8. WATER

Water is one of Lebanon's most precious resources. Unfortunately, while significant investments are made to tap water resources, very little is done to preserve it. Human activities exert strong pressures on both the quantity (water abstraction) and quality (water pollution) of water resources. In addition, many activities affect the water cycle (deforestation, dams, irrigation, drainage canals) thereby altering the conditions for water replenishment. For example, soil erosion (soil acts as a sponge) and the loss of plant cover (plants intercept rainfall) diminish groundwater recharge. Continued soil erosion and loss of plant cover (including forests), will lead to scarcer water resources and poorer water quality. Water quality will not improve until the practice of disposing untreated wastewaters on land and into streams and rivers stops.

This chapter provides an indicative assessment of the water situation in Lebanon. Section ٨,١ describes potential fresh water resources in the country. Section 8.2 describes current uses and functions of water and Section ٨,٣ provides a coarse assessment of water quality, including surface water, groundwater and coastal water and based on available data. Section ٨,٤ provides conservative estimates of the economic costs of water pollution impacts on health in Lebanon while section ٨,٥ highlights key policies and actions that influence the state of water resources in Lebanon. Outlook section ٨,٦ addresses future developments such as the privatization of the water supply sector.

8.1 Water resources

Lebanon is in a relatively fortunate hydrological position. It is estimated from isohyetal maps that the yearly precipitation results in an average yearly flow of 8,600 million cubic meter (Mm^3), giving rise to 40 major streams and rivers (including 17 perennial rivers) and more than 2,000 springs. Despite this seemingly abundant resource, Lebanon is poised to experience a water deficit within 10-15 years, unless sound and radical water management policies are developed and implemented (see Section 8.2.1). Water stress in neighboring countries including Syria, Jordan, the occupied territories and Palestine is a harsh reminder that Lebanon must rethink its water strategy in the shortest delay possible, protect water resources and use them more judiciously.

> Since the 1970s, no improvement has been made in quantifying water resources (surface and ground water). Today's surface water data are based on old measurements (1960s and 1970s) and do not take into consideration the impact of changes in land use and deforestation on aquifer recharge and surface runoff. Nor do those data account for the reduction in spring and river baseflows and in boreholes yields due to irrigation and other water uses (Sene and Marsh, 1999).

8.1.1 Water balance in Lebanon

Several studies have estimated the annual water balance in Lebanon. Although they contain certain inconsistencies, it is generally accepted that approximately 50 percent of the average yearly precipitation (8,600 Mm^3) is lost through evapotranspiration, while additional losses include surface water flows to neighboring countries (estimated by the Litani River Authority to represent almost eight percent) and groundwater seepage (12 percent). This leaves 2,600 Mm^3 of surface and groundwater that is potentially available, of which 2,000 Mm^3 is deemed exploitable. Table 8.1 summarizes the annual water balance.

Table 8. 1
Approximate Annual Water Balance

Description	*Yearly average flows (Mm³)*	
Precipitation		8,600
Evapotranspiration	(4,300)	
Surface water flows to neighboring countries		
- Flow to Syria:		
El Assi river	415	
El Kebir river	95	
- Flow to the occupied territories	160	
Hasbani river	(670)	
Groundwater seepage	(1,030)	
Net potential surface and groundwater available		2,600
Net exploitable surface and groundwater		2,000

Source: Various including Jaber, 1996; Al Hajjar, 1997; ESCWA, 1997; Comair, 1998; El-Fadel and Zeinati, 2000
Note: Precipitation estimated from isohyetal maps, and flows to Syria from National Litani Organization

The *net potential surface and groundwater available* includes water resources for which the cost of diversion/abstraction is prohibitive. The *net exploitable surface and groundwater* represent the total quantity of water that Lebanon can realistically recover during average rainfall years. It includes water that may be too polluted to use for domestic consumption (high treatment costs).

8.1.2 Precipitation regime

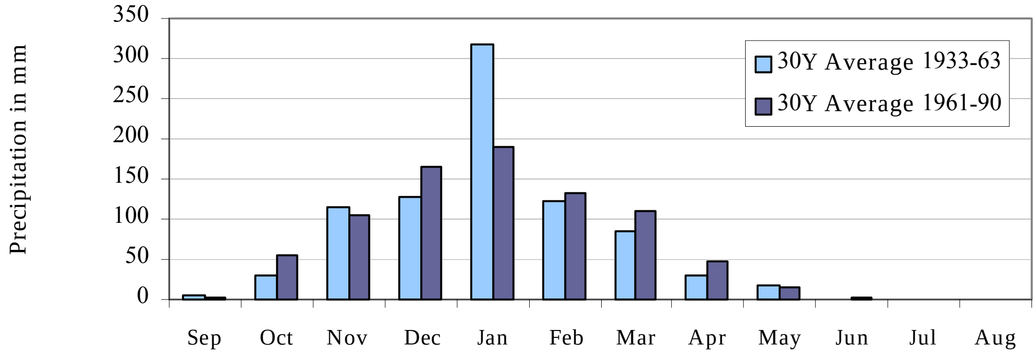
The Meteorological Service of Lebanon is located at the Beirut International Airport. It monitors meteorological parameters including temperature, humidity, rainfall, wind speed and direction, sunshine hours and barometric pressure. Prior to the war, Lebanon had more than eighty stations spread across the country. Many were subsequently damaged during the war and meteorological records were hence interrupted for several years. Several stations were rehabilitated in the 1990s (some with continuous and automatic data logging systems) and operations have resumed. In addition, several research centers and universities operate auxiliary weather stations including the American University of Beirut and the Saint Joseph University. The statistical monthly bulletins published by the Central Administration of Statistics provide meteorological records for Beirut, Tripoli and Zahle.

Precipitation in Lebanon is unevenly distributed. Up to 90 percent of total precipitation falls between November and April. Several parts of the country experience zero rainfall during the remaining six months, which implies the need for water storage to supply water during dry months. River runoffs peak during the wettest months with only small baseflows at all other times, when water is usually most needed.

> Snowmelt occurs at high altitudes and is quite abundant during high rainfall years. For example, during the exceptionally harsh winter of 1991-2, drivers in the area of Bsharre reported snow walls on each side of snow-cleared road more than 15 meters high on certain segments of the road!

Annual precipitation can reach up to 2,000 mm in some areas (Bsharre and Faraya in the western mountain range) and barely makes the 200 mm mark in others (Aarsal and Aah in the eastern mountain range). Coastal areas experience 600-1000 mm annual rainfall; neighboring mountain areas between 1000-1400 mm; and inland areas between 200-600 mm in the North and Central regions and 600-1000 mm in the South (Sene et al., 1999). Inter-annual variability of precipitation is also high throughout the country. Observational records for the drier inland regions show annual values ranging from less than 30 percent to more than 200 percent of the mean value. Such variability is more moderate in the coastal regions (± 60-80 percent of mean value). Figure 8.1 presents average rainfall in Beirut for two time periods, 1933-63 and 1961-90, and Table 8.2 shows recorded rainfall in Beirut, Tripoli and Zahle for the past five years.

Figure 8. 1
Average Rainfall Measured at BIA During Two Time Periods



Source: CAS Bulletin, No.1/2000

Table 8. 2
Recorded Rainfall for Years 1996 to 2000

Station	*Year*					*Average*		Balance (%)
	1996	1997	1998	1999	2000	1996-2000	1961-1990	
Beirut	827	733	658	487	834	708	825	86
Zahle	798	686	533	311	614	588	NA	NA
Tripoli	844	639	694	378	872	685	NA	NA

Source: CAS Bulletins 1996-2000

8.1.3 Surface water resources

Lebanon has 17 perennial streams and about 23 seasonal ones. Their combined length is approximately 730 km and their total annual flow averages 3,900 Mm^3. The 17 perennial streams are characterized in Table 8.3.

Table 8.4 presents the maximum and minimum monthly flow rates recorded for each river. While most river flows peak during March and April, some may reach maximum flow later during the year, such as the Aassi River which peaks in July. Minimum flows are typically recorded in the months of September and October. A perennial index was calculated to show the degree of flow variance between maximum and minimum flow periods. The higher the index, the smaller the variance. The Aassi River exhibits the highest flow index.

Table 8. 3
Characteristics of Lebanon's 17 Perennial Rivers

River	*Description*
13 Rivers	Flow west from their source in the Mount Lebanon range: Ostuene, Aaraqa, El Bared, Abou Ali, El Jaouz, Ibrahim, El Kalb, Beirut, Damour, Awali, Saitani, El Zahrani, Abou Assouad
Kebir River	Also flows west and traces the northern border of Lebanon with Syria
Litani River	Drains the southern Bekaa plain, crosses the southern periphery of the Mount Lebanon range and discharges into the sea north of Tyre
El Aassi River	Flows north into Syria draining the northern Bekaa plain
Hasbani River	Crosses the southern border and forms one of the tributaries of the River Jordan

Table 8. 4
Flow Data for the Perennial Rivers of Lebanon

River name	*Length (km)*	*Flow in Mm³*				*Perennial Index*
		Annual	*Average*	*Max*	*Min*	
El Kabir	58	190	6.02	13.9	1.8	0.13
Ostuene	44	65	2.07	4.01	0.8	0.20
Aaraqa	27	59	2.06	6.27	0.8	0.13
El Bared	24	282	8.94	15.2	2.7	0.18
Abou Ali	45	262	15.17	37.3	1.6	0.04
El Jaouz	38	76	2.40	6.18	0.4	0.06
Ibrahim	30	508	16.1	27.6	1.9	0.07
El Kalb	38	254	8.04	18.1	2.4	0.13
Beirut	42	101	2.59	10	0.1	0.01
Damour	38	307	13.8	32.7	0.6	0.02
El Awali	48	299	9.71	26.2	3.9	0.15
Saitani	22	14	0.73	1.3	0	0.00
El Zahrani	25	38	1.59	3.4	0.3	0.09
Abou Assouad	15	11	0.35	NA	NA	NA
Litani	170	793	12.5	30.8	4.3	0.14
El Aassi	46	480	16.4	20.9	11.5	0.55
Hasbani	21	151	4.8	11.3	1.6	0.14

Source: Various including Al Hajjar, 1997; CD&M, 1982; Acra and Inglessis, 1978

8.1.4 Groundwater

The estimates for the groundwater quantity available for exploitation range from 400 to 1,000 Mm³/year according to the source of information.[1] Snow cover is a principal source contributing to groundwater recharge. The country's limestone formations have

[1] Fawaz, 1992; Jaber, 1999; Amery, 2000; Al Hajjar, 2001; WB, 1998; ERM, 1995

many fissures and fractures, which enhance snowmelt as well as rainwater to percolate and infiltrate deep into the ground and feed these aquifers. Ultimately, the water in these layers either 1) remains stored in aquicludes, some may be exploited through wells while others remain in deep layers untapped; 2) reappears as surface waters, at lower elevations, in the form of springs that feed into rivers; 3) forms submarine springs discharging near the coastline or the sea; [2] or 4) is lost to deep layers and may reappear in the groundwater of neighboring countries.

This Section is largely based on a 1970 UNDP report of underground aquifers in Lebanon (UNDP, 1970).

Characterization of groundwater resources in Lebanon is imperative to determine the extent, hydrologic associations, storage capacity, quality, and retention time in each aquifer. In this context, a number of studies have been conducted the most comprehensive of which dates back to the 1970s.

The general repartition of groundwater along the Lebanese territory is a direct outcome of the lithology and structure characterizing the country. Hence, the country has been divided into two major and distinct hydrogeological provinces: the *Interior Province* comprising the eastern flanks of the Lebanon range, the Bekaa valley, and the western flanks of Anti-Lebanon; and the *Mediterranean Province* comprising the western flanks of the Lebanon range down to the sea. The line of divide between these two basins has been delineated as a fictitious line passing through the mountain tops of Mount Lebanon, Jabal Barouk, Jabal Niha, and the Lebanese Galilee.

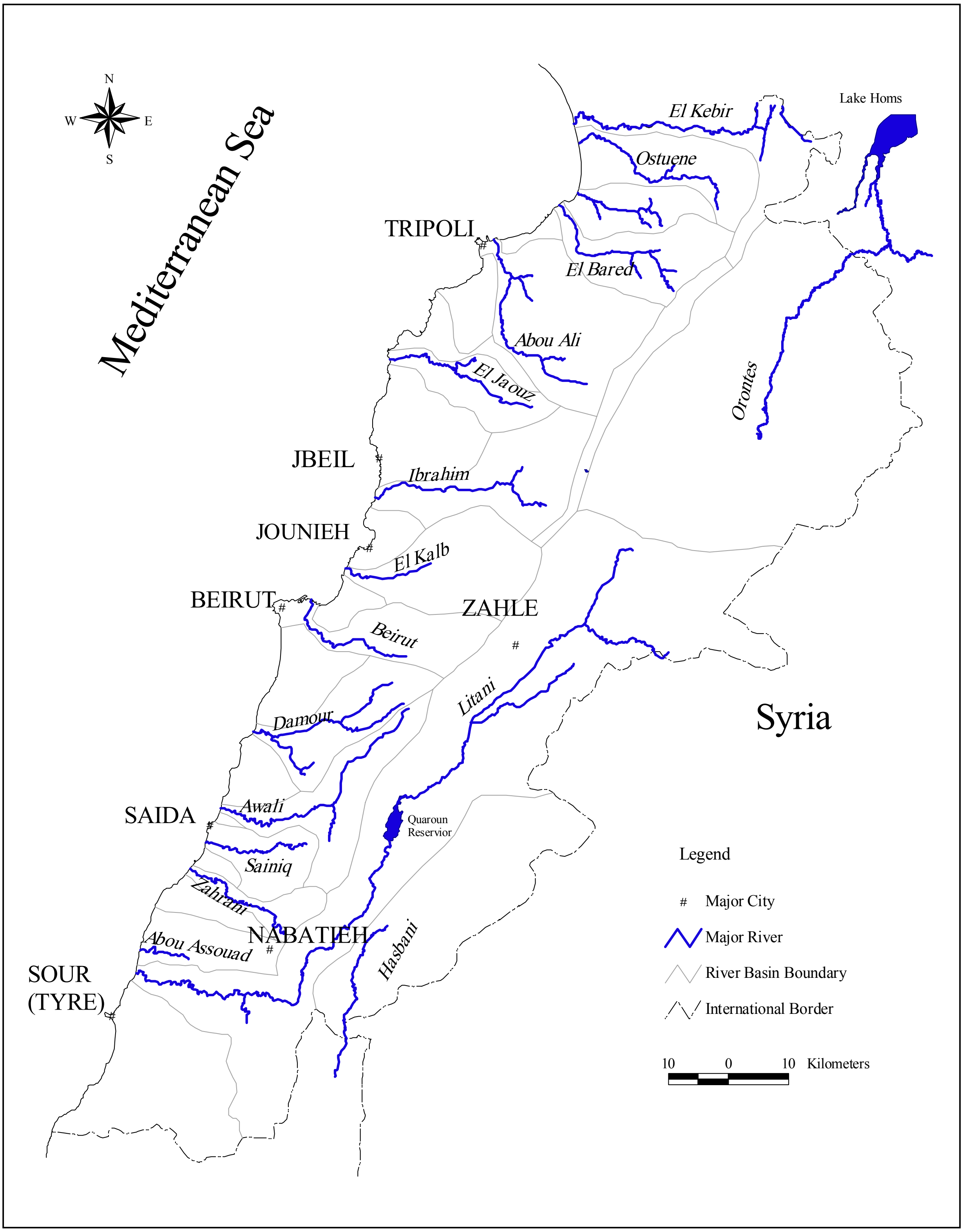
In both provinces several basins were identified and are classified according to the outcropping aquiferous lithologic formation: Kesrouan Limestone Formation aquifer (Jurassic age), Sannine-Maameltein Limestone Formation aquifer (two formations forming a single aquifer of Cenomanian and Turonian age respectively), the Eocene limestone aquifer (Eocene), the Neogene and Quaternary deposits of the Bekaa reserves, in addition to the following formations that are of importance only in the Mediterranean Province which are the Jebel Terbol Limestone Formation aquifer (Miocene age), the Abeih and Mdeirej (Aptian and Albian age) groundwater reserves, the Chouf Sandstone groundwater reserves, and the recent deposits groundwater reserves.

While the physical characteristics of these aquifers/basins are expected to remain the same since the initial studies were conducted, much of the hydraulic/hydrologic properties have changed due to uncontrolled groundwater tapping.

The drastic change in topography in just a few kilometers from the coast till the Bekaa valley and from the Bekaa valley till the summits of the Eastern Mountain Range directly affects water table levels. The geology of the country and mainly its structure (faults, etc.) have further complicated the issue whereby faults may act as either barriers or preferential flow paths for water thus segregating the same groundwater basin into sub-basins with different groundwater table levels. Furthermore, in karst terrains, which are widespread in the country, the hydrology is different from other types of terrains where diffuse flow of water dominates. In karst, water tends to concentrate along specific paths flowing in underground rivers and conduits until and through the phreatic zone, a phenomenon whereby the traditional concept of water table does not clearly apply resulting in the difficult task of delineating a general groundwater surface map difficult for the country not to mention the problem of data unavailability.

[2] Ghannam *et al.*, 1998; Ayoub *et al.*, 2000

Map 8.1
Major River Basins of Lebanon



Source: El-Fadel *et al.*, 2000a

8.2 Uses and functions

Agriculture is by far the largest consumer of water in Lebanon (as elsewhere in the region), followed by domestic and industrial uses. Auxiliary uses and functions of water include the generation of hydroelectricity (hydroelectric power plants), recreation (water parks and sports), and aquaculture.

8.2.1 Sectoral water consumption

There has been many attempts to estimate current and future water consumption in Lebanon. It is very difficult to determine the actual breakdown of water consumption as a large share of water in public distribution systems are lost through system leakages and most private wells are unlicensed and therefore not monitored. Nevertheless, there is a general consensus that agriculture represents between 60 and 70 percent of total water consumption. This share is likely to decrease over coming years as more water is diverted for domestic and industrial consumption (see Table 8.5). Section 2.3.1 provides a discussion of large-scale irrigation schemes. Section 8.2.2 examines water supply for domestic consumption and Section 3.2.3 provides a brief description of water consumption by the industrial sector.

It is also widely reported that current annual water consumption lies around 1,400 Mm^3. However, demand forecasts are conflicting, ranging from 1,897 Mm^3 (El-Fadel et al., 2000a) to 3,300 Mm^3 (Fawaz, 1992) for the year 2010. Whatever the rate of increase, water *consumption* remains inferior to actual water *demand*. In other words, if more water was available, more water would be consumed. All forecasts however do point to the imminence of a water deficit in Lebanon within the next 10-15 years.

Table 8. 5
Total Water Demand by Sector

Type of Use	*1990*		*1994*		*2015*	
	Mm^3/Y	Percent	Mm^3/Y	Percent	Mm^3/Y	Percent
Agriculture/Irrigation	875	72	950	74	1,700	60
Domestic	271	22	205	16	900	32
Industry	65	6	130	10	240	8
Total	**1,211**	100	**1,285**	100	**2,840**	**100**

Source: LEDO Indicator #25

8.2.2 Water supply for domestic consumption

According to the CAS Census of Buildings and Establishment (1996-97), 79 percent of buildings were connected to water supply networks. The highest rates of connection were recorded in Beirut and Kesrouan (93 and 94 percent, respectively), while the lowest were in Hermel and Akkar (41 and 49 percent, respectively). Some improvements have undoubtedly been made since, but there is no more up-to-date information (see Map 4.1 for water supply data at Caza level).

Water supplied to households originates from surface or ground water resources. Most of the country's 15 potable water treatment plants existed before the war and were rehabilitated and/or expanded. Between 1995 and 2001, average water treatment capacity increased by more than 50 percent (see Table 8.6).

Table 8. 6
Distribution and Flow Capacity of Water Treatment Plants in Lebanon

Region	*Water Board*	*Plant Location/Name*	*Capacity (m^3/d)*	
			1995 [/a]	2001 [/b]
Greater Beirut	Beirut	Dbaiye	230,000	430,000
	Ain El Delbe	Dachonieh	50,000	50,000
		Hazmieh	50,000	50,000
North	Tripoli	Haab	40,000	40,000
	Nabaa el ghar	Kousba	5,000	16,000
	Batroun	Nabaa Delleh	3,500	12,000
Mount Lebanon	Metn	El Marj lake	3,500	3,500
		Jeita	16,000	17,000
	Jbeil	Nahr Ibrahim	4,000	16,000
South	Saida	Nabaa Kfarwa	8,500	8,500
	Nabaa el-Tasse	Nabaa Azzibeh	4,000	4,000
	Sour	El Bass	6,000	12,000
		Ras el Ain	13,500	15,000
	Jabal Amel	Taybeh [/c]	8,000	8,000
Bekaa	Zahle	Berdawni	10,000	10,000
Total	**12 authorities**	**15 plants**	**452,000**	**692,000**

a / Source: METAP / ERM, 1995

b / Source: *Pers Comm* El Hassan Z, CDR / Water supply specialist

c / A new plant with a design capacity of 25,000 m^3 / day is under preparation

It is difficult to estimate current levels of domestic water supply. Several sources indicate that the target capacity is 160 liters per day per person. Actual delivery is presumably much lower, perhaps as low as 64 liters per day in some areas, due to high system and distribution losses (Jaber, 1999). Therefore, in addition to investing in production and treatment measures, the GoL is increasingly focusing on reducing system losses (which can reach 50 percent of total supply) and improving distribution.

8.2.3 Other uses of water

Not all water uses entail contamination of the water resource. For example, water gradients generate electricity in hydropower plants and water is also used for recreation in water parks. While these and other types of water uses do not directly pollute water resources, they do however entail other impacts such as reduced water flow in riverbeds and ground water mining.

Hydropower plants. Several rivers have been dammed to generate electricity as early as the 1960s. In recent years however the GoL has invested significant resources to capture snow water at high altitudes to sustain agricultural production during the dry summer period. With government funds as well as grant funding, the CDR, the MoEW, Green Plan and several NGOs have constructed many ponds and hill lakes. Because hydroelectric power plants rely on water gradients, there seem to be little interest in expanding existing hydroelectric plants or building new ones.[3] For example, only 15 years ago, the-then Ministry of Hydraulic and Electric Resources was exploring the feasibility of constructing more than 20 hydroelectric power stations (Amassian, 1984). Section 7.1.3 provides a discussion of Lebanon's hydroelectric power generation capacity and lists existing hydroelectric power plants (see Table 7.4).

[3] *Pers comm* Jaber B, MoEW, Senior WB Consultant

Recreational use. Water is increasingly used for recreational activities such as swimming pools and water parks. While beachfront swimming pools usually pump and treat seawater, inland swimming pools (villas, hotels and country clubs) presumably tap underground water resources at liberty. If this water is chlorinated for hygienic purposes, then it cannot be reused for agricultural production. Water parks are therefore heavy water consumers and should be monitored.

Waves is one of several water parks in Lebanon built in the past few years. It is located in Mar Roukoz/Mansourieh, on a pine forested hill. The park covers 60,000 m^2, the size of 160 basketball courts. It has three pools (wave pool, kid's pool and island pool), a 300-meter long, 6-meters wide river, and 2 km of slides that lead to a common landing pool area. Water is provided by deep wells on-site.

8.3 Water quality

Water quality is adversely affected by industrial, agricultural and domestic wastewaters. Leaching of pesticides and fertilizers from agriculture causes ground and surface water pollution. Industrial activity releases a wide range of chemical effluents into water courses, especially surface and coastal waters (see Table 8. 7). It is difficult to accurately estimate the pollution loads into water bodies from various economic sectors. Not only are data on effluent generation from industries scant and poorly monitored, there is also insufficient data on effluent disposal routes (i.e., direct discharge on land or into nearby water courses and the Mediterranean Sea, indirect discharge into sewer networks, with or without pre-treatment).

Table 8. 7
Potential Environmental Stresses on Water Resources

Economic Activity	*Source of Impact*	*Evidence of Stress*
Agriculture	Excessive use of surface and groundwater for irrigation	Seasonal water shortages
	Excessive application of agrochemicals	Possible contamination of groundwater from pesticides and nitrates
Industry	Discharge of liquid waste	Contamination of rivers and coastal waters
	Uncontrolled disposal of solid waste	Possible contamination of rivers and groundwater from leachate seepage
Transport	Use of leaded gasoline	Lead in rivers and coastal waters especially after storms
	Disposal of waste oils	Waste oil dispersal in rivers, wells and coastal waters
	Disposal of ballast water	Oil slick and tar balls on shores
Energy	Hydropower	Intermittent drying of river beds during summer
	Thermal power plants	Discharge of cooling water leads to thermal pollution of costal waters in the vicinity of thermal plants, disturbing marine ecology
Human Settlement	Uncontrolled sewage disposal and no monitoring of septic tanks	Bacterial contamination of ground and surface water
	Excessive use of ground water resources for domestic supply	Seawater intrusion in coastal areas

Source: Adapted from METAP/ERM, 1995

8.3.1 Wastewater discharges

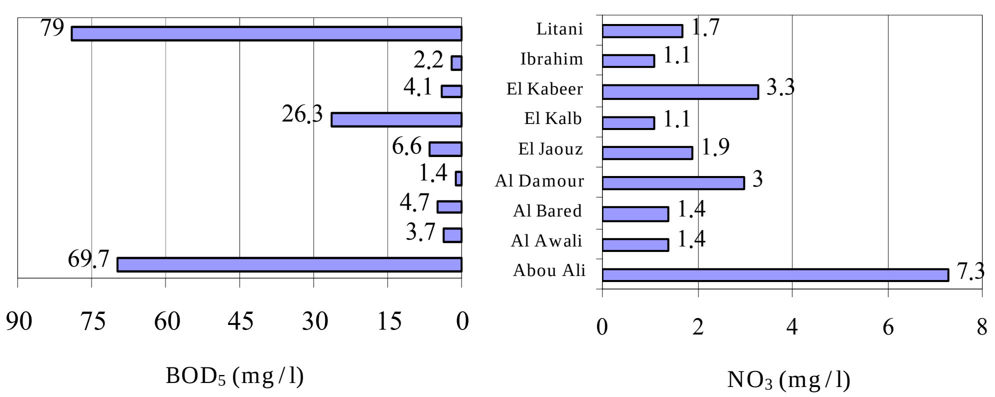
Water bodies receive or are affected by liquid effluents and solid waste from about four million people (CAS Study No. 9, 1998) and 22,000 industrial establishments (MoI, 2000). Chapter 1 estimated domestic effluent at 249 Mm^3 per year while previous reports estimated industrial effluents at about 22.3 Mm^3 per year (CDR/Dar Al Handasah, 1996). Sections 1.3.2 and 3.2.5 describe how the quantities of domestic and industrial wastewaters, respectively, were derived. Chapter 15 assesses wastewater management. In addition, sections 1.3.1 and 3.2.5 characterize municipal and industrial solid waste generation, while Chapter 14 analyzes current solid waste management practices.

8.3.2 Quality of surface water

Surface water quality data are available from sporadic sampling activities conducted by various institutions (National Center for Marine Sciences, Ministry of Public Health/Directorate of Central Laboratory, AUB Water Resources Center, Ministry of Energy and Water). Such data highlight spatial variations but do not account for temporal variations. Temporal variations in river quality would require continuous sampling and monitoring events– something Lebanon does not have.

In November 1999, a study conducted by the AUB Water Resources Center assessed the impact of waste disposal on water quality in nine major rivers in Lebanon (El-Fadel et al., 2000a). The results of water and sediment samples from 65 separate sampling sites showed generally high concentrations of BOD_5 (up to 154 mg/l at certain sites) as well as fecal and total coliforms. Figure 8.2 presents mean recorded values for BOD_5 and Nitrate levels (NO_3) in these rivers. High BOD_5 levels and coliform counts indicate that untreated domestic sewage is directly discharged into water bodies. High nitrate levels reflect the additional presence of diffuse sources of pollution, such as fertilizers from riverbank agriculture. For example, along the El Kebir River, major greenhouse systems are located immediately on the riverbank. Concentrations of total dissolved solids (TDS), chlorides, orthophosphates and sulfates varied from 17-464 mg/l, 8-85 mg/l, <0.1-1.72 mg/l, and 0.23-86 mg/l, respectively.

Figure 8. 2
BOD_5 and NO_3 Levels in Nine Rivers (Nov, 1999)



Source: El-Fadel *et al.*, 2001a

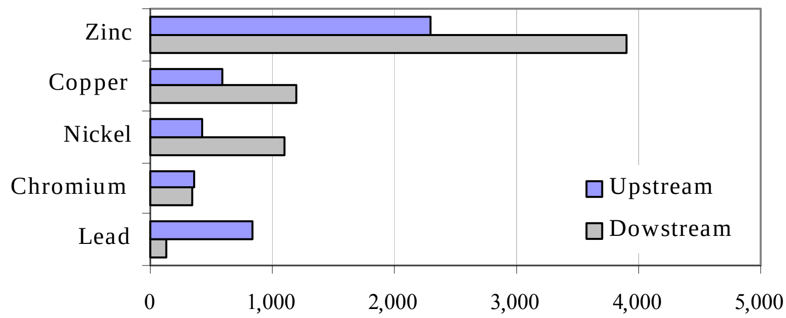
Box 8. 1
Quality of Litani River and Lake Qaroun

Swedish MVM Consult AB prepared for the MoE and the Litani River Authority a management plan for the Litani River and lake Qaroun watershed. Between November 1998 and May 2000, MVM assessed river quality by conducting intermittent monitoring of the river and tributaries from 16 sampling points. Currently, up to seven sewer networks of varying sizes discharge their effluents into the river. Baalbek, Houch el Rafqa, Qaa er Rim, Zahle, Chtoura, Qabb Elias, Bar Elias, Joub Jannine and Qaraoun discharge untreated sewage into the Litani or its tributaries. The river also receives industrial effluents from sugar-beet factories, paper factories, lead recovery plants, limestone crushers, agro-industries and poultry farms, tanneries and slaughterhouses.

Source: MoE-CDR/MVM, 2000

Open dumping also impacts surface water quality. Unlike controlled landfills, which are equipped with basal lining systems to intercept leachate, open dumps release leachate directly into the environment. Leachate will seep into groundwater or runoff into nearby watercourse. For example, the Litani River is affected by leachate released from five open dumps (Baalbeck, Sifri, Barr Elias, Zahle and Joub Janine). The impact of open dumping at the Zahle open dump (along the Berdawni River) was assessed. The results showed that heavy metal concentrations, including zinc, copper and nickel, were significantly higher downstream of the open dump (MoE-CDR/MVM, 2000). The study also found that the dump releases significant amounts of hydrocarbons and chlorinated organic substances including alkyl naphthalene and non-polar carbons. These pollutants indicate the presence of pesticide residues in the dump, presumably caused by the disposal of agro-chemical wastes. Figures 8.3 shows the extent of heavy metals released from the Zahle dump into the Berdawni River.

Figure 8. 3
Heavy Metals Concentrations in the Berdawni River (ppb in substrate)



Source: MoE-CDR/MVM, 2000

Lebanon does not have ambient standards for surface water quality. Decision 52/1 (1996) does however provide minimum water quality standards for aquatic life, including several heavy metals such as Zinc and Copper. The corresponding limit value for both Zinc and Copper is 1 mg/l.

8.3.3 Quality of groundwater

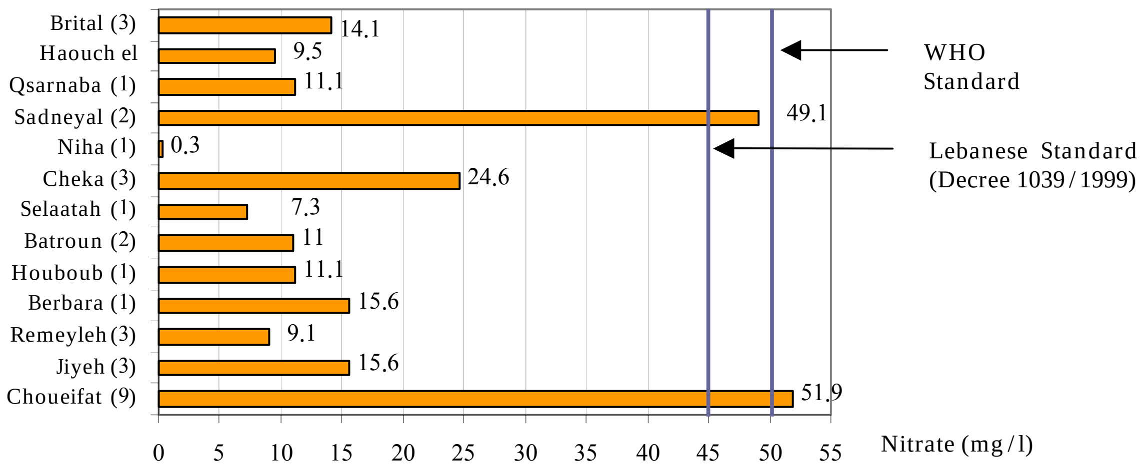
The prevalence of fissured limestone formations in Lebanon facilitates the seepage of liquid wastes into groundwater. Point sources of pollution include the discharge of domestic and industrial solid and liquid wastes, as well as routine or accidental spills (e.g., leaking underground storage tanks). Diffuse sources of pollution include mainly agrochemicals (pesticide residues and fertilizers) and seawater intrusion (water salinization).

Pollution from agro-chemicals

In 1999, the AUB Water Resources Center conducted a preliminary assessment of groundwater quality in Lebanon. A total of 31 groundwater samples from 13 different regions were analyzed for the presence of 16 pesticide compounds, including transformation products. The results showed that nitrate concentrations were moderately high in the sampled wells, especially along the coast, ranging from 0.3 mg/l in Niha to 51.9 mg/l in Choueifat (see Figure 8.4, numbers in parentheses indicate number of samples). The WHO and Lebanese standards for permissible NO_3 levels in drinking water are 50 and 45 mg/l, respectively. Generally, nitrate levels above 20 mg/l indicate human-based pollution (i.e. not naturally-occurring). Phosphate levels were within acceptable ranges.

In 1999, Lebanon imported 1,530 tonnes of pesticides and almost 32,000 tonnes of fertilizers (see Section 2.2.2 on agrochemicals).

Figure 8. 4
Nitrate Concentrations in 31 Wells in 13 Regions (mg/l)



Source : El-Fadel *et al.*, 2000b

Pesticide residues were detected in trace concentrations: aldrin (30 percent of the sampled wells), dieldrin (12 percent), heptachlor (12 percent) and heptachlor epoxide (9 percent). In general, however, levels were lower than the health advisory limits set by the USEPA.

Seawater intrusion

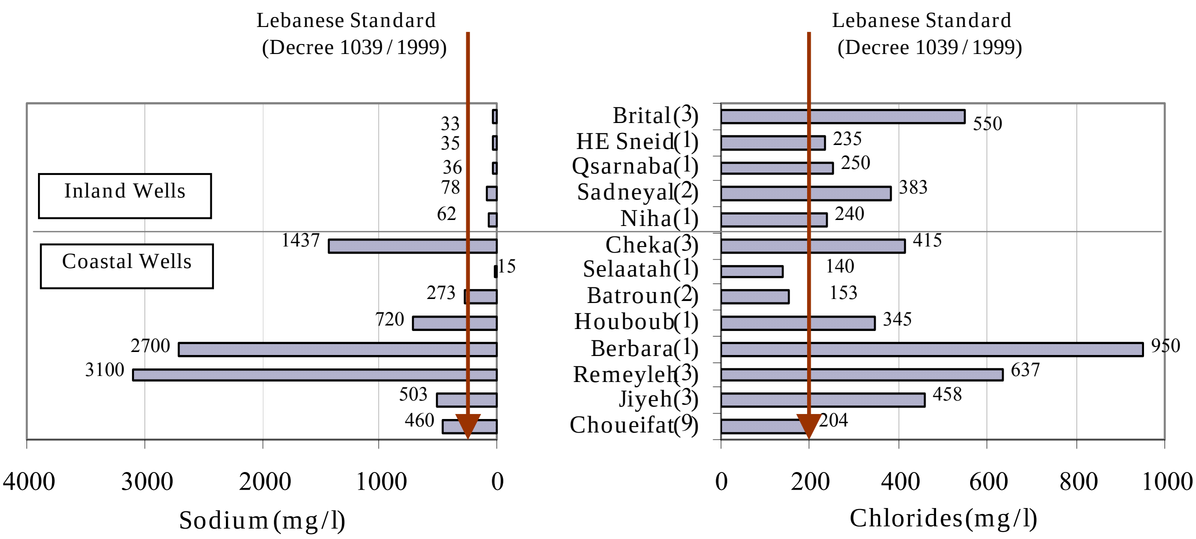
Over-pumping leads to higher chloride concentrations in groundwater. Over pumping implies that the rate of water abstraction is higher than the rate of recharge, leading to groundwater mining. In 1997, almost 42,000 buildings (nine percent of all buildings in Lebanon) were equipped with private wells.[4] Moreover, farmers across the country are suspected of having drilled countless more wells. A high sodium and chloride concentration in coastal groundwater is attributed to seawater intrusion. High chloride levels in mountain regions and the Bekaa are potentially attributed to fertilizer applications.

The 1999 groundwater screening campaign conducted in 1999 by the AUB/WRC supports earlier assertions of seawater intrusion. Chloride concentrations were generally above the WHO and Lebanese permissible limit of 250 and 200 mg/l, respectively. Sodium concentrations were well above the 200 mg/l WHO standard and 150mg/ml Lebanese standards for drinking water: sodium levels exceeded 5,000 mg/l in some wells!

Increased chloride concentrations of groundwater was also demonstrated in the Bekaa, where the demand for irrigation water is increasing rapidly. Farmers are digging wells at liberty, defying the most basic well standards such as permissible depth and minimum distance between wells. Figure 8.5 presents the chloride concentrations of 31 sampled wells in the Bekaa and coastal areas.

Seawater contamination of groundwater near the coast has been reported in Lebanon as early as the 1960s (Sadek and El-Fadel, 1998). This problem has reached a new scale of severity over the last two decades due to the expansion of coastal agglomerations. Rural-urban migration and population growth have increased demand for water all along the coast, and most particularly in and around the capital. Many new urban developments (e.g., housing and recreational resorts in mountain areas) rely in part or in full on underground water supplies. In the absence of strict enforcement of borehole specifications and permissible abstraction rates, the salt/freshwater interface shifts inland.

Figure 8. 5
Chloride and Sodium Concentrations in 31 Wells



Source: El-Fadel *et al.*, 2000b

[4] CAS Studies: 1996-98. See Map 4.1 for well data at Caza level.

8.3.4 Quality of coastal waters

Marine waters receive contaminated surface water from river outlets, raw or partially treated domestic and industrial wastewater from the coastal zone, agricultural runoff from coastal agriculture, leachate and drifting waste from seafront dumps, hydrocarbons from accidental or routine oil spills, and ballast water dumped illegally. Currently, there are about 53 wastewater outfalls along the coast (CDR/LACECO, 2000c). Coastal waters are also affected by countless beachfront resorts, numerous reclamation and sea embankment projects (new sea runway at the Beirut International Airport and Dbaye Marina).

Pollution from industries and thermal power plants

A field study conducted by the AUB Water Resources Center in 2000 presented a preliminary characterization of Lebanese coastal waters. Thirty samples were collected in September 2000 from 30 separate locations along the coast, from Tyre to Akkar. In addition to trace levels of several pesticides, the study found high concentrations of nickel, copper, chromium, lead and arsenic at several locations. Seven samples were collected at or near industrial hotspots. Table 8.8 presents the results of these samples as well as a background sample taken two km off the coast at the level of Chekka. Chromium levels were highest near the Dora industrial complex, which hosts half a dozen tanneries. Furthermore, thermal pollution was detected near the Zouk power plant where temperature was 1.5°C higher than the background level.

Table 8. 8
Heavy Metal Concentrations in Marine Coastal Waters Near Industrial Facilities

Industrial Hotspot	*Heavy metal concentration (µg/l)*				*Temp (°C)*
	Arsenic	*Lead*	*Zinc*	*Chromium*	
Background	**5.1**	**2**	**3.8**	**2**	**28.8**
Al Ghazieh	14	2	32	35	29.7
Jiyeh power plant	7.7	17	19	24	31.3
Dora industrial complex	51	2	24	100	29.1
Zouk power plant	47	2	17	81	30.3
Selaata chemical plant	10	2	9.6	36	28.7
Chekka cement plant	13	2	26	23	29.5
Akkar Future Pipes Industries	13	3	23	33	29

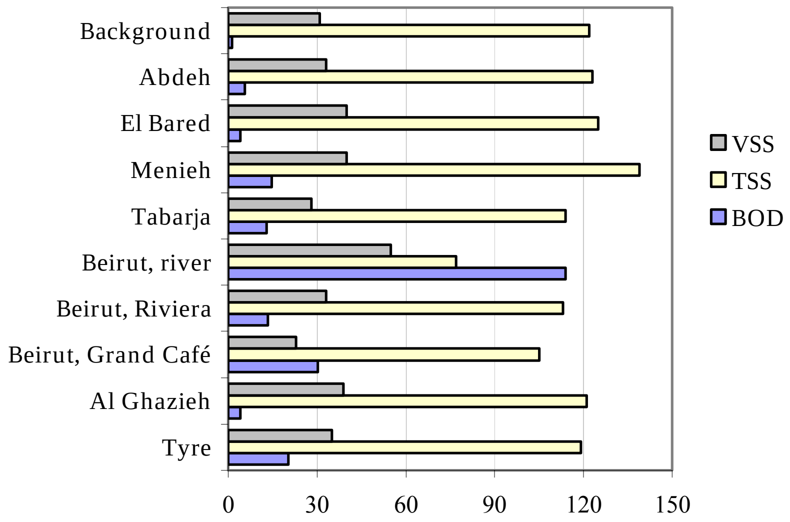
Source: El-Fadel *et al.*, 2000c

Pollution from sewage

Some 2.3 million people live in the coastal zone (see Section 1.2). They release approximately 950,000 m^3 of wastewater a day, most of it ending up in the sea (CDR/ECODIT-IAURIF, 1997). Of the 10 coastal areas monitored by the National Center for Marine Sciences, only one station (Batroun) was deemed fit for swimming based on the concentration of fecal coliforms. All other nine areas exceeded the WHO fecal coliform standard for recreation waters.

Figure 8.6 presents BOD, total suspended solids (TSS) and volatile suspended solids (VSS) levels in marine waters at nine different locations near sewage outfalls. While VSS and TSS near sewage outfalls do not depart significantly from background levels, BOD levels increase significantly (1.3 mg/l background level compared to 30.3 mg/l near Grand Café in Beirut).

Figure 8. 6
VSS, TSS and BOD Levels Near Sewage Outfalls (mg/l)



Source: El-Fadel *et al.*, 2000c

<u>Pollution from seafront dumps</u>

Solid waste disposal in beachfront dumps continues in Tripoli and Saida, but has stopped in Normandy and Borj Hammoud (see Section 11.4.2). Disposal of solid waste in uncontrolled landfills and waterfront dumps exacerbate the current pattern of seawater contamination. In the absence of clay or plastic liners, leachate seeps into groundwater and seawater resulting in both organic and inorganic contamination. Table 8.9 presents the estimated pollution loads from three major seafront solid waste dumps. No information is available on potential pollution loads from the Saida coastal dump.

Table 8. 9
Potential Pollution Loads into Mediterranean Sea From Seafront Solid Waste Dumps

Parameter	*Normandy dump* [a/]	*Borj-Hammoud dump*	*Tripoli dump*	*Total*
Dump surface Area (ha)	10	15	3	28
Leachate discharge (Mt/year)	80,000	120,000	24,000	224,000
Pollutants (concentration in leachate)				
BOD (300 mg/l)	24 Mt/yr	36 Mt/yr	7.2 Mt/yr	67.2 Mt/yr
Total N (3 g/l)	240 Mt/yr	360 Mt/yr	72 Mt/yr	672 Mt/yr
Heavy metals (3 mg/l)	240 Mt/yr	360 Mt/yr	72 Mt/yr	672 Mt/yr

[a/] Before rehabilitation works began (1998)

Source: CDR/ECODIT-IAURIF, 1997

In addition to the release of leachate, coastal open dumps are also the source of drifting debris and floating waste, which may sink to the bottom and cover the sea floor. The Professional Divers' Association (PDA) frequently reports that waste covers the sea floor at many locations off the coast, reducing photosynthesis and suffocating marine flora and fauna. Frequently observed waste include cans, tires, plastic materials, etc. Fishers report the gradual decline of the coralline reefs.

8.3.5 Quality of drinking water

Regional water authorities are responsible for procuring, treating and distributing potable water to households. Water is either chlorinated directly at the source (bore holes and springs) or treated at a centralized water treatment plant (see Section ٨,٢,٢ for an overview of treatment plants). However, potable water quality may then deteriorate during distribution (cross contamination by wastewater network, rusting water conduits, etc.) Therefore, when end-users receive potable water, in some cases it may not be safe for consumption, potentially leading to incidences of gastro-intestinal diseases (e.g., diarrhea, dysentery) and other infectious diseases (e.g., typhoid, hepatitis).

Epidemiological data on infectious diseases (including water-borne diseases) are slowly becoming available and provide some basis to assess trends. A compilation of the number of cases of infectious diseases, published by the Directorate of Preventive Medicine at the MOPH between 1995 and 2000, reveals that the annual number of cases of dysentery, hepatitis A and typhoid (leading types of water-borne diseases in Lebanon) has declined between 1995 and 2000. Regionally, however, the trend may differ. For example, while the number of reported cases has markedly declined in the South and Nabatiyeh, the Bekaa and North Mohafazas have experienced a sharp increase in the incidence of all three water-borne diseases (see Table 8.10).

Table 8. 10
Cases of Reported Water-Borne Diseases by Mohafaza (1995-2000)[5]

Reported diseases	*Mohafaza*						
	Beirut	Mount Lebanon	North	South & Nabatiyeh	Bekaa	Unspecified	Total
Year 2000							
Dysentery	5	17	69	5	245	13	354
Hepatitis A	20	12	135	19	36	17	239
Typhoid	32	110	371	45	140	31	729
Average for Years 1995-2000							
Dysentery	9	47	24	314	68	18	471
Hepatitis A	35	39	84	86	22	20	286
Typhoid	47	86	294	230	99	42	795

Source: Data supplied to ECODIT by MOPH / Directorate of Preventive Medicine

[5] Actual cases are likely to be much higher than the reported cases for two main reasons: (1) all hospitals do not report diligently all cases of infectious diseases to the MOPH and (2) a large number of patient-cases do not go to hospitals for treatment: these patients either consult private physicians/clinics or stay at home and are therefore not accounted for.

8.4 Economic impact of water pollution

Health impacts due to poor water quality are a major concern in Lebanon. In general, waterborne diseases, especially diarrheal diseases, are one of the leading causes of mortality and morbidity among children less than five years old. In addition, health problems resulting from exposure to water pollutants often result in health care expenditures and absence from work. In addition to health impacts, poor water quality increases the costs of water treatment (not estimated here) and encourages or forces people to buy more bottled water than they would normally buy if they had access to good quality drinking water.

Table 8. 11 presents the estimated costs of the impacts of water pollution on public health, including excess mortality and morbidity due to unsafe water supply (see Appendix H for the complete case study).

> Ecodit has calculated the costs of the health impacts of water pollution at US$7.3 million per year and the costs of excess bottled water consumption at about US$7.5 million (see Appendix H).
>
> The methodology used to estimate these costs always relies on very conservative estimates --i.e., the actual costs are likely to be much higher than what is presented here. In addition, water pollution results in many other hidden costs that are more difficult to quantify (e.g., drinking water treatment, contamination of aquatic life, reduction in fish catch, contamination of well water used for irrigation, chemical contamination from industrial sources). Therefore, the costs presented here tend to underestimate the actual costs of water pollution and should be used as a starting point for more thorough economic evaluation based on new information that may become available in the future.

Table 8. 11
Estimated Annual Costs of Excess Mortality and Morbidity Due to Water Pollution in Lebanon

Cost Category	*Number of persons or cases*	*Cost per person (US$)*	*Total cost (US$)*
Premature mortality	69	88,573	6,111,537
Hospital admissions due to diarrheal diseases	406		
--Dysentery	132	900	118,800
--Hepatitis A	72	1,750	126,000
--Typhoid	202	2,800	565,600
Emergency room visits	378	76.04	28,743
Restricted activity days	13,133	29.4	386,110
Total			**7,336,790**

Poor water quality also encourages people to buy more bottled water than they would normally buy if they had access to good quality drinking water. According to the survey on household budgets, [6] bottled water represents 0.6 percent of average annual expenses (LBP 40,182). By comparing local consumption with typical per capita consumption rates in select Mediterranean countries, it was estimated that Lebanon’s excess consumption due to water pollution is 7.6 liters per capita per year.

[6] CAS Study/ No.9, 1998

8.5 Key policies and actions

Policies and actions to reorganize the water sector in Lebanon are fragmented. The following sections will highlight key policies and actions to (1) reorganize the institutional framework for water management, (2) increase water supplies and (3) generate income from subscribers to public water distribution networks.

8.5.1 Key institutional developments

Law No. 241 (29/5/2000) reorganizes the existing 22 water boards into four Regional Water Authorities (see Table 8.12).[7] The Litani River Department[8] (LRD) is the only water authority to retain special responsibilities and functions that extend beyond its administrative region (natural boundaries of the Litani watershed). The LRD continues to be responsible for developing and manage irrigation water and associated works in the southern Bekaa and South Lebanon. Law 221/2000 provides a two-year transitional period for reorganizing the existing water boards into regional water authorities.

Table 8. 12
New Water Authorities in Lebanon (Law 241/2000)

Water Authority	*Location of Head Office*
Beirut and Mount Lebanon	Beirut
North	Tripoli
Bekaa (including North and South Bekaa)	Zahle
South (including Nabatiyeh)	Saida

8.5.2 Sector overview and spending

Between January 1, 1992 and December 31, 2000, CDR awarded 129 contracts worth a total of US$409.2 million in the water supply sector (CDR, 2001). Per March 2001, 60 percent of the awarded projects were completed. More than 95 percent of the total contract value are capital costs, almost four percent are technical assistance contracts and less than one percent are operation and maintenance contracts. Under the National Emergency and Rehabilitation Program I (NERP), the water supply networks of 19 water boards were rehabilitated and/or upgraded, including at least eight treatment plants, about 280 pumping stations, reservoirs and distribution systems. NERP I was financed by the WB and the EIB. NERP II, financed by the Kuwaiti Fund for Arab and Economic Development (KFAED), will rehabilitate and expand the water supply networks in the GBA. Under NERP II, the capacity of the Dbaye water treatment plant was recently extended to 430,000 m^3 per day at a cost of US$5.7 million: it will be further expanded by 70,000 m^3 per day. As per March 2001, 16 water supply projects were under execution and 13 others were under preparation.

[7] Law 241/2000 amended Law 221/2000 which created five regional water authorities (Beirut and Mount Lebanon, North Lebanon, North Bekaa, South Bekaa, and South Lebanon)

[8] The Arabic equivalent is *Maslaha*

8.5.3 Water pricing

Law 221 empowers regional water authorities to set and collect water tariffs for domestic and agricultural use. Subscription fees for domestic water supply vary among water boards. During the year 2001, tariffs ranged from LBP 65,000 per year (e.g., Dinniyeh, Bsharre) to LBP 231,000 per year (e.g., Metn and Beirut) for a 1-m^3/day gauge subscription.[9] Differences are partly due to water availability and distribution costs as gravity distribution is cheapest, while distribution by pumping is far more expensive. In Beirut and the Metn area, where water tariffs are highest, water is conveyed long distances and/or pumped from deep wells. In Bsharre and Dinniyeh, where water tariffs are lowest, water is available from springs and delivered by gravity. Table 8.13 presents the evolution of water tariffs between 1996 and 2000 for the Beirut and Dinniyeh water boards. Box 8.2 provides water cost data in the Middle East and North Africa region (MENA) for comparative purposes.

Table 8. 13
Evolution of Water Tariffs Between 1996 and 2000 for Select Regions
(in Thousand LBP for an Annual Subscription of 1m³/day)

Region	*Year*					% Increase (1996-2000)
	1996	*1997*	*1998*	*1999*	*2000*	
Akkar	100,000	100,000	134,100	134,000	160,100	60
Baalbeck-Hermel	110,000	132,000	132,000	132,000	132,000	20
Barouk	110,000	110,000	121,000	152,000	152,000	38
Beirut	158,400	158,400	182,160	200,500	230,500	46
Bsharre	65,000	65,000	65,000	65,000	65,000	0
Dinniyeh	75,000	75,000	75,000	75,000	75,000	0
Metn	127,100	152,800	180,600	210,100	231,100	82
Saida	99,000	115,000	147,000	148,000	148,000	49
Tripoli	132,000	132,000	132,000	132,000	165,000	25

Source: Data compiled and supplied to ECODIT by Jaber B, MoEW

Most households incur additional expenses to meet their water consumption. Assuming households with a 1-m^3/day gauge subscription actually receive and consume this amount of water per day, such households would be paying the equivalent of US$ 0.12/m^3 to US$ 0.42/m^3 of water. In fact, most households end up paying much more on a per cubic meter basis for two main reasons: (1) frequent and periodic water shortages (some areas report receiving water only a few hours per day) and (2) need to buy water from private haulers, at costs typically around US$5 to US$10 per cubic meter. In particular, secondary residences pay the full annual water subscription tariff even though they use the residence only a few weeks or months during the year. In short, as long as water meters are not installed, the price of water will remain unaffected by actual water consumption and people will pay the same amount regardless of the quantity of water actually delivered/ consumed. Users have no incentives to conserve water and waste is much more common.

[9] Water tariffs include a 10 percent municipal surcharge

Box 8. 2
Typical Water Tariffs in the MENA Region

In **Morocco,** current urban water tariffs range from $ 0.44 to $ 1.35 per cubic meter. They are expected to increase progressively, so that by 1998 they will cover operation and maintenance charges, as well as interest payments for capital investments. In irrigation, the average tariff is about 2 cents per cubic meter. In **Tunisia**, farmers pay about 5 cents a cubic meter for irrigation water, whereas the total cost for production and distribution is about 7 times higher. In **Jordan**, municipal water charges average about 38 cents a cubic meter; about one third of total costs; and in 1995 the irrigation water tariff was increased from about 1 cent to 2.5 cents a cubic meter; about half of average O&M costs incurred over the past ten years. In the occupied territories, the average tariff for urban drinking water is $ 1 a cubic meter, fully recovering the total cost, plus partly subsidizing agricultural water, sold on average for 40 cents a cubic meter. Agricultural water also receives subsidies from the state budget.

Source: World Bank. 1995

8.6 Outlook

In the wake of the projected water shortages that Lebanon will face within the next couple of decades, the MoEW has initiated several programs to better manage Lebanon's water resources through the formulation of a 10-year plan for the years 2000 till 2009 for water and wastewater management (currently divided into two 5-year plans). This is a first step towards proper, sustainable, and comprehensive water management. This proposed plan has five main components, four of which deal with water issues (see Table 8.14). The fifth component relates to electric infrastructure. Evidently the largest share was allocated to procuring additional water resource.

Table 8. 14
Budget Appropriation for 10-Year Plan.

Component of 10-Year Plan	*Budget Allocation (%)*
Procurement of additional exploitable water resources	66.7
Potable water supply projects	15.7
Irrigation schemes and wastewater plans	9.8
Assessment of river basins & their protection from pollution and flooding	5.1
Electric infrastructure	2.7
Total budget Per capita equivalent total budget (assuming a population of 4 million)	**US$ 850 Million** 212.5

Source: MoEW, 10-Year Plan

It is noteworthy that nearly two-thirds of the budget is allocated towards the procurement of additional water resources (i.e. supply-side measures). Such infrastructure investments aimed alleviating water shortages by increasing water supplies is potentially an economic as well as an ecologic burden on society. Concurrent efforts should be committed to improving water efficiency (water metering, lifting illegal connections, introducing on-farm practices for the efficient use of irrigation water), and securing alternative water resources, such as treated wastewater.

8.6.1 *Building dams and reservoirs*

Geologic formations (fractured karstic rocks) often preclude the feasibility of constructing conventional dams in Lebanon. To date, the only constructed reservoir dam is the Qaroun lake, built in 1964 and with a 160-220 Mm^3 retention capacity. Despite plans to construct up to 30 new small dam systems in Lebanon, only four proposed dams are currently being explored / executed (see Table 8.15).

Table 8. 15
Proposed Dams Under Study or Execution

Proposed dam location	*Design Capacity (Mm^3)*	*Status of Implementation*
Nour el Tahta / El Kebir River	40	Preliminary agreement between Lebanon and Syria concluded
Khardali / Litani River	85	Preliminary designs are being drafted
Bisri / Awali River	106	Detailed designs are underway
Massa-Yahfoufa / Yanta River	8	Feasibility study completed. Financing pending.

Source: Proceedings of the third Hariri Foundation Alumni Association conference in Beirut: *Water in Lebanon and the Middle East. The Reality of Water in Lebanon*. Beirut, 18 April 2001 (in Arabic). Conference sponsored by the MoEW.

8.6.2 *Privatization of water supply sector*

While the government has been advocating private sector participation in many sectors including water, many factors hinder this participation such as lack of written policies and action plans, an inadequate legal framework, and unclear procedures for creating and sustaining public-private partnerships. In the absence of an overall strategy, the government is pursuing a piecemeal approach, moving ahead with a management contract with a private operator in the city of Tripoli and considering other arrangements supported by the World Bank in Baalbeck. As these isolated efforts increase, different donors may encourage different or contradictory approaches. Private sector efforts grow, in part, out of recognition of the weak performance, inadequate staffing, and poor resources of the regional water authorities. These efforts are closely tied to a planned merger of the authorities, but a clear and broadly accepted understanding of the operational partnership among the center, regional authorities, and private operators has yet to emerge and should probably be an early step in the overall process.