences will increase within the next

30 years; The number of drought are projected to be between ~8 and ~25 (Rajsekhar & Gorelick, 2017).

Another study conducted by the National Oceanic and Atmospheric Administration (NOAA) in the United States shows there is a trend towards a drier climate in the Mediterranean Basin (Greenwood, 2017). Datasets of monthly precipitation records from 1900 to 2010, show that Middle Eastern countries are currently experiencing a pattern of increased drought. According to Greenwood (Greenwood, 2017), the World Bank report on water scarcity in the Middle East and North Africa shows that these regions are the most water-scarce regions of the world. The report classified Jordan as one of the most "hyper-arid" countries in the Middle East. In 1992, several old underground springs that feed many wetlands in some parts of Jordan such as the Al Azraq wetlands, Jerash, and Kerak had stopped flowing.

Regarding water pollution, the problem started in Jordan after the 1970s because of population increase, urbanization, and the development of land for industrial uses. Moreover, economic development during the past two decades has created a significant negative influence on the quality of the groundwater and surface water resources (MWI, 2009).

Concerning surface water pollution, there are three major rivers in Jordan, the Jordan, the Zarqa, and the Yarmouk. The Jordan River is saline and thus not directly suitable for drinking or irrigation. The Zarqa River flows near residential and industrial areas; therefore, it is substantially polluted by municipal and industrial waste. The Yarmouk River is the least polluted; however, much untreated municipal waste is dumped into the river. In addition to these rivers, King Talal Dam reservoir is the largest water

reservoir in Jordan. This reservoir is in danger from factories which emit untreated waste into it raising its water salinity and chemical levels (Hadadin & Ziad Tarawneh, 2007). A study conducted in 2010 on water samples from the Zarqa River, King Talal Dam, Wadi Al-Arab Dam, and Mujib Dam reported that 12 semi-volatile organic chemicals (SVOCs) exist in all water samples.

Moreover, the study shows that King Talal Dam and Zarqa River have a more significant number of pollutants and concentration levels (Zaater & Khater, 2017). Finally, a joint study about the water quality in Jordan conducted by the Water Authority of Jordan, Ministry of Environment, and the Royal Scientific Society indicated that 70% of spring water has biological contamination due to high fecal coliform counts from non-point pollution sources, including wastewater treatment plants operating over capacity. The study also shows that water resources have a significant level of toxicity as a result of industrial discharges and unregulated use of fertilizers and pesticides, which increase the concentration of nitrates and phosphorus in water (Jaber & Mohsen, 2001).

2.5.3 Demographic Factors

Jordan has witnessed an increase in its population due to demographic and political factors. The stability of the political system in Jordan creates a safe environment for refugees from its neighbouring countries: Palestine, Syria, Lebanon, and Iraq. Jordan has witnessed big waves of forced immigration from Palestine in 1948 and 1967 because of the Arab-Israeli war, from Lebanon in 1987 because of the civil war, from Iraq in 2001 because of the Gulf War, and lately from Syria because of the civil war in 2011. According to international treaties, Jordan has no right to prevent refugees from entering its borders (Costa, 2006).

The population of Jordan has increased from 5.6 to 7 million Jordanian people during the period from 2006 to 2014 in addition to 2.5 million people of other nationalities, making the current total population 9.99 million (WorldMeter, 2019). In addition to the waves of immigration, there is a big gap between the birth rate and death rate in Jordan. The birth rate in Jordan is relatively high; it is around 2.2% compared to the world average birth rate (1.8%) These statistics explain the big increase in Jordan's population which has almost doubled since 2006.

Accordingly, the demand for water has greatly increased while the water resources are minimal. For instance, Jordan's average share of water per capita in 1946 was 3,600 m³/year; but in 2014, the average share per capita decreased to 130 m³/year. This amount is expected to decrease to 100 m³/year, by the year 2025 which is equivalent to 10% of the average per capita rate in the rest of the Arab world (Jordan Ministry of Environment, 2016).

2.5.4 Political Factors

The political situation in the Middle East has a major impact on water sustainability in Jordan. The regional instability negatively influences the water scarcity problem in Jordan; this instability is a result of the Arab-Israeli disputes, the civil wars in the neighbouring countries, and the lack of Jordan's ability to enforce its water rights. As shown in Section 2.5.3, the vast growth of Jordan's population is caused mainly by the influx of war refugees from Jordan's neighbouring countries. The sudden growth of Jordan's population creates pressure on Jordan's water resources.

Also, the essential resources of surface water in Jordan, the Yarmouk River and Jordan River, originate outside Jordan's borders with their flows both diminishing and

unpredictable as a result of unequal distribution among riparian states or over-extraction through upstream damming and diversions (Yorke, 2013). Therefore, the allocated water that Jordan can get from these resources is governed by the wellbeing of the relationship between Jordan and these countries. Jordan made great efforts in securing its water share from the Yarmouk and Jordan Rivers by signing several water treaties with Syria and Israel. In 1955, Jordan, Syria, Lebanon, and Israel adopted what is called the 'Johnston Unified Water Plan' which was developed by the US ambassador Eric Johnston (Johnston, 2014). The plan gives Jordan, Syria, and Israel access rights to the shared water resources of Jordan, Hasbani, and Baniyas Rivers. A preliminary allocation gave Israel 394 MCM/year, Jordan 774 MCM/year, and Syria 45 MCM/year.

Moreover, the agreement allows Jordan (with a fund from the United States), to build the King Abdullah canal of a length of 110 km in the Jordan Valley below the Sea of Galilee. Similarly, it allows Israel to construct a similar National Water Carrier with a 85 km long system consisting of pipelines, open channels, tunnels, re-regulation pools and distribution reservoirs (Roger, 2004). Subsequently series of actions took place between Syria and Israel which led to tension between the Arabs and Israelis that led to the 1967 war. These actions resulted in the diversion of the Jordan River water flow by Israel and Syria, reducing the amount of Jordan's water share.

On October of 1994, Israel and Jordan signed the peace treaty. The treaty contains a particular article about water (Elmusa, 1995). The article has seven main points regarding water allocation from the Yarmouk and Jordan Rivers and the Araba groundwater. First, regarding the water allocation from the Yarmouk River, Israel pumps 12 MCM from the Yarmouk River during summertime, and Jordan gets the remainder.

During winter, Israel pumps 13 MCM and Jordan is entitled to the remainder. Moreover, subject to provisions, Jordan concedes to Israel pumping an additional 20 MCM from the Yarmouk in winter in return for Israel conceding to transferring 20 MCM from the Jordan River to Jordan during the summer period. Second, regarding the allocation of the Jordan River water, Israel accepted to transfer to Jordan an amount of 20 MCM of water during summertime in exchange for the 20 MCM Israel extracts from Yarmouk River during wintertime, with Jordan paying the operational costs. During wintertime, Jordan is entitled to store for its use a minimum average of 20 MCM of the floods in the Jordan River south of its confluence with the Yarmouk River. Third, Jordan is entitled to a quantity of 10 MCM/year of desalinated water from the desalination of about 20 MCM of saline springs diverted to the Jordan River. Israel will explore the possibility of financing the operation and maintenance costs of supplying the desalinated water to Jordan. Fourth, Israel and Jordan shall cooperate in finding other sources to supply Jordan with an additional 50 MCM/year of water that meets drinkable standards. Fifth, regarding the storage of water, both countries agreed to cooperate to build a diversion/storage dam on the Yarmouk River directly downstream of the point 121 Adassiya Diversion in Jordan. Sixth, both countries shall cooperate to build a system of water storage on the Jordan River, along their common boundary, between its confluence with the Yarmouk River and its confluence with the Tirat Zvi Wadi Yabis (Israel Ministry of Foreign Affairs, 2013). Seventh, the two countries agreed to alleviate the water shortage by developing existing and new water resources and minimizing water contamination and water waste. Despite the conflict between Israel and the neighbouring countries for a half-century, this treaty is considered a major achievement in water management for both Israel and Jordan.

In 1997, a second stage of the treaty began. This stage includes a requirement that Israel has to supply Jordan with 3000 m³/hour. The last stage of this treaty proposed that Jordan has to receive an additional 25 MCM of water per year. After that, Israel and Jordan signed an agreement to build a desalination plant on the Red Sea-Aqaba in 2013. While these treaties guarantee some access rights for Jordan to the water of Jordan and Yarmouk rivers, it was described by some analysts as minimal rights (Elmusa, 1995; Fischhendler, 2008)

Concerning the Yarmouk River, Syria agreed in 1987 to supply Jordan with 208 MCM/year, but Jordan reportedly receives only around 50 MCM. Water experts argue that Syria's construction of numerous dams upstream and the digging of wells has deprived Jordan of its rightful share under bilateral agreements (Yorke, 2013). Jordan also made agreements with Syria to build the Al Wehdah Dam at the Yarmouk River between the two countries; the dam started its operation in 2006 with a total capacity of 110 MCM (Hadadin, 2015).

2.5.5 Water Management Factors

Water management factors represent all the factors that have impact on providing water and water services for domestic, agricultural, and industrial sectors. The literature review shows a lack of water management with respect to the following factors:

Managing Groundwater Abstraction

The first water strategy (1998) regulated groundwater abstraction. The 2002 By-Law mandated that illegal wells shut down (MWI, 2004). Many experts believe that there is no real enforcement of this By-Law; this is due to many factors. First, there is a strong resistance from powerful landowners and farmers. These people are using their power to

excavate water wells legally or illegally in order to plant their lands with trees and enhance land value. According to some government officials, the number of overexploited wells in 2011 was 2000 wells; 50% of these were drilled illegally (Yorke, 2013). Second, a By-Law amendment in 2004 states illegal wells could register for inclusion in the Ministry of Water and Irrigation monitoring program. This By-Law contradicts the 2002 By-Law and makes it easy for people to violate the law (MWI, 2004). Third, government authorities in Jordan lack the ability to control and monitor the illegal drilling of water wells. Despite the legislation that prohibits drilling unlicensed wells, many people break the rules. In addition, there are many cases of water theft where landowners pump over the permitted amount despite the presence of water monitoring meters. For instance, in 2001 only 61% of the meters on Jordan Valley wells were functioning correctly. Also, water meters are not protected in a box closed with a padlock which makes it easy to tamper with them (Venot & Molle, 2008). The lack of regulating and monitoring groundwater abstraction has partially contributed to the water scarcity in Jordan. Table 1 shows that the documented water abstraction accounts for more than 51% in excess of safe yield with a deficit of 223.37 MCM in 2017.

Managing Water Tariffs for Agricultural Usage

Water tariffs also contribute to the water scarcity problem. Jordan's government has been criticized for the failing to enforce water regulations and setting low prices for water for agricultural use, which encourages farmers to grow plants that require large quantities of water. As indicated in Table 2, agriculture usage of water exceeds 50% of total water usage among all sectors. The government established policies for irrigation water use and set a block rate tariff. Between the years 1962-1992, the government provided

licenses to drill wells for agricultural use. Most of these licenses set a quota for each well at 75,000 m³/year and sometimes 100,000 m³/year. In 2002, Jordan's government passed the Groundwater Control Bylaw no. 85 to regulate groundwater abstraction in the highlands, which provides a quota of 150,000 m³/year per well and a block tariff system activated beyond that quota. Also, it was perceived as an essential law for controlling agricultural groundwater abstraction. However, in 2004, an amendment was introduced for lowering of the already low fees for the volumes abstracted in licensed wells of between 150,000 and 200,000 m³/year per well. After this amendment, these volumes were charged at \$0.007/m³ instead of \$0.035/m³ (Venot & Molle, 2008). Moreover, the 2004 amendment called for a revision of the block tariff in 2008. However, rates today still reflect those of 2004 and fees are often not collected, even from legal wells (Yorke, 2013).

Managing Water Loss and Non-Revenue-Water (NRW)

Water loss is defined as the water supplied or used which returns no revenue. Water loss can be technical loss which is caused by breakdown or leakage within the distribution pipe system, or it can be administrative loss due to broken water meters, human errors such as issuing incorrect bills, or weak governance (Al-Ansari et al., 2014b). Before 2007, the Water Authority of Jordan (WAJ) was responsible for allocating water to all sectors. WAJ reported that 55% of the municipally supplied water is lost to non-revenue water. According to one estimate (Yorke, 2013), the reported municipal NRW loss in 2009 was 137 MCM of the total municipal allocation of 320 MCM. The main factors that contributed to NRW are the leakage caused by the aged municipal water pipe networks, illegal pumping, illegal wells, theft, and inaccurate water meters. According to the statistics from the World Bank for the period 1999 to 2004, almost all the governorates in

Jordan lose about 50% of the supplied water, except Jerash that has the lowest percentage (see Table 3). Administrative loss accounts for 27% to 32.8% of which 11.8% is related to illegal water use, 10.6% is related to faults in water meters, 5.3% is related to faulty readings, and 3% is related to the faulty estimation of the volume of water consumed (Al-Ansari et al., 2014b)

Non-revenue water loss has stayed at a high level despite spending by Jordan's government spending on infrastructure repair funded by the USAID's Instituting Water Demand Management (IDARA) program. In addition, the government is favouring the involvement of the private sector in water and wastewater services. Thus, in 2007 the WAJ granted three private companies (Miyahuna, Yarmouk Water Company, and Aqaba Water Company) authorization to deliver water services to Aqaba in the south and northern governorates while WAJ remained in control of both bulk supply and distribution in the remaining governorate.

2.6 Water Scarcity in other Middle Eastern Countries

Water scarcity in Jordan can be better understood on the basis of comparison. Accordingly, it is helpful to examine the water situation in other Middle Eastern countries

Table 3 : Percentage of Water Loss in Governorates of Jordan from 1999 to 2004, source (Al-Ansari et al., 2014b)

Governorate	Amman	Irbid	Zarqa	Madaba	Balqa	Karak	Tafela	Maan	Mafraq	Ajloun	Jerash
1999	50.03	45.71	55.34	75.03	56.13	56.77	47.51	62.27	76.39	47.96	42.94
2000	50.29	44.34	54.75	58.21	54.73	56.35	41.34	59.86	74.57	44.67	44.71
2001	50.03	41.92	55.03	58.33	46.76	56.59	38.85	53.51	74.34	37.19	33.56
2002	47.29	42.16	55.78	50	53.94	51.91	44.58	52.31	70.61	40.56	37.18
2003	48.53	39.57	51.48	46.46	51.59	47.47	43.31	46.78	68.21	37.41	23.8
2004	44.89	35.08	51.2	46.5	53.86	47.51	41.25	45.19	64.5	28.19	29.38
Average	53.02	49.66	53.6	62.8	57.01	53.8	49.72	54.24	69.13	41.4	36.93

such as Syria, Iraq, and Iran. Those countries share with Jordan similar factors influencing water availability such as the impact of climate change and the geographical location, which lead to high evaporation during summertime. However, each of these countries has other reasons that lead to water scarcity. This section summarizes the water situation in Syria, Iraq, and Iran.

First, Syria is located to the north of Jordan. There are many similarities between the two countries in terms of geographical topology, Syria has three main big rivers, the Euphrates, Tigris, and Orontes that supply Syria with its water needs. The civil war in Syria that began in 2012 had a big influence on decreasing the share per capita for the Syrian population. Before the beginning of the civil war Syria was among the best middle eastern countries in terms of water availability (Fanack, 2018). The war created a big demographic change in which many people moved from rural to urban areas that lead to water scarcity in urban areas. According to a United Nations report (UN, 2018) more than 1.5 million people, mostly farmers, moved to urban areas. In addition, some rebel fighters gained control over some water sources such as the Tishrin hydroelectric dam on the Euphrates River. Other water sources were also contaminated during the civil war which created a water crisis. For instance, in 2017, the United Nations condemned the Syrian government for contaminating some water supplies with diesel and bombing other water facilities. The UNICEF reported that about 5.5 million people in Damascus and Rural Damascus as well as 1.8 million people in Aleppo were deprived of access to safe water. In other areas like Raqqa city, which is controlled by ISIS, people were digging their own wells because they cannot easily relocate to areas with clean water. The share per capita

declined from 12,185m³ in 1992 to 809 m³ during the war (Gleick, 2014).

Turning next to Iraq, the water situation in that country is similar to the water situation in Syria. Iraq has the Euphrates and Tigris Rivers that supply Iraq with most of the country's water needs, while the groundwater abstraction accounts for only 2%-9% of the overall needs. However, Iraq ranks among the countries that are most vulnerable to climate change which is expected to lead to rising temperatures and droughts.

According to Lossow (Lossow, 2018), Iraq at the domestic level suffers from a decline of water resources, poor water management and water policies, and conflicts for more than 30 years which aggravate the water crisis. The war created a mass destruction of water infrastructures and facilities that need major capital investment. The government became unable to manage upstream sources and enforce regulations for water pollution and sewage. In addition, people lack the awareness about water conservation. Farmers rely on inefficient flood irrigation and families leave taps running unnecessarily. According to the Arab Weekly Magazine (Arab Weekly Magazine, 2019) the United Nations estimated that Iraq's daily per capita water consumption is nearly double the world's standard.

On the international level, the neighbouring countries of Iraq, Turkey and Iran built several dams that caused a major decline in the water flow of the Euphrates and Tigris Rivers. For instance, the Tigris tributaries originating in Iran, account for 9%-13% of the Tigris waters. Iran has built a series of dams at these tributaries over the last decade, which resulted in a dramatic reduction of the river's inflow (Lossow, 2018)

The next comparison is with Iran. The water situation in Iran is a little different since Iran has a diverse topography. The lowest point in the South is 28 meters below sea level

and the highest point is Mount Damavand which is 5,671 meters above sea level. One-fourth of the country comprises deserts and almost one-fourth of it is arable. The rest is worn mountains and highlands. Temperatures can vary from -20 to $+50$ °C (Kaveh Madani, 2005)

Iran has water management issues which rely on curing the symptoms rather than finding the causes of the problem. The Water crisis in Iran is caused by the rapid growth of population and the inappropriate spatial population distribution, the inefficient agriculture sector and the mismanagement and thirst for development (Madani, 2014). Iran's water resources are declining as a result of drought, mismanagement, and conflicts. For instance, Lake Urmia considered as the largest lake in the Middle East and one of the world's largest hypersaline lakes has significantly shrunk as a result of frequent droughts and excessive diversion of the water. Lake Hamun is disappearing as a result of the conflict between Iran and Afghanistan over the Hirmand River and the mismanagement of water in the Iranian side of the watershed. The Zayandeh-Rud River in central Iran dries up seasonally which imposes pressure on agriculture, industry, and urban populations (Madani & Dinar, 2012). In terms of access to clean water, most Iranians have access to clean drinking water sources and sanitation facilities. Iran's domestic water supply has been generally good and significantly better than other Middle Eastern countries (Madani, 2005).

In conclusion, water scarcity in Syria, Iraq, and Iran can be related to similar natural factors such as climate change, precipitation change, and topography. In addition, the wars in Iraq and Syria led to the destruction of water infrastructures and poor water

management. However, these countries have rich water resources such as lakes and rivers which enable them to overcome some challenges.

In the case of Jordan, the situation is different as, the country is politically stable. However, Jordan lacks sustainable water resources and has a poor economic situation, in addition to other factors that affect water scarcity which were discussed in Section 2.5.

2.7 Summary

This chapter elucidates the water strategies and policies, water sources, water consumption, and the factors that impact water scarcity in Jordan. The literature review shows that Jordan has a potential water problem caused by political, demographic, environmental, and management factors. However, the main concern of this review is to examine the shortcomings of water management and its impact on water scarcity. The review reveals that water management in Jordan has some pitfalls related to ground water abstraction, non-revenue water, water theft, lack of water consumption monitoring, and low water tariffs in agriculture. These shortcomings encourage water consumption and abuse of groundwater and surface water resources. Although Jordan set many regulations regarding water consumption, the literature review did not provide a practical solution with respect to water management that can mitigate the water scarcity problem. Therefore, my research will examine the shortcomings of water management in order to propose a sustainable and non-expensive solution for water scarcity in Jordan.

Chapter 3 Applied Research Methodology

This chapter focusses on the research methodology for collecting data about water scarcity in Jordan for the purpose of investigating considerations that were not fully discussed in the literature review. The purpose of the research is to show that water management flaws have negative impacts on water scarcity in Jordan. The research started by focusing on the main research question that comes from the thesis problem explained in Section 1.5. The question asks whether ineffective water management contributes to the water scarcity problem in Jordan. This aspect of the research was carried out according to the general guidelines for conducting surveys in social science (Oxford University Press, 2019) and the requirements of the Ethics Committee at the University of Ottawa which approved the survey under the project H04-18-01 (see Appendix A).

3.1 The Methodology

The research methodology focusses on collecting data related to water usage, water management, and water services in Jordan. In addition to the literature review that is presented above, I used two methods for collecting data: interviews and distributing a survey.

The interviews were conducted with government officials in Jordan whose professional training and employment relates to the water sector in general. In addition, the interviews involved some people from academia, policy makers, and researchers who are interested in different water issues in Jordan. In contrast with the interview process, whose participants were selected based on professional experience and expertise, the questionnaires were distributed to anonymous university students who reside in different

cities in Jordan and to homemakers. To protect the anonymity of the participants no identifying information was collected from them. The aim of the questionnaire was to get an insight about water consumption and water quality from the point of view of consumers. The questions in the interviews and the questionnaire are aligned with the main research question. I paid attention to devising questions that aimed to collect accurate information about the quality of water, water management, water usage, and water services. For instance, the interview questions focused on understanding the obstacles that the government is facing with respect to water services. I tried to understand the short term and the long-term issues that hinder water sustainability in Jordan. Moreover, the interview questions aimed to understand the views of the officials and researchers that can help to overcome the water scarcity problem.

3.2 Sampling Strategy of the Interviews

The aim of choosing interviews is to have in depth information about the water situation in Jordan. The expert sampling strategy combined with the Snowball sampling (also known as chain-referral sampling) method were used to select the interviewees. In the expert sampling I targeted around 6 experts who have good knowledge about the water issues in Jordan. The Snowball was used to identify other possible participants who can contribute with more knowledge in order to enrich this research. The referral of the other interviewees was based on the nominations of the experts' sample. The Snowball strategy is a well-known method in which one primary data source can refer another data source (Davieres & Dawson, 2014).

Prior to the interviews, I searched for key persons through the Internet, and friends from the Ministry of Water and Irrigation in Jordan who could provide me with information about

water scarcity and management in Jordan. I used the Internet for searching the different departments of the Ministry of Water and Irrigation. I identified some names then I contacted them through emails for possible appointments for interviews. Originally, I identified 6 people, but after I started my interviews, some participants referred me to other officials, professors, and researchers from different ministries and universities. Those participants were chosen based on their expertise and positions. I received verbal permission from all interviewees to indicate their names and positions in my thesis, prior to the start of their interviews.

The total number of interviewees was 17 participants, this sample size was determined based on the theoretical saturation method. It represents experts from different fields that can offer different perspectives about water scarcity in Jordan. This sample size was enough to answer all questions related to my research problem.

Regarding the type of interviews, I designed a Semi-structured interview in which main questions are prepared prior to the interviews, and other question arose during the interviews. The reason for using a Semi-structured question types is that interviewees have different knowledge about the water issues in Jordan which implies bringing up different questions during the interviews in order to benefit the specific expertise of individual contributors.

3.3 Interview Questions

The interview questions with the government officials focus on the factors that impact water scarcity in Jordan such as water loss, water tariffs, water networks, and groundwater abstraction. The interviewees were asked to discuss the following questions:

- A. What are the causes of water scarcity in Jordan?
- B. What are the challenges that prevent the government from applying water policies successfully?
- C. What are the existing solutions that are adopted by the government to mitigate water scarcity?
- D. What are the current practices regarding water management?
- E. What are the best features of water management adoption in urban and rural areas?
- F. What are the measures the government is taking to decrease the loss of “non-revenue water”?
- G. How does the government manage the pricing of, or tariff of water? Should the tariff be (less or more)?

3.4 Conducting the Interviews

I conducted all the interviews during July 2018. I went to Jordan and interviewed some key persons from the Ministry of Water and Irrigation. All interviewees agreed to an audio recording of their interviews, and each signed a consent form. Each interview took around one hour on average. During some interviews, I was referred to other people who are not in my list. I contacted some of those people and scheduled interviews with them. Upon finishing all interviews, I transcribed all the recorded interviews into a hard copy. Most of my interview were conducted in Arabic, however they are translated into English. The interviews were then organized based on each participant, which includes all questions that have been asked. My work as interpreter helps me to interpret all information provided with integrity.

3.5 Interviews Data Analysis

I used the interpretive analysis technique for analyzing the data obtained from the interviewees. Interpretive analysis is a technique for analyzing qualitative data such as interviews (ER Services, 2020). Based on this approach, I followed several steps to analyse the collected data. First, I categorized the answers of the transcribed interviews according to a set of themes. The themes are decided based on their relative coherence for answering the research questions (Section 1.5). The interviewees' answers are categorized into the following three general themes.

Theme 1: The causes of water scarcity in Jordan and current practices

Theme 2: Existing solutions for water scarcity

Theme 3: The challenges for adopting solutions to water scarcity.

Second, I used the narrative approach to specify the answers that relate to water management. In other words, the answers on each theme are narrated to reflect only issues concerned with water management. For instance, in Theme 1, the interviewees provided different causes for water scarcity in Jordan, however, I extracted only those causes that are linked with water management such as the non-revenue water, groundwater abstraction, and farmers' practices. The same technique was applied to extract the required data from Theme 2 and Theme 3. Third, I wrote the narrated answers of the interviewees in my own language such that it represents their opinions and provided some of their quotes. Fourth, I commented on the interviewees' opinions about the causes of water scarcity in Jordan. Finally, I introduced my proposed solution for this problem based on the problems mentioned in the interviews and based on the existing government

solutions. My proposed solutions are from management perspective since I focused on solving the water scarcity by enhancing the management practices while existing government solutions mainly search for new sources of water.

3.6 Advantages and Limitations of Interviews

The interviews provided me with a wide range of information in a very short time about water scarcity in Jordan. Although the time was very limited, the interviewees were supportive. I had the freedom to ask the main questions and ask for more elaboration on certain aspects. I met experts at different levels including the former Minister of Water and Irrigation and engineers of different expertise, and university professors. I verified some statistics about water quality and water consumption that may be found in the literature, and I explored some issues about water management in Jordan. However, there are some limitations. First, the interview scheduling was not as planned. Some interviews had to be rescheduled since the intended interviewee was not available. Second, the allocated time for interviews was not as I expected. The average time of each interview was around one hour, however, each interview took about a day for preparation which includes leaving home early, dealing with traffic, waiting for the interviewee to be available, conducting the interview, and then returning home to listen to the interview, and write it out and translate it. Third, some interviews require permissions in order to enter certain places or to meet a certain person which I had not considered in advance. For instance, there was one case in which the employee refused to give me some information until they obtained authorization from his manager, which took more than expected time. However, I managed to finish all the scheduled interviews.

3.7 The Survey Questionnaire Objectives

The survey questionnaire (see Appendix C) serves the following objectives:

- Get feedback about the average amount of received water per capita/year; this includes the amount for each city and the average amount of all cities.
- Examine whether the received amount of water is satisfactory.
- Get feedback about the level of satisfaction about the quality of the received water.
- Understand the existing practices regarding water allocation in Jordan.
- Investigate the reasons that cause water scarcity in Jordan.
- Get insight into the practices that hinder applying proper water management that can lead to water sustainability.

3.8 Sampling Strategy for the Questionnaire

The questionnaire targets university students and homemakers. The original recruited sample to complete the questionnaire was 50 participants, however, using referrals the maximum sample size that I reached was 128. Most of the recruited students were recruited by university professors who are teaching them at the three mentioned Jordanian Universities. I identified four cities/districts (i.e., Amman, Al Mafraq, Al Zarqa, and Irbid) and asked to have assistance in identifying students from these cities. These cities were selected because they represent the major cities in Jordan with high population density. I was in Jordan and scheduled visits to three universities. The students were available, and the professors helped me in distributing the copies of the questionnaire through their lectures. I was able to get participants from other cities (i.e., Ar Ramtha, Jerash, Aqaba, Madaba, Ajloun, and Al Azraqa) too. The participants from these cities are university students. I distributed copies to more than 100 students which

Table 4: Number of Questionnaire Participants from Jordan Districts

District	Number of Participants	
	Students	Housewives
Amman	32	9
Irbid	11	3
Al Zarqa	26	7
Al Mafraq	18	2
Other Districts	20	0
Total Number of Participants	107	21

provides me with a diversity in the answers and provides a clearer pictures about water quality and water services within the sample. In addition, I was able to recruit around 28 homemakers who live in different cities in Jordan through my personal contacts. I believe, the selection of the university students can achieve several purposes: First, they might have a direct understanding as consumers about the water scarcity problem. Second, the student group came from diverse cities that represent different geographical locations in Jordan. The questionnaire was distributed to students from three Universities in Jordan: the Jordan University, Yarmouk University, and Al al-Bayet University.

The homemakers were especially valuable contributors because they are best situated to observe domestic water use for drinking, cooking, cleaning, and other purposes.

The participants came from four central districts in Jordan, namely, Amman, Irbid, Al Zarqa, and Al Mafraq. A small number of participants are from other districts; we chose to put them in the “Other Districts” category (see Table 4).

3.9 The Survey Questionnaire Design

The Survey questionnaire is used to explore the water situation in Jordan through the perspective of public users. The questionnaire contains 16 quantitative and qualitative questions categorized into four categories of questions namely, Demographic, Water Consumption, Water Quality, and Miscellaneous questions (see Table 5).

Most of the questions were closed-ended which allowed the participants to choose from a maximum of four options. The other questions were open-ended which allowed the participants to elaborate about certain aspects of the questionnaire aimed to collect information about the amount of domestic water use, the quality of water, and water services from people who live in different areas of Jordan. The questionnaire contained questions related to the following categories:

Demographic Questions: the demographic questions collected information about the participant's city, district, and the number of family members. The answers to the demographic questions were utilized to geographically locate understanding of water allocation, water consumption, and the quality of water services.

Water Consumption Questions: These questions asked about the amount of water received, how often water is received, and whether the received amount of water is sufficient for household needs. Moreover, there was a question about whether the participants' families have other water sources such as wells.

Miscellaneous Questions: These questions asked whether the participants are using water-saving equipment or water purification devices. They allow the participants to express other water-related issues or complaints. The answers from these questions can provide information about water shortage, water quality, and water service.

The questionnaire responses were collected, sorted, and categorized based on the cities of the participants. I used the Excel sheet to store the data and calculate the percentages and totals related to each question. Some participants did not answer some questions in the questionnaire, as detailed in the questionnaire findings. The calculated statistics represent numbers that can be used to describe the water usage and water quality. Moreover, the statistics obtained from the questionnaire were combined with the results obtained from the interviews and the literature review to answer the research questions.

3.10 Advantages and Limitations of the Survey Questionnaire

The responses from the questionnaire can provide estimation statistics about the water consumption and water quality in Jordan. However, since I used the convenience sampling strategy, the obtained results cannot be generalized. In addition targeting university students allowed for distributing many questionnaires and getting responses in a shorter time compared to the interviews. However, there were some limitations regarding the depth of information collected from the questionnaire. First, several students left some questions unanswered. Second, some participants estimated some answers in the questionnaire such as the amount of water consumption. These two

Table 5: Classification of the Questions of the Questionnaire

Question category	Question number
Demographic	q1- 3
Water Consumption	q4-6
Water Quality	q7-10
Miscellaneous	q11-16

limitations imply inaccuracy of the results obtained. Third, the survey results cannot be generalized since the convenience sampling strategy is applied, a better sampling strategy should represent several categories of Jordan's population in order to be able to generalize the findings. Fourth, some questions constrained the participants with certain choices. In other words, some questions do not allow a participant to express a different choice. For instance, question 4 ask how many times/week a customer receives water. The choices are: (a) once a week, (b) twice a week, (c) three times a week, and (d) more than three times. Option (d) should allow the participant to specify how many times. These kind of questions can cause a bias in the overall results.

3.11 Summary

This chapter provides insight about the research methodology used to investigate the water scarcity problem in Jordan. The proposed two-part research methodology relies on using semi-structured interviews with experienced professional observers and officials and a survey questionnaire administered to a range of water consumers in order to identify the factors that aggravate the water scarcity problem in Jordan.

Chapter 4 Results

Chapters one and two provide background information respecting various considerations that have an impact on water scarcity in Jordan. The findings show that water scarcity in Jordan is a multidimensional problem. There are natural factors such as precipitation rate, temperature, climate change, and the geography of Jordan. In addition, there are human made factors such as the population growth rate, immigration, water resource damage, and water management challenges. This chapter is concerned with the findings related to Questions 5 and 6 in Section 1.5, which are related to the research water management factors that impact water scarcity in Jordan. These factors are synthesized from the literature review, the interviews, and the survey questionnaire.

4.1 Results of the Literature Review

The findings of the interview indicate that Jordan indeed has a water scarcity problem. It is a multidimensional problem caused by many factors such as the lack of water resource, the geographical location of Jordan, and inadequate water management. The government of Jordan put forward some potential solutions for water management; however, it lacks the ability to implement of these solutions on the ground. The lack of the implementation is related to the social structure (tribal) of Jordan, the economic situation, and the lack of monitoring of water resources.

A closer look at the water strategies and water policies in Jordan shows that the government of Jordan is aware of the country's water scarcity challenges. The long-term Jordan water strategies demonstrate the need for facing water challenges through the implementation of different water policies and regulations. However, the literature review

shows that there are some shortcomings in these policies which are summarized as follows:

Groundwater abstraction

Groundwater is a strategic water resource for current and future generations. Although specific policies for protecting groundwater have been in place since 1998 (MWI, 2004, 2016), the government is very lenient in implementing these policies, especially in relation to the rules regarding illegal well drilling. The weakness in enforcing the regulations is due to limited monitoring and control over water resources. The government does not have enough human resources to track those who are illegally drillings wells, and many drilling operations remain undetected. Moreover, some people engaged in illegal drilling have significant influence on the government; therefore, only a very small fine is paid, and drilling continues. The Water Authority of Jordan (WAJ) law 18 of 1988 specified a fine no less than Jordanian Dinar (JD) 1000 and no more than JD 5000 if a person drilled unlicensed ground water wells or violated the conditions of the license issued to him (Saidam & Watt, 2006), I believe this fine is not enough for committing such violations since the benefit gained from drilling a well is more far than the maximum penalty. In addition, there are many cases of groundwater theft; people or farmers who have licensed wells exceed their pumping quota. Also, water meters installed on the wells are unprotected and easily tampered with (Venot & Molle, 2008).

Abuse of Groundwater Abstraction

Groundwater abstraction is used by the government as an easy and fast solution for meeting current water demand without considering the water needs for future

generations. During the years in which not enough rainfalls, rather than looking for a sustainable solution, the government is using the groundwater as a quick remedy. However, this leads to significant deficits, e.g. -237.7 MCM in 2017 (see Table 1).

Non-revenue Water (NRW)

The NRW another indicator of water mismanagement in Jordan (Al-Ansari et al., 2014b). The deteriorated water networks, water theft, and water administration are main causes for the water loss problem. As indicated in Section 2.5.5, more than 50% of the municipally supplied water is considered non-revenue water because of water loss.

Low Water Tariff for Irrigation

Jordan is a country that relies on agriculture; and the western part of Jordan is an agricultural area that relies on irrigation. Farmers are allowed to irrigate their crops using water from the Jordan River, the Yarmouk River, and King Talal Reservoir. Also, some farmers drill private wells on their own farms. In order to promote agriculture, the government is selling water to farmers at low prices. The amendment to the irrigation water policy in 2004 allows farmers an increased water pumping quota and reduced the charges from \$0.035/m³ to \$0.007/m³ (Venot & Molle, 2008). This amendment is another indication of poor water management. The government wants to promote agriculture on one hand, but this policy creates significant water loss on the other hand. Despite the water scarcity problem in Jordan, water tariffs in Jordan are among the lowest in the world (Yorke, 2013). The government responsibility is to shift farmers from planting crops that consume large quantities of water to other types of crops.

Limited Implementation of Water Policies

As mentioned earlier, Jordan has very good water policies in terms of the plans and recommendations; however, they lack real implementation and enforcement. Several researchers believe that the government cannot implement and enforce water policies on the ground. Instead of enforcing existing water policies and regulations, the government is looking for other water resources that are more costly.

4.2 Reporting the Interviews Findings

The interviewees provided different opinions about the causes of water scarcity in Jordan. Some interviewees relate the problem to the lack of water resources in Jordan, and the abuse of water resources and water use; others claim that water scarcity is related to water management. Although interviewees provide some evidence about the causes of water scarcity, these views imply that water scarcity is a multidimensional problem. This section elucidates the causes of water scarcity and the existing government solutions.

4.2.1 Causes of Water Scarcity

The results of the interviews show that water scarcity is mainly caused by the following:

Farmers Practices

The interviewees most familiar with agricultural practices believe that the agriculture sector contributes most to the water scarcity problem. Crop irrigation consumes more than 50% of the water reserve in Jordan. The frequent use of treated wastewater in agriculture can reduce the consumption of surface water and groundwater; however,

many farmers are reluctant to use treated wastewater. An expert researcher at the National Center for Agriculture research and extension (NCARE) relates this reluctance to the lack of awareness about the potential to use treated wastewater in agriculture. She indicated that farmers do not have enough awareness about the use of treated wastewater, and they have fears about using treated wastewater. The farmers do not have the confidence of using treated wastewater because they think it can cause cancer. Religious farmers believe the use of treated wastewater is considered cheating of consumers since this water is not clean; therefore, it is not good for irrigation.

On the other hand, some farmers abuse the use of wastewater in irrigation. According to the expert of (NCARE), farmers who have land around the wastewater plants purchase treated wastewater from these plants through cheap contracts. Those farmers feel positive about using the treated wastewater because they think the water is rich in phosphorus, fertilizers and other ingredients, which can improve the quality of crops. According to the contracts, treated wastewater has to be used through drip irrigation to avoid contamination since the purification of the wastewater is not enough to remove all bacteria. Some farmers violate the contracts and irrigate their plants using direct surface irrigation.

Non-revenue Water

The non-revenue water leads to a considerable water loss. The head of operations and maintenance department at MWI indicated that in year 2014 the non-revenue water was close to 50% of the total supplied water. The average annual supplied water is 456 MCM in which 208 MCM is counted as non-revenue water. If this loss can be saved, the domestic water supply quota can be increased by 70 liters per capita per day which is

around 100 m³/capita/year. According to an official in the Ministry of Environment, aged water networks cause 30% of the total loss in non-revenue water. The other 70% is related to water theft, illegal wells, and inaccurate water bills that do not represent the actual water consumption.

Lack of Monitoring and Control over Groundwater Abstraction and Drilling

Although groundwater policies prohibit drilling any well without a permit, many people are drilling secretly. Besides, the government is pumping more than the permitted amount as a quick remedy to respond the increasing demand for water. According to an interviewee who has observed court cases of illegal wells and groundwater, the main problem is the approach to national water security, which is not taken seriously enough by the government. For example, unlike Jordan, Israel considers water as one of its top national security issues. The interviewee mentioned that there are thousands of illegal wells in Jordan. Since Jordan is a tribal country in which many lands belong to tribes not to a specific person, therefore any person in the tribe can claim his right over land. This situation encourages some people to make illegal drilling. Every year the ministry has around 200 cases of illegal drilling wells. According to 2017 MWI statistics, there are around 1060 illegal wells, and around 30 million cubic meters of water over-pumping a legal advisor said:

“We do not have a court that is specialized in water crimes. We need judges that understand what water rules are, and what the rules that control the groundwater. In addition, the penal code is not a deterrent; the person who drills illegal wells can have a punishment of just three months prison and pay fine. In many cases, the

offenders get no punishment if he related to clans. The judges consider water as regular crimes”.

In addition, he indicated that many incidents of illegal drilling have taken place during the past decades and were reported in the new media. For example, on Feb 5, 2018 the MWI inspection cadres in coordination with the concerned authorities in the Directorate of Public Security, the Gendarmerie and the Royal Badia Forces carried out a raid on a number of water sites in the south of the capital and Mafraq in the north of the Kingdom. The squad teams found some people stealing water from main water lines as well as illegal drilling of water wells.

Rapid Change in Demography

Jordan is affected by the extreme movement of refugees from Palestine, Iraq, and Syria which creates serious challenges for water management. The unregulated refugees from the neighbouring countries combined with rapid population growth prevent policymakers from implementing long-term water policies that can guarantee fair water allocation for Jordanians. The population of Jordan is estimated at 10 million in 2019. One of the senators and a former minister of water irrigation indicated that the government could provide good water service for only 1.8 million people. However, the phosphate industry, agriculture, and other industries are equivalent to 4 million people. Also, Jordan hosts around 4 million of Syrian, Palestinian, and Iraqi refugees. The industries and the hosted refugees creates a big burden on Jordan which leads to a deficit not only in water but also in food and other commodities use.

The sudden increase of water demand requires the government to secure extra funds for maintaining water resources. According to an official who is familiar with water

resources management at the MWI, securing funding is the main problem that faces the government to take an action plan for allocating more water resources for Jordanians. A large number of Syrian refugees prevent Jordanians from getting enough water to cover their daily needs. Last year the prime minister announced that the government would provide 250 million Jordan Dinar (400 million USD) to support the water sector. This amount is not enough to cover the cost of maintaining the water network and drilling more water wells.

Multiple Water Authorities

Another problem related to water management is that Jordan does not have executive authority for water management. According to the experts of (NCARE) the Ministry of Water and Irrigation (MWI), Jordan Valley Authority, and other authorities have conflicts over the control of water distribution in Jordan.

According to a senior official at the Environmental ministry, the government is developing an action plan that incorporates all stakeholders in the water sector in the country to deal with all water problems by looking at the existing water policies to ensure better water services.

Water Tariff

The MWI pays a high price for water and sells it for a low tariff for agricultural and domestic use. One expert indicated that the MWI could not raise the water tariff for the agriculture sector because farmers do not have open markets for their products. Therefore, farmers might lose money by raising their water tariff. On the other hand, an Engineering official at MWI mentioned that water extraction and distribution involve a high cost; drilling for groundwater is very expensive because the government has to dig deep

into the ground. The Dissi water plan, for example, cost the government currently JD 2 for every cubic meter and the government sells it for only half JD or less (USAID, 2009). The government is looking for other alternatives of water resources such as desalination of water, but this is very expensive. A cheaper alternative would be subsidizing water-saving equipment and encourage people to use it.

4.2.2 Existing Government Solutions

The MWI and other government agencies are aware of the downsides of water management that affect water scarcity. Therefore, the government is applying the following solutions in order to mitigate the water scarcity problem.

Review and Establish New Water Policies

The government reviewed the water policies that aim to improve water services, to encourage the use of nonconventional water resources, and to improve the quality of water. A water resources management Engineer mentioned the National Water Strategy “Water for Life 2008-2022” (MWI, 2009) which has water policies related to groundwater sustainability, surface water, reallocation of water resources, substitution and reuse which means the use of treated wastewater in industries and agriculture instead of fresh water, energy, and sustainable energy.

A director at the Environmental ministry indicated that the government developed last year the National Green Plan to move toward a green economy. The plan concentrates on six main sectors in Jordan; energy, water, transportation, tourism, agriculture, and waste”. Regarding the agricultural sector, one expert mentioned that the government is promoting the use of non-conventional water for agriculture.

Secure More Water Resources

The government adopted different methods for securing more water resources and saving water. An Engineering official at WMI mentioned the government established in 2010 the National Center for Security and Crisis Management (National Center for Security and Crises Management-Jordan Media Institute, 2019) in order to legislate the use of sewage water. The legislation was amended in 2013 to add a code for buildings. The code mandates American quota specifications for the use of water equipment in buildings. The American Energy Policy Act of 1992 requires all U.S. plumbing industries to meet specific water-efficiency standards. For instance, showerheads should allow a flow of 2.5 gallons of water per minute and toilets should allow a water flow of 1.6 gallons per flush (Bourg, 2016). An Engineer at the Department of Management Awareness and Media at MWI said there are labs created by the Royal Scientific Society of Jordan for checking compliance with the American specifications. Unfortunately, the labs no longer exist. Hence, government control is absent. Checking the specification is left to the consumers who were use these machines, and most likely, they do not recognize if the water flows are high or normal. Also, in 2013, another quota which does not exist in the American code was added by the government of Jordan to apply harvesting water in buildings. This quota implies collecting rainfall water from the roofs of residential buildings and store it in special wells built in each building. However, this quota is not enforced fully by the government.

Reduce Dependency on Groundwater and Surface Water

The government is adopting some regulations to decrease ground water abstraction. According to an Engineer at WMI, in 1992 the government pronounced orders that prohibit digging wells in agricultural, and industrial areas. Also, the

government prohibited digging in the Zarqa water drainage basin for all uses. It made some decisions including fines and punishments for violators. Regarding the surface water, the government started to use technology such as UAVIS airplanes and satellites for monitoring and watching water resources, water bodies, transmission lines, the channel of King Abdullah, and all other water resources in Jordan.

According to an official at the Media and Awareness unit at the Ministry of Water and Irrigation, the legislation of 2013 requires that any water machine or water device component (shower, dishwasher, spring spray, etc.) meets the Americans quota specification. Usually there are two kinds of specification optional, and obligatory. Both the producer and consumer must commit to the obligatory specification whereas the optional is voluntary.

The difference between the American and Jordanian quota is that the American is subject to green building LEAD standard while the Jordanian quota must meet the minimum green building specification about water flows.

Regarding water harvesting from rainfall, the government amended the legislation to implement a harvesting code for buildings; however, the enforcement is not consistently applied. Sometimes builders cheat in order to decrease the cost of buildings. Besides harvesting rainfall in urban areas, the government is collecting rainfall in Badia to serve cattle breeders. The government built over 300 soil caverns that are spread throughout the Jordanian Badia in the eastern and southern desert sites. The quantity of the collected water in these sites is around 110 MCM. Before building these sites, cattle breeders were relying on the groundwater.

Table 6: Average Water Consumption for Participants and their Families

District	Total number of persons participants families	Received m ³ /Month	Average m ³ /capita/Year
Amman	233	431	22.19
Irbid	92	146	19.04
Al Zarqa	193	312	19.30
Al Mafraq	134	253	22.65
Other districts	116	252	26.06
Average annual consumption per capita for all cities			21.84

4.3 Reporting the Survey Questionnaire Finding

The questionnaire results provide insight about water consumption, and water quality and services. The water quality and services can reflect the strength or weakness of water management from the point of view of the public, the following themes emerged:

Average Amount of Water Received

The average amount of water consumption per capita per year for the participants' families was obtained based on the answers to questions 1-6 in the questionnaire, (see Table 5). I calculated first the average water consumption per capita for the participants and their families in each district. Then I used these averages to calculate the overall average consumption per capita for the participants' families as shown in Table 6. The table shows little variation among all districts in terms of the annual consumption per capita for the participants' families. The average annual consumption per capita for all districts is 21.84 m³. The obtained average consumption represents only water consumption for domestic use (i.e., drinking, cooking). It can be noticed from the collected data that Irbid city has the lowest average of the participants' families; it is 19.04 m³/year,

Table 7: Questions about Water Quality

Question	Option	No. of participants	Percentage
Q7. Smell	No Smell	118	92.2%
	Foul Smell	9	7%
Q8. Taste	No Taste	91	71.1%
	Bad Taste	35	27.3%
Q9. Clarity	clear	82	64.6%
	cloudy	14	11%
	dirty	31	24.2%
Q10. Overall water quality	Poor	30	23.4%
	Fair	22	17.2%
	Good	62	48.4%
	Excellent	2	0.016%

which can indicate several things such as population density, poor water services, or both. The literature review shows that the annual consumption per capita is 139 m³; In Jordan this number is calculated based on the overall water use in all sectors (i.e., domestic, industrial, and agricultural). Nonetheless, the domestic amount of 21.84 m³/participants family members/year as a proportion of 139 m³ is low compared with the world overall water consumption. For instance, the global overall average water consumption is 1385 m³/capita/year (Fischette, 2012).

Water Quality

Questions 7-10 ask participants about the quality of the water in terms of its smell, taste, and clarity as shown in Table 7. I calculated the percentage of each quality based on the options given to the users. As mentioned before, some questions were not answered by all participants, resulting in a calculated percentage less than 100%. For instance, the smell quality has the no smell and foul smell options. Nearly 92.2% of participants indicated that their household water had no smell. Regarding the water taste 71.1% reported no taste and 27.3% reported bad water taste. The overall quality option

showed that only 6.1% reported excellent quality, however, 48.4% reported good quality and 17.2% reported fair quality.

Miscellaneous Questions

Table 8: Miscellaneous Survey Questions about Water Services in Jordan

Subject	Option	No of participants	Percentage
Q11. Have you ever made a complaint about water services	Yes	36	28%
	No	90	70.3%
Q12. Are you satisfied about water services	Yes	71	55.4%
	No	56	43.8%
Q13. Do you have water saving devices	Yes	80	62.5%
	No	47	36.7%
Q14. Do you have water purification devices	Yes	55	43%
	No	72	56.2%
Q15. Do you fear of water shortage in the future	Yes	62	48.4%
	No	61	47.7%
Q16. Water usage for other purposes	Yes	72	56.2%
	No	54	42.2%

The rest of the questions (Q11-Q16) in the survey questionnaire focused on domestic water services, water saving devices, water purification, water shortage, and the use of water for other purposes such as irrigation. Table 8 shows the participants responses to these issues. Twenty-eight percent of the participants reported complaints about water services, while 70.3% have no complaints at all. The data shows that the overall satisfaction with water services was only 55.4%; while 43.8 participants are unsatisfied. Regarding the use of water saving devices, 62.5% of the participants

indicated that they use devices such as efficient showers head and water efficient faucets to conserve water in their homes. In addition, 43% of the participants use water purification devices such as water filters. Regarding the water shortages in the future, 48.4% reported that they have worries about water shortage. Finally, 56.2% of the participants indicated that they use water for other purposes such as gardens, irrigation, car washing, and other household purposes.

Averaging the results about water quality and water services of questions 10 from Table 7 and question 12 from Table 8 indicates that approximately 60% of the sample were happy with the level of services and the water quality in Jordan. The 60% is not so good since the other 40% of the sample were unhappy. This low level of customer satisfaction can be linked to some gaps in water management as it will be discussed in Chapter 5.

4.4 Summary

This chapter reported the water management aspects that have an impact on water scarcity in Jordan. The findings were obtained from the literature review, interviews, and the survey questionnaire. The literature review identified several water management shortcomings such as the inability of the government to regulate water abstractions and drilling wells. In addition, the review shows that the government is aware of the amount of non-revenue water loss, this problem cannot be solved easily since it requires a big budget for fixing the deteriorated water networks. The review indicated that the government reviewed and established new water policies in 2008 that aimed to improve water services. However, the implementation of long-term water policies has been limited due to rapid change in Jordan's demography, caused by the influx of war refugees.

The interview findings generally support the findings of the literature review in terms of ground water abstraction, lack of monitoring and control of water resources, rapid demographic change, and the non-revenue water. However, the interviews are more informative since they provided more details about non-revenue water.

The survey questionnaire findings indicate another dimension of the water management in Jordan which relates to the quality of water and water services. The level of satisfaction regarding water services and water quality is low. Only 60% of the participants are satisfied with existing water services and water quality which indicates issues in water management.

In conclusion, many researchers did not pay enough attention to the important role of water management in mitigating the water scarcity problem. The findings of this research indicate that Jordan government is unable to cope with these issues.

Chapter 5 Discussion and Conclusion

Jordan established new water policies in 1998 and amended them in 2008, to regulate water use in Jordan and achieve water resource sustainability. Nevertheless, the water scarcity problem in Jordan is aggravated because the government falls short in applying some parts of these policies. The findings from the literature review, the survey questionnaire, and the interviews reveal that poor water management in Jordan contributes significantly to the water scarcity problem. The government of Jordan understands there are problems that lead to poor water management practices. However, some barriers prevent Jordan from implementing effective water management.

Table 9 : Causes of Shortcomings of Water Management based on the Literature Review and Interviews

1- Economic situation	Aged water networks	Lack of human resources	Lack of water monitoring and control	Not enough dams to hold water in rainy years
2- Tribal and lobbyist influence	Unlicensed drilling of wells	Over pumping of water	Interference with water policymakers	Water theft
3- Lack of awareness about water scarcity	Not enough awareness in media about water scarcity	Officials do not have enough discussion with the public about water scarcity	The mentality of farmers and farming habits	The limited use of water saving devices in all sectors
4- Multiple authorities for water governance	Lack of cooperation among authorities	Conflicts of interest among authorities	Multiple changes to water management plans over time	
5- Illegal industrial and agricultural practices	Industrial chemical wastes dumped into water resources	Overuse of fresh water for industrial purposes	Not having enough wastewater treatment plants.	

This chapter encompasses three facets: a) a discussion about the negative impacts that prevent implementing effective water management practices, b) an evidence based solution for improving water management in Jordan, and c) the conclusions of this research.

5.1 Causes of Water Management Shortcomings

The shortcomings of water management in Jordan are caused by several factors. These factors are classified into five categories (see Table 9) in which each category can participate in several shortcomings.

5.1.1 The Impact of the Economic Situation

The results of the my research indicate that the effectiveness of water management can be measured by the degree to which the government can enforce its water regulations, meet public water needs, and improve water quality. The questionnaire and the interviews reveal that the government needs more financial and human resources in order to implement the plans concerning water services. Unfortunately, the economic situation does not allow the government to offer all the needed resources. This section provides an analysis of the impact of the economy in restricting the government from applying effective water management. The analysis is based on the findings from the questionnaire, interviews, and the literature review.

First, regarding the condition of water services infrastructure, the interviews show that most water networks in Jordan are rusty and deteriorated. This deterioration results from not having enough funds to maintain or renew those networks. The maintenance of the water networks is partial and based on urgent needs. According to an interview with the SG Assistance from the maintenance and operations at MWI, and the article by Yorke

(Yorke, 2013) aged water networks cause the loss of large amounts of water. Besides, a director at the Environmental ministry mentioned in his interview that aged water networks are the primary cause of 30% of the total loss of non-revenue water. If this amount can be saved, then it can make a significant difference for the freshwater situation in Jordan. The aged water networks not only cause water loss, but also affect the water service and water quality as indicated by the results of the questionnaire (see Table 7).

Regarding the interview results, some interviewees stated that the quality of drinking water when it is pumped from the source is according to the international standards of the World Health Organization (WHO). A Chemical Engineer from the Ministry of Environment mentioned that the ministry provides measures to control the quality of groundwater and surface water by measuring the turbidity and E-coli level in water. If the measures exceed the international specifications, water will not be pumped. The Ministry of Environment has 50 purification stations that the water should go through before supplying water to the public. He added, the water quality degradation is a technical problem related to the old water network and dirty water tanks.

Moreover, the MWI is also taking necessary action to ensure water quality. An Engineering official at MWI indicated that the ministry has labs to measure the levels of bacteria, chemical, and radiation in drinking water. The Ministry also follows the water quality safety plan that World Health Organization (WHO) prepared for every country. However, the challenges for providing good-quality water could come from the broken water pipes w are close to sewage. For instance, the ingredients of broken metal and plastic pipes affect the water quality especially they contain phosphorus and nitrogen.

Second, regarding ground water abstraction, the government is unable to manage the illegal use of water and well drilling as a result of limited financial resources. The MWI does not have enough funds to hire a sufficient workers, or to buy technologies that can control illegal water usage, water pumping, water theft, and illegal well drilling. As explained in the literature review, Al Ansari (Al-Ansari et al., 2014a) reported that the non-revenue water comprises 50% of the supplied water on average; Approximately 70% of this amount is related to water theft, illegal water use, and administrative loss which is caused by weak governance. Illegal wells and illegal water over pumping are not controlled fully by the government. These concerns indicate a weakness in water governance as a result of not having enough resources.

The third consequence of the economic situation is that large amounts of rainfall go to waste as a result of not having enough dams. This consequence is another indication of weak water management and limited investment. According to the statistics of the MWI, Jordan has twelve main reservoirs that hold floodwater, the capacity of these dams is about 335.3 MCM. The amount of rainfall fluctuates every year; in some years, some of these reservoirs do not reach their maximum capacities; in other years, some of these reservoirs exceed their capacities. For instance, the heavy rain that hit Jordan this year, 2019, caused flooding of several dams. Jordan can benefit mainly from rainfall by having more reservoirs or extending existing ones to increase storage. However, the current economic situation in Jordan cannot allow the country to build new dams and reservoirs or extend the current ones. The last dam that was built in Jordan is the Al Wehdah dam on the Yarmouk River in Jordan and Syria in 2006 (Hadadin, 2015).

5.1.2 The Impact of Tribal and Lobbyist Influence

Water control and monitoring are not only related to the economic situation in Jordan but are also related to demographic factors which have a significant impact on water management. Jordan's population has some powerful tribes and lobbyists. The monarchical system in Jordan provides much support to tribes and tribal leaders in exchange for loyalty and stability of the monarchy. These tribes live in large areas which they claim as their land and they have full authority to use it. According to the interviews, one of the main issues that the government is facing with these tribes is unlicensed well drilling in these land. The interviews show weak governance on well drilling. Although the MWI makes regular inspections for illegal wells, there are many incidents in which the MWI found illegal wells on private farms. The MWI inspectors could not enter these farms because they were owned by tribal leaders or by high-ranking officials. According to the interviews, if the government buried all illegal wells, it could save around 150 MCM/year. Although the government issues some licenses with a specific quota for well drilling in some remote areas, some lobbyists get licenses through their connection with higher authorities and violate the license agreement. For instance, they exceed their quota or use water for commercial purposes. Others do not even get a license and drill illegally.

5.1.3 The Impact of Awareness about Water Scarcity

An additional negative influence on water management is that many people in Jordan are not aware of the water scarcity problem. Besides, the government contributes without intention, to this problem. The lack of awareness about water use stems from the followings:

- The limited awareness in the media about water scarcity.
- Policymakers do not have enough discussion with the public about this problem.
- Bad practices of farmers.
- The limited use of water saving devices.

Water scarcity is a national security issue in Jordan that requires significant effort by the government to spread awareness among people about this issue. Media advertisement about water scarcity on radio, TV, social networks, and newspapers can have a great role in influencing people's behaviour regarding water consumption. The MWI and other water authorities should increase the effort regarding this issue. Occasional and limited advertisements appear only during summertime. The research shows an absence of the government in educating the public about the severity water scarcity and educating them about the different ways for water conservation.

The literature review also shows a lack of awareness among farmers. Employees from the Ministry of Agriculture and the United Nations Development Program (UNDP) are facing difficulties with farmers who have limited education; it is hard to convince them to stop growing water-intensive crops like citrus fruits simply because it is what they have grown historically. Also, they do not know how to grow crops that require little water (Denny et al., 2008). The other problem is the use of fresh water for irrigation. Although the government sets new plans that aim to decrease the use of freshwater for irrigation, many farmers are resisting the use of treated wastewater. An expert at the National Center for Agriculture Research and Extension (NCARE) relates this problem to the lack of awareness of farmers. Farmers fear using treated wastewater for irrigation for several reasons. Some of them believe that eating crops that are irrigated with treated wastewater

can cause cancer, and others believe irrigating their crops with the treated wastewater is cheating due to religious reasons; therefore, they avoid using it for agriculture.

Finally, water scarcity is related to the lack of awareness among the public about water conservation techniques. The questionnaire results show that a large percentage of people (63%) are using water saving devices; however, I was not able to verify whether these devices are installed in kitchens only or in both kitchens and bathrooms. In addition, the results indicated that 57% of participants use freshwater for other purposes such as watering gardens, washing cars, and washing floors. These findings indicate that many participants are still unaware of the water scarcity problem or they are reluctant to change their behaviour. In this regard, the government is spending reasonable effort regarding the specifications of the water devices that should be manufactured or imported. The interviews show that in 2013 the government enforced new specifications or quotas for water and sewage in buildings. The specifications indicate that any water machines or parts such as showers, spring sprayers, and dishwashers should meet the American quota specifications. In the agricultural sector; many farmers also are unaware of the benefits of using the drip irrigation technique for saving water.

5.1.4 The Impact of Multiple Authorities for Water Governance

A significant shortcoming in water management is related to the continuous change of authorities that have a claim on water governance. Prior to 1983 several authorities were responsible for water management such as the Natural Resources Authority (NRA), the Amman Water Supply and Sewerage Authority (AWSA), the Water Supply Cooperation (WSC), Jordan Valley Authority (JVA). In 1983, the Water Authority of Jordan (WAJ) took over all existing water and sewerage operations in the country; and

the JVA become responsible for irrigation and development in the Jordan Valley. In 1987, JVA and WAJ were brought under the umbrella of the Ministry of Water and Irrigation. At present, there are several independent authorities for water management in Jordan. Although the government claims that a change in water authorities would bring benefits concerning water management (Saidam et al., 2006), the frequency of change to date has prevented the development of effective long-term effective water management plans.

Furthermore, having multiple authorities for water governance might cause a conflict of interest among them. This was also emphasized in the interview with an expert at (NCARE) who said that several water authorities are participating in water management and distribution; however, there is a lack of cooperation and conflict of interest among these authorities.

5.1.5 The impact of Industrial and Agricultural Practices

Several new reforms have been appended to the industrial and agricultural sectors in Jordan regarding water use. However, these reforms have not been fully implemented or enforced for several reasons. First, there is not enough law enforcement officers on the ground to enforce the new regulations (i.e., There is no enough budget to hire enough officers). Second, the tribal and lobbyists' influence prevents government from applying these regulations since the regulations contradicts with their interest. Third, the existence of various water authorities creates conflicts among these authorities about which authority has the right to enforce what. Fourth, there is a lack of awareness among people in these sectors about the severity of the water scarcity problem which complicates the problem. In the absence of law enforcement and the lack of awareness, many violations have been recorded against industrial and agricultural firms. According

to the Jordan Times newspaper, authorities dealt with 30,000 violations regarding water resources since 2013 (Namrouqa, 2019).

Many people do not mind committing such violations because they can save some money, or they can get away without punishment. The interviews show many violations related to water theft, water over pumping, and illegal drillings. Also, there is freshwater exploitation in the industrial and agricultural sector; For instance, the Phosphate Company have 21 wells of freshwater used for industrial purposes (Strawn, 2007). In the agricultural sector, some farmers use the freshwater for irrigation. Both could reduce the pressure on freshwater by shifting to using treated wastewater. Finally, the government is not enforcing the regulations that prohibit industries from dumping their industrial waste into rivers or close to water resources. The interviews with officials revealed there are 30-40 factories around Al Zarqa River and King Abdullah Qanah that are dumping their chemical waste into these rivers. Finally, the government is not adequately enforcing restrictions on industrial firms whose consumption of water exceeds a specific limit to build their wastewater plant to decrease their dependence on freshwater.

Now that the factors negatively affecting water management have been reviewed, it is appropriate to turn to possible solutions that have the potential to strengthen water management.

5.2 Proposed Solutions for Water Scarcity in Jordan

This section recommends some proposed solutions for alleviating the water scarcity problem in Jordan based on the research findings. Although there are existing government solutions for solving water scarcity. These solutions concern mainly ways of finding new water resources such as water harvesting and water desalination. The

following proposed solutions focus on improving water management and practices which is less costly and sustainable. It should be noted that some of the proposed solutions interweave with existing government solutions.

Improve and Maintain Water Networks

Improving water networks in Jordan can provide many benefits in terms of water saving and water quality. The old water networks in Jordan account for 30% of the non-revenue water. In 2017, the total non-revenue water was 234 MCM (see Table 10); part of this amount (70 MCM) (Al-Ansari et al., 2014b) is related to network loss of domestic freshwater. Moreover, based on my findings, old water networks are responsible for the bad quality water in terms of the smell, taste and colour. The analysis shows that the existence of deteriorated water networks is related to the economic situation of the country. However, renewing old water networks should be a top priority for the government of Jordan and the MWI.

Enforce Groundwater Abstraction Regulations

Illegal wells and water abstraction have a significant impact on water scarcity. While the water policies in Jordan set regulations and laws for licensing well drilling and limiting groundwater abstraction, the research findings show many examples of violation. For instance, according to the interviews the number of documented illegally drilled wells in 2017 was 1060 wells; the water pumping from these wells exceeds 259 MCM. Also, as indicated in Table 1, the water deficit in 2017 was 223.37 MCM as a result of water abstraction. Most of these violations pass without any punishment because the wells belong to tribal leaders or high-ranking officials. In addition, the research highlighted one example in which some people license for a legitimate purpose, but they use the water

for commercial purposes. According to the interviews, the current laws regarding drilling illegal wells are not deterrent. For example, a person who drills an illegal well is subject to a three month prison sentence and small pay fines. The government should review all licensed and unlicensed wells and apply stricter punishments for anybody who violates the regulations.

Improve Water Monitoring and Administration

Water administration is related to the control over water theft, faulty water meters, faulty estimation of water consumption, and illegal use of water. The literature review shows administrative loss accounts for almost 30.7% of the non-revenue water (Al-Ansari et al., 2014b). The MWI and WAJ can improve water administration by adopting the following practices:

- Replace old water meters with new ones in order to ensure accurate meters readings.
- Secure water meters in locked boxes to avoid human tampering or deterioration due to harsh weather conditions.
- Provide technical training for employees who are responsible for collecting water readings and issuing water bills
- Make regular inspections of the water meters and water pipes to prevent water theft.
- Report suspicious activities to the local water administrators for more investigation and place hefty fines on people who acknowledge water theft or illegal use of water.

Promote Awareness among the Public about Water Scarcity

Promoting awareness among public about water scarcity can be an effective way for conserving water. For instance, based on the responses of the survey (see *Table 8*), 62.5% of the participants' families are using water devices. This percentage is acceptable. However, it can be improved through awareness. In addition, the table shows high percentage of people are using fresh water for other purposes which is an indication for a need for more awareness. Nowadays, the easiest and fastest way to spread awareness can be done through social media such as Facebook, Instagram and Twitter. In addition, teachers at schools and universities should take their role in educating students about this problem. The MWI can also send awareness messages to the public through Radio and TV stations, and water bills. The MWI can also give incentives by setting lower water prices for families whose water consumption does not exceed a specific quota.

Review and Enforce Water Policies in all Sectors

Agriculture consumes almost 50% of water used in Jordan. In 2017, the agriculture consumption of water was 551.8 MCM (see *Table 2*). Moreover, the consumption of agriculture from the surface water in 2017 was 154.4 MCM and 253.2 MCM from the groundwater. This amount is almost equivalent to the amount of domestic water consumption. Therefore, the government should review the agricultural policies and decrease the dependency on groundwater and surface water. The government should prohibit the growing of water-intensive crops and replace them with plants that are more profitable and need less water. There are many alternatives for water intensive crops that need less maintenance and generate good profits. For instance, clumping bamboo, ground covers, herbs and mushrooms are examples of some profitable crops that are

easy to grow and need less water and maintenance(Arab Weekly, 2019). Also, the government should increase the workforce for monitoring farmers who violate the pumping regulations. Finally, farmers should be encouraged to use drip irrigation in order to decrease water consumption.

Regarding the industrial sector, the government should impose regulations on factories who consume large water quantities by requiring them to build mini wastewater treatment plants so they can reuse the treated wastewater. Moreover, Universities should not be an exception; Jordan has 29 public and private universities hosting around 200,000 students (Jordan Times, 2014). Universities use water for domestic purposes and irrigation; however, only a few universities have wastewater treatment plants. The government should support the establishment of these plants in every university. According to an interview with a senior university representative of the Hashemite University, the University is in a process of establishing innovative projects; the first project is the wastewater treatment plant in which they use the treated water for irrigation. The second project is building a drinking water system that extracts water from the air.

5.3 Conclusion and Future Work

This thesis elucidates the factors that contribute to the water scarcity problem in Jordan. The fluctuation of the average annual rainfall and the semi-arid climate of the country have a significant impact on the average water share per capita; however, there are other factors that contribute significantly to this problem such as the growth rate, the influx of war refugees from the neighbouring countries, climate change, and water management.

The government is facing many challenges related to water management such as

problems in applying water policies, loss of non-revenue water, enforcing the use of treated water for agriculture, and providing better water services to the public.

Regarding the water policies, the government of Jordan reviewed its water strategy by including revised water policies for the use of water in the domestic, agricultural, and industrial sectors. These policies include: the Water Utility policy, the Groundwater Management Policy, the Irrigation Water Policy, the Wastewater Management Policy, and the Water Sector Action Plan (2002-2006). Jordan water strategy emphasized on the need for improved water resource management with special focus on water sustainability for present and future needs. The strategy stresses protection against pollution, and restricting the use of surface and groundwater to a permissible level. In addition, the strategy indicated that wastewater shall be collected and treated to allow its reuse for unrestricted, agricultural, and non-domestic purposes. The strategy also emphasized the importance of causing efficient groundwater recharge. The government is also trying to increase the water resources and to improve water quality and water services.

The focus of this research was on identifying the water management issues and proposing recommendation that can mitigate the water scarcity problem. I argued that water management has a significant impact on water scarcity. However, the identification of management issues is not an easy task since it can be influenced by many factors. As the former Minister of Water and Irrigation indicated, water management is more complex than one can imagine. The management level of water in any country is a function of the status of the economy, and social level (social status and education), and awareness of people and politics governance system.

In order to identify the water management issues, I proposed a set of research questions. Based on these questions, I conducted a literature review, a public questionnaire, and interviews with experts and officials in Jordan. The findings indicate that Jordan set excellent policies concerning groundwater, wastewater, and water for agricultural usage. However, water management suffers from several shortcomings that hinder the application of good water management and aggravates the water scarcity problem.

This research identified several issues that can have negative impacts on water management. These issues include the economic situation of the country, the social and political structure, tribal influence, lack of public awareness, illegal agricultural and industrial practices, and multiple water authorities. The sluggish economy of Jordan cannot allow the government to allocate the necessary funds for building and maintaining decent water networks, for decreasing the loss of non-revenue water, and for providing good water service. Moreover, the tribal and lobbyist's influence hinder the execution of the regulations that prohibit illegal drilling of wells, water over pumping, and illegal use of water. Existing agricultural practices can lead to the overuse of fresh water that could otherwise be used for domestic purposes.

This research outlined the existing actions that the government is taking toward improving water quality and water services in Jordan. These include initiatives to review and establish new water policies, to secure more water resources such as rainfall harvesting, and to decrease the amount of non-revenue water. I argued that looking for new water resources such as seawater desalination and rain harvesting is costly.

Therefore, I proposed improving some water management practices by addressing the existing shortcomings.

My proposed solution encompasses a set of recommendations that the government should apply in order to improve water management. The recommendations include; enforce water conservation regulations, improve water monitoring, promote awareness among people about water scarcity, review and improve existing water policies, and maintain water networks.

This solution has several benefits: first, it is inexpensive compared to other costly solutions such as seawater desalination and rain harvesting. Second, based on 1997 MWI statistics it shaped a total saving of 493 MCM/year if the water management practices are improved (see Table 10).

Third, the solution is sustainable if it is applied correctly and completely. It can act as a principle where the older generations can remind the new ones that water is equivalent to life. Finally, improving water management can provide better water quality and better water services.

Table 10: *Causes of Water Loss in Jordan Based on 2017 Data* (Ministry of Water and Irrigation, 2017)

Cause or Loss	Loss/MCM	Comment
Illegal wells abstraction	259	
Administrative loss	72	Domestic (non-revenue)
Water networks loss	70	Domestic (non-revenue)
Other loss	92	Illegal agriculture and industrial practices (non-revenue)
Total	493	

For a better implementation of recommendations, a joint effort is required from the public and the government. The public effort relies on promoting awareness about the severity of the water scarcity problem and on encouraging people to conserve water. The media, universities, and schools can participate in promoting awareness. On the other hand, the government effort should focus on applying harsh punishments equally to anybody who breaks water laws.

Regarding future research, interested researchers can use this work as a base for investigating other dimensions that have an impact on water scarcity in Jordan. In addition, researchers can look at the successful measures taken by other Middle Eastern such as Israel for mitigating the water scarcity problem.

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Appendix A. Ethics Approval



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UNIVERSITY OF OTTAWA

APPLICATION FORM FOR ETHICS APPROVAL

Researchers applying for ethics approval are expected to have read the *Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans* (2nd ed. 2010) as it sets out the ethical guidelines for conducting research with human participants. At the end of this application your signature attests to the fact that you have read this document. When completing this application form, be sure to respond to all items.

1. RESEARCH PROJECT REGISTRATION

1.1 Project title: Environmental Challenges and Sustainable Solutions for Water Scarcity in Jordan

1.2a Anticipated project dates Start date: 2018-07-01 Completion date: 2018-08-01

1.2b Is there a pending deadline by which ethics approval is required? Yes No

Deadline date: _____

Please provide reasons:



1.3 Principal investigator. ^a [If this is a 4th year, Master's or Doctoral project, indicate your supervisor's name

Name: Hanan Al Omari

Professor Ph.D. M.D. Miss Ms. Mrs. Mr. Other

Department : Institute of Environment Faculty : science

Address :

Telephone no.: Ext.: _____ Fax no.: _____

E-mail:

1.4 Thesis/Project Supervisor

Name: Jamie Benidickson

Professor Ph.D. M.D. Miss Ms. Mrs. Mr. Other

Department: _____ Faculty: Law

Address: _____

Telephone no: _____ Ext.: _____ Fax no.: _____

E-mail: _____

1.5 Co-Investigator

Name: _____

Role in research project: _____

Professor Ph.D. M.D. Miss Ms. Mrs. Mr. Other

Department: _____ Faculty: _____

Address: _____

Telephone no: _____ Ext.: _____ Fax no.: _____

E-mail: _____

Add a co-investigator

1.6 Type of research

Professor's research

Doctoral thesis

Master's thesis

Master's major research

4th year project

Independent study project

Other (Please specify): _____

Please append the thesis committee's approval

Please append the thesis committee's approval. In cases where there is no committee, append a letter signed by the supervisor indicating that the supervisor has reviewed and approves the proposed research project.

1.7 Funding information

Received Pending Not required

Name of funding
agency: _____

U of O RE No. or Cost Centre or Funding Agency Reference
No.: _____

Have you applied for preliminary authorization of release
of funds (1b approval)? Yes No



File No.: _____

2. RESEARCH PROJECT DESCRIPTION**2.1 Purpose: Describe the project and its objectives. Please include the research questions. (1 page)**

The purpose of the study is to collect information from public and government officials in Jordan about water quality and water scarcity. In addition, the study aims to investigate the procedures taken by the government of Jordan with respect to water management and water policies. The objective of this study is to propose sustainable solutions for water quality and water management based on the collected data and the literature reviews.

Research question: My research is centered around the following research questions

1. How atmospheric pollution affect the water quality in Jordan?
2. What are the impacts of agricultural pesticide in polluting surface water quality in Jordan?
3. What are the effects of waste treatment plans on the quality of surface and underground water?

2.2 Context: Situate the project in the scholarly literature and provide the rationale for the study. (1-2 pages)

Jordan is a Middle Eastern country that suffers scarcity of water. Water shortage in Jordan is always an issue that is considered by government officials, therefore, on the international level, Jordan is trying to secure its water resources by signing treaties with its neighboring countries; Syria and Israel. However, this is not a permanent solution for the water scarcity problem. The scarcity is resulted mainly by the drop of rainfall which has an impact on the reserve of ground and surface water. It is believed that climate change is contributed largely in this problem. According to (Jordan News, 2017) the country will suffers a decrease in rainfall by 30% by 2100 and the annual temperature will increase by 4.5 Celsius, especially with the absence of international climate change policy action. Also, this will result on doubling the number of drought compared to 2008-2010.

In addition, the environmental and agricultural issues in Jordan significantly contribute to the problem. The uncontrolled use of pesticides, fertilizers, and fungicides in agriculture play a major role in polluting the surface water. Furthermore, the uncontrolled waste, congested sewerage systems, and waste treatment plans all have negative impacts on the quality of water (Hadadin & Tarawneh, 2007).

Besides that, the rapid increase of population in Jordan as a result of war refugees from Palestine, Iraq, and Syria has contributed significantly to the increase demand of water.

Although Jordan is applying a set of policies to mitigate the shortage of water and improve water allocation decisions among sub-sectors, the policies are not considering seriously the impact of climate change, pollution and other factors on water availability. This research focuses on the environmental challenges and sustainable solutions for water scarcity in Jordan.

2.3 Methodology/Procedures: Describe all methods and procedures that will be used to obtain data and answer the research questions. (1-2 pages)

The research work focuses on identifying and analyzing the environmental factors that play a role in water pollution. The data will be obtained using different methods such as reviewing the studies the investigate the effects of pesticides, fossil fuel, and waste treatments plans on surface water and aquifers in Jordan. Moreover, the data will be collected from two main sources: the first, source is the governmental institutions in Jordan including (Ministry of water and irrigation, Ministry of Environment, Water Authority of Jordan, and Jordan Valley Authority). Also, documents related to the United Nations agreements and water policies, and publications that concern about the water scarcity and environmental issues in Jordan. Second, conducting personal interviews with officials from different governmental institutions as mentioned above. The interview with officials might take more than one time depends on the information provided. On the other hand, personal interviews will conducted with public people from different districts in Jordan including the cities of (Amman, Irbid, and Jerash) about their opinions of water distribution and water quality.

2.4 Data analysis: Describe how the data will be analyzed. (1 page)

Once the data is collected , the following steps will be applied:

- 1- Identify and summarize the main ideas .
- 2- Categorize the data and apply quantitative data analysis (statistics, rates, or numbers), and qualitative data analysis (descriptions, opinions, quotes) to get an accurate assessment and better understanding of overall situation.
- 3- Identify the relationship between the data and the differences if occur.
- 4- Identify the missing information , or unanswered questions .
- 5- Identify any significant changes over the years (e.g. rainfall rate, drought, quality and quantity water) by comparing the data.
- 6- Interpret the results and connect the ideas in descriptive paragraphs
- 7- Identify the challenges and solutions exist.
- 8- Propose a set of appropriate sustainable solutions in order to eliminate or minimize the risk of environmental factors. This can be achieved by proposing cooperation between public and private sectors or law enforcement and penalties for violators. In addition, compare the situation of Jordan with other countries that has the same water situation and investigate the strategies and technology they apply to enhance the efficient use of water. This can be achieved through literature review.

2.5 Describe the anticipated contribution of the research. (1 page)

Since water scarcity in Jordan is an alarming problem that can jeopardize the economy and the stability of the country, therefore, this research project will help examine this problem that will create a conflict about water. This research can shed the light on this problem and calls for an urgent action to support communities in crisis. The research could attract an important audiences such as UN agencies , private sectors, donors, and government of developed countries. This research is not just about water security it is also to protect the food security as a result of water securing. Thus, the Jordanian civil society should be more aware of the crisis that influence their life quality. Moreover, conducting such research project will participate in fill the gap of knowledge specially when quantitative data (surveys,interviews) are included.

2.6 References: Include author, year, title, journal, page numbers (1-2 pages)

Hadadin, N., & Tarawneh, Z. (2007). Environmental Issues in Jordan, Solutions and recommendations. *American Journal of Environmental Sciences*, 3(1), 30-36.

Jordan Times. (2014). Jordan world's second water-poorest country. Retrieved Jan 17, 2017

Salman, M. (Ed.). (2016). coping with water scarcity in Jordan-The role of Agriculture: Food and Agriculture Organization of the United Nation FAO

United Nations. (2017). United Nation Development Program. Retrieved Jan 17, 2017

Al-Kharabsheh, A. (1999). Ground-water quality deterioration in arid areas:a case study of the Zerqa river basin as influenced by Khirbet Es-Samra waste water (Jordan). *Journal of Arid Environments*, 227–239.

Al-Kharabsheh, A., & Alatoum, M. (2013). Effect of Agricultural Activities on Water Quality Deterioration of Mujib Basin, Jordan. *Current World Environment*, 8(3). Retrieved from [http://www.cwejournal.org/?p=5352\(2006\)](http://www.cwejournal.org/?p=5352(2006)) .

Economic and Socail Commisionfor Westren Asia. New York: United Nations.

Rogers, J. D. (2004). Water and Environmental Security in the Middle East. *Military Geography and Geology* , pp333-343.

Wolf, A., & Ross, J. (1992). The Impact of Scarce Water Resources on the Arab-Israeli Conflict. 32.

Al-Taani, A. A. (2012). Seasonal variations in water quality of Al -Wehda Dam North of Jordan and Water Suitability for Irrigation in Summer. *Arabian Journal of Geosciences* , 6 (4), pp 1131-1140.

T.M, A. S., A.M, B., & I.A, H. (2005). Water Resources Planing and Development in Jordan. pp 183-197.

Israel Ministry of Foriegn Affairs. (2013). Retrieved Jul 18,2013,from <http://www.mfa.gov.il/MFA/ForeignPolicy/Peace/Guide/Pages/Israel-Jordan%20Peace%20Treaty%20Annex%20II.aspx>.

3.1 Who is being

3. RECRUITMENT OF PARTICIPANTS

3.1 Who is being recruited? Describe the specific inclusion criteria for participants to be involved in the study.

Participants involved in this study are professionals in water management, officials working in water ministry, policy, irrigation, and environment, and public people from many different districts

3.2 Indicate the number of participants in the study.

Between 5-8 officials, and 20 people from different district in Jordan

3.3 What is the rationale for the intended number of participants?

Cover all aspects of the research problem in order to have a better understanding about the overall situation

3.4 In some cases, the number of interested participants who meet the inclusion criteria exceeds the desired number of participants.

Will all eligible individuals who volunteer be included in the study?

Yes No

If no, please describe how you will make the selection (e.g., first come/first served) and how participants will be informed of this.



3.5 In some studies, there are additional scientific criteria which require the exclusion of potential participants (e.g., medical condition, certain prescription medication). Does this apply to your study?

Yes No

If yes, please explain the exclusion criteria and the screening process.



3.6 Source of participants - Check all that apply:

Column A

- School Boards
- Correctional Services
- Agencies
- Mailing Lists
- Businesses, Industries, Professions
- Hospitals, Long Term Care Facilities or other
- Other - Please specify government, ministries

Column B

- uOttawa undergrad or graduate classes
- uOttawa Psychology ISPR
- Other uOttawa sources (e.g. Health Services Clinic, Pride Centre) - Please specify

Indicate the specific names and locations of any sources checked (excluding Psychology ISPR):

Ministry of Environment , Ministry of Water and Irrigation , Royal Jordanian Geographic Center (RJGC), and The National Center for Agricultural Research and Extension, (NCARE). "water and environment section" . All those are located in Jordan.

3.7 Who will be recruiting participants?

The researcher will recruit all the participants.

3.8 Are there any supervisory or trust-based relationships between persons conducting recruitment and the participants (e.g., professor-student, relative, friend, doctor-patient, therapist-client)?

Yes No

If yes, describe the relationships and the steps that will be taken to ensure that there is no coercion.



3.9 Describe how participants will be recruited. Please note that if participating organizations are being asked to distribute a recruitment invitation to potential participants, the researcher's contact information must appear on the recruitment invitation so that potential participants can contact the researcher directly.

Please append copies of all recruitment posters, advertisements, telephone scripts, letters of information, etc. that will be used for recruitment purposes.

The participants are contacted through their official emails and phone numbers. those are the people that will be contacted
 Dr. Jehad Alsawair
 Eng. Bassam Mohammed Al-Qaisi
 Thaer Almomani
 Awni Shaker
 professor Ziad Almeme
 Dr.Abeer Albalawneh

3.10 Is organizational or governmental permission needed to conduct research with the participants (e.g., school boards, employers, correctional services)?

Yes No

If yes, describe from whom permission is required and how this permission will be obtained. Include copies of all permissions.



3.11 Is research being conducted in another country?

Yes No



Please specify:

Jordan

Is local ethical clearance needed to carry out the research?

Yes No

If no, explain the circumstances why ethical clearance is not required.



The participants just need approval from my university so they be sure that the data will be used for research project only

If yes, include copies of all approvals or explain how such approvals will be obtained



4. PARTICIPATION

4.1 Describe what participants will be asked to do. Include how often participants will be asked to participate and how long each research activity will last. Please append any questionnaires, surveys, interview guides, focus group guides etc.

Participant will be asked to do interviews , The expected time for an interview will be around one hour; however most of the interviews depend on position of the interviewee and the type of provided information. The expected number of interviewees is about 5-8 government officials.

4.2 Provide the following details regarding the time and location of the data collection:

a) As relates to the specific participant population, describe when data collection will occur (e.g., interviews with school children will take place outside of class time; focus group sessions with professionals will take place during working hours).

The time of the interview will be within the work hours , also the location in the work place.

b) As relates to the specific participant population, describe the location of data collection (e.g., interviews with school children will take place in the library of John Smith Elementary School, located in Orleans, Ontario; focus group sessions will take place in a conference room in the John Smith office building located in Orleans, Ontario; interviews will take place in a coffee shop in Gatineau, Québec).

Interviews will take place in the both cities Amman and Irbid at the following addresses: Ministry of Environment , Ministry of Water and Irrigation , Royal Jordanian Geographic Center (RJGC), and The National Center for Agricultural Research and Extension, (NCARE). "water and environment section"

4.3 Will scientific equipment involving direct or indirect physical contact be used (e.g., electrodes, sensory devices, probes)?

Yes No

If yes, provide a description of the equipment and how it will be used.



4.4 Does the research involve any invasive procedures whereby a scientific instrument, such as an esophageal probe, will be inserted into the body?

Yes No

If yes, who will be performing the procedure? Please provide appropriate clearance from the Office of Risk Management.



4.5 Will audio recording be used in the study?

Yes No

If yes, which research activity(s) will be audio recorded?



Recording might be used through interviews to avoid any missing information

4.6 Will video recording or photography be used in the study?

Yes No

If yes, which research activity(s) will be video recorded or photographed? If video recordings or photographs will be used in future presentations, for conference purposes, etc. please ensure that participants are aware of this and that permission is obtained and documented in the consent form.



4.7 Will participants be compensated?

Yes No

If yes, provide details. Please note that since research participation is voluntary, participants are free to withdraw at any time without negative consequences. The Research Ethics Board requests that after a study has begun any participant who chooses to withdraw should still receive the compensation that had been offered. If for some reason participants will not be compensated after they have withdrawn from the study, please explain



5. ASSESSMENT OF RISKS

5.1 Indicate if the participants might experience any of the following:

Risk of physical harm (e.g., falling, muscle pain)	<input type="checkbox"/> Yes	<input checked="" type="checkbox"/> No
Physical discomfort (e.g., tiredness, weakness, nausea)	<input type="checkbox"/> Yes	<input checked="" type="checkbox"/> No
Risk of psychological or emotional harm (e.g., trauma)	<input type="checkbox"/> Yes	<input type="checkbox"/> No
Psychological or emotional discomfort (e.g., anxiety, stress, loss of confidence, regret for disclosing personal information)	<input type="checkbox"/> Yes	<input checked="" type="checkbox"/> No
Legal repercussions for participating in the study (e.g., possibility of being sued, charged with criminal activity)	<input type="checkbox"/> Yes	<input checked="" type="checkbox"/> No
Social repercussions (e.g., possibility of marginalization, being negatively judged by peers or employer)	<input type="checkbox"/> Yes	<input checked="" type="checkbox"/> No
Economic inconveniences (e.g., expenses incurred for participation, loss of income during time of participation)	<input type="checkbox"/> Yes	<input checked="" type="checkbox"/> No
Other inconveniences (e.g., long travel to research site, time consumed, disruption of family routines)	<input type="checkbox"/> Yes	<input checked="" type="checkbox"/> No

5.2 If you answered yes to any of the items in section 5.1, please complete (a) and (b) below.

(a) Describe the risks, discomforts or inconveniences.

(b) Specify the measures taken to mitigate such risks, discomforts or inconveniences. Please include names and contact information of appropriate resources to which participants can be directed if needed.

6. BENEFITS

6.1 Describe the benefits of the research to the participants.

6.2 Describe the benefits of the research to society.

7. PRIVACY OF PARTICIPANTS

Privacy concerns are strongest in regard to information that identifies a specific research participant. Collecting anonymous data is the most robust way of safeguarding the identity of research participants. Data which could enable the identification of participants, however, requires additional safeguards, such as removing identifiable information, using pseudonyms, or a code when working with the data and when disseminating research results. Particular attention is needed to ensure that participants in small communities or groups will be protected from inadvertent identification through a combination of identifiers such as date of birth, place of residence or unique personal characteristics.

7.1 Will any information be collected which would permit specific research participants to be identified through identifiers such as their name, address, social insurance number, personal health number, date of birth, place of residence, unique personal characteristic, etc.?

Yes No

If yes, what identifiers will be collected?



7.2 Please describe how the identity of the individuals will be safeguarded. If using pseudonyms or codes to remove identifiers, please describe who will have access to codes or pseudonyms to link data to

Personal information of the participants will not be stored in any media type, whether recording, videoing, or storing their information in any smart device or a computer. Also, their personal information will not be shown in the research

7.3 Are there any conditions under which the protection of the identity of participants cannot or will not be guaranteed (e.g., participant chooses to be identified, members of a focus group)?

Yes No

If yes, please explain how this will be addressed and how participants will be informed of this.



7.4 When presenting the results of the research, will research participants be quoted?

Yes No

If yes, describe how identifying information will be removed or altered ensuring that quotes do not reveal individuals' identities. In the case where quotes will reveal individuals' identities, please explain the reasons and include this information in the consent form.



7.5 If research participants will be quoted, will they be given the opportunity to review their transcripts?

Yes No Participants will not be quoted

If yes, please explain how research participants will have access to their transcripts. If sending transcripts via email, please explain the security measures being taken (e.g., encryption, password protection of documents). If no security measures are being contemplated, please inform research participants of the possible security risk in the consent form



8. CONFIDENTIALITY OF DATA

measures for safeguarding information, for the full life cycle of information - that is, its collection, use, dissemination, retention and disposal. Physical safeguards include use of locked filing cabinets and location of computers containing research data away from public areas. Administrative safeguards include development and enforcement of organizational rules about who has access to personal information about research participants. Technical safeguards include use of computer passwords, firewall, anti-virus, encryption and other measures that protect data from unauthorized access, loss or modification.

*Draft 2nd Edition of the Tri-Council Policy Statement: Ethics Conduct for Research Involving Humans
- Interagency Advisory Panel on Research Ethics - December 2008, p. 44.*

8.1 Who will conduct the data collection?

Principle researcher

8.2 Who will have access to the data?

- Principal Investigator
 Thesis/Project Supervisor

- Co-investigator
- Research Assistant
- Others (Please specify)

Any additional individuals who may have access to the data, who have not signed this form, such as research assistants, translators, interpreters, etc. must sign a confidentiality agreement.

No one will have access to the data

- 8.3 Describe the physical (e.g., locked office) and technical (e.g., encryption) safeguards that will be used to securely store all sources of data, such as written records, electronic data, audio/video recordings, questionnaires, etc. during the course of the study.**

The data will be saved on the researcher's personal computer

- 8.4 Indicate how long data will be conserved and the starting time of the conservation period (e.g., following publication, completion of project). It is recommended that all data (excluding clinical trial data) be conserved for a minimum of 5 years. Clinical trial data must be stored for at least 25 years.**

The master thesis will include all the data will be collected, therefore the data will be kept on the thesis

- 8.5 Describe how and where the data will be securely stored during the conservation period.**

The collected data will be saved on a recorder or hard copy paper.

- 8.6 Describe the methods of disposal for all types of data following the conservation period (e.g., shredding, secure deletion).**

The data will be deleted from the researcher's personal computer and the recording will be deleted also.

9. FREE AND INFORMED CONSENT

Free and informed consent means that individuals agree to participate in research voluntarily and that each participant understands as fully as possible the purpose of the research, what is required of him/her, and the potential risks and benefits. When the participant population is comprised of both Francophones and Anglophones, the University of Ottawa Research Ethics Board requires that consent forms be provided in both French and English.

- 9.1 Describe the procedures that will be followed to obtain informed consent from the participant or legal guardian. Attach all consent documents, including information sheets and scripts.**

Participants who have been chosen are contacted through Emails, or telephone. The information regarding my project and the type of data needed were provided to them. The list of participants who agreed to do the interviews is attached with this form.

- 9.2 If written consent is not appropriate or cannot be obtained, describe why this is the case and how free and informed consent will be obtained and documented.**

Consent is taken through messages or calls after explaining to the participants the details about the project. Written consent cannot be obtained since participants are in different country.

9.3 Who will be obtaining consent from the participants?

The Principal Investigator

9.4 Are there any supervisory or trust-based relationships between persons obtaining consent and the participants (e.g., professor-student, patient-doctor, relative, friend)?

Yes No

If yes, please describe and explain the measures taken to ensure that participants do not feel pressure to participate or perceive they may be penalized for choosing not to participate.



9.5 Does the project involve participants under the age of 18?

Yes No



Please specify group:

Engineers, researcher, manger, professor, author, and random of public

If yes, consent from the parent or guardian is normally required. In addition, participants under the age of 18 should also be given the opportunity to agree to their involvement in the study. This is done with an age-appropriate assent text. Please attach a copy of the consent form and the assent form.

If an exception to this requirement is being sought, please explain.



9.6 Could participants feel pressure to participate or perceive that they may be penalized for choosing not to participate in the study?

Yes No

If yes, please describe and explain the measures taken to ensure that participants do not feel pressure to participate or perceive they may be penalized for choosing not to participate.



9.7 Partial Disclosure/Deception: In certain research contexts, incomplete disclosure of relevant information or an element of deception is necessary for the successful conduct of the research. Will any of the procedures in this study include only partial disclosure of information to participants or an element of deception?

Yes No

If yes, provide a rationale for the partial disclosure or element of deception. Include a description of the procedures for debriefing the participants and giving them an opportunity to consent to having their data remain in the study. If debriefing is not a viable option, please explain. If a participant's data cannot be removed from the study even when requested by the participant, please set out the conditions which make it impossible (e.g., part



10. SIGNATURES**I/we the undersigned, certify that:**

- (a) I/we have read the *Tri-Council Policy Statement: Ethical Conduct of Research Involving Humans*(TCPS 2, 2010);
- (b) I/we have reviewed the application and are in agreement with the protocol as submitted;
- (c) I/we will not commence with recruitment and data collection for the proposed research project until ethics approval
approval
has been granted;
- (d) I/we will advise the Research Ethics Board of any revisions to the research arising before or after ethical approval is obtained;
- (e) I/we have the responsibility to disclose to the Research Ethics Board real, perceived or potential conflicts of interest;
- (f) I/we will not start the project, if funded by an external sponsor, until the contract/agreement has been approved by

Hanan Al Omari

4-4-2018

Signature of the Principal Investigator_____
Date

Jamie Benidickson

4-4-2018

Signature of the Thesis/Project Supervisor
(if applicable)_____
Date_____
Signature of the Co-investigator_____
Date

Remarks

Save as

Reset

Print



Université d'Ottawa University of Ottawa
Bureau d'éthique et d'intégrité de la recherche Office of Research Ethics and Integrity

Certificate of Ethics Approval

Health Sciences and Science REB

Principal Investigator / Supervisor / Co-investigator(s) / Student(s)

First Name	Last Name	Affiliation	Role
Jamie	Benidickson	Law / Law	Supervisor
Hanan	Al Omari	Science / Environmental	Student

File Number: H04-18-01

Type of Project: Master's Thesis

Title: Environmental Challenge and Sustainable Solutions for Water Scarcity in Jordan

Approval Date (mm/dd/yyyy)	Expiry Date (mm/dd/yyyy)	Approval Type
06/12/2018	06/11/2019	Initial

Special Conditions / Comments:
N/A



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Bureau d'éthique et d'intégrité de la recherche Office of Research Ethics and Integrity

This is to confirm that the University of Ottawa Research Ethics Board identified above, which operates in accordance with the Tri-Council Policy Statement and other applicable laws and regulations in Ontario, has examined and approved the application for ethical approval for the above named research project as of the Ethics Approval Date indicated for the period above and subject to the conditions listed the section above entitled "Special Conditions / Comments".

During the course of the study the protocol may not be modified without prior written approval from the REB except when necessary to remove participants from immediate endangerment or when the modification(s) pertain to only administrative or logistical components of the study (e.g. change of telephone number). Investigators must also promptly alert the REB of any changes which increase the risk to participant(s), any changes which considerably affect the conduct of the project, all unanticipated and harmful events that occur, and new information that may negatively affect the conduct of the project and safety of the participant(s). Modifications to the project, information/consent documentation, and/or recruitment documentation, should be submitted to this office for approval using the "Modification to research project" form available at: <http://research.uottawa.ca/ethics/submissions-and-reviews>.

Please submit an annual status report to the Protocol Officer 4 weeks before the above-referenced expiry date to either close the file or request a renewal of ethics approval. This document can be found at: <http://research.uottawa.ca/ethics/submissions-and-reviews>.

If you have any questions, please do not hesitate to contact the Ethics Office at extension 5387 or by e-mail at: ethics@uOttawa.ca.

Germain Zongo
Protocol Officer for Ethics in Research
For Daniel Lagarec, Chair of the Sciences and Health Sciences REB



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Consent Form

Master thesis topic: Water Management in Jordan and its Impact on Water Scarcity

Name of researcher: Hanan Al Omari
Institute of Environment, University of Ottawa- Canada

Supervised by: Professor Jamie Benidickson. Faculty of Law, University Of Ottawa

Invitation to Participate: I am invited to participate in the abovementioned master research thesis project study conducted by Hanan Al Omari, no fund provided until now.

Purpose of the Study: The purpose of the study is to collect information from members of the public and government officials in Jordan about water quality and water scarcity in Jordan. In addition, the study aims to investigate the procedures taken by the government of Jordan with respect to water management and water policies. The objective of this study is to propose sustainable solutions for water quality and water management based on the collected data.

Participation: My participation will consist essentially of providing information about water policies, water management plans, or water quality in Jordan and the environmental challenges. The expected time for an interview will be around one hour; however most of the interviews depend on the position of the interviewee and the type of provided information. The participants of this study are located at the capital city Amman, The expected number of interviewees is about 5-8 government officials.

Please put check for the following:” for officials use only”

- () I accept the use of audio recording during the interview.
- () I do not accept using audio recording during the interview.



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Risks: My participation in this study will not entail any risk, no sensitive personal information of any type will be collected that might cause any harm or risk to the participants of this study. The collected information will focus solely on water policies, management, and quality. Moreover, participants can have the option of not answering any question or even withdraw from the survey.

Benefits: My participation in this study will allow the researcher to understand the factors that have great impact on water scarcity and water quality problem in Jordan in order to propose future solutions for this problem. The participants will not receive any kind of incentives to perform this study; their participation is based on a volunteer work.

Confidentiality and anonymity: I understand that the information I provide will be used in the student thesis only for understanding the current situation about water scarcity and water quality in Jordan and that my confidentiality will be protected since the data about the study will be collected personally by the researcher and will not be accessible to unwanted third party or copied by third party. Only the researcher and her supervisor will have access to the data. The data will be destroyed in the suitable way by shredding data in paper and deleting electronic data.

Anonymity will be protected by not storing my personal information in any media type, whether recording, or storing my information in any smart device or a computer. Also, the project does not collect personal information. I am informed that if the interview is conducted during work hours and at my work place my anonymity cannot be fully guaranteed since some colleagues may come to know I have participated in the research. I am free to choose the place and time of the interview.

Conservation of data: If any data in the form of brochures or written articles collected from me will be on a form of hard copies; however, my answers will be saved on the researcher's personal computer for further analysis. The conservation period will be around 5 years. After that, the data will be deleted.

Voluntary Participation: I am under no obligation to participate and if I choose to participate, I can withdraw from the study at any time and/or refuse to answer any questions, without suffering any negative consequences. If I choose to withdraw, all data gathered until the time of withdrawal will be destroyed and not included in the study.

Acceptance: I, -----, agree to participate in the above research study conducted by **Hanan Al Omari** a graduate student associated with Environmental Institute, University of Ottawa which research is under the supervision of professor Jamie Benidickson

If I have any questions about the study, I may contact the researcher or her supervisor.



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uottawa.ca/environment/

If I have any questions regarding the ethical conduct of this study, I may contact the Protocol Officer for Ethics in Research, University of Ottawa, Tabaret Hall, 550 Cumberland Street, Room 154, Ottawa, Ontario K1N 6N5, Canada

Tel.: +1 (613) 562-5387

Email: ethics@uottawa.ca

There are two copies of the consent form, one of which is mine to keep.

Participant's signature: (Signature) Date: (Date)

Researcher's signature: (Signature) Date: (Date)

Appendix B. Interviews Forms

Interview Form

Interviewee: Expert and Researcher

Institution: Upper House of Parliament

Question 1: How we can reach water sustainability through proper management?

Question 2: Is there any project that works to find the location of moisture soil?

Question 3: Do you think that Jordan taking his fair share from Israel and Syria?

Question 4: Do you think that one of the wars will because of water?

Answer: No, this a myth, water generate life there is was no war through history

Question5: Based on the literature review Tabria Lake is polluted what do you think about that?

Question 6: Since we are ahead regarding management, why we have scarcity?

Question 7: What are the gaps in regulation and policies?

Question 8: How we can reach water sustainability?

Question 10: What are the strategies of Jordan that applied to their sectors?

Question 11: What is your suggestion about other legislation?

Question 12: Regarding the dead-red project? I read that this project will be started from Jordan because they have fewer restrictions on the environmental issues.

What do you think about that?

Interview Form

Interviewee: Researcher

Institution: The *National Center for Agriculture Research and Extension (NCARE)*

Question 1: What are the factors that affected the management?

Question 2: what kind of solutions you have to solve the previous problems regarding the management?

Question 3: What are the suggested solutions for the future?

Question 4: What are the main challenges you face as the agriculture sector?

Question 5: What kind of steps you made or planning to make to come over the challenges mentioned in question 4?

Interview Form

Interviewee: Chemical Engineer

Institution: Ministry of Environment (MOE)

Question 1: what are the projects that the ministry adopts muintregarding the ground water?

Question 2: What is your plan to achieve a balanced equation between demand and supply?

Question 3: What are the challenges that face you regarding the water scarcity?

Question 4: How can we come over these challenges?

Question 5: Is Drinking water good to drink and if yes why people rely on the bottled water?

Interview Form

Interviewee: An official

Institution: Ministry of Water and Irrigation (MWI)

Question 1: The best features of management adoption in urban and rural?

Question 2: What is the water resource for drinking?

Question 3: Is Tabaria Lake polluted?

Question 4: What are your strategies to reach water sustainability?

Question 5: Are these policies implemented?

Question 6: What are the challenges that the ministry face when providing water to the public?

Question 7: Do you have plans for water conservation?

Answer: The amount of water available is not enough for consuming so how we can conserve water.

Question 8: Why water served in some areas while others not?

Question 8: Are Environmental factors contribute to water scarcity?

Question 9: Is there any solution for drought?

Question 10: Where do you see the problem of water shortages?

Question 11: Did you find suitable solutions?

Question 12: Do you have a statistic of these areas how much the percentage?

Question 13: What do you do in this case when the whole city has illegal use?

Question 14: Is every city has it, water directors?

Question 15: What about the treaties between Jordan and Syria, does it allow Jordan to take its share fare from water?

Question 16: What do you think about the sandy aquifers?

Question 17: How much saving of water in these sandy aquifers?

Question 18: What other areas they have illegal use for water? What they make them do that?

Question 19: Is there any contamination in groundwater?

Question 20: Is there any cases about the sewage water that might affect the groundwater?

Question 21: What is your suggestion to reach water sustainability?

Question 22: What kinds of management do you think should be applied?

Interview Form

Interviewee: An official

Institution: Ministry of Water and Irrigation (MWI)

Question 1: What kind of awareness you do for the public regarding the water scarcity?

Question 2: What other steps you are taking regarding the water scarcity?

Interview Form

Interviewee: Engineer

Institution: Ministry of Water and Irrigation

Question 1: What kinds of projects you have to mitigate the climate change effects?

Question 2: What measurements you do to decrease non-revenue water?

Question 3: I know that the minimum standard per capita is 500 litter per day, so how this meets the international specification?

Question 4: What are the achievements regarding groundwater management?

Question 5: What are the main challenges of providing public water?

Question 6: Can you explain the water harvesting situation after insert harvesting code to the building in 2009?

Question 7: Is there any plan to protect water resources?

Question 8: What are the problems you face when monitoring the water resources?

Question 9: Regarding the agriculture sector, what type of management the ministry adopts?

Interview Form

Interviewee: An official

Institution: Ministry of water and irrigation

Question 1: What Gaps in management?

Question 2: What about the none-revenue water?

Question 3: In your opinion what is the main reasons of scarcity?

Question 4: How do you describe the maintenance of network?

Question 5: What are the gaps and challenges that face these groups?

Question 6: If we control the non-revenue water can we reach sustainability?

Interview Form

Interviewee: legal officer

Institution: private office

Question 1: How many illegal wells the country experiencing every year?

Question 2: What are the solutions in your opinion to stop the illegal wells?

Question 3: Why people do illegal wells?

Appendix C. Survey Questionnaire

Please Circle only one appropriate choice

1. District:

2. City/Town:

3. How many family members in your household?

- A. 1
- B. 2
- C. 3
- D. 4
- E. Over 4

4. How many times do you receive water per week?

- A. 1 time a week
- B. 2 times a week
- C. 3 times a week
- D. More than 3 times per week

5. Is the water quantity you receive sufficient for all your needs?

- A. Yes
- B. No

If not, is there any additional source of water.....

6. How many Cubic meter you receive monthly?

7. Please rate the quality of your drinking water by checking the number that matches your opinion.

- A. Poor
- B. Fair
- C. Goo
- D. Excellent

8. Generally how does your water smell?

- A. No smell
- B. Foul smell

9. Generally, how does your water taste?

- A. No taste
- B. Bad taste (please specify)

10. Generally, what does your water look like?

- A. Clear

- B. Cloudy
- C. Dirty

11. Have you ever made a complaint related to your drinking water in the past?

- A. No
- B. Yes (is the complaint related to quantity or quality)

12. Overall, are you satisfied with your drinking water service?

- A. Yes
- B. No (please specify)

13. Do you feel there is a threat of a drinking water shortage in the area where you live?

- A. No
- B. Yes (please specify)

14. Do you have water-saving devices (low-flow faucets, toilets, showerheads, etc.) installed in your home?

- A. No
- B. Yes (please specify)

15. Do you have equipment in your home to make the water quality better (Water softener, water purification)

- A. No
- B. Yes (please specify)

16. Do you use the water for other purposes such as (irrigation, farming,...others)

- A. No
- B. Yes (please specify)