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The Economics of Water Supply and Control:

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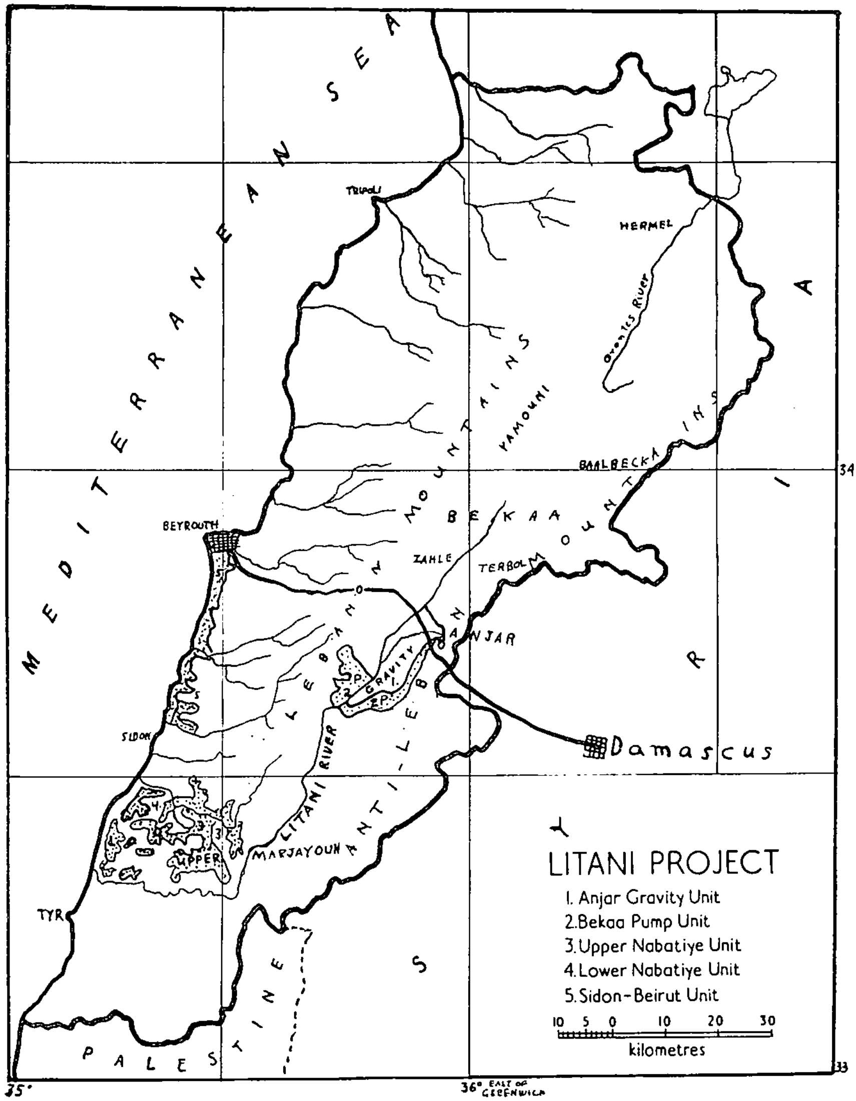
ECONOMICS OF IRRIGATION WATER IN THE LITANI RIVER BASIN OF LEBANON

CONSERVATION and efficient utilization of water resources in order to maximize agricultural output is of vital importance to the people of Lebanon. A population of over 1,500,000[1] is crowded into a mountainous country of approximately 10,000 square kilometres (4,000 square miles), of which not more than 30 per cent. is currently cultivated. Owing to the mountainous character of the topography and the semi-arid climate, it is very difficult and expensive to expand the cultivated area. The density of population is more than 375 per square mile and over 1,200 persons per square mile of cultivated land. With population increasing at the very rapid rate of about 2·5 per cent. per year[1] every feasible means of expanding agricultural output will have to be utilized if the level of living is to be raised.

Since the average gross returns from the sale of crops produced on a hectare ($2\frac{1}{2}$ acres; 10 dunums) of irrigated land are three to four times the value of the output from a hectare of land watered only by natural precipitation, provision of irrigation water for additional fertile dry land is the economical way to expand farm output. Accordingly, the government of Lebanon has constructed irrigation facilities on most of the rivers and streams of the country. These facilities provide water for irrigating a total of approximately 60,000 hectares, as shown in Table 1.

These projects utilize the greater part of the summer flow of the springs, streams and rivers. There are few sizeable reservoirs for storage of run-off from winter rains and melting snow because the mountain-sides and stream-beds consist mainly of porous and fissured layers of limestone rock which cannot be sealed in reservoirs except at considerable expense. Since no rain falls from June to October or November, the main source of water for expanding the irrigated area is storage of the run-off during winter and spring. Hence, the economics of constructing reservoirs on streams which flow through non-irrigated land must be studied to determine whether the increased value of the farm output produced with the stored water would

[1] *U.S. Operations Mission to Lebanon, 1956–1957 Progress Report,* p. 96.



MEDITERRANEAN SEA
TRIPOLI
HERMEL
Orontes River
YAMOUNI
LEBANON MOUNTAINS
BAALBECK
ANTI-LEBANON MOUNTAINS
BEYROUTH
BEKAA
ZAHLE
TERBOL
ANJAR
GRAVITY
SIDON
LITANI RIVER
MARJAYOUN
UPPER
TYR
Damascus
PALESTINE
34
33
35°
36° EAST OF GREENWICH
LITANI PROJECT
1. Anjar Gravity Unit
2. Bekaa Pump Unit
3. Upper Nabatiye Unit
4. Lower Nabatiye Unit
5. Sidon-Beirut Unit
10 5 0 10 20 30
kilometres

Fig. 1

amortize construction costs over a period of fifty to seventy-five years. Even though the cost of this stored water might be more than most farmers would be willing to pay, if the calculated benefits from the increased output should exceed the costs of providing the water, the government would be justified in constructing the reservoirs because of the contribution which this enlarged agricultural output would make to the economy of the country. The government could probably cover the deficit incurred by selling the irrigation water below

TABLE 1. *Number of hectares irrigated at present or to be irrigated by various projects in Lebanon*

Region	Approximate cultivated area (hectares)[1]	Number of hectares irrigated by government projects		
		Old[2]	New	Planned
Akkar plain (north)	12,000	2,000	0	10,000
Coastal plain from Tripoli to Tyr	28,000	7,800	5,000	11,100
Lebanon mountains	65,000	7,900	0	0
Plain of the Bekaa	125,000	42,300	10,000	2,700 10,400*
Totals	230,000	60,000	15,000	34,200

* Development plan for the Litani River Basin, to irrigate 21,500 hectares.

cost either by the gain from the hydro-electric power that could be generated below the dams, or from indirect taxes on the trade induced by the larger output of fruits and other farm products.

Engineering studies have indicated that utilization of the waters of the Litani River basin offers the best possibility of combining the provision of irrigation water with the generation of hydro-electric power on a self-liquidating basis. The Litani River drains the southern Bekaa, which is about 60 kilometres long and 10 to 12 kilometres wide between the coastal range of the Lebanon and the Anti-Lebanon mountains forming the boundary with Syria. The run-off from both mountain ranges collects in the Litani River basin, and constitutes an average annual flow of 641 cubic metres of water. Up to the present, most of the run-off has flowed into the Mediterranean Sea. Work is now under way to harness this water for irrigation and production of hydro-electric power. Consideration of the charges for the irrigation water and the price of electric power necessary

[1] Adapted from p. 42 of the Report of Sir Alexander Gibb and Partners, 1948.
[2] F.A.O. of the U.N. Centre on Land Problems in the Near East, Background Document B-23, October 1955.

to cover the annual operating expenses and the amortization of the construction cost of the project offers an interesting study in the economics of the control and utilization of water resources.

Litani River Development Project

The Litani River basin covers an area of 2,168 square kilometres. The upper six-tenths of the river flows through the broad, flat valley between the Lebanon and Anti-Lebanon mountains, which is called the 'Bekaa' in Arabic. This valley is the northern end of a geological fault which extends south through the Jordan Valley, the Dead Sea, and the Gulf of Aqaba. The soil in the Bekaa is generally fertile and in Roman times this high mountain plain was a granary for the legions of the Empire. Most of the villages are located on the bench land at the sides of the valley nestled against the mountains because of malaria mosquitoes which formerly infested the river bottoms. With the straightening of the river course and the development of drainage of the Ammik swamp area south of the Beirut–Damascus road in recent years, malaria has virtually disappeared and villages have grown up at various points along the upper reaches of the Litani.

In geologic time the Bekaa was a big lake which gradually filled up with gravel and silt washed down from the mountains on both sides to a depth of more than 100 metres in many places. Since much of the exposed rock on the mountain-sides is broken and fissured limestone with numerous subterranean caverns, the mountain-sides are porous and absorb most of the rains and water from melting snows. The soils of the valley floor also generally have a porous structure so that they absorb most of the precipitation. Consequently there is little erosion or run-off except when there is unusually heavy rain during a storm lasting several days.

The greatest amount of precipitation in the Bekaa occurs during the period from the beginning of November to the end of February when the weather is too cold for growing crops other than barley and wheat, vetches and lentils. These crops are planted in the autumn and make little growth until temperatures rise in the spring. When the rains continue through April and May in modest amounts, these winter crops yield a normal harvest in June. Wheat that is planted on land that can be irrigated during the critical months of March and April usually yields 50 per cent. more than that grown on rain-fed dry lands.

Potatoes and onions planted in February and March, as well as spring vegetables, require irrigation during spring and early summer to supplement the scanty rainfall. In areas where springs continue to flow during the summer, beans and vegetables for autumn harvest can be sown following the gathering of the spring crops. Apple trees in the Bekaa require irrigation at least once a month during the summer, and when supplied with adequate water grapes give double the yield of those on dry land. Hence, the great concern of Bekaa farmers is for increased amounts of irrigation water.

The dependance upon irrigation water for growing spring and summer crops is indicated by the data in Table 2 showing monthly precipitation and amounts of water required for irrigation. These data clearly show the necessity of storing the water from winter precipitation for irrigation.

TABLE 2. *Comparison of monthly precipitation with irrigation requirements*[1]

	Average precipitation at Ksara 1921–51 (cm.)	*Estimated irrigated requirements for 4,700 hectares in the Bekaa*
January	15·93	0
February	14·48	0
March	6·14	0
April	4·12	5,200
May	1·48	7,000
June	0·13	6,800
July	0·01	7,000
August	0·03	7,000
September	0·10	6,800
October	1·73	6,600
November	6·42	0
December	11·43	0

At present there are no reservoirs in the Litani watershed to impound for irrigation the winter rain water and the run-off of melting snow from the upper slopes of the mountains. Consequently, most of the precipitation which is not retained in the soil drains away to the sea. The existing irrigation facilities utilize the summer flow from various springs and the water which seeps from mountain-sides down through the sub-soil into the Litani and its tributary streams. Little of the stream flow is used for irrigation during the rainy season from November to March.

The southern section of the Bekaa, extending south from the head of the watershed at Baalbeck some 60 kilometres to where the

[1] *Development Plan for the Litani River Basin*, prepared by the U.S. Department of Interior for the U.S. Foreign Operations Administration, June 1954, vol. i, pp. iii, 5, 22.

mountains come together at Karaoun, contains roughly 80,000 hectares of cultivable land. Along the upper reaches of the Litani above Terbol and Rayak only 5 to 15 per cent. of the lands of the various villages are irrigated with water from the river, the tributary streams, and springs. Since 1952 a number of wells have been drilled in this area to provide water for fruit-trees and vegetables. These wells have approached full utilization of the underground water resources, as indicated by the drying up of a number of springs and a lowering of the water table. The main well at the American University of Beirut Farm was expected to deliver 1,000 gallons per minute in 1954 but is pumped dry in a few hours if more than 200 gallons per minute are taken out.

In the area south of the Beirut–Damascus highway, roughly half the land is irrigated. Existing irrigation facilities supply 37,000 hectares with water from the streams and springs and drainage from the Ammik swamp.

The need to conserve the waters from the Litani watershed for irrigation and generation of electric power during their drop from the 850-metre elevation of the Bekaa down to the sea led to the formulation of the development plan for the Litani River basin. This plan provided for the irrigation of 7,665 hectares of fertile dry land in the southern Bekaa and of 11,100 hectares in the coastal plain from Tyr north to Beirut. The plan called for integrating the water resources of the southern Bekaa to supply irrigation water at a uniform price for 10,400 hectares of land by means of canals from springs and from giant pumps at the Karaoun reservoir. Farmers who had paid an average of L.£142·3 per hectare for water pumped from the Litani would receive water from the canals for L.£50 per hectare.

To quote from the plan:

> The multiple-purpose plan of development for the Litani and Bisri River Basins is based upon the multiple uses of the available water. It will utilize the average annual flow of 541 million cubic metres in the Litani River Basin and 114 million cubic metres in the Bisri River Basin to irrigate approximately 21,500 hectares of land and to operate six power units for the production of hydro-electric energy. This hydro-electric energy is combined with thermal-produced energy in a co-ordinated, inter-connected, electric transmission system which will provide much fuller utilization of all the available water for energy production.[1]

The annual output of electric power is expected to total 1,250 million kilowat hours. This power is planned to provide the energy

[1] *Development Plan for the Litani River Basin*, loc. cit., pp. iii, 25.

for the expanding industries of the country. The three dams in the project will store 279 million cubic metres of winter run-off water to supplement the normal summer flow of the river for irrigation and generation of electricity.

A dam to be built at Karaoun, where the mountains close in on the Litani to form a gorge, will impound water to the height of 856 metres above sea-level. A tunnel 9 kilometres long through the Lebanon mountains will divert part of the flow of the river to a power-house on the Bisri River. The enhanced flow of the Bisri River will pass through two more power-generating stations on its way to the coast, where the waters will be utilized in the Kasmie irrigation project near Sidon.

The main flow of the Litani will go out from the Karaoun dam through the Sohmor, Kelia and Zrariye power-plants. Below the Kelia power-plant part of the water will go to the Upper Nabatiye irrigation project to supply water to 3,100 hectares of previously dry-farmed land. Below the Zrariye power-plant the remaining water will go to 3,900 hectares of farm land included in the Lower Nabatiye irrigation project.

It appears that, in the interest of maximizing the production of hydro-electricity, it was decided that the amount of water to be used for irrigation along the Mediterranean coast was to be the largest amount which could be furnished to farmers there on an economic basis. The Kasmie and previous projects furnished irrigation water to most of the more productive lands in the coastal plain. The water from the Litani is to be taken through canals and pipes to scattered areas of productive soil on the lower slopes of the mountains and along the sides of the foot-hills from Tyr to Beirut.

Irrigating a larger amount of the fertile Bekaa plain south of the Beirut–Damascus highway presents various engineering and economic problems. The main sources of the water in the Litani above the Ammik swamp are the Anjar and Chasmine springs. The development plan will improve and expand existing facilities to utilize all the water from these springs to irrigate 4,275 hectares which are not watered at present. The new canals will be concrete-lined to minimize seepage losses.

The Karaoun dam will impound the waters that drain away from the Ammik swamp area and those that come into the Litani lower down through underground seepage. This dam will have the capacity to store the water during years of high precipitation to supplement the deficient rainfall of dry years. The water held in this dam will be greater than the amount which could be used economically for irrigation in the coastal area, so that 3,390 hectares can be added to the area of watered land in the Bekaa. This new area will have to be supplied with water pumped from the Karaoun reservoir. It is planned to use electric pumps to lift the water 50 metres to a concrete-lined canal that will run north along the side of the mountain as far as Anjar. The development plan provided for the supplying of water from the canal by gravity to lands lying between it and the previously irrigated fields.

FIG. 2. Anjar Spring is a principal source of irrigation water for the southern Bekaa. The winter flow will be retained by the Karaoun dam for use during the dry summers.

The cost of the Litani River development project for irrigation and electric-power generation was estimated in 1954 at L.£341,920,000. In addition to the separate facilities for generating power and those for supplying irrigation water to the land, the dams for storing water together with the canals and tunnels carrying water to both powerhouses and irrigation canals are utilized jointly by the power and the irrigation divisions of the project. Accordingly, it is necessary to allocate to the irrigation and power divisions their equitable shares of the cost of constructing these jointly used facilities. The United States Bureau of Reclamation, which prepared the development plan for the Litani River basin, calculated this allocation of costs of construction on the basis of the difference in cost of the facilities which would be required to utilize the Litani and Bisri basin waters solely for the generation of electricity and the cost of the dual-purpose project.

By capitalizing the difference between the annual amortization costs of a single-purpose power project and that of the multi-purpose project, the Bureau calculated that the irrigation division should bear L.£59,000,000 of the cost of constructing the jointly used dams, tunnels and canals. The cost of the canals and other facilities for distributing the water to the land to be irrigated is estimated at L.£32,000,000, making the total construction cost of the facilities to irrigate 21,500 hectares L.£91,000,000. This makes the construction cost per hectare approximately L.£4,250. The annual cost of irrigation water will be roughly L.£270 per hectare, including operating expenses and amortization of the construction cost in fifty years at 6 per cent. interest.

Calculation of benefits from irrigation

The benefits from applying irrigation water to previously dry land were calculated by the Bureau of Reclamation as the difference between the gross crop income on irrigated land and the comparable income from dry land. Income data were obtained through a survey of 146 farms in the southern Bekaa for the 1951–2 crop year.[1] The income per hectare from dry-land farming and from irrigated production is indicated by the following tabulation:

TABLE 3

Returns from selected dry-land crops (Gross value/hectare)		*Returns from selected irrigated crops (Gross value/hectare)*	
	L.£		*L.£*
Wheat	340·5	Wheat	480·5
Barley	226·0	Potatoes	1440·0
Vetch (edible)	190·0	Onions	986·5
Vetch (cattle feed)	126·0	Sugar beets	1114·5
Chickpeas	319·5	Mixed vegetables	570·0
Mixed vegetables	117·5		
Average	253·0	Average	948·6

These comparative returns suggest that with irrigation water the gross returns per hectare can be increased by nearly L.£700 per hectare. Not all of the increase in value of products can be attributed to the water, because heavier applications of fertilizer are used on irrigated than on non-irrigated wheat. Substantial amounts of fertilizer are used with potatoes, onions and sugar beets but rarely on dry-land crops. The average cost of the inputs (other than labour)

[1] *Development Plan for the Litani River Basin*, loc. cit., pp. v, 33, 38.

per hectare of dry land was found to be L.£185·1 and L.£781·5 for irrigated land, including the customary rental charge for the use of the land. The returns to labour thus amounted to L.£67·9 per hectare of dry land and L.£167·1 per hectare of irrigated land. Thus, with irrigation water for his crops, the farmer netted almost L.£100 more return per hectare for his labour. When water is supplied to their lands farmers can earn more than double the labour income from dry-land crops.

The water charges suggested in the development plan were L.£50 per hectare in the area to be supplied with water pumped from the Karaoun reservoir and L.£32·5 in the gravity-flow area, owing to the reduced flow during the latter part of the summer. On this basis application of the proposed charges would result in a saving of L.£92·3–110·8 per hectare compared with the present water charges, with a corresponding increase in the labour-management earnings of farmers served by the Litani project.

Charges v. *costs of supplying irrigation water*

The above-mentioned comparisons showing the increased net labour returns per hectare from using irrigation water from the Litani project indicate that the execution of the development plan for the Litani River basin would contribute to higher incomes for the farmers. However, it should be pointed out that these comparisons overlook the fact that the proposed charges for irrigation water cover the distribution costs only and do not include the estimated costs of supplying this water.

The annual costs per hectare for the various units of the Litani irrigation scheme ranging from L.£31·2 for the Bekaa gravity unit to L.£55·1 for the Upper Nabatiye unit[1] include only the costs for distributing the water through the irrigation canals. They include the annual costs for operation and maintenance, plus the annual instalment necessary to repay the original cost in seventy-five years without any interest charge. This is in accord with the present Lebanese law governing charges for water supplied by government irrigation projects. Farmers often claim that the government should furnish them with irrigation water free of charge because other farmers get irrigation water without cost from springs and streams. In order to meet the demand for low-cost irrigation water, the law minimizes the charges as stated above and places a maximum limit of

[1] *Development Plan for the Litani River Basin*, loc. cit., pp. v, 35, 36.

L.£80 per hectare on the annual charge for water from government irrigation projects.

The above annual costs omit the annual costs for operation, maintenance, and amortization of the part of the cost of the dams, tunnels and canals that are used both for irrigation and electric-power generation purposes. When calculated on the basis of amortizing the share of the construction cost allocated to irrigation in fifty years and interest at 6 per cent., the annual charges amount to L.£3,743,200. The Bureau of Reclamation calculated on this basis because it considered that the government of Lebanon would have to borrow from abroad a substantial part of the cost of the project and would be obliged to repay the loans within fifty years at 6 per cent. interest. When the annual charges for the distribution canal system are recalculated on this basis, the costs of delivering water are materially increased to L.£106·5. The total cost of supplying irrigation water is again greatly increased when the annual charges for the share of the annual costs for the part of the dams, tunnels and canals attributed to irrigation, amounting to L.£237 per hectare, are included. The annual costs for the four units drawing water from the dams work out as follows:

TABLE 3. *Annual costs for irrigation units served by dams*[1] (*15,800 hectares*)

Items	*Total annual cost*	*Cost per hectare*
	L.£	*L.£*
1. Operation and maintenance expenses	502,200	32·0
2. Amortization in fifty years at 6 per cent. interest	4,922,200	311·5
3. Electric power for pumping water to South Bekaa unit; 10,295,000 kW.h. at 5 pts	514,750	39·0
Total annual costs per hectare		382·5

If the annual charges for irrigation water supplied through these units are set at the maximum allowed by Lebanese law, at L.£80 per hectare, the revenues collected on this basis would be L.£1,264,000 compared with the total costs of L.£5,939,150. The deficit would amount to L.£4,675,150 per year. If the charge per hectare is set at the L.£50 currently charged in the Kasmie project which adjoins the coastal areas to be irrigated with Litani water, the annual deficit would amount to L.£5,149,150.

[1] *Development Plan for the Litani River Basin*, loc. cit., pp. ix, 11.

The development plan called for covering this deficit with the excess revenues of the electric-power division of the Litani project. As indicated in Table 4 the total annual deficit in the irrigation division would amount to L.£5,318,500, while the surplus in the electric-power division would be L.£5,972,000. Thus the project would be expected to show an annual net surplus of roughly L.£653,500 per year. This is on the basis of charging 5 piastres per kilowatt hour for the electric power, which is the price of wholesale electric power in Beirut.

TABLE 4. *Annual budget of revenue and expenses for Litani irrigation-power project*

	L.£	L.£
I. *Irrigation Division*		
A. *Bekaa gravity flow unit*—5,700 hectares in Southern Bekaa		
1. Annual costs of furnishing water:		
(*a*) Operating and maintenance expenses	105,000	
(*b*) Amortization in fifty years at 6 per cent. interest	243,900	
Total annual costs (L.£61·2 per hectare)		348,900
2. Revenues at L.£31·5 per hectare (to cover costs calculated to amortize cost of project in seventy-five years at no interest, per existing Lebanese law)		179,550
Annual deficit from Bekaa gravity flow unit		169,350
B. *Four units supplied from Karaoun dam*—15,800 hectares		
1. Annual costs of furnishing water:		
(*a*) Operating and maintenance expenses	502,200	
(*b*) Amortization in fifty years at 6 per cent. interest	4,922,200	
(*c*) Electricity for pumping—10,295,000 kW.h. at 5 pts.	514,750	
Total annual costs (L.£382·5 per hectare)		5,939,150
2. Revenues at L£50 per hectare (charge set at that for Kasmie Project supplying irrigation water near Tyre)		790,000
Annual deficit from Karaoun Dam units		5,149,150
C. Total annual deficit of Irrigation Division		5,318,500
II. *Electric-power Division*		
A. Income from the sale of 1,250,000,000 kW.h. at 5 pts.		62,500,000
B. Expenses of producing power (including interest at 6 per cent.):		
1. Hydro-electric power	18,140,000	
2. Thermal generated electricity	20,250,000	
Total power production costs		38,390,000
C. Net earnings from generation of electricity		24,110,000
D. Annual amortization charge, fifty years at 6 per cent. interest		18,138,000
E. Surplus—to apply on deficit from Irrigation Division		5,972,000
F. Deficit from Irrigation Division		5,318,500
G. Net surplus—for contingencies and faster amortization		L.£653,500

Electricity for pumping water from Karaoun dam to the canal for Bekaa Pumped Water Unit (47,000 dunums) charged at price at which current is to be sold by Power Division. A lower charge would reduce the revenues of the Power Division correspondingly.

In making the comparison of the benefits accruing from the Litani development project with the costs, the Bureau of Reclamation listed the annual costs of operation and maintenance of the irrigation facilities plus amortization against the higher value of the irrigated crops. The annual costs for supplying irrigation water to the 21,500 hectares of land including the amortization charge computed on the basis of fifty years and 6 per cent. interest amounted to L.£2,030,100, whereas the average annual anticipated increase in the gross value of the crops on the newly irrigated lands was estimated at L.£12,187,000. These benefits are thus estimated as six times the costs of delivering the water to the lands. Even when the annual costs of the irrigation division's share of the dams, tunnels and canals used jointly with the electricity division, including amortization and amounting to L.£3,743,200, are added in, the total yearly costs of the irrigation programme, amounting to L.£5,773,300, are less than half the annual benefits.[1] The ratio of benefits to costs will be improved to the extent that the cost of constructing the Litani project is reduced below the estimates.

After evaluating the costs *v.* the benefits, the Bureau of Reclamation concluded:

> The expected benefits from irrigation development, and the proportionate share of revenue accruing to the hydro-power units make the entire plan as presented in this report feasible and economically justified and one which can be financed by normal procedures.[2]

It should be pointed out that both the increased output of farm products resulting from the application of irrigation water to the 18,365 hectares of land that was previously dry, and the larger expenditures for production supplies to grow the irrigated crops will generate several times this amount of increased purchasing power in the national economy of Lebanon. The supply merchants and marketing agencies will have to employ more workers to handle the production supplies and the farm products. These will spend their wages to buy food, clothing and other goods and services. The merchants and service agencies patronized by these workers will do more business and pay out more money. Additional trucking and transportation will be required. This will mean more expenditures for wages, fuel, repairs, spare parts, tires, &c., and thus contribute to an expanded volume of business in many phases of the economy of the

[1] *Development Plan for the Litani River Basin,* loc. cit., pp. ix, 11.

[2] Ibid., pp. xi, 2.

country. Thus, any development project which is financially self-liquidating and produces benefits valued at considerably more than the costs involved will make a worth-while contribution to improving the general welfare of the people of Lebanon.

Pumped-water unit omitted

The government of Lebanon has awarded contracts for the construction of the first stage of the development programme for the Litani River basin. However, the plan was modified in several respects, including the omission of the facilities to pump water to 4,700 hectares in the south end of the Bekaa. Eliminating this unit from the project makes available for other uses the 10,295,000 kilowatt hours of electricity which would have been required for pumping the water from the Karaoun dam 50 metres up the mountain-side to the canal which would have carried the water upstream a distance of over 20 kilometres to Anjar. It also eliminates the very high costs of operating this unit, amounting to L.£450 per hectare.

The pumping programme in question was proposed in order to give some benefit from the river-basin development programme to farmers whose lands furnished seepage water that increased the flow of the Litani below them, and to reduce the cost of water to those farmers who have been paying the cost of pumping water from the streams. The proposed charge of L.£50 per hectare would have reduced their water charges by roughly 65 per cent. and put them on the same basis as other farmers receiving water from government irrigation projects. The pumps would also have served to expand the agricultural output of the fertile lower Bekaa and the quantity of beet for sale to the new sugar factory built there recently.

Effects of changes in costs and outputs

The decision to abandon the plan of the Bureau of Reclamation for pumping water from the Karaoun reservoir to irrigate 4,700 hectares of class 1 land in the southern Bekaa raises the question of the economic feasibility of the project. From the economic standpoint, the profitability of using irrigation can be modified by changes in the costs of the production factors, the yields and the prices of the products. If the cost of the irrigation water could be reduced at the same time that yields were increased it might be profitable to use the high-cost water pumped from the Karaoun reservoir even though prices of farm products were lower than those found in the 1951–2 survey in the southern Bekaa. Therefore, let us consider the effects of certain changes which are within the range of possibilities.

1. In determining the cost of supplying a hectare of land with pumped water it was assumed that the price charged for the electricity for pumping the water should be the 5 piastres (1·6 cents U.S.) per kilowatt hour at which power was priced in the evaluation of the project by the Bureau of Reclamation. Plate VI-16 in the *Development Plan for the Litani River Basin* indicates that electricity can be generated with steam power for less than 2 pts. ($\frac{6}{10}$ cent U.S.) per kilowatt hour. If electricity for pumping is charged at 2 pts. per kilowatt hour, the cost of pumping water is reduced so that the cost per hectare in the Bekaa pumped-water unit would be reduced from L.£450 to L.£384 per year.

2. The average yields found in the 1951–2 survey were 13,930 kilogrammes per hectare for sugar beet, 12,000 kg. for potatoes and 12,233 kg. for onions. Observations indicate that better farmers in the Bekaa often get yields of 20,000 kg. per hectare with these crops. H. F. Allos and S. W. Macksoud reported that the yield of sugar beet at the American University Farm in the Bekaa in 1957 was 27,300 kg. per hectare with no fertilizer and low-moisture level irrigation.[1] When 500 kg. of nitrate and 1,000 kg. of superphosphate were used per hectare with high-moisture level irrigation the yield went up to 46,660 kg. per hectare. If Extension Farm Advisers from the Government Extension Service taught farmers improved production practices and methods, many producers should be able to attain yields of 20,000 kg. of onions and of potatoes per hectare and at least 27,000 kg. of sugar beet.

Substituting these higher yields, lower current prices, and higher charge for water in the costs and returns tabulation of the 1951–2 Bekaa Survey referred to earlier, we obtain the net income per hectare shown in Table 5.

This computation indicates that with obtainable yields of these irrigated crops selling at average or below average prices, the net returns from each crop are greater than the amount charged for labour even after paying L.£384 per hectare for the irrigation water—the cost of water calculated for the Bekaa pumped-water unit. The net returns per hectare shown in Table 5 suggest that farmers

[1] *Yield of Sugar Beets and Sugar Content as Influenced by Applications of Chilean Nitrate, Superphosphate, and Water*, American Univ. of Beirut, Publication No. 5, May 1958.

TABLE 5. *Estimated costs and returns per hectare from selected irrigated crops in the Bekaa* (L.£)

Crop	*Seed*	*Fertilizer*	*Labour*	*Rent*	*Other costs*	*Water*	*Total costs*
Onions	198·00	210·00	200·00	259·00	10·00	384·00	1,261·00
Potatoes	308·00	310·00	250·00	376·50	10·00	384·00	1,638·50
Sugar beet	50·00	235·00	250·00	257·50	10·00	384·00	1,186·50

Crop	*Yield (kg.)*	*Price (kg.)*	*Gross value*	*Total costs*	*Net returns*
Onions	20,000	0·08	1,600·00	1,261·00	339·00
Potatoes	20,000	0·10	2,000·00	1,638·50	361·50
Sugar beet	27,300	0·055	1,501·50	1,186·50	315·00

in the southern Bekaa who would follow the recommendations of the Extension Farm Adviser regarding cultivation practices could obtain double their present labour income even after paying the full cost of irrigation water pumped from the Karaoun reservoir. The above analysis leads to the conclusion that Lebanon would gain economically by pumping water from the Karaoun reservoir to expand the production of potatoes, onions and sugar beet in the Bekaa under the guidance of Extension Farm Advisers. If farmers were taught how to use irrigation water efficiently, the available amount of water could irrigate a substantially larger area and thereby expand further the output of these products. Or the water thus conserved could be used to grow fruits or other similarly high-priced products. Efficient use of irrigation water could also be stimulated by charging according to the amount used instead of a flat charge per hectare.

Check dams to conserve run-off

Farmers along the upper reaches of the Litani River north of Terbol will not benefit from the plan for the development of the river basin because there is no provision for storing the winter run-off where it could be transmitted by gravity to their fields in summer. In the mountains in the western United States many small check dams have been built in mountain ravines to hold back the water from melting snow. This water is released for irrigation of fields in the valleys below during the dry summer months. If such small check dams were built to hold the run-off of winter rains on the streams coming down out of the mountains on both sides of the Bekaa, part of this water would probably be available for summer irrigation of land in the Bekaa plain. Water which seeped into the rocky sides and bottoms of these small reservoirs would undoubtedly find its way into existing and future wells in the plain between the Beirut–Damascus highway and Baalbeck. This would increase the amount of irrigation water which could be pumped from them.

The cost of such check dams need not be great. A substantial part of their construction could be done by farmers during slack periods of farm work under the guidance of experienced engineers. They hold the prospect of providing farmers with additional irrigation water at a cost which would yield them worth-while returns from the greatly increased yields it would produce when applied to their present dry-land fields.

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