Rain water harvesting and management of small reservoirs in arid and semiarid areas

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Hydrology of Sindyaneh Wadi Basin in Syria

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1. GENERAL PRESENTATION :

1.1 Physiography :

The territory of Syria can be divided into three main physiographic units:
1. The Western Mountain Ranges
2. The Southern Plateaux
3. The Eastern Plains.

In the northern part of the country, the western mountains stretch northwards along the Mediterranean coast. The southern part of the western mountain ranges includes the Anti-Lebanon mountains (2600 m) and Jebel Esh-Sheikh (2814 m).

The southern Plateaux include the Hauran volcanic plateau in the south-west and the Hamad plateau in the south east.

The eastern plains include an arid steppe, and also a semi-arid region with the most fertile land in the country. The steppe includes Badiet-Esh-Sham and Badiet-Er-Rasafa, south of Euphrates river, and Badiet-El-Jezireh, north of Euphrates river. The semi-arid region includes the Homs- Hama plains, the Idlib-Aleppo plain and the northern Jezireh plains.

1.2 Climate :

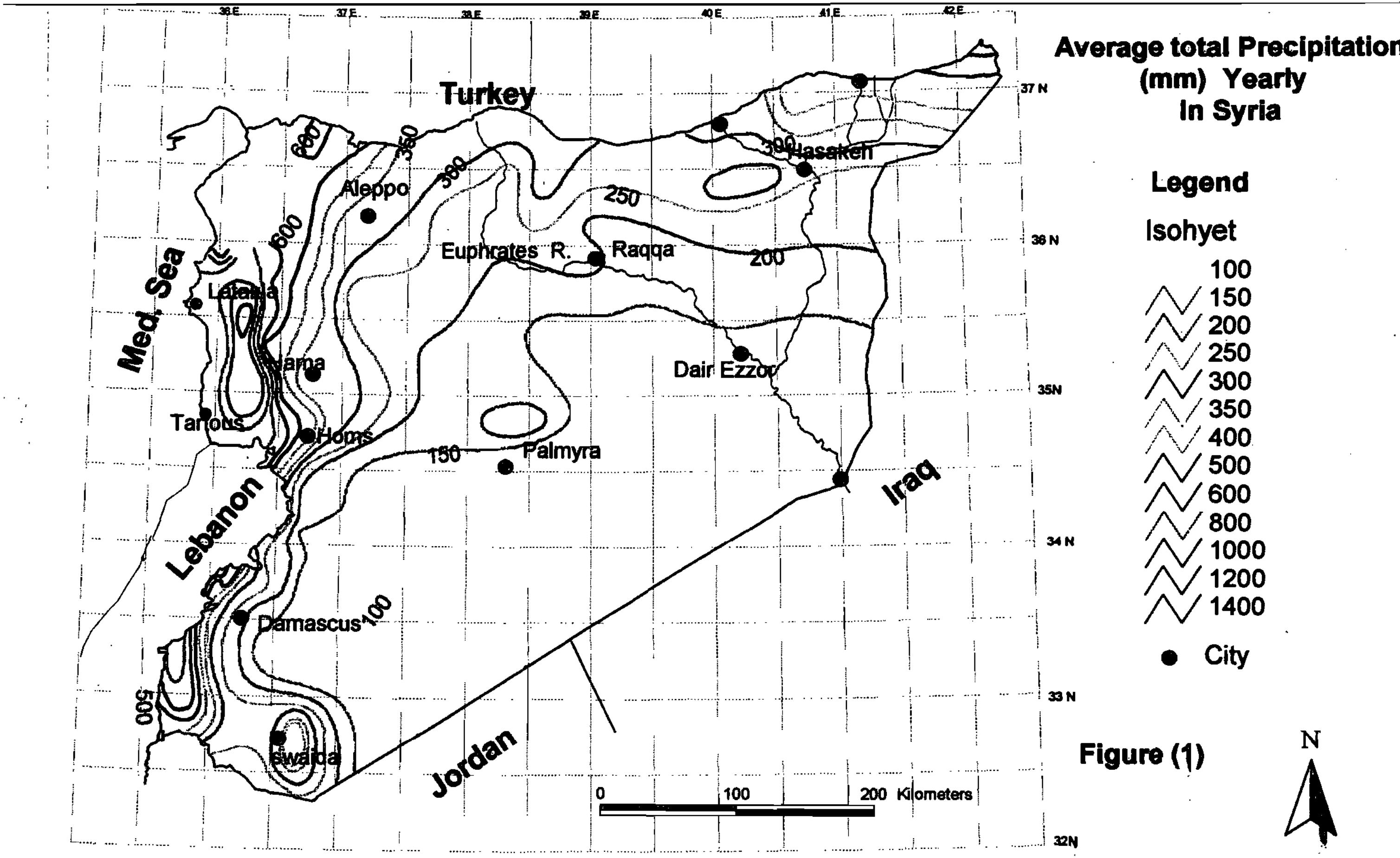
The climate of the Syrian Arab Republic is of the Mediterranean type, characterized by a cold rainy winter and a dry hot summer with two transitional periods in spring and autumn. The precipitation pattern is influenced mainly by two mountain belts: The western mountain ranges which run northward along coastline and the Tourus mountain ranges which extend along the northern boundary, mainly beyond the limits of the country.

The rainy season usually begins in September and ends in April with the possibility of heavy showers in May. High rainfall intensities are recorded in winter in the northern regions, and in spring or autumn in the southern and south-eastern regions. The rainfall distribution in the country is summarized in table (1,2).

Table (1)

Annual Rainfall and Evaporation

Name of Basin	**Area** Km^2	**Average Annual Rainfall**		**Av. An. Pot. Evaporation** mm
		mm	Billion m^3	
1. Barada & Awaj	8630	308	2.658	1600
2. Yarmouk	6724	287	1.930	1700
3. Assi	26446	316	8.357	1400
4. Coastal	5049	967	4.882	1200
5. Tigris & Khabour	21129	402	8.494	1600
6. Euphrates	46416	182	8.448	2000
7. Badia	70786	138	9.768	2000
Average		240		1900
TOTAL	185180		**44.537**	



Average total Precipitation
(mm) Yearly
In Syria
Legend
Isohyet
100
150
200
250
300
350
400
500
600
800
1000
1200
1400
City
Turkey
Iraq
Jordan
Lebanon
Med. Sea
Aleppo
Euphrates R.
Raqqa
Hasakeh
Dair Ezzor
Palmyra
Homs
Hama
Tartous
Damascus
Swaida
0
100
200 Kilometers
36 E
37 E
38 E
39 E
40 E
41 E
42 E
37 N
36 N
35N
34 N
33 N
32N
N

Figure (1)

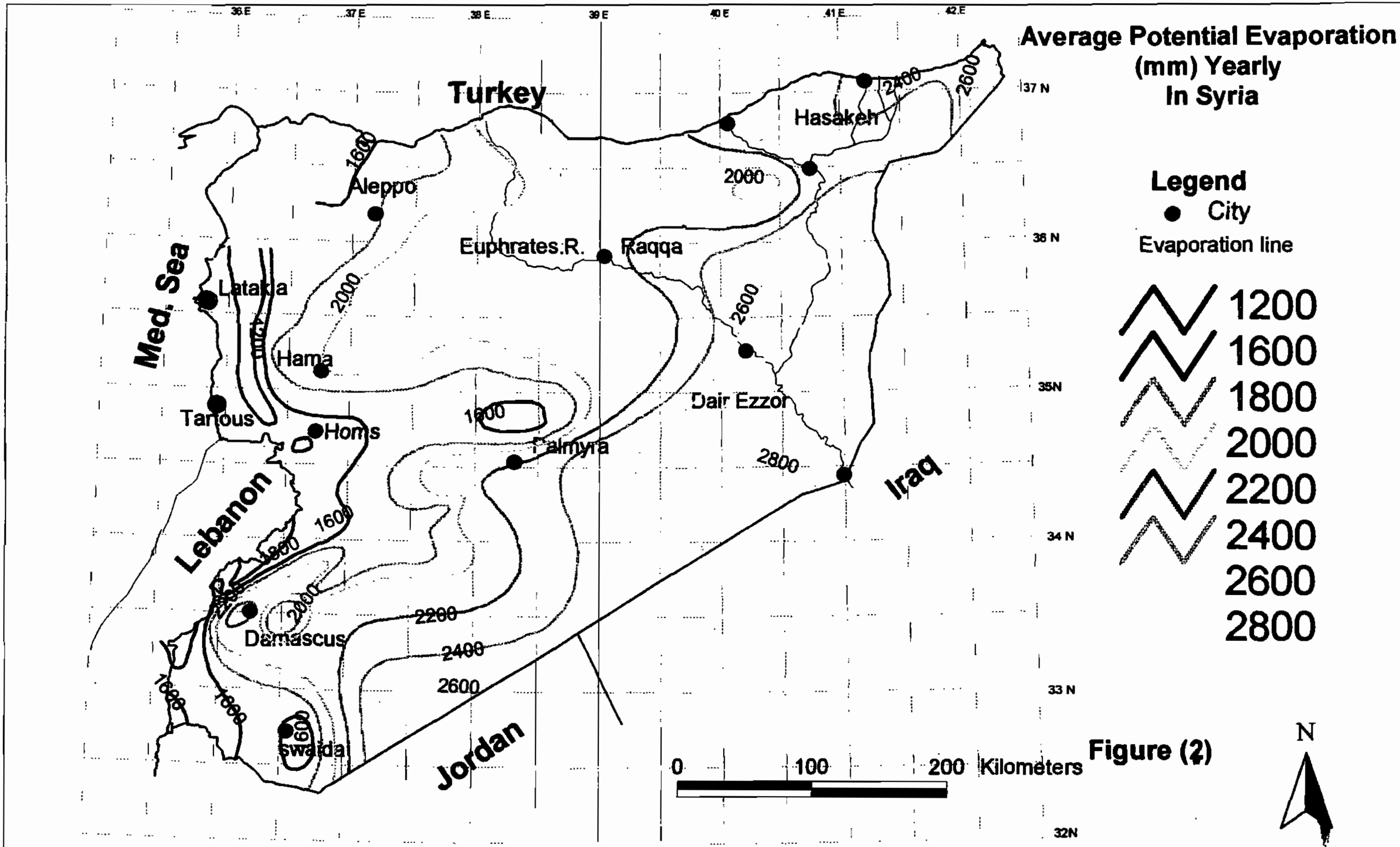

Average Potential Evaporation (mm) Yearly In Syria
Legend
City
Evaporation line
1200
1600
1800
2000
2200
2400
2600
2800
Turkey
Hasakeh
Aleppo
Euphrates.R.
Raqqa
Med. Sea
Latakia
Hama
Tartous
Homs
Palmyra
Dair Ezzor
Iraq
Lebanon
Damascus
Swaida
Jordan
0 100 200 Kilometers
N

Figure (2)

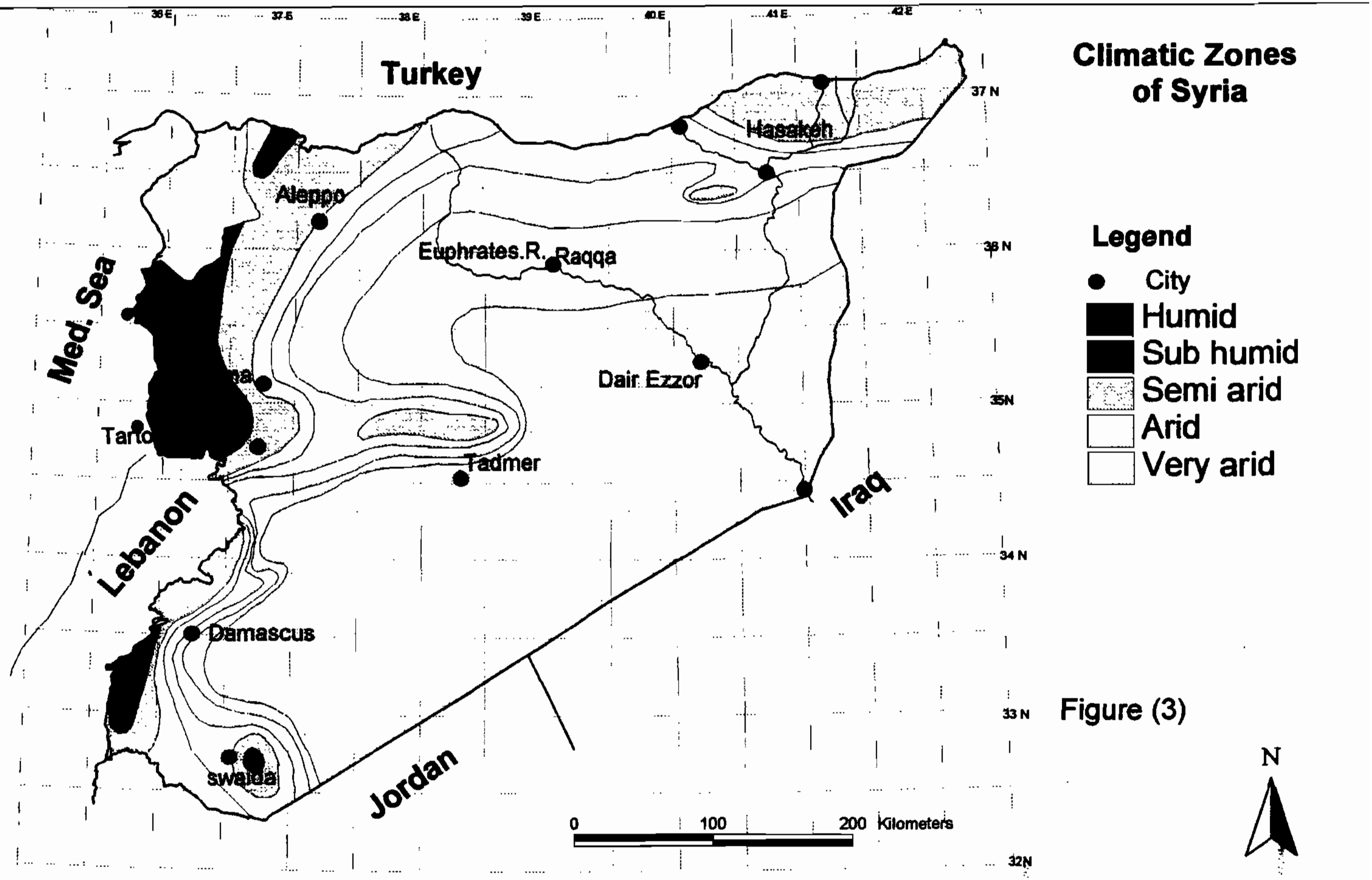

Climatic Zones of Syria
Turkey
Med. Sea
Lebanon
Jordan
Iraq
Aleppo
Euphrates.R.
Raqqa
Hasakeh
Dair Ezzor
Tadmer
Damascus
swaida
Legend
City
Humid
Sub humid
Semi arid
Arid
Very arid
0
100
200 Kilometers
N
37 N
36 N
35N
34 N
33 N
32N

Figure (3)

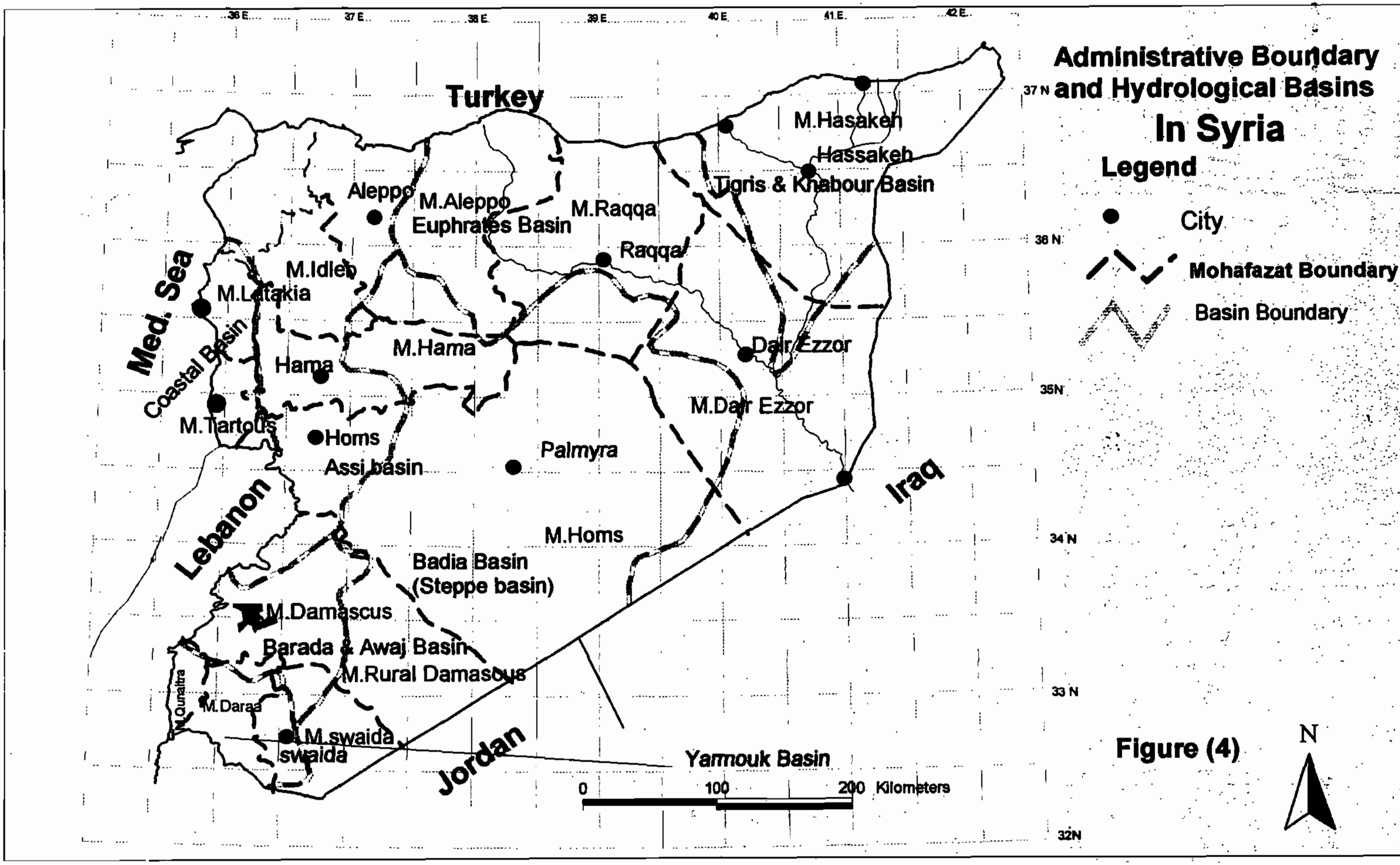

Administrative Boundary
and Hydrological Basins
In Syria
Legend
City
Mohafazat Boundary
Basin Boundary
Figure (4)
N
Turkey
Med. Sea
Lebanon
Jordan
Iraq
M.Hasakeh
Hassakeh
Tigris & Khabour Basin
Aleppo
M.Aleppo
Euphrates Basin
M.Raqqa
Raqqa
M.Idleb
M.Latakia
Coastal Basin
M.Hama
Hama
Dair Ezzor
M.Dair Ezzor
M.Tartous
Homs
Assi basin
Palmyra
M.Homs
Badia Basin
(Steppe basin)
M.Damascus
Barada & Awaj Basin
M.Rural Damascus
M.Qunaitra
M.Daraa
M.swaida
swaida
Yarmouk Basin
0
100
200 Kilometers
36 E
37 E
38 E
39 E
40 E
41 E
42 E
37 N
36 N
35N
34 N
33 N
32N

Table (2)

Rainfall Distribution in Syria (mm)

Region	Annual Rainfall	Maximum Rainfall within 24 Hours
South- Eastern Region	< 200	20-40
Northern Region and Jebel El Arab	200-400	40-70
Jawlan and Extreme North-East	400-600	60-90
Coastal Plains	800-1000	90-120
Western Mountain Region along the Coast	1200-1600	235

Potential evaporation rates range from 1200 to 2800 mm per annum.

The absolute maximum temperature rises above 40 C° in the interior region, starting from May. Between September and April, temperatures may drop below zero in most regions except in the coastal plains.

Figures (1) and (2) show the yearly averages of total precipitation, and potential evaporation in Syria respectively. Figure (3) shows the climatic zones of Syria.

1.3 Wadis :

Syria is endowed with mature clear hydrographic networks. The different shapes of these networks reflect the morphology, the precipitation regime, and the geologic formations.

Figure (4) shows the Syrian hydrographic basins which are in the mean time the principal hydrologic basins. Three main hydrographic groups can be distinguished in Syria:

1.3.1 Coastal Wadis:

Coastal wadis originate in the western foothills of the coastal mountains facing the Mediterranean sea, they cross the coastal plains forming parallel basins in general, then they empty in the Mediterranean sea. The totality of these basins is called the Coastal basin. In addition to the ephemeral wadis, there are perennial streams in the Coastal basin, namely Kabir Chamali, and Kabir Janoubi rivers.

1.3.2 Open Interior Wadis:

These wadis originate in the eastern coastal mountains, on the interior mountains, and on the hills. they cross the plains and hills and empty eventually in the sea. These wadis form the following three principal basins:

1.3.2.1 Assi Basin, consisting of Assi River and a group of ephemeral and perennial tributaries the most important of which is Afrin River. Assi river empties in the Mediterranean sea.

1.3.2.2 Middle Euphrates Basin: Euphrates Basin extends in Turkey (upper part), Syria (middle part), and Iraq (lower part). The Middle Euphrates Basin consists of the main river valley and a number of ephemeral and perennial tributaries, the most important of which are: Khabour river, Balikh river, and Sajour river. Euphrates river empties in the Arabian Gulf. The Middle Euphrates Basin (*Syrian Jezira*) is subdivided into two hydrologic basins: Tigris and Khabour Basin, and Euphrates Basin.

1.3.2.3 Yarmouk Basin: this is the upper part of Jordan Basin consisting of ephemeral and perennial tributaries, the most important of which are Yarmouk river and Banias river. Jordan river empties in the Dead Sea.

1.3.3 Closed Interior Wadis:

These wadis originate on the interior mountains, on the southern part of the Anti Lebanon mountains, and on the interior hills. They then cross the plains and the hills and empty in the internal depressions. These wadis form the following three principal basins:

1.3.3.1 Damascus Basin, consisting of a number of seasonal and perennial wadis, the most important of which are Barada River and Awaj River.

1.3.3.2 Aleppo Basin, consisting of seasonal and perennial wadis, the most important of which are Quaik River and Dahab River. Aleppo Basin has been recently split into two sub-basins, the eastern sub-sub-basin is considered as a component of Euphrates Basin, and the sub-western basin is considered as a component of Assi Basin.

1.3.3.3 Badia Basin, consisting of eight closed basins, the most important of which is Dawa Basin having an important groundwater potential and an integrated hydrographic network. There are no perennial wadis in the Badia Basin. The southern part of Badia Basin called Hamad is characterized by scattered shallow unintegrated ephemeral wadis due to low precipitation and to the existing geologic and lithologic conditions.

1.4 Water Resources:

The water resources originating inside the boundaries of the Syria Arab Republic are estimated to be 9700 MCM per year on the average. Table (3) gives a breakdown of the annual water resources by basin.

Table (3)

Annual Water Resources (MCM/Year)

Name of Basin	Water Resources			Total
	Springs	Renewable Ground water	Wadis	
1. Barada & Awaj	525	250	75	850
2. Yarmouk	250	25	200	475
3. Assi	1200	750	1000	2950
4. Coastal	500	275	1500	2275
5. Tigris & Khabour	1300	500	500	2300
6. Euphrates	50	150	300	500
7. Badia	15	175	160	350
Total	**3840**	**2125**	**3735**	**9700**

2. GEOGRAPHIC DISTRIBUTION AND STORAGE CAPACITIES OF SMALL DAMS IN SYRIA:

According to the definition of small dams adopted by the International Committee of Large Dams (ICOLD), a small dam is that one having a height less than 15 meters, and a storage capacity less than 1 MCM ($H \leq 15\,m$, $W \leq 1\,MCM$), the Syrian Arab Republic has already 43 small dams. Table (4) presents a break down of the specifications of these small dams by basin. Figure (5) shows the locations of these 43 small dams.

2.1 It can be noticed that small dams in Syria are unevenly distributed over the basins; most of them exist in Assi, Yarmouk, and Badia basins. This is due to the fact that in Assi and Yarmouk basins, the mountainous areas do not provide suitable topographic conditions for building medium and large dams, while in Badia the annual water resources are insufficient for medium dams.

2.2 The storage capacity of the impoundment lake is determined according to the topographic conditions and to the annual water runoff in the wadi in a humid year (probability 10% to 25%), rather than the average annual runoff. This rule has enabled the exploitation of more water, and rendered the topographic conditions of the dam site the governing factor for choosing the storage capacity.

Table (4) gives a brakedown of the number of small dams in each basin by storage capacity:

Table (4)

Basin / S Storage Capacity 1000 m^3	Barada & Awaj	Badia	Yarmouk	Assi	Coastal	Euphr. & Aleppo	Tigris & Khabour	Total
$S \leq 100$		1	3					4
$250 \geq S \geq 100$		2	2	3				7
$500 \geq S \geq 250$		4	1	5	2		1	13
$750 \geq S \geq 500$		4	2	1		1		8
$1000 \geq S \geq 750$	1	7	2	1				11
Total	**1**	**18**	**10**	**10**	**2**	**1**	**1**	**43**

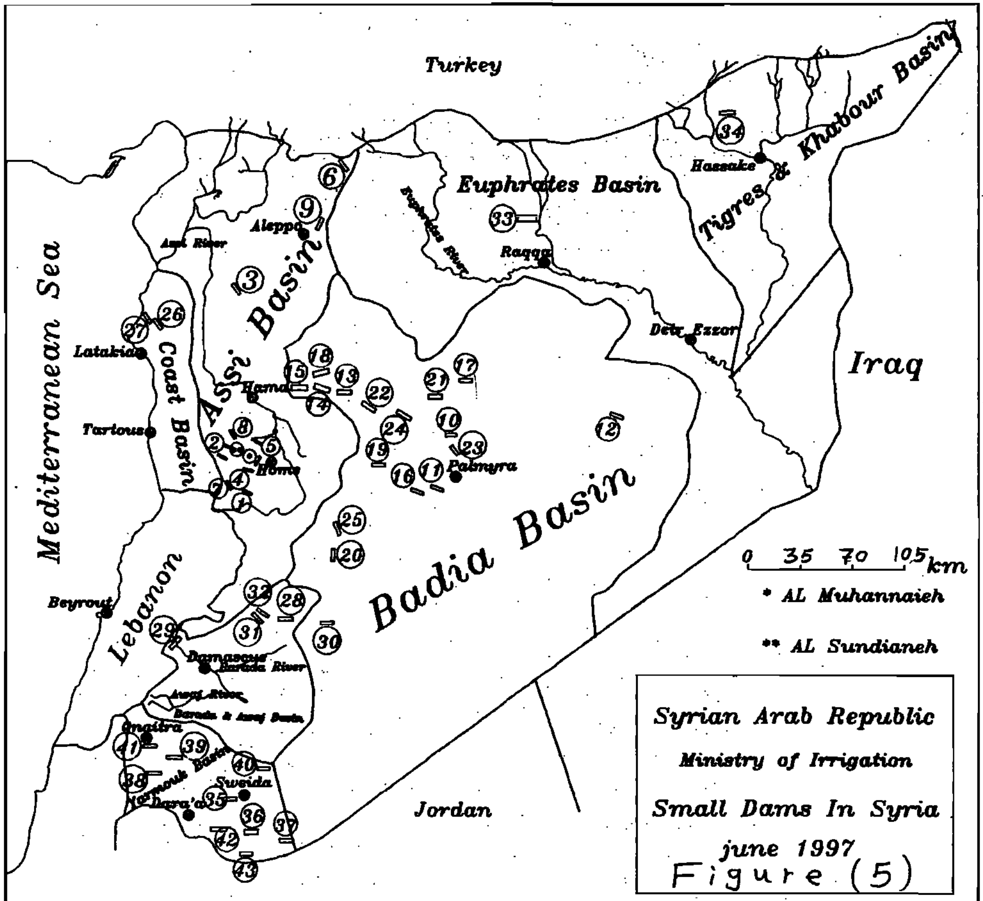

Turkey
Euphrates Basin
Tigres & Khabour Basin
Hassake
Aleppo
Raqqa
Deir Ezzor
Iraq
Mediterranean Sea
Latakia
Coast Basin
Assi Basin
Hama
Tartous
Homs
Palmyra
Badia Basin
0 35 70 105 km
* AL Muhannaieh
** AL Sundianeh
Beyrout
Lebanon
Damascus
Barada River
Barada & Awaj Basin
Jordan
Sweida
Syrian Arab Republic
Ministry of Irrigation
Small Dams In Syria
june 1997
Figure (5)

Table (4) . Characteristics of small dams in Syria.

SMALL DAM IN SYRIA

No.	Name of Dam	Basin	Hight (m)	Retention Volume M.m3	Lake Surface Hec	Construction Year	Chatchment Area (Km2)	Average Annual Precipitation (mm)	Design Annual Runoff Volume M.M3	Average Annual Stored Volume M.M3
1	Azaafaraneh	Assi	9	0.231	9	1966	3.6	350	0.2	0.2
2	Khurbet El_Hama	Assi	15	1.15	185	1967	10	600	1.15	1.1
3	Maaret Elnouman	Assi	11.2	0.229	8.6	1968	235	250	0.25	0.06
4	Al_Shundakieh	Assi	12	1.05	26.2	1968	8	600	1.44	1
5	Tlil	Assi	14	0.818	20.7	1968	7.4	550	1.02	0.58
6	Um _Ejlud	Assi	14.1	1.86	46.2	1969	58	280	1.86	0.14
7	Telkalakh	Assi	10	0.29	9	1970	1.75	1000	0.435	0.24
8	Al_Baroudien	Assi	13.2	0.31	8.6	1972	6.5	850	0.31	0.31
9	Nubbul	Assi	12	0.358	0.935	1993	12	400	0.358	0.1
10	Sulaim	Badia	11	0.75	7.5	1967	75	100	0.75	0.1

No.	Name of Dam	Basin	Hight (m)	Retention Volume M.m3	Lake Surface Hec	Construction Year	Chatchment Area (Km2)	Average Annual Precipitation (mm)	Design Annual Runoff Volume M ..M3	Average Annual Stored Volume M ..M3
11	Jbab Shakra	Badia	14	0.975	24.8	1968	380	200	1.3	0.633
12	Wadi El_Kabir	Badia	10	0.515	20	1968	263	200	0.85	0.16
13	Al_Azib	Badia	12	0.93	21.2	1969	250	250	0.93	0.15
14	Al_Albawi	Badia	13.5	1.4	300	1971	140	200	1.85	0.3
15	Al_Saan	Badia	9	1	3.2	1986	84.25	325	1.14	0.5
16	Abou Qelen	Badia	14	2	55.28	1987	206	200	2	1.02
17	Abou Faliag	Badia	12	1.36	468	1989	112	198	1.36	0.35
18	Asheihk Hilal	Badia	9.4	0.7	28.84	1989	276	200	1.3	0.225
19	Al_Mukharam	Badia	11	1.175	35.7	1991	55	250	0.825	0
20	Al_Hafar	Badia	9.8	0.35	11.5	1991	361	150	1.8	0.133
21	Al_Husiat	Badia	14.5	1.63	33.5	1992	260	200	1.63	0.8

No.	Name of Dam	Basin	Hight (m)	Retention Volume M.m3	Lake Surface Hec	Construction Year	Chatchment Area (Km2)	Average Annual Precipitation (mm)	Design Annual Runoff Volume M..M3	Average Annual Stored Volume M..M3
22	Al_Suna	Badia	10	0.39	15	1993	62	250	0.775	0.01
23	Tadmor	Badia	8	0.92	47.17	1993	150	130	1	0.285
24	Tel Ejoid	Badia	10.5	0.39	12.76	1994	68	260	0.884	0.025
25	Sadad	Badia	14	2.78	72.5	1996	180	150	1.1	0.25
26	Saqyet Sadek	Coast	10	0.38	136	1967	3.16	900	0.46	0.45
27	Koursana	Coast	15	0.39	2.9	1968	2.75	860	0.655	0.37
28	Al_ Qalamun	Damascus	15	1.63	43	1969	116	125	1.63	0.04
29	Wadi El_Qaran	Damascus	15	1.7	31.1	1969	60	350	1.7	1.5
30	Khan El_Manqura	Damascus	9	0.27	10.25	1971	18	140	0.27	0.05
31	Deir Atien west	Damascus	11.5	1.5	30	1980	105.6	250	1.5	0.01
32	Qara West	Damascus	12	0.8	8	1980	15	400	1.5	0

No.	Name of Dam	Basin	Hight (m)	Retention Volume M.m3	Lake Surface Hec	Construction Year	Chatchment Area (Km2)	Average Annual Precipitation (mm)	Design Annual Runoff Volume M .M3	Average Annual Stored Volume M .M3
33	Abou Kanef	Euphret	9	0.62	39	1968	4	225	0.62	0.13
34	Kanmah	Tig.&.Kha.	11.1	1.85	82.5	1967	160	265	1.7	0.55
35	Rsas	Yarmouk	8	0.03	0.9	1964	10	300	0.25	0.025
36	Al_Ain	Yarmouk	7.5	1.35	45.7	1965	26.3	530	2.92	0.65
37	Khazmeh	Yarmouk	8.5	0.25	6.6	1965	30	250	0.35	0.08
38	Al_Hujen	Yarmouk	8.24	0.85	37.5	1982	30	450	2.5	0.8
39	Rouininen	Yarmouk	10.7	1.03	52.4	1985	74	600	30	1.03
40	Shanba	Yarmouk	10	2	52.5	1986	75	400	2	0.65
41	Bouraiqa	Yarmouk	13	1.1	28	1987	14	700	1.06	1.05
42	Al_Butom	Yarmouk	12	2.1	58.82	1989	74	260	3.4	0.1
43	Salkhad	Yarmouk	10	0.55	6.47	1991	40	337	2.5	0.25

3. ENVIRONMENTAL, SOCIAL, AND ECONOMIC IMPACTS OF SMALL DAMS:

It is hard to evaluate the environmental and social impacts of the construction of small dams in Syria because of the lack of quantitative environmental and social data prior to dams construction, as well as the difficulties and complications inherent in preparing the studies necessary for that evaluation. The following discussion will merely mention the outstanding effects without using any analysis or statistics.

3.1 Environmental Impacts of Small Dams:

The majority of small dams were built in mountainous areas characterized by very high longitudinal slopes of wadis, or in Badia regions where the surface runoff is characterized by a high suspended and bed load content. After dam construction, it was noticed that the retention lakes have become a sediment trap due to the enlargement of the flow cross section upon entering the lake. This has naturally impeded the sediments from reaching the original areas at the end of the wadi course.

The formation of lakes and the subsequent rise up in the water levels in lakes have led to obvious changes in the morphology of the tributaries close to the main course. The erosion and sedimentation regime was substantially changed in the tributaries. The banks of the impoundment lakes were susceptible to scour due to wave formation during wind blowing. This effect could be attenuated by planting suitable plants around the lake or by stone revetment on the weak areas.

A lot of dam lakes were planted with fish, but the high turbidity of inflowing water especially in Badia dams has caused fish death. The sedimentation of suspended particles contained in the turbide water has resulted in the suffocation or death of fauna and flora originally existing in the bottom of the dam lakes and led to the formation of bacteria and pollutants.

Water stored in the lakes of some small dams is used as water supply for people and for livestock watering. Practice has proven that it is possible to get water of acceptable quality from these lakes if the following measures are taken:

1. Removal of trees and plants from the lake bottom, and sometimes the removal of the upper soil, prior to storing water and especially before the first filling up.

2. Prevention of any human, industrial, or agricultural waste from reaching the impoundment lake.

3. Control of eutrophication which may be accompanied by disgusting odour, and avoiding or deepening the shallow water areas.

4. The use of human, animal, and fish safe pesticides and insecticides to combat disease bearing organisms.

Besides the adverse environmental impacts of small dams, there are doubtless positive effects like:

1. Creating a local mild summer climate around the dam sites.
2. Increasing wind blowing over the lake surface and in the area which results in a mild atmosphere.
3. The green landscape (trees, plants, grass,...) in areas that were arid just before building the dams. Such areas were green only for short time after rainfall.
4. Migration of new kinds of birds and animals into the dam area. Such kinds are incomparable with the previously existing kinds prior to dam construction.
5. Reducing air pollution caused by the diesel engines that were used for pumping water from wells.

3.2 Social Impacts of Building Small Dams:

The Syrian climate, characterized by a short rainy winter and a long dry summer, implies providing water in summer either from groundwater or by storing water during winter for using it in summer. It is not always feasible to rely on groundwater which is in many times very deep or of inconvenient quality. Small dams represent the best alternative which has an advantage even over large dams. Small dams contribute in distributing the national water resources more evenly over the country, while large dams concentrate a huge quantity of water at the dam site and do not permit upstream areas to benefit from that quantity.

The distribution of water resources over numerous areas by small dams had many positive socio-economic impacts, the most important of which are:

1. The provision of domestic water for the inhabitants of Badia and mountainous regions has contributed in improving their hygienic conditions and resulted in a better urbanization level to people living around and downstream of the dam site.

2. The construction of small dams has created temporary jobs during the execution of the dam and its annexed structures, and created permanent work opportunities for the exploitation and maintenance of the dam.

3. The income increase resulting from the irrigation of previously rainfed arable lands has contributed in improving the living and cultural level of local inhabitants.

4. Most of the small dams implied the construction of new modern access roads. This has strengthened the mutual relations between urban and rural areas, and led to better level of civilization.

5. Many of the small dams became public tourist centers due to water and green areas. They became also points of contact for farmers from neighboring areas and contributed in developing mutual relations.

6. The amelioration of the conditions of rural areas due to the new water supplies has contributed in the contraction of migration into urban areas. Small dams have also encouraged many Bedouins to settle around their lakes.

The adverse social impacts of small dams are relatively few, they can be mentioned as follows:

1. The formation of impoundment lakes has led to the inundation of some arable lands and some houses already built in the area. The land owners were reimbursed, and house tenants were moved into other areas.

   There were strong objections against dam construction from inhabitants living upstream the dam sites, a complaint atmosphere was created among beneficiaries and damaged people. These problems were settled in the case of dams used for irrigation, the government has deprived the property of both the damaged and beneficiary lands and reallocated the reclaimed land to all land owners. By this way the hurt farmer could obtain a new irrigated land.

2. The new created lakes became attractive swimming centers for local inhabitants. The unsuperintended swimming causes the death of many people every year. In spite of warning, people still swim in the dam lakes; in the meantime, fencing the lakes is quite expensive.

3.3 Economic Impacts of Small Dams:

3.3.1 The money which was spent to transport water from remote water resources into thirsty areas has been saved. This applies for Swaida, Badia, and mountainous areas.

3.3.2 Economic studies have shown that the provision of water supply by small dams is much less expensive than by groundwater wells. The operation and maintenance costs of wells are higher than those of dams. Hard currency that was spent to equip, maintain, and operate wells has been saved.

3.3.3 Small dams have contributed in the attenuation of the overpumping of some irrigation wells.

3.3.4 Water stored in some of the small dams is used for supplementary irrigation of cereals in some rain irrigated areas. This has led to more and stable revenue.

The adverse economic impacts of small dams are very few, some arable lands were inundated and became no more productive, but this loss is incomparable with the gain of new irrigated lands.

4. HYDROMED PILOT RESERVOIRS:

Two hill reservoirs were selected to be as pilot sites for Hydromed project. The two sites are located west of Homs at about 200 Km from Damascus. The two reservoirs are Sindyaneh and Telkalakh hill reservoirs.

4-1 Sindyaneh Reservoir:

This reservoir was built in 1967, the catchment area is 4.2 Km2, the dam height is 12 m, and the impoundment volume is 360 000 m3. Several activities have been conducted on this site after it was selected as a pilot site.

1- The spillway threshold was restored and equipped with a staff for reading water levels.
2- The staffs for reading water levels in the lake were rehabilitated.
3- An automatic water level recorder and a rainfall recorder provided by Hydromed were installed.
4- Class A pan fer evaporation measurement was installed.
5- Preparations for measuring sedimentation in the lake were made.

4-2 Telkalakh Reservoir:

This reservoir was built in 1970, the catchment area is 1.75 Km2, the dam height is 10 m, and the impoundment volume is 290 000 m3. The activities that have been taking place after it was selected as a pilot site are:

1- The spillway threshold was restored and equipped with a staff for reading water levels.
2- The staffs for reading water levels in the lake were rehabilitated.
3- The already existing weather station was equipped with class A evaporation pan. This station has the following equipment: Rainfall recorder and rainfall gauge, hygrometer, temperature recorder, and maximum and minimum temperature thermometers.

5. PROCESSING OF INITIAL DATA ACQUIRED FROM SINDYANEH RESERVOIR:

The Sindyaneh Lake was equipped with an automatic recorder of type PLUVIO-LIMNI 92 recommended by ORSTOM. This equipment can record continuously the variation of the water level in the lake. It is also attached to a rainfall recorder. The data recorded are stored on a memory.

Since we have one year of continuous hydrological observation (November 1997-November 1998) a tentative estimation of the hydrological budget of the Lake has been conducted.

Using the softwares developed by ORSTOM within the framework of HYDROMED activities which include;

HYDROM : A data bank dealing with data related to water level in the lack, volume stored, surface flooded and outflow on the spillway.

PLUVIOM : A database dealing with pluviometry, daily and monthly precipitation data.

ARES : Used to calculate the intensity of rain and capacity of erosion.

SURFER : Used to calculate curves of thickness/surface/volume based on sedimentation measurements (Bathymetry).

The outputs of this primary study are described below;

- Estimation of flood and volume of water stored are shown in table 5. Which was constructed using HYDROM software. On this table we have mentioned only days with precipitation, beginning from 31 December 1997 and up to 30 November 1998. It is clear from this table that reservoir has been completely filled on 28 January 1998, then all the water coming to the lake has not been stored.

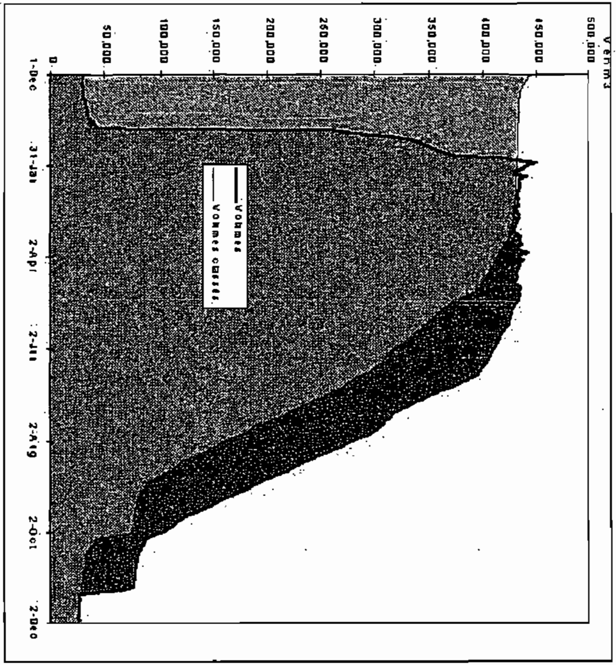
  From this table we can identify the storm event of 6-7 January 1998 where about 102 mm of precipitation was recorded and initiated a flood of 236600 m3. By the end of winter season we had about 434295 m3 of water stored.

- Figure (6-B) shows an analysis of different rainfall storms reflected as variation of water level in the lake (HCm to the left): we can see that by the end of January, the level of the water in the lake reached the level of the spillway. The reservoir stayed full of water until May, after that the water level and volume in the lake has decreased (Fig.6-A).

- An analysis of 2 floods arrived on 7th January 1998 and 28 to 31 January is also done on figures 7 and 8.

Table (5) Analysis of flood in Sindyaneh.

Date	Rain -fall	Init.Vol.	Fin. Vol.	Spill. flow	Storage	Vol. Flood	Run -off	Q_{max}	Qs_{max}
Date	mm	m3	m3	m3	m3	m3	mm	m3/s	l/s/km²
03/12/1997	6 0	29 260	29 970	0	710	710	0.19	0.020	5
05/12/1997	0.5	29 260	29 730	0	470	470	0 12	0.029	8
09/12/1997	27.0	29 020	30 450	0	1 430	1 430	0.38	0.153	40
16/12/1997	21.5	29 970	31 640	0	1 670	1 670	0.44	0.023	6
18/12/1997	14.0	31 160	33 070	0	1 910	1 910	0.5	0.019	5
23/12/1997	6 0	33 070	34 490	0	1 420	1 420	0.37	0.004	1
29-30/12/1997	23.5	34 490	37 350	0	2 860	2 860	0 75	0.043	11
31/12/1997	6.0	37 350	40 200	0	2 850	2 850	0.75	0.027	7
03/01/1998	0 5	40 200	41 400	0	1 200	1 200	0.32	0.019	5
04/01/1998	1.0	41 400	44 250	0	2 850	2 850	0.75	0.023	6
06-07/01/1998	102.0	44 250	280 850	0	236 600	236 600	62.3	9.960	2 621
10-16/01/1998	23.0	280 850	361 420	0	80 570	80 570	21.2	0.482	127
23-24/01/1998	19	361 420	374 900	0	13 480	13 480	3.55	0.105	28
25/01/1998	30.5	374 900	430 630	0	55 730	55 730	14.7	2.140	563
28/01/1998	26.5	430 630	448 210	44 855	17 580	62 435	16.4	3 980	1 047
29/01/1998	6.6	448 010	448 010	24 830	0	24 830	6 53	1.852	487
30/01/1998	7.4	443 380	443 380	19 150	0	19 150	5.04	1.226	323
06/02/1998	8.0	426 490	429 970	0	3 480	3 480	0.92	0.084	22
07/02/1998	51.5	429 970	434 560	78 374	4 590	82 964	21.8	10.263	2 701
14/02/1998	9	434 610	434 665	841	55	896	0.24	0.116	30
01/03/1998	4.0	428 810	433 450	0	4 640	4 640	1.22	0.030	8
17-20/03/1998	60.0	428 810	433 160	4 507	4 350	8 857	2.33	0.056	15
23/03/1998	17.5	434 610	434 650	2 213	40	2 253	0 59	0.191	50
24/03/1998	14 5	434 610	435 220	7 940	610	8 550	2.25	0 301	79
28/03/1998	4.0	429 970	433 450	96	3 480	3 576	0.94	0.065	17
29-30/03/1998	48.5	433 450	434 185	65 412	735	66 148	17.4	2.499	658
03-04/04/1998	15.5	433 450	434 644	17 393	1 194	18 587	4.89	1.156	304
13/04/1998	0.5	431 130	432 290	0	1 160	1 160	0 31	0.014	4
21/04/1998	33.5	429 970	434 540	614	4 570	5 184	1.36	0.407	107
22/04/1998	45.5	434 610	435 060	5 800	450	6 250	1.64	1.583	417
26-27/04/1998	10.0	432 290	434 295	1 995	2 005	4 001	1.05	0 059	16
15/11/1998	16.0	26 000	26 600	0	600	600	0.16	0 011	3
24/11/1998	0 5	25 600	26 000	0	400	400	0.11	0.038	10
29/11/1998	42	25 200	25 600	0	400	400	0.11	0.056	15
30/11/1998	20 5	25 200	28 100	0	2 900	2 900	0.76	0.222	58



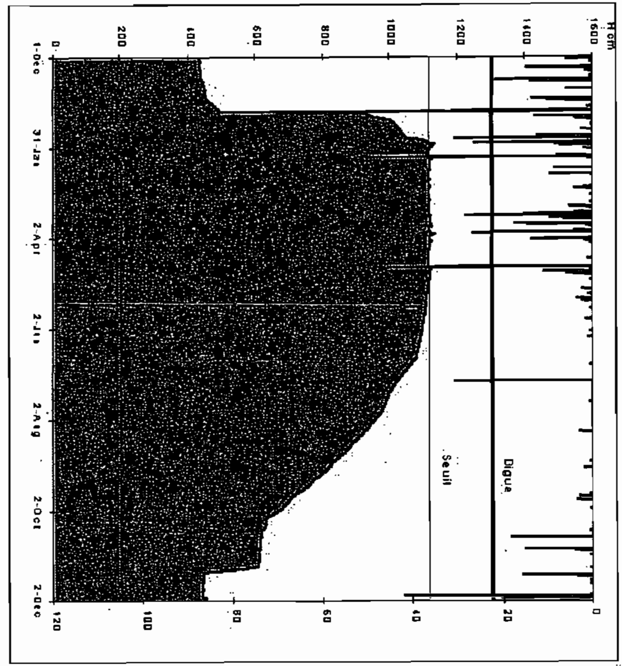


Fig. 6-A – Rerelationship between precipitation (in mm) and variation of water level in the lake expressed as H in Cm.

Fig. 6-B – Variation of volume of water stored in the lake from December 97 to 2 Dec. 98.

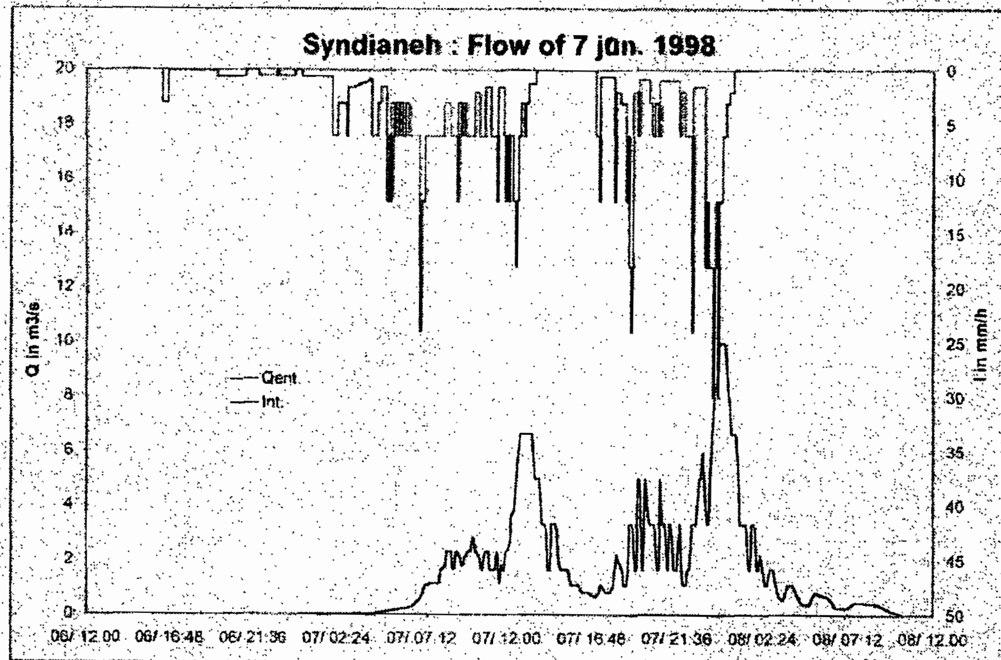


Fig. 7 – Flood analysis of rain storm event on 7 January 1998.

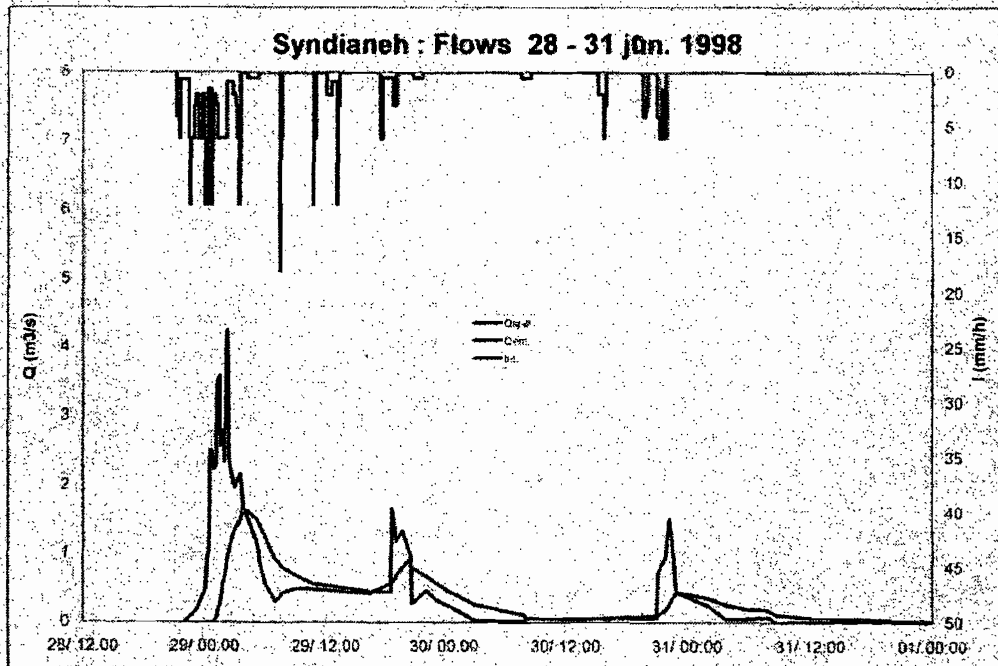


Fig. 8 – Flood analysis of rain storm event of 28-31 January 1998.

These Figures show the relationship between precipitation and quantity of runoff given as Q for a given time.

We can see the variation of discharge related to each quantity of precipitation.

- A tentative estimation of runoff coefficient has been done in figure 10 where we have as coordinates the precipitation in mm and runoff in mm expressed as thickness of water. The runoff coefficient could be estimated to vary between 30 to 40% , which is in good agreement with values known for such areas.

Conclusion:

It is the first time that a study on water budget of small catchment areas could be done in Syria. HYDROMED research programm has facilitated this work by providing the necessary equipment and the scientific support to conduct such study. The processing of initial data acquired from the pilot site of Sindyaneh has shown that the results obtained by using softwares produced by ORSTOM within the framework of HYDROMED programm, are in good agreement with observation. It was also possible for the first time in Syria to calculate the runoff coefficient for Sindyaneh basin.

Monitoring on the site will continue later, and a new campaign to measure the sediments in the lake will be done. Such measurement will help to estimate the rate of erosion on the watershed, which is a major question in Syria.

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SINDYANEH HILL RESERVOIR

Latitude : 34° 42 N **Longitude : 36° 25 E**
Y = 4843 Km **X = 377.8 Km**
Mohafazat : Homs **Basin : Assi**

Characteristics of Catchment Area:

Surface Area :.. **4.2**................. **Km²**

Annual Precipitation:.. **767**................ **m m**

Rainfall Stations : ....Sadd K. Hammam ....

Years Covered : ....**1972-1993**...

Annual Evaporation: .... **1370**............. **m m**

Length of Wadi : .... **4.2**................ **Km**

Maximum Altitude :.. **620**.............. **m**

Minimum Altitude :.. **500**............. **m**

Slope : ....**29**.............**m/Km**

Rocks : ....Basalt...

Soils : ....Clay ....

Sediments : ......Low Suspended Load ....

Socio-Economic Conditions: ..Well educated, medium to poor people .....

Characteristics of Lake :

Year of Construction : .... **1967**........

Volume of Retention (V) ....**360 000** .... **m³**

Surface of Retention (S) ....**90 000** .... **m²**

Ratio (V/S) ....**4** .... **m**

Dyke Height ....**12** .... **m**

Dyke Length ....**512** .... **m**

Nature of Spillway ....Lateral ....

Height of Spillway ....1 ....m

Width of spillway ....**12** ....**m**

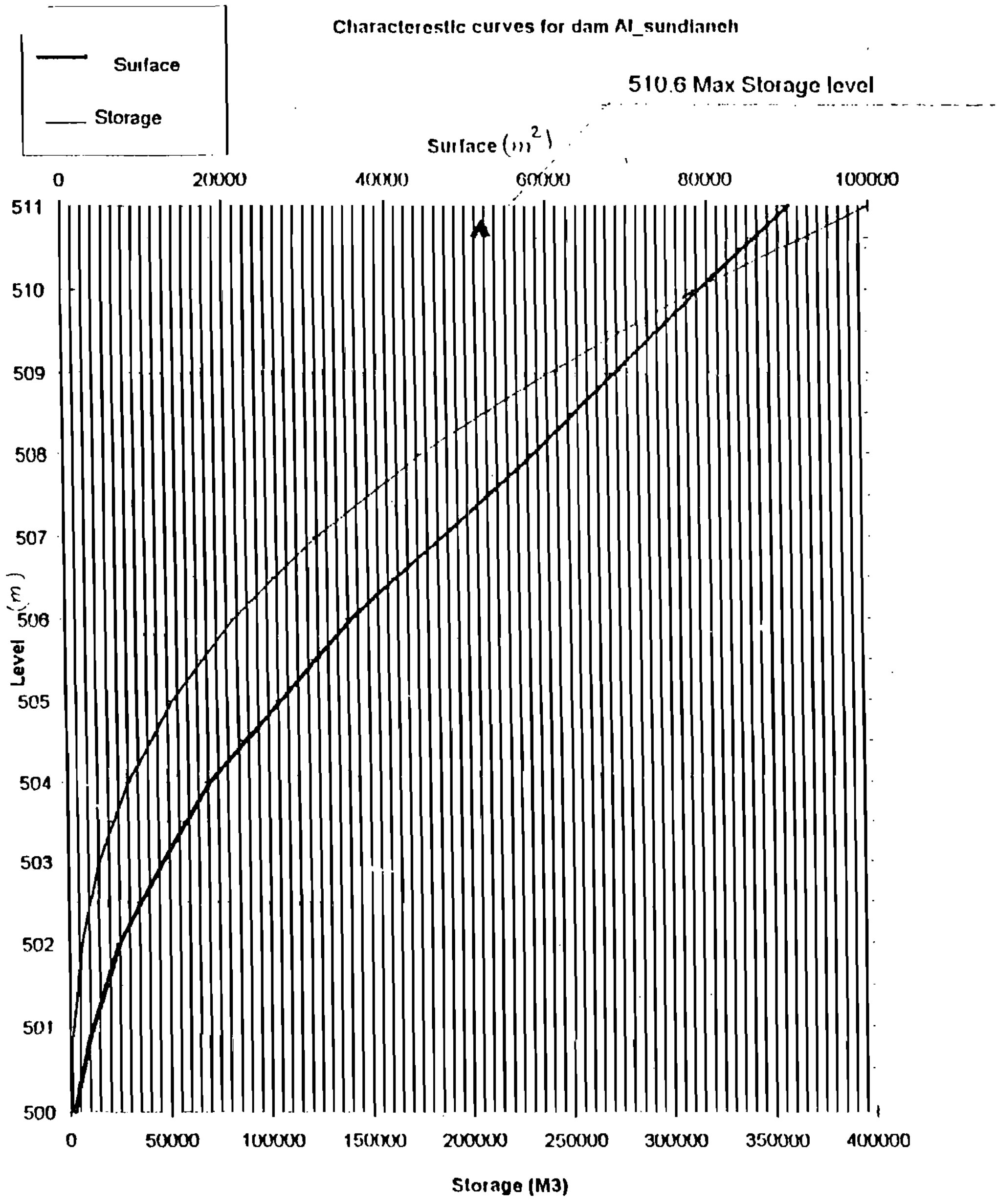
Maximum discharge of Spillway .... **20** ....**m³/Sec**

Diameter of Outlet Pipe ....**300** .... **mm**

Water Use : .... Irrigation ....

Water Quality :.................Hydrocarbonate ....

N.B. : No Crest for spillway.


Characterestic curves for dam Al_sundianeh
Surface
Storage
510.6 Max Storage level
Surface (m^2)
0
20000
40000
60000
80000
100000
511
510
509
508
507
506
505
504
503
502
501
500
Level (m)
0
50000
100000
150000
200000
250000
300000
350000
400000
Storage (M3)

							Station	SACD K.HAMAM					
		Longitude:		38.25 E		Latitude	34.42 N	Eleva		840 M.S.L			
HYD_YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JULY	AUG	SEP	YEARLY
72_73	73.3	74.4	24.2	85.6	39.2	130.8	59.7	0.3	24.8	0	0	0	492.1
73_74	28.4	58.8	123.6	140.5	81.5	63.1	60.4	0	0	0	0.4	0.7	557.4
74_75	10.2	137	87.1	72	227.8	63.2	55.8	9.9	0	0	0	0.9	663.7
75_76	1.1	111	168.9	117.5	205.2	86.3	131.2	27.4	0	12.2	0	20.1	880.9
76_77	156	56	102	123.2	87.1	202.8	28.5	7.3	7.2	0	0	0	789.9
77_78	37.4	26.2	111.7	144.4	84.8	116.9	28	23.2	0	0	0	0	572.6
78_79	29	10.6	78.6	157.9	40.6	80.8	30.1	26.1	0	0	0	0	453.7
79_80	79.7	153.9	96.8	251.7	97.4	170.1	173.6	15.2	0	0	0	0	1038.4
80_81	32.1	41.1	191.9	289.9	122.5	95	65.6	27.4	11.2	0	0	0	856.7
81_82	10.2	117.5	188.5	116.7	140.9	73.3	38.7	13.5	0	0	0	0	699.3
82_83	44.7	66.6	49.7	100.3	247.1	38.4	42.1	50.3	10.1	0	0	0	649.3
83_84	31.8	112.6	28.5	115.1	77.6	129.2	126.1	0	0	0	0	0	620.9
84_85	100	49.4	77.4	88.7	207.1	29.3	17.7	5.4	0	0	0	0	575
85_86	85.2	39.9	145.2	112	88.4	22.6	3.2	9.1	4.4	0	0	0	510
86_87	15.9	113	142.7	178.5	80.9	396.8	32	0	0	0	0	0	959.8
87_88	27.6	126	21.2	257.9	193.5	200.6	19.5	6.5	25.4	0	0	2.2	880.4
88_89	58.8	153.9	208.5	66.7	63.4	14.5	10.2	13.7	0	0	0	0	587.7
89_90	34	114.9	132.2	61.7	156.1	0	38.1	8.5	0	0	0	0	545.5
90_91	8.6	90.4	161.1	415.5	290.9	195.1	241.5	17.2	0	0	0	0	1420.3
91_92	121.5	86.7	432.5	419.9	180.9	13.3	0	60.6	58.7	0	0	16.4	1392.5
92_93	0	117.3	169.9	97.2	196.4	238.6	25.9	142.7	0	0	0	0	988
93_94	11.1	81.1	29.6										
										Xo=			767.34
										Secma=			274.01
										Cv=			0.3571

TELKALAKH HILL RESERVOIR

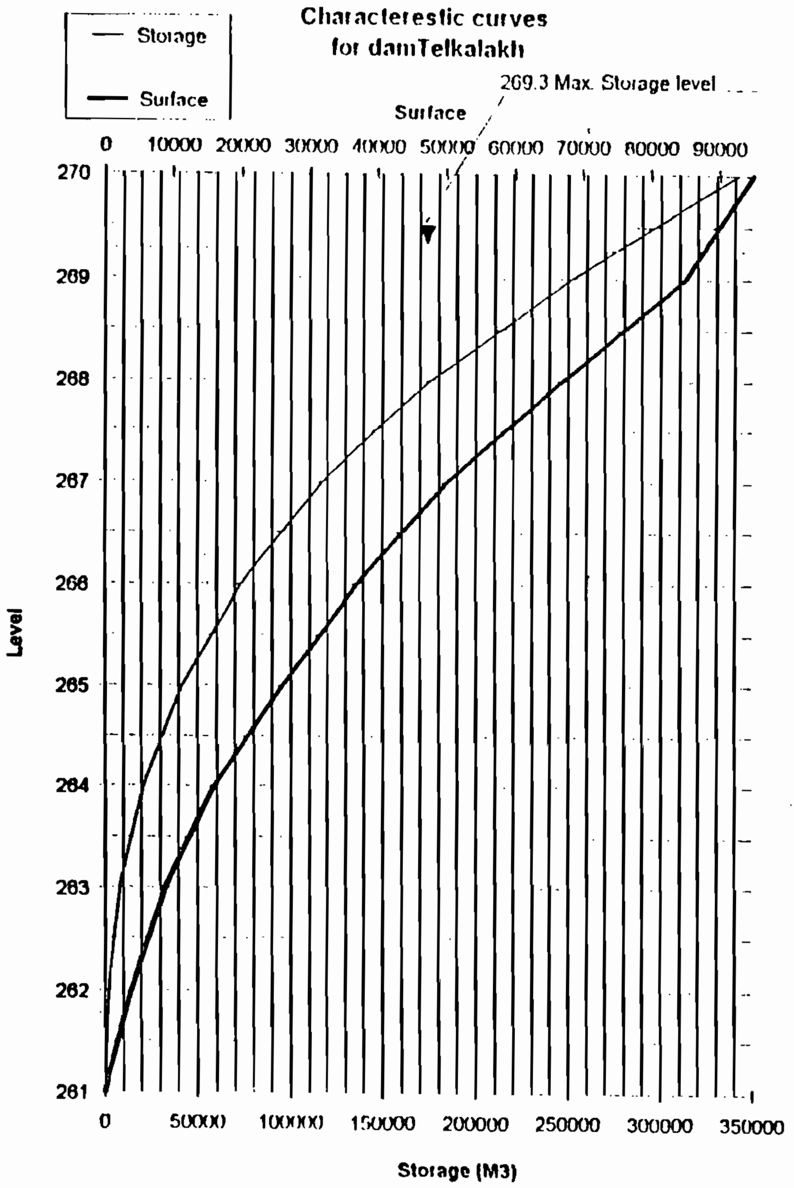
Latitude : 34° 41' N Longitude : 36° 16' E
Y = 3841.2 Km X = 361.5 Km
Mohafazat : Homs Basin : Assi

Characteristics of Catchment Area:

Surface Area :.. 1.75 .... Km^2
Annual Precipitation:.. 789................ m m
Rainfall Stations : ....Sadd Telkalakh ....
Years Covered : ....1971-1991..
Annual Evaporation: .... 1370............. m m
Length of Wadi : .... 3.3............... Km
Maximum Altitude :.. 390.............. m
Minimum Altitude :.. 210............. m
Slope : .... 54.5..........m/Km
Rocks : ....Basalt.......................................
Soils : ....Very thin Clay ....
Sediments : ......Medium .. ..
Socio-Economic Conditions: ..Poor to average standard ....

Characteristics of Lake :

Year of Construction : .... 1970........
Volume of Retention (V) ....290 000 .... m^3
Surface of Retention (S) ....90 000 .... m^2
Ratio (V/S) ....3.22 .... m
Dyke Height ....10 .... m
Dyke Length ....270 .... m
Nature of Spillway ....Lateral...
Height of Spillway .... 0.94 .... m
Width of spillway .... 20 .... m
Maximum discharge of Spillway ....7...........m^3/Sec
Diameter of Outlet Pipe ....300 .... mm
Water Use : .... Irrigation ....
Water Quality :.................Hydrocarbonate with high turbidity ....



Characterestic curves
for damTelkalakh
Storage
Surface
269.3 Max. Storage level
Surface
0 10000 20000 30000 40000 50000 60000 70000 80000 90000
270
269
268
267
266
265
264
263
262
261
Level
0 50000 100000 150000 200000 250000 300000 350000
Storage (M3)

								Monthly Amount of precipitation				(mm)	
							Station		SAD TEL KALAKH				
		Longitude:		36.16 E		Latitude	39.41 N		Eleva		225 M.S.L		
HYD_YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JULY	AUG	SEP	YEARLY
71_72	16.1	112.2	286.6	129.8	91.6	59.7	78.4	47.9	1	0	0	0	823.3
72_73	116.7	73.3	19.4	115.8	37.2	160.7	61.3	14.5	0	0	0	0	598.9
73_74	25.1	121.4	126.1	178.8	34.5	46.7	58.8	0	0	0	0	0	591
74_75	6.9	162.6	142.6	135.9	226.6	84.8	87.3	9.5	1.5	0	0	2.5	860.2
75_76	9.1	118.1	166.7	120.2	211.4	67.9	122.3	27.1	5.7	10	0	1	859.5
76_77	102.4	70.2	113.1	109.2	75	149.5	57.7	3.9	19.9	0	0	2.6	703.5
77_78	134	39.1	198.9	177.4	152.3	158.4	15.6	19.3	18.2	0	0	0	911.2
78_79	76	16.1	113.5	254.8	65.8	117	52.8	6.1	0	0	0	0	702.1
79_80	116.8	174.9	88.2	204.1	123.8	109.3	84.6	20.6	1.4	0	2.4	0.7	926.8
80_81	100.5	40.7	218.9	217.9	173.4	96.4	80.1	15.9	15.6	0	0	0	959.4
81_82	7.5	252.3	134.6	135.2	135.6	115.8	21.2	9.5	0	0	0	11.8	823.5
82_83	61.5	67.8	87.4	61.5	407.7	84	75.7	36.3	12.4	0	0	4.1	898.4
83_84	60.2	150.5	63.7	148	91	169.6	147.6	0	0	5.5	0	0	836.1
84_85	99.3	127.6	56.8	144.6	219.1	29.3	21.4	3.7	0	0	0	0.1	701.9
85_86	83.8	108.6	101.9	142.2	154.1	27.1	11.6	21.2	12	0	0	0	662.5
86_87	39.9	174.1	181.8	174.1	108	297	62.9	0	0	0	0	0	1037.8
87_88	73.7	136	252.8	258.3	203.2	150.1	34.1	7.8	2.8	0	0	11.5	1130.3
88_89	74.9	164.3	166.5	25.7	40	19.2	8	12	0	0	0	0	510.6
89_90	73.6	125.5	124	80.9	16	28.3	14	0	0	6.1	4.2	15.2	487.8
90_91	140.1	0	120.5	165.6	68.8	126.9	104	19.2	0	0	0	0.3	745.4
91_92	29.4	120.5	324.9										
92_93												Xo=	788.5
												Segma=	170.42
												Cv=	0.2161

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Lund Institute of Technology, Lund University
Sweden

Proceedings of the International Seminar
Rain water harvesting and management of small reservoirs in arid and semiarid areas

an expert meeting within the EU-INCO collaboration HYDROMED (Program for research on hill reservoirs in the semiarid zone of the Mediterranean periphery).
Lund University, 29 June - 2 July, 1998

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