Securing the Future of Water Resources for Beirut: A Sustainability Assessment of Water Governance in Beirut, Lebanon

Thesis submitted by

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Abstract

Securing a sustainable water future is an important issue for any nation, but it is a particularly challenging concern for many developing nations, and Lebanon is no exception. With recent and more extreme water shortages in the country, and the threat of facing a water crisis, it has become increasingly evident that such a crisis is not simply an issue of water availability, but a crisis of water governance that must be addressed. In Beirut, Lebanon, as in many metropolitan areas in the MENA region, water governance challenges include variable climate conditions and impacts of climate change, growing demands, limited water resources, and political instability. This study presents a sustainability assessment of water governance in Beirut, highlights the most pressing challenges faced in the water sector, and offers key recommendations to address these challenges.

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List of Abbreviations

BGR	Bundesanstalt fur Geowissenschaften und Rohstoffe (Federal Institute for Geosciences and Natural Resources)
BMLWE	Beirut and Mount Lebanon Water Establishment
BOD	Biological Oxygen Demand
CDR	Council for Development and Reconstruction
CEDARE	Centre for Environment and Development for the Arab Region and Europe
CNRS	National Council for Scientific Research
COD	Chemical Oxygen Demand
ELARD	Earth Link and Advanced Resources Development
ESCWA	Economic and Social Commission for Western Asia
EIB	European Investment Bank
GBA	Greater Beirut Area
GWP	Global Water Partnership
HDR	Human Development Report
LCWMC	Lebanese Centre for Water Management and Conservation
MENA	Middle East and North Africa
MOE	Ministry of Environment
MOEW	Ministry of Energy and Water
MOPH	Ministry of Public Health
NWSS	National Water Sector Strategy
OECD	Organization for Economic Cooperation and Development
RWEs	Public Regional Water Establishments

TSS	Total Suspended Solids
UNDESA	United Nations Department of Economic and Social Affairs
UNDP	United Nations Development Programme
UNECE	United Nations Economic Commission for Europe
UNESCO	United Nations Educational, Scientific, and Cultural Organization
UNHCR	United Nations High Commissioner for Refugees

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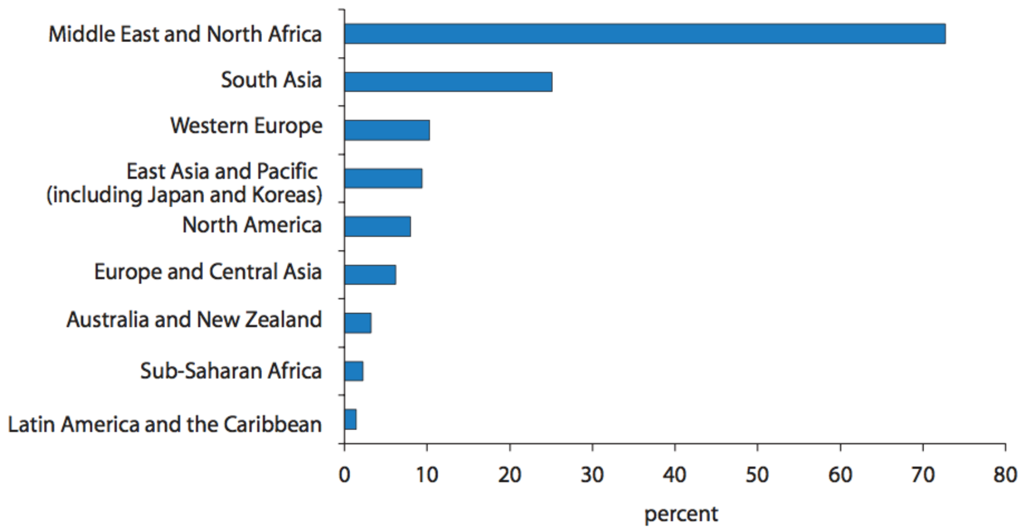
Chapter 1: Introduction

Regional Context: Water Scarcity in the MENA Region

Securing a sustainable water future is a key concern for any nation, but it is a particularly challenging task for many developing nations worldwide. It has long been an issue of concern for countries in the Middle East and North Africa Region, the most water scarce region in the world (CEDARE, 2004; UNDP, 2013; Varis and Tortajada, 2007; World Bank, 2007). Much of the region can be categorized as extremely arid, arid or semi-arid (ESCWA, 2007), so issues of water scarcity are not new to the region. However, what is of pressing concern in the region is the rate at which scarcity is becoming worse (Rached and Brooks, 2010). With more than 5 percent of the global population, the region receives only 2.1 percent of the world's average annual precipitation and contains 1.2 percent of annual renewable water resources (ESCWA, 2007; World Bank, 2007). For the last several decades of the 20th century, countries within the region were preoccupied with industrial and socio-economic development issues, ignoring the implications of increased water demand in the region. As populations and economies grew, governments became increasingly focused on securing water supply and expanding services; but in the absence of effective control measures and regulation mechanisms during that period, overexploitation of the limited water resources available in the region continued in a very rapid manner (ESCWA, 2007; World Bank, 2007). What resulted was a region that uses more of its renewable water resources than any other region in the world (Figure 1), with estimates showing withdrawals of close to 80 percent of total renewable water resources (World Bank, 2007).

Figure 1. Percentage of total renewable water resources withdrawn by region (World Bank, 2007)

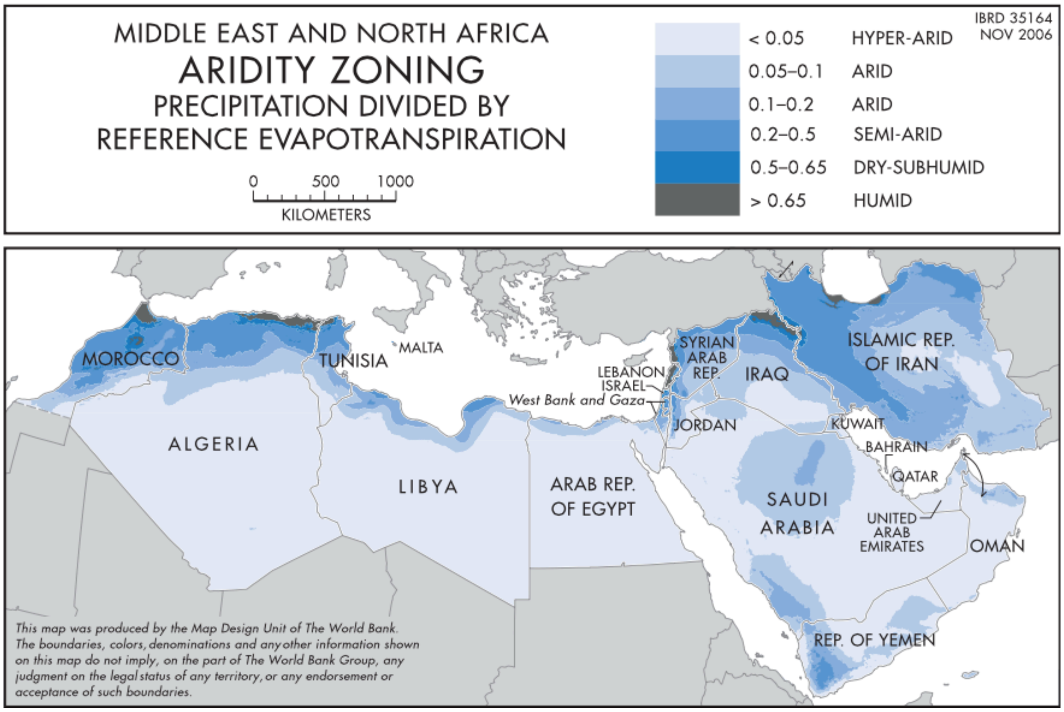


When discussing water security in any country or region, it is important to note that most publications refer to an acceptable minimum threshold of 1,700 m^3 per capita per year of renewable water. This threshold was devised based on estimates of water requirements for the domestic, industrial, agricultural, environmental, and energy sectors. If the figure drops below this threshold, a country or region is said to experience *water stress*. In countries and regions described as experiencing *water scarcity*, the estimated renewable water supply per capita per year is below 1000 m^3. If the situation is even more severe, and renewable water supply falls to below 500 m^3 per capita, a region is said to experience *absolute scarcity* (Falkenmark, et al., 1989; Gleick, 1996; Haddadin, 2002; HDR, 2006; World Bank, 2007; Shiklomanov, 1993). The situation in the

MENA region has gotten progressively worse, due to various challenges the region is faced with that have placed immense strain on the region's water resources (ESCWA, 2013; ESCWA, 2007; Haddadin, 2002; HDR, 2006; Sowers et al., 2011). Currently, estimated renewable water per capita in the region is between 1,100 m^3 and 1,200 m^3 per year (Rached and Brooks, 2010; HDR, 2006; World Bank, 2007). This figure has fallen from 4,000 m^3 in 1950, and is estimated to drop by roughly 50 percent by 2050, reaching a low of 550 m^3 per capita per year, compared to a current global average of 8,900 m^3 per person per year, and about 6,000 m^3 per person per year projected for year 2050 (ESCWA 2007; HDR, 2006; Rached and Brooks, 2010; UNDP, 2013; World Bank, 2007).

These estimates present a very bleak image of the water crisis in the region, but it is important to note that water availability across the region is highly variable. Water availability per capita varies greatly across the region, ranging between roughly 3,000 to 4,000 m^3 per capita per year in Iraq to figures well below the benchmark of 500 m^3 per capita per year in countries of the Gulf (HDR, 2006; Sowers et al., 2011; UNDP; 2013; World Bank, 2007). The region is dominated by arid and semi arid conditions (Figure 2), receiving between 0 to less than 250 millimeters of rainfall annually, with precipitation occurring throughout most of the region only during winter months. Summer dry periods can last between 6-10 months, with average temperatures usually around 30^{o} C, but often reaching over 40^{o} C in the region of the Gulf and Saudi Arabia. However, there is some variation across the region, with exceptions, most notably areas in the northwestern region and along the Mediterranean coast, which receive between 500 and 1000 millimeters of rainfall annually (ESCWA, 2007; Hotzl, 2008; Sowers et al., 2011; UNDP, 2013; World Bank, 2007).

Figure 2. Aridity across the MENA region (World Bank, 2007)



There are various environmental, social, economic, and political challenges in the MENA region that exacerbate the strain placed on water resources in this arid region. Some of the most notable and pressing challenges are the impacts of climate change, demographic trends in the region, and issues of water pollution. Impacts of climate change, already becoming a reality throughout the region, are posed to exacerbate the severity of water scarcity (Assaf, 2009; ESCWA 2013; Khater, 2010; Sowers et al., 2011). Projected annual precipitation is expected to fall between 10 to 20 percent in the Mediterranean region and northern parts of the peninsula, and could fall as much as 40 percent in some parts of the region (Hotzl, 2008; Issar, 2008; UNDP, 2011,2013). Combined with increases in temperatures, these conditions are expected to impact groundwater recharge, resulting in a 30 to 70 percent reduction in recharge for aquifers in the eastern and southern Mediterranean (ESCWA, 2013; Hotzl, 2008; Issar, 2008; UNDP, 2011, 2013). Coupled with demographic growth, climate change will have significant impacts on the availability and quality of water resources in the MENA region. The region is characterized by a rapid rate of population growth, with a total population of around 360 million in 2014, expected to nearly double by 2050, reaching roughly 634 million (World Bank, 2015). Urban populations are also set to grow, making up over 50 percent in 2014, and projected to grow to over 70 percent by 2050 (ESCWA, 2013; UNDP, 2013; World Bank, 2015). Unplanned migration of millions of refugees due to issues of security and political instability, combined with these population growth estimates will create increases in demands on water resources in a region that is already struggling to meet them (ESCWA, 2013; UNDP, 2011, 2013; World Bank, 2008). In addition to concerns across the region regarding the available quantity of water to meet ever growing demands, there are major water pollution issues of both surface and groundwater resources (ESCWA 2013; Haddadin, 2002; Sowers et al., 2011; UNDP 2013; Varis and Tortajada, 2007; World Bank, 2008). Water pollution from agricultural, industrial and domestic activities, in addition to the impacts of overexploitation of the resource, has led to severe deterioration of water resources and in turn intensifying water scarcity throughout the region. The situation is most severe in Egypt, Lebanon, Jordan, the State of Palestine, and Syria, where dumping of raw and partially treated wastewater from agriculture, industry and public municipalities into water courses, a cause for major health concerns, and adverse impacts on groundwater resources as well (ESCWA 2013; Haddadin, 2002; Sowers et al., 2011; UNDP 2013; Varis and Tortajada, 2007; World Bank, 2008). These pressing concerns have led governments across the region to question whether technical and engineering solutions alone can address these challenges, with a shift of attention to political and managerial solutions, exploring options for new forms of water governance structures as to help address the water crisis in the region.

A Crisis of Water Governance?

The approach to water governance is still an evolving one. A review of current literature on the subject yields several definitions by various international institutions, with no specific universally accepted definition. However it is evident that water governance is replacing the previously relied upon paradigms of sustainable water management and integrated water resource management by both national water institutions and international organizations (Biswas & Tortajada, 2010; Castro, 2007; Gunawansa et al., 2013; Tortajada, 2010). There are several working definitions of the term water governance, presented by various international institutions. Presented here are the most generally accepted definitions of the term, and the definitions that will be used in this study when referring to the concept of water governance. In 2003, the Global Water Partnership defined water governance broadly as “the range of political, social, economic, and administrative systems that are in place to develop and manage water resources, and delivery of water services, at different levels of society” (Rogers and Hall, 2003). According to several United Nations agencies, water governance can be perceived as “comprising all social, political, economic and administrative organizations and institutions, as well as their relationship to water resources development and management. It is concerned with how institutions operate and how regulations effect political actions and societal concerns through formal and informal instruments” (UNDESA, et al., 2003). The UNDP emphasizes the important role of civil society, and considers water governance to include political, economic and social processes and institutions through which governments, private sector, and civil society make decisions about how best to use, allocate, develop, and manage water resources (UNDP, 2004).

It is generally agreed upon within the MENA region, that although water crisis is indeed an issue of physical scarcity, it can also be viewed as a crisis of water governance (Rached and Brooks, 2010; UNDP, 2013; Varis & Tortajada, 2007; Wessels, 2009). Physical scarcity can be mitigated, to an extent, by institutions that are capable of ensuring that water is extracted in ways that are ecologically sustainable, used in ways that are efficient, and distributed in ways that are socially equitable, a task that the region views as vital in coping with issues of water scarcity in the region. In order to meet escalating demands, countries within the region need to develop water governance frameworks that are better able to develop and manage their already vulnerable water resources (UNDP, 2013; Kajenthira and Murthy, 2013; Varis & Tortajada, 2007). There are many challenges inhibiting progress in water governance throughout the region, including, but not limited to, overlapping institutional responsibilities, inefficient institutions, centralized decision-making, ineffective regulation and enforcement, insufficient funding, and limited public awareness (UNDP, 2013). Although these challenges are numerous and often extremely difficult to address, institutions within the MENA region are beginning to shift their attention from technical solutions to these problems to more governance oriented ones, and making steps towards progress in addressing these challenges (Rached & Brooks, 2011; UNDP, 2013).

Study Overview

Within the context of the MENA region, Lebanon is commonly perceived as one of the more water resource "rich" countries with respect to others in the region (Darwish, 2004; Makdisi, 2007; MOE, 2011; Sowers et al., 2011). However, the country still suffers from many of the same challenges that are facing the region as a whole (Darwish, 2004; Jurdi et al., 2003; Makdisi, 2007; Sowers et al., 2011). Recent water shortages in the country, with Lebanon experiencing some of its driest winter seasons in over a century, have drawn attention to the shortcomings of the country's water governance structure overall. Experts and government officials recognize that Lebanon is facing a water crisis, and that the problem is not simply a problem of water availability, but a water governance problem, and that changes need to be made to address this crisis (Farajalla et al., 2015; Riachi, 2014).

The overarching goal of this thesis is to examine how water resources are governed in Lebanon, and to assess the sustainability of water governance and the implications on the future of water resources for the country's capital, and most populated urban center, Beirut. A related goal is to offer policy recommendations based on the findings of this assessment.

To guide this study, the following research questions were designed:

- What is the state of water resources currently available to Beirut?
- How are water resources currently governed in Beirut? How is water supplied to the area, what purposes is it used for, and how do governmental institutions, stakeholders, laws, and policies impact this system?
- How sustainable is the current water governance regime, and what improvements could be made to help ensure sustainability of the resource for the future?

Chapter 2: The Case of Lebanon

Background, Geography and Climate

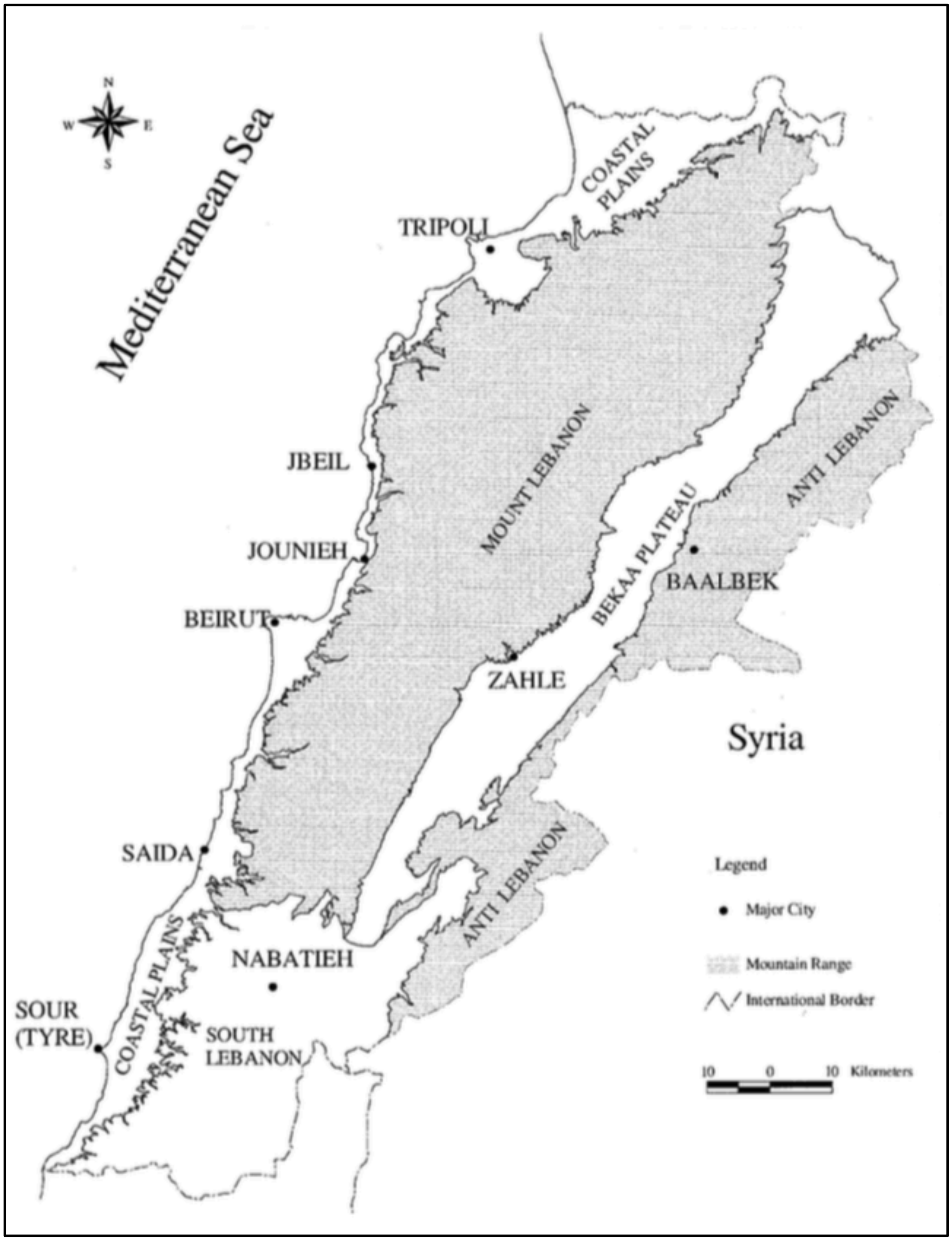
Lebanon is a relatively small country located at the eastern end of the Mediterranean Sea, 10,450 km^2 in size, stretching 210 km from north to south along the coast, and an average of 50 km inland. It is bordered by Syria in the north and east, and by Palestine and Israel in the south. The total population is estimated at 4.5 million, with an annual population growth rate estimated at 1.2 percent (World Bank, 2015), a rough estimate considering that the last national population census was conducted in 1932 (ESCWA, 2013). The Lebanese population is concentrated in coastal urban areas, with estimates showing that approximately 88 percent reside in urban areas, and over 80 percent reside along the coast. Population density is estimated at 445 persons per km^2, and nearly one third of the population is concentrated in the country's capitol and largest city of Beirut (Comair, 2007; Geara et al., 2010; World Bank, 2015). GDP per capita is estimated at 10,057 US dollars, higher than that of some countries in the region, but significantly lower than that of the more affluent oil producing countries (Rached and Brooks, 2010; World Bank, 2015).

The current political situation in the region has significant implications on population in the country, with the war in Syria resulting in an influx of refugees into the country. It is important to note that current national population estimates do not account for refugee populations, which were estimated to have reached nearly 1.8 million at the end of 2015 (UNHCR, 2014). Such a large increase in population is expected to place severe strain on the country's already weak infrastructure and limited resources. Lebanon has a long history of political instability and insecurity, having suffered from a long civil war that ended in 1991, and several conflicts with Israel throughout the 1990s and early 2000s, which have had detrimental impacts on infrastructure throughout the country (Darwish, 2004; Kunigk, 1999; Makdisi, 2007; Verdeil, 2008).

Although relatively small in size, Lebanon is characterized by its diverse terrain, and can be divided into four main regions (Figure 3), each exhibiting different physiological features (Comair, 2007; Darwish, 2004; El-Fadel et al., 2000; El-Fadel et al., 2001):

1. A flat and narrow fertile coastal strip running north to south along the Mediterranean Sea, with an average width of 2 to 3 km.
2. The Mount Lebanon mountain chain parallel to the coastline with mean elevations of 2,200 m and peaks at roughly 3,000 m.
3. The Bekaa Plateau, a fertile land depression at an average altitude of 900 m, l25 km long and a width between 7 km in the south to 20 km wide in the north.
4. The Anti-Lebanon mountain chain, which runs north to south, east of the Bekaa Plateau and bordering Syria, with elevations of up to 2800 m.

Figure 3. Physiography of Lebanon, divided by region (El-Fadel et al., 2000)



The climate in Lebanon can generally be described as Mediterranean, with heavy rains during the winter season, with roughly 90 percent of all precipitation occurring between December and May, and dry arid conditions for the remaining part of the year, with varied conditions across the four regions previously described (Amery, 2000; Comair, 2005; Comair, 2007; El-Fadel et al., 2000). Average annual temperature varies by region, estimated at 20^{o}C along the coast, 16^{o}C in the Bekaa valley, and less than 10^{o}C at higher elevations in the Mount Lebanon and Anti-Lebanon mountain ranges. Mean annual temperatures across the country are presented in Figure 4. Average annual rainfall is estimated at around 800 mm, but also varies highly across the country. Estimates range from as low as 200 mm/year in the northeastern region, 700 to 900 mm/year in coastal regions, to as high as 1500 mm/year in the peaks of Mount Lebanon (Arkadan, 2008; Comair, 2005; Comair, 2007; El-Fadel et al., 2000; Hajjar, 1997; MOE, 2011; Mudallal, 1989). Figure 5 presents mean annual precipitation levels across the country. Lebanon also receives precipitation in the form of snow in the mountain ranges at altitudes above 1,700. Yearly precipitation at altitudes in the form of snow is estimated at around 3 Mm^3 on average, but varies highly from year to year (El-Fadel et al., 2000; Shaban et al., 2004). Climate change is predicted to have drastic impacts on climate conditions across the Middle East, resulting in significant impacts on water resources. Lebanon is one of the countries in the region that is predicted to suffer from the most significant impacts, with estimates of temperature increases between 1^{o}C to 2^{o}C and as much as a 20 percent decrease in precipitation by 2040, resulting in an extended hot dry season with significant implications on water resource availability (Arkadan, 2008; Assaf, 2009; Bou-Zeid, and El-Fadel, 2002; ESCWA, 2013b; Khater, 2010; MoE et al., 2011; Shaban, 2008).

Figure 4. Mean annual temperature across Lebanon (MOE, 2011)

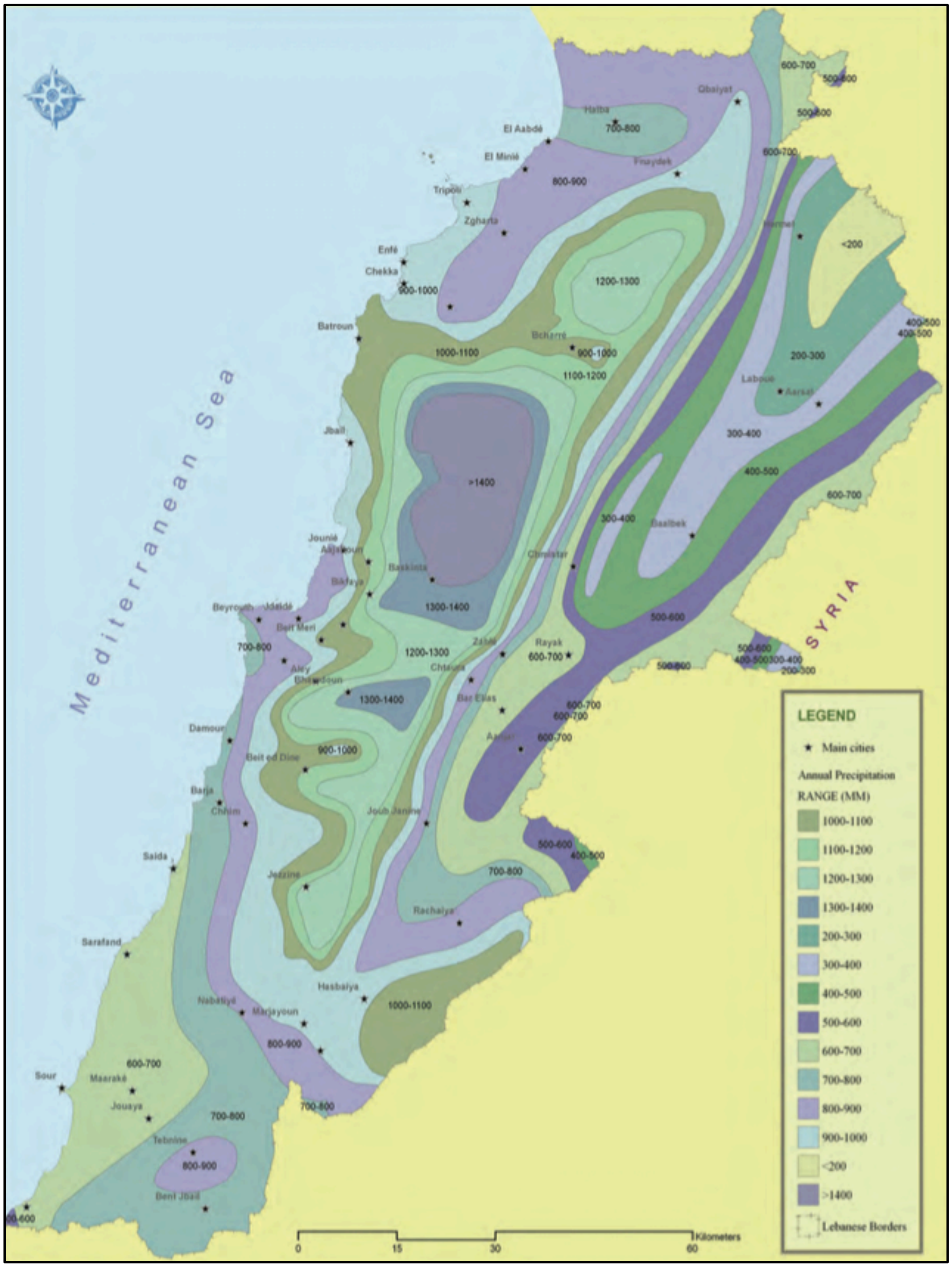


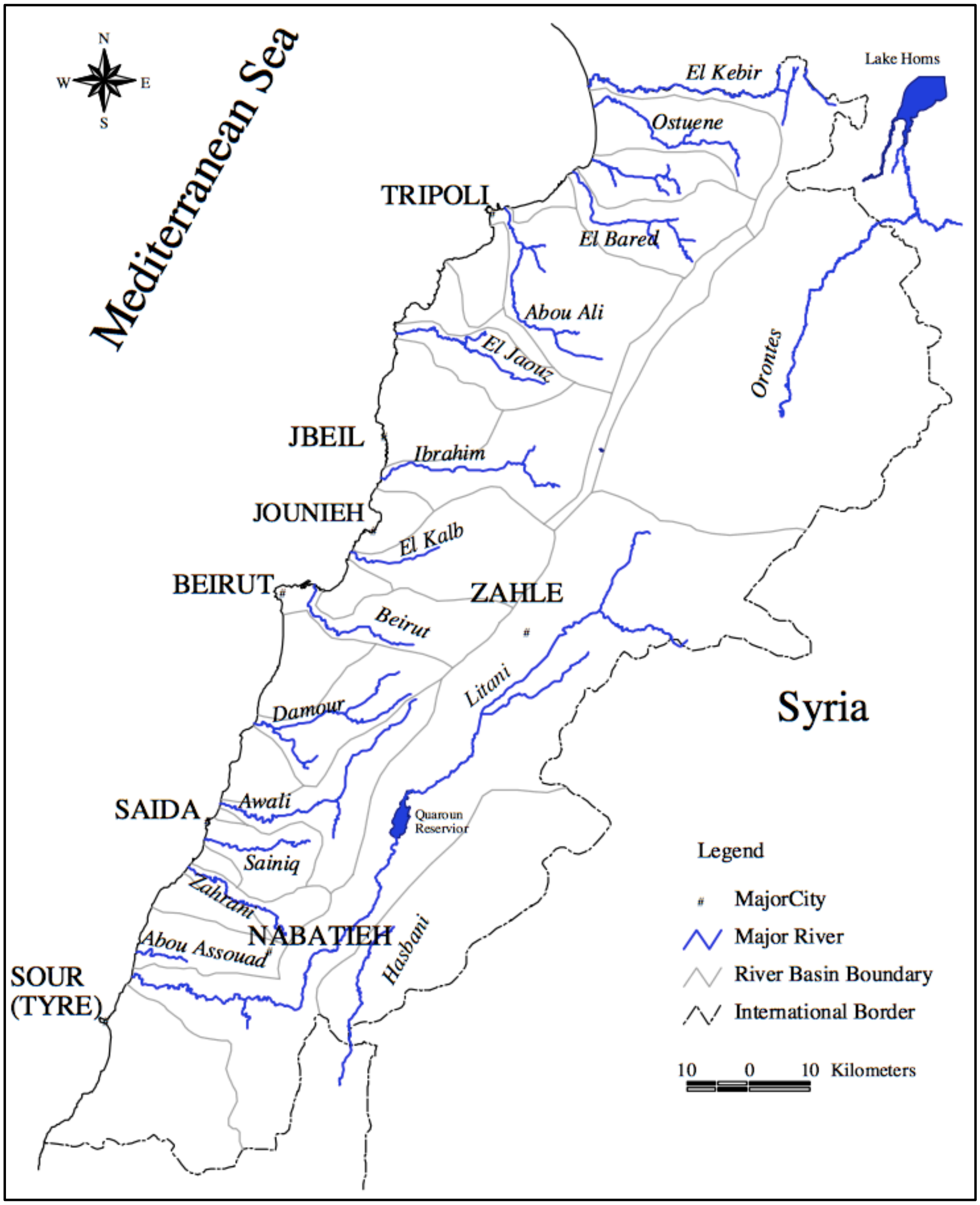
Figure 5. Mean annual precipitation levels across Lebanon (MOE, 2011)

Water Resources and Water Balance

Surface Water Resources

Lebanon is divided into two main hydrologic regions, the Mediterranean (or coastal) watershed, with an area of 5,500 km^2, which gives rise to the majority of the country's perennial rivers flowing from the western slopes of the mountain ranges to the sea; and the interior watershed, with an area of 4,700 km^2, which is the source of several rivers including the country's longest river, the Litani (Abdulrazzak and Kobeissi, 2002; Amery, 2000). There are 40 streams in Lebanon, with 17 classified as perennial rivers, shown in Figure 6 (Amery, 2000; Al Hajjar, 1997; Comair, El-Fadel et al., 2000; Jaber, 1993). The total length of perennial rivers is estimated at 730 km, with a total annual flow of about 3,400 million m^3. However there is some variation in these figures depending on the source due to lack of accurate primary data sources and conflicting opinions in identification of main river tributaries (Amery, 2000; Comair, 2006; El-Fadel et al., 2000; MOE et al., 2011). Lebanon's highest river flows are the Litani, El Awali, Ibrahim, and the Orontes (El-Fadel et al., 2000; MOE et al., 2011). There are also an estimated 5,050 springs in Lebanon, with total yearly yields estimated to exceed 1,200 million m^3 (MOEW, 2010; MOEW and UNDP, 2014). Only 9 major springs are currently monitored, but measurements are not representative of actual total flow of the springs since extracted water at the spring source is not accounted for in many cases (MOE et al., 2011; MOEW and UNDP, 2014). The majority of these waterways are heavily polluted, primarily as a result of uncontrolled discharge of municipal wastewater, improper solid waste disposal, industrial effluents, and agricultural runoff (Comair, 2006; Geara et al., 2010; El-Fadel et al., 2000; MOE, 2012; MOE et al., 2011; USAID, 2011b).

Figure 6. Perennial rivers of Lebanon (El-Fadel et. al, 2000)



Groundwater Resources

Characterization of groundwater resources in Lebanon at the national level is severely limited, with little reliable data available particularly on the quantitative aspects of these resources. A recent study was conducted by the UNDP in partnership with the MOEW, funded by the Government of the Republic of Italy, in order to assess groundwater resources in Lebanon. Prior to this study, no study had been conducted at the national scale since a study conducted in 1970 by the UNDP (MOE et al., 2011; UNDP and MOEW, 2014). About 65 percent of the surface of Lebanon is covered with carbonates karstic formations, which are characterized by springs, caves, sinkholes, and a unique hydrology system. The two main aquifers in the country are the Kesrouane Jurassic aquifer and the Sannine-Maameltain aquifer, both of which are mainly composed of karstic carbonate rocks, and together cover about 5590km^2 of Lebanese territory, more than 50 percent of the country's surface area (UNDP and MOEW, 2014). Groundwater in karstic aquifers tends to flow along well-developed karstic underground channels at relatively high velocity, resulting in low storage capacity in these types of aquifers (Bakalowicz et al., 2008; UNDP and MOEW, 2014).

The MOEW/UNDP study identified 51 groundwater basins, and found significant declines in groundwater table levels in most of these groundwater basins compared to groundwater table levels estimated in the UNDP 1970 report, indicating overexploitation of these resources. Only coastal groundwater basins showed groundwater table levels similar to those estimated in the previous study, because the extracted water is being directly replaced by seawater intrusion, with significant impacts on groundwater quality as a result (UNDP and MoEW, 2014). Various local studies of coastal groundwater quality have shown that this is indeed the case, with rapid increases in salinity as result seawater intrusion (Acra and Ayoub, 2001; El Moujabber, et al., 2004; El Moujabber et al., 2006; Korfali, and Jurdi, 2010; Menti et al., 2004).

Estimates of annual available groundwater resources vary greatly depending on the source, ranging from 500 million m^3 to over 4,000 million m^3, and it is important to note that data related to groundwater gains and losses from one basin to another, deep percolation, losses to sea, and discharge from springs is either unavailable or unreliable (MOE et al., 2011; MOEW, 2010; UNDP and MOEW, 2014). The importance of groundwater resources in Lebanon should not be underestimated, with groundwater resources accounting for over 50 percent of water used for irrigation, and over 80 percent of potable water sources, highlighting the need for enhanced monitoring of groundwater resources in order to more accurately quantify available resources and work towards ensuring sustainable management of these resources in Lebanon (Bakalowicz et al., 2008; El-Fadel et al., 2014; Geara, et al., 2010; MOE, 2011; MOE, 2012; UNDP and MOEW, 2014).

Water Storage Features

Lebanon currently has two dams, the Qaroun dam on the Litani River, and the Chabrouh dam which captures rain runoff and runoff from Laban Spring. The storage capacities of these dams are 220 million m^3 and 8 million m^3 respectively, of which only 45 million m^3 are being used for water supply and irrigation, and the rest of which is used for hydroelectric power generation (Comair, 2006; MOE et al., 2011; MOEW, 2010). The Ministry of Energy and Water plans to expand the country's water storage portfolio by building 17 dams across the country, adding an additional 670 million m^3 of surface storage capacity. Figure 7 presents a map prepared by the ministry, showing all the proposed dam sites. This plan was originally proposed in 2000 as a 10 year plan to be substantively completed by 2010, but little progress has been made in meeting these goals due to political and financial constraints, with only the Chabrouh dam completed and operational since the plan was initiated (CDR, 2014a; MoE, 2012; MoE et al., 2011; MoEW, 2010). In some cases, local communities have voiced fierce opposition to dam construction, citing the adverse environmental impacts on local ecosystems and the unsuitability of geologic conditions to dam construction, postponing the start of construction of several dams (CDR, 2014a).

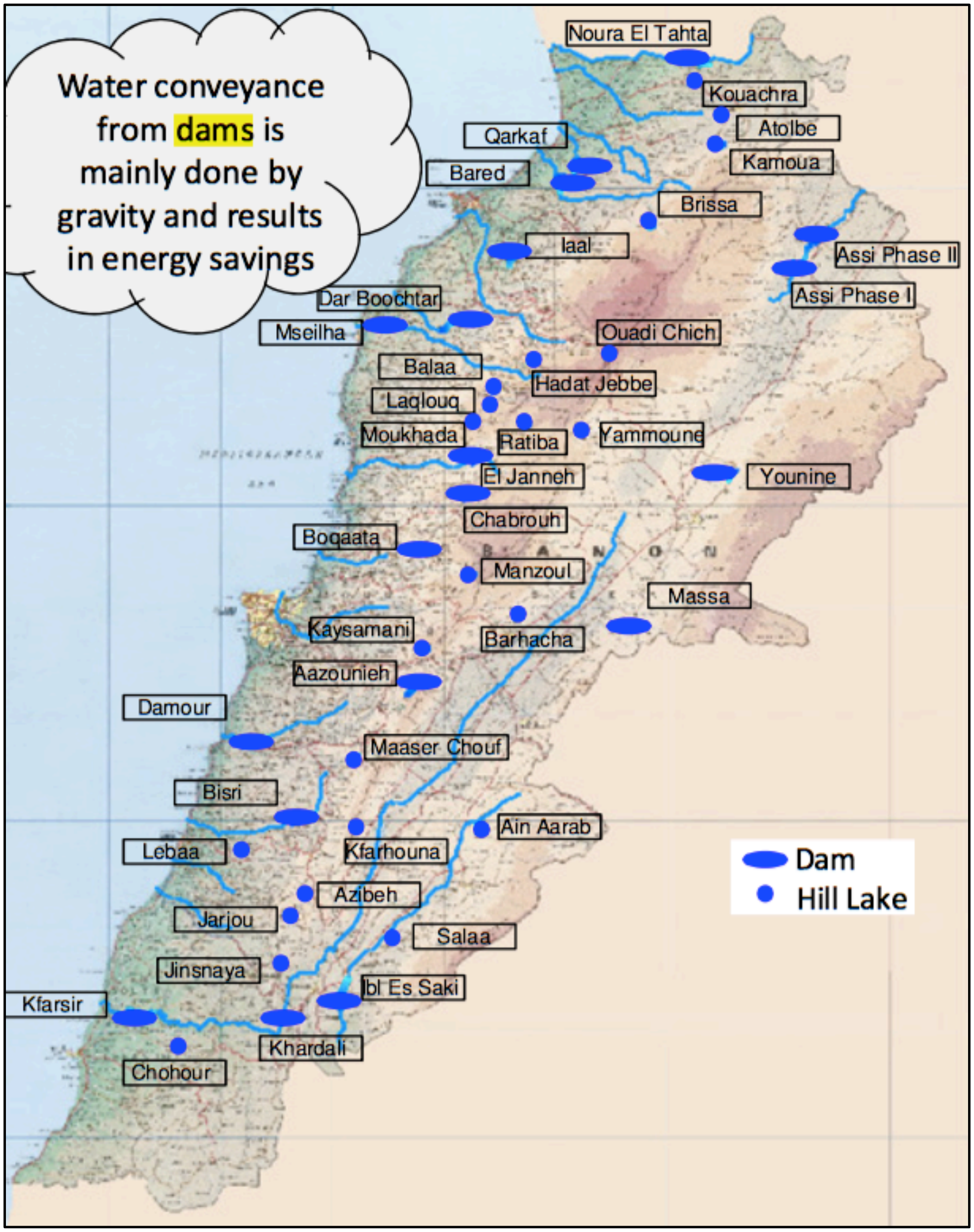


Figure 7. Map of proposed dams and hill lakes presented in National Water Sector Strategy (MOEW, 2010)

Water Balance

Estimates of annual available water resources in Lebanon vary depending on the source. The inconsistencies among estimates can be attributed to several factors. Different sources use different estimates of annual precipitation, data needed to make these estimates is often lacking or unreliable, and most of the estimates currently available rely on data sources from the mid 1960s and 1970s (El-Fadel et al., 2000; Geara et al., 2010; MOE et al., 2011; UNDP and MOEW, 2014). The most commonly relied upon estimates are presented in Table 1, with typical average annual available water resources estimated at around 2,700 million m^3 (MOE, 2012; MOE et al., 2011; MOEW, 2010).

Table 1. Annual water balance for Lebanon for an average year

Description	**Yearly average flows** (million m^3)
Total precipitation	8,600
Surface water evapotranspiration losses	- 4,500
Surface water flow to neighboring countries	-700
Groundwater flow	
Losses to sea	-400
Losses to neighboring countries	-300
Subtotal	-700
Total renewable resources available	2,700
Surface	2,200
Groundwater	500

Water Demand

By Sector: Domestic, Agricultural and Industrial

Data availability on water uses in Lebanon is generally unavailable or unreliable; the only available information is based on estimates and projections generated using input parameters on population, per capita water consumption, network efficiency, total irrigated area, irrigation consumption, and industry demand. There are varying estimates of total water demand, ranging from 1,473 million to 1,530 million m^3 per year, estimates generated for 2010 (MoE, 2012; MoE et al., 2011; MoEW, 2010; World Bank, 2010). The agricultural sector has the largest water demand in the country, consuming around 60 percent of total water demand at the national level. The domestic sector demand is estimated at 30 percent, while industrial demand is estimated at 10 percent of total annual water demand (MoE, 2012; MoE et al., 2011; MoEW, 2010; World Bank, 2010). The most heavily relied upon estimates of annual water demand by sector are presented in Table 2.

Table 2. Estimates of annual water demand by sector (million m^3)

Sector	**MOEW, 2010**	**World Bank, 2010**
Domestic	505	467
Industrial	158	163
Agricultural	810	900
Total Demand	1,473	1,530

Annual water demand is projected to increase drastically over the next 15 years, with estimates predicting that demands will begin to exceed annual available water resources. The World Bank estimates that by 2030, total annual water demand will reach 2,818 million m^3, and domestic sector demand will more than double in size (World Bank, 2010). Estimates by the Ministry of Energy and Water are more conservative, projecting that by 2035 annual water demand will be around 1,802 million m^3, but could reach as high as 2,518 million m^3 in a high demand scenario. These projections are presented, by sector, in Table 3 (World Bank, 2010) and Table 4 (MOEW, 2010).

Table 3. World Bank estimates of annual water demand by sector, 2010 to 2030 (million m^3)

Sector	**2010**	**2020**	**2030**
Domestic	467	767	1,258
Industrial	163	268	440
Agricultural	900	1,020	1,120
Total	**1,530**	**2,055**	**2,818**

Table 4. Ministry of Energy and Water estimates of annual water demand by sector, 2010-2035 (million m^3)

Sector	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**
Domestic	505	460	427	467	512	562
Industrial	158	146	138	153	170	190
Agricultural	810	877	935	983	1,021	1,050
Total	**1,473**	**1,483**	**1,500**	**1,603**	**1,703**	**1,802**

Lebanon already struggles to meet water demands, particularly in urban areas. Due to the deficit between water supply and demand, water rationing is common practice in urban centers throughout Beirut and the Mount Lebanon region (MOE, 2012; MOE et al., 2011). The situation is particularly dire during the dry season, with as little as half of total water demand being met (MOEW, 2010; World Bank, 2010). Table 5 shows estimates of demand and supply at the national level by sector during dry season months, highlighting the deficit between the two (MOE et al., 2011; World Bank, 2010). This gap between water supply and demand will continue to grow and become more severe if left unaddressed, and both technical and policy solutions need to be explored if this challenge is to be addressed effectively.

Table 5. Estimates of demand and supply between July-October 2010 in Lebanon (million m^3)

Sector	World Bank Estimates (2010)
Domestic	233
Industrial	65
Agricultural	765
Total Demand	**1063**
Total Supply	**675**
Deficit	**388**

Moving Towards Sustainable Water Governance

Lebanon is already facing many challenges in managing its water resources, and it is evident that these challenges will continue to grow, placing severe stress on both water resources and Lebanese society. The Lebanese government has a long history of unsustainable and ineffective water governance, something that is often identified as one of the main obstacles facing the water sector (Comari, 2006; Ghiotti and Riahci, 2013; MOE, 2011; MOE et al., 2011; Rached and Brooks, 2010; UNESCO and CNRS, 2006; World Bank, 2012). The country's water resources are under stress from many of the same challenges that face the region as a whole, including population growth, rapid urbanization, economic growth, climate change, pollution, in addition to the lack of effective management and water governance (Farajallah et al., 2015; MOE et al., 2011; UNDP, 2013; Rached and Brooks, 2010). In 2010, the Ministry of Environment estimated that Lebanon's annual available water per capita was approximately 926 m^3, and projected that number would drop to around 800 m^3 over the next ten years, although some estimates predict a more drastic decrease (MOEW, 2010). These estimates indicate that Lebanon is experiencing water scarcity, with annual available water per capita below the 1,000 m^3 benchmark, indicating that water resources need to be managed more efficiently on a long-term basis, and highlighting the need for effective sustainable water governance in the country.

The scope of studies assessing water governance and management in Lebanon from a national perspective is quite limited. Research on the subject is more extensive from a regional perspective, with regional literature making reference to issues of water governance in Lebanon. At the Arab regional level, there is general consensus that in order to address water scarcity, improved water governance is necessary. This will require more than efforts to increase water supply, but will also require strengthening of national institutions and developing methods to increase transparency and accountability in the water sector (UNDP, 2013; Varis and Tortajada, 2007). Throughout the region, attention has been shifting from technical and engineering solutions to more policy and management oriented solutions, however progress has been slow, and effective implementation lacking, with some countries making more progress than others (Hamdy and Choukr-Allah, 2012; Rached and Brooks, 2010).

At the national level, there are various challenges to improving water governance within Lebanon. Some of the most pressing challenges identified in the literature were: overlap in roles and responsibilities, low implementation capacity, and weak accountability at the institutional level; an outdated and fragmented legal framework with weak enforcement; lack of national water information and data needed for effective policy design and sector planning; and inequitable distribution of water resources regionally and across sectors (Comair, 2006; Farajalla et al., 2015; Ghiotti and Riachi, 2013; World Bank, 2012). However some steps have been taken to move towards a more sustainable and effective form of water governance, most notably institutional reform and the establishment of a National Water Sector Strategy. Institutional reform was set in motion by Law 221, which was passed in May 2000, and amended by Laws 241 and 337 in August 2000 and December 2001 respectively. Based on these laws, the water sector in Lebanon is to be primarily managed by the Ministry of Energy and Water at the national scale, and by four newly established Public Regional Water Establishments at the regional level (Abdulrazzak and Kobeissi, 2002;

Chatila, 2003; Comair, 2006; Farajalla et al., 2015; UNDP, 2013). However, over a decade after these reforms were initiated, progress is still slow due to ineffective implementation of the reform, which has created uncertainty over responsibilities, and poor coordination between agencies (Farajalla et al., 2015; World Bank, 2012). In 2010, the Ministry of Energy and Water developed a National Water Sector Strategy (NWSS), which was adopted by the Council of Ministers in 2012. The goal of the NWSS is "to ensure water supply, irrigation, and sanitation services throughout Lebanon on a continuous basis and optimal service levels, with a commitment to environmental, economic and social sustainability" (MOEW, 2010). It is an ambitious plan, heavily focused on infrastructure development, mainly to augment current water supply, with little focus on other mechanisms for improving governance in the water sector, and is facing challenges in implementation due to various political and economic constraints (Farajalla et al., 2015; MOEW, 2010; World Bank, 2012).

Chapter 3: Analysis Framework and Methodology

In order to assess the sustainability of water governance and its implications on water supply in Beirut, an overall understanding of the water governance regime is needed. Gaining a comprehensive understanding of the water governance regime of a region can aid in providing an account of the sustainability of the regime, and promoting policy innovation and reform where necessary (Pahl-Wostl and Kranz, 2010; Pahl-Wostl et al., 2013; Quay, 2010;

Wiek and Larson, 2012). For the purposes of this study, an analysis approach that guides sustainability assessments of water governance regimes, and aids in identifying intervention points for policy improvements, specifically designed for the study of urban water systems was sought out. After researching several water governance analysis frameworks, a recently developed framework for evaluating the sustainability of urban water governance regimes, designed by Wiek and Larson, was selected (2012). The systems framework for analyzing and assessing water governance regimes is a holistic, actor-oriented analysis framework, which places focus on the major interacting activities involved in water governance decisions (Wiek and Larson, 2012). The framework consists of two major components: (i) an integrated analysis of the water governance regime, and (ii) a sustainability assessment of the analyzed water governance regime, which are outlined in this chapter.

Integrated Analysis of Regional Water Governance Systems Framework

The first step of this approach is an analysis of the regional water governance regime, an activities-oriented framework with a focus on what people do with water within the system, with "doing" defined in a comprehensive sense to include actions such as extracting, distributing, using, and recharging water, as well as the activities that influence them such as planning, researching, monitoring, reporting, and regulating (Wiek and Larson, 2012). People, for the purpose of this analysis, are defined as the potential governance actors who are affected by and affecting the water system, and who can coordinate their activities to have some impact on how the water system functions (Ostrom, 2011, 2009;

Wiek and Larson, 2012). This analytical framework consists of three components that build upon each other, (i) boundaries of the regional water system, (ii) activity domains, and (iii) the systematic cause-effect structure, which are outlined in detail in the following sections.

Boundaries of the Regional Water System

In order to conduct the assessment, *boundaries of the regional water system* need to be defined. There are various ways in which regional water systems can be delineated, either as a socio-political unit at various levels such as a city, metropolitan area, state or governorate, or as a biophysical unit such as river basins or groundwater basins. Even though a specific scale is selected, it is important to keep cross-scale interactions in mind because they are critical for any governance assessment (Pahl-Wostl et al., 2010; Wiek and Larson, 2012). For the purposes of this study, the Greater Beirut Area was selected for analysis, since it is the largest urban area in Lebanon, and continuously suffers from the most drastic water shortages in the country.

Activity Domains

Second, *activity domains* are used to outline what actors do with water resources, and help provide an understanding of major water resource decisions being made in within the region. Since this framework is designed to assess water governance efforts, the focus is placed on actions and activities related to water resources and the water sector. The following types of activity domains are identified, along with specific examples of activities that would fall under each domain.

a. Supplies: where water supplies are sourced from, and how water resources are acquired, allocated and managed.
    - Sourcing, diverting and extracting water from rivers, aquifers, and reclaimed water.
    - Water storage activities, including building and maintaining dams and other infrastructure.
    - Allocating and administering the rights and access to water sources, whether through formal legal codes or informal social rules.
    - Evaluating, assessing, and planning for water supplies.

b. Deliveries: how water is distributed, treated, and delivered to end users through engineered or natural infrastructure.
    - Pumping, piping, and transporting water through established infrastructure.
    - Treating water to meet water quality standards for potable water.
    - Monitoring and managing the quality of water resources being distributed through various sources, as well as the monitoring the state of infrastructure.

c. Demands: how people consume and conserve water for various purposes.
    - Water uses for various sectors, domestic, agricultural and industrial.
    - Conserving water/managing demand by enhancing water use efficiency through technological innovation, behavioral change, education on conservation, and policy mechanisms restricting use.
d. Outflows: how water is transported and treated after use, including how sewage and effluent are handled moving through the system.
    - Transporting and treating wastewater, including building and maintaining infrastructure.
    - Recycling and treating wastewater for reuse
    - Activities that influence wastewater in general such as planning, regulating, monitoring and promoting different treatment methods.
e. Cross-cutting Activities: how policy and administration, legal framework, research and assessment, and civic participation and advocacy interact with and influence the former activity domains.
    - Planning, managing, regulating, and controlling through policy-making and administrative mechanisms.
    - Studying, monitoring, evaluating, and informing through research that enables a better understanding of the system.

- Engaging with stakeholders to negotiate various water resource decisions.

Systemic Cause-Effect Structure

Since the end purpose of this framework is to make recommendations to improve water governance regimes, an understanding of the activities, outcomes and impacts of the activities, and insight into the causes and drivers of these activities is needed. To do this, the *systemic cause-effect structure* is used to describe the actors and drivers of the activities, the outcomes of the activities, and interactions with various components of the water system. This structure builds on the Institutional Analysis and Development Framework designed by Ostrom (2011), providing information on actors and their guiding intentions and rules that drive their actions. Within each activity domain, the actors involved in water resource decision-making are identified in order to understand how they interact with other actors and institutions (social system), hydrological resources and ecosystems (ecological system), human infrastructure (technological system), and external influences (perturbations). Each of these systems is described below:

a. Social

    Water activities are influenced by and in turn influence social structures and processes, so it is vital to consider the actors, their particular roles within the system, the actions they take, how they interact with other actors in the system, and the rules that guide their decisions and actions.

b. Ecological

Activities related to any aspect of a water system rely on and impact the natural environment within which the system operates. Within the assessment, geological, hydrological, ecological and other natural processes are taken into consideration, including processes such as climate variability and its impacts on the water system, and how the use and distribution of water impacts the quantity and quality of the resource itself.

c. Technological

Water activities are heavily dependent on man-made infrastructure and facilities, so it is important to describe them within the analysis. Such infrastructure includes extraction and retention facilities for water supply, water delivery networks, and treatment facilities.

d. Perturbations

It is important to consider potential stressors or disturbances to the system, since they can have significant impacts on decisions made within the system. Perturbations include issues such as climate change, shifts in population growth and migration, and changes in the political system within which water decisions are made.

Sustainability Assessment of Water Governance

The second component of the framework consists of a sustainability assessment of the analyzed water governance regime. This assessment is based on a comprehensive set of principles for sustainable water governance against which a water governance regime can be evaluated, derived from literature on integrated water management and general sustainability criteria (Gibson, 2006; Grigg, 2011; Pahl-Wostl et al., 2010; Wiek and Larson, 2012). The sustainability principles for water governance are outlined below, and the template used to link these principles and their key features to the activity domains within the water governance system is presented in Table 6.

1. Social-ecological system integrity – balancing anthropogenic needs and demands of water with those the natural ecosystem.
2. Resource efficiency and maintenance – ensuring that the greatest benefit is received from using as little water as possible while minimizing excessive uses (efficiency) and avoiding irreversible negative outcomes (maintenance).
3. Livelihood sufficiency and opportunity – ensuring fair access to a sufficient quantity and quality of water to meet needs such as: livelihood needs for drinking, eating, sanitation, and economic activities that are dependent on water resources.
4. Civil engagement and democratic governance - encouraging participation and collaboration among relevant stakeholders and

decision makers, considering the needs, interests, and perspectives of local actors and individuals connected to the resource.

5. Inter-generational and intra-generational equity – ensuring equitable access to a sufficient quantity and quality of water, as well as ecosystem services, for both current and future residents.
6. Interconnectivity from local to global scale – ensuring allocation and management of water resources across upstream and downstream regions.
7. Precaution and adaptability – anticipation of potential problems and challenges, as well as mitigation and planning in response to them.

Assessment Methods

The selected analysis framework will be used in this study to examine water resource governance and assess the sustainability of the water governance regime in Beirut, Lebanon. Data and evidence for this analysis was gathered from secondary data sources. These secondary sources include published literature on water governance and water resources in Beirut, and Lebanon in general, documents published by various ministries in Lebanon that are important actors in the water governance regime, national policy documents, and reports published by various organizations that play important roles in Lebanon's water sector, particularly the United Nations, World Bank, and USAID.

Table 6. Sustainability assessment template (Wiek and Larson, 2012)

Sustainability Principle	Key Features	Activity Domains
1. Social-ecological system integrity	a. Maintain minimum flows in surface water	Supplies
	b. Maintain or enhance quality of water resources	Deliveries
	c. Ensure aquifers are not over extracted	Supplies/Demands
	d. Recognize and coordinate demands and impacts within the appropriate physical unit	Supplies/Demands
2. Resource efficiency and maintenance	a. Reduce water use or enhance water-use efficiency	Demands
	b. Reuse water or recycle wastewater for various uses	Demands/Outflows Supplies/Deliveries
	c. Eliminate water loses	Supplies/Demands
	d. Groundwater extraction should not exceed recharge	
3. Livelihood sufficiency and opportunity	a. All people have access to sufficient quantity and quality of water for domestic and economic purposes and overall wellbeing.	Supplies/Demands
4. Civil engagement and democratic governance	a. Involve all groups who affect or are affected by water governance efforts in decision making	Cross-cutting
	b. Elicit the full array of interests and perspectives through various stages of governance	Cross-cutting
	c. Establish collaborative endeavors for water governance	Cross-cutting
5. Inter-generational and intra-generational equity	a. Ensure fair distribution of benefits and costs among all actors and stakeholders	Cross-cutting
	b. Facilitate stakeholder representation based on demography, geography and interest	Cross-cutting
	c. Ensure representation of future generations	Demands
6. Interconnectivity from local to global scales	a. Reduce or eliminate negative impacts on other regions	Supplies/Demands/Outflows
	b. Plan within the watershed or groundwater basin context	Supplies/Demands
	c. Recognize and coordinate between local actors and broader scale stakeholders	Cross-cutting
7. Precaution and adaptability	a. Anticipate potential water shortages and water quality problems	Cross-cutting
	b. Mitigate potential water shortages and water quality problems	Cross-cutting
	c. Adapt to water shortages and water quality problems	Cross-cutting

Chapter 4: Water Governance in Beirut, Lebanon

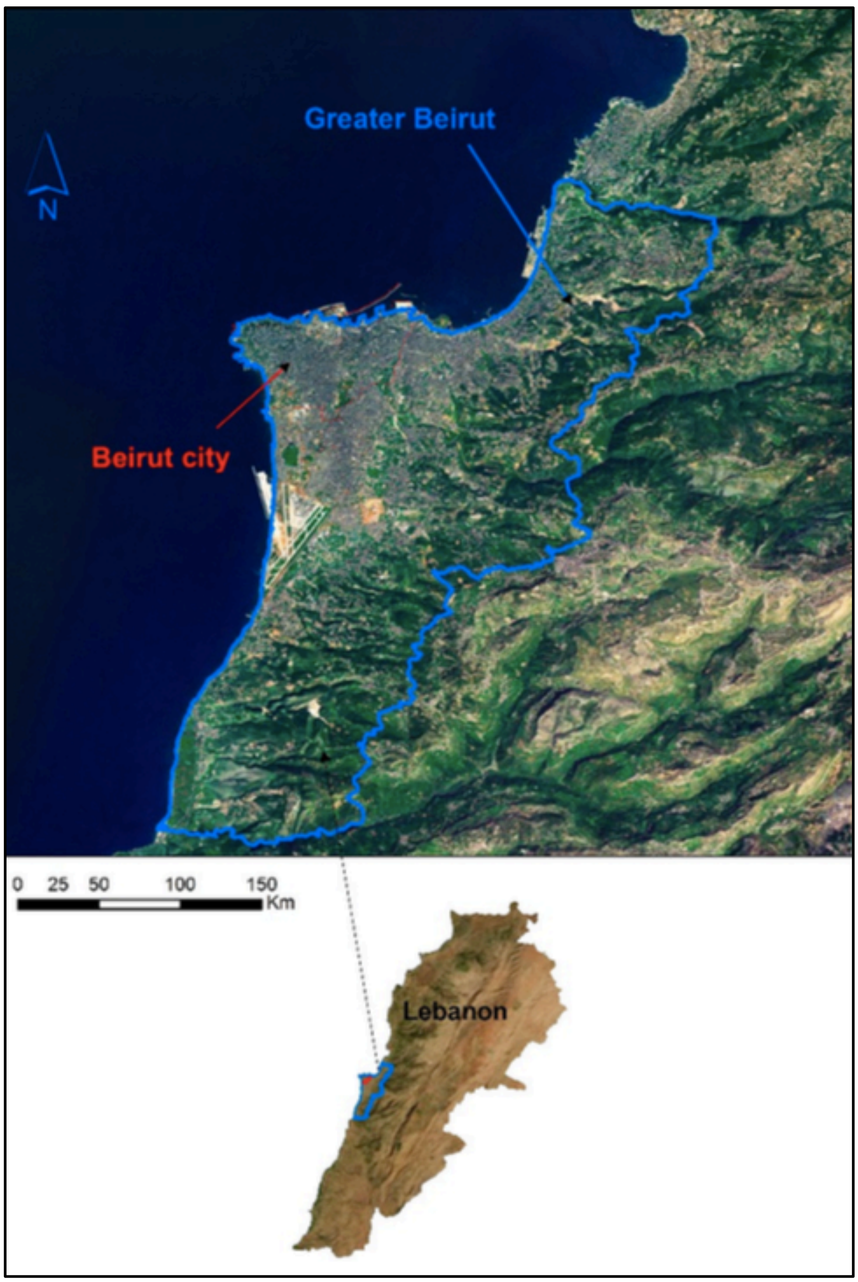
Greater Beirut

The area selected for the purposes of this study is the Greater Beirut Area (GBA), which includes the city of Beirut and its northern and southern suburbs. The GBA is located in the central coastal area of Lebanon, and covers approximately 233 km^2 of Lebanese territory, making up a little over 2 percent of the country's total area (Faour and Mhawej, 2014). The area is characterized by its high population density, with an estimated population of close to 2 million people. Average population density is measured at approximately 6,500 persons per km^2, but is as high as 21,938 persons per km^2 within the city proper (CAS, 2007; Faour and Mhawej, 2014; MOE, 2012; MOE et al., 2011). Figure 8 shows the location of the Greater Beirut Area within Lebanese territory.

Water Supplies

The insufficiency of water supply to the Greater Beirut Area is a problem that is widely acknowledged by the Lebanese government, the ministries involved in the water sector, the international agencies that support water sector projects in the country, and various national research institutions (CDR, 2014a; Geara et al., 2010; Farajalla et al., 2015; MOE et al., 2011; MOEW, 2010; USAID, 2011a; World Bank, 2012). The Ministry of Energy and Water, established in 1966 by Law 20/66, is the main agency responsible for the water sector at the national level. Water sector reform under Law 221/2000 and its amendments, has resulted in changes in the responsibilities of the Ministry, which include in its mandate overall water resource management and planning, establishment of plans for utilization and distribution of water resources, design of major water facilities, and oversight of the regional water establishments.

Figure 8. Map of the Greater Beirut Area (Faour and Mhawej, 2014).



The Beirut and Mount Lebanon Water Establishment (BMLWE), one of the four regional water establishments created under Law 221, is responsible for water sector management within the Beirut and Mount Lebanon region, within which the Greater Beirut Area is located. The BMLWE is responsible for planning, building, operation and maintenance of water supply and distribution networks and sewage treatment plants, as well as ensuring the quality of water supplied to the GBA.

BMLWE Supplies

The BMLWE currently supplies Beirut with water from two primary sources, the Jeita Spring, which is the largest spring in the country, and the Kashkoush spring, both located to the north of Beirut (CDR, 2014a; MOE et al., 2011; MOEW, 2010). Recent studies have estimated that average annual discharge from Jeita is approximately 172 MCM, and 70 MCM from Kashkoush spring (MOEW and UNDP, 2014; BGR and CDR, 2013). During the dry season, when discharge from Jeita and Kashkoush is low, the BMLWE supplements the supply with groundwater from 26 wells near Jeita, north of Beirut, and 13 groundwater wells located in the southern suburbs of Beirut (CDR, 2014a; Korfali and Jurdi, 2009; MOE et al., 2011; MOEW, 2010). From these sources, roughly 270,000 m^3/day is supplied to the GBA, a quantity that is not sufficient meet total estimated demands, resulting in an average deficit of close to 165,000 m^3/day (MOE et al., 2011; World Bank, 2010). In order to cope with this severe shortage, the BMLWE is required to ration water supplied to Beirut, especially during summer months, when water is supplied through the public network on average around 3 hours/day (Karnib, 2015; MOE et al., 2011; MOEW, 2010; USAID, 2011a; World Bank, 2012). The Ministry of Energy and Water, in cooperation with and funding from the World Bank and the Islamic Development Bank, is working on two large-scale projects to help address these large deficits in water supply to the GBA, the Bisri Dam, and the Awali-Beirut Conveyor (MOEW, 2010; World Bank, 2012). The Awali-Beirut Conveyor will supply the GBA with 250,000 m^3/day during the dry season, and the Bisri Dam will supply an additional 500,000 m^3/day. Efforts on these projects are currently underway, with estimated completion by 2020, but it should be noted that progress has been slow and often interrupted due to various political factors (CDR, 2014a; MOEW, 2010; World Bank, 2012).

In addition to concerns about the inadequate quantity of water supplied to Beirut by the BMLWE, the quality of water supplied from the two springs is a major concern. An assessment of pollution hazards in the Jeita Spring Catchment, conducted by the German Federal Institute for Geosciences and Natural Resources (BGR), in cooperation with the Ministry of Energy and Water and Council for Development and Reconstruction, found a significant number of severe pollution sources within the catchment. Both point and non-point sources, and the pollutants from each source, were identified, including but not limited to wastewater, petroleum products, industrial effluents, medical waste, and agricultural runoff (BGR, 2013). A complete list of hazard sources and generated pollutants identified in the study can be found in Appendix A. There are several pieces of legislation requiring the protection of surface and groundwater resources (Order No. 144/1925), the protection of catchment areas (Order No. 320/1926), and the establishment of protection zones for water resources and recharge areas (Decree No. 10276/1962). However, existing legislation is outdated, dating back to the 1920s and 1960s, and is not implemented. The Ministry of Environment, as outlined in its mandate by Law 216/1993 is responsible for controlling pollution, regulating activities that impact natural resources, and enforcing environmental regulation, but lacks the capacity to implement and enforce legislation for the protection of water sources provided to Beirut (BGR, 2013; Chatila, 2003; Farajalla, et al., 2015; MOE et al., 2011; World Bank, 2012).

Alternative Supplies

Due to the unreliability and frequent rationing of water supplied by the BMLWE, water users in Beirut heavily rely on alternative sources of water, mainly illegal private wells, bottled water, and water tankers. There are no accurate estimates of the number of illegal private groundwater wells in the GBA, nor are extraction rates from these wells monitored (Farajalla et al., 2015; Geara, 2010; MOE, 2011; MOE et al., 2011; MOEW, 2010; MOEW and UNDP, 2014; USAID, 2011a; World Bank, 2012). In efforts to halt excessive extraction of groundwater through private wells in Beirut, the Lebanese government passed Law 86/87 in 1967, prohibiting groundwater exploitation for private use in the

Greater Beirut Area; however, this law was not implemented. The Ministry of Energy and Water estimates that there are as many as 18,000 illegal private wells in the GBA, with extraction rates estimated close to 100 MCM/year (MOEW, 2010). Exploitation of groundwater resources through heavy reliance on illegal private wells has resulted in deterioration in the quality of groundwater, with numerous studies showing increased salinity as a result of saltwater intrusion (Acra and Ayoub, 2001; El-Moujabber et al., 2004; Korfali and Jurdi, 2010; Saadeh, 2008; MOEW and UNDP, 2014), and numerous other contaminants included but not limited to fecal coliform bacteria and heavy metals (Korfali and Jurdi, 2007, 2009). Consumers also rely on water purchased through water tanker/truck distribution services if they do not have access to private wells or as an additional source during the dry season (Farajalla et al., 2015; Karnib, 2015; Korfali and Jurdi, 2009; MOE et al., 2011; MOEW, 2010; USAID, 2011a). Tankers transport water from private wells throughout Beirut, and distribute it to households and industries at a service fee, unregulated by the government (Farajalla et al., 2015; Korfali and Jurdi, 2009; MOE et al., 2011; USAID, 2011a). The majority of consumers within the GBA rely on bottled water as their primary source of potable water, due to a lack of trust in the quality of water sources provided by the BMLWE (Farajalla et al., 2015; Geara, 2010; Korfali and Jurdi, 2009; Makdisi, 2007; MOE et al., 2011; USAID, 2011a). The bottled water industry has grown drastically in the country in recent years, with the majority of companies operating without any regulatory authorization by the government (Farajalla et al., 2015; MOE et al., 2011; Semerjian, 2011; USAID, 2011a). It is estimated that roughly 68 percent of consumers in Beirut rely on bottled water for drinking water and household purposes (Korfali and Jurdi, 2009), and Lebanon is ranked as the 11^{th} leading country by per capita consumption of bottled water within the global bottled water market, consuming on average 112 liters/person (Beverage Marketing Corporation, 2014; Semerjian, 2011). Reliance on these supplemental sources of water not only poses a public health risk due to lack of regulation, but also places a significant financial burden on consumers. Estimates show that over 70 percent of total household expenditure on water goes to private suppliers of water, and as much as 20 percent of low income household salary is spent on water purchased from private sources (Korfali and Jurdi, 2009; MOE et al., 2011; World Bank, 2010).

Water Deliveries

Raw water supplies for the Greater Beirut Area are transferred from the main BMLWE sources of Jeita Spring, Kashkoush Spring, and supplementary wells is transferred through the Jetia-Dbayeh conveyor and brought to the Dbayeh water treatment plant, located to the north of Beirut city. From the Dbayeh treatment plant, treated water is pumped to a main storage reservoir in the Ashrafieh neighborhood within the city. Water is then pumped to two subsidiary reservoirs located in the Burj Abou Haidar and Tallet El-Khayat neigborhoods. Finally, treated water is brought to consumers through the Beirut potable water network (BGR and CDR, 2011; CDR, 2014a; ESCWA et al., 2011; Geara et al., 2010; Korfali and Jurdi, 2009; MOE et al., 2011; MOEW, 2010). Estimates of water loss through the network range from 40 percent to 60 percent depending on the source, and is often noted as one of the major challenges the BMLWE faces in supplying Beirut with a sufficient quantity of water (BGR and CDR, 2011; Comair, 2007; MOE, 2012; MOE et al., 2011; MOEW, 2010; USAID, 2011a; World Bank, 2012).

Jeita-Dbayeh Conveyor

The Jeita-Dbayeh conveyor was originally built in 1870, when Beirut first began relying on Jeita Spring as its main source of water (BGR and CDR, 2011; Karkabi, 2009). When first built, the conveyor was an open channel, but was later rehabilitated and covered with concrete slabs (BGR and CDR, 2011). Even though sections of the conveyor have been renewed, the majority of the infrastructure is over 100 years old (BGR and CDR, 2011; Comair, 2007; USAID, 2011a; World Bank, 2012). Water travels 5.5 km through the conveyor from the intake at Jeita spring to the water treatment plant in Dbayeh, as shown in Figure 9. Through the Jeita-Dbayeh conveyor, a maximum of 255,000 m^3 of water can be delivered to Beirut per day, with the capacity of the conveyor measured at 3.1 m^3/s (BGR and CDR, 2011). Due to the age and poor maintenance of the infrastructure, and illegal connections to the conveyor, as much as 30 percent of water transported is lost through this process, and water is exposed to various sources of pollutants (BGR and CDR, 2011; CDR, 2014a; USAID, 2011a). Figures in Appendix B show examples of conditions throughout the conveyor.

Figure 9. Distance traveled by the Jeita-Dbayeh Conveyor (BGR and CDR, 2011)

Dbayeh Water Treatment Plant

The Dbayeh water treatment plant, located 12 km north of Beirut city, is the only water treatment plant currently servicing the Greater Beirut Area (BGR and CDR, 2011; CDR, 2014a; MOE et al., 2011; MOEW, 2010; USAID, 2011a; World Bank, 2012). Operated by the BMLWE, it treats water from the Jeita and Kashkoush Springs and the cities public wells, using aeration, coagulation, sand bed filtration and chlorination for treatment (BGR and CDR, 2011). A recent project was carried out by the Council for Development and Reconstruction, the main governmental agency tasked with planning and executing large-scale rehabilitation and construction projects in various sectors, expanding the plant's maximum treatment capacity from 320,000 m^3 per day to 430,000 m^3 per day (CDR, 2014a). Assessments by several international aid agencies indicate that the facility itself is poorly maintained, causing deterioration of the treatment system and overall quality of treated water (BGR and CDR, 2011; USAID, 2011a; World Bank, 2012). After water is treated, it is pumped to the main storage reservoir in Achrafieh, and from there it is pumped to storage reservoirs in Bourj Abou Haidar and Tellet El-Khayat located within the city of Beirut (Korfali and Jurdi, 2009; MOEW, 2010). An aerial image of the Dbayeh water treatment plant is shown in Figure 10.

Figure 10. Aerial image of the Dbayeh Water Treatment Plant (BGR and CDR, 2011)

GBA Distribution Network

The Greater Beirut Area has the highest rate of connection to the public water distribution network in Lebanon, estimated at 93 percent (CDR, 2014a; MOE et al., 2011; MOEW, 2010). The majority of the network is between 10 to 30 years old, however consistent documentation of age and conditions of the network is often lacking (Geara et al., 2010; MOE et al., 2011; USAID, 2011a; Verdeil, 2008; World Bank, 2012). The age of the Beirut water distribution network is presented in Table 7.

Table 7. Age of distribution network in Greater Beirut Area (MOEW, 2010)

Age (years)	Percent of Distribution Network
Less than 10	23
10-20	15
20-30	11
30-40	8
40-50	5
Greater than 50	2
Unknown	36

Water leakage through the system is a major issue of concern, with estimates of 50 to 60 percent water loss through the distribution network (Comair, 2006; Geara et al., 2010; MOE et al., 2011; MOEW, 2010; USAID, 2011a; World Bank, 2012). The BMLWE is responsible for network management and rehabilitation, but does not have the necessary financial or technical capacity to do so (USAID, 2011a; World Bank, 2012). In addition to water losses, the leaky network poses severe risks to public health, with wastewater often contaminating the potable water network. Although the BMLWE is the main authority required to ensure the quality of potable water distributed in the GBA, the Ministry of Public Health is also required to monitor potable water to ensure compliance with water quality standards. However, water distributed through the network does not meet set standards, with some studies showing as much as 20 percent of water tested contaminated with total coliform and *E.Coli* (Geara et al., 2010; Korfali and Jurdi, 2009, 2007; MOPH and WHO, 2013). To address these issues, the CDR is carrying out a project to rehabilitate the network, funded by the Kuwait Fund for Arab Economic Development, with a projected completion date by 2020 (CDR, 2014a).

Water Demands

Demand Estimates

With its large population size, highest population density in the country, and highest rate of connection to the water network in the country, the GBA has the highest domestic water demand compared to other regions in the country (Geara et al., 2010; MOE, 2012; MOE et al., 2011; MOEW, 2010; USAID, 2011a; World Bank, 2010). It is estimated that the domestic sector alone makes up roughly 60 to 70 percent of total water demand in Beirut depending on the source (MOE et al., 2011; MOEW, 2010; World Bank, 2010; Yamout and El-Fadel, 2005). Table 8 presents current estimates and future water demand projections for the domestic sector, non-domestic sector, and unaccounted for water. These figures are based on population estimates, with domestic consumption of 150 l/c/d. Due to heavy urbanization and lack of data on actual water consumption by sector, consumption by the industrial and agricultural sector are combined and reported as non-domestic consumption. Estimates on unaccounted for water are also reported, which include physical losses due to leaks in the network, and losses due to illegal connections (MOE et al., 2011; MOEW, 2010; USAID, 2011a; World Bank, 2012; World Bank, 2010).

Table 8. Estimates of Water Demand in GBA in m^3/day, 2010 – 2030 (MOE et al., 2011; World Bank, 2010)

Year	Domestic Consumption	Non-Domestic Consumption	Total Consumption	Unaccounted for Water	Total Demand
2010	255,000	76,500	331,500	99,450	430,950
2015	268,074	80,422	348,496	87,124	435,620
2020	281,819	84,546	366,364	73,273	439637
2025	296,268	88,880	385,148	77,030	462,178
2030	311,458	93,437	404,895	80,979	485,874

Demand Management Efforts

In addition to plans to increase water supply to Beirut, the Ministry of Energy and Water and the BMLWE also recognize the importance of implementing demand management strategies if Lebanon's water resources are to be sustainably managed (Geara et al., 2010; MOE, 2012; MOEW, 2010; UNDP, 2013; UNDP and MOEW, 2010; USAID, 2011a; World Bank, 2012). However, due to heavy reliance of consumers on private water sources, and lack of monitoring of water use in Beirut by the BMLWE, this has proven to be a particularly challenging task. In efforts to address this challenge, the MOEW, with the support of the UNDP, established the Lebanese Centre for Water Management and Conservation (LCWMC). The main role of the LCWMC is to build technical capacity on overall sustainable water management strategies within the MOEW and respective water establishments in the country, including the BMLWE, and raise national public awareness on water conservation through educational campaigns and collaboration with involved stakeholders to promote demand management in various sectors (UNDP and MOEW, 2010).

While increasing public awareness on water conservation is an important task, progress in demand management cannot be made without accurate data on water consumption. Less than 40 percent of water connections in the Beirut area are metered (MOEW, 2010; USAID, 2011a; World Bank, 2012). The MOEW, in cooperation BMLWE is currently working on installation of water meters throughout the GBA as part of the implementation of the National Water Sector Strategy, with a goal of reaching 95 percent coverage by 2020 (MOEW, 2010). The current flat rate tariff structure provides no incentive for consumers to conserve water resources or for the BMLWE to improve service delivery (Chatila, 2004; MOE et al., 2011; MOEW, 2010; USAID, 2011a; World Bank, 2012). Consumers are charged a flat fee of $157 a year for water provided through the BMLWE network, which is based on theoretical estimates of total water delivered daily (MOEW, 2010; USAID, 2011a). Water bill collection rates are also low, further exacerbating the issue, with only 60 percent of water bills collected by the water establishment in Beirut (USAID, 2011a). In its National Water Sector Strategy, the MOEW proposes the institution of a volumetric tariff structure by 2020, once meters have been installed (MOEW, 2010).

Outflows

The GBA, and Lebanon overall, suffer from a severely inadequate wastewater sector (CDR, 2014b; Geara et al., 2010; MOE et al., 2011; MOEW, 2010; USAID, 2011a; World Bank, 2012). According to Law 221 and its amendments, the Ministry of Energy and Water is responsible for wastewater management planning and setting treatment standards at the national level, while the BMLWE is directly responsible for planning, building, and operating wastewater networks and treatment plants servicing the GBA. However, the BMLWE does not have the technical capacity nor the financial resources to do so, as indicated in interviews with staff members of the water establishment (CDR, 2014b; MOEW, 2010; USAID, 2011a; World Bank, 2012). The Ministry of Environment also plays a role in wastewater management, and has set standards for treated wastewater discharge as outlined in ministerial decision No. 8/1-2001. Due to the inability of the MOEW, MOE, and the BMLWE to manage Beirut's wastewater, the CDR has had a very large role in the rehabilitation and construction of wastewater treatment plants and networks in the GBA, and throughout the country (CDR, 2014b; MOE et al., 2011; MOEW, 2010; USAID, 2011a; World Bank, 2012). With funds acquired through international aid agencies, the CDR has led capital spending in the country's wastewater sector, spending well over $250 million on wastewater projects for the GBA over the past several years (CDR, 2014b).

The city of Beirut has the highest rate of connection to the wastewater network in the country, estimated at around 98 percent, followed by Beirut's suburbs, with connection rates at 90 percent (CDR, 2014b; Geara et al., 2010; MOE et al., 2011). The CDR is currently executing major projects funded by the Islamic Bank for Development, which aims at rehabilitating Beirut's wastewater network and constructing a new stormwater drainage network separate from the wastewater network, to be completed by 2020 (CDR, 2014b). The CDR is also managing another project, the expansion and upgrade of the GBA's only wastewater treatment plant, Al Ghadir Preliminary Wastewater Treatment Plant. The existing pretreatment plant, completed in 1997, is located in the southern suburbs of the GBA, 7 km from Beirut city, and operated by a private company subcontracted by the BMLWE. Once water is collected and pretreated, the wastewater is discharged into the Mediterranean through one main sea outfall, which extends 2.6 km off shore (EIB, 2012). Discharges from the Ghadir plant do not currently meet the standards set by the Ministry of Environment, with high levels of COD, BOD5, TSS, ammonia, phosphorus and nitrogen in addition to other pollutants (EIB, 2012; Geara et al., 2010). To address this, the expansion and upgrade project seeks to increase Ghadir's wastewater treatment capacity from the current level of 50,000 m^3/day to 290 m^3/day, and upgrade the plant from a preliminary treatment to primary treatment by 2020 (CDR, 2014b; EIB, 2012). The MOEW, in cooperation with the CDR, have also planned for an additional wastewater treatment plant for the GBA, the Dora wastewater treatment plant, to serve the GBA's growing northern suburbs, but have not been able to secure funding for this project (CDR, 2014b; Geara et al., 2010).

Perturbations and Cross-cutting Issues

In the Greater Beirut Area, and throughout Lebanon overall, a number of critical issues have significant impacts on the governance of the water resources sector. These issues include, but are not limited to: climate change, population growth and migration, and political instability. The impact of climate change on water resources in Lebanon is expected to be significant as a result of decreases in precipitation and changes in rainfall patterns, increases in temperature which will result in increased evapotranspiration, decreases in snow cover density, and decreases in surface water and groundwater recharge (Arkadan, 2008; Assaf, 2009; Bou-Zeid, and El-Fadel, 2002; ESCWA, 2013b; Khater, 2010; MOE, 2011; MoE et al., 2011; Shaban, 2008; UNDP, 2013). Increases in temperature of up to 2 ^{o}C, a 20 percent decline in precipitation, up to 40 percent reduction in volume of snow cover are some of the expected impacts of climate change that Lebanon will experience by 2040 (Khater, 2010; MOE, 2011; UNDP, 2013). With these changes, a 16 percent reduction in overall available water resources in the country is expected, making sustainable water governance in the GBA and the country overall, an even more challenging task than it is already (MOE, 2011).

Another major issue that has very serious implications for water governance in the GBA and the country as a whole is population growth, and more specifically growth due to the recent influx of Syrian refugees as a result of the ongoing crisis in Syria (Mudallali, 2013; Republic of Lebanon, 2015; UNHCR, 2014; World Bank, 2013). Roughly 1.8 million Syrian refugees have fled the crisis in Syria, which has resulted in a 40 percent increase in Lebanon's total population in just over 4 years (Republic of Lebanon, 2015; UNHCR, 2014). The UNHCR estimates that roughly 25 percent of Syrian refugees in the country reside in the Beirut area (UNHCR, 2016). It is estimated that this large population increase has led to an increase in annual domestic water demand of around 70 million m^3, which is close to 15 percent of the country's total annual domestic water demand (Republic of Lebanon, 2015; World Bank, 2013). This drastic increase in population as a result of the Syrian crisis is placing a severe strain on already constrained water and wastewater infrastructure throughout the country and particularly in heavily urbanized areas, including the GBA (Mudallali, 2013; World Bank, 2013).

Finally, political instability is a major challenge to sustainable water governance in the GBA, just as it is throughout much of the MENA region (ESCWA, 2013b; Farajalla et al., 2015; UNDP, 2013; USAID, 2011a; Verdeil, 2008). Lebanon's long history of conflict and political instability, suffering from a number of several wars in recent history, has resulted in detrimental impacts on both water and wastewater infrastructure in the GBA and throughout the country (USAID, 2011a; Verdeil, 2008). Political instability has also had an impact on political will to address the challenges faced in the water sector in Lebanon overall. Lack of political will has resulted in poor planning in the water sector, poor implementation of plans when they do exist, and little to no enforcement of existing laws and regulations (Farajalla et al., 2015; MOE et al., 2011; USAID, 2011a). Public discontent with the lack of political will within the Lebanese government to address issues in the water sector, and the inability of the government to provide basic services is growing. Public discontent, most recently sparked by Lebanon's solid waste management crisis, has resulted in an increase in citizen activist movements demanding access to basic services, including reliable potable water (Hume and Tawfeeq, 2016; Khouri, 2015). These movements could result in an increase in political will in the water sector by pressuring authorities to begin to address these issues more effectively (Khouri, 2015; Makdisi, 2013; Nagel and Staeheli, 2016).

Chapter 5: Sustainability Assessment of Water Governance in the Greater Beirut Area

Based on the examination of water governance in the Greater Beirut Area presented in the previous chapter, a sustainability assessment was conducted using the sustainability principles previously outlined in Table 6. The following chapter presents the success and challenges of the GBA water governance regime based on this assessment.

Social-Ecological System Integrity

Although Beirut does not overextract water from its two main sources, the Jeita and Kashkoush springs, there is a severe strain placed on groundwater throughout the GBA. Overexploitation of groundwater resources through both the BMLWE's public wells and the numerous illegal private wells has had detrimental and potentially irreversible impacts on groundwater quality, as various studies on groundwater in the area have shown (Acra and Ayoub, 2001; Bakalowicz et al., 2008; El-Moujabber et al., 2006; El-Moujabber et al., 2004; Korfali and Jurdi, 2010; Menti et al., 2004; MOEW and UNDP, 2014). Plans by the MOEW to increase supply to the GBA through the Awali-Beirut Conveyor and Bisri Dam project will have negative impacts on the ecological integrity and biodiversity of the natural systems where this project is to be located, but these impacts were not deemed significant enough stop the project (ELARD, 2010; MOE et al., 2011).

Contaminated water delivered to consumers in the GBA, as a result of pollution in the groundwater catchment areas of Jeita and Kashkoush Springs, poor maintenance and operation of the Dbayeh water treatment plant, and exposure to pollutants through the leaky water distribution network, posses a very significant threat to public health (Karnib, 2015; Korfali and Jurdi, 2009; Korfali and Jurdi, 2007; MOPH and WHO, 2013). The alternative sources that consumers within the GBA rely on to supplement inadequate public supplies do not only pose health risks because they are not monitored or regulated by public authorities, but also place a significant financial burden on consumers, especially those of low-income (Korfali and Jurdi, 2009; MOE et al., 2011; World Bank, 2010). Rehabilitation of Beirut's water network by the CDR is one step in the right direction towards addressing this very pressing issue.

Recent studies have provided new data on groundwater resources in the country, and produced new maps delineating groundwater basins throughout the country, which could prove to be very useful for promoting the ecological integrity of these systems (BGR and CDR, 2013; MOEW and UNDP, 2014). This information provides a new opportunity for authorities involved in water governance activities, including the MOEW and BMLWE, to make more informed decisions throughout the water sector, but whether or not they will make use of such information remains to be seen.

Resource Efficiency and Maintenance

Beirut's water supply and distribution networks suffer from very low efficiencies, with network losses as high as 60 percent, an issue that is noted as a major concern in almost every government and international agency report cited in this study. Rehabilitation of the area's distribution network is one of the most important steps towards increasing the efficient use of water resources in the GBA.

The MOEW, in cooperation with the BMLWE is also working on efforts to reduce water demands. The first step in these efforts was the establishment of the LCWMC, which is encouraging water conservation through public awareness and education campaigns (UNDP and MOEW, 2010). Without metering all public connections in the GBA, it will be very challenging to reduce consumption and increase efficient use of water resources through public awareness campaigns alone. The current flat tariff structure that the BMLWE has in place is also another barrier to increasing efficiency, providing no incentive for consumers to reduce water use. It is also important to note that the amount of water consumed through alternative sources such as illegal private wells, and water tanker services is not monitored or regulated, further complicating the situation. And although it is generally agreed that groundwater resources are being overextracted, the lack of data on extraction rates from illegal wells throughout the GBA has made it difficult to fully assess the detrimental impact of these extractions (MOE et al., 2011; MOEW, 2010; MOEW and UNDP, 2014).

In the National Water Sector Strategy, the MOEW briefly outlines plans to increase efficiency of water use through the introduction of the use of effluent for artificial groundwater recharge (MOEW, 2010). However, due to the many challenges the wastewater sector in the GBA currently is faces, and the lack of primary treatment of wastewater, it seems unlikely that wastewater reuse will be a feasible option in the near future, at least until all major wastewater projects are completed by the CDR within the GBA (CDR, 2014b; MOEW, 2010; MOEW and UNDP, 2014).

Livelihood Sufficiency and Opportunity

It is quite evident from the state of potable water services and wastewater treatment services currently provided by the BMLWE to the GBA that the basic needs of its residents are not being met. Consumers do not have 24-hour access to potable water through the public network, due to rationing by water authorities. Water quantity isn't the only issue of concern, as most residents express distrust in the quality of water provided through the public network (Geara et al., 2010; Karnib, 2015; Korfali and Jurdi, 2009; Korfali and Jurdi, 2007; MOE, 2012; MOE et al., 2011; MOPH and WHO, 2013; USAID, 2011a; World Bank, 2012). People are exposed to pollutants through the public water network from various sources, including untreated wastewater, resulting in the prevalence of water-borne diseases in the community (Karnib, 2015; Korfali and Jurdi, 2009; Korfali and Jurdi, 2007; MOPH and WHO, 2013; USAID, 2011a). Heavy reliance on vended water sources, especially bottled water for drinking and household purposes, places a significant financial burden on consumers. These factors contribute to inequitable access to the necessary water supplies to sustain basic needs, with low-income communities placed at a disadvantage due to high costs of water from private sources (Korfali and Jurdi, 2009; MOE et al., 2011; USAID, 2011a; World Bank, 2012).

Civil Engagement and Democratic Governance

Power in water governance in the GBA is largely held by a few governmental agencies, primarily the MOEW, CDR, and BMLWE, which have the most extensive and significant roles and responsibilities in the water and wastewater sectors. The MOE and MOPH can be viewed as secondary governmental stakeholders in water governance, as they both have fewer responsibilities in the sector and less capacity to perform those responsibilities. International aid agencies, including USAID, the World Bank, the Islamic Development Bank, and the Kuwait Fund for Arab Economic Development, as the largest funders in the water and wastewater sector, play a very significant role in water governance particularly through investment in infrastructure and institutional capacity building efforts (Farajalla et al., 2015; MOE et al., 2011). Private water companies also hold a significant amount of power in the water sector due to the heavy reliance of consumers on water from these sources (Farajalla, et al., 2015; USAID, 2011a). There is significant overlap in the roles and responsibilities of governmental institutions involved in water governance activities, and a lack of coordination between organizations and projects, especially between donor funded projects (Farajalla et al., 2015; Ghiotti and Riachi, 2013; MOE et al., 2011; USAID, 2011a). This is often noted as one of the major challenges to effective sustainable water governance in the GBA, and the country overall.

Although there are a myriad of governmental and international agencies involved in water governance in the Greater Beirut Area, community engagement is minimal, with little to no representation of community interests in water governance efforts. This further exacerbates public distrust in government actors in the sector, trust that is already lacking due to poor provision of services. The only major effort authorities have made to engage the community has been through the LCWMC's public outreach and education campaigns seeking to manage water demands. There is currently no institutionalized process for public participation in water governance, and no avenue for the community to hold the agencies in the sector accountable for their actions or the quality of services they provide (Farajalla, et al., 2015; MOE et al., 2011; World Bank, 2012). The lack of official avenues for citizen participation, combined with increasing public discontent with the quality of services being provided, has resulted in a surge in activist movements and public protests, the effects of which on water governance in the GBA are still unknown, as the situation is still unfolding (Hume and Tawfeeq, 2016; Khouri, 2015).

Inter-generational and Intra-generational Equity

Access to potable water through the public network is limited, and although the average number of hours of available service for the GBA is reported for the wet and dry season, hours of service are not uniform across the region. This results in inequities in the quantities of water received by consumers in different parts of the GBA through the public network. The price of private water sources can become cost inhibitive for low-income consumers, particularly during the dry season when these sources are in high demand, further increasing inequity in access to water (Korfali and Jurdi, 2009; MOE et al., 2011; USAID, 2011a; World Bank, 2012). In terms of exposure to pollutants through water sources, low-income communities are again at a disadvantage, since their ability to rely on bottled water as their main source of potable water is limited by the high cost of this source compared to water from tanker delivery services which are more polluted, and their ability to privately treat water using water filtration and purification systems is also limited due to the high cost of such systems (Geara et al., 2010; Korfali and Jurdi, 2009; USAID, 2011a).

Equity in terms of the representation of all stakeholder interests is also a major area of concern in water governance in the GBA, due to the lack of opportunity for public participation in the sector. Interests of refugee communities are minimally represented, with their needs for water and wastewater sector services often viewed as a major source of stress on already inadequate infrastructure (World Bank, 2013). With such large inequities in access to water and wastewater services among the current generation of GBA's residents, concern for equitable access to resources for future generations is lacking. While concerns about decreases in total renewable water resources and increases in future demands are frequently expressed by government agencies, there are no references to the long-term impacts of such a deficit, if left undressed, on future generations.

Interconnectivity from Local to Global Scales

Decision making in the water and wastewater sectors is largely done at the level of political jurisdictions, either at the national level, or at the level of the regional water establishments, such as the BMLWE, with little interconnectivity between the local, regional, and national levels. The impacts of decisions made with regards to disposal of wastewater and other pollutants in the groundwater catchments of the Jeita and Kashkoush springs on Beirut's water supply are not currently taken into consideration by local authorities in the catchment areas (BGR, 2013; BGR and CDR, 2013). The MOEW's plans for the Bisri dam and Awali-Beirut conveyor project to increase future water supply to the GBA do not adequately consider impacts on the local communities where the project will be located (CDR, 2014a; ELARD, 2010; MOE, 2012; MOEW, 2010). Poor treatment of wastewater discharged by the Ghadir pre-treatment plant in the southern region of the GBA has had disproportionate negative impacts on coastal communities in that region, communities that will continue to suffer from the impacts of that pollutant source until the facility receives necessary upgrades

(EIB, 2012). Another major challenge to tracking impacts of water governance activities within the GBA across various scales is the lack of monitoring of water resources at the national level and the poor quality of available data (BGR and CDR, 2013; ESCWA, 2013b; Farajalla et al., 2015; Geara et al., 2010; MOE, 2012; MOE et al., 2011; MOEW and UNDP, 2014; USAID, 2011a; World Bank, 2012).

The disconnect between the local, regional and national levels is further exacerbated by the lack of planning and coordination between the agencies at various levels. The lack of coordination between the MOEW and CDR, generally operating at the national level, results in a disconnect between these agencies and regional authorities at the level of the BMLWE servicing the GBA. Poor technical and financial capacity within the BMLWE to carry out mandated water governance responsibilities, often results in intervention by the MOEW or CDR, further complicating matters (MOE et al, 2011; USAID, 2011a; World Bank, 2012).

Precaution and Adaptability

The Greater Beirut Area is already experiencing severe water shortages and water quality problems, a situation that will only be further exacerbated by impacts of climate change, and the increasing pressures of urbanization and population growth on supplies and demands (Assaf, 2009; ESCWA, 2013b; Hotzl, 2008; Kajenthira and Murthy, 2013; Khater, 2010; MOE, 2012; MOE, 2011; Shaban, 2008; Sowers et al., 2011). The refugee crisis has also placed an additional burden on water resources by drastic increases in demand that could not have been anticipated (Republic of Lebanon, 2015; World Bank, 2013). Communities within the GBA have managed to adapt to governance failures in the provision of water services thus far by relying heavily on private water sources, and overextraction of groundwater resources, short term solutions which are neither economically nor environmentally sustainable. Insufficient resources and inabilities to conduct assessments, develop plans, and execute necessary operation and maintenance tasks limits adaptive capacity, throughout agencies involved in water governance, but especially at the level of the BMLWE (USAID, 2011a; World Bank, 2012). Inadequate data and limited knowledge about quantity and quality of resources inhibits monitoring of resources and further limits effective planning and adaptation measures (ESCWA, 2013b; Farajalla et al., 2015; MOE, 2012; MOE et al., 2011; MOEW and UNDP, 2014; Sowers et al., 2011; USAID, 2011a; World Bank, 2012). Plans presented by the MOEW in its National Water Sector Strategy (2010), and projects to augment Beirut's water supply currently under way by the CDR (2014a) both emphasize centralized, technocratic strategies and supply augmentation methods, with little or not consideration given to more sustainable adaptation methods. Dependence on foreign aid as the primary sources of funding for these plans further limits adaptive capacity, as execution of these plans is solely dependent on acquisition of donor funds. Meanwhile, weak political will by government officials to enforce regulations and execute existing plans in the water and wastewater sectors creates gridlock, slows and even halts progress towards achieving goals set out through water and wastewater sector planning, (Farajalla et al., 2015; MOE et al., 2011; USAID, 2011a).

Chapter 6: Looking to the Future: Recommendations and Conclusions

The Greater Beirut Area faces many pressing water governance challenges, including growing deficits in safe and reliable water supplies, degradation of available resources, increasing demands and low efficiencies throughout the sector, inequities in all aspects of water governance ranging from access to resources to the ability to participate in governance activities, a general lack of enforcement of existing regulations, and weak institutional capacities of actors throughout the sector. Meanwhile, projections of future declines in available water resources as a result of climate change, deteriorating water quality, and growing demands, will only place further pressures on the sector and will require more effective water governance measures (ESCWA, 2013b; Farajalla et al., 2015; Hamdy and Choukr-Allah, 2012; Rached and Brooks, 2010; UNDP, 2013; Varis and Tortajada, 2007). Efforts to improve water governance in the Beirut area, and more generally at the national level, such as the institutional reform of the water sector under Law 221 and its amendments, and the establishment of a National Water Sector Strategy by the MOEW, albeit slow and minimal compared to the magnitude and urgency of the current challenges faced, are examples of small steps forward. Based on the assessment of water governance in the GBA, a number of recommendations to address identified challenges are presented in the following sections.

Ensuring Access to Safe and Reliable Water Supplies

Improving access to potable water resources within the GBA through public sources is a necessary task, one that can be achieved by increasing supplies provided to the area to meet growing demands, and protecting current and future water supplies from pollutants. The MOEW plans to increase water resources supplied to the Beirut area primarily through the Bisri Dam and Awali-Beirut Conveyor project, which is seen as the only long-term solution to augment the regions water supplies (MOEW, 2010). Before additional sources of water are acquired and investments are made in new infrastructure, the MOEW and BMLWE should seriously consider rehabilitation of the already existing Jeita-Dbayeh Conveyor, to supply more water from the Jeita and Kashkoush springs (BGR and CDR, 2011). Alternative sources for Beirut's water supply should also be explored in more detail, including rainwater harvesting in the short-term, and the use of treated wastewater and aquifer recharge in the long-term as more wastewater treatment plants become operational throughout the country (MOEW and UNDP, 2014). Diversifying and increasing water sources used for the GBA's water supply could help reduce the need for water rationing, and in turn reduce dependence on water from private vendors and illegal wells. Since the MOEW and BMLWE are planning to increase water supplies for the GBA, the concept of environmental water should be considered if these resources are to be sustainably managed. Limits on extraction and minimum flows for river and groundwater systems need to be set through legislation if resources are to be protected and sustained for future generations (MOE et al., 2011). Allocating water resources for ecological purposes can help protect against water shortages, allowing for water to be shifted from ecosystems to essential uses to protect livelihoods during periods of scarcity.

Water quality is also a major concern, with the current supply from Jeita and Kashkoush Springs already exposed to pollutants from the source, in addition to exposure throughout the distribution process due to aging infrastructure. Projects rehabilitating the GBAs distribution infrastructure are already underway, but the BMLWE needs to take measures to protect supplies from the source. Recent studies have accurately delineated the catchment areas of these springs, giving authorities the opportunity to use this data to make more informed decisions with regards to protection of these resources (BGR, 2013; BGR and CDR, 2013). Groundwater protection zones within the catchment areas of Jeita and Kashkoush should be established, and specific landuse regulations should be imposed and enforced within vulnerable areas to ensure protection of the water resources. A special task force could be established within the MOE to ensure compliance with regulations within catchment areas, a strategy that has proved effective in protecting quality of water resources in other countries in the region (OECD, 2014). This strategy could be applied in the future for the protection of additional sources of water supply that may be acquired for the GBA. Improving wastewater networks and treatment plants, efforts that are currently underway by the CDR, will also help improve water quality, minimizing pollutants from discharge of untreated wastewater. Pollution of private water sources, particularly water provided through tanker delivery sources and illegal wells, is also of concern. Quality of water provided through vendors, including bottled water, should be regulated, and potable water quality standards already set by the MOPH can be used to ensure quality.

Demand Management and Efficiency Measures

In order to increase efficiency of water use in the GBA, reduction of water loss through the water distribution networks must be a priority. Rehabilitation of the distribution network within the Beirut area is already underway, but rehabilitation of the Jeita-Dbayeh Conveyor must also be a priority if efficiency throughout the whole system is to be achieved. The BMLWE must ensure continued efficiency of rehabilitated and new infrastructure through proper maintenance, and can do so by establishing leakage detection and repair programs and conducting regular condition assessments (Grigg, 2012; World Bank, 2012).

Although community outreach and education campaigns encouraging water conservation efforts are an effective demand management tool, the BMLWE cannot rely solely on these strategies for demand management. Metering and water tariffs are necessary if water demand is to be managed effectively throughout the GBA, and will enable the BMLWE to improve it's level of service and maintain improvements in the long-term (Farajalla et al., 2015; Hamdy and Choukr-Allah, 2012; Rouse, 2013; World Bank, 2012). Installation of meters throughout the GBA must be a priority, and the BMLWE should work with the MOEW to ensure that all network connections in the region are covered. Once connections in the GBA are metered, an appropriate volumetric tariff structure must be introduced and implemented. In order to ensure transparency in the charge setting process, the BMLWE should work with an independent body, such as an international governmental organization, while encouraging consumer participation in the process (Rouse, 2013; World Bank, 2012; Zeitoun, 2009). It will be important to consider consumer reliance on alternative sources of water, including water tankers, bottled water, and illegal private wells, as volumetric tariffs could inadvertently encourage increased dependence on these sources, especially exploitation of groundwater resources through illegal wells. Metering will also help produce more accurate data on water consumption in the BMLWE, enabling the water establishment to plan more effectively for future supply and demand management strategies.

Promoting Community Engagement

Currently there is no official means for community participation in the water governance process in Beirut, with minimal participation through demand management outreach and education programs by the LCWMC. Water users have no access to reliable information concerning water planning, and no right to participate in the decision-making process in the water sector. If sustainable water governance is to be achieved in the region, water authorities, specifically at the regional level of the BMLWE, need to begin shifting community engagement efforts from passive forms towards more active forms public participation (Hamdy and Choukr-Allah, 2012; Ozerol et al., 2013; Grigg, 2011; Sowers et al., 2011; UNDP, 2013; USAID, 2011a). Lack of trust in the water authorities, increased public awareness, and concern about the impacts of poor water and wastewater services on public health and overall human wellbeing, have resulted in a surge in public activism and protests over the past year (Hume and Tawfeeq, 2016; Khouri, 2015). The MOEW and CDR have devised national plans in both the water and wastewater sectors, with little to no engagement of the communities impacted by these plans. Stakeholders need to be equally represented to ensure equity in access to resources and distribution of potential impacts throughout communities. Government actors involved in the sector can ensure public participation through a variety of mechanisms, including supporting and facilitating the establishment of a Beirut water user association, supporting research centers and studies on the sector, and guaranteeing legal rights to access information generated, creating avenues for public participation in water resource planning and decision-making in the sector, in addition to the outreach and education programs already in existence, all strategies that are proving effective in promoting sustainable water governance throughout the Arab region (UNDP, 2013).

Institutional Reform and Capacity Building

The water governance structure in Lebanon has undergone recent reform, primarily with respect to the roles and responsibilities of governmental institutions within the water sector. Interpretation of the roles and responsibilities of the MOEW and the water establishment, specifically the BMLWE in the case of Beirut, as outlined by Law 221 and its amendments, has created uncertainty and confusion throughout the sector (Farajalla et al., 2015; USAID, 2011a; World Bank, 2012). Overlap between the responsibilities of the MOEW at the national level and the BMLWE at the regional level is apparent, and the amount of autonomy afforded to the BMLWE and other regional water establishment still remains unclear. There is also overlap in the roles and responsibilities between the MOEW and other ministries involved in water governance activities, mainly the CDR, MOE, and MOPH, exacerbated by a general lack of coordination between these agencies. Operational decrees to clarify the exact responsibilities of each agency within the water sector, and official means of coordination between these institutions need to be established in order to address these issues.

In addition to clarifying the roles and responsibilities of institutions within the water sector, there is an overwhelming need to strengthen their capacities to effectively perform mandated responsibilities. Addressing human resources and skill deficiencies through training and organizational development programs is the first step towards increasing overall capacity from within each institution. Establishing monitoring, feedback and assessment mechanisms throughout the sector is an effective tool for building capacity within the institutions, allowing for the generation and access to more reliable data on water governance issues, which can be used to inform sector planning and policy decisions (Grigg, 2011; Hamdy and Choukr-Allah, 2011; Rached and Brooks, 2010; UNDP, 2013). The need to strengthen the weak political will within the sector and create an enabling environment for institutions to implement legislation and regulations is very urgent, a reality that cannot be ignored in attempts to address issues in the water and wastewater sectors, since these factors are essential requirements for effective sustainable water governance (Biswas and Tortajada, 2010; Farajalla et al., 2015; Hamdy and Choukr-Allah, 2011; UNDP, 2013; USAID, 2011a).

This assessment of water governance in the Greater Beirut Area offers insights into current conditions and recommendations for a shift from current unsustainable practices in the water and wastewater sector towards a more equitable and sustainable water governance structure. The region is experiencing severe challenges in managing water resources, challenges that will only continue to grow if left unaddressed. Key steps towards a more sustainable system include: rehabilitating and properly maintaining infrastructure, ensuring protection of water sources from continued exposure to pollutants, increasing efficiency throughout the system and taking more serious measures to manage demands, enhancing community participation in water governance activities and decision making on current challenges and planning for future possibilities, and increasing institutional capacity of key actors in the sector. These lessons in understanding what the challenges to sustainable water governance are within the GBA and how they could potentially be addressed can be applied to other urban areas in the country, helping to minimize or even prevent such future challenges in other regions. In the face of dwindling supplies, environmental change, and pressures from growing populations, building adaptive capacity through increased research and monitoring of resources, community participation in planning and decision-making, and stimulating the political will to address these challenges are all critical for sustainable water governance that is equitable, effective, and efficient in Beirut, and throughout the country as a whole. This is a challenge that will by no means be an easy one to address, considering the current political situation in the country and the region, but is essential if access to water resources is to be improved and sustained for current and future generations.

Appendix A: Pollutants Generated by Major Hazard Sources to Groundwater in the Jeita Spring Catchment

Hazard Source	Generated Pollutants
Sewerage Systems	Pollutants found in wastewater: viruses, microorganisms (e.g. E.coli, Legionella pneumophila, Clostridium, Pseudomonas aeruginosa, Enterococcus faecalis, Giardia lamblia, Cryptosporidium parvum), nitrogen, heavy metals, organic matter content as well as trace organics like endocrine disrupting compounds and pharmaceutically active compounds.
Gas Stations	Fuel, lubricants, waste oils, solvents, antifreeze
Generators	Diesel
Cars Reparation Workshops	Petroleum products
Residential Heating Systems	Petroleum contamination (mainly diesel)
Dry Cleaning Facilities	Dense non-aqueous phase liquids (DNAPLs)
Industries (Injection wells, various chemicals & solid wastes disposal sites)	Liquid and solid industrial contamination: mainly heavy metals, and other hazardous chemicals
Agriculture (protected and open field crops production)	Pesticides (Endosulfan, arsenic, dicamba, atrazine, prometon, and solvents such as carbon tetrachloride), fertilizers (nitrates), herbicides (Paraquat, glyphosate), hormones, and solid wastes.
Feedlots and Slaughterhouses	Infectious wastes: manure, animal carcasses, used litters, etc. slaughtering wastes (Specific Risk materials, organs, bones, blood, carcasses, etc.), pharmaceuticals, disinfectants.
Illegal dumpsites	Household wastes, construction wastes (mainly PVC, dioxins, heavy metals, arsenic, lead, chromium and polychlorinated biphenyls), industrial solid wastes, slaughtering wastes, and pharmaceuticals
Quarries	Backfills, drill and blast operations (explosives, nitrates, etc), rocks processing (bitumen, calcareous sludge), fuel and oil storage and disposal.
Hospitals and Healthcare Clinics	Infectious waste, chemicals, heavy metals (e.g. Hg), detergents, Radioactive wastes, wastewater, household waste.
Hotels, Restaurants and Residences	Wastewater, household hazardous waste, and diesel and oil disposal.
Illegal Groundwater Wells	Ease infiltration of all nearby contamination
Military Facilities	Explosives and heavy metals.

Appendix B: Images of Conditions in Jeita-Dbayeh Conveyor

(BGR and CDR, 2011)

Appendix C: Legal Note

Several laws and regulations relevant to the water sector in Lebanon and specifically the GBA are noted throughout this study. However, due to the fact that legal texts are in Arabic, and not readily available through online sources, references made to the laws and regulations in this study are based on information available in literature on legal aspects of the water sector in Lebanon, and government publications that list these laws and regulations. All documents used to obtain information on laws and regulations pertaining to the water sector are cited in the References section of this document. The table below lists the laws and regulations referenced in this study.

Laws and Regulations	
Order No. 144, 1925	Protection of surface water and groundwater resources
Order No. 320, 1926	Protection of catchment areas
Decree No. 10276, 1962	Protection zones for water sources and recharge areas
Law 20, 1966	Creation of the Ministry of Water and Electrical Resources
Law 86/87, 1967	Prohibits groundwater exploitation for private use in the Greater Beirut Area
Law 216, 1993	Creation of the Ministry of Environment
Law 221, 2000 (amended by Laws 241 and 337)	Institutional reform of the water sector
Decision No. 8/1, 2001	Limit values for stack emissions and effluent discharge

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