Created by a Law dated on 14 August 1954 and rectified later on 30 December 1955:

- Execute the Litani River Master Plan
- Execute the hydro-electrical power generation and electrical networks and its connection to the electrical distribution networks

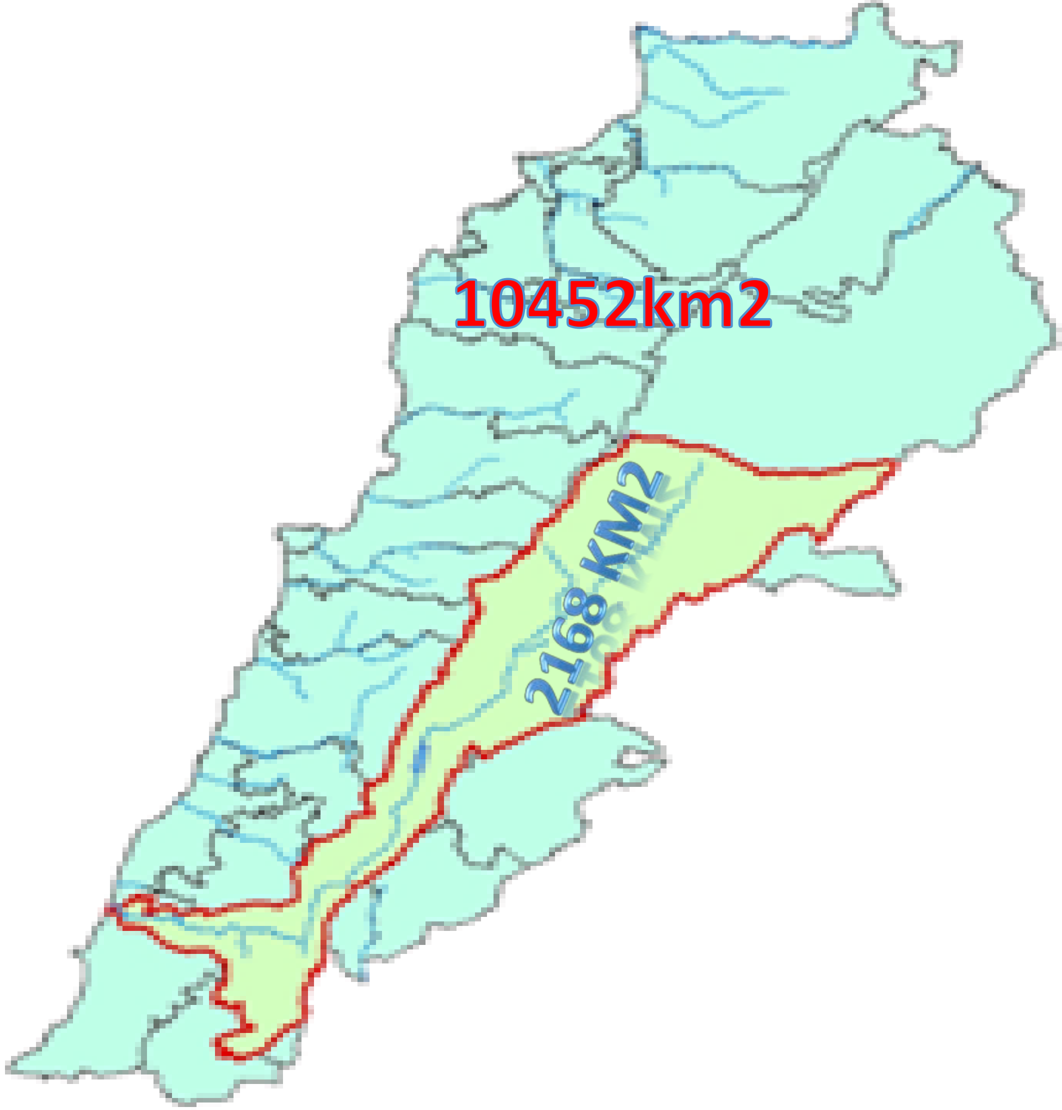
By different decrees, the government of Lebanon adds the following tasks:

- Hydraulic measurements on all Lebanese rivers
- Irrigation schemes studies
- Provider of potable water for south of Lebanon
- Responsible of irrigation schemes in southern Bekaa and south Lebanon
- Study and supervision of Dams

A new Environmental department was created in 2006 to assess the water quality of Litani River & tributaries

Litani River Watershed

- The largest with 2168 square Kilometer representing 20% from the total Lebanese area



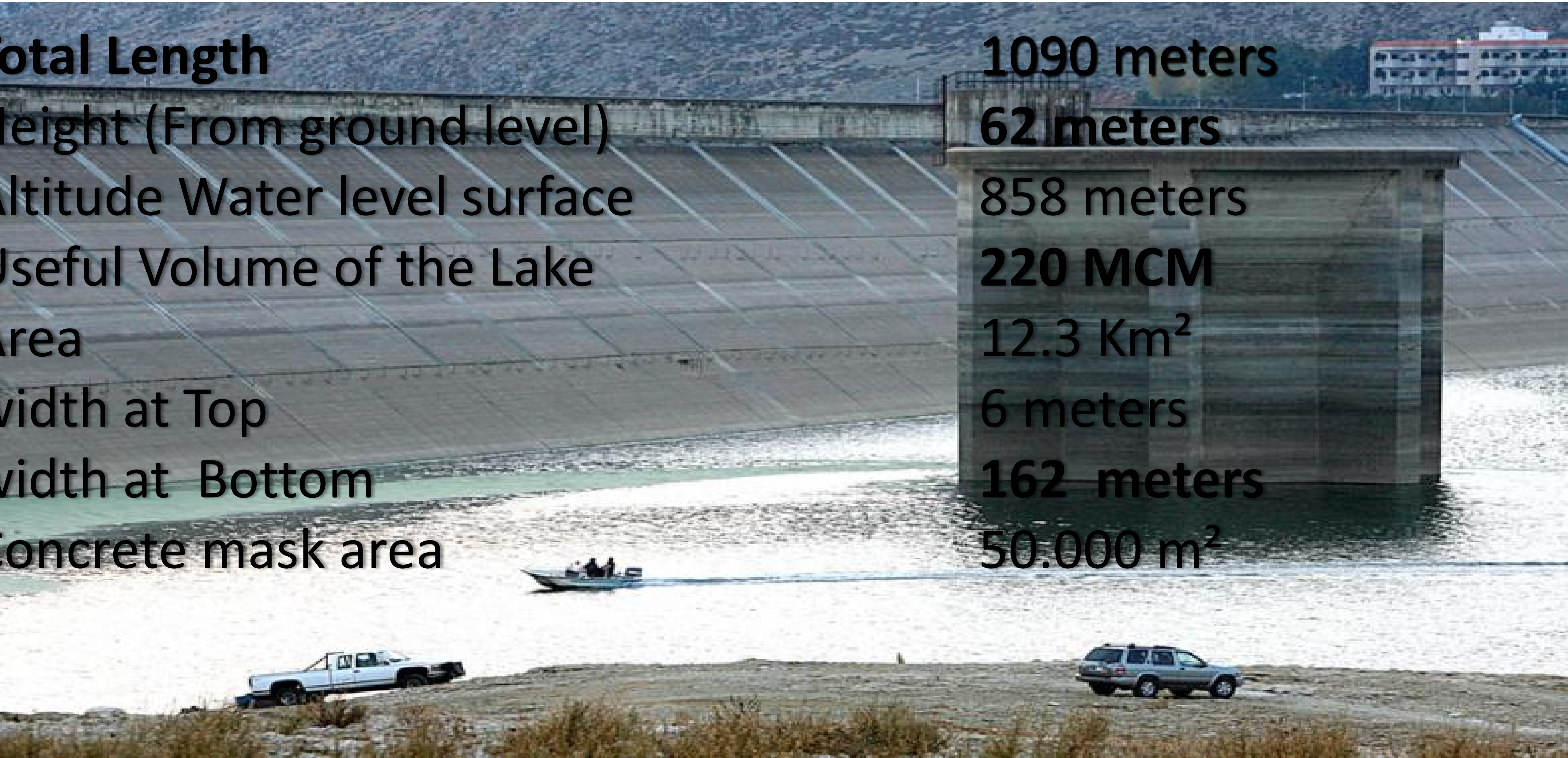
Fadi Doumit
San Diego - Feb 11 2016

Litani River

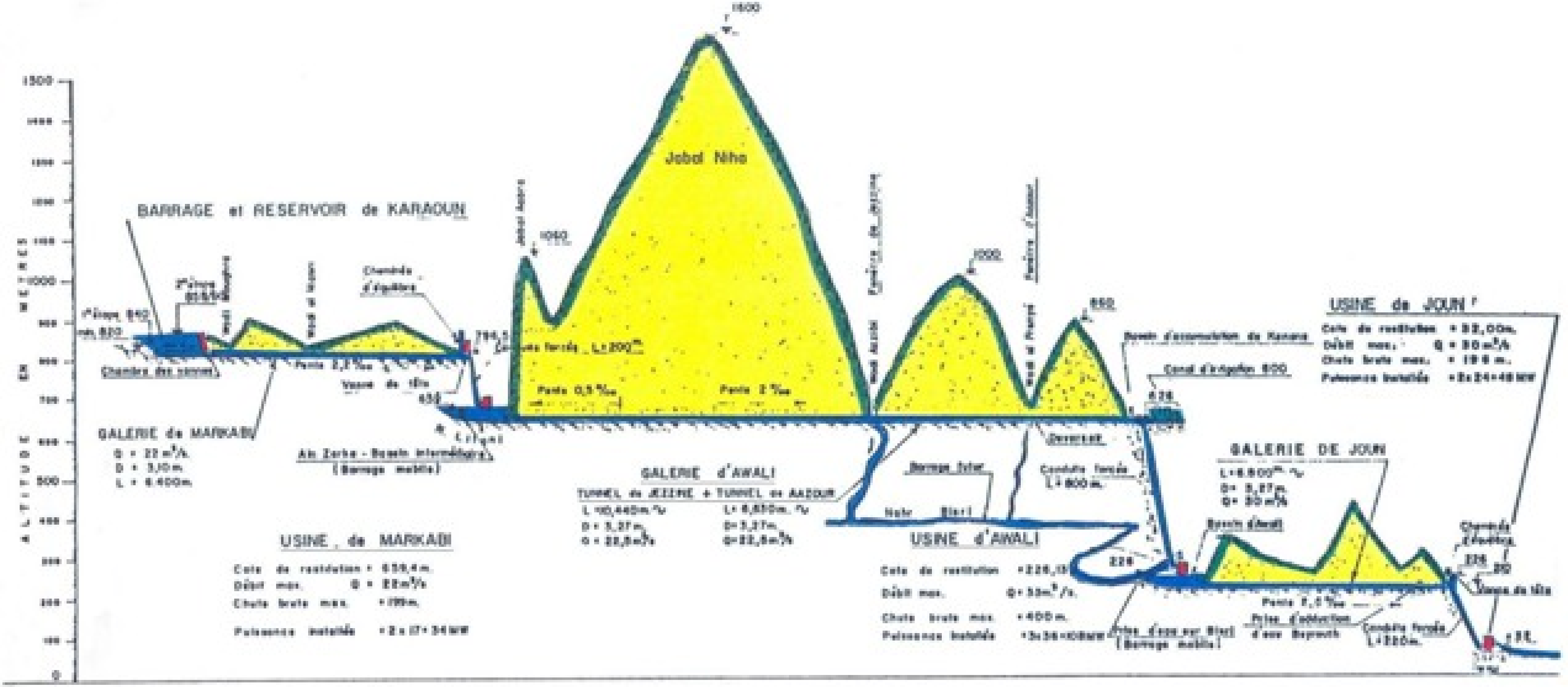
- Totally running in Lebanese territory along 170 Km
- 60 Km of tributaries

- Average annual Flow rate around 750 million cubic meter
- 30% From the total Flow of all Lebanese Rivers

Karaoun Dam Characteristics



otal Length	**1090 meters**
leight (From ground level)	**62 meters**
ltitude Water level surface	858 meters
seful Volume of the Lake	**220 MCM**
rea	12.3 Km^2
vidth at Top	6 meters
vidth at Bottom	**162 meters**
oncrete mask area	50.000 m^2

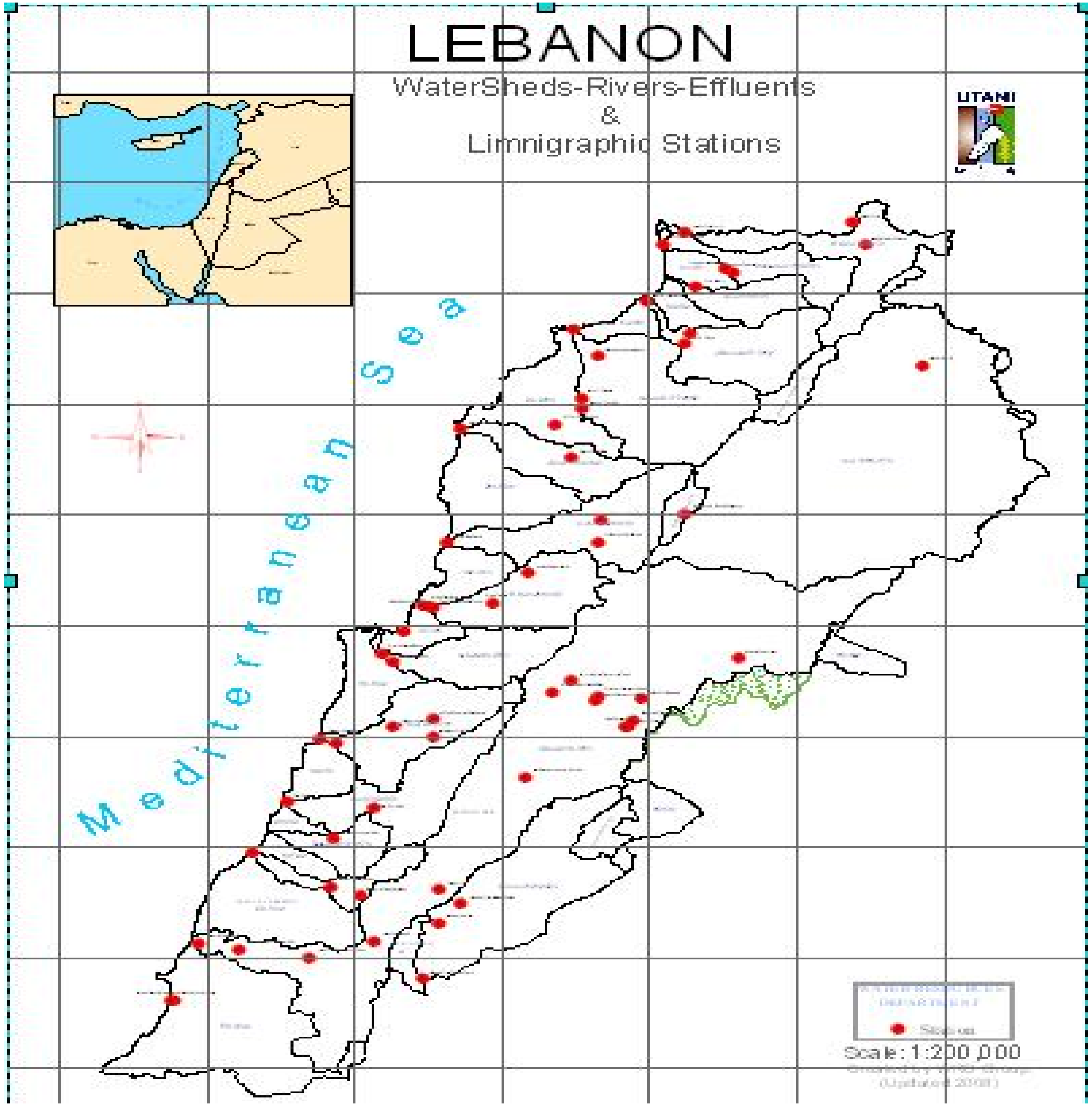


1600
1500
1000
0
Jabal Niha
BARRAGE et RESERVOIR de KARAOUN
1050
1000
850
GALERIE de MARKABI
L = 6.400m.
Ain Zarka - Bassin intermédiaire
(Barrage mobile)
USINE de MARKABI
Cote de restitution
Débit max.
Chute brute max.
Puissance installée
GALERIE d'AWALI
TUNNEL de JEZZINE + TUNNEL de AAZOUR
Nahr Bisri
USINE d'AWALI
Cote de restitution
Débit max.
Chute brute max. = 400 m.
Puissance installée
Conduite forcée
USINE de JOUN
Cote de restitution
Débit max.
Chute brute max.
Puissance installée
GALERIE DE JOUN

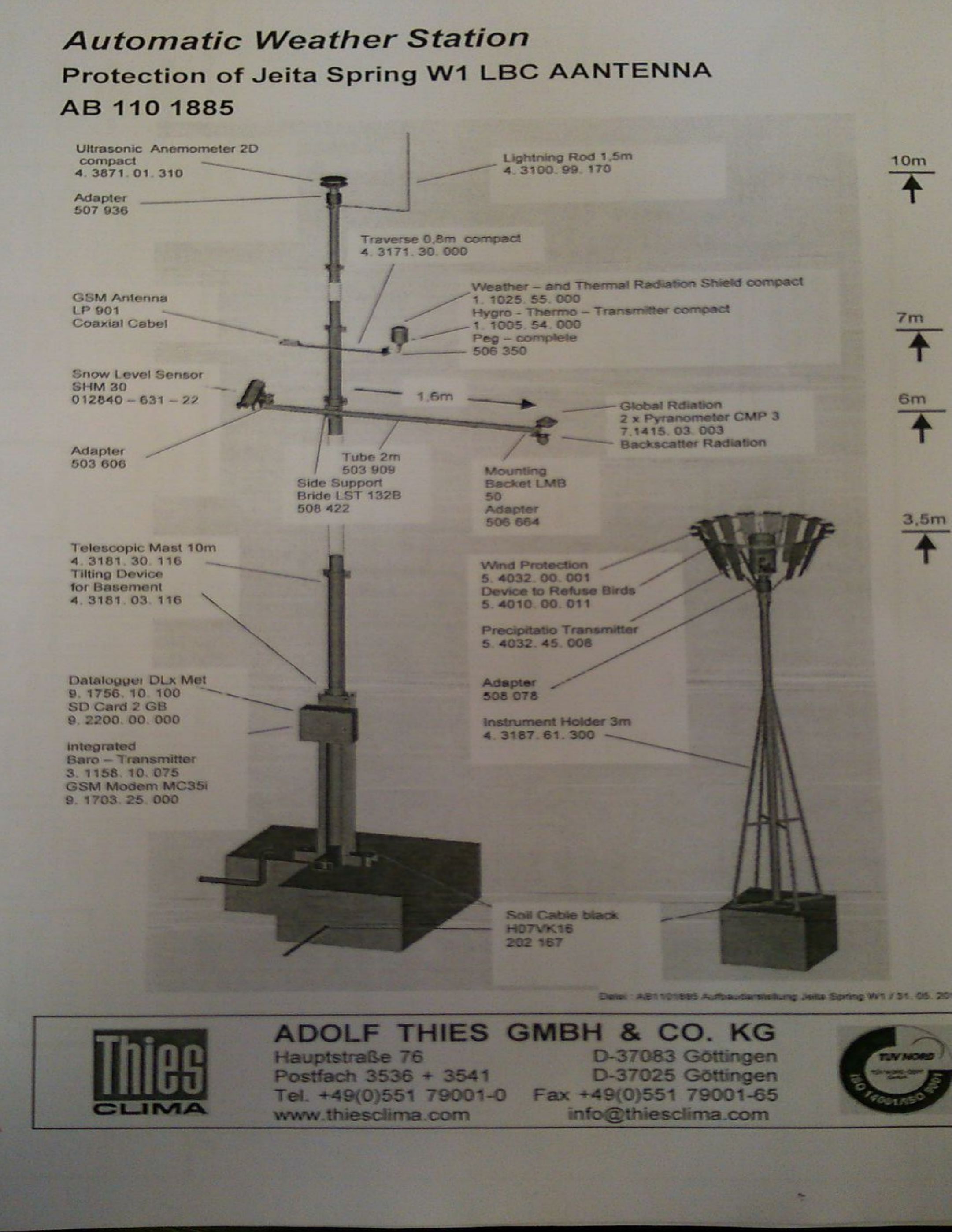
Water Monitoring

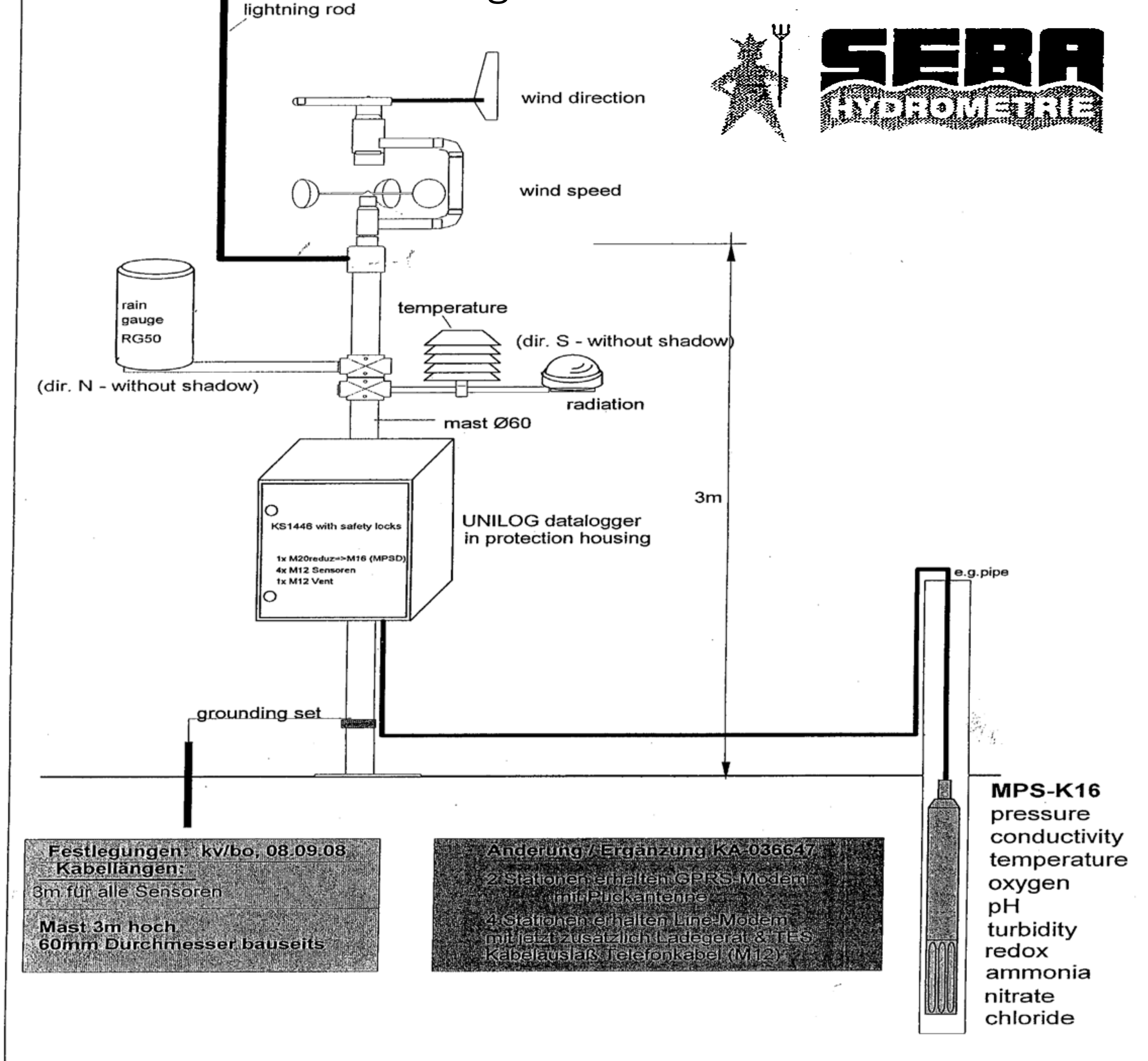
Surface gauging stations on most of Lebanese rivers and tributaries

In addition we have 12 monitoring wells in upper litani basin measuring under ground water level and several weather stations



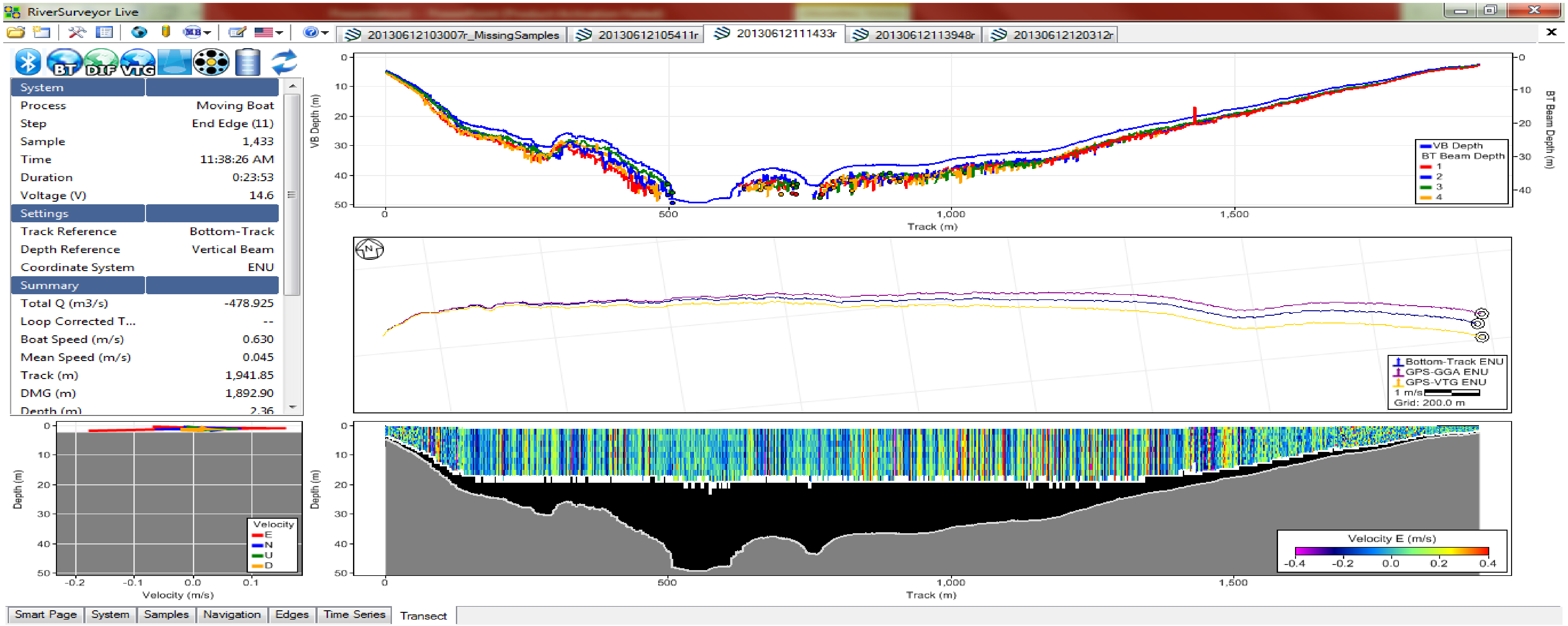
Full monitoring station

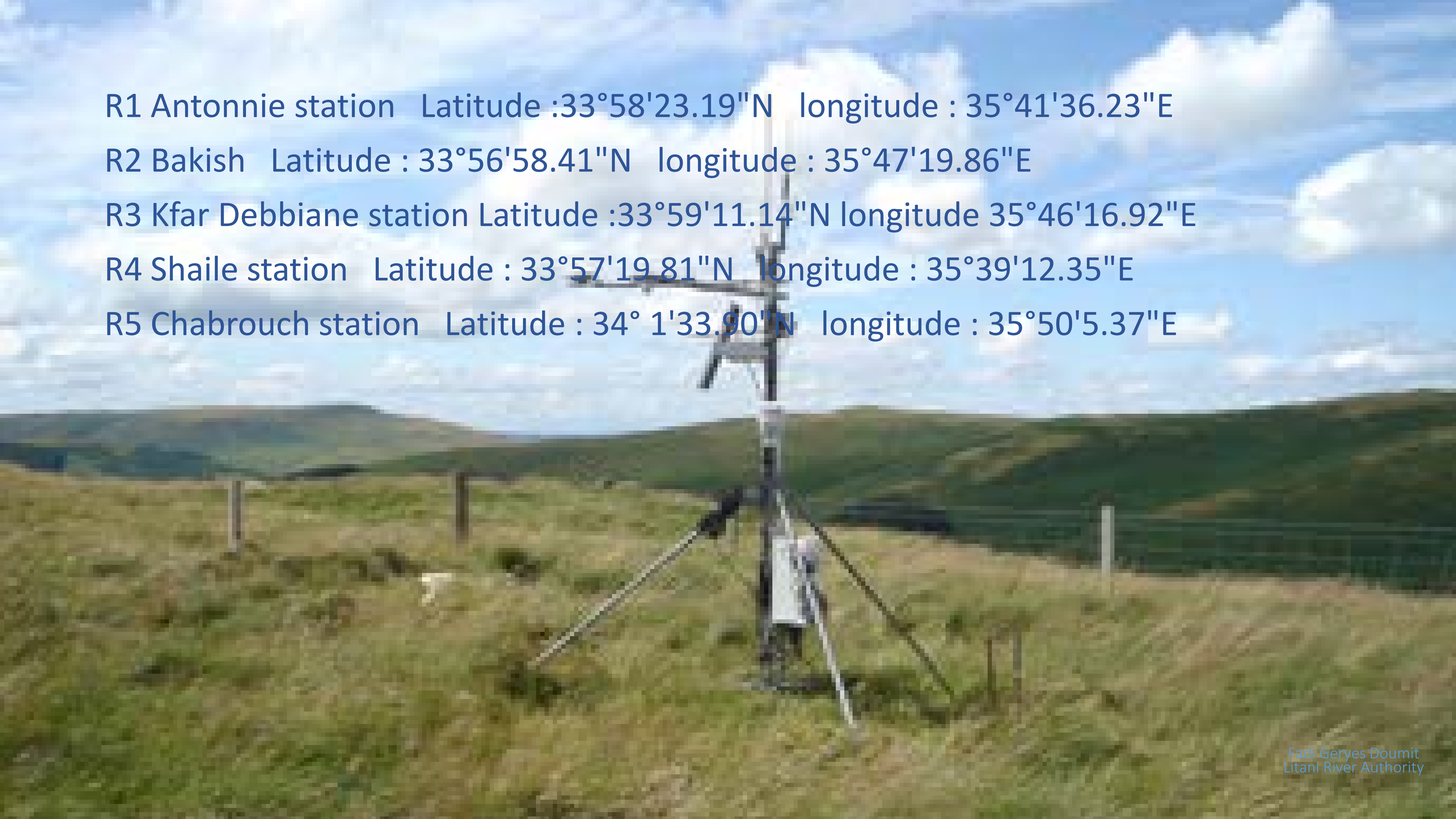




Advanced Surface Water Measurement

Advanced Surface Water Measurement





R1 Antonnie station Latitude :33°58'23.19"N longitude : 35°41'36.23"E

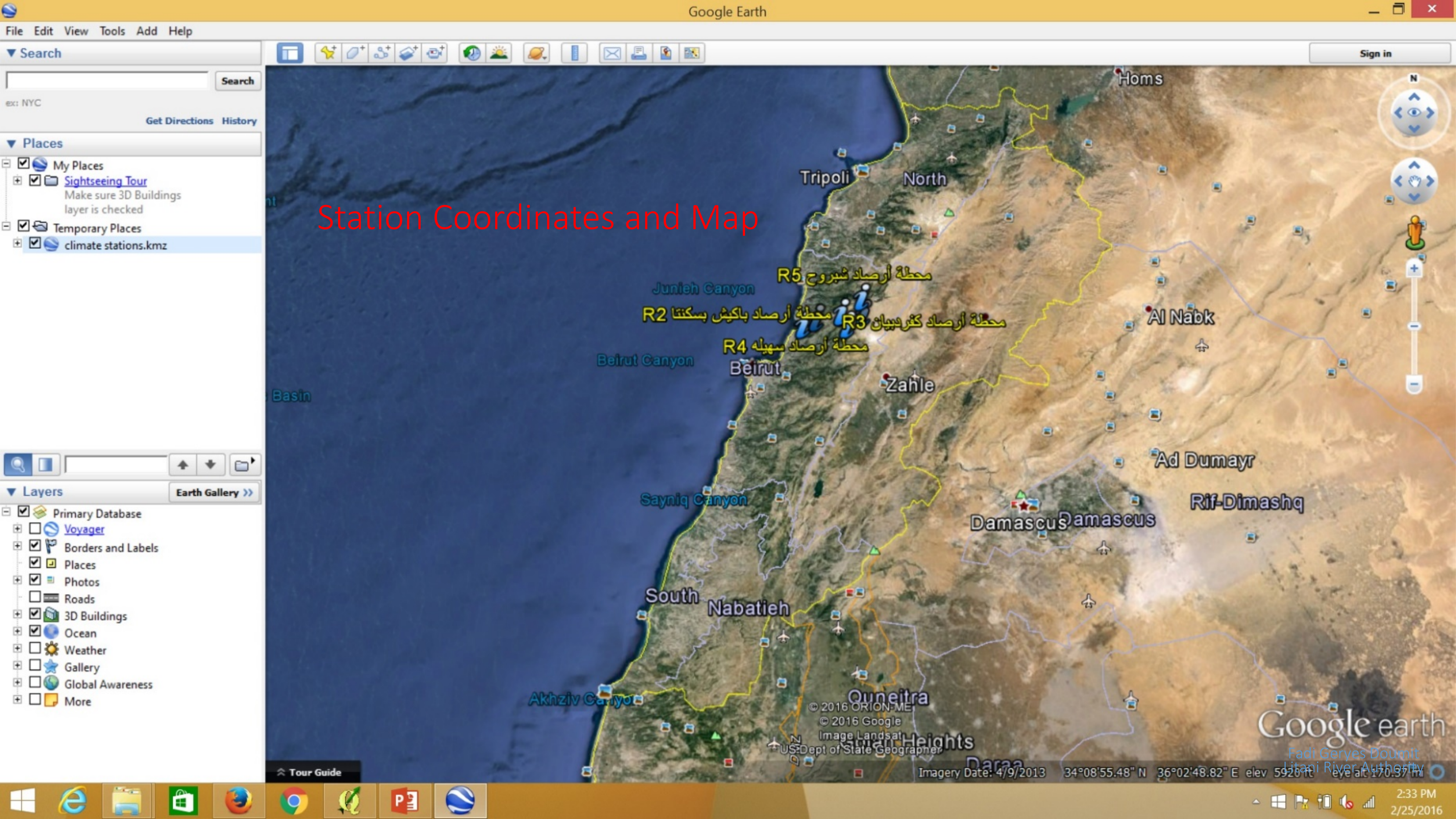
R2 Bakish Latitude : 33°56'58.41"N longitude : 35°47'19.86"E

R3 Kfar Debbiane station Latitude :33°59'11.14"N longitude 35°46'16.92"E

R4 Shaile station Latitude : 33°57'19.81"N longitude : 35°39'12.35"E

R5 Chabrouch station Latitude : 34° 1'33.90"N longitude : 35°50'5.37"E

Station Coordinates and Map



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FROM THE AMERICAN PEOPLE

LITANI RIVER BASIN MANAGEMENT SUPPORT PROGRAM

LITANI RIVER FLOOD MANAGEMENT REPORT
MAY 2012

SUSTAINABLE FLOOD PREVENTION GUIDELINES (UN/ECONOMIC COMMISSION FOR EUROPE, 2000)

Seven basic principles and approaches:

- Flood events are a part of nature.
- Human interference into the processes of nature has increased the threat of flooding.
- Flood prevention should cover the entire catchment area.
- Structural measures will remain important elements of flood prevention and protection, especially for protecting human health and safety, and valuable goods and property.
- Everyone who may suffer from the consequences of flood events should also take precautions on their own.
- Human uses of floodplain should be adapted to the existing hazards.
- In flood-prone areas, preventive measures should be taken to reduce the possible adverse effects on aquatic and terrestrial ecosystems.

While managers and engineers are quick to go for structural solutions such as embankments and

The main findings are that the Litani River Basin suffers from three types of flooding:

- Flooding from the Litani River and Major tributaries (Ghzayel, Berdawni, Qabb Elias); this is due to natural floodplain characteristics, compounded by lack of riverbed maintenance, existence of obstructions such as insufficient road bridges and irrigation weirs or other illegal constructions in the riverbed, dumping of all type of solid and hazardous waste, etc.
- Seasonal flooding from minor channels (Howayzek, Oqeyber, Faregh) mostly due to lack of agricultural drainage; this is due to the impermeability of soils (mostly clayey), and poor maintenance and disappearance of many drainage ditches in farm lands; and
- Local flooding in urban areas (Bar Elias, Marj) during winter rains for lack of storm /sewage networks

The flood of February 2003 was found as historically significant because:

- It is one of the two largest floods in human memory, in addition to possibly 1968;
- The flood caused significant damages:
  - Thousands of hectares of cultivated areas in the Beqaa valley were inundated
  - The West Bekaa was transformed into a series of isolated islands only accessed by the mean of boats or heavy trucks
- It is a recent flood and hence the collection of field information from residents is possible;
- Discharge and level data is available for this flood (from LRA gauging stations)

It was thus used as design flood to calibrate the flood model, assess floodable areas, recommend flood mitigation measures and design flood protection works.

TOPOGRAPHIC SURVEY

Based on the findings of the field survey, a topographic survey was defined and carried out in order to build the computer model. The area surveyed is situated in the upper and mid catchments of the Litani River between Haouch er Rafqa and the Qaraoun Lake in the Bekaa. About 150 river cross sections were surveyed along with 40 identified highwater levels from the 2003 flood.

A Digital Elevation Model was also purchased to provide accurate topography of the central Bekaa and thus provide good support for the mapping of flood risk areas.

HYDROLOGIC STUDY

The peak discharge of the February 2003 flood has been estimated at 182 m3/s in Joub Jenine

Litani	M1 - Marj (868.91m)	L19 (869.02m)	-11
	M2 - Marj (868.36m)	L19A (868.55m)	-19
	D2 - Dalhamieh (882.426m)	L12 (882.3m)	12.6
	MK1 - Mkharit (891.818m)	L9 (891.71m)	10.8
	TA1 - Tell Amara (903.703m)	L6 (903.57m)	13.3
Ghzayel	Damascus Road Gauging Station (868.406m)	G1 (868.47m)	-6.4
	R2 - Rawda (867.209m)	G2 (867.1m)	10.9
	M12 - Marj (866.613m)	G4 (866.60m)	1.3
	B8 - Bar Elias(873.951m)	HO1-B (873.8m)	15.1
	B1 - Bar Elias - Howayzek (871.02m)	HO1-A (871.12m)	-10
	DR1 - Damascus Road - Oqayber (870.521m)	O1 (870.54m)	-1.9
Faregh	H2 - Haouch El Harimeh (865.108m)	F1(865.3m)	-19.2
Berdawni	Damascus Road Gauging Station (871.98m)	B9(871.8m)	18

FLOOD MAPPING

The main objective of the computer flood mapping is to delineate the flood-prone areas, and to define water depths within these areas. Three sets of maps covering the central Bekaa valley from Rayak to Joub Jenine have been thus established:

- Between Haouch el Harim and Mansoura.

- Finally one for the 2003 flood, which confirms the observed flooding, a 2-3 km wide area along the Litani River from Dalhamiye to Mansoura, impacting mostly Bar Elias, Marj and Haouch el Harim.

In all flooded areas, different levels of depths have been identified (0-20cm, 20-50cm, 50-100 cm, 100cm+) to inform about increasing flood intensities.

HUMAN ACTIVITIES INCREASING THE IMPACTS OF FLOODS

Through the field survey and flood analysis, several types of improper human practices and mismanagement were found to exacerbate flood extent and damages:

- Lack of maintenance and vegetation growth in riverbeds
- Direct dumping of solid waste and worksite debris in waterways the riverbed
- Presence of improperly designed bridges or culverts with undersized openings
- Tampering with riverbeds and banks: construction of farmer diversion weirs, ponds and pump sumps, local levees, etc.

Specific bottlenecks are insufficiently sized bridges, where backwater impacts can elevate upstream water levels by 30 cm and much more. Most of these bridges with insufficient sections are situated in the upper part of the Litani river in addition to secondary tributaries such as Howayzek, Oqayber and Faregh.

RECOMMENDATIONS FOR FLOOD PROTECTION AND MITIGATION

The flood management approach is that:

- Protecting all areas for all types of floods is impossible since there can always be a larger flood than the one used to design protections, and can quickly become expensive when it involves infrastructure works; and

- Protecting urban areas should be the priority while rural areas should be kept as expansion areas (flood volumes need to go somewhere and cannot be simply channeled through).

Flooding damage can be prevented or at least significantly mitigated with simple foreseeing urban planning measures. The following recommendations are meant to enhance the safety of persons, limit the damage to property and the nuisances for human activities, while ensuring the free flow of water and the conservation of areas designated for flood expansion. They consist of prohibitions on land use and requirements and recommendations to prevent damage:

Flooded zone with flooding	Where	Urban development

1.2. REPORT / STUDY OBJECTIVES

The objective of this report is to develop a flood management plan for the Upper Litani River, that is to:

i. Define flooding events, in terms of duration, extent, damages, and produce mapping of floodable and risk areas for different magnitudes of floods.

ii. Identify structures and urban development and agricultural practices negatively impacting floods and their impacts.

iii. Define structures and river management works that will decrease/mitigate the impact of floods.

iv. Prepare recommendations to promote urban development and agricultural practices that mitigate flooding in the Litani river basin.

Most of the report findings, notably the definition of risk areas and of mitigation works, is based on the use of a flood model for the Upper Litani River, that is a mathematical flood model which was developed through:

- A topographical survey to collect river geometry;
- A field survey to collect 2003 maximum flood levels from witnesses and pictures;

- A calibration process whereby the flood model parameters are adjusted so that the model flood levels (for 2003 discharges) are close (+/- 30 cm) to the witnessed flood levels.

The flood model can then be used to represent other floods than 2003, either smaller and thus more likely to happen, or larger and thus less likely to occur but more likely to cause damage.

1.3. PROJECT AREA

The area concerned by this study is situated in the upper and mid catchments of the Litani River.

The upper sub-catchment covers approximately half of the basin (50%), having a considerable width (up to 30 km), and hosting the major springs yielding in the basin. The middle sub-catchment covers 20% of the basin and imbeds the Quaroun Lake. Slope gradient shows a moderate increase from upper sub-catchment to middle sub-catchment.

Its total area is provided in figure 1.1 and includes the following villages and towns:

Haouch er Rafqa, Temnine el Tahta, Rayak, Haouch Hala, Tell Amara, Dalhamieh, Bar Elias, El Marj, El Establ, Haouch el Harime, Ghazze, Mansoura, Tell Znoub, Joub Jannine…

2.2. PRINCIPLES OF FLOOD MANAGEMENT

The United Nations and Economic Commission for Europe Sustainable Flood Prevention Guidelines (UN/ECE 2000) outline seven basic principles and approaches:

- Flood events are a part of nature.
- Human interference into the processes of nature has increased the threat of flooding.
- Flood prevention should cover the entire catchment area.
- Structural measures will remain important elements of flood prevention and protection, especially for protecting human health and safety, and valuable goods and property.
- Everyone who may suffer from the consequences of flood events should also take precautions on their own.
- Human uses of floodplain should be adapted to the existing hazards.
- In flood-prone areas, preventive measures should be taken to reduce the possible adverse effects on aquatic and terrestrial ecosystems.

The UN/ECE guidelines focus on recommendations for water retention areas, land use, zoning and risk assessment, structural measures and their impact, and early warning and forecast systems. Public awareness, education, and training comprise another important element of preventive strategies.

3. INTRODUCTION TO FLOOD MODELS

3.1. DEFINITION OF A FLOOD

A flood is an overflow of an expanse of water that submerges land. The EU Floods directive defines a flood as a temporary covering by water of land not normally covered by water. In the sense of "flowing water", the word may also be applied to the inflow of the tide. Flooding may result from the volume of water within a body of water, such as a river or lake, which overflows or breaks levees, with the result that some of the water escapes its usual boundaries.

While the size of a lake or other body of water will vary with seasonal changes in precipitation and snow melt, it is not a significant flood unless such escapes of water endanger land areas used by man like a village, city or other inhabited area.

Floods can also occur in rivers, when flow exceeds the capacity of the river channel, particularly at bends or meanders. Floods often cause damage to homes and businesses if they are placed in natural flood plains of rivers. While flood damage can be virtually eliminated by moving away from rivers and other bodies of water, since time out of mind, people have lived and worked by the water to seek sustenance and capitalize on the gains of cheap and easy travel and commerce by being near water. That humans continue to inhabit areas threatened by flood damage is evidence that the perceived value of living near the water exceeds the cost of repeated periodic flooding.

3.2. PURPOSE OF A FLOOD MODEL

Preventing and/or mitigating flood damage to human, lives, constructions and activities due to flooding is commonly done through:

- An assessment of past flood events, based on an extensive field survey, which involves visual inspections of structures and unrepaired damage, identification of possible high water marks, riverbed erosions and other hydro-morphological signs. The interview of witnesses is also essential to inform the extent, duration, and impact of the floods, even if such accounts have to be cross-referenced. The field survey allows to identify properly all features impacting flows, both natural (meanders, riverbed changes, and artificial (bridges and other structures or obstructions, embankments, etc.) and their level of impact.
- A topographic survey (defined during the field survey) that provides essential hydraulic data such as river cross-sections, opening and sections of bridges, crests of riverbanks, weirs and embankments, etc.
- A hydrological study based on available data from gauging stations such as flood discharges and water levels.
- The use of a flood model, which allows to:

- First properly describe past (known) flood events, so as to better understand these (through the mapping and floodable areas, the definition of high risk buildings and areas, the identification of bottlenecks such as bridges, etc.)
- Then extrapolate to other types of floods, either larger or simply different, to assess their potential impact on structures, constructions and human activities at large;
- Also simulate flood protection or mitigation measures (channel improvements, construction, modification or replacement of structures such as bridges and embankments, construction of reservoirs, etc.) and to assess their influence on flood impacts and potential damage.
- Finally define integrated flood protection plans that combine different activites (from urban planning
- Also simulate flood protection or mitigation measures (channel improvements, construction, modification or replacement of structures such as bridges and embankments, construction of reservoirs, etc.) and assess and compare their influence on flood impacts and potential damage;
- Finally define integrated flood protection plans that involve and combine the most effective, sustainable and cost efficient measures in terms of structures as well as practices and activities (from more responsible urban planning to better agricultural practices).

The various types of flood models are reviewed hereafter.

Most of the Litani River Basin occupies Central and South Bekaa Valley. The valley is sandwiched between Mount Lebanon to the west and the Anti-Lebanon mountain to the east. Winter precipitations fall heavily on both ranges and engender heavy flows which then spread across the valley whose bottom is almost flat and with a low north-south slope (on average 2.5 m/km). Floods are thus common occurrences but with the growth of human activities (farming and urban areas), their impacts are increasing.

According to witnesses' accounts and to information collected during the field survey, it was deducted that from 1962 to present, the flood of February 2003 is one of the two highest floods in addition to possibly 1968. In other years like 1992 people talk about smaller floods. The fact that limited recollection exists regarding other large historic floods can be understood from a combination of factors:

- Past floods had less impacts as people were more informed about floods and floodable areas and were either avoiding such areas (in terms of constructions and farming) or else coping with the events; urban growth has, as often, pushed people to occupy "riskier" areas and thus increased the related impacts;

- Lebanon has had its share of traumatic events in the past 35 years and floods are not necessarily the most dramatic ones, thus preventing good recollection; population changes and moves make it also difficult to find long-term senior residents with a good memory of past floods;

- Clayey soils make also for regular flooding of the valley along the Litani river and it is thus difficult to distinguish between lack of proper agricultural drainage and actual river flooding (as discussed

4.1.4. FLOOD OF 2003

The heavy rains in February 2003 pounded the Lebanese territory and caused great losses. The February 2003 flood is one of the biggest historical floods ever encountered in the Litani. It occurred after approximately 10 consecutive days of heavy rainfall in combination with snowmelt. 36 mm of rainfall were recorded during one day at the station of Haoush el Omara (Zahle) in the Bekaa Valley (in reference to Assafir newspaper 22/2/2003).

The area in the valley affected by flooding is reported to be more than 400 km2, extending from north of Damascus road near the village of El Delhamieh to Job Jannine. The circulation was partially or completely stopped in more than three locations on Damascus road.

In the Bekaa valley, the meteorological station of Haoush el Omara has recorded 772.4 mm of rainfall since winter has started whereas it was only 451.1 mm in the same period of previous year. It must be noted that the average calculated over 30 years is 447 mm and that the recorded rainfall is the maximum since 1969 (Meteorological department, International Airport of Beirut).

The Qaraoun Dam has a maximum capacity of 220 MCM and regulates the downstream discharge. Flooding during the first part of February 2003 caused the Litany River Authority LRA to open the security outlets starting from February 16th (in reference to Al-Mustaqbal newspaper 15/2/2003) causing damages in the region located downstream the dam.

The flood caused big damages, 80% of the cultivated area in the Beqaa valley have been totally inundated (in reference to L'Orient le Jour newspaper 20/2/2003). The losses are huge and the most affected regions are: Haouch el Harime, El Khiara, Ghazze, El Mansoura and El Nasriyeh (in reference to Assafir newspaper 2/2003). The West Bekaa was transformed to a series of isolated islands only accessed by the mean of boats or heavy trucks (in reference to Al Anwar newspaper 22/2/2003).

4.1.5. CONCLUSION ON THE FLOOD EVENTS

The Flood of 2003 was the result of heavy rains during several short periods of time in addition to rainfall on snow producing snowmelt which produced a large water runoff.

The floods in the Litani River basin area can be divided into two categories:

6. FLOOD MAPPING

6.1. INTRODUCTION

The main objective of this task was to delineate the flood-prone areas, and to define the potential water depths within these areas. The elevations of the water levels provided by the HEC-RAS computer model are compared to the elevations of the ground in the Valley and thus provides water depths. A Digital Elevation Model (with a 1-m accuracy) was used here to give better information (then existing topographic maps) on the topography of the valley. Data sources were thus:

- **Topographic Survey:** Consisting of cross-sections along the Litani River and Tributaries.
- **1/20,000 Topographic Maps.**
- **Digital Elevation Model (DEM):** a 1m DEM was purchased and covered most of the area under study. An existing 5m DEM (lower accuracy) was used to extend to cover fringe areas.

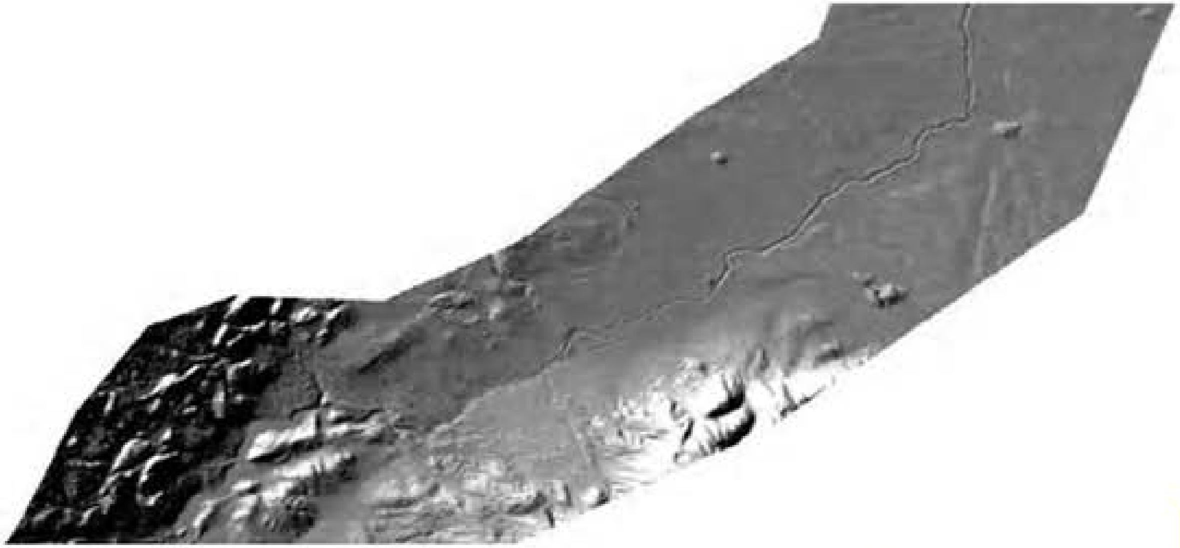

Figure 6.1: Existing Digital Elevation Model (DEM) with Lower Accuracy

Figure 6.1: Existing Digital Elevation Model (DEM) with Lower Accuracy

6.2. RESULTS

The resulting maps represent flooded areas for three different floods:

- A repeat of the 2003 flood, which is exceptional (period of return of 70 years, that is a 1.5 % of happening every year);
- A 25-year flood (85% of 2003), with a 4% chance of happening annually;
- A 10-year flood (70% of 2003), with a 10% chance of happening annually.

Each flood is represented though five maps covering the Litani river from Dalhamiyeh to Joub Jenine:

7. FLOOD AGGRAVATING ACTIVITIES AND OTHER HUMAN IMPACTS

Floods are natural events that happen with or without human presence. Risks and property damages are a direct consequence of people decisions to live in areas prone to flooding. While prevention and mitigation measures can be taken to reduce significantly the risks and potential damages, conversely there are also many human decisions and activities that can increase flood extent, duration and impacts. Such human actions activities need to be identified and reversed or prevented when possible. They include by order of importance:

- Riverbed maintenance;
- Bridges; and
- Riverbed infringements and other detrimental activities.

7.1. RIVERBED MAINTENANCE

A riverbed is a constantly evolving natural feature. Large floods will erode riverbanks and enlarge the riverbed, while prolonged periods of low flows will favor vegetation development, sedimentation, formation of bars. The lateral shifting of a riverbed can in some instances be quite significant, and can of course cause damage to farmlands and real estate property.

The usual human response is to stabilize banks by gabions, riprap or concrete channelization. Unfortunately this approach is expensive and can in the medium to long term create instabilities. For example concrete banks will accelerate the river flow, and thus increase the bottom erosion, which can jeopardize the stability of the banks and of bridges. Lining also the bottom is even more expensive, and often not sustainable while turning the river into a "dead" pipe by preventing any fauna or flora development. Moreover channelizing and increasing the river flow simply transfers flood issues and erosion further downstream.

Riverbed management is thus a difficult comparison between protecting human activities and property without worsening the situation and in parallel ensuring that the river remains healthy for riparians and biodiversity.

There is currently no planned approach to riverbed maintenance of the Litani. It is the role of the Ministry of Energy and Water which intervenes on an ad-hoc basis, that is:

- After large floods such as 2003 to increase the conveyance capacity of the river; and
- When the development of vegetation and accumulation of solid waste (residential and industrial/construction garbage) reaches such a level that riparians are complaining about it (complaints are actually about the smell which comes mostly from the sewage content of the river).


Thank You
Fadi Geryes Doumit
Litani River Authority