3.3 Digital Balancing Model

3.3.1 Concept of DBM

DBM, standing for Digital Balancing Model, was developed by the JICA Study Team and transferred to counterparts of MEW (Ministry of Energy and Water) with its usage technology. In order to formulate a master plan for water resources management in Lebanon, the Team conducted "the Study on Water Resources Management in the Republic of Lebanon" from 2002 to 2003. Through the course of the study, the Team collected a lot of data related to water resources management including water demand and water supply parameters. Successively, the Team entered the data into the GIS database, which is a database controlled by GIS software, in order to unify data management. At the same time, the Team developed DBM as a supplement of the GIS database system.

DBM is a part of GIS database system. Under the control of GIS software, GIS database can normally process and output the data. However, for the predictive calculation of water demand and possible water supply in the future, the standard functions are not sufficient except for the skilled user having much knowledge about GIS. For this reason, DBM is prepared to enable any ordinal user to do such processing easily by customizing necessary operations of GIS. Consequently, DBM with GIS database plays a significant role in water resources management.

DBM is defined as a tool that *"can make predictive calculations of water demand and possible water supply in the future based on GIS Database and can output them on a designated basis."*

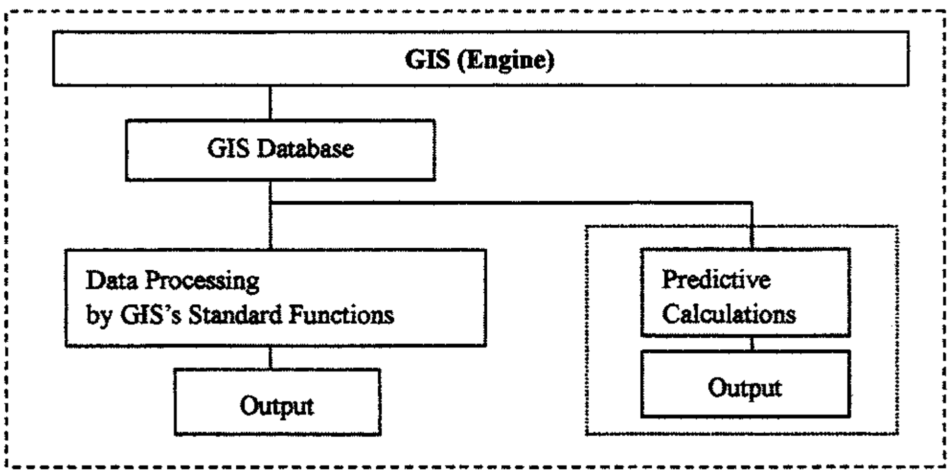


Figure 3.3-1 GIS Database System

3.3.2 Overview of DBM

As shown in Figure 3.3-2, DBM consists of four main components, ("window") named after their functional characteristics. Full-scale structure is illustrated as DBM System Diagram in the attached Operation Manual.

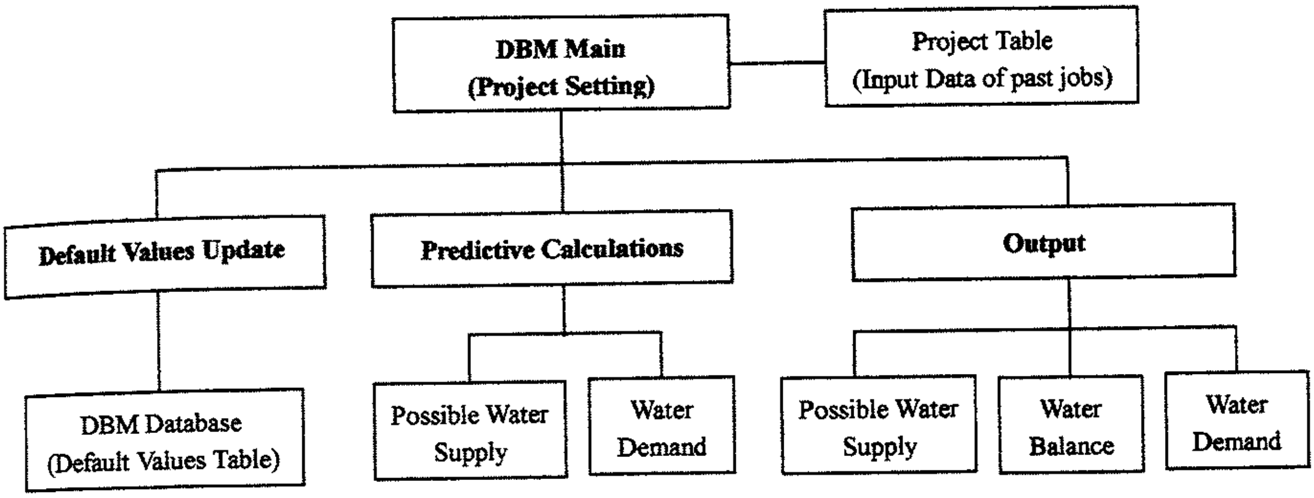


Figure 3.3-2 DBM Structure

Table 3.3-1 Main Function of DBM

Component	Description	Function
DBM Main	This component can manage project data such as input and output data.	- Control project data - Delete project data
Default Values Update	This component can update default values. But the usage is limited to an administrator.	- Change default values - Update default values
Predictive Calculations	This component can calculate water demand and supply from 2002 to 2030. The user does not need to input all parameters every operation, because DBM has default values of all parameters. If needed, the user can simply modify the default values.	- Change default values - Refer to previous input data - Calculate dam development potential - Calculate reuse of wastewater - Calculate residential water - Calculate non-residential water - Calculate tourism water - Calculate industrial water - Calculate irrigation water
Output	This component can create some excel files of input and output data, and link some tables with thematic maps. When the output on GIS maps is required, the user can draw the maps reflecting and/or overlapping the DBM results by an application of the standard functions.	- Create some excel files such as input data, possible water supply, water demand, water balance. - Link some tables with thematic maps.

Data retention forms for basic data, classified by spatial and time bases, are shown in Table 3.3-2.

Table 3.3-2 Data Retention Form

Data	Spatial Basis	Time Basis
Socio-Economic Frame - Population & Population growth rate - Establishment	Demand Area (Caza + Greater Beirut, Saida)	Annual data, varing for 2002-2030
Agricultural Frame (schemed and large scale) - Irrigate area - Cropping pattern and irrigation method	Irrigation schemes	Annual data, varing for 2002-2030
Agricultural Frame (existing small-scale) - Cropping pattern and irrigation method - Irrigate area	Demand Area (Caza + Greater Beirut, Saida)	Annual data, constant for 2002-2030
Water Resources Potential - Surface water - Groundwater	Supply Area (Watershed)	Monthly data, constant for 2002-2030

All the calculations can be output with this component. The user sets output parameters such as "Output Area", "Output Time" and "Output Style". DBM prepares three kinds of output styles, map, chart and table. Each style has the follwing characteristics.

Map: It has the most apparent effort in spatial perception, but does not present details. Mainly it is used for presentation.

Chart & Table: They present details, which map cannot express.

DBM prepares three kinds of "Output Time", i.e. monthly, seasonal and annual. Seasonal means wet and dry seasons, defined as below.

Dry season: April to October (7 months)
Wet season: November to March (5 months)

"Output Area" includes six kinds of areas. Table 3.3-3 shows output matrix between calculations and output areas.

Table 3.3-3 Output Matrix

Predictive Calculation \ Output Area		Administrative area: Demand area (Caza)	Administrative area: Mohafaza	Administrative area: Lebanon	Water Authority	Irrigation area	Watershed
Demand	Domestic Water	○	○	○	○	-	○
	Industrial Water	○	○	○	○	-	○
	Leakage Water	○	○	○	○	-	○
	Irrigation Water	○	○	○	○	○	○
Supply	Surface water	-	-	○	○	-	○
	Groundwater	-	-	○	○	-	○
	Reuse of wastewater	-	-	○	○	-	○
Balance (between Demand & Supply)		-	-	○	○	-	○

○: able to express

- : not able to express

3.3.3 Sample of Output

(1) Input Data Output Form

All the input data used in the predictive calculation can be output to the excel file and linked to the map's attribute data.

Table 3.3-4 List of Excel Sheet

Sheet Name	Descriptions
Project	Project information such as project name, establishing date
Supply Water	Surface water and groundwater development potential
Dam	Dam name, starting year and development potential
Wastewater Reuse	Wastewater reuse parameters
Growth Rate	Growth rate of population and industry
Residential	Population and per capita consumption
Non-Residential	Non-residential parameters
Tourism	Tourism water parameters
Industry	Industrial water parameters
Leakage	Leakage water parameters
Irrigation	Existing and proposed irrigation scheme parameters
Application	Application ratio of existing and proposed irrigation scheme
Irrigation (caza)	Caza irrigation (small scales) parameters
Application (caza)	Application ratio of Caza irrigation (small scales)

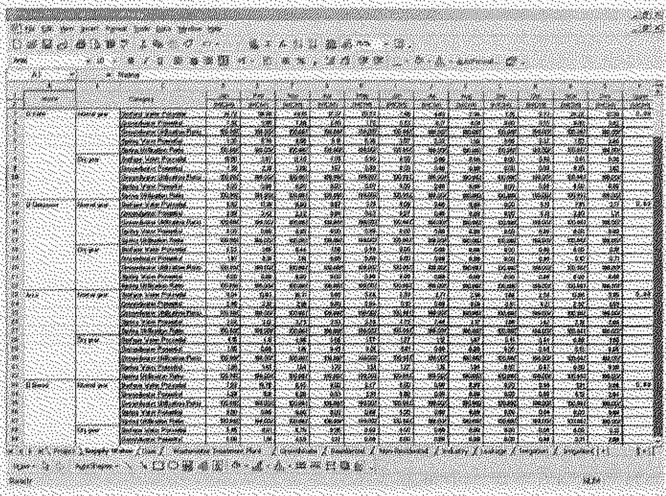


Figure 3.3-3 Sample of Input Data Output Form

Table 3.3-5 List of Map's Attribute Data

Item	Descriptions
Domestic	Population, non-residential class by Caza from base year to 2030.
Industrial	Industrial class, establishment by Caza from base year to 2030.
Leakage	Coverage ratio of domestic water network, coverage ratio of industrial water network and leakage ratio by Caza in base year to 2030.

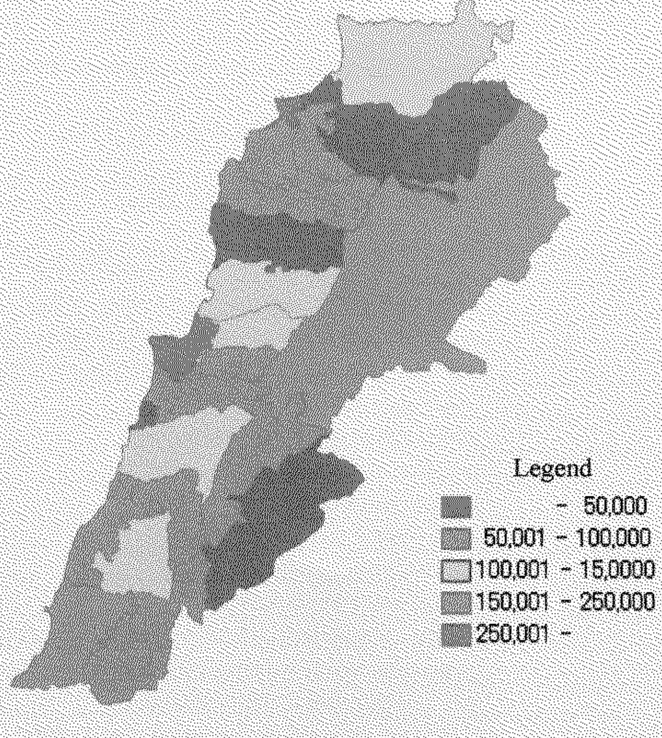
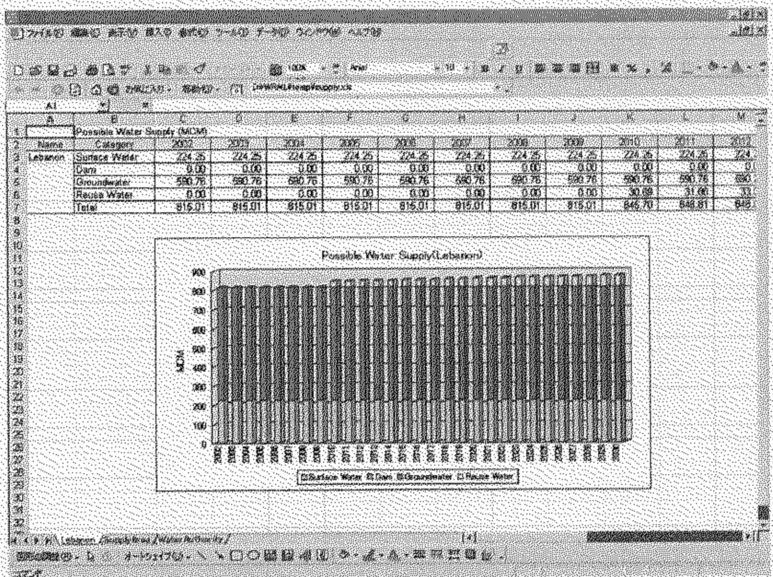


Figure 3.3-4 Population Map

(2) Possible Water Supply (Water Resources Potential and Reuse of Wastewater) Output Form

Calculation results can be output into the table & chart of the respective excel sheets in monthly/yearly basis. Besides, the results can be summarized for the whole Lebanon, supply areas and water authority areas. Stacked type bar chart is provided to show surface water development potential, groundwater development potential and reuse of wastewater. The data are linked to the map's attributed data.



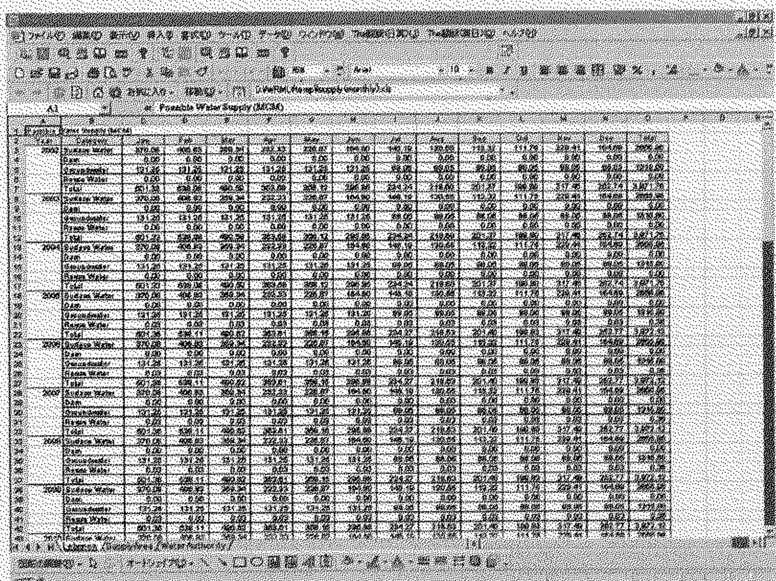


Figure 3.3-5 Sample of Possible Water Supply Water Output Form (yearly & monthly)

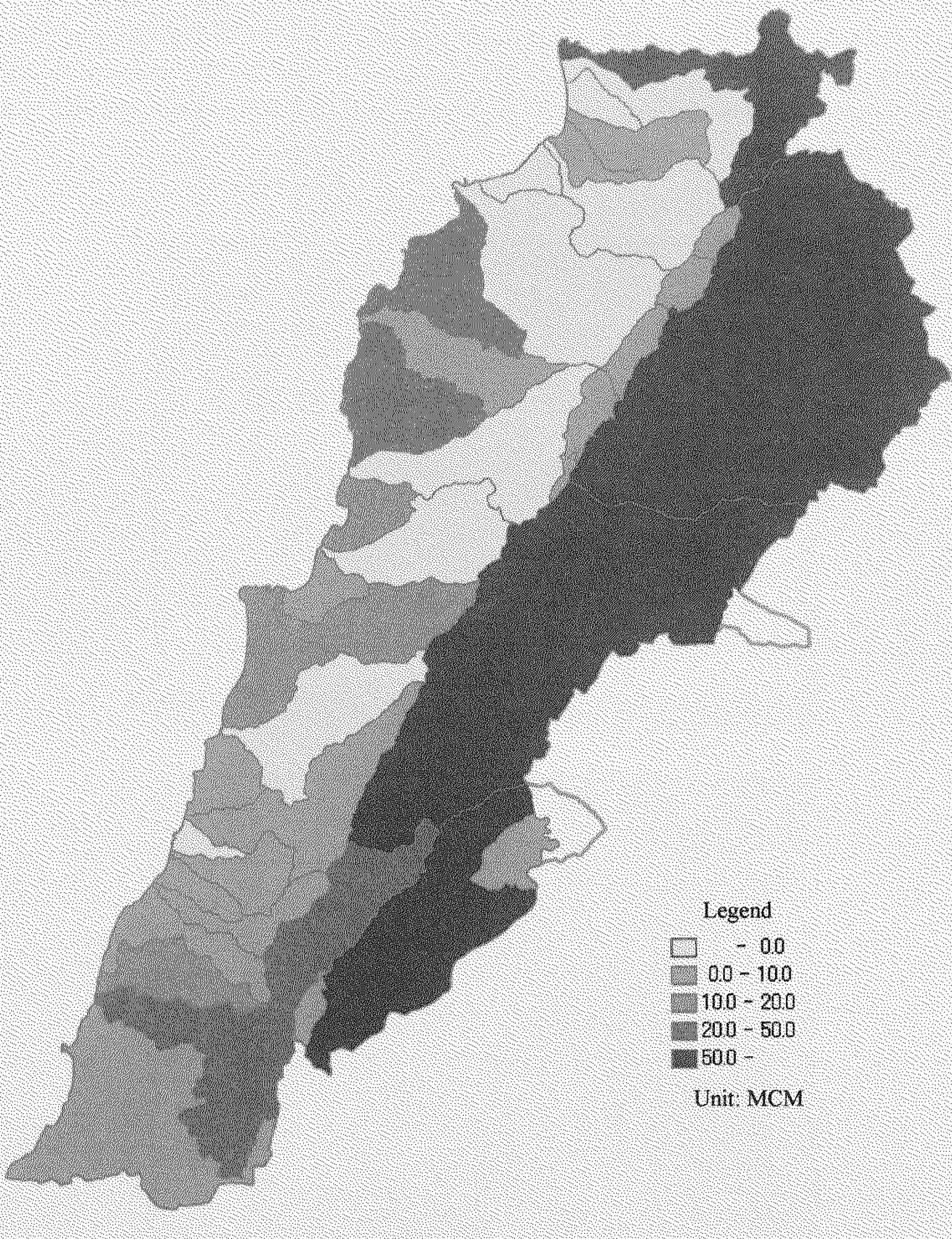
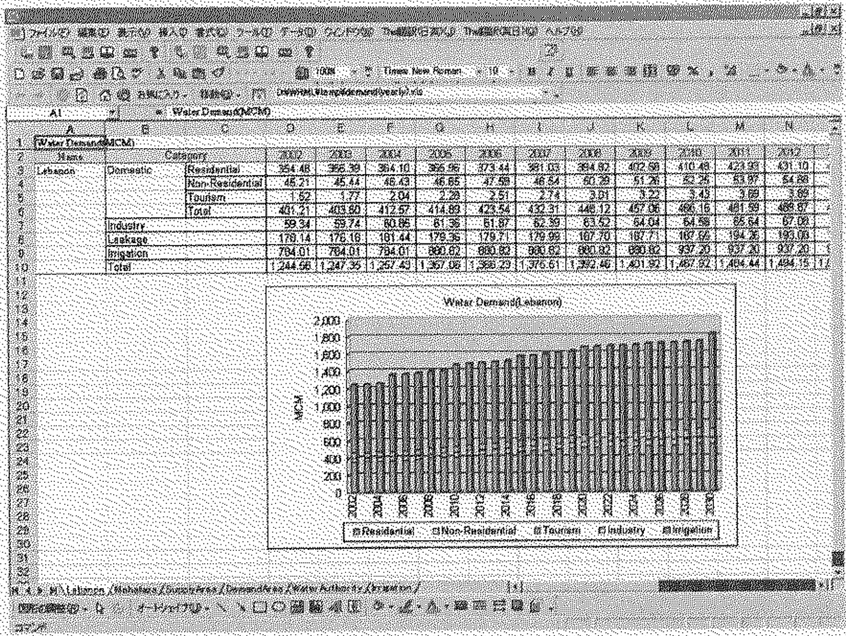


Figure 3.3-6 Sample of Supply Water Map

(3) Water Demand Output Form

Calculation results can be output into the table & charts of the respective excel sheets in the monthly/yearly basis. Beside, results can be expressed for the whole Lebanon, Mohafaza, Caza, Water Authority areas. Clustered type bar chart is provided to show the results from the different aspects. The data is linked to map's attribute data.



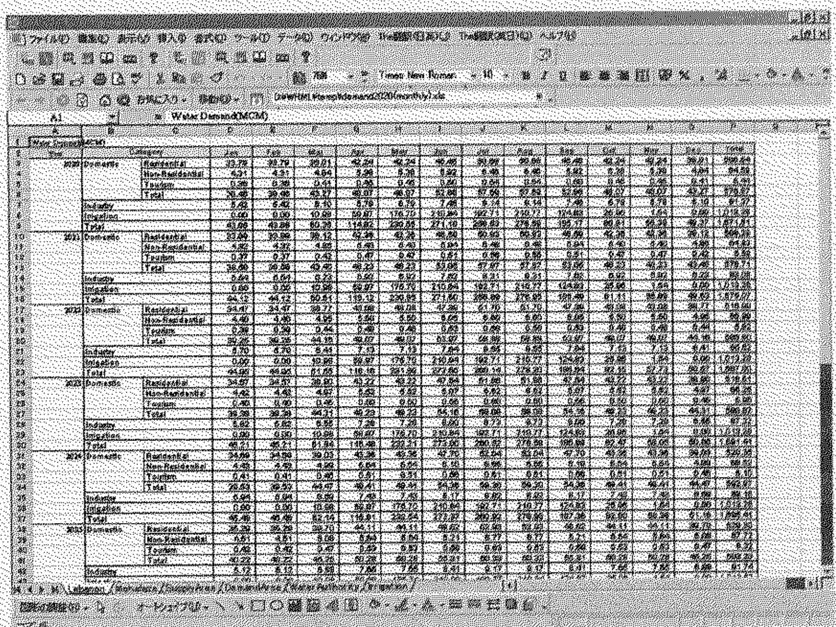


Figure 3.3-7 Sample of Water Demand Output Form (yearly & monthly)

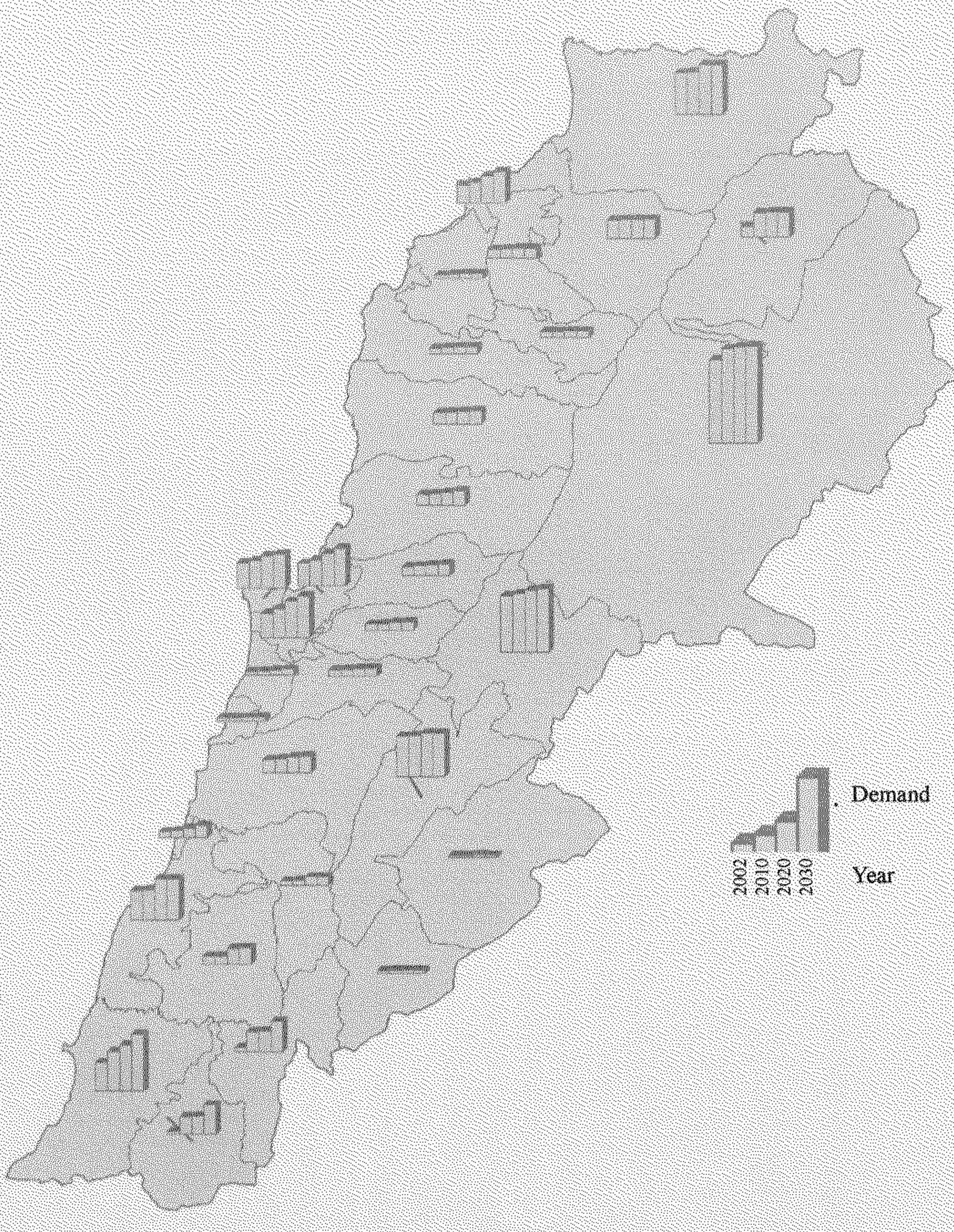


Figure 3.3-8 Sample of Total Water Demand Map

(4) Water Balance Output Form

Both calculation results of water demand and water supply can be output into an excel file. Water balance is displayed on the table and chart by showing demand and supply together. Water balance can be indicated for the whole Lebanon, water authority areas and watersheds supply area. Cluster type bar chart is applied to the graphical presentation. The data is linked to map's attribute data.

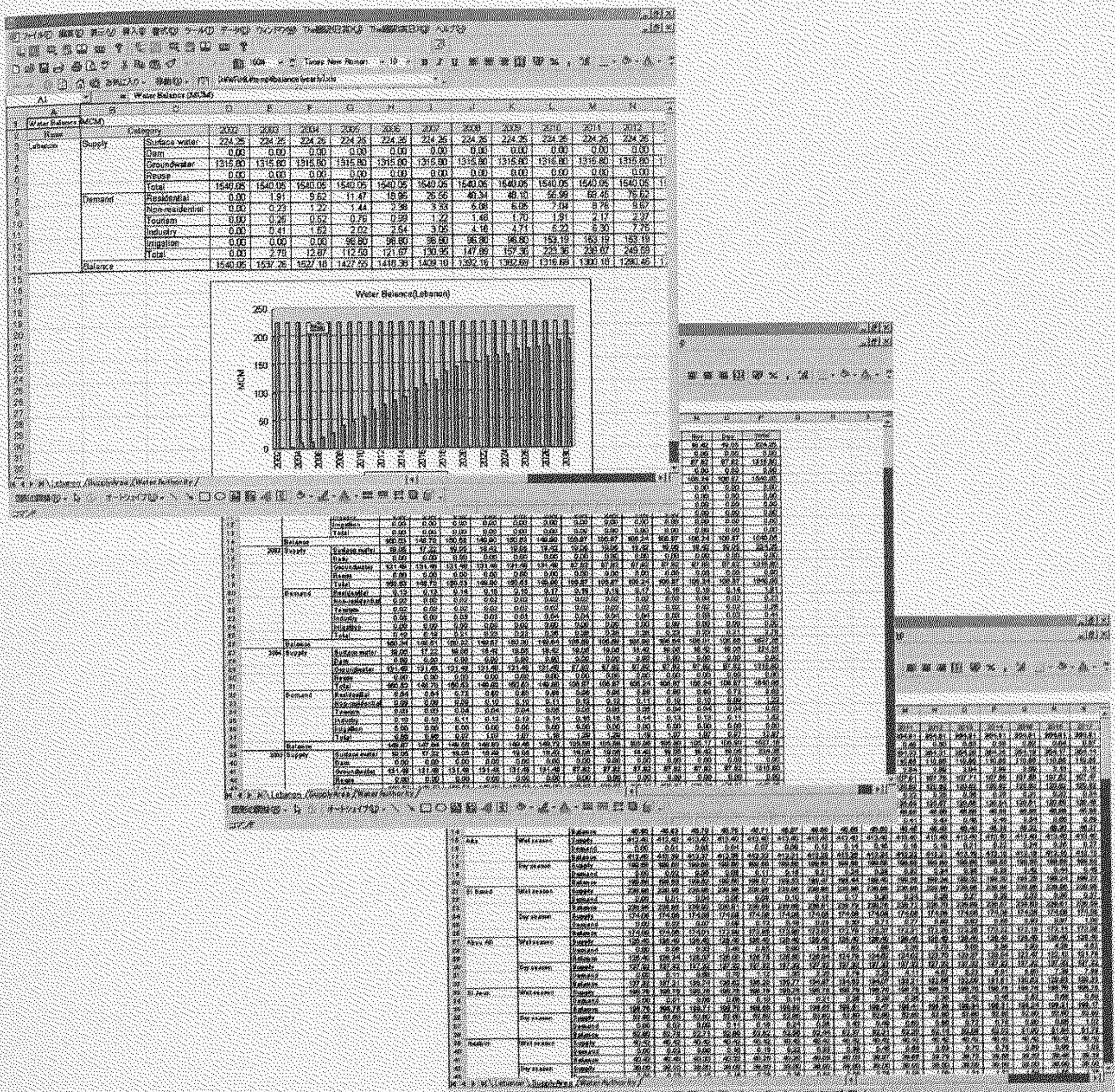


Figure 3.3-9 Sample of Water Balance Output Form (yearly, monthly & seasonal)

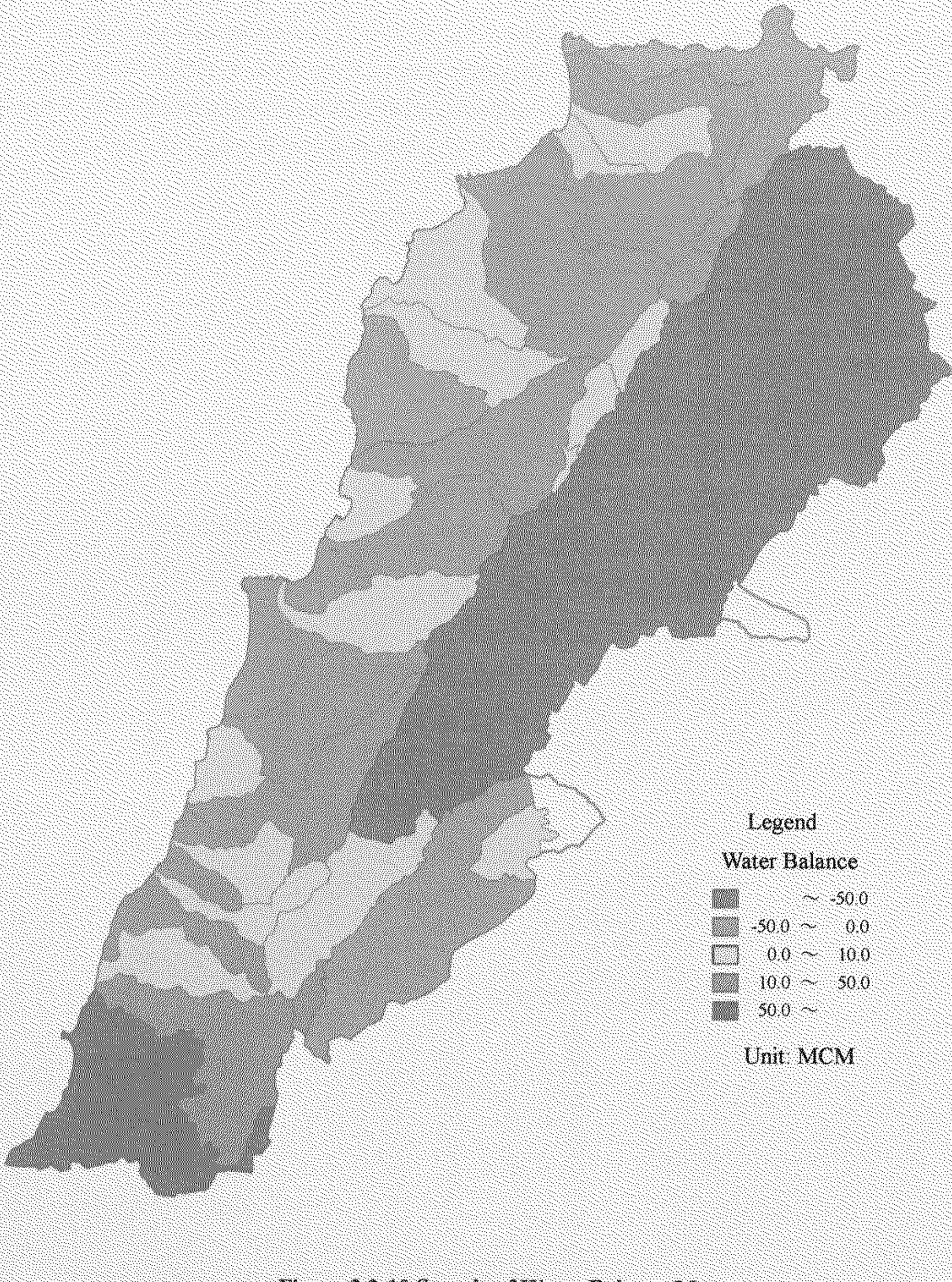


Figure 3.3-10 Sample of Water Balance Map

CHAPTER 4

WATER RESOURCES

CHAPTER 4 WATER RESOURCES

4.1 Water Resources Potential

4.1.1 Results of SSM Simulation

(1) Surface water balance

Through the SSM simulation study, many hydrological parameters such as rainfall amount, recharging volume, evapotranspiration volume, surface runoff, groundwater level, groundwater flow, and so forth, at daily basis in every sub-basin are calculated and stored in a hard disk. Thus, the volumes of information obtained through the simulation were quite large amount.

The current surface water balance was rearranged from the results of simulation, as Table 4.1.1. (In an average of the latest 10 years, and details are attached in ANNEX 4). The column of "Rain" means total precipitation in the catchment area, "Inlet/Runin" means the water transferred or running into the basin from the other basin. "Spring" is the water once infiltrated into the ground and flowed up to the ground and therefore counted as the gain of surface water. "Recharge" is all infiltration volume, and "Evap" means the water volume lost by evapo-transpiration. "Intake" is the water volume actually taken from the river through the simulation, and it is not same with the volume given to the model as the current surface water intake, as explained before.

Table 4.1.1 CURRENT WATER BALANCE (Unit: 1,000 m3)

		Area	Surface Water Balance							
			In			Out				Balance
92-01 Ave.	Basin	(Km2)	Rain	Inlet/Runin	Spring	Recharge	Evap	RunOff	Intake	
Kebir	[1-5]	333.5	251,520	0	38	118,751	90,350	43,786	492	-1,821
Ostuene	[6-9]	169.6	127,962	0	10,331	45,749	45,718	45,830	1,836	-840
Akkar	[10-13]	133.1	100,429	0	8,728	44,278	32,487	33,322	289	-1,220
Bared	[14-17]	266.3	200,761	0	111,835	112,912	59,262	136,054	5,739	-1,371
Abou Ali	[18-22]	484.9	365,627	0	159,877	187,479	109,030	228,617	3,630	-3,252
Jouz	[23-26]	186.3	137,862	0	9,983	69,852	45,618	33,265	429	-1,319
Ibrahim	[27-30]	346.7	259,532	0	282,647	149,276	86,954	306,988	1,951	-2,988
Kelb	[31-33]	254.9	192,166	0	106,203	69,512	62,696	165,591	1,975	-1,405
Beirut	[34-37]	309.9	228,052	0	28,427	118,119	77,932	60,809	2,355	-2,738
Damour	[38-41]	186.2	139,555	0	84,472	66,285	44,690	108,875	5,730	-1,554
Awali	[42-45]	334.5	248,681	54,508	100,908	96,448	96,432	213,739	2,676	-5,197
Saintaniq	[46-48]	161.9	116,582	0	1,844	68,948	40,512	9,903	307	-1,244
Zahrani	[49-51]	104.1	75,831	0	7,346	48,119	26,032	9,539	403	-916
A Assouad	[52-53]	160.1	112,279	0	1,107	63,388	47,416	3,369	875	-1,662
Litani	[54-64]	2,231.3	1,661,272	0	85,809	931,747	641,286	107,612	76,996	-10,557
Assi	[65-69]	1,848.8	1,393,617	6,683	73,595	683,504	465,464	306,781	15,808	2,343
Hasbani	[70-73]	587.4	442,789	0	5,857	204,071	159,775	85,768	943	-1,910
S.TOTAL	**73**	**8,099.5**	**6,054,517**	**61,191**	**1,079,007**	**3,078,436**	**2,131,656**	**1,899,848**	**122,433**	**-37,652**
Percentage	(%)	80.4%	100.0%	1.0%	17.8%	50.8%	35.2%	31.4%	2.0%	
Coastal Basin	[74-97]	1,690.7	1,213,947	0	58,007	605,034	469,686	195,581	14,562	-12,911
Individuals	[98-99]	286.0	215,575	0	85,020	137,750	66,946	97,639	271	-2,011
S.TOTAL	**26**	**1,976.7**	**1,429,522**	**0**	**143,027**	**742,784**	**536,633**	**293,220**	**14,834**	**-14,922**
Percentage	(%)	2.8%	100.0%	0.0%	10.0%	52.0%	37.5%	20.5%	1.0%	-1.0%
G.TOTAL	**99**	**10,076**	**7,484,039**	**61,191**	**1,222,033**	**3,821,220**	**2,668,289**	**2,193,068**	**137,267**	**-52,574**
Percentage	(%)	100.0%	100.0%	0.8%	16.3%	51.1%	35.7%	29.3%	1.8%	-0.7%

34.7%

As shown in the Table, the surface water balances of almost all river basins are minus, and thus, the total water balance of all basins is also a little bit minus. And these minus volumes are supplied by a groundwater. In the Table, "Spring" is an outflow of groundwater, and therefore it is counted as an input of item of the surface water. Conversely, it is counted as an output item in the groundwater system. Thus, the recharge volume must be considered in two ways, as a total recharge volume and as a net recharge volume excluding the spring volume.

The surface water balance of the whole country is simply summarized as:

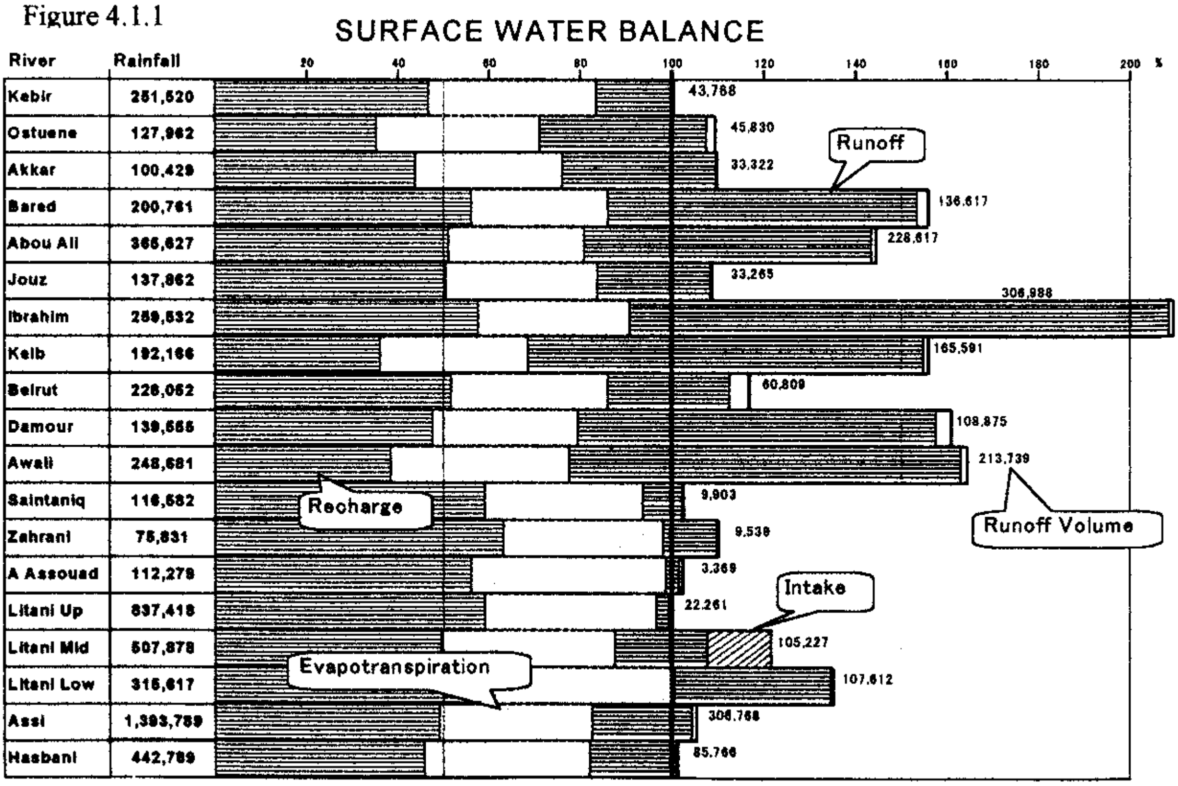
	Item	Amount (%)	(% to Rain)
In			
	Rainfall	7,500 MCM/year (85.5%)	100.0%
	Run-in/Inlet	60 MCM/year (0.7%)	0.8%
	Spring	1,200 MCM/year (13.9%)	16.3%
	Total	**8,800 MCM/year (100%)**	**117.1%**
Out			
	Recharge	3,800 MCM/year (43.3%)	52.0%
	(Net recharge)	2,600 MCM/year (29.5%)	34.7%
	Evapo-trans.	2,700 MCM/year (30.3%)	35.7%
	Runoff	2,200 MCM/year (24.9%)	29.3%
	Intake	140 MCM/year (1.6%)	1.8%
	Total	**8,800 MCM/year**	**117.9%**

Above table suggests the total surface water balance including spring, inlet, and intake amounts is almost balancing, but in considering to the rainfall, both "in" and "out" amounts are exceeding 100%, and the balance is in small minus.

(2) Abnormality of surface runoff

Besides the total water balance, a remarkable characteristic of water balance in Lebanon is heavy unbalance (or it can be called as "abnormality") of surface runoff against the rainfall. Normally, the rainfall is the source of water in a certain basin, and some parts of the precipitation are evapo-transpirated, retained in the soil, infiltrated to recharge groundwater, and the remains flow out as a river. Therefore, the amount of surface runoff is usually around one third of the precipitation or less than that. However, in Lebanon, the yearly runoffs of some of the rivers exceed the yearly rainfall amount. Figure 4.1.1 shows the surface water balance against the total rainfall. In

Figure 4.1.1



the figure, the yearly rainfall amount of each river basin is shown in the second column, and it is indicated as 100% line. All of the output items such as recharge, evapotranspiration or runoff are calculated by percentage to the rainfall, so normally; the total of these must be at near 100% line.

As shown in the figure, some of the rivers: the Bared, Abou Ali, Ibrahim, Kelb, Damour, and Awali, have quite high runoff rates of more than 60%. Especially, the Ibrahim has a river runoff of more than the total precipitation of the river basin. The other rivers, mentioned above, also indicate very large over-runoff if consider about the other factors such as an evapotranspiration or a recharging amount. It is a quite abnormal phenomenon under the natural condition.

It is come from the unique hydrogeological situation of Lebanon. That is, most of the country is underlain by calcareous base rocks, and most of them are karstic limestones which have high infiltration ratio and very high permeability, as well as karst caves or underground river channels. The rainfall infiltrated into the ground removes easily to the neighboring areas beyond the basin boundary through quite pervious karstic rocks or underground channels, and flows out as springs to recharges river-flow or forms an origin of a river. Thus, some of the river can have abnormally large runoff through groundwater movement beyond the basin boundary.

(3) Groundwater table and movement

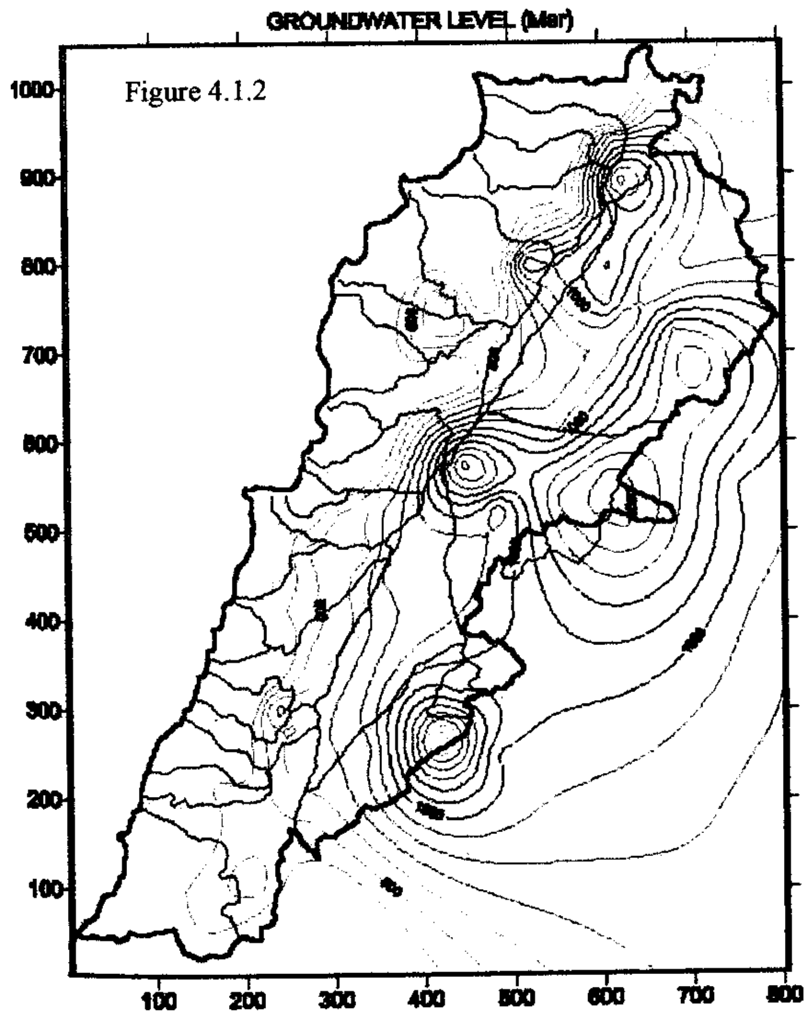


Figure 4.1.2

SSM calculates water balance in combination between surface and groundwater systems, based on precipitation, evapotranspiration, infiltration ratio, runoff coefficient, permeability, and Strativity of the ground. On the course of simulation, SSM estimates the volumes of groundwater movement and elevation of groundwater table in daily basis. Using the output file on groundwater elevation, the contour map of groundwater at any day can be drawn up. Figure 4.1.2 shows the contour of groundwater table at the beginning of March 1996, when the almost average year with current 10 years. As the figure indicates, the zones with the highest groundwater table are shown along the two mountain ranges but the groundwater table is rather higher at the Anti-Lebanon than the one in Lebanon Mountain Range as a tendency. The highest groundwater table in Lebanon Mountains is found at the north of Zhale, eastern slope of the mount Sannine (sub-basin No.55). As shown in the figure, the high groundwater elevations are scattered along the both mountain ranges, and the situation causes the groundwater movement beyond the river basin boundaries.

SSM estimates the volume of groundwater movement at every groundwater links. Figure 4.1.3 shows directions and volumes of groundwater movement inter sub-basins (yearly average at 1996). Two major groundwater flows can be distinguished clearly in the figure. Among two, the largest flow is running down the Bekaa Plane to south, and the main flow turns to west to pour into the sea and a tributary goes further south, to out of the country. Another major groundwater flow is found in north Bekaa, which goes up to north and goes out to Syria, along with the Assi River. In the Coastal Region, groundwater flows are mainly in monoclinic towards the Mediterranean Sea but some flows goes to the neighboring basins beyond the boundary, and these irregular flows cause or support the abnormal runoff of the river as mentioned in the previous section.

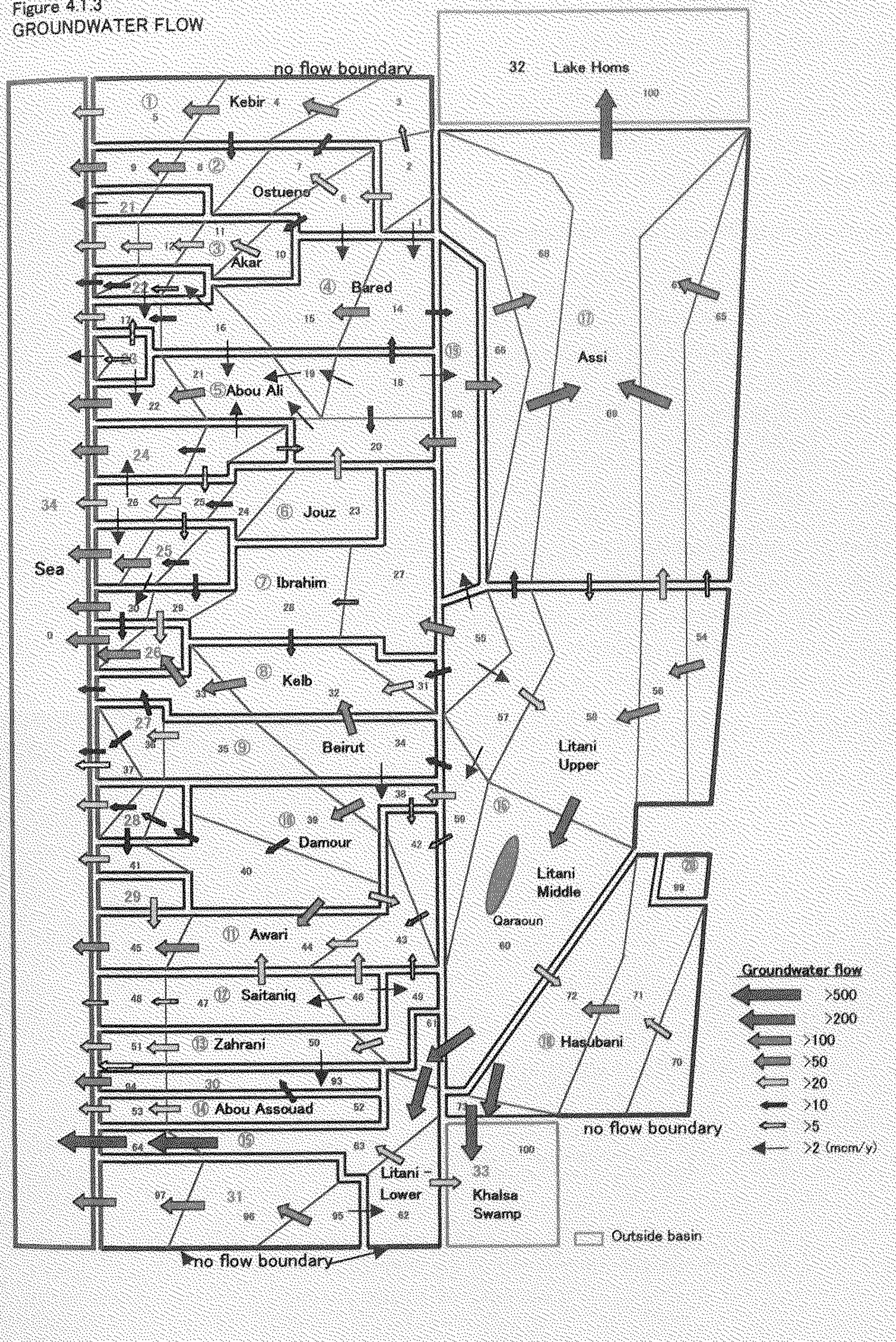
(4) Groundwater balance

As same with the surface water balance, the groundwater balance is rearranged as Table 4.1.2. (In an average of the latest 10 years, and details are attached in ANNEX 4).

Table 4.1.2 **CURRENT WATER BALANCE** (Unit: 1,000 m3)

			Groundwater Balance						
		Area	In		Out			Balance	Volume
92-'01 Ave.	Basin	(Km2)	Recharge	GInflow	PmpUp	SprUp	GOutflow		
Kebir	[1-5]	333.5	118,751	0	20,932	38	114,687	-16,906	10,909,330
Ostuene	[6-9]	169.6	45,749	65,792	30,510	10,331	90,917	-20,217	3,942,469
Akkar	[10-13]	133.1	44,278	16,145	18,303	8,728	49,559	-16,167	2,971,683
Bared	[14-17]	266.3	112,912	45,218	13,657	111,835	30,183	2,455	7,860,158
Abou Ali	[18-22]	484.9	187,479	98,569	20,512	159,877	123,450	-17,791	14,920,980
Jouz	[23-26]	186.3	69,852	6,708	16,272	9,983	74,616	-24,312	5,413,656
Ibrahim	[27-30]	346.7	149,276	197,813	16,545	282,647	63,088	-15,190	6,297,798
Kelb	[31-33]	254.9	69,512	119,864	3,392	106,203	87,096	-7,315	5,728,840
Beirut	[34-37]	309.9	118,119	18,409	3,964	28,427	119,991	-15,855	8,122,575
Damour	[38-41]	186.2	66,285	115,207	3,582	84,472	85,350	8,088	6,344,904
Awali	[42-45]	334.5	96,448	105,784	3,268	100,908	97,590	466	6,211,775
Saintaniq	[46-48]	161.9	68,948	1,882	13,620	1,844	67,360	-11,994	4,650,250
Zahrani	[49-51]	104.1	48,119	11,019	7,857	7,346	54,588	-10,653	3,030,097
A Assouad	[52-53]	160.1	63,388	876	5,470	1,107	51,229	6,459	7,382,489
Litani	[54-64]	2,231.3	931,747	858	24,933	85,811	870,582	-48,721	78,590,310
Assi	[65-69]	1,848.8	683,504	58,698	11,052	73,595	715,287	-57,732	70,195,820
Hasbani	[70-73]	587.4	204,071	34,156	6,584	5,857	287,808	-62,022	23,107,250
S.TOTAL	**73**	**8,099.5**	**3,078,436**	**896,998**	**220,453**	**1,079,009**	**2,983,379**	**-307,407**	**265,680,384**
Percentage	(%)	80.4%	100.0%	29.1%	7.2%	35.1%	96.9%	-10.0%	
Coastal Basin	[74-97]	1,690.7	605,034	168,117	92,756	58,007	675,378	-52,989	41,326,900
Individuals	[98-99]	286.0	137,750	106,971	6,511	85,020	180,815	-27,625	12,442,920
S.TOTAL	**26**	**1,976.7**	**742,784**	**275,088**	**99,266**	**143,027**	**856,193**	**-80,614**	**53,769,820**
Percentage	(%)	2.8%	100.0%	37.0%	13.4%	19.3%	115.3%	-10.9%	
G.TOTAL	**99**	**10,076**	**3,821,220**	**1,172,086**	**319,719**	**1,222,035**	**3,839,572**	**-388,021**	**319,450,204**
Percentage	(%)	100.0%	100.0%	30.7%	8.4%	32.0%	100.5%	-10.2%	

Figure 4.1.3
GROUNDWATER FLOW



Because of the hydrogeological characteristic of Lebanon, as mentioned above, the groundwater balance is also complicated. Normally, an input item in the groundwater system is only "recharge", and an output items are "groundwater Outflow" and artificial "Pumping Up". However in Lebanon, the input item includes "Groundwater Inflow" resulted by groundwater movement beyond the basin boundary, and the output item involves "Spring Up" which is the groundwater volume once infiltrated into the ground but spring out to the ground as springs.

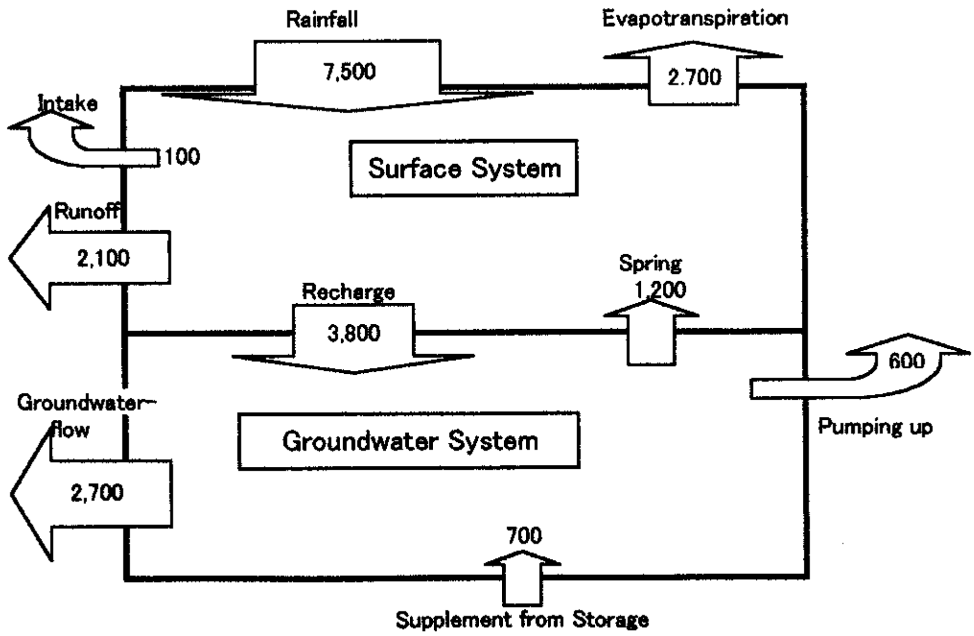
The groundwater balance in the country is simply summarized as follows:

	Item	Volume	(%)	(% to Recharge)
In	Recharge	3,800 MCM/year	(76.5%)	100 %
	G. Inflow	1,200 MCM/year	(23.5%)	30.9%
	Total	**5,000 MCM/year**	**(100%)**	**130.7%**
Out				
	G. Outflow	3,800 MCM/year	(76.9%)	100.5%
	Spring Up	1,200 MCM/year	(24.5%)	32.0%
	Pump Up	600 MCM/year	(12.2%)	16.0%
	Total	**5,700 MCM/year**	**(113.6%)**	**148.5%**

As easily recognized from above table, total output factors of the groundwater system is larger than the input factors, and the total balance is minus. The deficit in the balance, around 700 MCM/year in an average, is supplemented from the total groundwater storage. The latest 10 years, since 1962 to 2001, include continuous three years of drought from 1997 to 1999, and it must be the reason why the average groundwater balance is totally in minus.

Thus, the current water balance in total is summarized as Figure 4.1.4.

Figure 3.1.4 Current Water Balance of Lebanon (average of latest 10 years)



4.1.2. Water Resources Potential

After the simulation under the current condition, a natural water balance was also simulated. It is the simulation under the natural condition: without any artificial water intake, and it indicates the water resources potential in Lebanon.

(1) Surface water resources potential

The natural surface water balance simulated by SSM, in an average of the latest 10 years, is shown in Table 4.1.3 (Further details are attached in ANNEX 4).

The Table indicates, as same with the simulation under the current condition, almost all of the river basins (and the small coastal basins also), except the Assi Basin, have deficits in their water balances, large or small. And the particular basins show abnormally high runoff rates of more than 60% or as high as 126%. The situation is explained by a unique hydrogeological setting of Lebanon as mentioned above.

Table 4.1.3

NATURAL WATER BALANCE

			Surface Water Balance							
		Area	In			Out				SurfBal
92-01 Ave.	Basin	(Km2)	Rain	RunIn	Spring	Recharge	Evap	RunOff	Intake	
Kebir	[1-5]	333.5	251,520	0	9,180	118,913	91,014	53,240		-2,467
Ostuene	[6-9]	169.6	127,962	0	13,062	45,970	45,950	49,978		-875
Akkar	[10-13]	133.1	100,429	0	13,437	44,305	32,646	38,269		-1,353
Bared	[14-17]	266.3	200,761	0	138,488	114,204	59,346	167,123		-1,425
Abou Ali	[18-22]	484.9	365,627	0	153,598	187,412	109,125	226,098		-3,411
Jouz	[23-26]	186.3	137,862	0	11,468	69,876	45,991	35,100		-1,638
Ibrahim	[27-30]	346.7	259,532	0	301,024	149,687	86,978	326,882		-2,991
Kelb	[31-33]	254.9	192,166	0	117,496	69,621	63,056	178,751		-1,762
Beirut	[34-37]	309.9	228,052	0	34,336	118,189	78,362	68,866		-3,029
Damour	[38-41]	186.2	139,555	0	102,140	66,816	45,097	131,413		-1,630
Awali	[42-45]	334.5	248,681	0	83,170	62,434	85,897	186,910		-3,389
Saintaniq	[46-48]	161.9	116,582	0	2,653	68,955	40,787	10,993		-1,499
Zahrani	[49-51]	104.1	75,831	0	8,947	48,152	26,282	11,462		-1,119
A Assouad	[52-53]	160.1	112,279	0	5,665	63,712	48,952	8,259		-2,979
Litani	[54-64]	2,231.3	1,661,272	0	584,914	1,317,408	662,952	280,971		-15,146
Assi	[65-69]	1,848.8	1,393,617	0	153,074	686,114	469,108	396,868		-5,400
Hasbani	[70-73]	587.4	442,789	0	11,305	203,224	160,240	92,895		-2,266
S.TOTAL	**73**	**8,099.5**	**6,054,517**	**0**	**1,743,957**	**3,434,991**	**2,151,782**	**2,264,060**		**-52,379**
Percentage	(%)	80.4%	100.0%	0.0%	28.8%	56.7%	35.5%	37.4%		-0.9%
Coastal Basin	[74-97]	1,690.7	1,213,947	0	86,752	605,518	474,825	237,950		-17,594
Individuals	[98-99]	286.0	215,575	0	94,871	138,318	68,736	107,029		-3,637
S.TOTAL	**26**	**1,976.7**	**1,429,522**	**0**	**181,623**	**743,836**	**543,560**	**344,978**		**-21,231.4**
Percentage	(%)	2.8%	100.0%	0.0%	12.7%	52.0%	38.0%	24.1%		-1.5%
G.TOTAL	**99**	**10,076**	**7,484,039**	**0**	**1,925,580**	**4,178,827**	**2,695,343**	**2,609,058**		**-73,610**
Percentage	(%)	100.0%	100.0%	0.0%	25.7%	55.8%	36.0%	34.9%		-1.0%
						30.1%				

The surface water balance of the whole country in natural condition is simply summarized as:

In	Item	Amount (%)	(% to Rain)
	Rainfall	7,500 MCM/year (79.5%)	100.0%
	Spring	1,900 MCM/year (20.5%)	25.7%
	Total	**9,400 MCM/year (100.0%)**	**125.7%**
Out			
	Recharge	4,200 MCM/year (44.4%)	55.8%
	(Net recharge)	2,250 MCM/year (23.9%)	30.1%
	Evapo-trans.	2,700 MCM/year (28.6%)	36.0%
	Runoff	2,600 MCM/year (27.7%)	34.9%
	Total	**9,500 MCM/year (100.8%)**	**126.7%**

Above table suggests the total yearly precipitation in the country (10 years average) is around 7,500 MCM, and among it 2,700 MCM (36%) is lost by an evapotranspiration, 4,200 MCM (55.8%) is infiltrated into the ground but 1,900 MCM is returned up to the ground through springs, and thus 2,250 MCM (30.1%) is recharging groundwater. Finally, total around 4,500 MCM/year (Runoff + Spring: 2,600+1,900=4,500) is the total surface water resources potential.

(2) Groundwater resources potential

In the same manner, a groundwater balance under the natural condition, in an average for latest 10 years, is estimated by SSM, as shown in Table 4.1.4.

Table 4.1.4 NATURAL GROUNDWATER BALANCE (Unit: 1,000 m3)

		Area	In		Out			SubBal	Volume
92-'01 Ave.	Basin	(Km2)	Recharge	GInflow	PmpUp	SprUp	GOutflow		
Kebir	[1-5]	333.5	118,913	0		9,180	133,454	-23,721	11,061,710
Ostuene	[6-9]	169.6	45,970	69,548		13,062	106,507	-4,050	3,990,999
Akkar	[10-13]	133.1	44,305	17,617		13,438	52,938	-4,454	2,984,815
Bared	[14-17]	266.3	114,205	49,859		138,488	35,631	-10,055	7,902,512
Abou Ali	[18-22]	484.9	187,412	82,441		153,598	130,696	-14,440	14,945,790
Jouz	[23-26]	186.3	69,876	6,938		11,468	77,126	-11,780	5,472,477
Ibrahim	[27-30]	346.7	149,686	209,013		301,024	65,928	-8,253	6,314,365
Kelb	[31-33]	254.9	69,621	126,237		117,496	88,259	-9,898	5,803,493
Beirut	[34-37]	309.9	118,189	21,433		34,336	125,826	-20,540	8,165,352
Damour	[38-41]	186.2	66,816	122,779		102,140	89,372	-1,918	6,354,083
Awali	[42-45]	334.5	62,434	114,541		83,170	98,187	-4,381	6,209,584
Saintaniq	[46-48]	161.9	68,955	1,933		2,653	79,493	-11,259	4,686,055
Zahrani	[49-51]	104.1	48,153	11,919		8,947	56,300	-5,176	3,049,543
A Assouad	[52-53]	160.1	63,713	1,052		5,665	61,883	-2,784	7,410,801
Litani	[54-64]	2,231.3	1,317,411	428		15,158	883,847	-150,926	84,660,720
Assi	[65-69]	1,848.8	686,117	53,906		153,074	730,693	-143,746	70,862,010
Hasbani	[70-73]	587.4	203,226	41,672		11,305	290,955	-57,361	23,183,780
S.TOTAL	**73**	**8,099.5**	**3,435,000**	**931,316**	-	**1,174,202**	**3,107,095**	**-484,743**	**273,058,089**
Percentage	(%)	80.4%	100.0%	27.1%		34.2%	90.5%	-14.1%	
Coastal Basin	[74-97]	1,690.7	605,518	161,236		86,752	736,152	-56,150	41,715,560
Individuals	[98-99]	286.0	138,318	103,248		94,871	175,608	-28,912	12,675,180
S.TOTAL	**26**	**1,976.7**	**743,835.6**	**264,483.4**	-	**181,623.3**	**911,759.4**	**-85,061.8**	**54,390,740.0**
Percentage	(%)	2.8%	100.0%	35.6%		24.4%	122.6%	-11.4%	
G.TOTAL	**99**	**10,076**	**4,178,836**	**1,195,800**	-	**1,355,825**	**4,018,855**	**-569,804**	**327,448,829**
Percentage	(%)	100.0%	100.0%	28.6%	-	32.4%	96.2%	-13.6%	

In the Table, the item of "SubBal" means a sub-surface water balance and it includes some other miscellaneous items than major spring out or groundwater outflow, so that the balance is not equal to the direct calculation of "In" and "Out". In any rates, groundwater balances in all of the basins are in deficit, because the latest 10 years include the continuous three years drought.

The groundwater balance in the country is simply summarized as follows:

	Item	Volume	(%)	(% to Recharge)
In	Item	Volume	(%)	(% to Recharge)
	Recharge	4,200 MCM/year	(77.8%)	100 %
	G. Inflow	1,200 MCM/year	(22.2%)	28.6%
	Total	**5,400 MCM/year**	**(100%)**	**128.6%**
Out				
	G. Outflow	4,000 MCM/year	(74.8%)	96.2%
	Spring Up	1,900 MCM/year	(35.6%)	45.8%
	Total	**5,900 MCM/year**	**(110.5%)**	**142.1%**

Only from the direct calculation of "In – Out" suggests around 10% of deficit in this 10 years average. The total groundwater resources potential in the country is, thus, roughly estimated as 3,500 MCM/year as Recharge + Inflow – Spring Up.

Both surface and groundwater balances for every river basin at each year for the latest ten years, at the current condition, are attached in ANNEX 4. Same manner but in the natural condition are also presented as ANNEX 4.

4.2 Surface Water Development Potential

4.2.1 Development Strategy

Definition of surface water development potential is the maximum volume of surface water available for the future water use, and surface water is defined as water flowing in river. Since most of spring water flows into river regardless of their use in upstream, spring water is included in surface water in this Study. Besides, the potential analysis of spring water separated from surface water is not possible due to limitation of spring discharge data.

Surface water development depends on water resources management policy. For example, the volume of surface water to be developed depends on the drought return period adopted. If the downstream eco-system or recreational water were significant, an idea of maintenance discharge would need to be introduced. Considering the present and future use of surface water, 1) return period of drought year, 2) maintenance discharge and 3) direct intake/storage facility of water are examined as development strategy.

(1) Drought Year

Determination of the return period of drought year is associated with the safety degree of water supply and cost for water development. If the long return period were adopted for water development, the water supply would be secured against severe drought but simultaneously the cost for development would become large. For example, a development plan for 10-year return period drought costs more than that for 5-year return period drought; however, insecure water supply hinders growth of the socio-economy. To adopt the feasible target of return period, the future socio-economic framework and hydrological conditions in Lebanon need to be considered.

Since Lebanon has a high potential for economic development and actually economy is very active after the cease of civil war, the stable supply of water is one of crucial factors to sustain the economic development. It means that the safety degree of future water supply should be set as high as other developed countries.

Annual precipitation ranges 600 – 1,000 mm in the coastal area, 900 – 1,700 mm in Mt. Lebanon and 200 – 900 mm in the Bekka valley. Those figures show high values compared to other middle east countries. A main issue in the hydrological characteristics is the distinct seasonal variation of precipitation that almost all precipitation concentrates during the wet season (November to March). This characteristic limits the use of surface water by direct intake but water during the wet season can be used by storage facilities. Therefore, as long as the proper water resources management is applied, the high safety degree of water supply can be maintained.

10-year return period drought is adopted for the water use planning in this Study, considering cases in the developed countries. It implies that the water supply will be secure against 10-year return period drought.

(2) Maintenance Discharge

In general, maintenance discharge is defined as discharge maintained even during the drought for navigation, fishery, scenery, prevention of saline problem, prevention of river mouth clogging, protection of river structures, maintenance of groundwater table, preservation of eco-system, water quality control of river flow and so on. The present water use, such as domestic water, industrial water and irrigation, is necessary to be considered for the water resources development from the water right point of view; however, it is examined separately from the maintenance discharge. Thus, the maintenance discharge does not include the present water use.

In Lebanon, there is no example to apply the maintenance discharge so far. Although Ministry of Environment has designated Lake Yammouneh as the nature reserve and has proposed countermeasures to mitigate water quality degradation and preserve eco-system in several water bodies, Lake Qaraoun, Lake Yammouneh and Aamiq Marsh, neither designation nor countermeasure proposal is associated with the maintenance discharge.

As discussed in Chapter 2.3 (Meteorology and Hydrology) and the following Chapter 4.2.2 (Development Potential by Direct Intake), there is no flow during the dry season in 5 rivers (El Jouz, Beirut, Saitaniq, Zahrani and Abou Assouad rivers) out of 17 rivers in Lebanon. Besides, even the rivers that there is flow during the dry season, their volumes are very limited. For example, drought discharge (discharge exceeding this volume for 355 days in a year) in 10-year return period drought is less than 0.200 m^3/sec in those rivers, except El Kabir, Arka, Abou Ali, and El Assi rivers. This low discharge during the dry season might be a reason why there is no example of maintenance discharge in Lebanon.

However, considering the future socio-economic framework and necessity of nature preservation, maintenance discharge should be introduced with the following reasons.

1) Tourism: Tourism is an important sector in Lebanon and the rapid growth of this sector is expected. According to the Ministry of Tourism, there is an intention to increase the number of visitors from 900,000 at present to 6,000,000 in future. Water flow during the summer, equipped with park, restaurant and so on, is one of tourist attraction, particularly for tourists from the Middle East. Besides, the water flow contributes to maintain the scenic areas.

2) Recreational Use of Water: In the summer, Lebanese enjoys the scenery of water flow. Area along river is already developed with restaurants, cafes and so on, wherever there is water flow with nice view. Since recreational use of water is considered as one of the water rights, some discharge has to be maintained for this use.

3) Preservation of Eco-system: There are flora and fauna existing along the watercourses. Considering the significance to preserve existing eco-system, some discharge has to be maintained.

In this Study, the maintenance discharge is applied to rivers that there is currently flow during the dry season. To determine the volume of maintenance discharge involves the detailed studies, such as identification of eco-system and recreational use of water, impact assessment of water environment on tourism, etc., that are out of scope of this Study. Therefore, 50% of the drought discharge (discharge exceeding this volume for 355 days in a year) in 10-year return period drought is assumed to be the maintenance discharge.

(3) Direct Intake/Storage Facility

Surface water is developed by either direct intake from rive and spring or storage facilities, such as dams, and hill lakes. In general, development without storage facilities costs lower compared to development with storage facilities. Therefore, the surface water development gives the priority to the direct intake, and the storage facility is considered when the direct intake cannot satisfy the water demand.

In this Study, surface water development potential is divided into the development potential by direct intake and by storage facility. Thus, two kinds of development potential were estimated individually as discussed in the following sections.

4.2.2 Development Potential by Direct Intake

(1) Definition of Terms Used

Surface water development potential by direct intake is expressed by the following equation.

$$Q_{sp} = Q_{355} - Q_m - Q_u$$

Where Q_{sp}: surface water development potential
Q_{355}: drought discharge in the target drought year
Q_m: maintenance discharge
Q_u: present water use (domestic, industrial & irrigation)

Figure 4.2-1 shows the duration curve of the gauging station No. 223 located in Ibrahim river as an example. Based on the duration curve, the following 4 discharges are defined for the water resources management in Japan. Drought discharge used for evaluation of development potential varies depending on country. For example, $Q_{90\%}$, that is 329th daily discharge on the duration curve, is used in UK, while $Q_{10,7}$, that is 7 days continuous discharge in 10-year return period drought, is adopted in U.S.A and Brazil. Although the definition is different, values of those discharges are almost same. Thus, in this Study, the Japanese definition was adopted.

1) High Discharge: 95th daily discharge from the maximum, discharge exceeding this volume for 95 days in a year (26 % of a year)
2) Normal Discharge: 185th daily discharge from the maximum, discharge exceeding this volume for 185 days in a year (50 % of a year)

3) Low Discharge: 275th daily discharge from the maximum, discharge exceeding this volume for 275 days in a year (75 % of a year)

4) Drought Discharge: 355th daily discharge from the maximum, discharge exceeding this volume for 355 days in a year (97 % of a year)

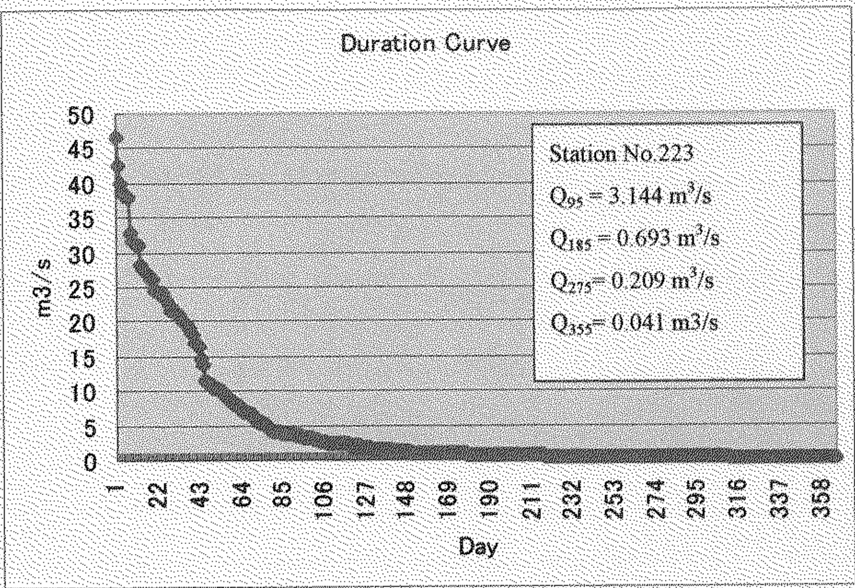


Figure 4.2-1 Duration Curve of Ibrahim River in 2000 Hydrological Year

Figure 4.2-2 shows the daily discharge of the gauging station No. 223 located in Ibrahim river in hydrological year of 2000 (September to August). Since 2000 is the drought year with 10-year return period, the development potential by direct intake is obtained by subtracting the maintenance discharge from the drought discharge (Q_{355}) as shown in the figure.

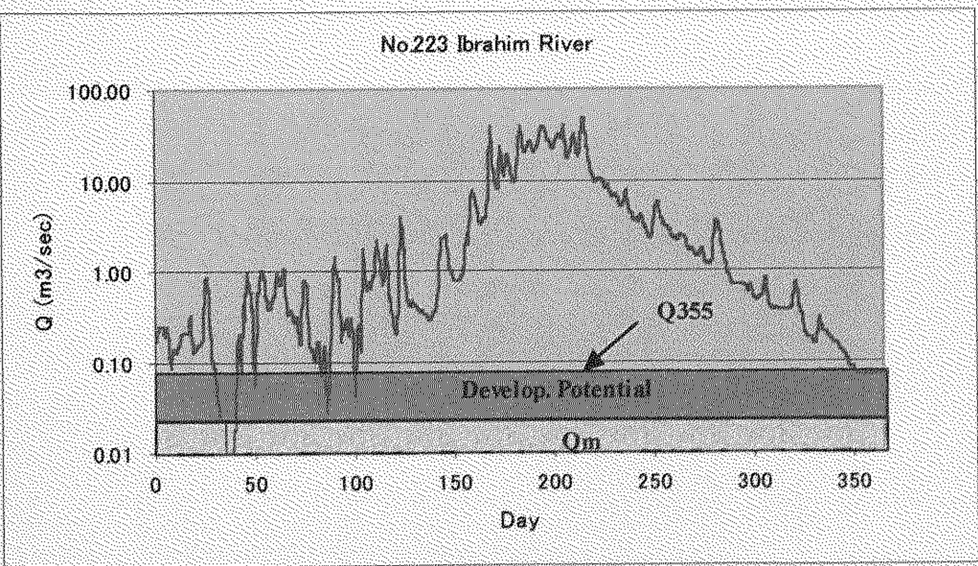


Figure 4.2-2 Concept of Surface Water Development Potential by Direct Intake

(2) Development Potential

The following conditions and assumptions are adopted to estimate the surface water development potential in each river basin.

- 10-year return period drought is adopted as the target for stable water supply. Annual discharge data from 1965 to 2000 are used to determine a year of 10-year return period drought. However, there is a long cease of observation during 1970's and 1980's.
- Maintenance discharge is applied to rivers that there is some flow during the dry season. Volume of the maintenance discharge is assumed to be 50% of the drought discharge (Q_{355}).
- Potential estimate is based on daily discharges collected from LRA (Litani River Authority). Correlation of river basins with discharges and specific discharge (discharge divided by catchment area) are applied to fill data gaps to maintain at least last 10 years daily discharge.
- River basins that have independent hydrological characteristics, such as El Assi, Litani and El Hasbani rivers, cannot be correlated. Therefore, the available discharge data in 1960's and 1970's are used.
- Observed discharge data are the result of subtraction of present water use (domestic, industrial and irrigation) in upstream from natural discharge. Since the Study deals with the observed discharge data, it can be assumed that the present water use is already considered. Thus, the above equation for the surface water development potential becomes "$Q_{sp} = Q_{355} - Q_m$".
- In accordance with S/W (Scope of Works), the JICA Study does not discuss the Lebanese shares of international rivers. Thus, the whole potential regardless of shares among countries was examined.

Drought discharge in 10-year return period drought ($1/10Q_{355}$) was estimated for a gauging station in each river basin and successively the surface water potential by direct intake was determined. Table 4.2-1 shows the result of development potential estimate by direct intake.

Table 4.2-1 Surface Water Development Potential by Direct Intake

No.	Basin	Gauging Station Drought Discharge						Basin/Sub-basin Development Potential				
		Station	Catchment Area (km^2)	1/10 Drought Year	Annual Q (MCM)	1/10 Q355 (m^3/s)	Specific q ($m^3/s/100\ km^2$)	Adjusted q ($m^3/s/100\ km^2$)	Basin Area (km^2)	1/10 Q355 (m^3/s)	Qm (m^3/s)	Develop. Potential (m^3/s)
1	El Kabir	101	437.0	98	114.69	1.011	0.231	0.231	970.0	2.241	1.121	1.120
2	Ostouene	106	103.0	65	24.95	0.122	0.118	0.118	173.7	0.205	0.103	0.102
3	Arka	108	102.0	99	27.52	0.535	0.525	0.525	136.3	0.716	0.358	0.358
4	El Bared	111	264.0	69	133.83	0.300	0.114	0.114	270.4	0.308	0.154	0.154
5	Abou Ali	117	466.0	92	107.75	0.946	0.203	0.203	498.7	1.012	0.506	0.506
6	El Jouz	120	189.0	99	31.46	0.004	0.002	0.000	193.0	0.000	0.000	0.000
7	Ibrahim	223	326.6	2000	137.86	0.041	0.013	0.013	352.5	0.046	0.023	0.023
8	El Kelb	228	257.5	98	67.45	0.154	0.060	0.060	264.3	0.159	0.080	0.079
9	Beirut	234	217.0	72	32.88	0.000	0.000	0.000	230.0	0.000	0.000	0.000
10	Damour	239	77.0	2000	15.34	0.049	0.064	0.064	293.0	0.188	0.094	0.094
11	Awali	473	222.0	2000	58.94	0.141	0.064	0.064	305.1	0.195	0.098	0.097
12	Saitaniq	477	108.0	2000	3.89	0.000	0.000	0.000	111.2	0.000	0.000	0.000
13	Zahrani	480	96.0	2000	6.93	0.000	0.000	0.000	106.6	0.000	0.000	0.000
14	Abou Assouad	481	18.0	69	0.21	0.000	0.000	0.000	155.2	0.000	0.000	0.000
15	Litani-North	354	126.0	99	42.39	0.018	0.014	0.000	1,538.1	0.000	0.000	0.000
		355	878.0	84	29.43	0.000	0.000					
	Litani-Middle	489	1,808.0	74	138.02	1.182	0.065	0.002	276.3	0.006	0.003	**0.003**
	Litani-South	490	2,066.0	2000	77.64	1.059	0.051	0.002	380.1	0.008	0.004	**0.004**
		493	2,153.0	2000	62.97	0.050	0.002					
16	El Assi	345	1,221.0	98	246.14	5.887	0.482	0.482	1,893.1	9.125	4.563	4.562
17	El Hasbani	496	448.0	71	26.00	0.020	0.004	0.004	568.5	0.023	0.012	0.011
Remarks	Litani-North:	Although the drought discharge is available in some tributaries flowing through Mt. Anti Lebanon, almost all river flow during the summer is consumed in Bekka plain for irrigation. Thus, it is assumed that there is no water available for future intake.										
	Litani-Middle & South:	The flow available at the gauging station No. 489 and 490 is considered for downstream irrigation schemes, mainly Qasmieh. It is obvious from rapid decline of discharge after intake of Qasmieh. Thus, the drought discharge downstream from the intake was adopted.										
	El Kabir & Assi:	They are international rivers but shares between two countries are not considered for the potential estimate.										
	El Hasbani:	Discharges of Wassani spring that is located near border are not considered due to the lack of data.										
Note	1/10 Q355: Drought discharge (exceeding this volume for 355 days in a year) in 10 years return period drought, 1/10 Drought Year: 10 years return period drought, Annual Q: Annual discharge, Specific q: Specific drought discharge, Adjusted q: Specific drought discharge considering the past trend, present water use, Qm: Maintenance discharge = 50% of drought discharge, Develop. Potential: Development potential by direct intake											

"$1/10Q_{355}$" (drought discharge in 10-year return period drought), "Q_m" (maintenance discharge) and "Q_{sp}" (surface water development potential by direct intake) of 17 river basins are described in Table 4.2-1. Regarding the international rivers, such as El Kabir, El Assi and El Hasbani, basin area, "Q_{sp}" and "Q_m" were calculated for hydrological boundary neglecting shares with neighboring countries. Thus, the figures in the table express the basin/sub-basin total at river mouth/downstream end.

Since Litani river has the large basin area, 2,194.5 km^2, it was divided in three sub-basins. Considering the existing and proposed dam sites, sub-basins were determined as follows.

Litani-North:	Upstream from Qaraoun dam, including the central and south Bekka
Litani-Middle:	Basin between Qaraoun dam and proposed site for Khardale dam
Litani-South:	Downstream basin from Khardale dam site to river mouth

"$1/10Q_{355}$" shows the volume of river flow available at least for 355 days in a year and those in most of rivers are less than 1 m^3/s, except El Kabir, Abou Ali and El Assi rivers that maintain relatively high discharge even during the summer. On the other hand, in 5 rivers (El Jouz, Beirut, Saitaniq, Zahrani and Abou Assouad rivers), "$1/10Q_{355}$" are 0 due to the long cease of river flow during the summer. Litani has a different characteristic from other rivers. Since the present river water use for irrigation in Bekka is intensive, "$1/10Q_{355}$" becomes 0 in Litani-North.

Assuming that "Q_m" is equal to 50% of "$1/10Q_{355}$", "Q_{sp}" of each river was evaluated. The river flow in Litani-Middle and Litani-South during the dry season (from April to October) is mainly for the downstream irrigation, especially for the Qasmieh irrigation scheme, that extends along the coastal area until EL. 100m. Besides, the river flow in those sub-basins includes not only runoff in the sub-basins but also discharge from the Qaraoun dam to satisfy the downstream irrigation requirement. Therefore, "Q_{sp}" in those sub-basins is based on the discharge data of a gauging station downstream from the last intake.

"Q_{sp}" of El Assi river is the largest (4.562 m^3/s) followed by El Kabir (1.120 m^3/s), Abou Ali (0.506 m^3/s), Arka (0.358 m^3/s) and El Bared (0.154 m^3/s). Seasonal variation is very large in Lebanese rivers; however, in those 5 rivers the relatively high discharge is maintained even during the dry season. There is a tendency that "Q_{sp}" is higher in the north and lower in the south, except El Assi, Litani and El Hasbani with particular hydrological characteristics.

The total of surface water development potential by direct intake amounts to 7.113 m^3/s without consideration of Lebanese shares for international rivers. Since it is assumed that the present water use (domestic, industrial and irrigation) is already considered in "Q_{sp}" estimate, 7.113 m^3/s is available volume for the future water demand. This total potential can meet roughly the water demand of the population of 3 million, assuming that the unit consumption rate is 200 litter/capita/day.

4.2.3 Development Potential by Storage Facility

In Lebanon, the surface water development is mainly conducted by storage facilities, such as dams and hill lakes, due to high seasonal fluctuation of river discharge. Besides, topographical features that most of rivers flow in gorges hinder the surface water development by direct intake. In the following section, the surface water development potential by storage facility is discussed based on the proposed surface water development by MEW and LRA.

(1) Existing and Proposed Surface Water Development Projects

MEW (Ministry of Energy and Water) and LRA (Litani River Authority) are main executing authorities for planning and implementation of the surface water development. The service area of LRA is the southern Lebanon bounded by Awali and Litani river basins in north. Awali and Litani river basins are included in the LRA service area and significant water resources. The rest of area in Lebanon, the northern part, is covered by the MEW service.

In 1999, MEW formulated the 10-Year Work Plan for the period of 2000 to 2009 as the mid-term plan, to conduct the study, land acquisition and construction associated with water resources development, domestic water supply, wastewater treatment, irrigation and river rectification. Its project components have been revised several times depending on the progress. As of March 2003, there are 19 dams and 17 hill lakes proposed in the 10-Year Work Plan as the surface water development projects. Table 4.2-2 summarizes the proposed projects and their locations are shown in Figure 4.2-3. Storage volume of water after completion of all projects would be 726 million m^3/year.

In 1999, LRA also formulated the 5-Year Plan for the period of 1999 to 2003. LRA tasks in the field of surface water development are almost same as MEW and only difference is its service area. Since MEW has the overall responsibility for water resources development, LRA proposals in the 5-Year Plan associated with surface water development in Bekaa and south Lebanon are included in the MEW's 10-Year Work Plan.

So far, only the Aydamoun hill lake was completed and the construction of Chabrouth dam has launched in 2002. Besides, Assi dam is currently under the detail design (D/D) and its construction is expected to start in 2003. However, since most of proposed projects are still at either preliminary study or just project identification phase, they require the further studies, such as feasibility study and detail design, depending on the present status. Detail design has been completed for 5 projects (Qamouaa hill lake, Brissah hill lake, Bisri dam, Qaisamani hill lake and Yammouneh hill lake) out of 34 projects at the study phase. Availability of information/specifications for dams and hill lakes depends on study completed. Based on the literature extraction, the information/specifications are summarized in Annex.

Table 4.2-2 Surface Water Development Proposed in MEW 10-Year Work Plan

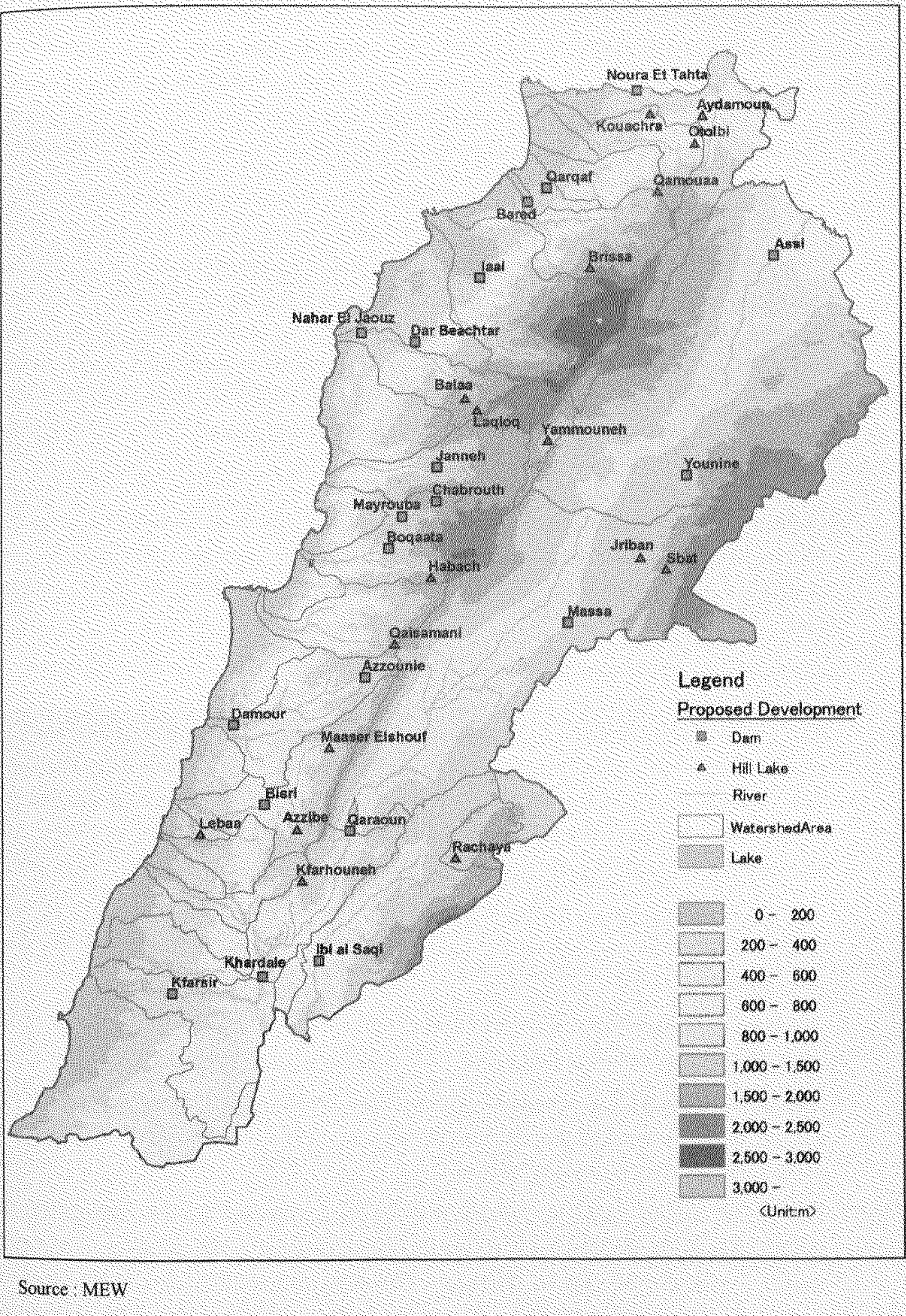
No.		Dam	Hill Lake	Capacity (million m^3)	Purpose	Work Done	Present Phase
North Lebanon	301	Noura Et Tahta		70.00	c	PS	2002 study proposal
	302	Qarqaf/ Wadi Jamous		20.00	a	no study	2002 study proposal
	303	Bared		40.00	c	PS	2002 study proposal
	304	Iaal		10.00	b	PS	2002 study proposal
	305	Nahar El Jaouz/Mousailah		20.00	f	no study	2002 study proposal
	306	Dar Beachtar		55.00	c	PS	CDR program 1&2
	307		Kouachra	0.35	a	no study	2002 study proposal for rehabilitation
	308		Aydamoun	0.30	a	**executed**	
	309		Otolbi	1.00	c	no study	2002 study proposal
	310		Qamouaa	1.00	e	D/D	CDR proposal for execution
	311		Brissa	1.00	b	D/D	CDR program 2
	312		Balaa	1.00	b	no study	under 2002 study
	313		Laqloq	0.80	c	no study	2002 study proposal
Mount Lebanon	201	Janneh		30.00	g	no study	2002 study proposal, technical difficulty anticipated
	202	Chabrouth		8.00	b	D/D	**under execution**
	203	Mayrouba		20.00	c	no study	
	204	Boqaata		7.00	b	PS	2002 study proposal
	205	Azzounie		8.00	b	no study	2002 study proposal, technical difficulty anticipated
	206	Damour		60.00	b	PS	CDR program 1&2
	207	Bisri		120.00	i	D/D	not financed yet
	208		Habach	0.55	b	PS	CDR program 1
	209		Qaisamani	0.55	b	D/D	to be executed in 2002
	210		Maaser Elshouf	2.00	c	no study	2002 study proposal
Bekka	501	Assi		37.00	c	D/D	already financed and to be executed in 2003
	502	Younine		7.00	a	PS	2002 study proposal
	503	Massa		7.00	c	PS/FS	under D/D
	504		Yammouneh	4.50	h	D/D	to be implemented in 2002
	505		Jriban	0.7-1.0	d	no study	2002 study proposal
	506		Sbat	0.7-1.0	d	no study	under 2002 study
	507		Rachaya	< 1.0	c	no study	under 2002 study
South Lebanon & Nabatieh	401		Lebaa	0.96	b	FS	CDR program 1
	402		Azzibe	0.70	b	PS	CDR program 1
	403		Kfarhouneh	1.20	c	PS	2002 study proposal
	601	Kfar sir		10.00	a	no study	LRA proposal
	602	Khardale		128.00	c	PS	LRA proposal
	603	Ibl al Saqi		50.00	a	no study	2002 study proposal, technical difficulty anticipated
Total				725.91	at maximum		

Note: Work Done
PS: Preliminary Study
FS: Feasibility Study
D/D: Detailed Design

Purpose
a: irrigation
b: domestic
c: irrigation & domestic
d: irrigation, domestic, flood control
e: irrigation & tourism
f: domestic & industrial
g: domestic & hydro-power
h: irrigation, domestic, tourism
i: domestic, industry, irrigation, hydro-power

CDR 3 Year Program
CDR Program 1: Preparation of D/D and Tender Document
CDR Program 2: Construction

MEW
2002 study proposal: conducted by MEW



Source : MEW

Figure 4.2-3 Location of Proposed Surface Water Development by MEW

Although CDR (Council for Development and Reconstruction) has sought the external fund for projects and simultaneously MEW has implemented some projects using the internal fund, completion of all projects within the period for the 10-Year Work Plan might be optimistic, particularly dam projects that require a long consideration of technical and environmental aspects. Thus, it is necessary to decide priority of each project in accordance with the future water demand.

(2) Dam Storage Volume and Development Potential

The scope of work of this Study does not include the dam study, such as identification of potential site, topographical and geological investigation, design and so on. However, since the development potential is not only function of the storage volume but also the inflow discharge and recovery period to be allowed, the development potential of dams was evaluated, based on the following conditions and assumptions. The evaluation in this Study is associated with only hydrological factors but not associated with other factors for dam design, particularly topographical and geological aspects.

- Evaluation of the development potential by dam is limited to projects proposed in the 10-Year Work Plan formulated by MEW because the Study does not cover identification of dam/hill lake potential sites. Besides, MEW has already identified those potential sites.
- Since 10-year return period drought is adopted for the water resources management, consecutive daily discharges for 10 years from 1991 to 2000 are applied to estimate dam inflow as long as discharge data are available or correlation with neighboring river basin is conducted to fill data gaps. El Assi, Litani and El Hasbani rivers have no daily discharge data during 1991-2000 and cannot be correlated with other basins due to the distinct hydrological characteristics. Thus, the available daily discharge data in 1960's and 1970's and even monthly average were used for the dam inflow estimate.
- It is assumed that observed discharge data are the result of subtraction of present water use in upstream from natural discharge. Thus, the present water use is already considered in discharge data.
- The same maintenance discharge determined in evaluation of the potential by direct intake is applied to dam outflow.
- As mentioned in the above, the present intake is already considered in discharge data. As a result, it can be assumed that the present water use in downstream is secured as long as the dam drains the maintenance discharge.
- Some dams, such as Qarqaf, Chabrouth, Boqaata, Bisri, Qaraoun, Younine, Kfarsir and Ibl al Saqi, aim to supply water only during the dry season for either irrigation or domestic supply to mitigate the summer shortage. Therefore, two scenarios, water development throughout the year and water development only during the dry season, are applied to estimate the development potential for those dams.

- Seepage depends on geological characteristics of dam site; however, the scope of Study does not include such detailed geological study. Thus, it is excluded from the dam storage simulation.
- Relations between water level of dam and reservoir area are not available in the most of dams proposed. Besides, the rough estimate shows that evaporation from the reservoir induces around 5% decrease in development potential. Thus, evaporation from the reservoir is excluded from the dam storage simulation.
- Since the storage volumes of hill lakes are relatively small (less than 1 million m^3/year), it is assumed that the storage volume recovers annually and is equal to the development potential.

Based on the above conditions and assumptions, the development potential by dam is simulated by the following equations.

$$Q_{in} = Q_{gauge} \times A_{dam} / A_{gauge}$$

$$Q_{sd1} = Q_{in} - Q_m$$

$$Q_{sd2} = Q_{sd1} - Q_d$$

$$C_t = C_{t-1} - Q_{sd2,\,t} \times 86.4 \geqq 0$$

$$Q_{out} = Q_{in} + (C_t - C_{t-1}) / 86.4 - Q_d$$

Where Q_{in}: dam inflow discharge (m^3/s)

Q_{gauge}: daily discharge at gauging station (m^3/s)

A_{dam}: catchment area of dam (km^2)

A_{gauge}: catchment area of gauging station (km^2)

Q_{sd1}: surplus/deficit of discharge at dam (m^3/s)

Q_m: maintenance discharge (m^3/s), 50% of $1/10Q_{355}$ where available

Q_{sd2}: surplus/deficit of discharge at dam after intake of developed water (m^3/s)

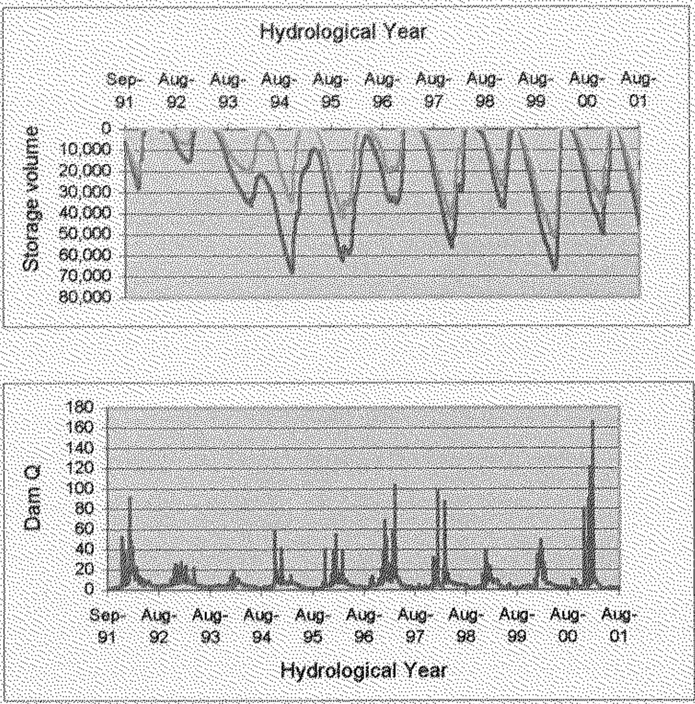
Q_d: newly developed water by dam (m^3/s)

C: empty capacity of dam reservoir (1,000 m^3)

Q_{out}: discharge drained from reservoir to downstream (m^3/s)

t: time series (day)

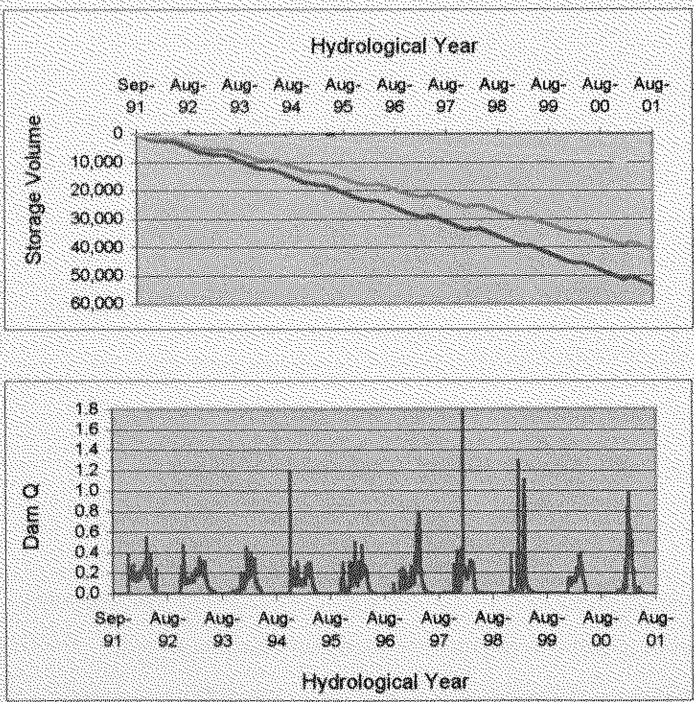
Each dam proposal was evaluated based on the simulation and the feasible water development by dam was determined, assuming that the discharge tendency in simulation will continue. Recovery period of 4 years is allowed at maximum. The results of simulation are shown in Figure 4.2-4, Figure 4.2-5 and Figure 4.2-6 as examples. Table 4.2-3 summarizes the estimate of development potential by dam in terms of only hydrological aspect.



No. 301 Noura Et Tahta		
Planned Storage (MCM)		70
Catchment Area (Km^2)		552
Maintenance Q (m^3/s)		0.638
Gauging Station		No. 101
Water Development	Q (m^3/s)	Storage V (MCM)
Case 1	4.70	68.08
Case 2	4.00	51.45
Case 3	3.00	29.81

1st figure: Storage Volume (1,000 m^3)
2nd figure: Dam Inflow (Q= m^3/s)

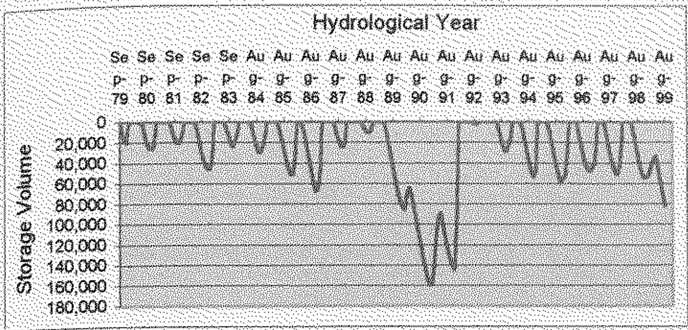
Figure 4.2-4 Surface Water Development by Dam (Noura Et Tahta Dam)



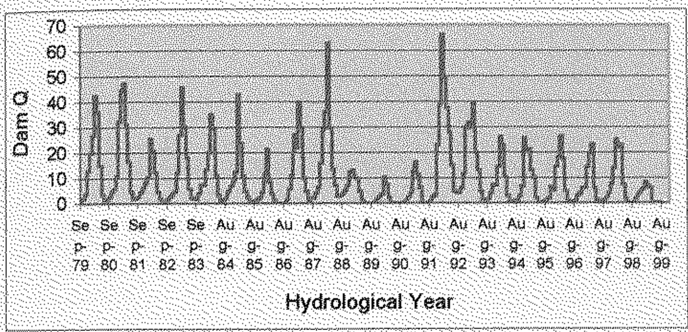
No. 306 Dar Beachtar		
Planned Storage (MCM)		55
Catchment Area (Km^2)		10
Maintenance Q (m^3/s)		0
Gauging Station		No. 120
Water Development	Q (m^3/s)	Storage V (MCM)
Case 1	0.24	53.42
Case 2	0.20	40.79
Case 3	0.10	9.96

1st figure: Storage Volume (1,000 m^3)
2nd figure: Dam Inflow (Q= m^3/s)

Figure 4.2-5 Surface Water Development by Dam (Dar Beachtar Dam)



No. 500 Qaraoun		
Planned Storage (MCM)		160
Catchment Area (Km^2)		1538
Maintenance Q (m^3/s)		0.108
Gauging Station		Dam
Water Development	Q (m^3/s)	Storage V (MCM)
Case 1	4.47	159.98



1st figure: Storage Volume (1,000 m^3)
2nd figure: Dam Inflow (Q= m^3/s)

Figure 4.2-6 Surface Water Development by Dam (Qaraoun Dam)

Noura Et Tahta dam is planned to be located in the middle reaches of El Kabir river, which is one of international rivers in Lebanon. Figure 4.2-4 simulates the daily change of dam storage in the last 10 years with 3 cases of water development. Allowing 4-year recovery period of dam storage, 4.7 m^3/s, equivalent to 148 million m^3/year, can be developed at maximum. The stable discharge in El Kabir river enables water development more than the planned storage capacity (70 million m^3).

The catchment area of Dar Beachtar dam is only 10 km^2. Due to the very limited catchment area, dam inflow is not sufficient to recover the dam storage with even water development of 0.1 m^3/s (throughout the year), as shown in Figure 4.2-5. Thus, this dam is not feasible to collect and store water from its catchment area. Actually, additional inflow by conveyance of water from another basin is originally planned in the MEW study proposal.

Qaraoun dam, constructed in 1964, is located in Litani river and only existing dam in Lebanon. Monthly average discharge data, instead of daily discharge, were applied to simulate the daily change of dam storage for 20 years. 40-year return period drought in 1989 let the dam storage reach the full capacity (160 million m^3) and the recovery of storage took 3 years. Figure 4.2-6 is a case for water development throughout the year and intake of 4.47 m^3/s (141 million m^3/year) is possible with the maximum recovery period of 3 years. If the development were limited only during the irrigation period from April to October, the development of 6.5 m^3/s (205 million m^3/year) would be possible.

Table 4.2-3 Summary of Dam Simulation (1)

Code No.	Dam	Intake Period	Water Development (m^3/s)	Storage Capacity (MCM)	Recovery Period (Year)	Remarks
201	Janneh	year	1.9	29.46	1	1) Decline in discharge since 1998
			1.5	21.52	1	2) 1998 (1/20), 2000 (1/10)
			1.0	11.71	1	
202	Chabrouth	year	0.16	7.50	-	1) Sharp decline in discharge since 1997
			0.13	4.10	-	2) 1998 (1/10), 2000 (1/20), 1999 (1/7)
			0.10	1.81	1	3) Small catchment area (11 km^2)
		June – September	0.43	7.76	-	
			0.35	4.60	-	
			0.30	3.20	1	
203	Mayrouba	year	0.75	19.91	-	1) Sharp decline in discharge since 1997
			0.70	15.73	-	2) 1998 (1/10), 2000 (1/20), 1999 (1/7)
			0.60	10.30	1	
204	Boqaata	year	0.20	6.28	-	1) Sharp decline in discharge since 1997
			0.15	2.59	1	2) 1998 (1/10), 2000 (1/20), 1999 (1/7)
			0.10	1.60	1	3) Small catchment area (17 km^2)
		June – September	0.53	6.71	-	
			0.45	4.67	1	
			0.40	4.07	1	
205	Azzounie	year	0.21	7.05	-	1) Decline in discharge since 1998
			0.15	3.99	2	2) 1998 (1/20), 2000 (1/10)
			0.11	1.96	2	3) Small catchment area (13 km^2)
206	Damour	year	2.2	55.24	2	1) Decline in discharge since 1998
			2.0	45.08	2	2) 1998 (1/20), 2000 (1/10)
			1.5	22.54	1	
207	Bisri	year	3.2	115.03	-	1) Decline in discharge since 1998
			2.5	60.46	2	2) 1998 (1/20), 2000 (1/10)
			2.0	35.03	2	
		May – October	5.8	115.58	-	
			5.0	89.47	2	
			3.8	51.32	2	
301	Noura Et Tahta	year	4.7	68.08	4	1) Stable discharge
			4.0	51.45	2	2) 1998 (1/10), 1993 (1/20)
			3.0	29.81	1	
302	Qarqaf	year	0.16	17.90	-	1) Decline in discharge since 1997
			0.13	10.17	-	2) 1998 (1/20), 1999 (1/10)
			0.10	3.60	-	3) Small catchment area (11 km^2)
		April – October	0.27	18.62	-	
			0.20	7.43	-	
			0.12	1.60	2	
303	Bared	year	4.4	35.04	1	1) Stable discharge
			4.0	25.75	1	2) 1998 (1/6), 1969 (1/10)
			3.5	15.86	1	
304	Iaal	year	0.07	8.44	-	1) Stable discharge
			0.05	3.02	-	2) 1992 (1/10), 1998 (1/20)
			0.03	0.55	1	3) Small catchment area (4 km^2)

Simulation period: Sep. 1991 – Aug. 2001 unless specified in Remarks, Year indicated: Hydrological Year, MCM: million m^3, Parenthesis: Drought return period, : possible water development

Table 4.2-4 Summary of Dam Simulation (2)

Code No.	Dam	Intake Period	Water Development (m^3/s)	Storage Capacity (MCM)	Recovery Period (Year)	Remarks
305	Nahar El Jaouz	year	0.85	18.62	1	1) Decline in discharge in 1998 & 1999
			0.50	10.67	1	2) 1998 (1/15), 1999 (1/10)
			0.30	6.20	1	
306	Dar Beachtar	year	0.24	53.42	-	1) 1998 (1/15), 1999 (1/10)
			0.20	40.79	-	2) Small catchment area (10 km^2)
			0.10	9.96	-	
		year	2.0	47.19	-	1) Water conveyance from Abou Ali river
			1.8	36.58	2	basin: 70% of discharge at No. 112
			1.5	21.20	2	gauging station
500	Qaraoun	year	4.47	159.98	3	1) Existing dam
						2) 1989 (1/40), 1990 (1/10), 1998 (1/20)
		April – October	6.50	159.20	3	3) Simulation: Sep. 1979 – Aug. 1999
501	Assi	year	4.95	35.59	1	1) Sharp decline in discharge since 1998
			4.50	24.94	1	2) 1998 (1/10), 1999 (1/20)
			4.00	14.08	1	3) Simulation: Sep. 1991 – Aug. 2001
502	Younine	year	0.46	6.85	1	1) Small catchment area (5km^2)
			0.40	5.92	1	2) Dam inflow: from Yammouneh spring
			0.35	5.15	1	3) Simulation: Sep. 1998 – Aug. 2001
		April – October	0.46	6.85	1	4) Discharges in winter are large enough
			0.40	5.92	1	to satisfy both water demand and dam
			0.35	5.15	1	storage.
503	Massa	year	0.35	6.46	-	1) Decline in discharge since 1999
			0.30	3.98	2	2) 1999 (1/10), 2000 (1/20)
			0.25	2.98	1	3) Simulation: Sep. 1993 – Aug. 2001
601	Kfarsir	year	0.99	9.85	1	1) High annual discharge fluctuation from
			0.90	8.30	1	185 MCM to 1,319 MCM
			0.80	6.64	1	2) Simulation: Sep. 1966 – Aug. 1972
		April – October	1.1	9.64	1	3) Both cases are with Khardale dam
			1.0	8.17	1	
			0.8	5.86	1	
602	Khardale	year	5.4	82.48	-	1) High annual discharge fluctuation from
			4.5	44.51	1	160 MCM to 1,200 MCM
			4.0	33.58	1	2) Simulation: Sep. 1965 – Aug. 1972
603	Ibl al Saqi	year	1.23	49.94	-	1) Sharp decline in discharge in 1972
			1.10	39.61	3	2) Simulation: Sep. 1966 – Aug. 1974
			0.70	17.66	2	
		April – October	1.94	49.81	2	
			1.80	44.63	2	
			1.50	33.57	2	

Simulation period: Sep. 1991 – Aug. 2001 unless specified in Remarks, Year indicated: Hydrological Year, MCM: million m^3, Parenthesis: Drought return period, : possible water development

In most of cases shown in Table 4.2-3 and Table 4.2-4, the decline in discharge from 1998 lowers the water development by dam due to 10-year return period drought or more severe drought occurred during a period between 1998 and 2000. If the discharge were high enough, much more water would be able to be developed with the storage capacity proposed by MEW. For example, the storage capacity planned for Mayrouba dam is 20.0 million m^3; however, due to relatively small discharge than expected, only water of 0.6 m^3/s can be developed and it requires the half of planned storage, 10.3 million m^3. If the present discharge tendency continued in future, a plan of Mayrouba dam would be over-investment. Regarding 10 dams out of 20 dams, the less water development than expected reduces the storage volume of dam. On the other hand, Noura Et Tahta dam can develop the water of 4.7 m^3/s, equivalent to annual volume of 148 million m^3 that is more than double of the planned storage volume (70 million m^3). It implies that the water development by Noura Et Tahta dam is very efficient because of stable discharge.

Chabrouth, Boqaata, and Bisri dams have an objective to develop water only for the dry season. It means that the winter water is stored in dam reservoir and used in summer. If the water development is limited to the particular period, those dams can develop water more than double of development throughout the year. For example, if Chabrouth dam supplies domestic water only during June - September to satisfy the demand of summer population, it can develop 0.3 m^3/s that is three times more than all year development (0.10 m^3/s). Ibl al Saqi dam is also for irrigation purpose. Thus, if the intake from the dam is limited to only irrigation period (April – October), 80% more water can be developed.

Although Qarqaf, Younine and Kfarsir dams also aim to develop water only for the dry season, the difference between development throughout the year and development for the particular period is very small. This is due to relatively high discharge in winter so that winter discharge can meet both water demand and dam storage.

Qaraoun dam can develop the water of 4.47 m^3/s that is almost same volume as the storage volume despite the fact that two successive drought years (40-year return period in 1989 and 10-year return period in 1990) took 4 years to recover the full storage. Two cases of simulation were conducted as described in Table 4.2-4. If the water supply by Qaraoun dam is limited to irrigation only (April – October), it can develop 6.50 m^3/s. In future, irrigation use will dominate the dam operation but hydro-power generation will be continued during the wet season and peak hours, according to LRA. Thus, the water development throughout the year is more realistic.

Water development by Kfarsir and Khardale dams interact to each other because they are planned to be located in Litani river. If Khardale dam develops the water at maximum, the discharge drained to Kfarsir dam in downstream will be reduced so that Kfarsir dam cannot develop as much as existing alone. As a result, Kfarsir dam would be possible to develop 0.99 m^3/s throughout the year or 1.10 m^3/s only during the irrigation with the existence of Khardale dam.

Due to the small catchment area, Chabrouth, Boqaata, Azzounine, Qarqaf, Iaal and Dar Beachtar dams can develop limited amount of water. Those dams might be equipped with additional discharge by water conveyance from other river basins or some particular springs. Since the information to specify those additional discharges is not available, the water conveyance from another basin was assumed for only Dar Beachtar dam.

The simulation in Table 4.2-3 and Table 4.2-4 does not consider the Lebanese shares in international rivers, such as El Kabir, El Assi and El Hasbani, because the Study does not cover the international political issues. Thus, the results show the potential in terms of hydrology and the available volume for Lebanon might be reduced based on an agreement with neighboring countries.

Table 4.2-5 summarizes the surface water development potential by dam based on the storage volume simulation. Since Qaraoun dam is an existing dam, it has to be excluded from the surface water development potential. However, after completion of Canal 900 and 800 irrigation schemes, the water use of Qaraoun dam will be completely different from the present use. As a result, the water allocation of Qaraoun dam needs to be adjusted for the future water use. Thus, Qaraoun dam is included in the surface water development potential.

Table 4.2-5 Surface Water Development by Dam

Code	Dam	Development Type	Develop. Water		Recovery Period (year)	Required Storage Volume (MCM)	Planned Storage Volume (MCM)
			Q (m^3/s)	Annual Q (MCM)			
301	Noura Et Tahta	year	4.70	148.2	4	68.1	70.0
302	Qarqaf	irrigation	0.12	3.8	2	1.6	20.0
303	Bared	year	4.40	138.8	2	35.0	40.0
304	Iaal	year	0.03	0.9	1	0.5	10.0
305	Nahar El Jaouz	year	0.85	26.8	1	18.6	20.0
306	Dar Beachtar	year	1.80	56.8	2	36.6	55.0
201	Janneh	year	1.90	59.9	1	29.5	30.0
202	Chabrouth	year	0.10	3.2	1	1.8	8.0
		summer	0.30	9.5	1	3.2	
203	Mayrouba	year	0.60	18.9	1	10.3	20.0
204	Boqaata	year	0.15	4.7	1	2.6	7.0
		summer	0.45	14.2	1	4.7	
205	Azzounie	year	0.15	4.7	2	4.0	8.0
206	Damour	year	2.20	69.4	2	55.2	60.0
207	Bisri	year	2.50	78.8	2	60.5	120.0
		May-October	5.00	157.7	2	89.5	
500	Qaraoun	year	4.47	141.0	3	160.0	160.0
		irrigation	6.50	205.0	3	159.2	
501	Assi	year	4.95	156.1	1	35.6	37.0
502	Younine	year/irrigation	0.46	14.5	1	6.9	7.0
503	Massa	year	0.30	9.5	2	4.0	7.0
601	Kfarsir	year	0.99	31.2	1	9.8	10.0
		irrigation	1.10	34.7	1	9.6	
602	Khardale	year	4.50	141.9	1	44.5	85.0
603	Ibl al Saqi	year	1.10	34.7	3	39.6	50.0
		irrigation	1.94	61.2	2	49.8	
Total				1143.8		624.7	824.0

year: water development throughout the year
irrigation: water development during irrigation (April - October)
summer: water development from June to September
Storage Volume = Active Storage
Annual developed water & required storage: in the case of development throughout the year

4.2.4 Overall Surface Water Development Potential

Surface water development potential consisting of development by direct intake and by storage facility is summarized in Table 4.2-6. Regarding hill lakes with small storage capacity compared to the dam, it is assumed that their storage volumes recover annually. Thus, the storage capacities of hill lakes proposed by MEW are equal to the development potential.

Table 4.2-6 Surface Water Development Potential

River Basin		Direct Intake		Dam		Hill Lake	Total
No.	Name	(m^3/s)	(MCM)	(m^3/s)	(MCM)	(MCM)	(MCM)
1	El Kabir	1.120	35.32	4.70	148.22	0.30	183.84
2	El Ostouene	0.102	3.22	0.00	0.00	1.35	4.57
3	Arka	0.358	11.29	0.00	0.00	1.00	12.29
4	El Bared	0.154	4.86	4.40	138.76	1.00	144.62
5	Abou Ali	0.506	15.96	0.03	0.95	0.00	16.91
6	El Jouz	0.000	0.00	0.85	26.81	1.80	28.61
7	Ibrahim	0.023	0.73	1.90	59.92	0.00	60.65
8	El Kelb	0.079	2.49	0.85	26.81	0.55	29.85
9	Beirut	0.000	0.00	0.00	0.00	0.00	0.00
10	Damour	0.094	2.96	2.35	74.11	0.55	77.62
11	Awali	0.097	3.06	2.50	78.84	2.70	84.60
12	Saitaniq	0.000	0.00	0.00	0.00	0.00	0.00
13	Zahrani	0.000	0.00	0.00	0.00	0.00	0.00
14	Abou Assouad	0.000	0.00	0.00	0.00	0.00	0.00
15	Litani-North	0.000	0.00	4.77	150.43	2.00	152.43
	Litani-Middle	0.003	0.09	4.50	141.91	1.20	143.20
	Litani-South	0.004	0.13	0.99	31.22	0.00	31.35
16	El Assi	4.562	143.87	5.41	170.61	0.00	314.48
17	El Hasbani	0.011	0.35	1.10	34.69	0.00	35.04
19	Others	0.000	0.00	0.12	3.78	0.00	3.78
21	Others	0.000	0.00	1.80	56.76	0.00	56.76
27	Others	0.000	0.00	0.00	0.00	0.96	0.96
34	Others	0.000	0.00	0.00	0.00	4.50	4.50
36	Others	0.000	0.00	0.00	0.00	1.00	1.00
	Total	7.113	224.330	36.270	1,143.820	18.910	1,387.060

Development Potential by Dam: intake throughout the year

MCM: million m^3/year

Surface water development potential depends on the river basin. 7 river basins, El Kabir, El Bared, Ibrahim, Damour, Awali, Litani (North and Middle sub-basin) and El Assi, have high potential of surface water development exceeding 50 million m^3/year, while 5 river basins, El Ostouene, Beirut, Saitaniq, Zahrani and Abou Assouad, have either no potential or very limited potential due to hydrological characteristics.

The total surface water development potential amounts to 1,387 million m^3/year with construction of all dams and hill lakes proposed by MEW. Due to the high seasonal fluctuation of discharge, only 16.2% of surface water development can be achieved by direct intake and most of surface water development (83.8%) requires dams and hill lakes.

10-year return period drought is applied to evaluate the surface water development potential by direct intake. Besides, the development potential by dam is simulated for 10 years as long as discharge data are available. Thus, it can be assumed that the surface water development potential in Table 4.2-6 is available water against 10-year return period drought.