Water conservation in Lebanon: Feasibility study of a small-scale pilot dam project on the Al-Zahrani River, Lebanon

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1. ABSTRACT

Lebanon is one of these countries that need water. However, some scientists claim that there is sufficient water in Lebanon, but the reality is the contrary. This is due the fact that there is a lack of water in Lebanon. More than that current studies show that 70% of surface water goes to the sea. To solve this problem, we should have an effective technical and economical solution. For that, we have an opinion, which is under study, in order to congregate water behind small-scale dams into lakes. These lakes called mountain lakes.
As a typical project, we take the Alzahrani River. In this river are more than 18.9 million cubic meters of water, which annually goes to the sea during wintertime and springtime.
In order to achieve this pilot small-scale dam project, we must have the correct land surveying, geological, that hydrological, geotechnical, structural, and environmental information. After, we will formulate this information for further research that can be typical for along side of the basin of (Al-Zahrani) River and all the small rivers of Lebanon, and Arab world.

Key words: Water conservation, small gravity dams, Mountain Lakes, hydro-geology, water flow, structure, hydrology, environmental implications,

2. INTRODUCTION

Water is becoming a scarce commodity in Lebanon and the Middle East in general. Additionally in many places even though it is found in optimum amounts, there are numerous problems associated with management, distribution and quality. Conservation is a pressing issue. Small dams are one solution that could alleviate this shortage and distribution in a country like Lebanon, which has many Rivers that flows in most cases to the sea without proper exploitation. Studies show that 70% of the surface water flows into the Mediterranean without proper and sustainable exploitation of the water resources please see the Algorithm of the water quantities in Lebanon on the figure1).

Although the construction of large-scale dams reevaluated internationally, and even some dams are de-commissioned, there is a plan to built more than ten large dams in Lebanon. However, Lebanon's mountainous topography renders itself well to the design and construction of small mountain lakes, behind a small concrete gravity or arch dams, for conservation purposes. In this paper work, we choose thee Al- Zahrani River as a pilot project, in the south of the country as a typical case in hand whereby 18.9 Mm^3 of water practically flow into the sea without a clever exploitation.

The River flows primarily during winter and spring and during the rest of the year, it practically dries up. The Al Wadi Al-Akhdar, which was a well-known touristic area and as such exploited by many restaurants is practically non-existent and the restaurants are out of business because of improper use of the River waters.

In order to conserve and have water available throughout the year it is propose to look into the feasibility of small dams along the course of the River. This might result in a better exploitation of the resource and better allocation for the various uses: agriculture domestic etc. The Al-Tasse source rends itself to such a feasibility study.

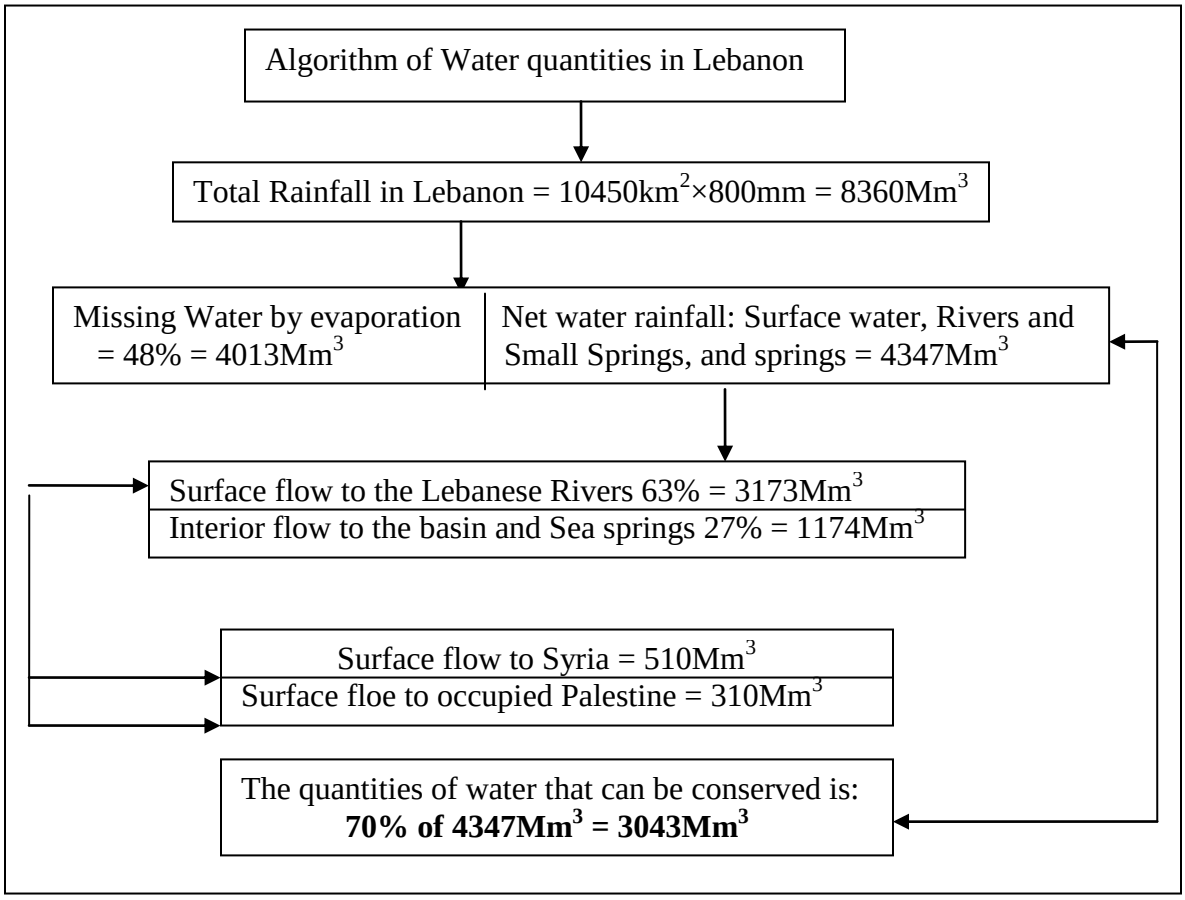


Figure 1: Algorithm of water quantities in Lebanon

3. OBJECTIVE

The objective of this study is the conservation of water, and the suitable use of the surface water such: Rainwater, Rivers, and Sea and land small springs. This objective will be achieved by the construction of small concrete gravity or arch dams, and for Sea springs will be achieved by the construction of marine terminals in the shoreline of Lebanon, this is a functional plan for the water conservation in Lebanon.

The research about marine terminals can be discussed in other paper work, but our study currently concentrated on the small gravity or arch dams for

mountain Lakes. In addition, the need of water in Lebanon from 2003 up to Year 2010 indicated in the Figure 2).

	Year 2003	**Year 2010**
Drinking Water	400 Mm^3	**900 Mm^3**
Irrigation	700 Mm^3	**2100 Mm^3**
Industry	100 Mm^3	**250 Mm^3**
Total	**1200 Mm^3**	**3300 Mm^3**

Figure2:The Quantities of water need in Lebanon, from this year up to year 2010.

This figure shows according to the last research that, the need of the water conservation in Lebanon is necessary and the problem of shortages of water is evitable.

In order to achieve this above motioned need of water we proposed a plan to built small gravity dams at all the small Rivers and Sprigs in Lebanon.

4. METHODOLOGY

The proposed small dam will be a small concrete gravity or arch dam. The following major investigations will conduct:

4.1: Multidisciplinary Approach

We have reached an era when the Engineer must cooperate with members of other disciplines if this pilot project is to be completed for optimum benefits and minimum adverse effects, an example of the number of disciplines involved, relative to the Alzahrani dam project is indicated in the figure 3 below.

Civil Engineering	Sanitary Engineering	Hydraulic Engineering
Structural Engineering	Electrical Engineering	Illumination Engineering
Air Pollution Engineering	Acoustic Engineering	Demography
Landscape Architecture	Construction Methods Analysis	Ecology
Geography	Environmental Engineering	Geomorphology
Geology	Hydrology	Hydrography
Meteorology	Soil	Agricultural Economics
Biology	Forestry	Range Management
Fish	Wildlife	Legal

Figure 3: Shows the multidisciplinary approach

4.2: The environmental implications

1) Land inundation: The creation of a reservoir will inundate frequently good land, and may cause people to dislodgment of people, in our project, this condition is resolved, and no loss of productivity and personal hardship.
2) Wildlife: There is no species can be destroyed during the construction period
3) Archaeology*:* There is no inundation of items of value.
4) Beauty: Areas of beauty will not change.
5) Retention of silt from the lower valley, which would normally enrich the land, is solved by excavation of shafts before the Lake
6) River Regime - a period of dry Riverbed below the dam will occur
7) Flood Warnings - alteration of natural flow can be serious to inhabitants and wildlife
8) Effects of Storage on Quality of Water

9) Fish - Nitrogen Problem
10) Water-Bourne diseases
11) Requirement of fish ladders for fish to continue spawning
12) Induced Earthquakes consequent to filling large reservoirs
13) Climatological Change.

14) Access roads during construction destroying the natural environment 15) River pollution from:

- Waste water from excavations
- Construction and removal of cofferdams
- Wash water from concrete and aggregate plants
- Oil leakage and waster disposal
- Sewage and storm water
- Soil erosion during reservoir cleaning

15) Other effects:
1. Fire Risks
2. Aesthetic appearance of final dam
3. Air pollution
4. Noise pollution
5. Dust pollution

4.3: The project site:

The site chosen for the study is the Al wadi Al-Akhdar, approximately 5 km inland from the city of Nabatieh; and 75 km from Beirut (figs. 4 and 5).

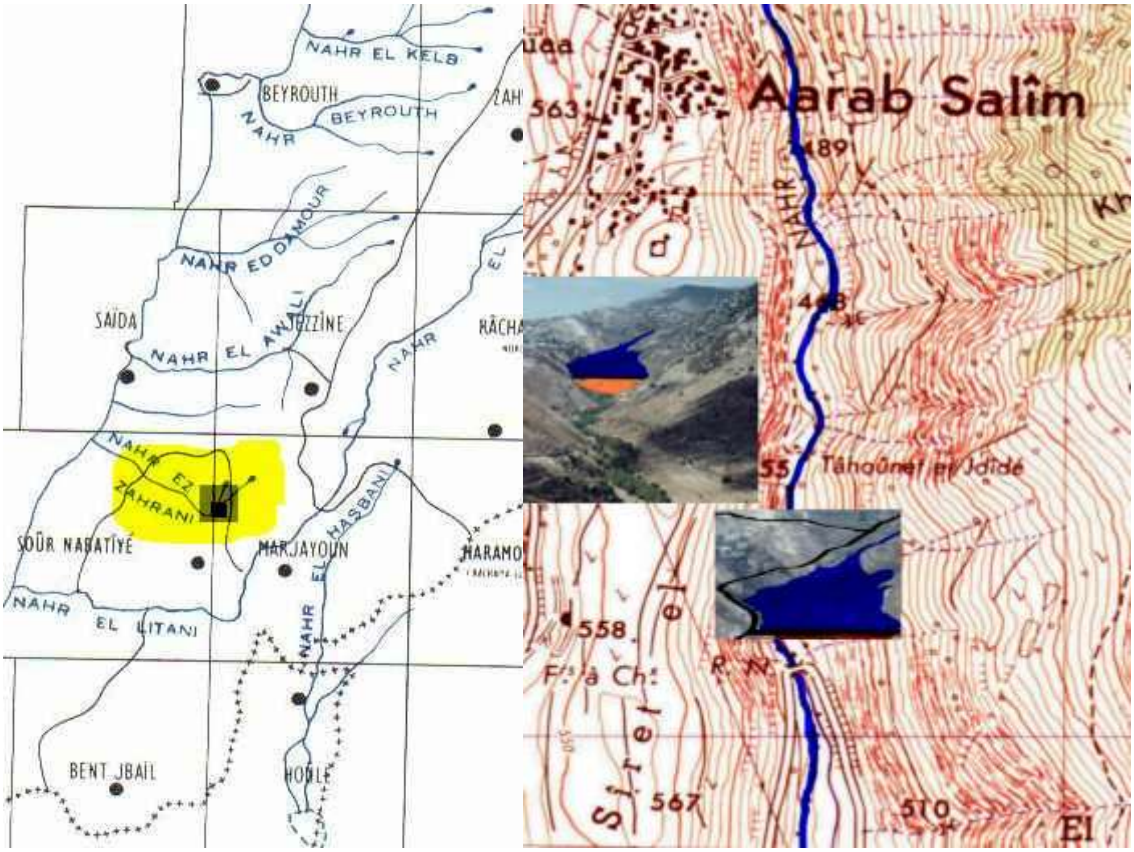


Figure 4: Map of Lebanon's Rivers. **Figure 5: Site of the dam on the Alzahrani River**

The actual surveys, studies and the EIA did determine the actual site of the small-proposed pilot concrete gravity or arch dam).Also we select three sites for three dams, earth and concrete gravity and arch dam, and in our study we concentrate on one site on the area of En Nqaip.

The streambed elevation of the dam site is about (elevation of the waddy Alzahrani + the elevation of the dam.) which is about 540+12 meters near the area of En Nqaip.

Precipitation in the Alzahrani watershed averages 700-800 millimeters per year, with virtually zero rainfall occurring from June through September.
Stream flow from the watershed, in the Embouchure station only, and according to the database taken from the Alitani office from 1965 to 1973

shows the average (0.887) m^3/s, and for Al-zharani River the total quantities are equivalent to about (27.6) Mm^3 per year, and this was before the complete exploitation of the Altasee source.

In addition to that, we should notice the drought during the last 13 Years, which is shows the diminishing of the monitored quantities of water.

4.4: The geological and geotechnical study:

Based on available information, a geologic land survey will be conducted. Additionally any land use plans that are available will be consulted. GIS and any other source of information will be used in view of eventually having an EIA.

Geological faults as indicated in the figure 6), which should be treated, and prepared by using the conventional method testing, or by using the non conventional methods such as electrical physics and seismic wave reflection using tomography, or by any other methods will be treated in other separated paper work.

The reservoirs for the proposed Alzahrani dam extend about 500 meters upstream of Axis A-A on the Alzahrani River. The reservoir is not wide through its length.

The stratigraphy in the reservoir is mainly a stone with marl and argillaceous interbaded. In the vicinity of the dam site, there is a sequence of interbaded limestone and marls that extends from Axis A-A upstream for about the entire riverbed at the proposed dam location, the Alzahrani River is presently cutting floodplain and terrace deposits. The present floodplain and active river deposits are only in wintertime and having maximum thickness of 50 centimeters in the River bad**.**

Figure 6: The geology of the Sites of these dams area is differing between (Limestone and marl limestone).

These deposits are composed of silt, sand, gravel and cobbles. These lacustrine deposits are nearly all lowly clayey soils with occasional sandy lenses of variable thickness.

4.5: The hydrological and hydro geological study:

Basic hydro geological and climatologic data has been collected and used in order to determine the availability of water and in view of planning reservoir release patterns over 12 months if possible. Studies will be based on a constant release during the six driest months of the year: June to November.
For laboratory testing, there were close collaboration with the faculty of Engineering of the Lebanese University and the Litany Water Authority. In addition, private engineering firms are approach for assistance in acquiring some instrumentation see the survey results and the tables of water flow as shown in the appendix (.1)

4.6: The survey study:

A complete survey study was conducted for the lake and the dam site, and sections was taken for the lake each five meters and for the dam each one

meter, please see on figure 7 and 8 respectively the complete contour line and the colored view of the Lake surface.

And see the appendix (2) all the field and laboratory surveying work

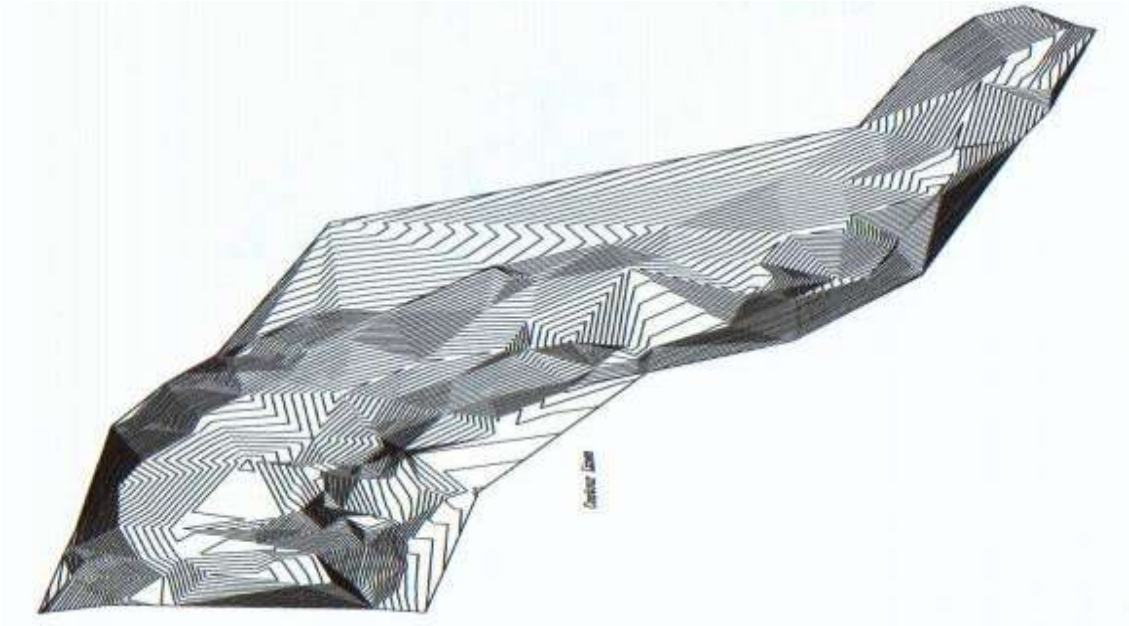


Figure 7: Complete contour line of the Lake

Figure 8: Colored plan view of the Lake surfaces.

4.7: Financial study and project Costs:

The construction cost estimate for this project in 2003 $US, and the financial analyses are provided in the figure 9)

Dam Crest Elevation	552 m
Release Rate	0.3 m^3/s
Water Supply	500,000 to 750,000 m^3
Cost of Money	7%
Escalation Rate	4%
Period of Amortization	20 years (2005 to 2025)
Period of Construction	3 years and 1 years each dam (beginning in 2005)
Construction Cost (2004)	$US 750,000.00 which are: 500,000.00 for the first dams + 250,000.00 for the construction of the road and the cost for the site conversation with environmental works.
Interest During Construction	$US 50,000.00
Average Unit Cost of Water (2004)	$US 200/1,000 m^3
O,M&R (First Year)	$US 10,000.00
Annual Cost (First Year)	$US 750,000.00
Annual Cost (Second Year)	$US 500,000.00
Annual Cost (third Year)	$US 500,000.00
Total Cost for three years	$ US 1,750,000.00

Figure 9: Project costs for related pilot project

4.7: The dam design and structural design using ordinary software (Program Excel)

4.7.1: Concrete gravity and arch dam design and analysis were including the flowing:

1) Loads: Primary Loads, Secondary Loads, Exceptional Loads, Load combination

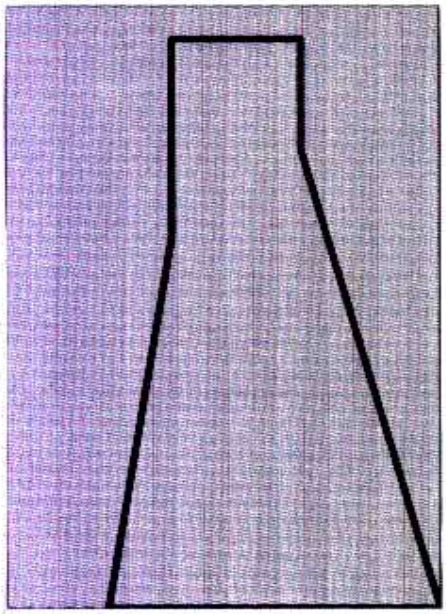
2) Concrete Gravity Dam Analysis:
a) Rotation and Overturning.
b) Translation and Sliding:
1) Sliding factor, 2) shear friction factor, 3) Limit equilibrium factor,
c) Overstress and material failure

3) Stress analysis for gravity dam using elastic theory, and using finite element method elastic analysis and elasto-plastic analysis.
4) Arch dam analysis: Arch geometry and profile, constant angel profile, Cupola profile Arch stress analysis using elastic ring theory.
4.7.2) using (Excel program our students did find a solution of each dam in (small concrete gravity dam project as is shown down), however the research continue for arch dam).

Concrete gravity dam design using Excel Program:

This Dam design is for a Dam located on a **flat Rock** soil
For a 1m length of the Dam

Concrete GravityDam



	Enter Data			
ϕu =	15	deg	=	0.261799 rad
H =	17	m		
z_3 =	3	m		
z_2 =	4	m		
z_1 =	16			
γc =	2500	Kg/m^3		
$\gamma\omega$ loads =	981	Kg/m^3		
$\gamma\omega$ =	1000	Kg/m^3		
η =	1			
θ =	0	deg	=	0 rad
β =	25	deg	=	0.436332 rad
Up width =	0.35	% =		5.95 m

0.00	0.00
-15.33	0.00
-12.33	11.20
-12.33	17.00
-6.38	17.00
-6.38	13.69
0.00	0.00

A_1 =	16.79965	m^2	0x =	13.33366667	0y = 3.732633	m
A_2 =	101.15	m^2	0x =	9.3075	0y = 8.5	m
A_3 =	1.47E-15	m^2	0x =	6.3835	0y = 14.79297	m
A_4 =	1.22E-14	m^2	0x =	6.3835	0y = 6.84473	m
A_5 =	43.69333	m^2	0x =	4.255666667	0y = 4.563153	m
A_t =	161.643	m^2	0x =	-8.36039269	0y = 6.940365	m
P_m(Self weight) =	404107.5	Kg				
P_m(Self weight) =	404.1075	Ton				
P_{wh} =	125568	Kg			Oy = 5.333333	m
P_{wv} =	33558.88	Kg	Ox =	-14.07936412		
	7648	Kg			Oy =	m
P_{ww} =	3659.583	Kg	Ox =	-0.621743544		

For system with drainage type **WD** . If no drainage exists then type **ND**

K_d =	0.33					
wd						
Pu drain =	98174.66	Kg	Ox =	-10.4006	y1 = 4.9334	m
P_u =	98174.66	Kg	Ox =	-10.4006		m

ϕ_s =	30	deg	=	0.523599	rad	
γ_s	1900	Kg/m³				
Ka =	0.333333					
	2859	Kg			Oy =	m
H_s =	2	m				
	9000	Kg			Oy =	m
E_{eff} =	14	GN/m²				
fn =	18.34146	Hz				
α_h =	0.15					
α_v =	0.075					
P_{emh} =	60616.12	Kg	Ox =	-8.36039269	Oy =	6.940365 m
P_{emv} =	30308.06	Kg	Ox =	-8.36039269	Oy =	6.940365 m
z_{max} =	16	m				
C_e =	0.63					
P_{ewh} =	15966.72	Kg			Oy =	6.4 m
P_{ewv} =	2516.916	Kg	Ox =	-14.07936412		m

∑M+ =	3899161	Kg m
∑M- =	2597894	Kg m
∑V =	315360.1	Kg
∑H =	205152.8	Kg

Stability Of Dam

Over Turning Stability

Fo =	1.500893	> 1.25	YES	>1.5	YES

Sliding Stability

Fss =	0.650535	< 0.9	YES

Note that for F_{SF} we neglect the downstream Passive Wedge Resistance Pp if occuring

Cohesion c =	150000	Kg/m²
Friction tanϕ =	1.3	

Shear Friction Factor

F_{SF} =	11.01614	> 3	YES

Limit Equilibrium Factor F_{le} = F_{SF} when horizontal sliding plane

F_{le} =	11.01614	> 1.3	YES

Stress Analysis: Gravity method

The study of the stresses occures on the base plane of the dam

Vertical Normal Stresses

∑V excluding up lift =	413534.8	Kg
∑M* @ centroid of base =	1023003	Kg m
e =	2.473801	m
At up stream σzu =	-6821.71	Kg/m^2
At down stream σzd =	73880.5	Kg/m^2

Horizontal Shear Stresses

τ_u =	6033.602	Kg/m^2
τ_d =	0	Kg/m^2

Horizontal Normal Stresses

At up stream σ_{yu} =	14079.3	Kg/m^2
At up stream σ_{yd} =	0	Kg/m^2

Principle Stresses

At up stream σ_{1u} =	-8438.41	Kg/m^2
At up stream σ_{3u} =	15696	Kg/m^2
At down stream σ_{1d} =	79184.88	Kg/m^2
At down stream σ_{3d} =	0	Kg/m^2

Permissible Stresses

k'_d =	0.4	
F'_t =	1.3	
σ'_t =	240000	Kg/m^2
z =	16	m

σ_{zu} min = -178337 Kg/m^2

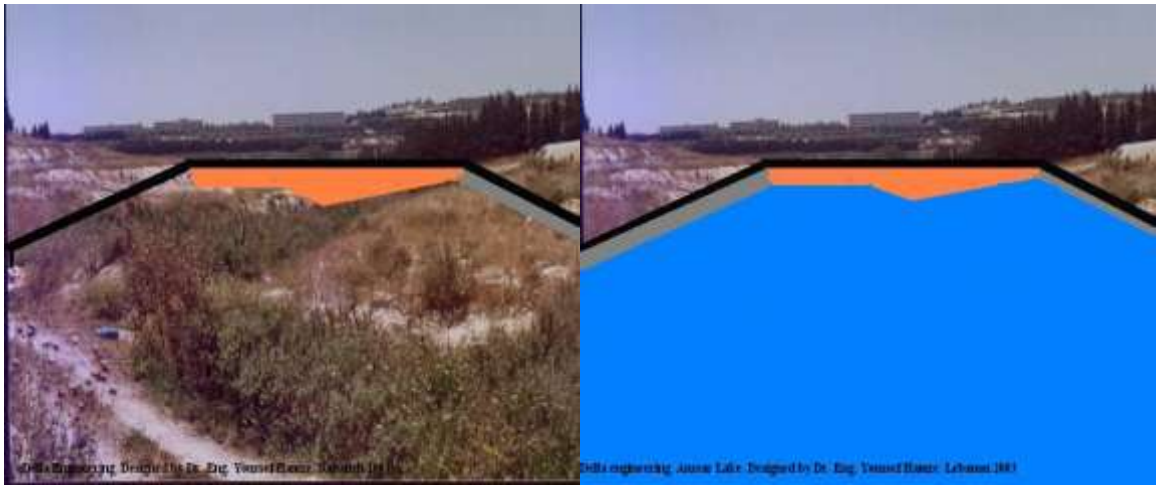
At up stream σ_{zu} < σ_{zu} min — YES

Volume per 1 m width = 161.643 m^3

1 $ =	1500	L.L		
1 m^3 Concrete =	120	$	=	180,000.00 L.L
Cost per 1m width =	19,397.16	$	=	29,095,736.98 L.L

4.7.3: Examples of small dams considered sites and Lakes in different places:

Arabsalim, En Nqaip proposed sites and lakes **Arabsalim- proposed dams**



Ansaar, Alhoue proposed site site and Lake **Ansaar- Alhoue proposed**

Jubaa, Jlichaa proposed site **Jubaa- Jlichaa proposed dam and lake**

Figure 10: Examples of proposed sites and dams in different places on the Rivers.

5. CONCLUTION AND RECOMMENDATIONS

1) The Quantities of water needed in Lebanon up to Year 2010 are 3300 Mm^3, and the available quantities of surface water not exploited are 3043 Mm^3, which mean the need of these quantities of water is not evitable.

2) The construction of large-scale dams reevaluated internationally, and even some dams are de-commissioned, there is a plan to built more than twenty large dams in Lebanon. However, Lebanon's mountainous topography renders itself well to the design and construction of small mountain lakes, behind a small concrete gravity or arch dams, which are friendly to the environment, and to the economy, and having excellent safety conditions.

3) By this pilot project (small concrete gravity dam) used for water conservation purposes, we did create a small mountain lake behind it, that can be used in addition to the drinking water, turistic, fishing and irrigation purposes.

4) This pilot project can be repeated on the same river in order to conserve all the surface water goes to the sea in the winter and spring time, at good design conditions and good costly manner,

5) This pilot project is applicable for every small River and springs in Lebanon or in Arab Word, Also in the all World.

6) This project needs to be finance and achieve by the help from the local Governments, and Municipalities which they did have high interest of such project, or by the help from the International organizations.

7) For this project, we have many options for selecting sites with appropriate conditions such as large area for the reservoir that located far away from the geological faults.

8) We can avoid the realty conditions, by choosing the sites owned by local Municipalities.

9) Easley we can choose the sites applicable for (EIA) Environmental Implementation Acts.

10) In case of existing very low permeable soil, and not using geotextile as water proofing, the lake will help in slowly feeding the water table.

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