25X1

Page Denied

Sanitized Copy Approved for Release 2011/06/21 : CIA-RDP80T00246A003400510001-7

FOR OFFICIAL USE ONLY

25X1

WATER RESOURCES INVESTIGATIONS

for the

NAHR EL KELB BASIN

REPUBLIC OF LEBANON

RECONNAISSANCE REPORT

FOR OFFICIAL USE ONLY

Prepared for the
INTERNATIONAL COOPERATION ADMINISTRATION
by the
UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

DENVER, COLORADO

February, 1958

IN REPLY REFER TO:

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
WASHINGTON 25, D. C.

February 3, 1958

Mr. E. N. Holmgreen, Director
Office of Food and Agriculture
International Cooperation Administration
Washington 25, D. C.

My dear Mr. Holmgreen:

Under the general provisions of the Special Project Agreement between the Bureau of Reclamation and the Foreign Operations Administration for Technical Assistance in Water Resources Development, Lebanon, signed September 1, 1954, the Bureau of Reclamation has prepared the attached report on the Nahr el Kelb Basin, Lebanon.

This report covers a water resources reconnaissance of the Nahr el Kelb Basin in northeastern Lebanon and indicates the water and land resources potentialities of that basin. The data on which this report is based are purely of a reconnaissance nature, and are only indicative of the actual conditions existing in this river basin. We wish to emphasize the recommendation in the report that the collection of much additional physical data must be undertaken as a part of a detailed investigation before any construction on a definite development plan can be undertaken.

This report is the sixth of nine such basin reports to be completed under this agreement. Additional reports will be transmitted at a later date.

Sincerely yours

W A Dexheimer

Commissioner

In duplicate

Enclosure

Prepared By

United States Department of the Interior
Bureau of Reclamation

for the

International Cooperation Administration

Water Resources Investigations

NAHR EL KELB BASIN

LEBANON

RECONNAISSANCE REPORT

Natural Resources Division
United States Operations Mission to Lebanon
Beirut, Lebanon
May, 1956

SUMMARY

This reconnaissance report describes the investigations made, the data collected, the conclusions drawn, and the recommendations made with regard to the development of the water resources of the Nahr el Kelb Basin in Central Lebanon about 11 kilometers northeast of Beirut.

The basin contains about 260 square kilometers and extends from the crest of the Lebanon Mountains to the Mediterranean Sea. Elevations in this basin vary from about 2,630 meters to sea level. Outcrops of Cretaceous and Jurassic age predominate throughout the basin. These have been extensively folded and faulted. Many springs occur and produce most of the streamflow, particularly during the dry season. Water from such springs in the mountain section has been partly developed for village water supply and for terrace irrigation.

Water is diverted from the river to irrigate about 120 hectares of fertile land in the coastal section north and south of the river and for a domestic water supply for the city of Beirut. Expansion of the coastal irrigation system is impracticable due to the lack of irrigable land.

Very meager hydrologic data are available. The development proposed herein has been based upon limited streamflow records. They appear reasonable, but the short periods of measurement are not sufficient for a definite hydrologic study. The study indicates a total surface water discharge of about 250 million cubic meters in an average water year and 121 million cubic meters in a minimum water year at the El Mokhada Gaging Station. Storage at the Mayrouba Reservoir Site would help firm the power production and furnish additional domestic water for future developments.

Existing and expected power production from approved developments, are believed ample for Lebanon's needs for about 15 years. The power development proposed consists of 5 hydroelectric plants and one thermal plant. The hydro plants would have an installed capacity of 103,200 kilowatts and the thermal plants, 65,000 kilowatts. Estimated salable energy production in an average water year would be about 274 million kilowatt-hours from the hydro plants and 371 million from the thermal plant. A 69,000-volt transmission system to connect these plants to Beirut, and a 35,000-volt system to provide power for the local area, are proposed; however, final determination of the transmission system voltage levels should be made in future detailed studies. The total estimated cost of the power development is LL. 134,000,000, and the estimated annual cost would be LL. 18,551,000. Power benefits as measured by the annual cost of the cheapest alternative source of power is LL. 21,900,000. Comparison with the estimated annual cost shows a benefit-cost ratio of 1.2 to 1 for the proposed power development. Assuming a market for all energy produced, and a rate of five piasters per kilowatt-hour, expected revenue from power production in an average water year would be LL. 32,250,000.

This report recommends that:

1. The plan proposed herein for the rehabilitation of the existing irrigation system, development of the power production, and expansion of the domestic water supply be adopted by the Government of Lebanon as a preliminary plan for the development of the water resources of the Nahr el Kelb Basin;

2. Detailed investigations, including the collection of 10 years of additional hydrologic data, additional surveys, geologic data, extensive foundation investigations of the Mayrouba Reservoir Site, comparative preliminary designs for Mayrouba Dam, power market studies, repayment analyses, and additional data on all phases of the proposed power development, be undertaken and completed before final design and construction of the proposed power development be undertaken;

3. The additional power development proposed herein for the Nahr el Kelb Basin be studied in detail for construction as soon as market conditions warrant and sufficient data are available as a result of the detailed project investigations proposed herein, provided that no other major power developments, other than that of the Litani River Project, are authorized before the Nahr el Kelb development;

4. Final determination of the transmission system voltage levels should be left to future detailed transmission studies of the entire country, which should include consideration of all the potential hydroelectric developments. The Ministry of Public Works expedite their development program for village water supply and that it be expanded to include all of those villages in the Nahr el Kelb Basin whose present water supply is inadequate. The Government of Lebanon establish a program to educate and train water users in the proper use of irrigation water and modern agricultural practices.

Following are tabulations of "Pertinent Data Proposed Hydroelectric Power Development Nahr el Kelb Basin."

PERTINENT DATA - PROPOSED HYDROELECTRIC POWER DEVELOPMENT - NAHR EL KELB BASIN

Feature	Hardoun Unit	Mayrouba Unit	Qlayaat Unit	Balloune Unit	Jeita Unit
Dam and Reservoir	(5 dams)				
Crest Elevation	1521-1632m.	1, 217 m.	795 m.	363 m.	60 m.
Storage Capacity	Nil	$20x10^6$ m^3	Nil	150, 000m^3	Nil
Tunnel	Free-flow	Free-flow	Free-flow	Free-flow	--
Diameter	2.0 m.	2.2 m.	2.2 m.	2.2 m.	--
Length	250 m.	1, 900m.	2, 300m.	2, 500m.	--
Conduit					
Diameter	--	--	--	2.2 m.	--
Length	--	--	--	2, 500m.	--
Canal					
Capacity	1.5-4 m^3/s	10 m^3/s	--	--	15 m^3/s
Length	9, 620m.	3, 200m.	--	--	1, 900m.
Penstock					
Diameter	1.1 m.	1.8 m.	1.8 m.	1.9 m.	2.2 m.
Length	1, 400m.	800 m.	1, 180m.	820 m.	125 m.
Power Plant					
Gross Head	296 m.	362 m.	422 m.	270 m.	36 m.
Turbines	Impulse	Impulse	Impulse	Impulse	Reaction
Generators	1-10, 000kw.	2-14, 500kw.	2-17, 000kw.	2-13, 000kw.	1-4, 200kw.
Total Capacity	10, 000 kw.	29, 000kw.	34, 000kw.	26, 000kw.	4, 200kw.
Annual Generation (million kwh.)	33	54	68	100	19

TRANSLITERATION

Certain inconsistencies in the spelling of place names may be noted on maps and in the text. Difficulties in transliterating Arabic words into exact French or English equivalents have resulted in a wide variation of spellings on the original maps and documents used for this report. Generally, the spelling used in this report, is that shown on the topographic quadrangle sheets prepared by the Institut Geographie National, Ministere Des Travaux Publics et Des Transports, Paris, France. It should be noted, however, that the phonetic pronunciation of names is similar regardless of the spelling.

Other inconsistencies occur in the use of certain Arabic words which are often retained in the French and English versions of proper names. For instance, the word "Nahr" is the Arabic word for "river," "Jebel" or "Jabal" is "mountain," "Ain" is "spring," "Nabaa" is "source," etc. Local usage has often dictated the use of certain of those Arabic words on maps and in the text.

CONVERSION FACTORS

This report has been prepared primarily for use in Lebanon where units of measure are in the metric system. Therefore, metric units and Lebanese currency units have been used throughout this report. The following conversion factors are shown for the convenience of the reader:

1 meter (m) = 39.37 inches = 3.281 feet

1 kilometer (km) = 0.621 miles

1 square meter (m^2) = 10.76 square feet

1 hectare (ha) = 10,000 square meters = 2.47 acres

1 cubic meter (m^3) = 1,000 liters = 35.315 cubic feet

1 liter (l) = 0.264 gallons

1 million cubic meters ($m^3 \times 10^6$) = 810.7 acre-feet

1 kilogram (kg) = 2.205 pounds

1 Pound Lebanese (LL.) = 100 Piasters Lebanes (PL.) = 0.310 Dollars U. S.

1 Dollar U.S. ($) = 3.22 Pounds Lebanese (Exchange rate April 30, 1956).

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF PLATES

LIST OF PLATES (Continued)

APPENDIX

LIST OF PLATES (Continued)

SECTION I

INTRODUCTION

This water resource reconnaissance investigation of the Nahr el Kelb Basin has been made at the request of the Ministry of Public Works for Lebanon. The purpose of this investigation was to determine the potentialities for development of the water resources of this basin. A tentative plan for the development of such resources has been formulated. The results of this investigation and the details of the proposed plan are discussed in this report.

This investigation has disclosed that very meager physical data are available upon which to base a plan for the development of this basin. Therefore, the plan proposed herein has been based upon a number of basic assumptions since actual data were not available. These assumptions must be substantiated, or modified, by more detailed investigations before the execution of the proposed plan is undertaken. However, this plan is presented to serve as a framework upon which additional investigations may be based. It is intended primarily as an indication of the potentialities for water development in this basin and as a guide to the planning of the future investigations required.

Future investigations should include the collection and analysis of adequate hydrologic data; detailed topographic mapping of critical areas; geologic exploration at sites proposed for major development structures; and the expansion of the domestic water supply program for Beirut and all other towns and villages in the area. These proposed investigations are discussed in detail in Section IX - ADDITIONAL INVESTIGATIONS NECESSARY.

Authority and Scope

A project agreement between the United States of America Operations Mission to Lebanon and the Ministry of Public Works for Lebanon was signed on October 1, 1953 and amended June 10, 1954. A new project agreement covering this same project was signed March 31, 1955. This agreement provided a joint technical cooperation project in the field of Water Resources Development Planning and was requested by the Ministry of Public Works by letter dated March 7, 1953. The agreement authorized joint action for reconnaissance investigations and reports on the water resource potentialities of Lebanon, other than the water resources potentialities included in the Litani River Investigation Report.

The plan of action authorized in this project agreement, as amended, limited these studies to preliminary hydrologic investigations, including stream gaging; reconnaissance-type field surveys, including land classification; geologic investigations; and a review of existing plans, proposals, and projects. Reconnaissance reports will be prepared for each major stream, or river basin, selected jointly for investigation by the Project Engineer of the Operations Mission to Lebanon Special Project, and the Director General of the Ministry of Public Works.

The Director General, by letter of January 20, 1954, proposed that the following eleven river basins in Lebanon be included in this reconnaissance investigation, and these have been jointly agreed to by both agencies:

- Nahr el Bared
- Nahr Ostouene
- Nahr el Assi
- Nahr Ibrahim
- Nahr Arka
- Nahr Abou Ali
- Nahr el Kelb
- Nahr Beirut
- Nahr el Kebir
- Nahr Damour
- Nahr el Awali

The general locations of these eleven rivers are shown on Plate I-1. A reconnaissance report to cover the potential water resources in each of these basins has been requested by the Ministry of Public Works.

The 1956 Project Agreement, signed April 26, 1956, deleted the originally proposed reconnaissance investigations for the Nahr el Kebir and Nahr el Awali Basins. The Nahr el Kebir forming the North boundary of Lebanon between Lebanon and Syria, is an international stream. Therefore, a basin report cannot be completed on this stream without the cooperation of the Government of Syria. An agreement between the two countries on the division of the water has not been reached.

A separate report for the Nahr el Awali Basin is not deemed necessary as development of this stream was included in the "Litani River Basin Development Plan" which was officially presented to the Government of Lebanon in July 1954.

This report describes the investigations made, the data collected, the conclusions drawn, and the recommendations made, regarding the water resource potential of the Nahr el Kelb Basin. The general area included in this basin is shown on Plate I-1 and its detailed description in Section II - GENERAL DESCRIPTION.

Cooperation and Acknowledgements

The Ministry of Public Works for Lebanon has been jointly responsible for this investigation and report, and has contributed funds and personnel to assist in its execution and completion. Mr. Ibrahim Abd-el Al, Director General of Concessions and Representative of the Ministry of Public Works, and his staff, have cooperated with the Operations Mission to Lebanon. Their assistance is greatly appreciated. Other agencies of the Lebanese Government have also contributed information and data used in this investigation.

The United States Embassy in Beirut and the United States Operations Mission to Lebanon have made available personnel and facilities needed to assist in carrying out these investigations.

Most of the United States personnel responsible for these investigations and report were employees of the Bureau of Reclamation, United States Department of the Interior, who were assigned to the United States Operations Mission to Lebanon - Special Project for this work. Other United States personnel engaged in this work were International Cooperation Administration employees. Able assistance was given by Lebanese engineers and technicians on various phases of the work.

The power companies in Lebanon have supplied valuable statistical and engineering data that have been incorporated into the power market and power resource investigations that were made as a part of the Litani River Investigations. These data have provided much source material for this report.

Previous Studies and Reports

A number of missions, consulting firms, and individuals have made investigations and studies relating to the problems involved in the development of the natural resources of Lebanon. The reports of such groups have generally been available for use in this investigation and have been most useful in furnishing background material and basic data. Credit has been given wherever possible when such material has been utilized. The following is a brief description of the principal source reports with footnote designations as used throughout this report:

The United States - Lebanon Agricultural Mission.[1] This mission was organized jointly in 1946 by the United States Departments of State and Agriculture, at the request of the Lebanese Government. Its assignment was to assist Lebanon on problems relating to agricultural development. The report of this mission, after intensive study, included recommendations and suggestions to the Lebanese Government for solving the agricultural problems of Lebanon.

1/ United States Department of Agriculture - Report of the United States - Lebanon Agricultural Mission - Office of Foreign Agricultural Relations - Washington, D. C., September, 1948.

The Economic Development of Lebanon.[2] The Government of Lebanon entered into an agreement on December 27, 1946 with the firm of Sir Alexander Gibb and Partners, Consulting Engineers, of London, England, to "investigate and report on the economic development of Lebanon." The report by this firm contains a study of the economics of Lebanon and recommendations regarding land and water utilization, communications, industry and commerce. It proposed a "Long Term Plan" for the development of the country.

The United Nations Economic Survey Mission for the Middle East.[3] This report, in two volumes, dated December 28, 1949, was prepared by an Economic Survey Mission of the United Nations under the chairmanship of Gordon R. Clapp. This Mission was established by the United Nations Conciliation Commission for Palestine to "examine the economic situation in the countries affected by the recent hostilities, and to make recommendations to the Commission for an integrated programme..." This Mission secured the services of a staff of experts who made a rapid study of the refugee problem, the economy of the Middle East area, and of various measures which might be undertaken to alleviate some of the economic problems in this area. This Mission reported in part, in connection with its survey of Lebanon, as follows:

> "...Complete development of the water resources of the country is essential to the future economy, as it will be the means of increasing agricultural productivity through irrigation, as well as creating opportunities for a greater industrial development by utilizing low-cost hydroelectric power."

Development Plan for the Litani River Basin.[4] This report was prepared by the United States Department of the Interior, Bureau of Reclamation, for the United States Foreign Operations Administration, at the request of the Lebanese Government, as a part of the Technical Assistance Program to Lebanon. It was presented to the Lebanese Government by the United States Ambassador to Lebanon on July 21, 1954, and subsequently adopted by that Government. This report presents an over-all plan for the development of the water resources of the Litani and Bisri (El Awali) River Basins. It is referred to herein as the Development Plan for the Litani River Basin. It has furnished a considerable amount of basic data used in this report.

Nuclear Power Plants

In this report it was assumed that modern oil-burning, steam-electric power plants would be used to firm the power produced by the proposed hydroelectric development. The lack of proven experience, with respect to atomic power plant costs, prohibits a rational economic comparison of fossil fuel (oil, coal, etc.) with nuclear fuel power plants. Until additional cost data becomes available, as a result of actual experience with experimental nuclear power plants in the United States, Great Britain, and elsewhere, it is impractical at this time to make any comparative cost estimates of atomic and conventional power plants in Lebanon.

Although nuclear fuels have a very high concentration of energy per unit weight, which greatly reduces the mass of fuel required at the power plant when compared to conventional fuels, the proximity of large petroleum reserves in the Middle East, and the existence of two major petroleum pipeline terminuses in Lebanon, greatly reduces the advantage of low fuel-mass requirements of nuclear power plants. The availability of atomic fuels during emergencies and the reliability of nuclear power during operation are still questionable. Atomic fuel costs are unclear and uncertain, since fuel processing costs are unknown. A comparison of fossil and nuclear fuel costs is highly speculative.

2/ Gibb, Sir Alexander, and Partners - The Economic Development of Lebanon - Beirut, Lebanon, 1948.

3/ United Nations - Final Report of the United Nations Economic Survey Mission for the Middle East - Lake Success, New York, Dec. 28, 1949.

4/ United States Bureau of Reclamation - Development Plan for the Litani River Basin - Beirut, Lebanon, June, 1954.

Also, depreciation costs of the reactor portion of atomic power plants are unknown. Rational analyses of nuclear power plant economics, including the determination of fixed charges, operating costs, and fuel costs, must await improved cost estimating techniques based upon proven experience. However, at the time it is necessary to design the thermal power plants proposed in this report, sufficient information may be available to permit a reasonable study of the economic possibilities of atomic power plants in Lebanon.

SECTION II

GENERAL DESCRIPTION

Location

The Nahr el Kelb rises in the western slopes of the Lebanon Mountains and flows generally westward to enter the Mediterranean Sea about 11 kilometers northeast of Beirut, Lebanon. Its drainage basin of about 260 square kilometers, is located in Central Lebanon between 33° 54' and 34° 03' North latitude and 35° 36' and 35° 55' East longitude. This basin is all mountainous and is bordered on the north by the drainage basin of the Nahr Ibrahim; on the east by that of the Nahr Litani; and on the south by the Nahr Beirut Basin. The general location of this basin in Lebanon is shown on Plate I-1, its principal streams and other drainage features on Plate II-1, and its condensed profiles on Plate II-2.

Basin Description

The crest of the Lebanon Mountains forms the east rim of this basin for a distance of about 11 kilometers. The crest elevation of Jabal Sannine, a part of this range, is 2,630 meters. The area drained by this stream is made up of steep-sided mountain ridges of limestone and marl, separated by canyon-type valleys with narrow bottoms and steep profiles.

The drainage pattern of the Nahr el Kelb is essentially dendritic with the main river forming the stem and the Nahr es Salib, Nahr es Samm, Nahr Hassen and Ouadi Hardoun forming the veins of the leaf.

Physiography

The Lebanon Mountains form the eastern boundary for the Nahr el Kelb Basin and separate it from the Nahr Litani Basin. The mountainous section of the Kelb Basin is made up of numerous ridges, or spurs, extending westward from the main crest line. Between these ridges, the Nahr el Kelb and its tributaries have carved deep valleys and narrow gorges. There is very little level, or near level, land in this basin. The central part is underlain by the Jurassic series which has been elevated from sea level to its present position since Mesozoic time and is generally known as the Jurassic horst. Bordering this area, is a zone of Cretaceous formations and near the sea are Tertiary deposits. Lava masses have extruded through faults and fissures around the edge of the Jurassic horst. Much of this igneous material is basaltic in character, although some of it is scoria and tuff.

Major faults extend laterally through the central part of this basin where the Jurassic horst has occurred. One of these lies along, and approximately parallel to, the course of the Nahr el Kelb from Nabaa Leben to the sea. A number of these faults supply water to the large and small springs found in many places throughout the river basin. A geologic reconnaissance of the entire basin was made as a part of this investigation.

The deep gorges and steeply eroded valleys of the Nahr el Kelb and its tributaries have confined the proposed engineering development of the basin to the main stem of the Nahr el Kelb and its most northerly tributary, the Nahr es Salib. The Nahr es Samm and the Nahr Hardoun were eliminated due to the intermittent character of the streamflow, and the lack of acceptable reservoir storage sites.

The engineering reconnaissance indicated that the maximum benefits in the basin, both from power and domestic water supply, could be achieved by development of the Nahr el Kelb and the Nahr es Salib alone. These proposals are discussed more fully under Section VI - POWER DEVELOPMENT. The geology of the basin is discussed in Section IV - GEOLOGY.

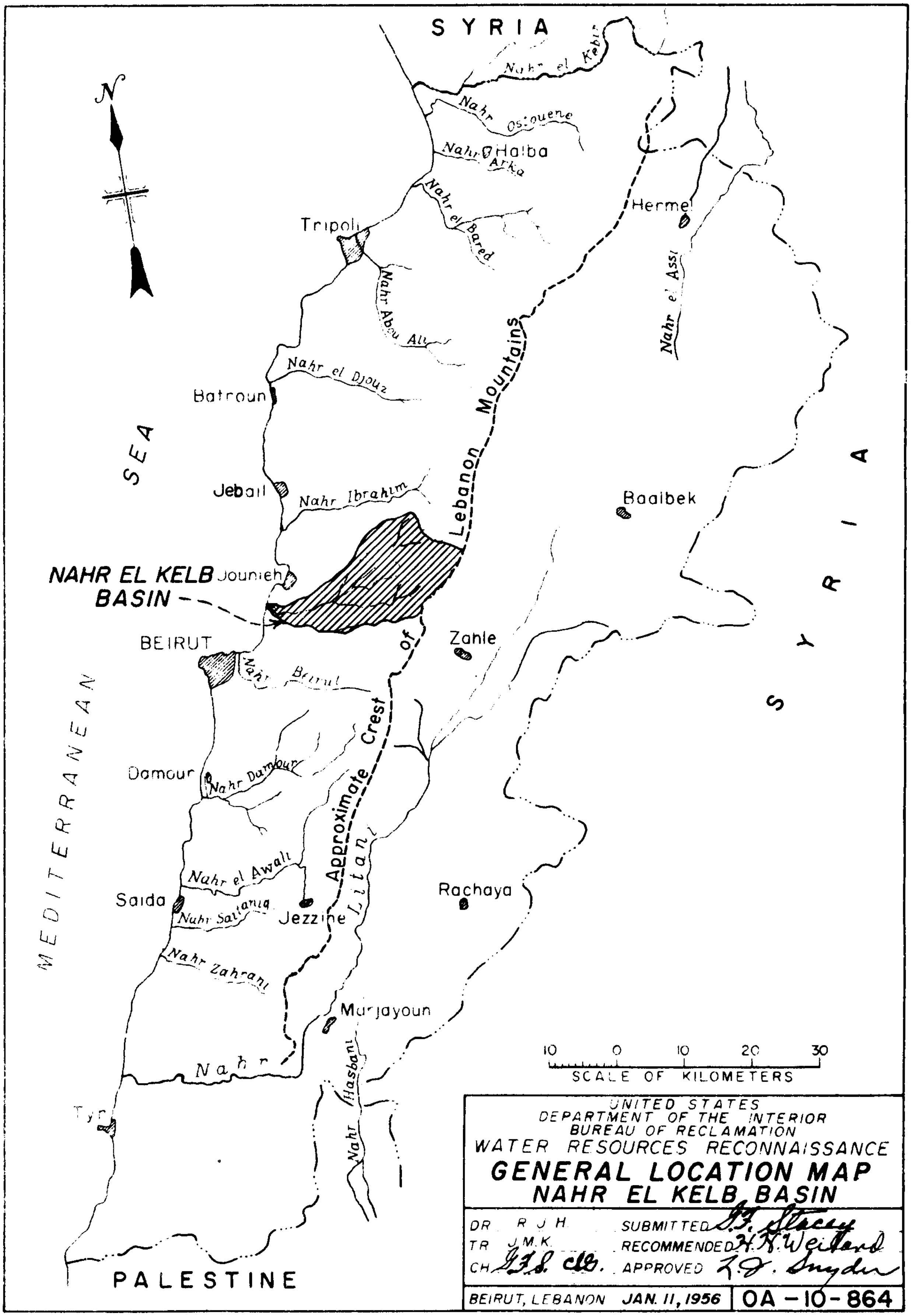
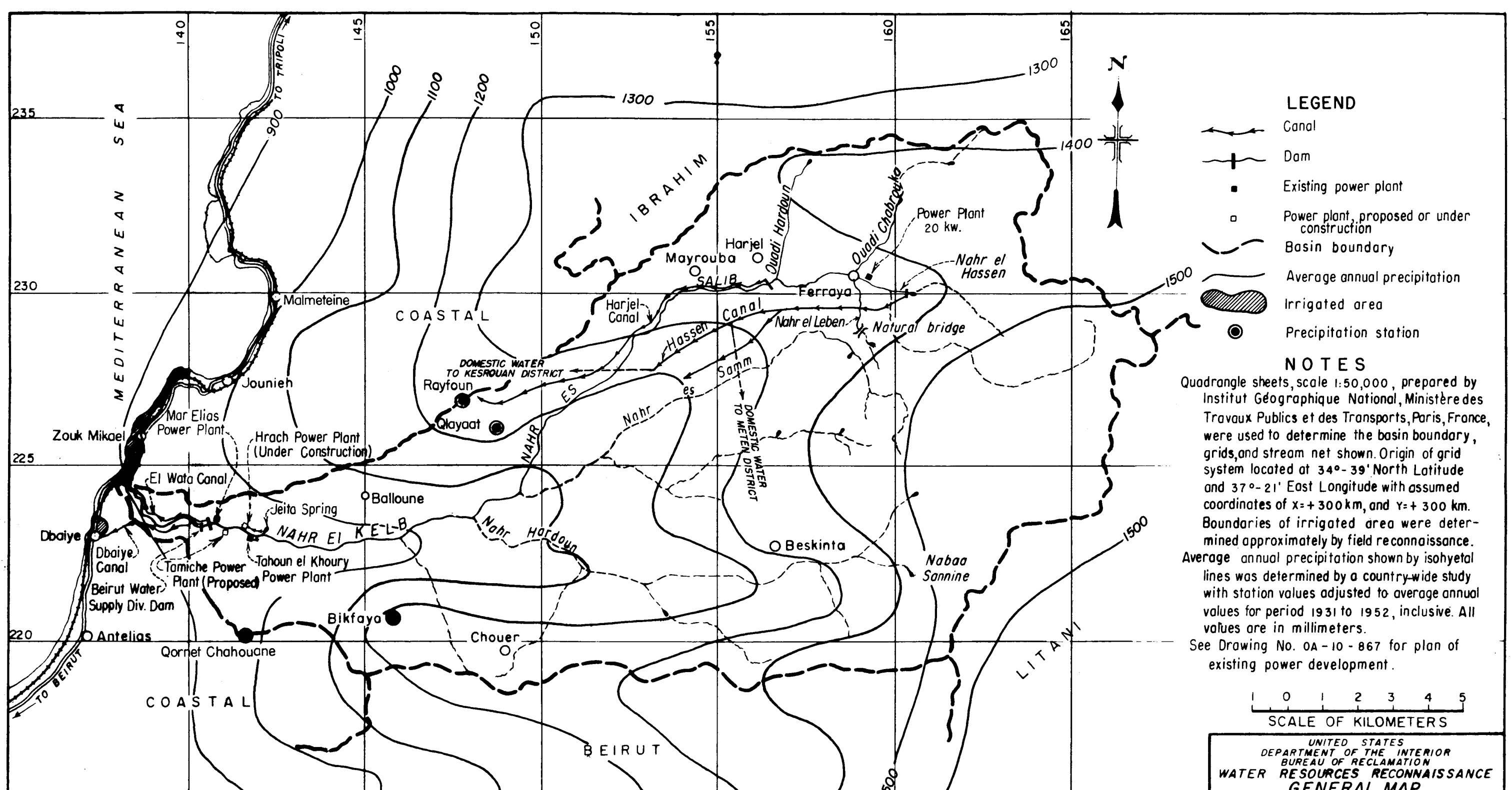
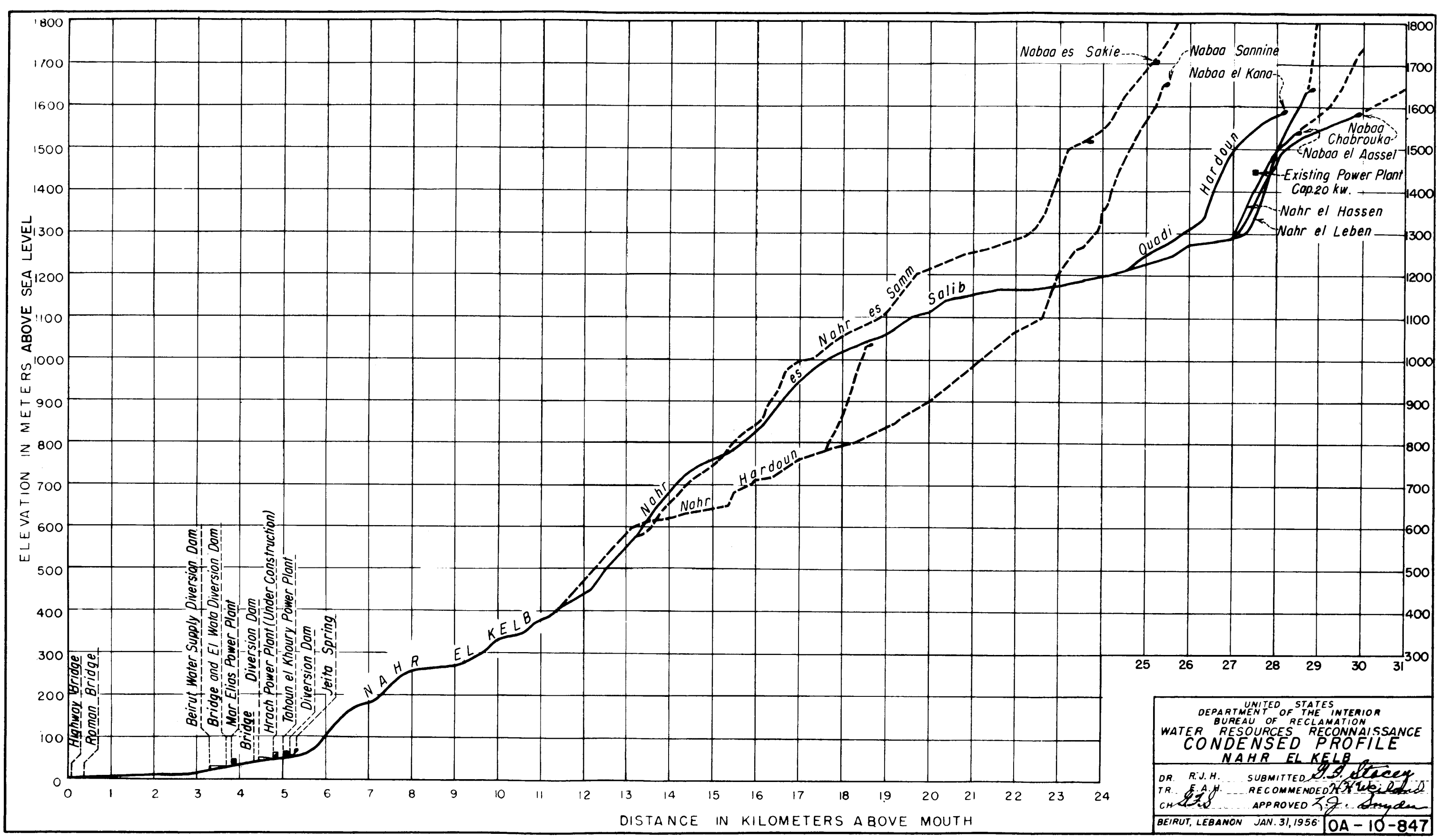

SYRIA
N
Nahr el Kebir
Nahr Ostouene
Nahr Arka
Halba
Nahr el Bared
Tripoli
Hermel
Nahr Abou Ali
Nahr el Assi
Nahr el Djouz
Batroun
SEA
Lebanon Mountains
Jebail
Nahr Ibrahim
Baalbek
NAHR EL KELB BASIN
Jounieh
BEIRUT
Zahle
Nahr Beirut
MEDITERRANEAN
SYRIA
Crest of
Approximate
Damour
Nahr Damour
Nahr el Awali
Saida
Nahr Saitaniq
Jezzine
Litani
Rachaya
Nahr Zahrani
Marjayoun
Nahr
Nahr Hasbani
Tyr
10 0 10 20 30
SCALE OF KILOMETERS
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
WATER RESOURCES RECONNAISSANCE
GENERAL LOCATION MAP
NAHR EL KELB BASIN
DR R J H
TR J M K
CH
SUBMITTED
RECOMMENDED
APPROVED
BEIRUT, LEBANON JAN. 11, 1956
OA - 10 - 864
PALESTINE

PLATE I-1



LEGEND
Canal
Dam
Existing power plant
Power plant, proposed or under construction
Basin boundary
Average annual precipitation
Irrigated area
Precipitation station
NOTES
Quadrangle sheets, scale 1:50,000, prepared by Institut Géographique National, Ministère des Travaux Publics et des Transports, Paris, France, were used to determine the basin boundary, grids, and stream net shown. Origin of grid system located at 34°-39' North Latitude and 37°-21' East Longitude with assumed coordinates of x=+300 km, and y=+300 km.
Boundaries of irrigated area were determined approximately by field reconnaissance.
Average annual precipitation shown by isohyetal lines was determined by a country-wide study with station values adjusted to average annual values for period 1931 to 1952, inclusive. All values are in millimeters.
See Drawing No. OA-10-867 for plan of existing power development.
SCALE OF KILOMETERS
MEDITERRANEAN SEA
TO TRIPOLI
TO BEIRUT
COASTAL
IBRAHIM
SALIB
BEIRUT
LITANI
Malmeteine
Jounieh
Zouk Mikael
Mar Elias Power Plant
Hrach Power Plant (Under Construction)
El Wata Canal
Jeita Spring
NAHR EL KELB
Dbaiye
Dbaiye Canal
Tamiche Power Plant (Proposed)
Tahoun el Khoury Power Plant
Beirut Water Supply Div. Dam
Antelias
Qornet Chahouane
Bikfaya
Chouer
Balloune
Beskinta
Nabaa Sannine
Rayfoun
Qlayaat
DOMESTIC WATER TO KESROUAN DISTRICT
DOMESTIC WATER TO METEN DISTRICT
NAHR ES
Nahr es Samm
Nahr Hardoun
Hassen Canal
Harjel Canal
Harjel
Mayrouba
Ouadi Hardoun
Ouadi Chabrouha
Power Plant 20 kw.
Nahr el Hassen
Ferraya
Nahr el Leben
Natural bridge
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
WATER RESOURCES RECONNAISSANCE
GENERAL MAP
NAHR EL KELB BASIN
BEIRUT, LEBANON JAN. 26, 1956
OA-10-846

PLATE - II - I



ELEVATION IN METERS ABOVE SEA LEVEL
DISTANCE IN KILOMETERS ABOVE MOUTH
Highway Bridge
Roman Bridge
Beirut Water Supply Diversion Dam
Bridge and El Wata Diversion Dam
Mar Elias Power Plant
Bridge
Diversion Dam
Hrach Power Plant (Under Construction)
Tahoun el Khoury Power Plant
Diversion Dam
Jeita Spring
NAHR EL KELB
Nahr
Nahr Hardoun
Nahr es Samm
Salib
Quadi
Hardoun
Nabaa es Sakie
Nabaa Sannine
Nabaa el Kana
Nabaa Chabrouka
Nabaa el Aassel
Existing Power Plant Cap. 20 kw.
Nahr el Hassen
Nahr el Leben
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
WATER RESOURCES RECONNAISSANCE
CONDENSED PROFILE
NAHR EL KELB
DR. R.J.H.
TR. E.A.H.
SUBMITTED
RECOMMENDED
APPROVED
BEIRUT, LEBANON JAN. 31, 1956
OA - 10 - 847

PLATE II - 2

Soils

In general, the soils of the Nahr el Kelb Basin consist largely of upland soils developed from underlying limestone, with minor areas of alluvial soils located in the ouadis. Upland soils are usually shallow, stony loams and clay loams, situated on moderate to steep slopes. Surface drainage is good to excessive, depending on slope characteristics. Extensive terracing has been accomplished on these lands in order to utilize every square meter of tillable soil. Soil erosion has been active over the centuries, with the result that large areas are almost barren masses of rock, with little soil or vegetal cover. Uncultivated lands support a fair growth of drought resistant shrubs and trees.

Population

There are no published data available on population in the Nahr el Kelb Basin. However, an approximation of the population in this basin has been determined by sampling interviews in the villages of the area. This sampling indicates that there are 15 principal villages and several smaller villages in the basin. These villages have a total wintertime population of about 43, 500, and a summertime population of about 74, 000.

Agriculture

Cultivation has been carried out in the Nahr el Kelb Basin since ancient times. Even today agricultural methods are primitive. The land is generally plowed by ox team with iron-shod wooden plows, or dug by hand. Harvesting of grain is commonly done with a hand sickle, after which the unthreshed grain is loaded on camels, or donkeys, and is taken to the village threshing floor. Threshing is accomplished by riding over the grain with a flat wooden sled, the underside of which is imbedded with small stones to cut the straw from the wheat or barley. Grain and chaff are separated by winnowing.

In contrast, it is not unusual to see an imported hand-operated or machine-operated threshing machine, or a farmer plowing a field with a modern tractor and plow. Modern methods are being slowly adopted. Joint efforts of American and Lebanese officials to establish experiment stations, demonstration farms, and an extension service will hasten the acceptance of improved practices. Factors preventing the use of better methods, such as poor land tenure status, or lack of adequate credit, are under study. The solution of these problems will release the peasant from age-old bondage, and may result in great increases in productivity.

Although the majority of the people lead an agrarian life, few actually live on the land. Most of them live in small villages, from which they move to the fields in the morning and to which they return at night. The farm house, constructed of stone or sun-baked mud, combines living quarters and shelter for farm animals.

Livestock are of minor importance in the farm economy of the Nahr el Kelb Basin. They include small numbers of goats, sheep, cattle, donkeys, and chickens.

Many stone-walled terraces have been constructed over the centuries on the hilly mountainous lands of the Nahr el Kelb watershed. A number of these areas are irrigated from springs. The principal crops grown in this section include deciduous fruits (apples, pears, cherries, etc.), vegetables, grains, and olives.

Manufacturing

Many small industries are located in the basin and in the adjacent coastal areas. These industries consist mainly of wool, cotton and silk spinning and weaving mills, processing plants for fruits, vegetables, olive oil and leather, manufacturing plants for floor and roof tiles, concrete pipe, plumbing supply and fabricating plants for wood and steel products. Most of these products are exported to other areas in Lebanon with a small percentage being exported to other countries. Future industrial expansion in Lebanon will probably greatly increase these activities in the Nahr el Kelb Basin and adjacent coastal areas.

Electric Power Supply

There are three small hydroelectric generating plants, aggregating about 300 kilowatts in capacity, existing in the Nahr el Kelb Basin. These plants are used to supply the coastal town of Jounieh and other villages in that area. A hydroelectric plant of 2,000-kilowatts capacity is under construction near the Jeita Spring, and another plant of 900-kilowatts capacity is planned to supply Bikfaya and other upland villages. Most of the villages in the Nahr el Kelb Basin are now interconnected by a 5.5-kilovolt transmission system. This system has a 25-kilovolt interconnection with the municipal system of the Electricity Company of Beirut. Indications are that demands for power in this basin will increase at a rate considerably above the average for other rural areas in Lebanon. It will be necessary to import power into this basin from the neighboring Nahr Ibrahim Basin and the Beirut power system until such time as the proposed Nahr el Kelb power development is well underway. After completion of the proposed Nahr el Kelb development considerable amounts of power will be available for export to the Beirut area.

Domestic Water Supply

The domestic water supply for the many villages in the Nahr el Kelb Basin, and for several villages in adjacent basins to the north and south, is presently taken from four main sources; Nabaa el Aassel, Nabaa Memboukh, Nabaa Jozat, and Jeita Spring. Thirteen villages on the north side and 16 villages outside the basin (total summertime population of 52,934) are supplied with water from Nabaa el Aassel. An additional 25 villages on the south side and 16 villages outside the basin (total summertime population of 61,274) receive water from both Nabaa el Aassel and Nabaa Memboukh. Six small villages (total population of 2,626) are supplied by Nabaa Jozat. Beirut, the capital city of Lebanon, and several coastal villages (total population of 500,000 to 600,000) are supplied by water from Jeita Spring.

An extensive network of pipes and canals is required to carry the water from these springs to the many villages they serve. Plate VII-1, Section VII - DOMESTIC WATER SUPPLY, shows the existing water supply systems and the location of several of the larger springs.

Two large water supply projects which will take water from Jeita Spring and Nabaa Jamajeme are now under construction. The two projects, scheduled for completion before or in early summer 1956, will more than double the amount of water that is now available for domestic water supply in the Meten district. Plate VII-2, Section VII, shows the four water supply systems that will serve the villages in the Nahr el Kelb basin after the completion of projects now under construction.

Sanitized Copy Approved for Release 2011/06/21 : CIA-RDP80T00246A003400510001-7

SECTION III

HYDROLOGY

Climate

Lebanon is on the eastern shore of the Mediterranean, between 33° and 35° North latitude and has a present-day climate of the Mediterranean type. This is moderately cold, windy, and wet in winter and warm and dry in summer and fall. The coastal area is semi-tropical, but the mountain slopes and interior valleys are cooler, with frost and snow occuring during the winter in the Lebanon and Anti-Lebanon Mountains. The climate in the Nahr el Kelb Basin is classed as "wet" during the months of December, January, and February; as "humid" during March and November; "semi-humid" during April; and as "arid" from May through October. Snow and frost occur at the higher elevations between November and April, and each year snow remains on the ground in the headwater areas until July or August.

Wind

Wind records, including direction, velocity, and wind-kilometers traveled, have been maintained at Beirut since about 1920. Wind observations include direction and force on the Beaufort Scale for each of the eight principal points of the compass, and total kilometers of wind movement per day. These data are published in the "Monthly Bulletin" of the Observatory of the American University of Beirut. These data are indicative of the wind that occurs in the western section of the Nahr el Kelb Basin.

In 1952 a recording anemometer was installed at the College of Machmouche as a part of the Litani River Basin Investigations. This station is about 900 meters above sea level and is on the coastal side of the Lebanon Mountains. It is located about 45 kilometers southwest of the Nahr el Kelb Basin, but its wind records are indicative of wind conditions to be expected over the mountain section of this basin. The anemometer at Machmouche does not record wind velocity, and the maximum velocities attained each year at Beirut are not published. It is estimated however, that the maximum velocity to be expected in the Nahr el Kelb Basin will not exceed 50 meters per second. The storage reservoir proposed for this basin will be relatively short. Since wind set-up and wind wave heights will not be major design consideration, they have not been determined.

Temperature

Beirut is about 15 kilometers southwest of the centroid of the Nahr el Kelb Basin (See Plate I-1), but it is the nearest point where temperatures are recorded. Temperature extremes at Beirut, for the years 1924 through 1953, are shown on Table III-1. Average monthly temperatures at this station for the same period, are shown in Table III-2. These temperatures are representative of the coastal plain section of the Nahr el Kelb Basin. They should be decreased by about 6° C. for each 1,000 meters of increase in elevation, to be representative of the mountain section of the basin. During the period 1924 through 1953, the maximum daily temperature at Beirut was 43.2° C. on May 10, 1941; the minimum was 0° C. on January 3, 1942. Beirut mean monthly temperatures have ranged from 13.9° C. in January to 29.1° C. in August, with a yearly mean temperature of 21.6° C.

Humidity

Humidity is relatively high throughout the year in the coastal section of Lebanon. In winter this high humidity results from the action of Atlantic, or Mediterranean, cyclonic disturbances transporting large amounts of moisture from such bodies of water to Lebanon. In summer the short passage of the monsoonal air over the eastern Mediterranean saturates its lower layers sufficiently to maintain high coastal humidity, but not enough to produce precipitation in the mountain areas. This high humidity results in frequent heavy dew which distinctly benefits vegetation in the coastal area.

TABLE III - I

TEMPERATURE EXTREMES
BEIRUT - LEBANON
(All values in Degrees - Centigrade)

Year	January		February		March		April		May		June		July		August		September		October		November		December	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1924	20.4	7.9	22.9	6.7	27.9	9.7	33.4	12.5	27.5	15.6	29.8	19.4	31.7	22.1	32.2	22.8	31.8	21.5	30.7	15.7	27.0	11.4	21.2	5.1
1925	17.3	3.8	25.8	6.7	32.6	10.1	26.4	7.4	34.2	14.6	29.3	17.2	31.5	20.1	31.9	22.8	31.8	21.3	30.3	18.0	28.4	14.6	22.9	8.4
1926	19.4	8.9	20.5	8.7	24.6	10.4	30.9	9.6	33.1	14.8	33.5	18.7	31.9	21.3	31.5	21.5	31.2	20.2	30.1	17.8	28.4	15.0	24.6	10.1
1927	19.9	9.1	20.6	3.9	28.7	10.4	26.7	10.6	33.2	15.1	31.8	20.1	33.3	21.1	32.9	23.3	31.7	22.6	30.0	17.1	29.2	11.1	21.0	9.1
1928	20.8	7.9	22.8	3.9	29.1	4.2	37.7	12.6	36.2	16.7	31.6	18.3	32.8	22.2	33.7	23.6	32.0	22.1	30.9	16.1	28.7	12.4	24.4	7.8
1929	19.3	4.3	22.1	1.6	24.2	7.8	28.7	10.1	35.6	16.1	31.9	18.7	32.7	21.1	33.9	22.3	33.9	20.8	30.2	16.9	26.4	11.7	20.6	9.2
1930	18.8	8.6	21.6	8.4	27.2	9.4	31.0	11.4	33.3	15.3	33.9	19.7	33.6	21.7	35.1	22.7	33.3	20.5	30.6	19.0	26.1	13.2	22.8	11.3
1931	22.7	6.6	20.5	9.2	28.4	6.2	28.4	11.8	34.3	14.3	32.2	19.3	33.9	21.1	33.7	23.3	38.8	19.9	30.1	17.8	25.1	11.0	22.2	7.4
1932	19.2	6.8	27.3	1.0	25.9	7.9	31.7	10.5	32.1	12.9	32.3	19.0	34.3	20.1	34.3	21.8	32.4	21.1	30.8	20.4	31.0	12.2	22.1	8.1
1933	20.2	6.3	24.9	8.4	23.0	8.0	24.9	9.8	28.7	15.6	36.1	17.2	31.3	20.1	37.1	21.4	30.7	18.9	28.3	16.4	26.9	13.8	23.3	5.2
1934	22.1	5.6	23.2	4.7	26.7	10.5	26.9	12.9	28.2	15.6	33.5	18.4	34.2	21.2	34.4	22.9	32.8	20.6	30.1	18.5	25.9	18.2	21.5	10.7
1935	24.1	8.5	26.7	5.8	26.0	10.8	32.8	11.8	38.5	15.9	32.8	21.5	34.4	21.8	34.0	21.2	32.9	17.8	30.1	16.0	24.9	11.6	21.2	11.3
1936	21.3	11.1	22.7	7.8	26.0	9.7	37.3	12.3	33.3	16.3	31.6	18.6	34.8	21.3	34.6	23.3	33.2	20.6	33.6	19.1	28.5	9.9	22.1	5.3
1937	22.1	5.7	21.1	9.4	23.3	10.9	33.1	13.5	31.8	14.1	31.8	18.4	33.1	22.6	33.8	22.9	33.1	22.2	38.1	15.3	26.4	13.8	26.4	10.8
1938	23.5	8.2	19.1	4.4	22.4	6.6	30.9	10.8	32.6	14.6	31.5	19.5	33.7	22.2	35.0	23.7	33.6	19.3	30.4	17.7	27.5	10.6	22.9	10.2
1939	18.3	8.3	20.0	8.3	23.6	6.4	37.8	11.7	34.2	15.3	33.2	15.6	34.4	21.8	34.3	21.8	34.2	21.8	33.1	19.4	25.8	10.6	23.8	9.1
1940	19.5	5.5	19.8	8.5	29.5	8.0	32.5	10.6	38.5	13.6	34.8	12.8	34.2	20.2	34.0	20.8	33.6	20.5	34.0	15.6	27.7	11.2	21.9	8.5
1941	23.2	8.6	24.5	8.9	27.1	8.7	30.6	11.0	43.2	16.5	33.0	19.9	33.2	22.0	34.6	22.8	22.8	19.4	30.0	17.7	30.0	12.7	19.8	8.9
1942	23.1	0.0	27.0	9.4	27.5	5.9	28.3	12.6	37.0	16.7	40.7	20.1	34.8	21.2	34.2	22.7	32.7	21.1	33.4	16.4	26.1	12.4	21.2	11.6
1943	21.4	5.8	21.1	5.9	23.4	2.3	27.8	8.4	32.5	15.5	32.0	16.8	33.2	21.7	33.7	22.8	36.8	22.3	36.4	17.2	28.2	16.9	23.3	11.2
1944	22.8	7.1	27.4	7.8	28.4	8.9	32.1	10.7	28.9	13.7	34.3	18.4	33.7	22.3	34.4	22.4	33.0	17.8	30.6	18.3	27.2	12.5	21.1	10.7
1945	19.4	7.2	19.1	6.8	26.2	6.3	27.3	12.2	34.0	15.3	33.9	19.4	36.6	21.7	35.6	22.9	34.8	21.2	29.9	17.8	27.2	10.7	23.1	10.2
1946	18.3	7.4	20.1	6.2	25.6	9.1	27.6	9.6	30.9	15.3	32.8	19.8	36.0	22.8	35.1	21.2	37.1	20.1	34.8	16.9	27.9	15.7	24.6	10.7
1947	18.9	9.7	23.8	10.6	28.8	10.7	33.9	11.2	32.1	16.1	34.2	19.6	36.0	23.3	35.3	23.7	34.2	22.4	31.2	14.2	26.8	12.9	25.4	9.0
1948	24.1	8.7	20.2	2.7	27.4	6.2	29.3	10.1	30.8	14.6	33.7	18.4	32.9	21.7	33.7	22.5	32.5	21.4	29.4	13.9	28.2	8.3	19.7	6.1
1949	18.1	6.1	18.7	1.7	27.2	6.5	23.3	7.4	35.5	16.1	31.6	17.9	32.9	21.1	33.1	21.4	32.8	18.3	30.1	17.4	30.2	15.7	23.3	9.0
1950	21.7	1.5	21.8	0.6	27.4	10.0	36.0	10.5	31.9	15.0	32.1	19.4	32.5	22.2	32.8	22.2	33.8	21.4	30.4	16.2	25.0	13.6	23.1	11.8
1951	21.0	7.8	20.0	9.9	31.8	10.2	29.5	12.2	34.1	16.8	31.6	20.3	33.2	23.0	33.7	23.6	33.6	21.6	32.1	11.7	26.6	11.3	20.7	5.4
1952	19.2	5.2	23.1	7.2	25.7	8.2	29.6	7.6	31.7	15.7	36.7	18.8	33.4	21.4	35.6	23.2	33.5	23.3	30.2	20.0	26.1	14.4	26.4	10.7
1953	24.3	6.8	24.5	5.6	24.0	5.6	25.1	10.8	33.7	15.0	31.3	19.4	34.8	22.2	33.8	22.5	32.4	20.6	31.2	18.3	29.8	6.4	21.9	5.6
Extremes in Period	24.3	0.0	27.4	0.6	32.6	2.3	37.8	7.4	43.2	12.9	40.7	12.8	36.6	20.1	37.1	20.8	38.8	17.8	38.1	11.7	31.0	6.4	26.4	5.1

Note:
Data shown are for the American University at Beirut and were taken from Monthly Bulletins, Republic of Lebanon Climatological Service.

TABLE - III - 2

AVERAGE MONTHLY TEMPERATURE
BEIRUT - LEBANON
(All values in Degrees - Centigrade)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	MEAN
1924	14.10	14.50	16.90	19.50	22.20	26.08	28.22	28.66	27.77	24.55	19.84	15.11	21.45
1925	12.13	14.74	18.23	17.94	22.22	23.05	27.21	28.41	27.39	24.91	21.73	17.09	21.25
1926	14.40	14.49	16.09	19.60	23.08	26.05	27.80	27.40	26.86	24.21	21.01	16.48	21.46
1927	15.01	12.97	17.12	18.50	23.60	26.70	29.36	29.00	27.90	25.15	21.13	16.14	21.88
1928	14.99	13.42	15.26	21.20	24.33	26.27	28.58	29.29	28.01	24.62	20.80	16.35	21.93
1929	12.98	13.12	15.50	18.44	23.98	25.96	28.10	29.06	27.33	24.19	20.96	15.58	21.27
1930	13.81	14.84	17.30	20.01	22.70	26.51	28.66	29.23	27.97	25.02	20.42	17.49	21.99
1931	14.89	14.60	17.03	19.28	22.58	26.14	29.31	29.63	28.60	24.82	18.78	15.00	21.72
1932	12.90	14.28	16.35	18.56	21.72	25.75	28.08	29.03	27.41	25.96	20.38	14.96	21.28
1933	13.42	15.32	15.79	17.51	22.23	25.05	26.98	27.94	26.23	23.43	21.35	15.60	20.90
1934	13.56	12.50	17.67	19.86	22.98	26.49	28.47	29.44	27.75	24.99	21.24	15.81	21.73
1935	14.72	14.34	17.07	19.46	25.41	28.16	28.66	29.13	28.14	24.76	18.57	16.52	22.08
1936	15.56	15.12	17.49	20.39	22.85	25.66	28.59	29.88	27.36	24.99	20.37	14.42	21.90
1937	12.20	15.34	17.63	20.55	23.05	26.37	28.68	29.29	28.33	24.98	20.54	16.76	21.98
1938	13.77	13.35	14.48	19.14	22.18	26.02	29.01	29.86	27.70	24.65	18.33	15.85	21.19
1939	14.30	14.12	15.60	19.93	24.03	25.46	28.90	29.47	28.10	26.11	19.64	16.62	21.86
1940	14.62	15.33	16.97	20.39	22.99	26.15	28.12	28.55	26.89	24.72	19.53	16.44	21.72
1941	15.68	15.98	16.33	20.41	25.23	26.99	28.49	29.17	26.79	22.64	19.75	13.88	21.78
1942	12.31	14.60	16.11	19.17	23.55	27.51	28.84	28.63	26.60	22.97	19.56	15.97	22.15
1943	12.90	12.79	14.01	17.04	22.42	25.18	28.00	28.98	27.74	25.25	21.88	17.02	21.10
1944	13.61	14.73	16.80	19.66	21.87	26.47	28.50	28.38	26.81	24.48	19.20	16.09	21.38
1945	14.04	13.54	14.82	18.64	23.76	27.11	29.85	29.98	28.34	23.62	20.32	15.52	21.63
1946	14.16	13.87	15.91	19.57	22.46	26.43	29.10	30.04	28.46	24.73	21.88	16.87	21.96
1947	13.79	15.52	18.07	20.55	23.90	26.84	29.20	29.65	27.56	24.31	19.88	17.51	22.23
1948	15.49	14.16	13.66	18.54	22.26	26.15	28.31	28.74	27.14	23.72	19.21	13.65	20.92
1949	12.51	11.63	15.30	16.13	23.61	26.04	27.89	28.44	26.24	23.98	21.79	16.12	20.81
1950	12.18	12.64	16.18	21.54	22.40	26.61	28.59	28.65	27.98	23.76	19.88	17.32	21.48
1951	14.86	15.15	17.93	20.14	23.19	26.45	28.84	29.40	28.36	23.39	19.01	14.21	21.74
1952	13.85	14.67	15.50	19.16	22.70	25.90	25.05	29.59	29.13	25.11	19.94	17.43	21.50
1953	14.64	14.71	13.31	18.60	22.34	26.36	29.08	29.50	26.09	24.30	17.40	13.39	20.81
Mean Monthly	13.91	14.21	16.21	19.31	23.06	26.20	28.42	29.08	27.56	24.47	20.14	15.91	21.56
Max. Monthly	15.68	15.98	18.23	21.54	25.23	28.16	29.85	30.04	29.13	26.11	21.88	17.51	22.23
Minimum Monthly	12.13	11.63	13.31	16.13	21.72	23.05	25.05	27.40	26.09	22.64	17.40	13.39	20.81

Note:
Data shown are for American University at Beirut and were taken from Monthly Bulletins, Republic of Lebanon Climatological Service.

TABLE III - 3

RELATIVE HUMIDITY - BEIRUT
AMERICAN UNIVERSITY OBSERVATORY
(All values in percent)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Aver.
1938	77.7	69.1	71.1	72.6	70.9	69.9	66.5	66.0	59.1	63.9	70.4	75.3	69.4
1939	75.0	72.5	72.3	72.7	69.1	68.2	65.6	60.4	64.2	66.7	67.3	72.4	68.9
1940	73.7	75.3	67.5	71.6	66.3	66.1	68.0	63.9	66.0	69.0	70.2	72.1	69.1
1941	71.9	73.0	74.5	70.0	64.6	64.9	66.1	66.1	64.7	66.9	70.3	74.4	69.0
1942	75.5	75.0	77.7	75.9	73.3	68.2	67.5	70.2	68.4	74.4	76.6	73.2	73.0
1943	78.7	77.7	74.6	78.1	73.5	71.2	70.3	71.4	66.4	71.3	72.6	75.5	73.4
1944	72.9	71.9	74.4	75.7	74.3	71.8	67.3	67.9	69.5	69.9	74.7	71.8	71.8
1945	70.3	70.2	66.4	68.5	72.1	65.1	63.6	64.8	64.0	61.7	67.0	68.5	66.9
1946	68.5	71.4	75.8	77.5	73.5	71.0	68.6	68.9	71.6	70.5	76.9	79.2	72.6
1947	84.1	80.7	80.9	78.2	78.9	73.3	63.8	66.2	66.3	69.9	74.7	72.6	74.1
1948	76.7	78.3	80.6	83.4	84.5	70.7	71.4	75.4	83.6	81.4	81.4	82.2	79.1
1949	79.9	81.7	77.2	84.5	82.9	82.3	80.3	67.5	69.7	74.9	69.0	74.0	77.0
1950	67.2	68.9	70.8	66.3	72.0	66.5	66.8	65.2	66.1	63.8	72.5	68.3	67.9
1951	63.6	67.3	71.0	69.0	70.9	73.0	67.2	72.0	71.0	63.0	62.0	67.0	68.1
1952	78.6	73.4	68.3	67.7	66.4	75.0	72.0	73.0	71.0	66.0	60.0	57.0	69.0
1953	65.6	68.0	66.9	70.8	68.7	67.2	68.3	64.9	61.5	63.4	66.7	66.0	66.5
Aver.	73.7	73.5	73.0	73.9	70.3	70.3	68.3	67.7	67.7	68.6	70.7	71.8	71.0

The Lebanon Mountains form an effective barrier which prevents much of this moist air in summer from escaping into the interior, hence the lower summer humidity in interior areas. The orographic action of this barrier causes much of the winter moisture to precipitate on the western side and just over the crest of these mountains. Enough moisture is carried over to create high winter humidity throughout Lebanon.

Relative humidity records have been maintained for a number of years at the American University of Beirut. Short records are available at other stations. Table III-3 shows the mean monthly values at Beirut for the period 1938 through 1953. These are believed to be representative of the humidity to be expected in the Nahr el Kelb Basin.

Precipitation

Precipitation stations at Qlayaat, Bikfaya, and Qornet Chahouane are in the Nahr el Kelb Basin; other stations at Reyfoun, Ghosta, Zouk Mikael, and Kaa er Rime are in the vicinity of this basin. The locations of these stations are shown on Plate III-1. Table III-4 shows a comparison of precipitation records at these stations and at Beirut, 12 kilometers southwest of the western end of the Nahr el Kelb Basin.

TABLE III-4

PRECIPITATION RECORDS

Station	Elevation (meters)	Period of Record (years)	Average Annual Precipitation Recorded (mm)	Average Annual Precipitation Adjusted (mm)
Qlayaat	1050	1944-1955	1226	1145
Bikfaya	900	1948-1955	1377	1229
Qornet Chahouane	670	1949-1955	910	905
Reyfoun	1050	1949-1955	1276	1341
Ghosta	750	1948-1955	1346	1204
Zouk Mikael	80	1949-1955	1003	939
Kaa er Rime	1250	1940-1955	1240	1184
Beirut	34	1876-1955	882	882

Daily precipitation recorded at these stations during the period, with the exception of that at Beirut, is published in the "Monthly Bulletin" of the Climatological Service. Precipitation records for Beirut are published in the "Monthly Bulletin" of the Observatory at the American University at Beirut. Monthly and yearly totals of the precipitation recorded at the stations in the Nahr el Kelb Basin are shown on Tables III-5 to III-7.

Average annual isohyetals were prepared for Lebanon, based on records for the period 1931 to 1952. All short-term stations were adjusted to the average for the longer term stations at Tripoli, Beirut, and Ksara. Average annual isohyetals for the Nahr el Kelb Basin are shown on Plate II-1. They indicate that the average annual precipitation over this basin is about 1285 millimeters.

Additional automatic rainfall stations at Ferraya and Beskinta, as well as two snow survey courses, are proposed for the Nahr el Kelb Basin. These are included in a general plan proposed for additional hydrologic data collection throughout Lebanon. Tentative locations for these stations are shown on Plate III-1. The need for these stations is discussed in Section IV - ADDITIONAL INVESTIGATIONS NECESSARY.

Evaporation

Investigations for the Development Plan for the Litani River Basin[4/] included a careful analysis of available evaporation data for Lebanon. The values shown in Table III-8 were determined for expected monthly evaporation from the proposed Bisri Reservoir. These have been assumed to be applicable to any reservoirs that may be planned in the Nahr el Kelb Basin.

TABLE III-5

MONTHLY PRECIPITATION

QLAYAAT - LEBANON
Altitude - 1075 meters

Year	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Total
1944-45	0	54	280	183	304	209	144	64	13 1/	8	0	0	1259
1945-46	0	17	112	218	142	329	256	17	169	0	0	0	1260
1946-47	7	48	3 1/	114	461	176	44	59	84	8	0	0	1004
1947-48	23 1/	25	189	80	243	266	236	115	67	0	0	0	1244
1948-49	7	11	230	265	266	350	275	150	0 1/	0	0	0	1554
1949-50	36	5 1/	34	262	465	61	82	40	104	0	0	0	1089
1950-51	27	99	93	220	167	195	79	123	14	0	0	0	1017
1951-52	8	121	135	392	129	271	232	54	2	0	0	0	1344
1952-53	0	16	137	174	245	326	284	59	9	0	0	0	1250
1953-54	3	0	248	148	319	284	109	119	6	0	0	0	1236
Aver. 1944-54	10	40	146	206	274	247	174	80	47	0	0	0	1226

1/ Estimated from corrolation with record at Zouk Mikhayel

Sanitized Copy Approved for Release 2011/06/21 : CIA-RDP80T00246A003400510001-7

TABLE III-6

MONTHLY PRECIPITATION

BIKFAYA - LEBANON
Altitude - 900 meters

Year	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Total
1948-49	3	21	279	282	313	433	276	167	0	0	0	0	1774
1949-50	36	0	31	240	290	146	173	43	149	1	0	0	1109
1950-51	11	138	68	248	188	132	92	112	7	0	0	0	996
1951-52	11	95	149	386	164	308	240	76	2	0	0	0	1431
1952-53	1	39	197	182	329	350	354	73	9	0	0	0	1534
1953-54	4	1	282	159	361	364	114	124	10	0	0	0	1419
Aver. 1948-54	11	49	168	249	274	289	208	99	29	0	0	0	1377

TABLE III-7

MONTHLY PRECIPITATION

QORNET CHAHOUANE - LEBANON
Altitude - 670 meters

Year	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Total
1949-50	21	0	11	205	261	52	48	21	123	0	0	0	742
1950-51	12	133	59	208	135	108	79	94	5	0	0	0	833
1951-52	5	55	144	274	115	235	159	54	4	0	0	0	1045
1952-53	1	22	182	102	201	229	222	25	7	0	0	0	991
1953-54	1	3	225	113	236	176	68	105	19	0	0	0	946
Aver. 1949-54	8	43	124	180	190	160	115	60	31	0	0	0	910

TABLE III - 9

MONTHLY DISCHARGES

NAHR EL KELB AT EL MOKHADA
(Millions of cubic meters)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1949	-	-	68.27	57.02	55.80	24.82	14.44	6.93	4.01	3.81	3.41	8.06	-
1950	31.23	18.01	38.88	26.60	15.47	11.16	6.43	3.80	3.14	4.23	3.27	15.80	178.02
1951	30.47	23.28	19.12	24.21	13.53	10.86	3.88	3.07	2.68	3.17	4.27	27.37	165.91
1952	32.33	65.62	55.42	35.36	16.47	12.08	9.54	4.15	3.46	3.22	5.29	10.90	253.84
1953	19.80	50.02	58.42	58.15	30.34	22.13	12.22	3.78	3.21	3.17	9.74	18.12	289.10
1954	66.12	67.34	64.32	62.99	41.72	32.15	32.01	5.03	3.19	2.90	3.15	9.48	390.40
1955	10.15	21.63	38.61	31.58	16.04	8.66	3.96	2.94	2.82	2.34			
Average	31.68	40.98	49.00	42.27	27.05	17.41	11.78	4.25	3.21	3.26	4.86	14.96	250.71

TABLE III - 10

DISCHARGE MEASUREMENTS OF NAHR EL KELB AT EL MOKHADA, LEBANON

In cubic meters per second

Meas. No.	Date of Measurement	Gage Height (Meters)	Measuring Section: El-Wata Canal-Rt. Bank Q1	Measuring Section: River Channel Q2	Measuring Section: Small Ir-rig.Canal Lt.Bank Q3	Measuring Section: Dbaiye Water Supp. Canal Q4	Measuring Section: Small Ir-rig. Canal Lt. Bank Q5	Total Discharge Q	Discharge Corresp.to Gage Height of Recorder Q - Q1	Measurement Analysation: Applied gage height shift (Meters)	Measurement Analysation: Percentage difference from rating table
1	June 16,1949	0.445	0.780	(Not measured)		2.690	-	(Not measured)		-	-
2	June 17,1949	0.46	0.929 1/	8.018	-	2.526	-	11.473	10.544	+.08	-1.1
3	Aug. 12,1949	0.34	0.814	2.901	-	-	-	3.715	2.901	-	-4.0
4	Oct. 8,1949	0.035	1.815 2/	0.494	-	-	-	2.309	-	-	-
5	Apr. 21,1950	0.54 3/	0.373	9.411	-	2.685	-	12.469	12.096	-	+8.2
6	July 7,1952	0.48	0.877 4/	1.828	0.026	2.652	.000	5.383	4.506	-.09	+3.2
7	Nov. 22,1952	-0.02	0.508	0.000	0.000	1.266	.000	1.774	1.266	-	0
8	June 2,1953	0.54 3/	0.645	(Not Meas)	0.026	2.693		(Not measured)		-	-
9	June 2,1953	0.54	-	-	-	-	8.599 5/	11.963	11.318	-	+1.3
10	June 30,1953	0.535	1.000	6.150 6/	0.000	-	-	7.150	6.150	-.09	+0.8
11	July 28,1953	0.455	0.750	2.470	-	-	-	3.220	2.470	-.14	+0.4
12	Oct. 17,1953	-0.17	0.696	0.000	0.000	1.191	.002	1.885	1.193	+.10	0
13	Nov. 4,1953	-0.17	0.718	0.000	0.000	1.203	.034	1.887	1.203	+.11	0
14	Apr. 19,1954	0.74	0.464	18.715	-	2.634	-	21.813	21.349	-	-0.7
15	Oct. 21,1954	-0.10 3/	0.765	-	-	1.053	-	1.818	1.053	-.06	-0.9
16	Nov. 17,1954	-0.11 3/	0.67	-	-	0.98	-	1.65	0.98	-.10	-1.0
17	Dec. 20,1954	0.08 7/	0.45	-	-	1.43	-	1.88	1.43	-	-0.7
18	Jan. 19,1955	0.38	0.55	0.55	-	2.49	-	3.59	3.04	-.04	+0.7
19	Mar. 2,1955	0.345	0.53	4.03	-	-	-	4.56	4.03	+.04	-1.0
20	Mar. 23,1955	0.59	0.504	11.39	-	2.476	-	14.370	13.866	-	+0.7
21	Apr. 7,1955	0.52	0.55	8.24	-	2.58	-	11.37	10.82	-	+6.7
22	May 11,1955	0.48	0.65	5.82	-	1.24		7.71	7.06	-.02	+0.6
23	June 13,1955	0.465	1.04	3.74	-	-	-	4.78	3.74	-.09	-1.1
24	July 11,1955	0.188	0.91	-	-	1.69	-	2.60	1.69	-	+2.4
25	Aug. 11,1955	-0.14	0.75	1.08	-	-	-	1.83	1.08	-	0
26	Sept.16,1955	-0.16	0.66	-	-	1.18	-	1.84	1.18	+.08	+0.9
27	Oct. 6,1955	-0.256	0.79	0.87	-	-	-	1.66	0.87	-.04	0
28	Oct. 18,1955	-0.262	0.77	0.86	-	-	-	1.63	0.86	-.05	0
29	Nov. 8,1955	0.045	0.493	1.166				1.659	1.166	-.12	0

1/ 0.929 is max. discharge of canal upstream from spillway.
2/ Power supply canal above the power plant.
3/ Gage Height from recorder chart

4/ Max. canal discharge below spillway.
5/ Measured 200 meters aboveKelb Cafe.
6/ Measurement above diversion dam.
7/ Gage height estimated - recorder stopped.

TABLE III - 11

DAILY DISCHARGE OF NAHR EL KELB AT EL MOKHADA, LEBANON
CALENDAR YEAR 1949

(Cubic meters per second)

Day	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1			12.2	31.4	29.3	11.7	8.06	4.07	1.7	1.44	1.4	1.2
2			11.7	26.7	28.8	11.7	7.54	3.78	1.7	1.44	1.4	1.2
3			13.8	23.1	27.2	11.2	7.02	3.78	1.7	1.44	1.4	1.2
4			15.8	73.6	26.2	12.2	8.06	3.26	1.7	1.44	1.4	1.2
5			15.3	21.0	25.2	12.7	7.02	3.02	1.7	1.44	1.4	1.2
6			13.8	19.0	23.6	11.7	6.9	3.02	1.7	1.44	1.4	1.2
7			12.2	16.9	23.6	11.2	6.8	3.51	1.6	1.44	1.3	1.2
8			12.2	15.3	24.6	10.1	6.6	3.26	1.6	1.44	1.3	1.2
9			13.3	15.3	29.3	10.1	6.3	3.26	1.6	1.44	1.3	1.2
10			12.2	18.4	30.8	10.1	6.2	3.51	1.6	1.44	1.3	1.2
11			11.7	20.0	28.3	10.1	6.0	3.26	1.6	1.44	1.3	1.2
12			19.5	20.5	27.7	10.1	5.8	* 3.02	1.6	1.42	1.3	1.2
13			24.6	18.4	24.1	10.1	5.7	2.80	1.6	1.42	1.3	1.2
14			18.4	19.0	22.6	9.10	5.5	2.61	1.5	1.42	1.3	1.20
15			15.8	21.0	22.6	9.62	5.3	2.61	1.5	1.42	1.3	1.20
16			16.4	26.2	20.5	10.1	5.2	2.46	1.5	1.42	1.3	1.20
17			17.9	22.1	20.5	* 9.62	5.0	2.46	1.5	1.42	1.3	1.20
18			20.5	21.0	21.0	9.10	4.8	2.10	1.5	1.42	1.3	1.20
19			20.0	21.0	20.0	8.58	4.7	1.92	1.5	1.42	1.3	1.20
20			19.5	21.5	17.9	8.58	4.6	2.00	1.5	1.42	1.3	1.20
21		11.7	24.6	20.0	16.9	7.54	4.4	2.00	1.5	1.42	1.3	1.24
22		11.7	32.9	19.0	15.3	8.58	4.3	2.10	1.44	1.4	1.3	1.27
23		11.2	56.8	19.0	14.8	9.62	4.2	2.10	1.44	1.4	1.3	1.27
24		12.7	35.0	20.5	14.3	9.62	4.0	1.85	1.44	1.4	1.3	1.27
25		13.3	32.4	22.6	14.3	8.06	3.9	1.8	1.44	1.4	1.3	1.28
26		13.8	26.7	24.6	14.3	7.54	3.78	1.8	1.44	1.4	1.3	1.69
27		15.8	31.4	24.6	13.3	7.02	3.78	1.8	1.44	1.4	1.3	12.7
28		13.3	61.7	24.6	12.7	6.54	3.78	1.8	1.44	1.4	1.3	24.1
29		—	54.7	29.8	12.7	7.02	4.07	1.8	1.44	1.4	1.3	14.8
30		—	76.5	33.9	11.7	8.06	3.78	1.8	1.44	1.4	1.2	6.10
31		—	40.7	—	11.7	—	4.07	1.7	—	1.4	—	3.51
Total	(21-28)	103.5	790.2	660.0	645.8	287.30	167.16	80.26	46.36	44.04	39.5	93.23
Mean	(21-28)	12.94	25.49	22.00	20.83	9.58	5.39	2.59	1.55	1.42	1.32	3.01
m3x106	(21-28)	8.94	68.27	57.02	55.80	24.82	14.44	6.93	4.01	3.81	3.41	8.06

Note: No gage-height record July 6-25, Aug. 25 to Sept. 21, Oct. 22 to Dec. 13; discharge estimated on basis of records for station on Nahr Ibrahim at Bazhal, recorded range in stage and weather records.
Shifting-control method used May 12 to July 5, July 26 to Aug. 8, 16.

* Discharge measurement made on this day.

TABLE III - 11

DAILY DISCHARGE OF NAHR EL KELB AT EL MOKHADA, LEBANON
CALENDAR YEAR 1950

(Cubic meters per second)

Day	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	3.02	6.54	11.7	11.7	7.54	5.00	3.51	1.47	1.3	1.1	1.19	1.51
2	7.02	9.10	20.5	12.2	6.10	5.34	4.37	1.47	1.3	1.10	1.20	1.35
3	17.4	8.06	20.5	15.8	6.10	5.34	4.07	1.47	1.3	1.1	1.20	1.33
4	12.7	7.54	31.4	20.5	6.54	5.00	3.51	1.47	1.3	1.1	1.20	1.49
5	36.1	7.02	40.7	14.8	9.62	4.68	3.26	1.47	1.3	1.1	1.22	2.33
6	18.4	5.70	22.6	12.2	9.62	4.07	3.26	1.45	1.3	1.1	1.20	1.80
7	7.02	5.00	24.6	10.1	6.10	3.78	3.26	1.45	1.3	1.1	1.22	1.61
8	7.02	4.68	17.4	7.54	5.34	3.78	3.02	1.45	1.3	2.10	1.20	1.57
9	5.34	4.68	12.7	7.02	5.00	3.78	3.26	1.45	1.3	1.2	1.22	1.51
10	4.07	4.68	22.1	6.10	4.37	4.07	3.26	1.45	1.3	1.1	1.22	1.51
11	3.51	4.68	22.6	10.7	6.10	5.00	3.26	1.45	1.2	1.1	1.22	1.45
12	32.4	4.68	16.9	12.7	8.06	5.00	3.51	1.44	1.2	1.1	1.22	1.38
13	24.6	5.00	13.8	8.58	9.10	5.00	2.80	1.44	1.2	1.1	1.20	1.33
14	15.3	5.34	11.7	7.02	6.10	5.34	2.10	1.42	1.2	1.1	1.20	1.33
15	9.10	5.70	11.2	7.02	5.34	4.68	2.00	1.42	1.2	1.1	1.22	1.32
16	6.10	5.70	10.7	7.54	5.00	4.37	1.92	1.42	1.2	1.1	1.24	1.30
17	4.68	5.70	10.1	8.06	5.34	3.78	1.80	1.42	1.2	1.1	1.42	1.30
18	3.78	5.70	10.1	10.1	5.34	3.78	1.69	1.42	1.2	1.1	1.53	1.30
19	4.07	6.54	8.58	11.7	6.10	3.78	1.65	1.44	1.2	1.1	1.45	1.32
20	4.37	7.02	7.54	11.7	6.10	4.07	1.63	1.44	1.2	1.1	1.33	1.30
21	7.02	10.1	7.02	*11.2	5.00	4.07	1.57	1.40	1.2	1.1	1.30	1.30
22	25.7	14.3	6.54	10.7	4.68	4.37	1.59	1.40	1.2	9.10	1.30	1.30
23	19.5	12.2	6.10	10.1	4.07	4.07	1.61	1.40	1.2	4.68	1.28	1.32
24	24.6	12.7	6.10	10.7	3.78	4.07	1.80	1.4	1.2	1.76	1.27	1.33
25	16.9	11.7	7.54	10.7	3.78	3.78	1.55	1.4	1.1	1.63	1.27	1.47
26	11.7	10.7	8.58	9.62	4.07	3.78	1.55	1.4	1.1	1.5	1.27	1.42
27	9.10	9.10	6.54	9.10	4.68	4.37	1.53	1.4	1.1	1.3	1.28	1.38
28	6.54	8.58	13.3	8.58	5.70	3.78	1.55	1.4	1.1	1.2	1.25	1.37
29	5.34	—	16.4	7.02	5.34	3.78	1.51	1.3	1.1	1.2	1.25	1.80
30	4.68	—	13.3	7.02	4.37	3.51	1.51	1.3	1.1	1.2	1.27	39.8
31	4.37	—	11.2	—	4.68	—	1.49	1.3	—	1.2	—	101.
Total	361.45	208.44	450.04	307.82	179.06	129.22	74.40	44.01	36.4	48.97	37.84	182.83
Mean	11.66	7.44	14.52	10.26	5.78	4.31	2.40	1.42	1.21	1.58	1.26	5.90
$m^3 x 10^6$	31.23	18.01	38.88	26.60	15.47	11.16	6.43	3.80	3.14	4.23	3.27	15.80

Calendar Year 1950: Max 101 Min 1.10 Mean 5.65 $m^3 x 10^6$ 178.02

Note: Recorder float resting on top of sediment deposit in gage well Aug. 24 to Oct. 7, 9-21, 26-31; discharge estimated on basis of records for station on Nahr Ibrahim at Bashal, recorded range in stage and weather records.

* Discharge measurement made on this day.

TABLE III - 11

DAILY DISCHARGE OF NAHR EL KELB AT EL MOKHADA, LEBANON
CALENDAR YEAR 1951

(Cubic meters per second)

Day	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	29.8	4.07	5.70	8.58	7.02	3.78	1.92	1.2	1.10	1.01	1.1	4.37
2	15.3	4.07	5.34	8.58	6.54	4.07	1.92	1.2	1.08	1.00	1.1	3.51
3	9.62	3.51	5.70	7.54	6.10	3.51	1.85	1.2	1.08	1.00	1.1	3.02
4	7.54	3.51	6.54	7.02	5.70	3.51	1.76	1.2	1.07	1.01	1.1	3.51
5	6.54	4.37	5.00	6.54	5.70	3.51	1.67	1.2	1.07	1.03	1.3	4.07
6	5.00	5.00	5.34	7.54	5.34	3.78	1.57	1.17	1.06	1.01	1.5	3.51
7	21.0	4.68	5.70	7.54	5.00	5.00	1.53	1.17	1.06	1.01	1.72	2.80
8	12.2	4.07	5.70	6.54	5.34	4.37	1.51	1.16	1.06	1.38	1.57	2.46
9	8.06	4.07	6.10	6.54	6.10	4.68	1.49	1.16	1.07	1.47	1.38	2.80
10	5.34	3.78	6.10	6.10	6.10	5.00	1.47	1.16	1.07	2.00	1.33	2.21
11	4.68	3.51	5.34	5.70	6.10	5.34	1.5	1.16	1.06	1.37	1.30	2.00
12	4.07	3.51	5.34	5.70	6.10	5.00	1.4	1.14	1.1	1.14	1.25	1.67
13	3.78	3.02	5.00	5.34	5.70	4.68	1.4	1.16	1.1	1.25	1.24	3.26
14	3.26	3.26	5.34	5.70	5.70	5.70	1.4	1.14	1.0	1.44	1.24	19.5
15	3.02	3.51	5.34	5.70	5.34	5.70	1.4	1.14	1.0	1.24	1.24	19.0
16	6.10	3.78	5.34	5.70	5.00	5.34	1.4	1.14	1.0	1.20	1.24	17.9
17	10.7	3.78	5.34	6.54	4.37	5.34	1.4	1.13	1.0	1.19	1.24	11.7
18	7.02	17.4	5.70	7.54	5.70	5.70	1.4	1.14	1.0	1.17	1.24	38.9
19	7.54	29.3	5.70	17.4	5.00	5.34	1.4	1.14	1.0	1.16	1.25	27.2
20	11.2	30.8	5.70	10.1	4.07	5.00	1.4	1.22	1.0	1.14	1.20	17.4
21	22.6	38.3	5.70	5.70	3.78	4.37	1.3	1.13	1.0	1.11	1.19	15.3
22	48.7	25.7	5.70	4.68	4.07	4.37	1.3	1.11	1.0	1.11	1.19	12.7
23	34.4	17.9	6.54	4.68	4.68	4.07	1.3	1.11	1.00	1.20	1.19	12.7
24	17.9	13.3	6.54	14.8	4.37	3.78	1.3	1.13	1.00	1.16	1.19	13.8
25	12.2	10.7	13.8	33.6	3.78	3.26	1.3	1.11	1.01	1.16	1.19	12.2
26	8.58	8.58	17.4	24.1	3.78	2.61	1.3	1.11	1.00	1.16	1.53	10.7
27	7.02	7.02	11.7	16.4	3.51	2.33	1.3	1.08	1.00	1.14	1.67	9.62
28	6.10	6.10	11.7	11.7	4.37	2.21	1.3	1.10	.99	1.13	1.42	9.10
29	5.00	--	11.7	9.10	4.37	2.21	1.3	1.10	.99	1.13	1.51	10.1
30	4.37	--	10.1	7.54	4.07	2.10	1.2	1.10	1.01	1.1	11.7	10.1
31	4.07	--	9.10	--	3.78	--	1.2	1.10	--	1.1	--	9.62
Total	352.71	270.60	221.34	280.24	156.58	125.66	44.89	35.51	30.98	36.72	49.42	316.73
Mean	11.38	9.66	7.14	9.34	5.05	4.19	1.45	1.15	1.03	1.18	1.65	10.22
m^3x10^6	30.47	23.38	19.12	24.21	13.53	10.86	3.88	3.07	2.68	3.17	4.27	27.37

Calendar Year 1951: Max 48.7 Min 0.99 Mean 5.26 m^3x10^6 166.01

Note:- Recorder float resting on top of sediment deposit in gage well July 11 to Aug. 5, no gage-height record Sept. 12-22, Oct. 30 to Nov. 6; discharge estimated on basis of records for station on Nahr Ibrahim at Bazhal, recorded range in stage and weather records.

TABLE III - 11

DAILY DISCHARGE OF NAHR EL KELB AT EL MOKHADA, LEBANON
CALENDAR YEAR 1952

(Cubic meters per second)

Day	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	9.10	19.5	13.3	20.5	14.8	3.02	4.68	1.80	1.5	1.22	1.3	2.61
2	8.58	45.5	15.8	19.5	11.2	4.07	4.37	1.69	1.5	1.20	1.2	1.85
3	8.06	93.2	20.5	20.5	9.62	5.00	4.68	1.67	1.4	1.20	1.4	1.65
4	8.06	126.	16.4	21.0	8.58	5.00	4.68	1.63	1.4	1.20	1.3	1.61
5	8.06	90.5	13.8	22.1	8.06	4.37	4.68	1.61	1.4	1.20	1.22	1.55
6	10.7	41.9	12.7	19.5	8.06	4.07	4.37	1.61	1.4	1.20	1.22	1.53
7	17.9	29.8	12.2	17.4	7.54	3.78	*4.37	1.61	1.4	1.20	1.22	1.49
8	14.8	26.2	14.8	16.4	7.54	4.37	4.07	1.59	1.4	1.20	1.22	1.45
9	13.3	24.6	22.1	14.8	8.06	5.34	4.07	1.57	1.4	1.20	1.22	1.45
10	12.7	20.5	37.8	12.2	8.06	5.34	4.07	1.6	1.4	1.20	1.22	1.47
11	11.2	26.7	33.9	9.62	6.54	5.00	4.07	1.6	1.4	1.20	1.24	1.5
12	13.3	21.5	31.9	8.58	6.54	5.34	4.07	1.55	1.4	1.22	1.80	1.6
13	23.6	17.9	27.7	7.54	6.10	5.00	4.07	1.5	1.4	1.20	1.44	4.0
14	19.0	16.4	24.1	6.54	6.10	4.68	4.07	1.5	1.4	1.20	1.30	12.
15	15.8	15.3	26.2	5.70	5.70	4.68	3.51	1.5	1.4	1.20	1.25	4.07
16	20.0	13.8	24.6	5.34	5.34	4.37	3.26	1.5	1.3	1.19	1.28	3.78
17	16.4	12.7	24.1	5.34	5.00	4.37	3.26	1.5	1.3	1.17	1.20	4.37
18	14.3	11.7	20.5	5.70	5.00	4.37	3.51	1.5	1.3	1.19	1.25	4.07
19	13.3	11.2	18.4	10.1	5.00	4.37	3.26	1.5	1.3	1.17	1.25	4.07
20	12.2	10.7	18.4	36.1	4.37	4.37	3.26	1.5	1.3	1.19	1.25	5.00
21	11.7	10.1	31.4	17.4	3.78	4.37	3.51	1.5	1.3	1.17	1.25	4.37
22	11.2	10.7	22.1	12.7	3.78	5.00	3.26	1.5	1.30	1.19	*1.25	4.37
23	11.2	9.62	19.0	10.7	4.37	5.00	3.26	1.5	1.30	1.17	1.38	4.68
24	10.7	10.1	16.9	9.10	4.07	5.34	2.80	1.5	1.24	1.17	1.32	4.07
25	9.62	9.62	15.8	8.58	4.07	5.34	2.80	1.5	1.22	1.19	10.7	3.26
26	8.58	8.58	15.8	8.06	5.00	5.34	2.80	1.5	1.20	1.20	4.68	8.58
27	8.58	8.06	16.9	9.62	5.00	5.34	2.80	1.5	1.20	1.22	3.51	16.9
28	8.58	7.54	17.9	10.7	4.07	4.68	2.61	1.5	1.20	1.2	3.51	6.54
29	8.06	9.62	17.9	11.2	3.26	4.37	2.10	1.5	1.20	1.2	4.07	4.37
30	7.54	--	19.0	26.7	3.02	4.07	2.10	1.5	1.20	1.2	3.78	3.78
31	8.06	--	19.5	—	3.02	—	2.00	1.5	--	1.4	--	4.07
Total	374.18	759.54	641.4	409.22	190.65	139.76	110.42	48.03	40.06	37.26	61.23	126.11
Mean	12.07	26.19	20.69	13.64	6.15	4.66	3.56	1.55	1.34	1.20	2.04	4.07
m^3x10^6	32.33	65.62	55.42	35.36	16.47	12.08	9.54	4.15	3.46	3.22	5.29	10.90

Calendar Year 1952: Max 126 Min 1.17 Mean 8.03 m^3x10^6 253.84

Note:- Recorder float resting on top of sediment deposit in gage well Aug. 10 to Sept. 21, no gage-height record Oct. 28 to Nov. 4, Dec. 11-14; discharge estimated on basis of records for station on Nahr Ibrahim at Bashal, recorded range in stage and weather records. Shifting-control method used June 17 to Aug. 5.

*Discharge measurement made on this day.

TABLE III - 11

DAILY DISCHARGE OF NAHR EL KELB
AT EL MOKHADA, LEBANON
CALENDAR YEAR 1953

(Cubic meters per second)

Day	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	4.07	5.34	15.3	65.2	16.9	10.7	6.10	1.72	1.3	1.2	1.19	2.80
2	5.00	5.00	16.4	43.7	15.3	*11.2	5.70	1.72	1.3	1.2	1.20	2.80
3	7.02	5.00	16.4	35.5	13.8	11.2	5.34	1.65	1.3	1.2	1.20	2.80
4	6.10	5.00	16.4	29.3	12.2	10.7	6.10	1.59	1.3	1.2	*1.20	3.02
5	5.00	7.54	14.3	25.2	11.7	9.62	7.54	1.57	1.3	1.2	1.20	3.26
6	4.07	13.8	16.9	23.1	14.8	9.62	7.54	1.53	1.3	1.24	1.20	3.02
7	4.37	14.8	24.6	22.6	19.0	10.7	7.02	1.53	1.3	1.19	1.27	2.61
8	3.78	11.7	20.5	21.5	14.8	10.7	6.54	1.47	1.3	1.14	1.30	2.46
9	3.78	40.5	17.4	22.1	11.7	10.1	6.54	1.44	1.2	1.16	1.30	2.21
10	4.37	53.4	21.0	21.5	13.3	10.1	6.10	1.44	1.2	1.16	1.3	2.10
11	15.3	39.5	32.9	22.1	13.3	9.62	5.00	1.42	1.2	1.16	1.3	1.92
12	16.9	33.4	43.1	23.1	10.7	10.1	6.54	1.40	1.2	1.16	1.30	1.80
13	14.3	23.6	29.3	25.2	10.1	10.1	6.10	1.40	1.2	1.17	1.32	1.76
14	9.62	19.0	24.6	23.1	10.1	9.62	5.70	1.38	1.2	1.17	1.30	1.72
15	6.10	17.4	25.7	19.5	12.7	9.62	5.00	1.37	1.2	1.17	1.30	1.67
16	5.00	22.6	22.1	20.0	13.3	9.62	3.78	1.35	1.2	1.19	1.30	1.67
17	5.34	24.1	19.5	22.6	12.7	9.62	4.37	1.35	1.19	*1.19	1.30	1.67
18	4.68	37.2	21.5	22.6	12.7	8.58	4.37	1.35	1.20	1.17	1.61	2.80
19	4.68	32.4	22.1	20.5	10.1	7.02	4.07	1.33	1.20	1.17	3.02	4.37
20	4.37	36.1	23.1	17.4	9.10	6.54	3.26	1.35	1.19	1.17	3.51	3.78
21	4.07	24.1	21.0	16.4	9.10	6.10	3.2	1.33	1.20	1.19	3.26	3.26
22	6.54	19.0	19.0	15.3	9.10	6.10	3.1	1.32	1.20	1.19	2.80	3.02
23	9.10	16.9	17.9	14.3	8.06	6.10	3.1	1.32	1.20	1.17	2.33	3.26
24	11.7	16.9	16.4	13.3	7.02	6.10	3.1	1.32	1.22	1.19	12.7	6.54
25	12.7	14.3	15.3	13.3	8.06	6.54	3.02	1.33	1.20	1.19	29.3	27.7
26	12.7	12.7	15.3	13.8	9.62	6.54	2.61	1.30	1.38	1.20	14.3	20.0
27	10.1	14.3	16.9	14.3	9.10	6.10	2.61	1.30	1.28	1.20	7.54	14.3
28	8.58	13.3	20.0	14.3	8.06	6.10	2.33	*1.28	1.22	1.20	4.37	13.3
29	7.54	-	24.6	15.3	8.06	5.70	1.92	1.30	1.22	1.20	3.51	12.7
30	6.54	-	27.2	16.9	8.06	* 5.70	1.92	1.30	1.2	1.20	3.02	11.7
31	5.70	-	39.5	-	8.58	-	1.85	1.30	-	1.19	-	43.7
Total	229.12	578.88	676.2	673.0	351.12	256.16	141.47	43.76	37.10	36.73	112.75	209.72
Mean	7.39	20.67	21.81	22.43	11.33	8.54	4.56	1.41	1.24	1.18	3.76	6.77
m^3x10^6	19.80	50.02	58.42	58.15	30.34	22.13	12.22	3.78	3.21	3.17	9.74	18.12

Calendar Year 1953: Max. 53.4 Min. 1.14 Mean 9.17 m^3x10^6 289.10

NOTE:- Recorder float resting on top of sediment deposit in gage well Sept. 1-16, no gage-height record July 21-24, Sept. 30 to Oct. 5, Nov. 10, 11; discharge estimated on basis of records for station on Nahr Ibrahim at Bashal, recorded range in stage and weather records.
Shifting-control method used June 17 to July 20, 25 to Sept. 10, 18-29, Oct. 6 to Nov. 9, 12-22.

* Discharge measurement made on this day.

TABLE III - 11

DAILY DISCHARGE OF NAHR EL KELB
AT EL MOKHADA, LEBANON
CALENDAR YEAR 1954
(Cubic meters per second)

Day	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	36.1	24.1	23.6	41.3	18.4	12.7	14.8	5.34	1.33	1.14	1.04	1.44
2	22.6	21.0	22.6	33.4	19.0	11.7	14.8	4.37	1.33	1.14	1.04	1.44
3	29.8	22.6	22.1	26.7	19.0	12.2	14.3	2.61	1.33	1.14	1.04	1.42
4	28.3	29.8	22.1	23.6	18.4	12.2	13.8	2.33	1.30	1.14	1.04	1.40
5	29.3	30.3	25.7	29.8	18.4	11.7	14.3	2.21	1.28	1.13	1.03	1.63
6	22.1	25.2	26.2	27.2	17.9	11.7	13.3	2.10	1.30	1.1	1.03	2.61
7	18.4	22.1	23.6	25.2	18.4	11.7	13.8	1.92	1.30	1.1	1.03	2.61
8	18.4	20.5	22.6	23.6	17.9	11.7	13.8	1.80	1.28	1.10	1.01	2.10
9	23.1	27.2	22.6	22.1	16.4	12.7	13.8	1.80	1.28	1.10	1.01	1.72
10	17.4	38.3	23.1	28.3	15.8	14.3	13.8	1.72	1.25	1.10	1.01	1.61
11	18.4	37.2	21.0	30.8	15.8	13.3	13.3	1.69	1.24	1.10	1.01	1.53
12	33.4	34.4	20.0	25.2	15.8	12.2	13.3	1.72	1.22	1.10	1.01	1.49
13	36.1	30.8	21.0	22.6	15.3	11.7	13.3	1.67	1.22	1.08	1.01	1.47
14	25.7	28.3	21.0	28.3	14.8	11.7	13.3	1.63	1.22	1.08	.99	1.42
15	21.0	28.3	20.0	24.1	13.8	11.7	13.3	1.61	1.20	1.08	.99	1.40
16	17.9	25.2	19.0	25.2	13.8	11.2	13.8	1.61	1.20	1.07	.99	1.40
17	16.4	23.6	25.7	24.1	13.3	11.2	13.3	1.59	1.22	1.06	*1.06	1.4
18	14.8	23.1	33.9	23.1	13.3	11.2	13.8	1.57	1.20	1.06	1.14	1.4
19	13.3	32.9	25.7	22.1	*13.8	12.2	15.3	1.55	1.19	1.06	1.24	1.4
20	15.8	36.1	22.1	21.5	13.8	12.7	13.8	1.55	1.19	1.06	1.19	*3.0
21	15.3	29.8	25.2	21.5	13.8	13.3	12.2	1.53	1.19	*1.06	1.20	9.0
22	18.4	26.7	28.8	24.1	13.8	13	12.2	1.53	1.19	1.06	1.27	7.0
23	36.1	25.2	30.8	23.1	14.3	13.3	12.2	1.51	1.20	1.06	1.42	6.0
24	32.4	24.6	30.3	21.0	14.8	13.3	9.62	1.51	1.24	1.06	2.61	10.
25	26.7	27.2	25.7	20.0	14.3	12.7	7.02	1.49	1.20	1.06	1.92	6.10
26	25.2	31.4	23.6	19.0	14.3	13.3	7.02	1.49	1.16	1.06	1.55	4.68
27	41.9	28.3	22.6	17.9	14.8	13.3	8.06	1.47	1.16	1.06	1.45	4.07
28	30.3	25.2	22.1	17.9	15.8	12.7	7.54	1.38	1.16	1.06	1.40	5.34
29	23.6	-	23.6	17.9	15.3	12.2	6.54	1.32	1.16	1.06	1.37	7.02
30	28.3	-	23.6	18.4	14.8	13.3	5.34	1.32	1.16	1.04	1.40	7.02
31	28.8	-	24.6	-	13.8	-	5.70	1.32	-	1.06	-	9.62
Total	765.3	779.4	744.5	729.0	482.9	372.1	370.44	58.26	36.90	33.58	36.50	109.74
Mean	24.69	27.84	24.02	24.30	15.58	12.40	11.95	1.88	1.23	1.08	1.22	3.54
m^3x10^6	66.12	67.34	64.32	62.99	41.72	32.15	32.01	5.03	3.19	2.90	3.15	9.48

Calendar Year 1954: Max. 41.9 Min. 0.99 Mean 12.38 m^3x10^6 390.40

NOTE:- No gage-height record June 22, Oct. 6, 7, Dec. 17-24; discharge estimated on basis of records for station on Nahr Ibrahim at Bashal, recorded range in stage, and weather records. Shifting-control method used Aug. 24 to Oct. 5, 8 to Dec. 16, 23-31.

* Discharge measurement made on this day.

TABLE III - 11

DAILY DISCHARGE OF NAHR EL KELB AT EL MOKHADA, LEBANON
CALENDAR YEAR 1955

(Cubic meters per second)

Day	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	7.54	2.9	5.00	12.7	7.54	5.34	1.76	1.13	1.14	0.95	0.87	
2	6.10	2.80	* 4.68	13.8	6.54	4.68	1.72	1.11	1.14	.94	.86	
3	5.34	2.80	5.00	14.3	7.54	4.68	1.69	1.11	1.13	.92	.86	
4	4.68	3.51	5.34	14.3	8.06	4.68	1.69	1.10	1.13	.91	.86	
5	4.07	4.07	5.70	13.3	6.54	4.68	1.69	1.10	1.14	.91	.86	
6	3.51	17.9	11.7	12.7	6.10	5.00	1.67	1.10	1.14	* .88	.86	
7	3.26	20.5	12.7	* 10.7	6.10	4.68	1.67	1.10	1.14	.88	.86	
8	3.26	13.8	9.62	13.3	6.54	4.37	1.67	1.10	1.14	.88	*	
9	3.02	11.2	8.06	17.4	7.02	4.68	1.65	1.10	1.14	.88		
10	2.80	9.62	7.02	17.4	8.06	5.34	1.65	1.10	1.16	.88		
11	3.02	29.8	6.54	21.1	* 7.54	4.68	* 1.65	* 1.08	1.16	.88		
12	4.07	17.9	14.8	17.4	7.02	4.07	1.61	1.08	1.16	.88		
13	4.37	13.8	16.9	15.8	6.54	* 4.07	1.57	1.08	1.16	.87		
14	6.54	11.2	16.4	14.8	6.10	3.78	1.53	1.07	1.16	.87		
15	5.00	9.10	24.6	13.8	5.70	3.26	1.53	1.07	1.17	.87		
16	4.07	8.06	35.0	12.2	5.34	2.61	1.51	1.07	*1.16	.87		
17	3.51	7.54	29.8	11.2	5.34	2.80	1.51	1.07	1.14	.87		
18	3.02	6.54	30.8	10.7	5.34	2.46	1.51	1.08	1.10	* .86		
19	* 3.02	6.10	26.7	10.7	6.10	2.21	1.45	1.08	1.08	.86		
20	3.02	5.70	21.0	10.1	6.10	2.33	1.33	1.08	1.06	.85		
21	3.26	5.34	18.4	9.62	5.34	2.61	1.32	1.08	1.04	.86		
22	2.80	6.54	16.4	9.10	5.70	2.21	1.32	1.10	1.01	.86		
23	3.02	6.54	* 15.3	8.06	5.34	2.00	1.30	1.10	1.00	.84		
24	2.80	6.10	14.3	8.06	5.00	2.00	1.30	1.10	1.00	.84		
25	3.26	5.70	13.3	9.10	5.00	1.92	1.30	1.10	.99	.84		
26	3.26	5.34	12.2	10.1	4.37	1.85	1.28	1.10	.99	.83		
27	3.26	5.00	12.2	9.10	4.37	1.85	1.28	1.11	.97	.85		
28	3.26	5.00	13.3	8.58	4.37	1.80	1.25	1.11	.99	.86		
29	3.2	—	11.7	8.06	4.68	1.80	1.20	1.13	.97	.85		
30	3.1	—	11.2	8.06	5.00	1.80	1.14	1.13	.97	.85		
31	3.0	—	11.2	—	5.34	—	1.14	1.14	—	.87		
Total	117.44	250.40	446.86	365.54	185.67	100.24	45.89	34.01	32.68	27.06	6.03	(1-7)
Mean	3.79	8.94	14.41	12.18	5.99	3.34	1.48	1.10	1.09	.87	.86	(1-7)
$m3x10^6$	10.15	21.63	38.61	31.58	16.04	8.66	3.96	2.94	2.82	2.34	0.52	(1-7)

Note: No gage-height record Jan. 29 - Feb. 1; discharge computed on basis of records for station on Nahr Ibrahim at Bazhal, recorded range in stage, and weather records. Shifting-control method used Jan. 1-28, Feb. 2 to Mar. 19, Apr. 16 to June 21, Aug. 13 to Nov. 7.

* Discharge measurement made on this day.

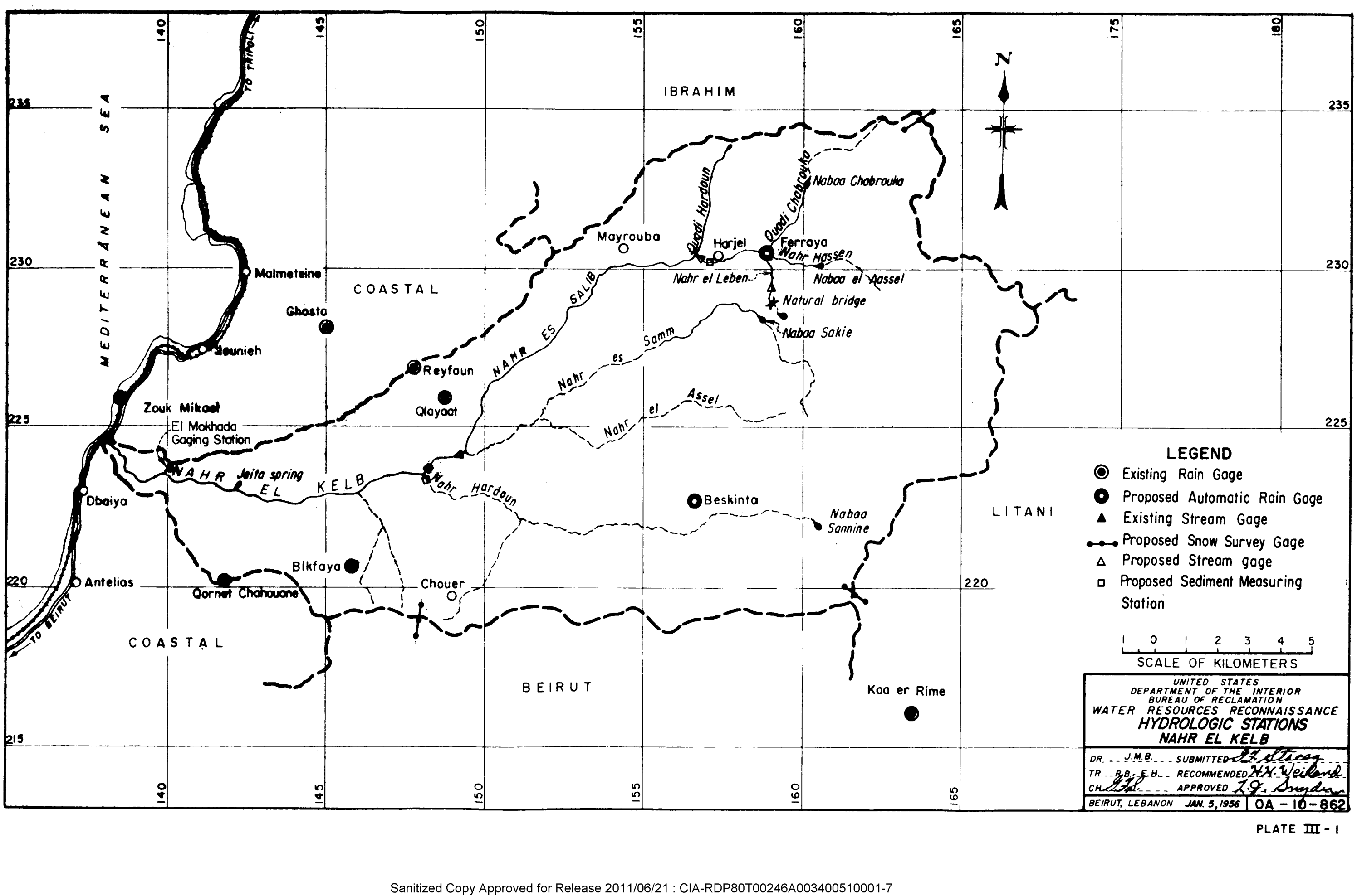

IBRAHIM
MEDITERRANEAN SEA
TO TRIPOLI
TO BEIRUT
Malmeteine
Jounieh
Zouk Mikael
El Mokhada Gaging Station
Dbaiya
Antelias
COASTAL
Ghosta
Reyfoun
Qlayaat
Jeita spring
NAHR EL KELB
Nahr Hardoun
Bikfaya
Qornet Chahouane
Chouer
Mayrouba
Harjel
Faraya
Ouadi Hardoun
Ouadi Chabrouka
Naboa Chabrouka
Nahr Hassen
Nahr el Leben
Nabaa el Assel
Natural bridge
Nabaa Sakie
NAHR ES SALIB
Nahr es Samm
Nahr el Assel
Beskinta
Nabaa Sonnine
LITANI
BEIRUT
Kaa er Rime
LEGEND
Existing Rain Gage
Proposed Automatic Rain Gage
Existing Stream Gage
Proposed Snow Survey Gage
Proposed Stream gage
Proposed Sediment Measuring Station
SCALE OF KILOMETERS
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
WATER RESOURCES RECONNAISSANCE
HYDROLOGIC STATIONS
NAHR EL KELB
DR. J.M.B. SUBMITTED
TR. R.B. E.H. RECOMMENDED
CH. APPROVED
BEIRUT, LEBANON JAN. 5, 1956 OA-10-862

PLATE III - I

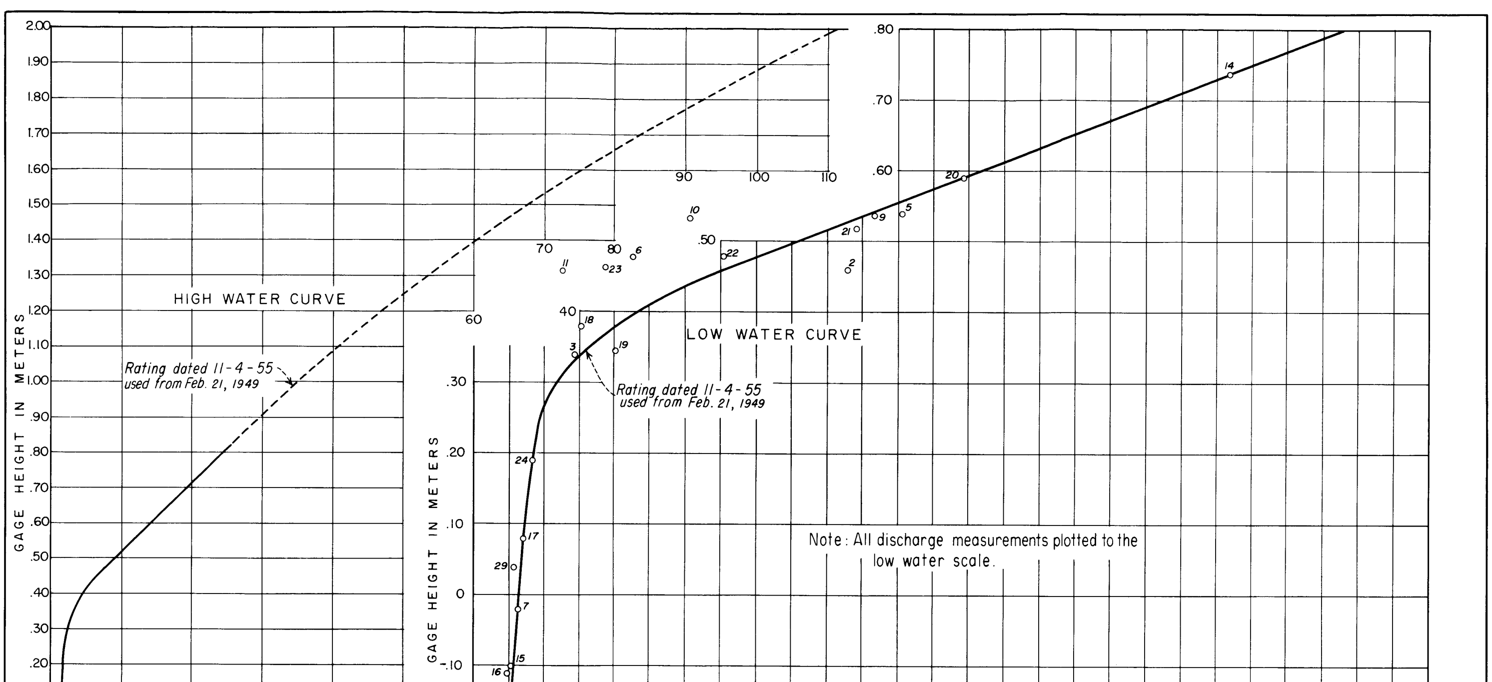

HIGH WATER CURVE
Rating dated 11-4-55 used from Feb. 21, 1949
GAGE HEIGHT IN METERS
DISCHARGE IN CUBIC METERS PER SECOND (HIGHER WATER)
LOW WATER CURVE
Rating dated 11-4-55 used from Feb. 21, 1949
Note: All discharge measurements plotted to the low water scale.
DISCHARGE IN CUBIC METERS PER SECOND (LOW WATER)
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
WATER RESOURCES RECONNAISSANCE
STAGE-DISCHARGE RATING CURVE
EL MOKHADA GAGE
NAHR EL KELB
DR. J. M. B. SUBMITTED
TR. J. M. K. RECOMMENDED
CH. APPROVED
BEIRUT, LEBANON JAN 10, 1956
OA-10-861

PLATE III - 2

TABLE III-8

AVERAGE MONTHLY RESERVOIR EVAPORATION

(Millions of cubic meters)

Month	Evaporation	Month	Evaporation
September	-0.3	March	0.0
October	-0.3	April	-0.1
November	-0.2	May	-0.2
December	0.0	June	-0.2
January	+0.1	July	-0.3
February	+0.1	August	-0.3
		Total:	-1.7

Stream Flow

A gaging station was installed by the Ministry of Public Works on the Nahr el Kelb at El Mokhada on February 21, 1949. The location of this station is shown on Plate III-1. This station has been operated by that agency since its installation. The drainage area above the El Mokhada station is 249 square kilometers. Average monthly discharges as determined from the records at this station, are shown in Table III-9. These discharges do not include that of the El Wata Canal which starts from a diversion 250 meters above the gaging station.

Since 1949 about 29 measurements have been made at the El Mokhada gage. The results of these measurements are shown in Table III-10 and have been used to establish the stage-discharge relation for that gage as shown in Plate III-2. The established rating curve was used throughout the period of gage-height record with applicable shifting control. No high-water measurements have been made at the El Mokhada gaging station. The rating curve was extended beyond the 0.80 meter gage height by averaging four synthetic methods. Therefore, the high-water portion of the stage-discharge rating curve should be used with extreme caution until it can be verified by actual discharge measurements. Average daily discharges at the El Mokhada gaging station, for calendar years 1949 through 1955, are shown on the seven sheets of Table III-11.

Average Year Discharges

Mean monthly discharges compiled from the monthly discharge records available and shown in Table III-9, were determined for the station at El Mokhada. The values shown in Table III-12 have been assumed to represent the average year discharges at the El Mokhada gage.

TABLE III-12

MONTHLY DISCHARGES - AVERAGE YEAR

NAHR EL KELB AT EL MOKHADA

(Millions of cubic meters)

Month	Discharge	Month	Discharge
September	3.21	March	49.00
October	3.26	April	42.27
November	4.86	May	27.05
December	14.96	June	17.41
January	31.68	July	11.78
February	40.98	August	4.25
		Total:	250.71

Minimum Year Discharges

The monthly discharge records shown in Table III-9 for El Mokhada gage were carefully considered. It has been assumed that each of the minimum monthly values shown in this table might occur during a single 12-month water year at El Mokhada and that such a combination of minimum monthly discharge represents the minimum year to be expected. The monthly discharges for this minimum year at El Mokhada are shown in Table III-13.

TABLE III-13

MONTHLY DISCHARGES - MINIMUM YEAR

NAHR EL KELB AT EL MOKHADA

(Millions of cubic meters)

Month	Discharge	Month	Discharge
September	2.68	March	19.11
October	2.34	April	26.60
November	3.15	May	15.45
December	8.06	June	8.66
January	10.15	July	3.88
February	18.00	August	2.94
		Total:	121.02

Areal Flow Distribution

The flows shown in Tables III-12 and III-13 represent average and minimum year flows in the Nahr el Kelb at the gage at El Mokhada. The monthly volume of flows in other parts of this basin during both the average water year and the minimum water year, could not be assumed to vary directly with the contributing drainage areas. It was observed that the Nahr el Kelb above the Jeita Spring was entirely dry during the 1955 irrigation season, because the flow in the upper reaches of the stream had been entirely appropriated for irrigation and domestic water supply usage. The flow of the Nahr es Salib, a tributary of the Nahr el Kelb, was entirely diverted into the Harjel Canal, or English Canal as it is officially called, immediately below the town of Harjel. The flow that entered the El Wata Canal and passed the El Mokhada gaging station during the summer and early fall of 1955, came from Jeita Spring seepage and small springs between Jeita spring and the gaging station. Table III-14 lists all known miscellaneous discharge measurements made in the Nahr el Kelb Basin. These measurements, in conjunction with those listed in Table III-10, were used to estimate the available flow at the potential dam sites.

The estimated available flows at the Jeita, Balloune, Qlayaat, and Mayrouba dam sites were considered to vary directly with the contributing drainage areas in respect to the flow of the Nahr el Kelb immediately above the Jeita Spring. This flow equals the flow at the El Mokhada gaging station plus the flow into the El Wata Canal, minus the flow from Jeita Spring and the seepage below Jeita Spring. The known measurements were analyzed to estimate the flows of the Jeita Spring and the seepages between Jeita and the gaging station. The monthly flows for the average and minimum years for the Jeita Spring are shown in Table III-15.

TABLE III-14

MISCELLANEOUS DISCHARGE MEASUREMENTS
NAHR EL KELB BASIN

(Cubic meters per second)

Location	Date	Discharge
Nahr es Salib at Harjel	Aug. 8, 1955	0.142
	Oct. 13, 1955	0.137
	Oct. 18, 1955	0.142
Harjel Irrigation Canal	Aug. 9, 1955	0.075
	Oct. 13, 1955	0.052
Nabaa el Aassel	Nov. 20, 1938	0.362
	Oct. 3, 1939	0.262
	Oct. 1, 1940	0.287
	July 30, 1947	0.462
	Oct. 21, 1948	0.201
	Aug. 14, 1951	0.312
	Oct. 22, 1951	0.219
	Nov. 2, 1951	0.220
	July 4, 1952	0.500
	Oct. 13, 1955	0.218
	Nov. 29, 1955	0.532
Nabaa el Leben	Aug. 8, 1955	0.051
	Oct. 13, 1955	0.022
	Nov. 30, 1955	0.182
Nabaa el Kana	Dec. 2, 1955	0.057
Nabaa Chabrouka	Dec. 2, 1955	0.027
Nahr Chabrouka, Div. Dam Site	Dec. 2, 1955	0.068
Nabaa es Sakie	Dec. 6, 1955	0.027
Jeita Spring (in Grotto)	Dec. 8, 1952	1.786
	Nov. 5, 1953	1.674
	Oct. 18, 1955	1.117
Achouche Spring	Dec. 8, 1952	0.479
	Nov. 5, 1953	0.263
Source de Tannoury	Oct. 1955	0.008
Ain es Souane	Nov. 29, 1955	0.002
Ain Tannour	Nov. 29, 1955	0.003
Nabaa Sannine	Aug. 12, 1955	0.026
	Oct. 10, 1955	0.015
Nabaa el Mogharah	Jan. 12, 1956	0.075
Nabaa Bakich) Anna Bakich	Jan. 9, 1956	0.008
) Group	Jan. 9, 1956	0.003
Nabaa Jafar	Jan. 9, 1956	0.008
Nabaa Ghabieh	Jan. 12, 1956	0.011
Nabaa el Jozat	Jan. 13, 1956	0.141

TABLE III-15

ESTIMATED MONTHLY DISCHARGES OF JEITA SPRING
AND
SEEPAGE BETWEEN JEITA SPRING AND EL MOKHADA GAGING STATION

(Millions of cubic meters)

Month		Average Year Discharge	Minimum Year Discharge
September		5.18	4.67
October		5.49	4.42
November		5.18	4.48
December		5.36	4.55
January		5.89	4.96
February		6.05	5.08
March		7.63	6.29
April		8.55	7.00
May		9.91	8.04
June		9.07	7.13
July		8.57	6.43
August		6.03	5.09
	Totals:	82.91	68.14

It was extremely difficult to compute the average and minimum year flows for the potential dam sites in the extreme upper end of the Nahr el Kelb Basin. No discharge measurements have been made at the sites except the single measurements made in November and December of 1955. Although flow would otherwise exist at these sites during the entire year, all flows of these small tributaries are used for irrigation during the growing season, except that of El Aassel whose major diversion is for municipal water supply. In the estimate of flows for these diversion dam sites, it was considered that these prior water rights would be respected and that no flows would be available during the irrigation season for new diversions. The estimated flows at these upper sites (Hardoun, Chabrouka, El Aassel, El Leben, and Fakra) were based on the single measurements and on information of the spring and stream flow characteristics as supplied by local residents. The flows at these sites should be used with extreme caution, since the estimates were based on such extremely limited data.

Available Irrigation Water

In the mountain section of the Nahr el Kelb Basin a number of springs have been developed for domestic water supply and for irrigation. Canals have been constructed over the centuries for conveying the water from these springs to points where it is used for these purposes. No measuring devices have ever been installed at these springs or on these canals, and water distribution is made by estimation. A limited number of discharge measurements were made at some of these springs during 1955 as a part of the Lebanese-American technical assistance program for village water supply. The results of these measurements are shown in Table III-14 and in Table VII-1 in Section VII - DOMESTIC WATER SUPPLY.

Table III-14 shows that most of these springs have relatively small discharges. Field reconnaissance indicates that there is insufficient water available to appreciably increase the extent of the irrigated areas. Likewise, as indicated in Section VII, most of the available water in the mountain section will be required for village water supply and for the existing irrigation development. Therefore, no values have been determined for the amounts of water being used, or of that available for future use. Provision has been made for future measurement of the water available at springs and in the canals in the mountain section, as well as those in the coastal section. The need and proposed program for this work are discussed in Section IX - ADDITIONAL INVESTIGATIONS NECESSARY.

Water is diverted from the Nahr el Kelb into the El Wata Canal to irrigate limited areas of land in the bottom of the valley and a small area north of this basin along the coast. The diverion for the El Wata Canal is located about 250 meters above the El Mokhada gaging station. Some flow measurements have been made on this canal as shown in Table III-10, and indicate a diversion of 0. 37 to 1. 04 cubic meters per second. A staff gage was established in the canal in October 1955 with the expectation that the Ministry of Public Works would obtain daily stage readings so that daily diversions of flow could be calculated. Flow discharge in the El Wata Canal cannot be correlated to the stage records obtained at the gaging station. The miscellaneous discharge measurements of the canal were carefully considered to evolve an estimate of the monthly diversions of flow for the minimum and average years. These discharges are shown in Table III-16.

TABLE III-16

ESTIMATED MONTHLY DIVERSIONS INTO EL WATA IRRIGATION CANAL

(Millions of cubic meters)

Month		Average Year Discharge	Minimum Year Discharge
September		1. 40	1. 71
October		1. 87	2. 06
November		1. 56	1. 27
December		1. 48	1. 20
January		1. 80	1. 47
February		1. 59	1. 29
March		1. 70	1. 38
April		1. 19	1. 50
May		1. 67	2. 09
June		2. 12	2. 70
July		2. 00	2. 44
August		1. 60	2. 01
	Totals:	19. 98	21. 12

Water is also released from the Dbaiye Water Supply Canal through gate valve turnouts to supply irrigation flow to small areas of land on the southside, or left bank, of the Nahr el Kelb. The amount of water diverted is very small, as shown in the listing of Table III-10.

All of the land suitable for irrigation in the area below the gaging station has been developed for many years, and no expansion of such areas is contemplated. However, the water rights for these irrigated areas probably antedate those owned by the city of Beirut and used for its municipal water supply. Therefore, these irrigation rights will probably continue to be respected and sufficient water will probably be released for them, even if all of the water appears to be necessary for domestic water supply, unless these water rights could be subordinated with equitable compensation. It is estimated that such irrigation diversions at present amount to a maximum of about 1. 0 cubic meters per second. However, with proper care and use of the irrigation water, the diversions could probably be reduced to a third of this amount.

From the very limited information supplied by residents in the upper reaches of the Nahr el Kelb, estimates have been made of the amount of water that is diverted for irrigation use in the tributaries where the construction of diversion dams is contemplated. The estimate of monthly flows for the average and minimum years are listed in Table III-17.

TABLE III-17

ESTIMATED MONTHLY DIVERSIONS INTO
IRRIGATION AND MUNICIPAL WATER SUPPLY SYSTEMS
UPPER NAHR EL KELB BASIN

(Millions of cubic meters)

(Avg = Average year Min = Minimum year)

Month	Harjel Canal		Ouadi Hardoun		Ouadi Chabrouka		El Aassel		El Leben		Fakra	
	Avg	Min	Avg	Min	Avg	Min	Avg	Min	Avg	Min	Avg	Min
Jan.	--	--	--	--	--	--	1.00	1.00	--	--	--	--
Feb.	--	--	--	--	--	--	1.00	1.00	--	--	--	--
Mar.	--	--	--	--	--	--	1.00	1.00	--	--	--	--
Apr.	--	--	--	--	--	--	1.00	1.00	--	--	--	--
May	--	0.31	1.60	0.33	1.40	0.50	2.30	1.90	--	0.60	0.40	0.20
June	0.62	0.62	0.74	0.41	0.75	0.49	1.40	1.60	1.40	0.54	0.18	0.18
July	0.62	0.51	0.80	0.27	0.78	0.27	1.30	1.10	0.64	0.25	0.17	0.09
Aug.	0.48	0.41	0.40	0.17	0.40	0.14	1.10	0.86	0.32	0.13	0.08	0.04
Sept.	0.38	0.36	0.20	0.10	0.21	0.07	0.82	0.67	0.20	0.09	0.04	0.02
Oct.	0.42	0.36	0.05	0.07	0.06	0.04	0.72	0.58	0.07	0.06	0.01	0.01
Nov.	--	0.36	--	--	--	--	1.00	0.75	--	0.03	--	--
Dec.	--	--	--	--	--	--	1.00	1.00	--	--	--	--
Total:	2.52	2.93	3.79	1.35	3.60	1.51	13.64	12.46	2.63	1.70	0.89	0.44

Water Used for Power Production

Water from Jeita Spring is used for power production at the lower Nahr el Kelb (Mar Elias) Power Plant. This plant has a head of 11 meters and an installed capacity of 160 kilowatts in two units. Omar Ajam, Chief of the Electric Service, Ministry of Public Works, reports that the water capacity of this plant is 2.4 cubic meters per second, but that during the summer months there is only sufficient water to operate one of the units. Discharge from this plant enters the Nahr el Kelb above the El Mokhada gaging station and is included in the discharge shown for that station in Table III-9.

There is another power plant immediately below Jeita Spring on the south bank of the Nahr el Kelb. Also, a new power plant is under construction on the north bank, about 500 meters below the upper plant. Data and characteristics of these plants are discussed in Section IV - POWER DEVELOPMENT. A small run-of-the-river plant is on the Nahr Hassen below Nabaa el Aassel.

Water for Domestic Water Supply

The Nahr el Kelb is the principal source of the water supply for the city of Beirut. The intake for the Beirut Water System is below the Mokhada gage, and all water entering the system is measured at the El Mokhada gage. Values shown in Table III-9 include the water diverted for domestic use in Beirut. Additional details are given in Section VII - DOMESTIC WATER SUPPLY.

Estimated Flows for Power Production

Sites Selected. Nine dam sites were selected as locations for potential power plant diversion structures in the Nahr el Kelb Basin. Only the Mayrouba site has any appreciable storage capacity. The following tabulation indicates the general location of these dam sites and shows the area on the contributing drainage basin above each site. Plate VI-2 shows the location of the dam sites with respect to the proposed basin development.

Dam Site	Stream	Drainage Area Above Dam Site (sq. km.)
Jeita	Nahr el Kelb	247
Balloune	Nahr el Kelb	215
Qlayaat	Nahr es Salib	92
Mayrouba	Nahr es Salib	82
Hardoun	Ouadi Hardoun	4.4
Chabrouka	Ouadi Chabrouka	15
El Aassel	Nahr Hassen	14
El Leben	Nahr el Leben	2.1
Fakra	Nahr es Samm	15

Available Water in a Minimum Year. The monthly discharges shown in Table III-13 for the minimum year were transferred to all of the above sites, by the methods previously outlined. The resulting flows are shown in Table III-18.

Available Water in an Average Year. The monthly discharges shown in Table III-12 for the average year were transferred to all of the diversion dam sites by the methods previously explained. Table III-19 shows the available monthly flows at the diversion dam sites for an average year.

Inflow Spillway Design Flood - Mayrouba Reservoir

The Mayrouba Dam Site, proposed in this investigation, will create a storage reservoir located as shown on Plate VI-2. The reservoir would have a drainage area of about 82 square kilometers. Streams in this area have steep mountain slopes. There is little vegetation over the drainage area, but the geology is such that it has a definite karstic terrain. Faults, solution channels, and other errosive processes evident in the area are characteristics which indicate a fairly high retention capacity. This is further indicated by a number of sizable springs in the upper and middle parts of the basin. Snow occurs over the upper parts of this basin and accumulates in most years to considerable depths at the higher elevation. There are believed to be no evidences of snow appreciably effecting flood runoff because of the slow and even snowmelt. The snow, however, tends to produce a somewhat higher base flow in the streams during the summer season, and thus it contributes additional water when most needed for irrigation, municipal water supply, and firm power production. Also, it is the main source of water supply for the springs found in the basin. In general, the surface drainage areas above the springs are small, but judging from the quantity of flow from these springs, the source of water from snowmelt must be from a much larger underground drainage area than is indicated on the surface. Snowmelt has been disregarded in the determination of the inflow design flood.

The lack of precipitation data for this basin and the very meager and poor streamflow data available, make it impracticable to develop an inflow design flood for the Nahr el Kelb Basin from such data. The absence of similar information from the other coastal basins in Lebanon made it necessary to use the data from other areas, where hydrologic characteristics appear to be similar to those of the Nahr el Kelb Basin.

Unitgraph Derivation. The section of Southern California between Los Angeles and San Diego, and between Los Angeles and San Luis Obispo, resembles generally the coastal section of Lebanon. The San Gabriel, the San Luis Rey, the San Diego Rivers, and other small streams, drain the Los Angeles - San Diego area of California which is flanked on the north and on the east by the San Gabriel and Santa Ana Mountains. The Santa Clara, the Ventura, the Santa Ynez and the Santa Maria Rivers drain the Los Angeles - San Luis Obispo area of California which is flanked on the north and east by the northern end of the San Gabriel Mountains. These are predominently sedimentary areas but the formations are generally sandstones, shales, and conglomerates, rather than limestone as in Lebanon. Generally, it contains more vegetative cover than in the karstic limestone terrain of Lebanon; however, its relative runoff is believed to be about the same. Therefore, the values for the Southern California coastal area are believed to be indicative of the runoff peaks and volumes in the rivers of the coastal area of Lebanon.

Sanitized Copy Approved for Release 2011/06/21 : CIA-RDP80T00246A003400510001-7

TABLE III - 18

AVAILABLE WATER AT DIVERSION DAM SITES - MINIMUM YEAR

(Units in millions of cubic meters)

Month	Jeita	Balloune	Qlayaat	Mayrouba	Hardoun	Chabrouka	El Aassal	El Leben	Fakra
Sept.	0	0	0	0	0	0	0	0	0
Oct.	0	0	0	0	0	0	0	0	0
Nov.	0	0	0	0	0.07	0.04	0	0.04	0.011
Dec.	4.79	4.19	1.89	1.70	0.12	0.12	0.4	.40	.044
Jan.	6.76	5.92	2.66	2.40	.21	.43	1.3	1.0	.12
Feb.	14.46	12.65	5.69	5.12	.33	.63	1.7	1.3	.21
Mar.	14.43	12.63	5.68	5.11	.62	1.2	2.9	1.9	.44
Apr.	21.45	18.77	8.44	7.60	.91	1.6	3.5	2.3	.70
May	9.67	8.46	3.80	3.42	.34	.50	0	.6	.20
June	4.30	3.76	1.69	1.52	0	0	0	0	0
July	0	0	0	0	0	0	0	0	0
Aug.	0	0	0	0	0	0	0	0	0
Total:	75.86	66.38	29.85	26.87	2.60	4.52	10.8	7.54	1.725

TABLE III - 19

AVAILABLE WATER AT DIVERSION DAM SITES - AVERAGE YEAR

(Units in millions of cubic meters)

Month	Jeita	Balloune	Qlayaat	Mayrouba	Hardoun	Chabrouka	El Aassal	El Leben	Fakra
Sept.	0	0	0	0	0	0	0	0	0.0
Oct.	0.15	0.13	0.06	0.05	0.06	0.06	0	0.07	.008
Nov.	1.26	1.10	0.50	0.45	0.12	.12	0	.17	.022
Dec.	11.27	9.86	4.43	3.99	0.22	.38	1.0	1.0	.091
Jan.	28.07	24.56	11.03	9.93	0.51	1.2	2.0	2.5	.25
Feb.	37.14	32.50	14.61	13.15	1.1	1.7	2.6	3.1	.42
Mar.	43.81	38.33	17.23	15.51	2.7	3.2	4.1	4.8	.88
Apr.	35.51	31.07	13.96	12.57	4.9	4.4	4.8	5.7	1.43
May	19.13	16.74	7.52	6.77	1.6	1.4	1.4	3.1	.40
June	10.64	9.31	4.19	3.77	0.76	.75	.5	0	.18
July	5.30	4.64	2.09	1.88	0	0	0	0	0
Aug.	0.33	0.29	0.13	0.12	0	0	0	0	0
Total:	192.61	168.53	75.75	68.19	11.97	13.21	16.4	20.44	3.681

The shape and size of the drainage area above the Mayrouba Dam Site resemble the area above the Casitas Dam Site on Coyote Creek, in the Ventura River Basin of the California coastal area. Coyote Creek has a streamflow record beginning in 1927, and there are a number of rainfall stations in the vicinity of this basin. The dimensionless unitgraph for the Casitas Dam Site shown on Plate III-3, was derived in December 1953 by the United States Bureau of Reclamation, Region 2 Office. It has been adopted for use in determining the inflow spillway design flood for the Mayrouba Reservoir in the Nahr el Kelb Basin.

Lag data for streams in the same section of Southern California, discussed above, were considered in selecting a lag value for the Nahr el Kelb Basin. Plate III-4 shows the lag relationship curve for Southern California Streams in which the parameter of lag in hours was plotted on log-log paper versus the parameter factor of $L \times L_{ca} / S^{\frac{1}{2}}$, in which L = length in miles of longest watercourse from point of collection to boundary of drainage area; L_{ca} = length, in miles, along watercourse from point of collection to a point opposite the centroid of the area, and S = overall slope, in feet per mile, of longest watercourse, L. A lag time of 1.43 hours was adopted for the area above the upper end of the Mayrouba Reservoir Site on the basis of the calculated $L \times L_{ca} / S^{\frac{1}{2}}$ factor of 1.56. Using this lag time, a 15-minute unit hydrograph was computed from the dimensionless graph shown on Plate III-3. This unit hydrograph, shown on Plate III-5, has been used to determine the inflow spillway design flood for the Mayrouba Reservoir.

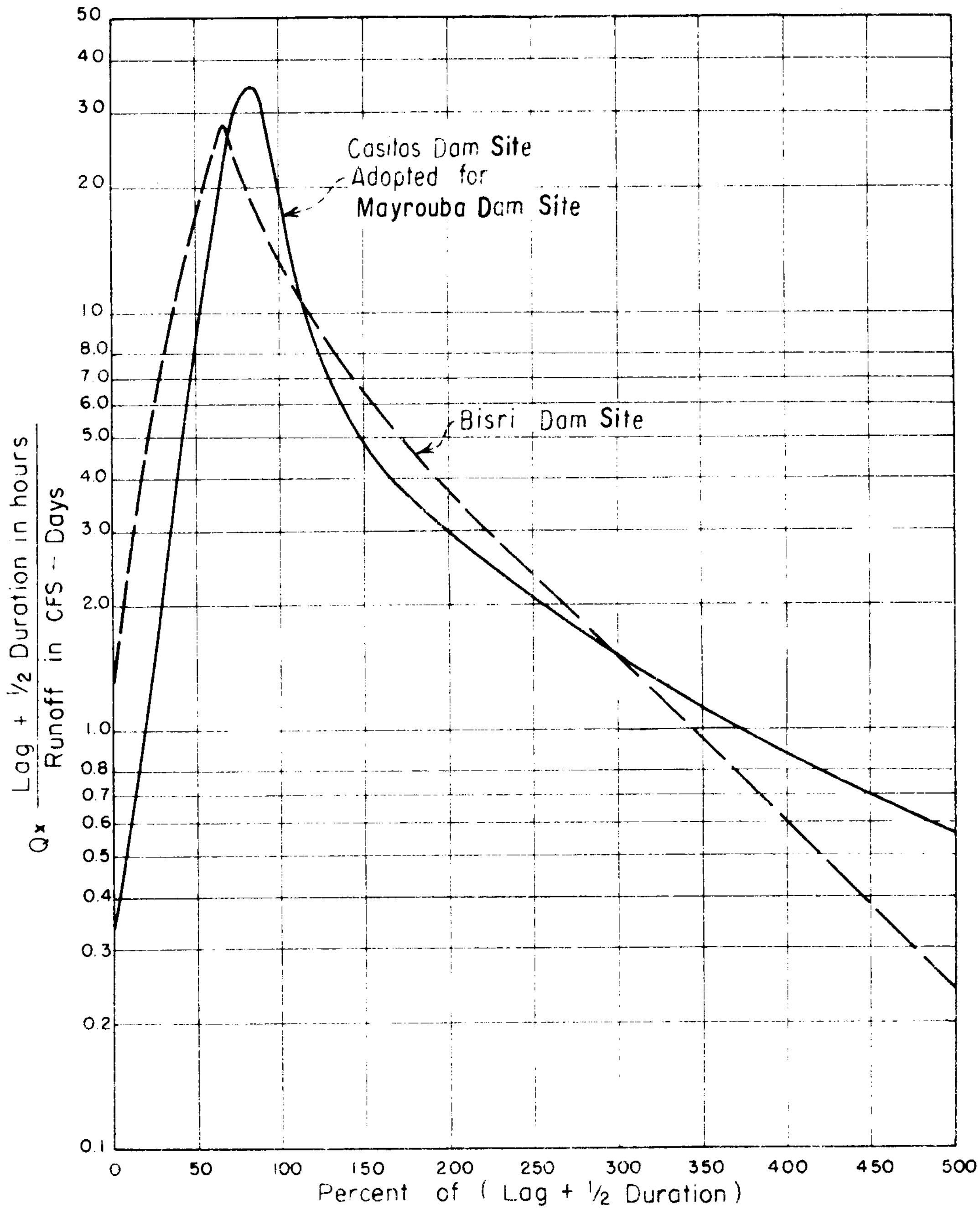
Design Storm. The Lebanon coastal drainage basins are directly exposed to moist air moving in from the Mediterranean Sea. During periods when well-developed low pressure systems form in the Eastern Mediterranean, these basins will generally experience heavy orographic-type precipitation in addition to that resulting from convergent processes associated with the storm itself. In most respects these basins are similar to the Southern California coastal region.

A comparison was made of the design storm values recommended for the Bisri Dam Site drainage basin as presented in the Development Plan for the Litani River Basin[4/] and that used over the Coyote Creek drainage basin above Casitas Dam Site. This comparison indicated that the incremental precipitation value for the most intense 6-hour period of the Bisri design storm is probably too small. It is believed that the long-duration design storm value derived for Casitas Dam Site would be appropriate for use in the derivation of the inflow design flood for Mayrouba Dam Site. This gave a total precipitation of 74.93 centimeters in 65 hours. The distribution of this storm is shown on Plate III-6. This storm would produce the maximum flood volume of runoff.

Although extremely rare, there is evidence of short-duration storms of high intensity occurring in Lebanon. The storm of December 17, 1955 centered over the Nahr Barsa and the Nahr Abou Ali above the city of Tripoli. It produced approximately 102 millimeters of precipitation in two hours. Undoubtedly, topography exerted some influence in the production of this heavy precipitation; however, it appears physically possible for precipitation of this areal extent to occur anywhere along the windward side of the Lebanon Mountains. The distribution of this high-intensity and short-duration storm is shown on Plate III-6. This storm would produce the maximum peak runoff.

Retention Rates. No data are available to determine the actual retention rates in the Nahr el Kelb Basin. However, studies made for the Development Plan for the Litani River Basin and those for Southern California, indicate that a retention rate of 0.1 inch per hour, or 2.54 millimeters per hour, is applicable to the Nahr el Kelb Basin.

Design Flood Hydrograph. Inflow design floods were computed for the Mayrouba Reservoir using the design storms, the unit hydrograph, and the retention rate discussed above. The hydrographs computed for these floods are shown on Plate III-7. The high-intensity and short-duration storm produced a peak discharge of 1,140 cubic meters per second and a 12-hour flood volume of 7.9 million cubic meters from a rainfall excess of 9.68 centimeters. The long-duration design storm produced a peak discharge of 775 cubic meters per second and a 3-day flood volume of 49 million cubic meters from a rainfall excess of 59.98 centimeters. These runoff values include a base flow for the Nahr el Kelb at the Mayrouba Dam Site of one cubic meter per second.



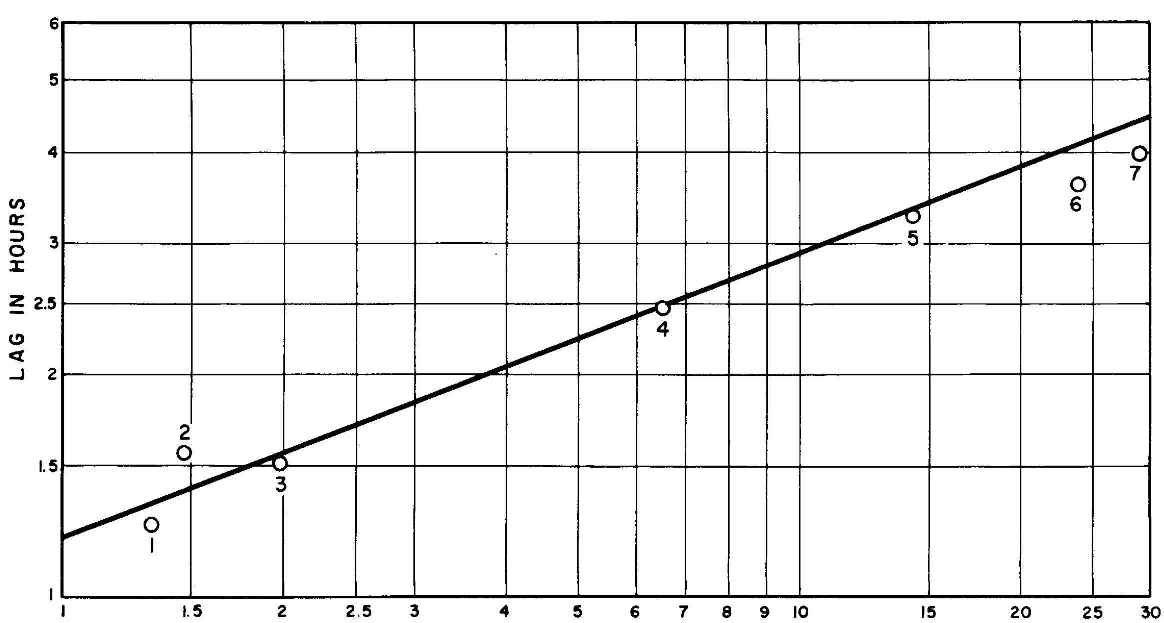
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
WATER RESOURCES RECONNAISSANCE

DIMENSIONLESS GRAPH
MAYROUBA DAM SITE
NAHR EL KELB

DR ______ SUBMITTED David E. Donley
TR E.A.H. RECOMMENDED
CH D.E.D. APPROVED L.F. Snyder

BEIRUT, LEBANON JAN. 4, 1956 | OA – 10 – 849

PLATE III - 3



$\frac{L \times L_{ca}}{S^{1/2}}$

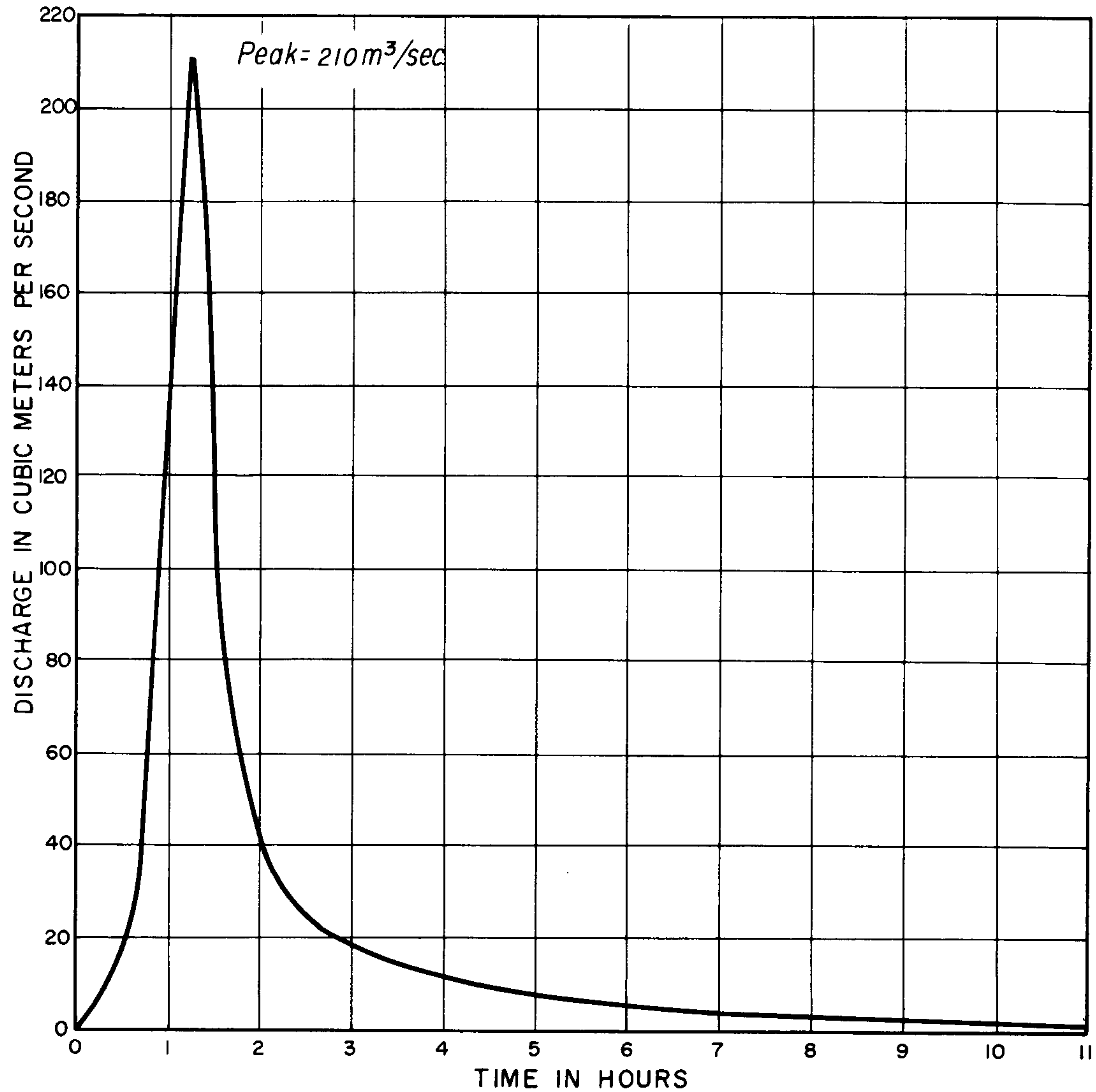
No.	STREAM AND STATION
1	Eaton Wash at Eaton Dam, California.
2	W. Fork San Gabriel River at San Gabriel Dam No.2, California.
3	San Dimas Creek at San Dimas, California.
4	Tajunga Creek at Tajunga Dam No. 1, California.
5	San Gabriel River at San Gabriel Dam No. 1, California.
6	Temecula Creek at Pauba Canyon, California.
7	Murrietta Creek at Temecula, California.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
WATER RESOURCES RECONNAISSANCE
LAG RELATIONSHIP CURVE
SOUTHERN CALIFORNIA STREAMS

DR. J.M.B. SUBMITTED J.M. Busalacchi
TR. R.B. RECOMMENDED G.J. Stacey
CH. J.M.B. APPROVED K.K. Weiland

BEIRUT, LEBANON DEC. 6, 1956 OA-10-559

PLATE III-4



NOTES

The unit hydrograph shown was developed from a dimensionless unitgraph determined from a similar area in Southern California. It has a volume of 820,000 cubic meters of runoff that would result from 10 millimeters of precipitation occurring in a 15-minute period over 82 square kilometers of the Nahr el Kelb above the Mayrouba Dam Site. A lag of 1.43 hours was assumed.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
WATER RESOURCES RECONNAISSANCE

15-MINUTE UNIT HYDROGRAPH

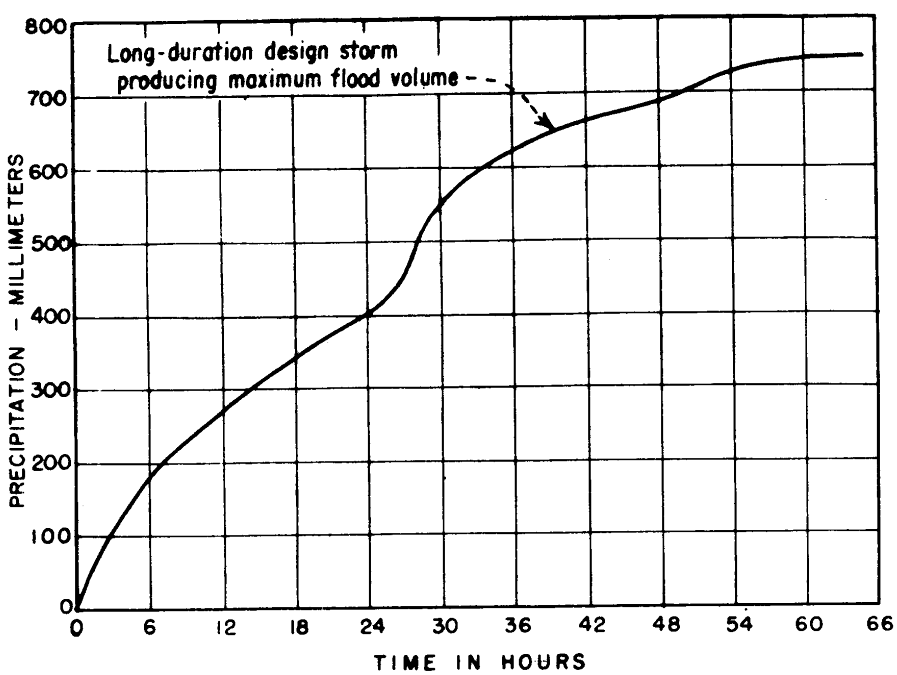
MAYROUBA DAM SITE

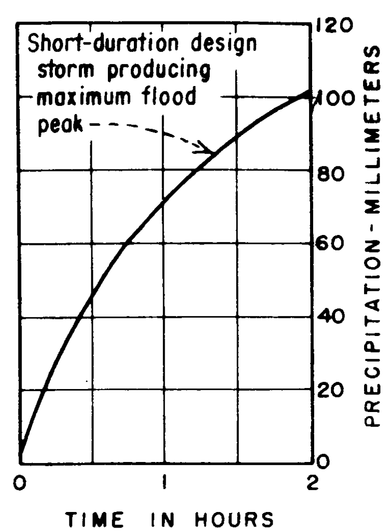
NAHR ES SALIB - NAHR EL KELB BASIN

DR. J.M.B. SUBMITTED
TR. E. H. RECOMMENDED
CH. APPROVED

BEIRUT, LEBANON MAR. 28, 1956 **OA-10-859**

PLATE III-5





NOTE:

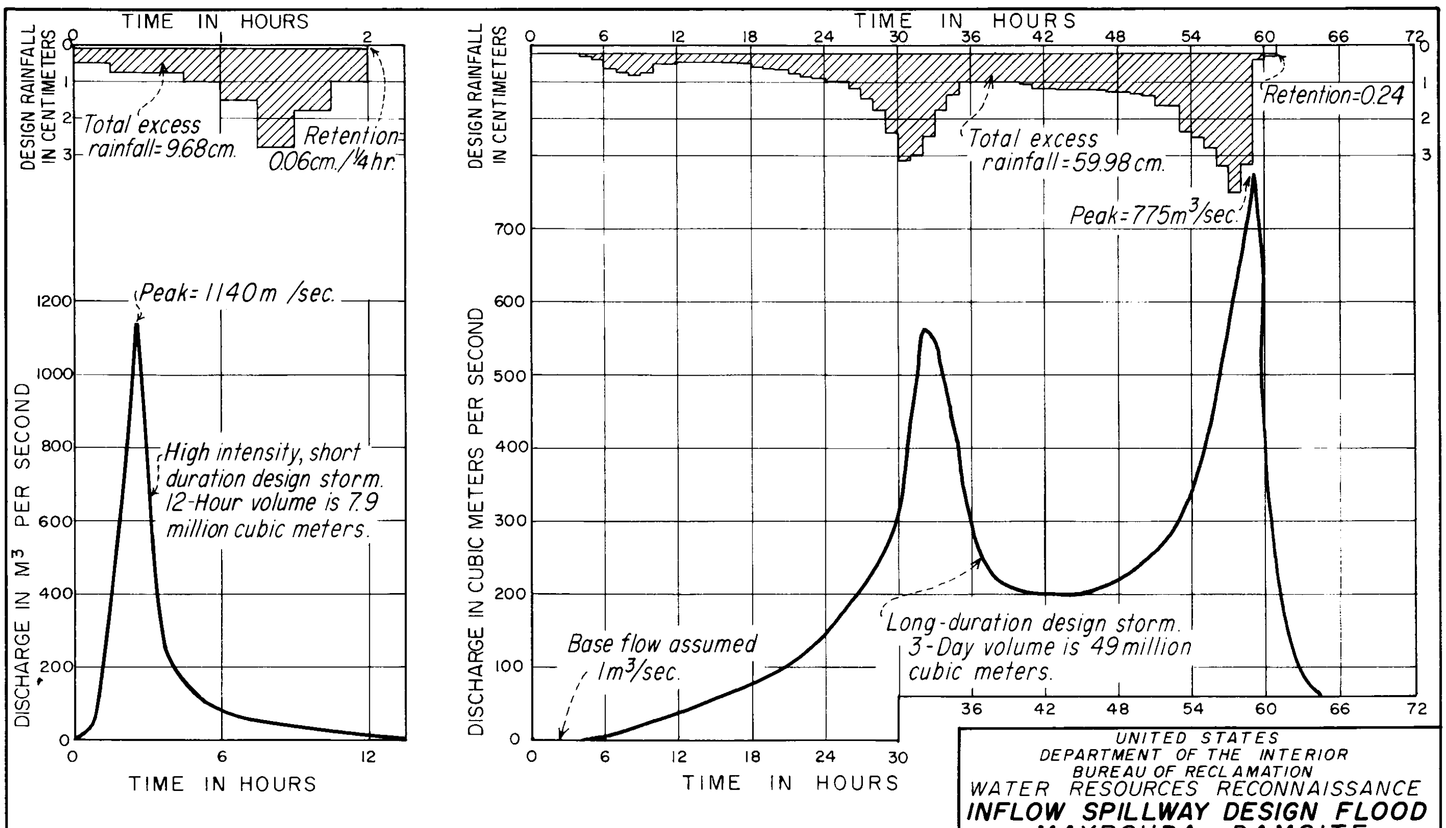
The long-duration design storm was adopted from the Casitas Flood Study of Southern California. The short-duration design storm approximates the observed 2-hour precipitation at Amione and Tripoli, Lebanon during the Dec. 17, 1955 storm.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
WATER RESOURCES RECONNAISSANCE

DEPTH – DURATION CURVE
SPILLWAY DESIGN STORM
NAHR EL KELB BASIN

DR. D.E.D SUBMITTED
TR. J.M.K. RECOMMENDED
CH. APPROVED
BEIRUT, LEBANON APR. 15, 1955 OA-10-863

PLATE III-6



Note: Inflow spillway design flood was determined by the Unit Hydrograph Method. Drainage area above site is 82 km2.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
WATER RESOURCES RECONNAISSANCE

INFLOW SPILLWAY DESIGN FLOOD
MAYROUBA DAMSITE
NAHR EL KELB BASIN

DR. J.M.B. SUBMITTED J. M. Busalacchi
TR. J.M.K. RECOMMENDED H. H. Weiland
CH. J. M. B. APPROVED L. J. Snyder
BEIRUT, LEBANON MAR. 28, 1956 OA - 10 - 860

Floods in Lebanon can be expected to occur during the 5-month period between November 1 and March 31 each year. The highest ones are most likely to occur between December 1 and March 31. It is believed that the inflow design flood would occur in this period. Insufficient data are available to determine whether or not a seasonal variation should be anticipated in the magnitude of this flood. It has been assumed that it would occur with the same magnitude any time between December 1 and March 31 in the Nahr el Kelb Basin.

Routing Recommendation. It is recommended that the Mayrouba Reservoir be assumed full at the beginning of the inflow design flood. Both floods should be routed through the reservoir to determine the size of the spillway. The amount of surcharge storage will determine which of the two inflow designs will be critical in the design of the spillway.

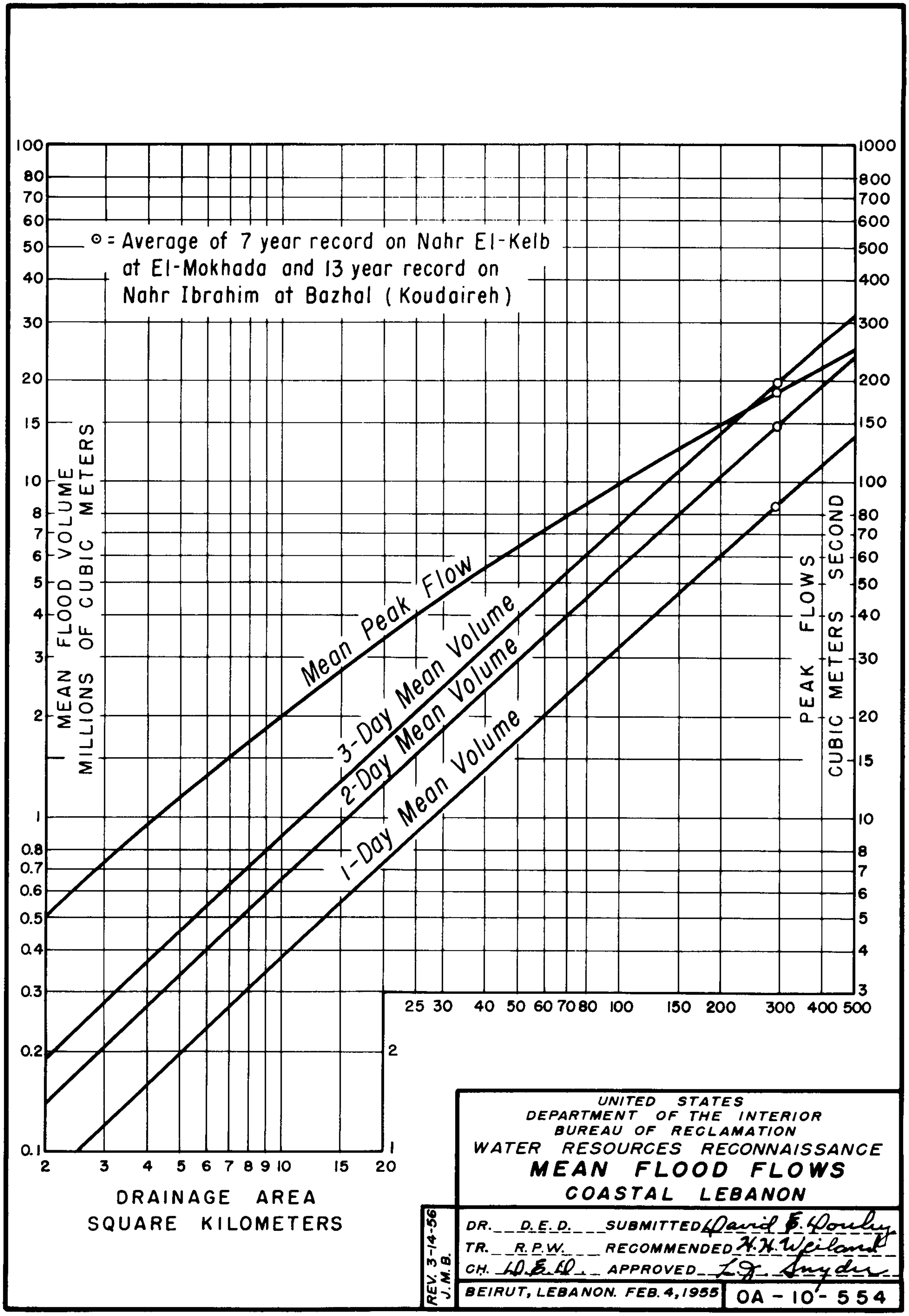
Spillway Design Floods - Diversion Dams

There are 7 years of recorded streamflow available in the Nahr el Kelb and 13 years of recorded streamflow available in the Nahr Ibrahim (both of which are coastal stream basins) for flood frequency analyzation. The mean of annual maximum peak flows and the mean of annual maximum 1-, 2-, and 3-day volumes, were determined for the drainage areas above the gaging stations on the Nahr el Kelb at El Mokhada and on the Nahr Ibrahim at Bazhal. From these values, a weighted average value was determined on a station-year basis. This resulted in an average drainage area determination of 293 square kilometers, a mean of annual maximum peak flow of 184 cubic meters per second, and a mean of annual maximum 1-, 2-, and 3-day flood volume of 8.5, 14.7, and 19.7 million cubic meters, respectively. These values were plotted on log-log paper versus the above determined drainage area. A curve, parallel to Creager's world envelope curve was drawn through the plotted values to represent a relation between mean of annual maximum peak flow versus drainage area. The curves representing the mean of annual maximum flood volumes were drawn through the plotted values and parallel to a volume envelope curve derived for streams in the Western United States by Mr. B. S. Barnes, formerly with the Bureau of Reclamation, Denver, Colorado. These curves, shown on Plate III-8, have been assumed applicable to all drainage areas in the coastal section of Lebanon.

Coefficients of variation (C. V.) and coefficients of skew (C. S.), for use in the Hazen method of flood frequency determination were computed for the gaging stations on the Nahr el Kelb at El Mokhada and on the Nahr Ibrahim at Bazhal. These values are shown as follows:

Station	Item	Peak Flow (m^3/sec.)	1-Day Volume ($m^3 \times 10^6$)	2-Day Volume ($m^3 \times 10^6$)	3-Day Volume ($m^3 \times 10^6$)
El Mokhada	C. S.	0	1.57	2.19	2.32
Bazhal	C. S.	0.63	2.12	2.16	2.25
El Mokhada	C. V.	0.27	0.47	0.46	0.49
Bazhal	C. V.	0.25	0.54	0.56	0.57

It is believed that the C. S. and C. V. values obtained for the peak flows are too low, because (1) the duration of streamflow records are short, and (2) the stage-discharge rating curves for both stations had to be extended by synthetic methods to define the medium and high-water portions of the rating curves which may give too low a discharge for the extreme high recorded gage heights. Also, the recording instruments at both stations are of such type that the pen of the instrument does not reverse when it reaches the top of the chart, and so may fail to record the maximum peak stage. Higher peaks are further substantiated by the results of the unchecked, indirect determination of about 830 cubic meters per second for the flood on the Nahr Barsa near Tripoli, Lebanon on December 17, 1955, for a drainage area of about 59 square kilometers.



⊙ = Average of 7 year record on Nahr El-Kelb at El-Mokhada and 13 year record on Nahr Ibrahim at Bazhal (Koudaireh)
Mean Peak Flow
3-Day Mean Volume
2-Day Mean Volume
1-Day Mean Volume
MEAN FLOOD VOLUME
MILLIONS OF CUBIC METERS
PEAK FLOWS
CUBIC METERS SECOND
DRAINAGE AREA
SQUARE KILOMETERS
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
WATER RESOURCES RECONNAISSANCE
MEAN FLOOD FLOWS
COASTAL LEBANON
DR. D.E.D. SUBMITTED David E. Donley
TR. R.P.W. RECOMMENDED H.H. Weiland
CH. W.E.W. APPROVED L.T. Snyder
REV. 3-14-56 J.M.B.
BEIRUT, LEBANON. FEB. 4, 1955
OA - 10 - 554

PLATE III-8

It was concluded that the average of the C.S. and C.V. values as calculated for the 1-, 2-, and 3-day flood volumes for the Nahr Ibrahim at Bazhal be used for the flood frequency studies of the Lebanese coastal streams. A coefficient of variation of 0.56 and a coefficient of skew of 2.18 were used in the analyses of the flood frequency studies for both peak discharge and flood volumes. The application of these average values to the mean flows as determined above, resulted in the frequency curves shown on Plates III-9 through III-17 for the diversion dam sites selected in the Nahr el Kelb Basin. It was concluded in the flood frequency studies that for any dam site having a drainage area less than 5.0 square kilometers, consideration should be made for base flow if those sites are located immediately below natural springs. The base flow was considered to be the average flow for the maximum month during the average year. The base flow was added to the frequency values for both the Hardoun and El Leben Diversion Dam Sites.

All of the proposed diversion dams will be relatively minor structures. The spillways for all of them have been designed to carry the 50-year flood as determined by the above methods. The peak flow values for the 50- and 100-year floods, in cubic meters per second, as shown by the curves on the above mentioned plates, are as follows:

Frequency in Years	Jeita	Balloune	Qlayaat	Hardoun	Chabrouka	El Aassel	El Leben	Fakra
50	473	437	260	30	78	72	17	78
100	571	527	314	35	94	87	20	94

These values seem reasonable for use in this type of reconnaissance survey. Because of the limited data available for these studies, the peak flows should be recomputed when additional flood flow data becomes available.

Diversion During Construction

The frequency curves shown on Plates III-9 through III-17 have been used to determine the flows for which diversion should be planned during the construction period. It should be noted, that all floods in Lebanon occur during the 5-month period between November 1 and March 31, with the highest floods most likely to occur between December 1 and March 31. Therefore, any construction activities which can be carried out between April 1 and October 31, may have their diversion requirements greatly reduced. The values shown in Table III-20 have been taken from the frequency curves on the above plates and have been adopted for the selected diversion dam sites.

TABLE III-20

DIVERSION REQUIREMENTS DURING CONSTRUCTION

Diversion Dam	Frequency Years	Peak (m^3/second)	Volume (Millions of Cubic Meters) 1-Day	2-Day	3-Day
Mayrouba	5	114	3.50	6.02	8.12
	10	149	4.56	7.84	10.6
	25	200	6.12	10.5	14.2
Balloune	5	206	8.45	14.7	19.7
	10	268	11.0	19.1	25.6
	25	360	14.8	25.6	34.4
Jeita	5	223	9.50	16.6	22.2
	10	291	12.4	21.7	28.9
	25	390	16.6	29.1	38.8
Qlayaat	5	123	3.89	6.73	9.04
	10	160	5.07	8.77	11.8
	25	215	6.81	11.8	15.8

TABLE III-21

MAXIMUM RECORDED STREAM FLOW
SOUTHERN CALIFORNIA STREAMS

No.	Stream	Station	Drainage area Km^2	Peak discharge Rate $m^3/sec.$	Peak discharge Date	Maximum runoff Volume m^3x10^6	Maximum runoff Dates (incl.)
1	San Gabriel River	near Azuza	546	2,662	3/2/38	116	3/2 - 3/5/38
2	San Gabriel River	above San Gabriel Dam No. 1	523	2,549	12/20/24		
3	E. FK. San Gabriel River	near Camp Bonita	228	1,303	3/2/38	66.1	2/28 - 3/8/38
4	W. FK. San Gabriel River	at Camp Rincon	264	963	3/2/28	76.9	3/1 - 3/4/38
5	W. FK. San Gabriel River	above San Gabriel Dam No. 2	105	702	3/2/38		
6	Rogers Creek	near Azuza	15.8	234	3/2/38	3.64	2/28 - 3/4/38
7	Devils Canyon	above San Gabriel Dam No. 2	40	651	3/2/43		
8	Tujunga Creek	near Sunland	275	1,416	3/2/38	46.0	3/2 - 3/5/38
9	Big Tujunga Creek	at Tujunga Dam	211	963	3/2/38		
10	N. FK. Mill Creek	above Tujunga Dam No. 1	15.0	207	3/2/38		
11	Arroyo Seco	near Pasadena	42	244	3/2/38	9.99	3/1 - 3/3/38
12	Millard Canyon	near Montrose	7.0	146	3/2/38		
13	Rubio Creek	at Rubio Falls	2.3	57	3/2/38		
14	Day Creek	near Etiwanda	12.4	119	3/2/38	4.50	2/28 - 3/4/38
15	Cucamonga Creek	near Upland	26	292	3/2/38	8.70	2/28 - 3/4/38
16	Lytle Creek	near Fontana	121	714	3/2/38	32.7	3/1 - 3/4/38
17	San Antonio Creek	near Claremont	44	606	3/2/38	15.5	3/1 - 3/6/38
18	San Jacinto River	near San Jacinto	363	1,274	2/16/27		
19	San Dieguito River	near Escondido	785	2,039	1/27/16		
20	San Luis Rey River	near Mesa Grande	541	1,659	1/27/16	103	1/25 - 2/2/16
21	San Luis Rey River	near Pala	834	2,124	11/12/44		
22	Santa Ysabel Creek	near Mesa Grande	150	595	1/27/16	45.0	1/27 - 1/31/16
23	Santa Ysabel Creek	near Ramona	285	804	1/27/16	71.3	1/27 - 2/1/16
24	San Diego River	near Lakeside	264	447	1/28/16	78.9	1/27 - 1/31/16

Note:
Data taken from information furnished by the Bureau of Reclamation, Denver, Colorado.

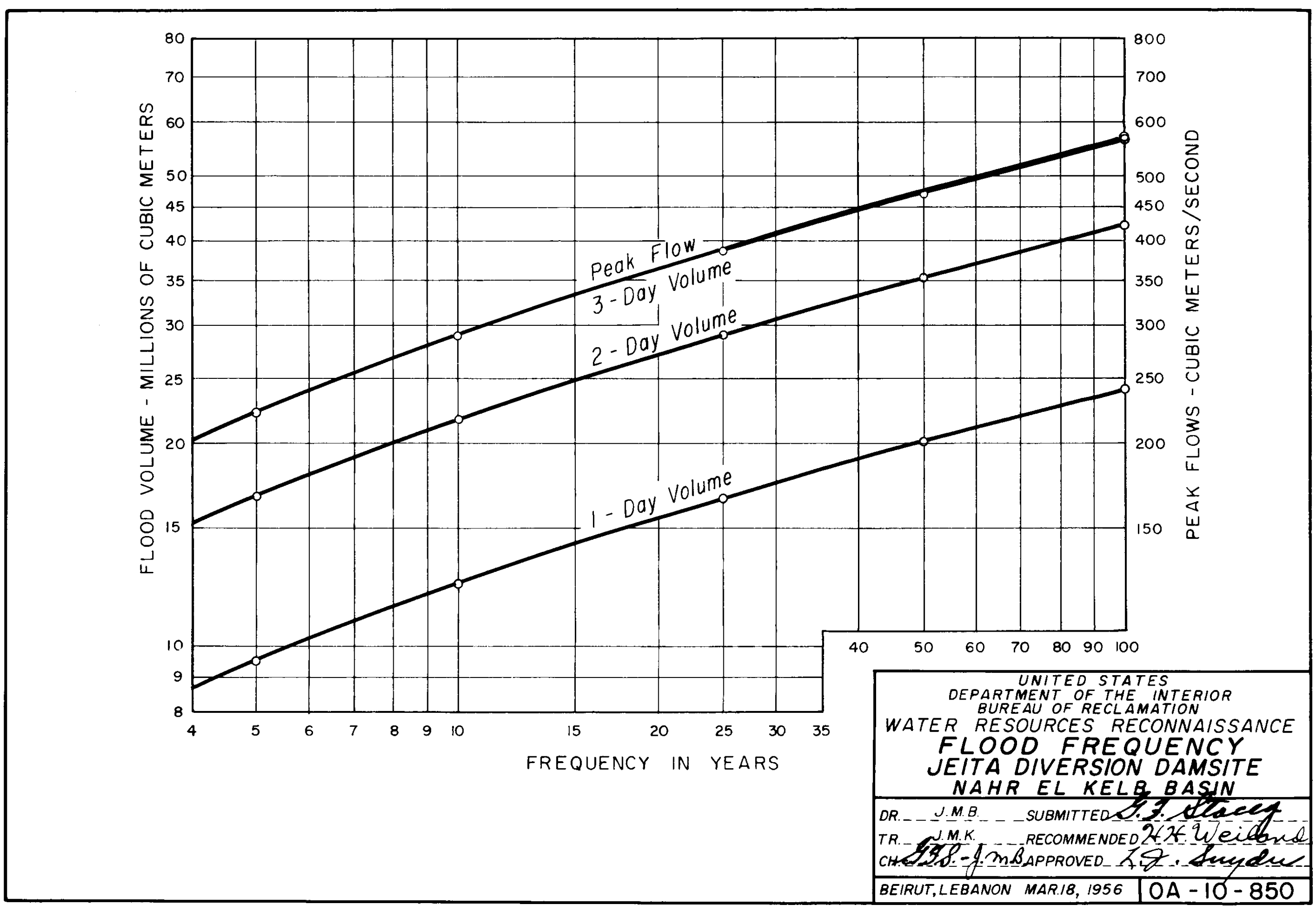
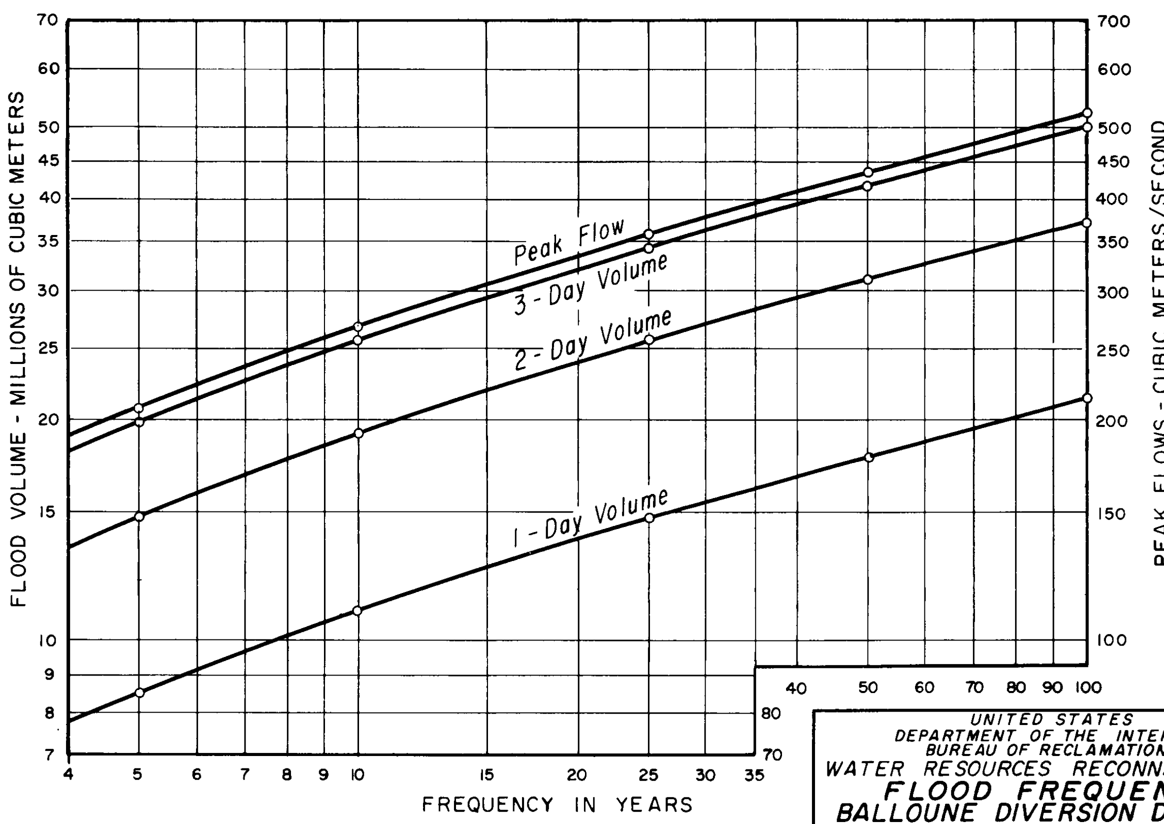

FLOOD VOLUME - MILLIONS OF CUBIC METERS
PEAK FLOWS - CUBIC METERS/SECOND
FREQUENCY IN YEARS
Peak Flow
3 - Day Volume
2 - Day Volume
1 - Day Volume
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
WATER RESOURCES RECONNAISSANCE
FLOOD FREQUENCY
JEITA DIVERSION DAMSITE
NAHR EL KELB BASIN
DR. J.M.B. SUBMITTED
TR. J.M.K. RECOMMENDED
CH. APPROVED
BEIRUT, LEBANON MAR.18, 1956
OA-10-850

PLATE III - 9



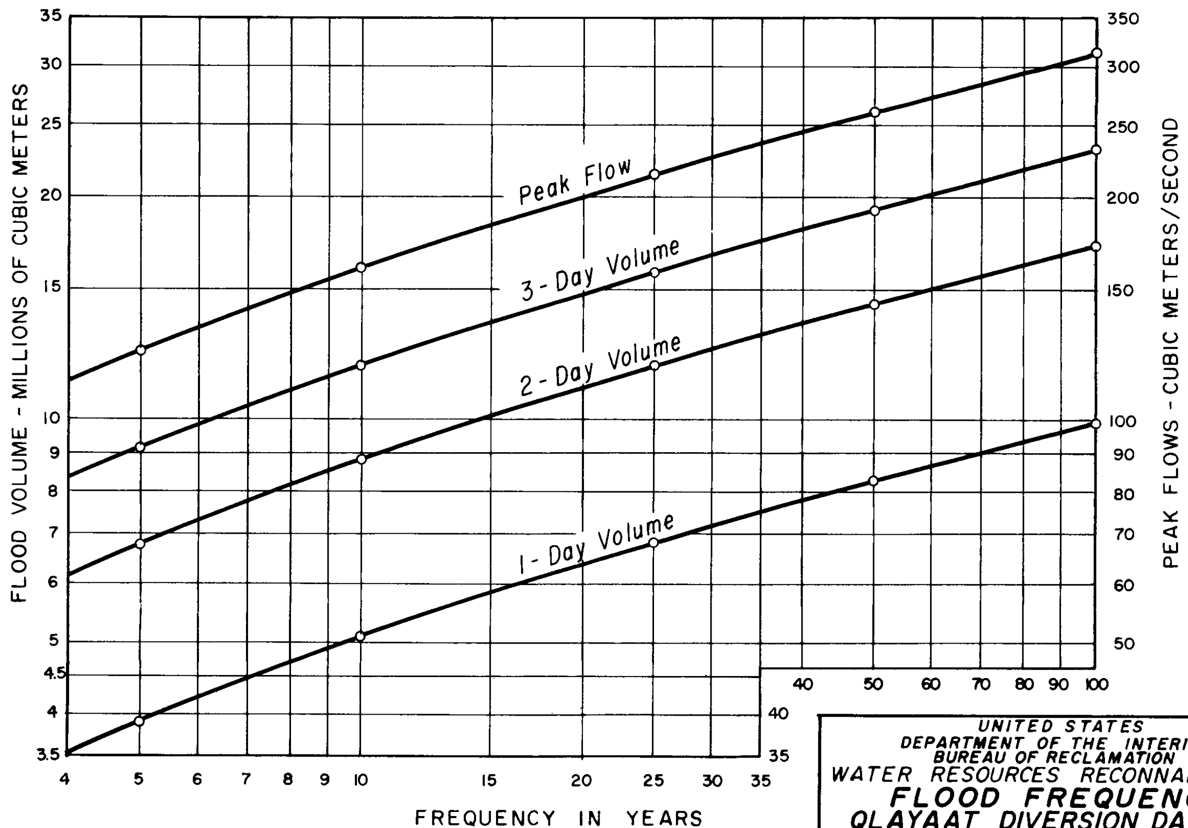
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
WATER RESOURCES RECONNAISSANCE

FLOOD FREQUENCY
BALLOUNE DIVERSION DAMSITE
NAHR EL KELB BASIN

DR. J.M.B. SUBMITTED G.F. Stacey
TR. J.M.K. RECOMMENDED H.H. Weiland
CH. G.S.S. J.M.B. APPROVED L.J. Snyder

BEIRUT, LEBANON MAR.18, 1956 | OA-10-851

PLATE III-10



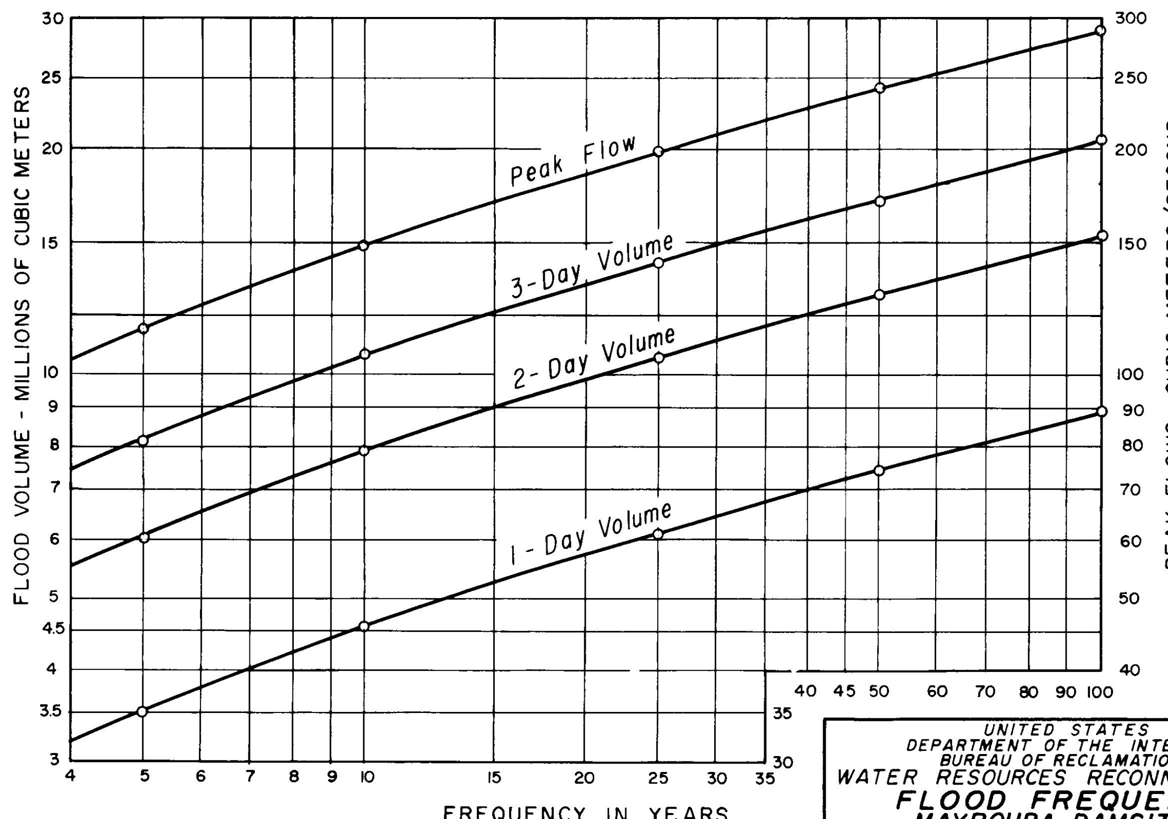
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
WATER RESOURCES RECONNAISSANCE

FLOOD FREQUENCY
QLAYAAT DIVERSION DAMSITE
NAHR EL KELB BASIN

DR. J.M.B. SUBMITTED
TR. J.M.K. RECOMMENDED
CH. APPROVED

BEIRUT, LEBANON MAR. 18, 1956 **OA - 10 - 852**

PLATE III-11



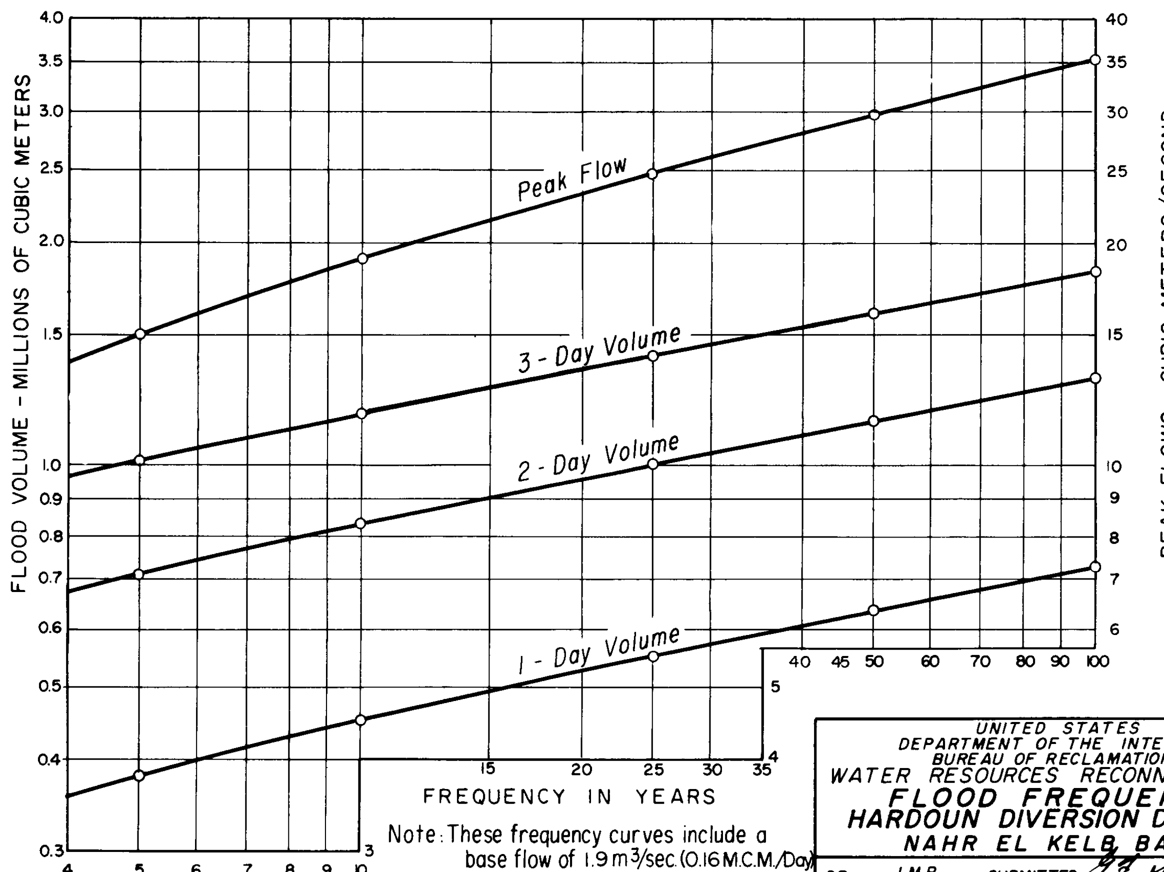
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
WATER RESOURCES RECONNAISSANCE

FLOOD FREQUENCY
MAYROUBA DAMSITE
NAHR EL KELB BASIN

DR. J.M.B. SUBMITTED [signature]
TR. J.M.K. RECOMMENDED [signature]
CH. [signature] APPROVED [signature]

BEIRUT, LEBANON MAR. 18, 1956 | **OA - 10 - 853**

PLATE III - 12



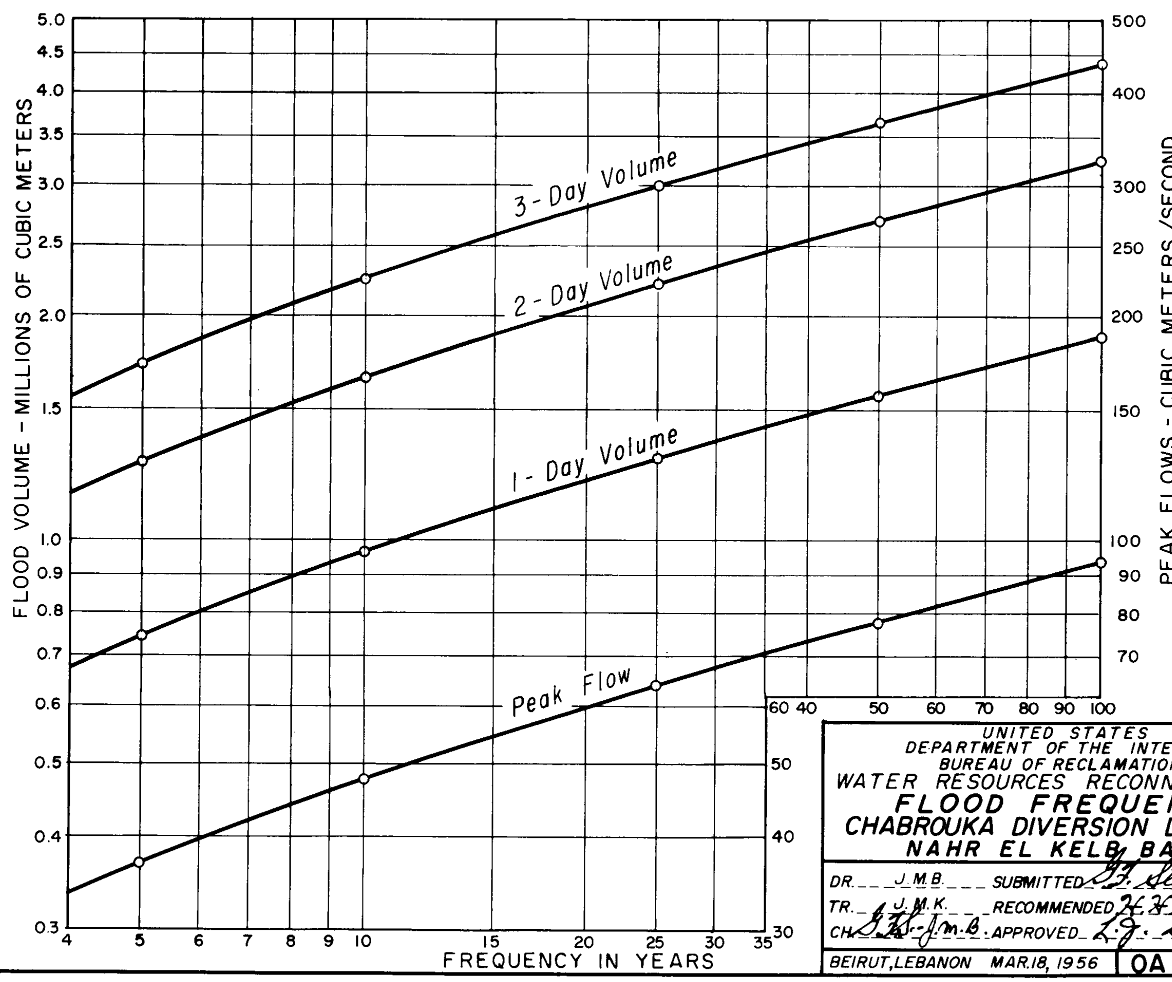
Note: These frequency curves include a base flow of 1.9 m³/sec. (0.16 M.C.M./Day) from the springs above the damsite which was estimated as the mean flow from the springs for the month April in an average year.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
WATER RESOURCES RECONNAISSANCE

FLOOD FREQUENCY
HARDOUN DIVERSION DAMSITE
NAHR EL KELB BASIN

DR. J.M.B. SUBMITTED G.T. Stacey
TR. J.M.K. RECOMMENDED H. K. Weiland
CH. G.T.S.-J.M.B. APPROVED L. G. Snyder

BEIRUT, LEBANON MAR. 3, 1956 | **OA-10-854**



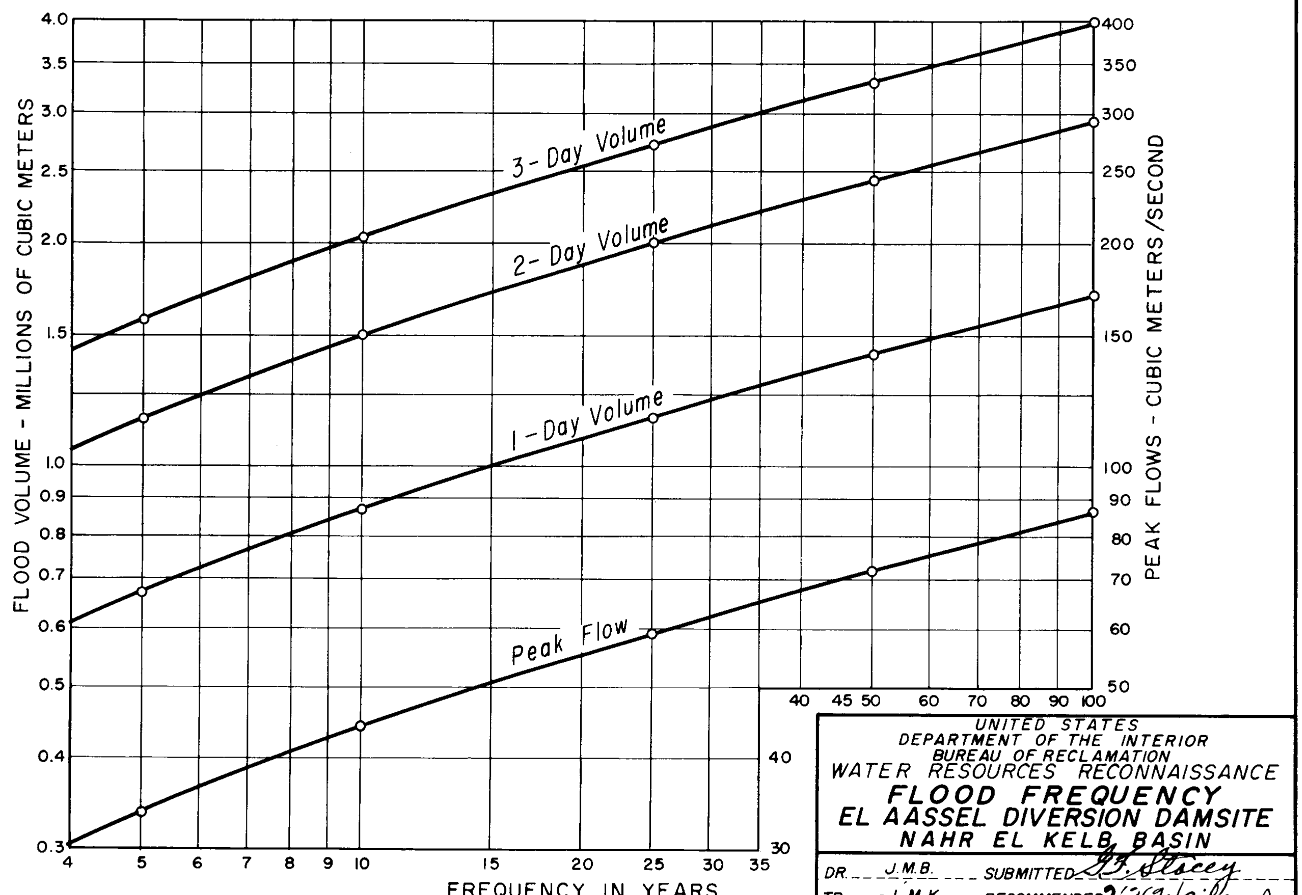
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
WATER RESOURCES RECONNAISSANCE

FLOOD FREQUENCY
CHABROUKA DIVERSION DAMSITE
NAHR EL KELB BASIN

DR. J.M.B. SUBMITTED G.F. Stacey
TR. J.M.K. RECOMMENDED H.F. Weiland
CH. G.K. J.M.B. APPROVED L.J. Snyder

BEIRUT, LEBANON MAR.18, 1956 **OA - 10 - 855**

PLATE III - 14

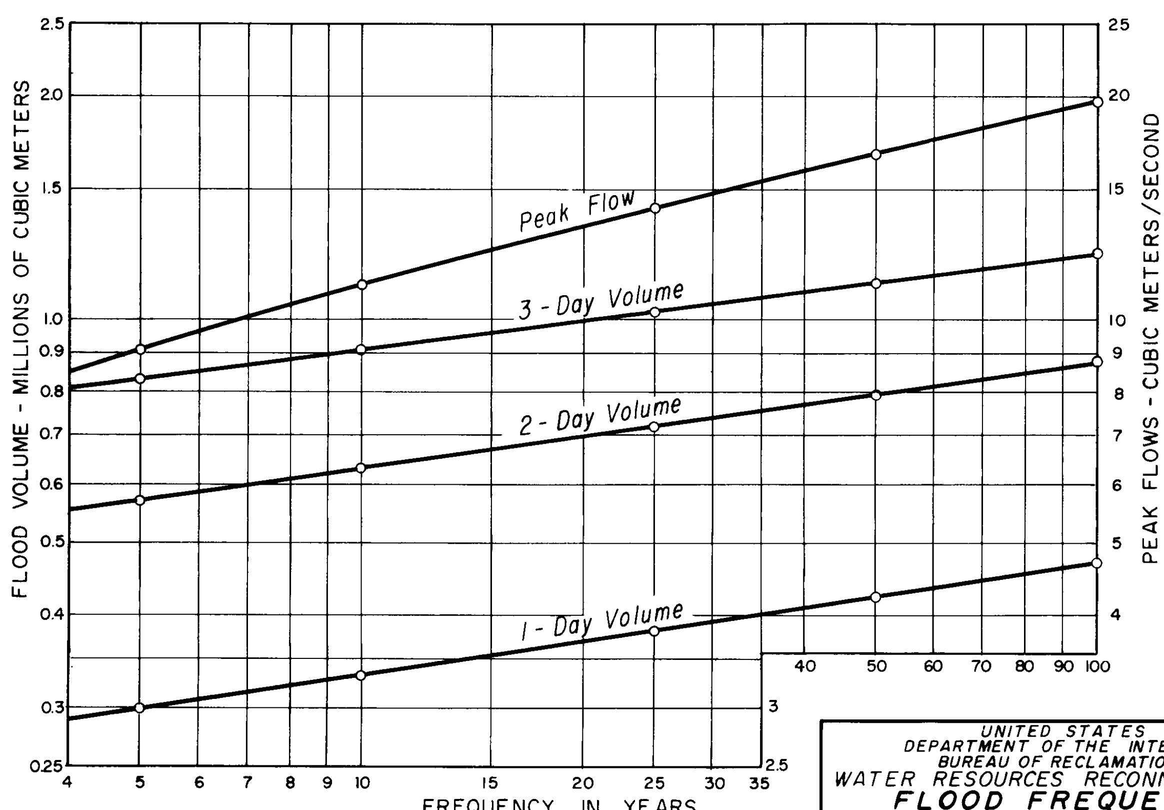


UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
WATER RESOURCES RECONNAISSANCE

FLOOD FREQUENCY
EL AASSEL DIVERSION DAMSITE
NAHR EL KELB BASIN

DR. J.M.B.	SUBMITTED G. T. Stacey
TR. J. M. K.	RECOMMENDED L. K. Weiland
CH. G.T.S.-J.M.B.	APPROVED L. G. Snyder
BEIRUT, LEBANON MAR.18, 1956	OA - 10 - 856

PLATE III - 15



Note: The frequency curves include a base flow of 2.2 m³/sec. (0.19 M.C.M./Day) from the springs immediately above the damsite which was estimated as the mean flow from the springs for the month of April in an average year.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
WATER RESOURCES RECONNAISSANCE

FLOOD FREQUENCY
EL LEBEN DIVERSION DAMSITE
NAHR EL KELB BASIN

DR. J.M.B. SUBMITTED G.T. Stacey
TR. J.M.K. RECOMMENDED H.H. Weiland
CH. G.T.S. - JMB APPROVED L. J. Snyder

BEIRUT, LEBANON MAR. 21, 1956 **OA - 10 - 857**

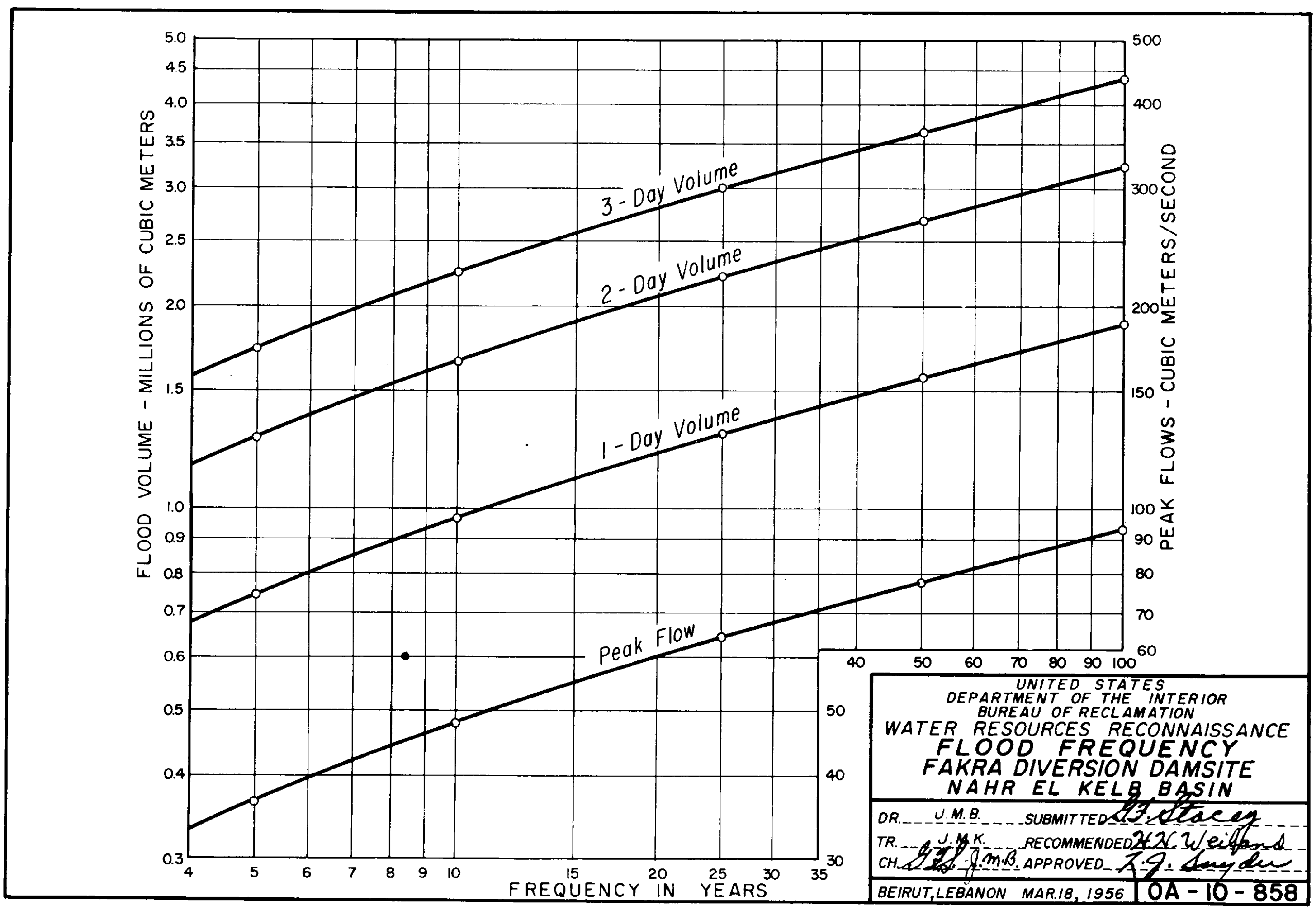


PLATE III - 17

Sanitized Copy Approved for Release 2011/06/21 : CIA-RDP80T00246A003400510001-7

TABLE III-20 (Continued)

DIVERSION REQUIREMENTS DURING CONSTRUCTION

Diversion Dam	Frequency Years	Peak (m^3/second)	Volume (Millions of Cubic Meters) 1-Day	2-Day	3-Day
Hardoun	5	15.0	0.38	0.71	1.01
	10	18.9	0.45	0.83	1.17
	25	24.8	0.55	1.00	1.40
Chabrouka	5	37	0.74	1.27	1.72
	10	48	0.96	1.65	2.24
	25	64	1.29	2.22	3.00
El Aassel	5	34	0.67	1.15	1.56
	10	44	0.87	1.50	2.03
	25	59	1.17	2.01	2.73
El Leben	5	9.1	0.30	0.57	0.83
	10	11.1	0.33	0.63	0.91
	25	14.2	0.38	0.72	1.02
Fakra	5	37	0.74	1.27	1.72
	10	48	0.96	1.65	2.24
	25	64	1.29	2.22	3.00

Maximum Expected Floods

Maximum recorded runoff rates and maximum recorded volumes for the Southern California coastal area previously discussed, are shown on the envelope curves of Plates III-18 and III-19, and are listed on Table III-21. A curve parallel to Creager's world envelope curve of peak discharge was drawn through the highest of the plotted points on Plate III-18, to represent an envelope curve of peak flows for the Lebanon coastal streams. A curve parallel to Barnes' envelope curve of flood volumes in Western United States was drawn through the highest of the plotted points on Plate III-19, to represent an envelope curve of flood volumes for the Lebanon coastal streams. The results of the indirect peak-discharge determination of the recent flood on the Nahr Barsa near Tripoli substantiates the use of the Southern California maximum peak envelope curve for the coastal streams of Lebanon. No comparable data are available to substantiate the envelope curve for maximum flood volume.

The maximum flood peaks and volumes to be expected at the dam sites selected in the Nahr el Kelb Basin, were determined from the above curves. These are shown in Table III-22.

TABLE III-22

ENVELOPE CURVE VALUES OF PEAK DISCHARGE AND VOLUME VALUES AT VARIOUS DAM SITES

Dam Site	Drainage Area (km^2)	Peak Flow (m^3/sec.)	Volume ($m^3 x 10^6$)
Jeita	247	1,900	74
Balloune	215	1,750	66
Qlayaat	92	1,060	31
Mayrouba	82	995	28
Hardoun	4.4	115	1.8
Chabrouka	15	305	5.6
El Aassel	14	290	5.3
El Leben	2.1	60	1.0
Fakra	15	305	5.6

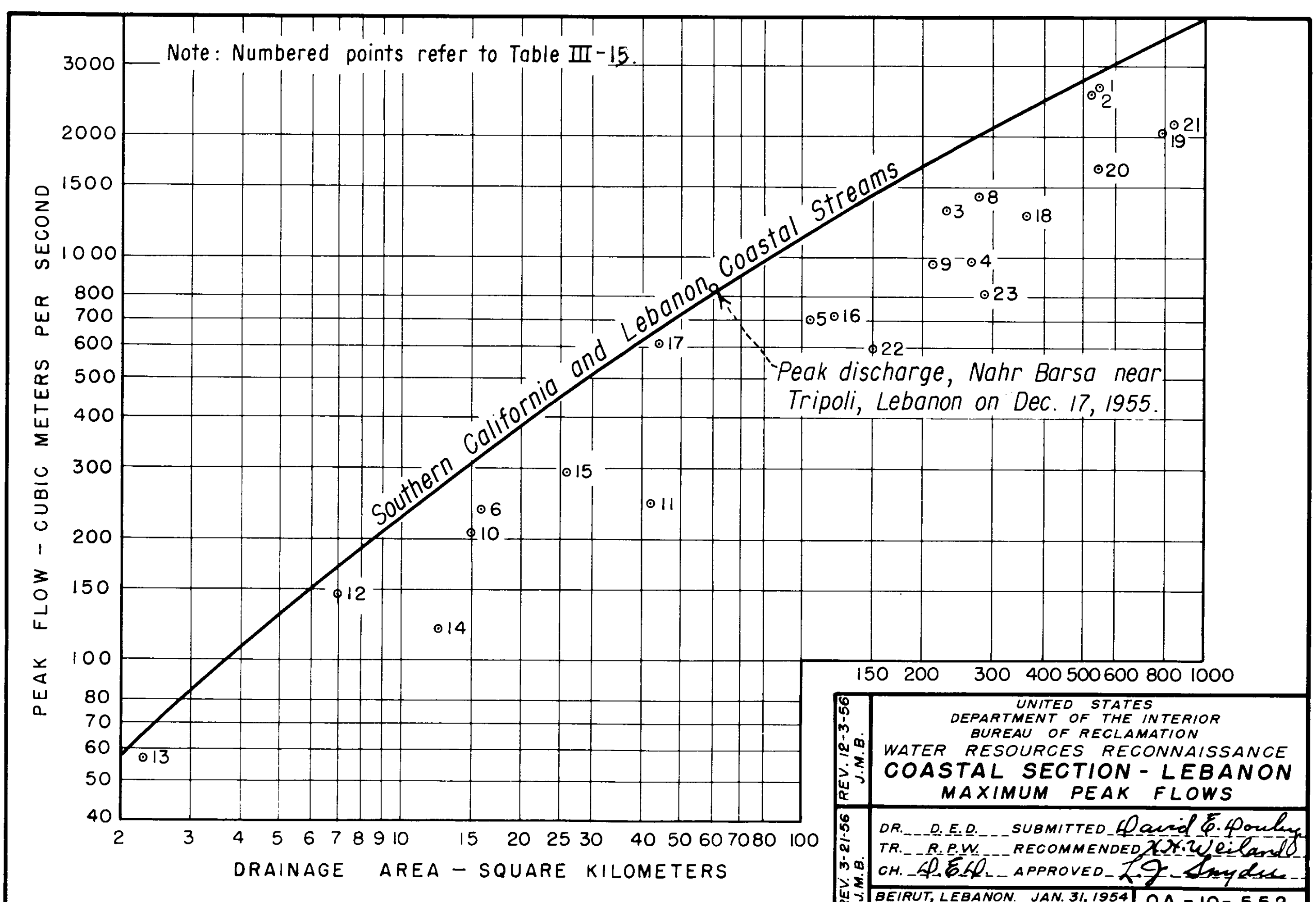

Note: Numbered points refer to Table III-15.
PEAK FLOW - CUBIC METERS PER SECOND
DRAINAGE AREA - SQUARE KILOMETERS
Southern California and Lebanon Coastal Streams
Peak discharge, Nahr Barsa near Tripoli, Lebanon on Dec. 17, 1955.
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
WATER RESOURCES RECONNAISSANCE
COASTAL SECTION - LEBANON
MAXIMUM PEAK FLOWS
REV. 12-3-56 J.M.B.
REV. 3-21-56 J.M.B.
DR. D.E.D. SUBMITTED David E. Donley
TR. R.P.W. RECOMMENDED K.H. Weiland
CH. D.E.D. APPROVED L.J. Snyder
BEIRUT, LEBANON. JAN. 31, 1954
OA-10-552

PLATE III-18

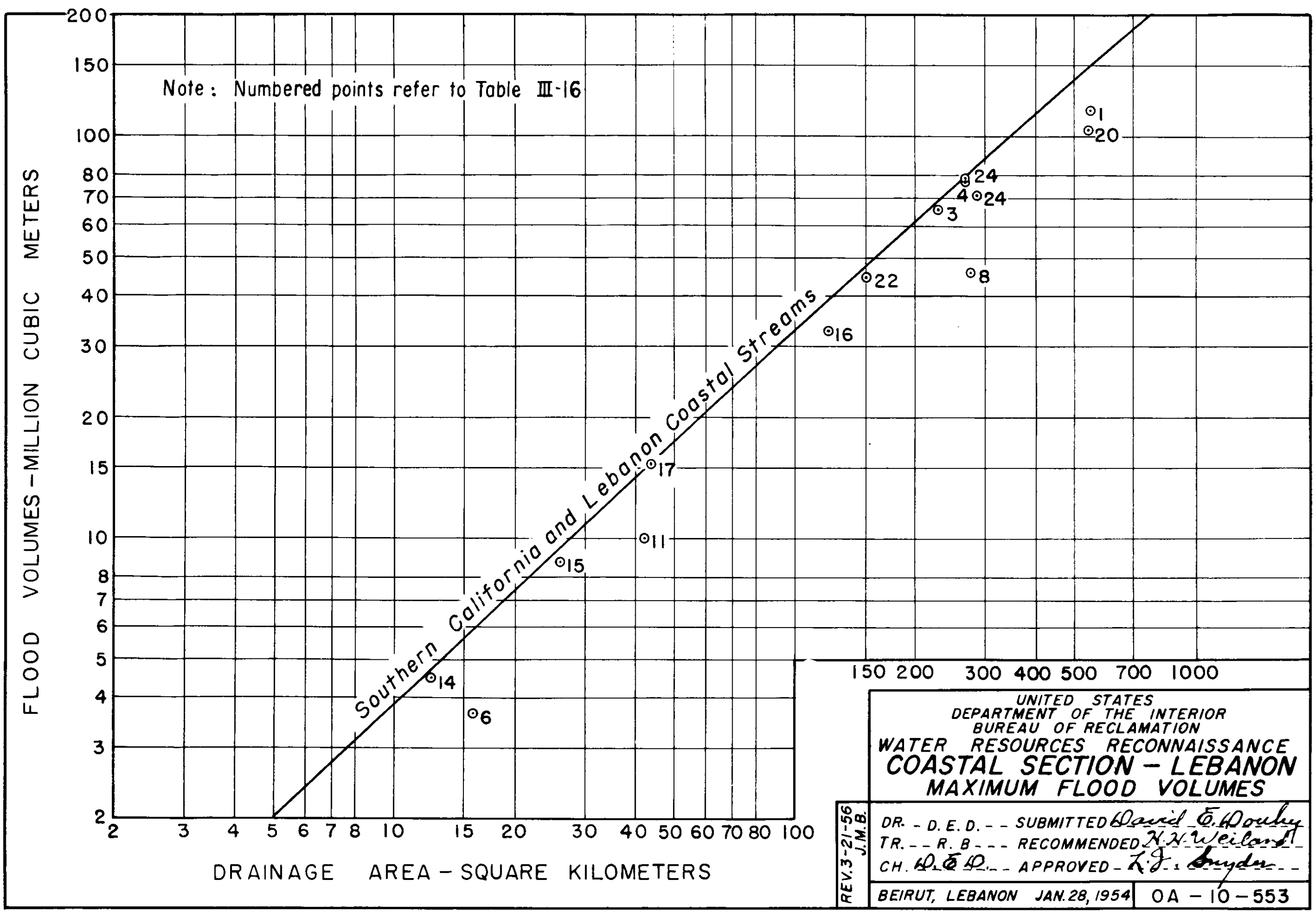

Note: Numbered points refer to Table III-16
FLOOD VOLUMES-MILLION CUBIC METERS
DRAINAGE AREA - SQUARE KILOMETERS
Southern California and Lebanon Coastal Streams
2 3 4 5 6 7 8 10 15 20 30 40 50 60 70 80 100
150 200 300 400 500 700 1000
2 3 4 5 6 7 8 10 15 20 30 40 50 60 70 80 100 150 200
1 20 24 4 24 3 22 8 16 17 11 15 14 6
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
WATER RESOURCES RECONNAISSANCE
COASTAL SECTION - LEBANON
MAXIMUM FLOOD VOLUMES
DR. - D. E. D. - - SUBMITTED David E. Donley
TR. - - R. B - - - RECOMMENDED H. H. Weiland
CH. D. E. D. - - APPROVED - L. J. Snyder
REV. 3-21-56 J.M.B.
BEIRUT, LEBANON JAN. 28, 1954
OA - 10 - 553

PLATE III-19

The maximum flood peak at the Mayrouba Storage Dam Site, as shown by the above table, is 995 cubic meters per second and the maximum flood volume is 28 million cubic meters. The short-duration design flood peak is about 1.2 times the above mentioned envelope curve value. The long-duration design flood volume is about 1.8 times the envelope curve value. It is recommended that the most critical of the two alternate spillway design floods be used in the design of the spillway.

The ponds behind these dams, except at Mayrouba, will be small and will have little effect upon flood flows. The 20 million cubic meters of storage behind Mayrouba will tend to reduce floods on the Nahr el Kelb. It appears doubtful that this reservoir will be operated for flood control. Therefore, no credit for flood control benefits have been taken for its effect on floods. Hydrographs for the various expected floods at the diversion dams have been omitted, since flood routing through the various ponds was not necessary to determine the size of the required spillways.

Sedimentation

No sedimentation measurements have ever been made in the Nahr el Kelb Basin. The karstic character of much of the headwater area in this basin tends to reduce surface runoff as well as its velocity. Many of the mountainsides in the upper part of this basin have been terraced for agricultural use for centuries. This further reduces surface runoff and locally increases retention rates. Rainfall generally occurs at moderate intensities although during the rainy season cloudbursts are uncommon. The decomposition of the limestones underlying almost all of this basin, has formed clay-type soils that are resistant to erosive processes. Sedimentation, except for movements resulting from infrequent land slides, plays a minor role in the erosion of the basin. Although no data are available to show the amount of sediments transported by this river, it is believed to be normally relatively small, except for period following large land slide as occurred in 1955 near the village of Beskinta.

While it is realized that the average annual concentration of sediment in the Bisri River of South Lebanon is about 1300 parts per million, it is believed that the sediment transport of the Nahr el Kelb would be 25 percent or less than that of the Bisri. This could cause a substantial depletion to the storage capacity of the proposed Mayrouba Reservoir. It is recommended that sediment measuring stations be established in the Nahr el Kelb Basin as soon as possible, probably two stations above the Balloune Diversion Dam on Nahr Hardoun and on Nahr es Salib and one on the Nahr es Salib in the vicinity of Harjel. Exact locations would be determined by a reconnaissance survey. Sediment sampling should be concentrated during the winter and spring seasons when most of the runoff occurs. The summer flows are mostly from springs and they carry practically no sediment loads. A proposed program for sediment sampling for this basin is discussed in Section IX - ADDITIONAL INVESTIGATIONS NECESSARY.

Quality of Water

The waters of the Nahr el Kelb have been used over the centuries without any visible or apparent detrimental effects either to the soil or crops. Only one chemical analyses of the Nahr el Kelb waters is shown to have been made. The sample was taken in November 1923. The chemical analyses of the sample is shown in Table III-23. The water appears suitable for irrigation. Nevertheless since the sample was obtained over 30 years ago, a water quality sampling program should be initiated as soon as possible to ascertain whether there has been any change in the chemical analyses of the Nahr el Kelb waters. Sampling of water should be made in all seasons of the year and for varying stages of stream flows. A minimum of three factors must be known in order to make an estimate of water quality for irrigation use: (1) the total concentration of dissolved solids, (2) the relative proportion of sodium to other cations, and (3) the concentration of boron.

TABLE III-23

QUALITY OF SURFACE WATER-ANALYSIS FOR
NAHR EL KELB BASIN1/

(November 1923)

Aspect	Clear
Smell	None
Taste	Pleasant
Dissolved oxygen	0.0071
Total degree of hardness	16.5°
Permanent degree of hardness	10°
Dry extraction at 100° C.	0.2118
Dry extraction at 180° C.	0.2003
Loss at 180° C	0.0115
Alkalinity expressed in Calcium Carbonate	0.165
Chlorides expressed in Sodium Chloride.	0.0361
Sulphates expressed in Calcium Sulphate	0.0185
Chlorides expressed in Chlorine	0.0218
Sulphates expressed in Sulphuric Anhydride (SO_3)	0.0108
Organic matter (Alkali Procedure), Absorbed Oxygen.	0.0026
Organic matter (Acid Procedure), Absorbed Oxygen	0.00008
Ammonia $OHNH_4$	None
Nitrites	None
Nitrates, expressed in nitrogen per liter	0.0003
Phosphates.	None
Sulphured Hydrogen	None

Analyses of the Deposition at 180° C.

Silica	0.0035
Alumina and Iron	0.0017
Lime CaO	0.0649
Magnesia MgO	0.0182

Hypothetical Grouping of Elements

Silica, Alumina, and Iron	0.0052
Chlorides and Sodium Chlorides	0.0361
Calcium Sulphate	0.0185
Calcium Carbonates.	0.1023
Magnesium Carbonate	0.0382
Losses	0.0115

1/ Copy of the analyses of Beirut water done by Dr. Guigues, Director of the Chemical Institute, November 1923. Note by Dr. Jean Misk: "The degree of hardness of the Beirut water is done by me every month. It is remarked after this long observation that this degree increases during summer to a maximum of 19° and decreases during the 4 months of rain to 13°."

Note: All quantities, except where indicated, are in grams per liter of water. Hardness determined by French method.

SECTION IV

GEOLOGY

Previous Geologic Reports

Several of the reports mentioned in Section I - INTRODUCTION, contain discussions of the surface geology in Lebanon. In addition, the French Geologist, Louis Dubertret, has published several articles covering the general geological aspects of the country. These include "Sketch of Physical Geography of Lebanon, Anti-Lebanon and Damascus Region, " June 1948 and "Discussion of the Possibility of Creating Reservoirs at Karaoun and Khardale, " August 1950. Dubertret has also prepared areal geologic maps of much of Lebanon on 1:50, 000 scale. These include the Nahr el Kelb Basin. Other reports covering the coastal geology of northern Lebanon are: "The Quaternary Coast of the Region of Tripoli (Lebanon)" by Rene Wetzel and Jean Holler, and "General Character of the Quaternary Vertige" by Darwin H. Jepsen, October 1952.

General Geology of the Area

Lebanon extends about 190 kilometers in a northeast-southwest direction along the eastern shore of the Mediterranean Sea. It is roughly rectangular in shape with a maximum width of about 75 kilometers. The Lebanon mountain range, paralleling the coastline, rises almost from the sea to elevations exceeding 2, 600 meters, A second mountain range, the Anti-Lebanon, roughly parallels the Lebanon range at a distance of some 40 kilometers to the east, and rises to about the same elevation. Between the two ranges is the Bekaa, a high, flat valley 10 to 12 kilometers in width, which extends from the north of Lebanon southward approximately three-fourths the length of the country.

The Lebanon and Anti-Lebanon Mountains and the intervening Bekaa section are the northern continuation of one of the world's major fault systems which extends from Africa along the Dead Sea through Jordan and Lebanon into Syria and Turkey. The mountains are essentially fault blocks which have been uplifted differentially by vast tectonic movements. The core of the Lebanon Mountains is a great Jurassic massif of limestone and dolomite surrounded by the intricately folded and faulted deposits of Cretaceous, Tertiary, and Quaternary Age.

Nearly all of the geological formations outcropping in Lebanon are composed of limestone or dolomite. The limestones are interbedded with varying amounts of calcareous clay in certain formational members and are known as marls, or marly limestone. Dolomite, which contains magnesium as well as calcium, is found throughout the geologic column, particularly in the Upper Cretaceous and Jurassic formations. The dolomite is also interspersed with marly zones. Sandstones are confined almost entirely to the base of the Cretaceous formation. This section of the geologic column also contains occasional beds of carbonaceous shale or marl. Local sheets of basalt cover sections of the country, generally as fissure flows. Volcanism occurred near the middle of the Cretaceous Period and continued into the Quaternary.

The land surfaces are greatly eroded near the center of Lebanon in the Beirut Area, but rise steeply eastward to the crest of the Lebanon Mountains. The narrow, deep valleys separating the many spurs on the western side of the Lebanon Range have resulted in many steep slopes permitting the exposure of extensive outcropping in each of the basins draining the area. The region as a whole presents a mature appearance geologically; the soil cover is generally shallow, and in many areas is lacking altogether. The west side of these mountains, from their crest down to the Coastal Plain, exhibits a typical limestone terrain occasionally modified by deposits of other types. Its surface and subsurface features have been influenced by the characteristic response of soluble rocks to weathering and erosion.

Geological Reconnaissance

The headwaters of the Nahr el Kelb rise on the western slope of the mountain barrier in an area of Cretaceous outcrop. The water is gathered in three distinct tributary systems and flows through deposits of Jurassic age in steeply eroded and often narrow canyons, to the confluence south of the village of Balloune. The names of the principal tributary streams are the Nahr es Salib, the Nahr es Samm, and the Nahr Hardoun. At the confluence, the Nahr el Kelb proper is formed and flows in a generally westerly direction across steeply dipping outcrops of Jurassic, Cretaceous, and Miocene age before reaching the Mediterranean Sea.

The Nahr el Kelb basin contains several planes of major faulting, extensive secondary faulting, and localities of marked structural deformations. A geological reconnaissance of the entire basin was made during this investigation, but since the proposed engineering development of the basin is restricted to the Nahr el Kelb and the Nahr es Salib, geological reconnaissance mapping was confined to these two streams. These drawings, which also contain a generalized geologic column of the formations outcropping in the region, are shown on Plates IV-1 and IV-2.

Seismology

The network of major and minor faults, which exist throughout Lebanon, is striking evidence of the great crustal distrubance and associated seismic activity that occurred during the Cretaceous, Tertiary and Recent Periods. A study of seismic records compiled by the Ksara Observatory, Ksara, Lebanon, indicates that strong earthquakes have occurred quite frequently during historic time. The most recent destructive earthquake occurred on March 16, 1956 and created widespread damage, particularly in Southern Lebanon. Some 140 people died and more than 30, 000 were left homeless. The intensity of the quake at its epicenter was measured at between 8 and 9 on the Rossi-Forel scale.

The Yammoune Fault extends along the eastern side of the Lebanon Mountains. It is one of the two major fault zones bordering the Bekaa. Uplift along this fault created the Lebanon Mountains. Movement along this major crustal break or along the many associated minor faults, may be expected at any time in the future and may affect any part of Lebanon. Therefore, the design of all structures to be built in the various river basins of Lebanon should include adequate provisions for earthquake stresses.

Ground Water

The relatively thin, sparse layer of soil with its high infiltration rate, and the many areas of outcropping strata possessing a high degree of permeability, absorb most of the annual rainfall and snowmelt. Surface runoff is small and in many areas almost nonexistent. As a rule, rainfall intensity is so low that it does not exceed the soil infiltration rate, or the rate at which the permeable strata can absorb it. Surface runoff occurs only after prolonged periods of precipitation have saturated the soil layer and have completely filled the interstices and fractures in the formations near the surface. This condition is responsible for the many dry, or intermittent, ouadis found in all of the major drainage basins in Lebanon. The thin, sparse soil layer with its limited soil moisture capacity, is also responsible for the limited vegetal cover over much of the area.

The great thickness of the strata making up the limestone terrain, as well as the high degree of folding and faulting, has permitted considerable ground water storage to accumulate under most of the area. The marl, or marly limestone layers, interspersed between the porous and fractured massive limestone or dolomite beds, have provided horizons along which ground water can be concentrated and stored. The development of the extensive system of faults when the Lebanon Mountains were formed, has provided barriers that result in further concentration of water, as well as planes of weakness along which outlet channels for the ground water concentration have developed. The high solubility of the material along these outlet channels has allowed them to be greatly enlarged by water action during geologic time and to become more effective outlets. The many large springs in Lebanon are generally the surface end of underground channels and are the spillways or outlets of the ground water concentration.

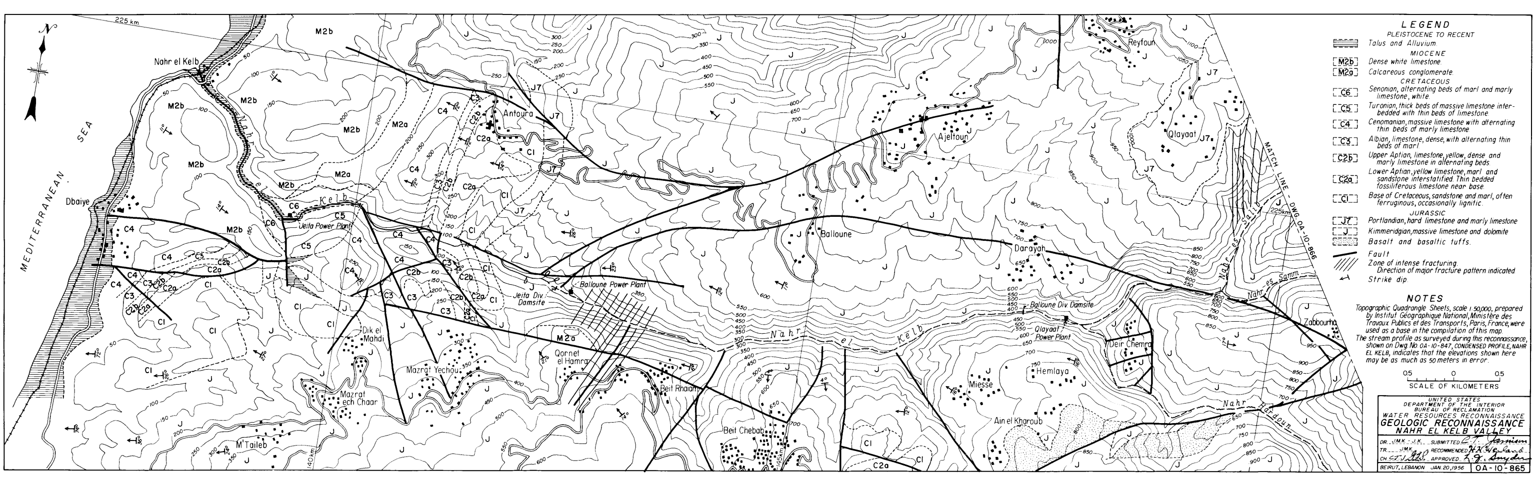
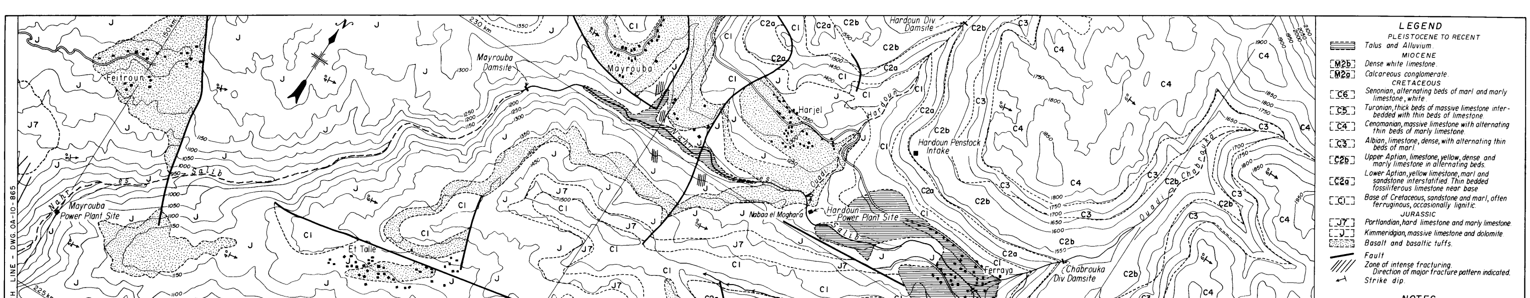

LEGEND
PLEISTOCENE TO RECENT
Talus and Alluvium.
MIOCENE
M2b Dense white limestone.
M2a Calcareous conglomerate.
CRETACEOUS
C6 Senonian, alternating beds of marl and marly limestone, white.
C5 Turonian, thick beds of massive limestone inter-bedded with thin beds of limestone.
C4 Cenomanian, massive limestone with alternating thin beds of marly limestone.
C3 Albian, limestone, dense, with alternating thin beds of marl.
C2b Upper Aptian, limestone, yellow, dense and marly limestone in alternating beds.
C2a Lower Aptian, yellow limestone, marl and sandstone interstatified. Thin bedded fossiliferous limestone near base.
C1 Base of Cretaceous, sandstone and marl, often ferruginous, occasionally lignitic.
JURASSIC
J7 Portlandian, hard limestone and marly limestone
J Kimmeridgian, massive limestone and dolomite
Basalt and basaltic tuffs.
Fault
Zone of intense fracturing. Direction of major fracture pattern indicated.
Strike dip.
NOTES
Topographic Quadrangle Sheets, scale 1:50,000, prepared by Institut Géographique National, Ministère des Travaux Publics et des Transports, Paris, France, were used as a base in the compilation of this map.
The stream profile as surveyed during this reconnaissance, shown on Dwg. No. OA-10-847, CONDENSED PROFILE, NAHR EL KELB, indicates that the elevations shown here may be as much as 50 meters in error.
0.5 0 0.5
SCALE OF KILOMETERS
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
WATER RESOURCES RECONNAISSANCE
GEOLOGIC RECONNAISSANCE
NAHR EL KELB VALLEY
DR. J.M.K. - J.K. SUBMITTED C.T. Jarrison
TR. J.M.K. RECOMMENDED H.H. Weiland
CH. C.T.J. G.T.S. APPROVED L.G. Snyder
BEIRUT, LEBANON JAN. 20, 1956
OA-10-865
MEDITERRANEAN SEA
Nahr el Kelb
Dbaiye
Antoura
Ajeltoun
Reyfoun
Qlayaat
Balloune
Darayah
Jeita Power Plant
Balloune Power Plant
Jeita Div. Damsite
Balloune Div. Damsite
Qlayaat Power Plant
Deir Chemra
Zabbourha
Dik el Mahdi
Mazraat Yechou
Qornet el Hamra
Beit Rhaoum
Mazraat ech Chaar
M'Taileb
Beit Chebab
Miesse
Hemlaya
Ain el Kharoub
Nahr el Kelb
MATCH LINE - DWG. OA-10-866

PLATE IV - 1



LEGEND
PLEISTOCENE TO RECENT
Talus and Alluvium.
MIOCENE
M2b Dense white limestone
M2a Calcareous conglomerate
CRETACEOUS
C6 Senonian, alternating beds of marl and marly limestone, white.
C5 Turonian, thick beds of massive limestone interbedded with thin beds of limestone
C4 Cenomanian, massive limestone with alternating thin beds of marly limestone.
C3 Albian, limestone, dense, with alternating thin beds of marl.
C2b Upper Aptian, limestone, yellow, dense and marly limestone in alternating beds.
C2a Lower Aptian, yellow limestone, marl and sandstone interstatified. Thin bedded fossiliferous limestone near base.
C1 Base of Cretaceous, sandstone and marl, often ferruginous, occasionally lignitic.
JURASSIC
J7 Portlandian, hard limestone and marly limestone.
J Kimmeridgian, massive limestone and dolomite.
Basalt and basaltic tuffs.
Fault
Zone of intense fracturing. Direction of major fracture pattern indicated.
Strike dip.
NOTES
Topographic Quadrangle Sheets, scale 1:50,000, prepared by Institut Géographique National, Ministère des Travaux Publics et des Transports, Paris, France, were used as a base in the compilation of this map.
The stream profile as surveyed during this reconnaissance, shown on Dwg. No. OA-10-847, CONDENSED PROFILE, NAHR EL KELB, indicates that the elevations shown here may be as much as 50 meters in error.
0.5
0
SCALE OF KILOMETERS
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
WATER RESOURCES RECONNAISSANCE
GEOLOGIC RECONNAISSANCE
NAHR EL KELB VALLEY
BEIRUT, LEBANON FEB 10, 1956
OA-10-866
MATCH LINE - DWG. OA-10-865
Feitroun
Mayrouba Power Plant Site
Mayrouba Damsite
Mayrouba
Harjel
Hardoun Div Damsite
Hardoun Penstock Intake
Nabaa el Mogharo
Hardoun Power Plant Site
Et Talle
Ferraya
Chabrouka Div Damsite
Mazraat Kfardebane
Allelia
Fertain
Et Toute
Fakra Div Damsite
Nabaa es Sakie
El Leben Div Damsite
El Aassel Div Damsite
Nabaa el Aassel

PLATE IV-2

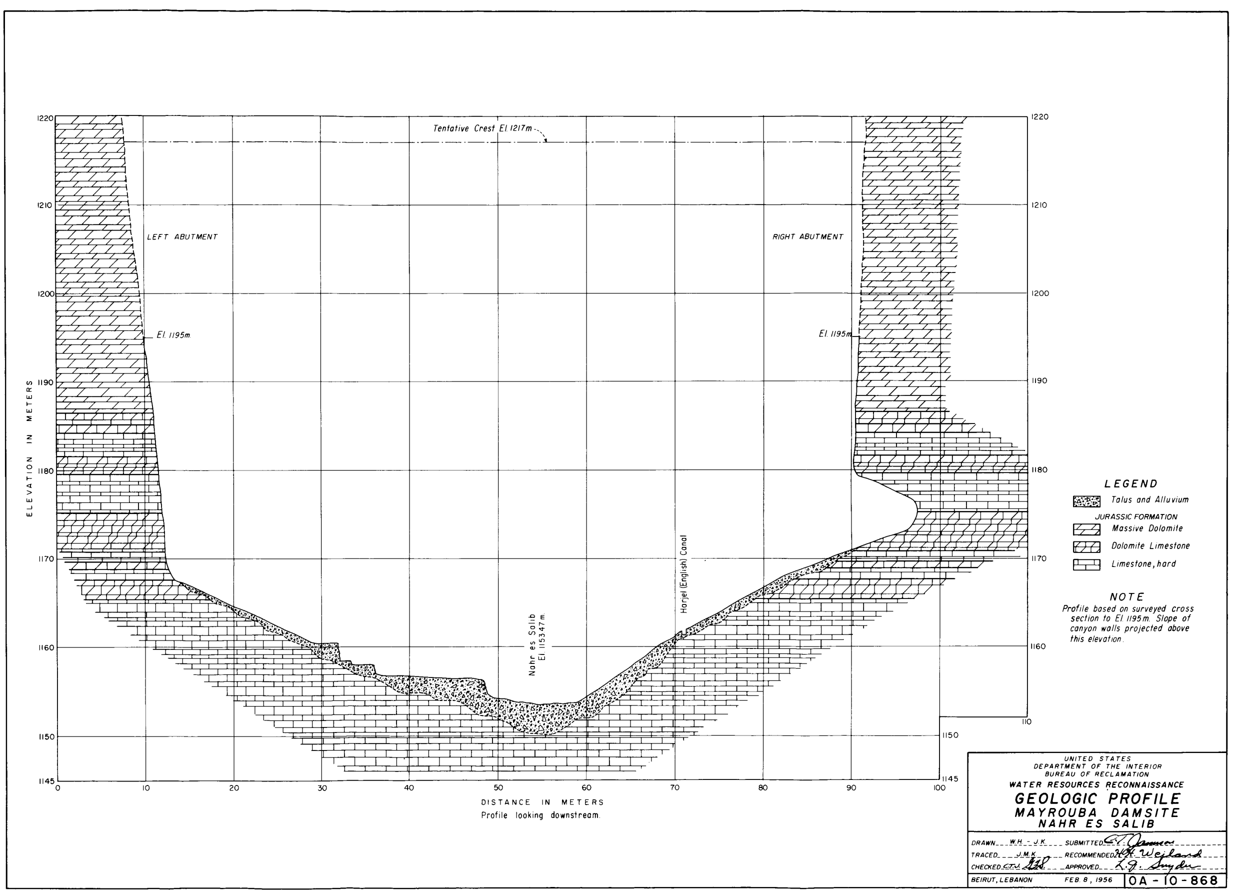

Tentative Crest El. 1217m.
LEFT ABUTMENT
RIGHT ABUTMENT
El. 1195m
El. 1195m
Nahr es Salib
El. 1153.47m.
Haryel (English) Canal
ELEVATION IN METERS
1220
1210
1200
1190
1180
1170
1160
1150
1145
110
0
10
20
30
40
50
60
70
80
90
100
DISTANCE IN METERS
Profile looking downstream.
LEGEND
Talus and Alluvium
JURASSIC FORMATION
Massive Dolomite
Dolomite Limestone
Limestone, hard
NOTE
Profile based on surveyed cross section to El. 1195m. Slope of canyon walls projected above this elevation.
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
WATER RESOURCES RECONNAISSANCE
GEOLOGIC PROFILE
MAYROUBA DAMSITE
NAHR ES SALIB
DRAWN W.H. - J.K.
SUBMITTED
TRACED J.M.K.
RECOMMENDED H.H. Weiland
CHECKED C.T.J.
APPROVED L.G. Snyder
BEIRUT, LEBANON
FEB. 8, 1956
OA - 10 - 868

PLATE IV - 3

The accumulated volume of the ground water concentration is demonstrated by the more or less uniform flow of many of these springs throughout the year and by the relatively low and even temperature of the water. Springs of this type are the main source of most of the rivers in coastal Lebanon and are responsible for the flows maintained in many rivers throughout the dry period between May and November each year.

Nahr el Kelb Basin Springs

A geological reconnaissance of a number of the more important springs in the Nahr el Kelb Basin was made as a part of this investigation to determine their suitability as a source of potable water for the adjacent villages. A discussion of these springs follows. Their locations are shown on Plate VII-1, and their potential use for village water supply is shown in Table VII-1.

Nabaa el Aassel. This spring is about 1,600 meters east of the village of Farraya and at an elevation of about 1,550 meters. Farraya has an elevation of about 1,330 meters.

A large fault trending in a northeasterly direction disturbs the Lower and Middle Cretaceous formations and probably the underlying Jurassic formation. The fault concentrates the water collected in the Middle Cretaceous formation under the high plateau and releases it into the talus of the fault scarp. The water forming Nabaa el Aassel issues from this talus.

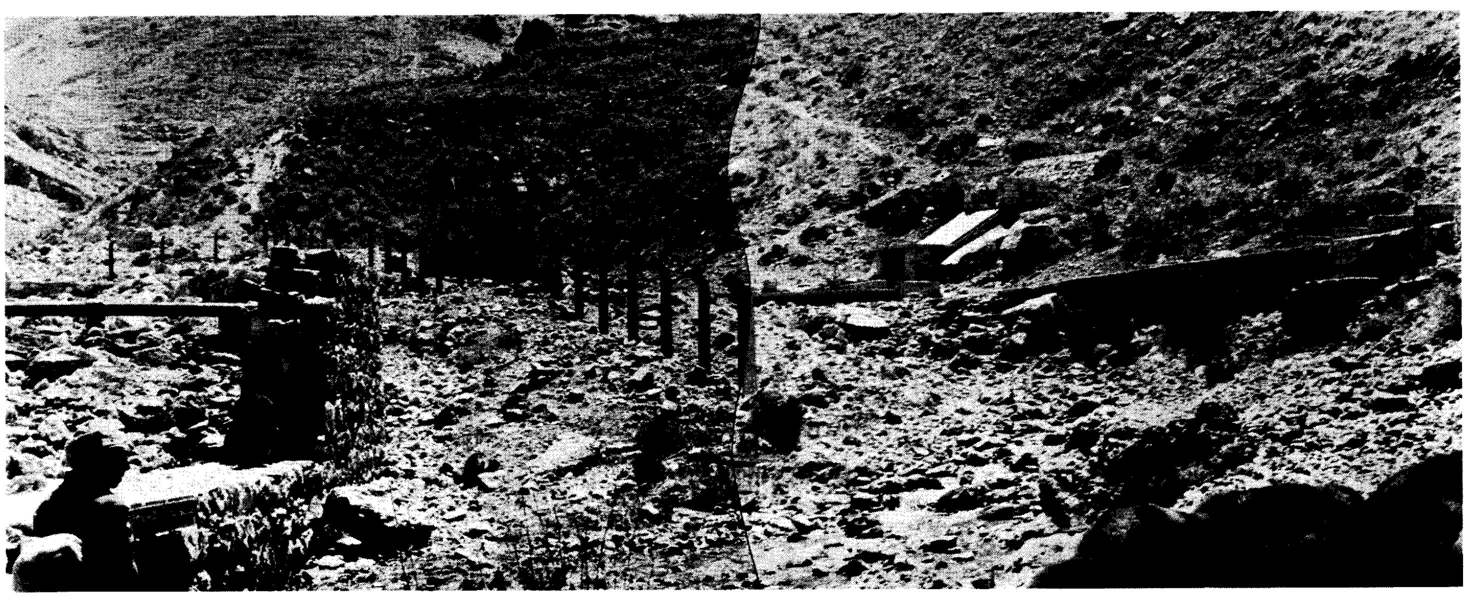
The Government of Lebanon has begun the development of part of this spring by digging a tunnel into the talus at the point of greatest discharge. Other rising points of the spring were neglected and part of the water available escapes under the talus outside of the tunnel. Over the past 17 years the following intermittent measurements of the spring flow have been recorded.

Date	Discharge (Liters per second)	Date	Discharge (Liters per second)
November 20, 1938	362	October 22, 1951	219
October 3, 1939	262	November 2, 1951	220
October 1, 1940	287	July 4, 1952	500
July 30, 1947	462	October 13, 1955	218
October 21, 1948	201	November 29, 1955	532
August 14, 1951	312		

Inasmuch as the rising point of Nabaa el Aassel is covered by talus and water issues from various places to form a zone of springs, it is suggested that the talus covering the spring zone be cleared away to expose the jointed rocks which feed the spring, and that a drain 15 to 20 meters in length be dug at right angles to the principal fracture pattern of the underlying rock to an elevation about one meter below the level of the existing tunnel. Such a modification will probably capture the water now escaping at lower levels through the talus.

Nabaa el Leben. The Lebanese government has developed and improved the spring of Nabaa el Leben which is about 5,000 meters eastnortheast of the village of Mazrat Kfardebiane. The elevation of the spring is about 1,650 meters. The elevation of the village is about 1,265 meters.

A continuation of the same fault that feeds Nabaa el Aassel is responsible for the existence of Nabaa el Leben. Snowmelt on the high plateau provides most of the water for the spring. During 1955, three discharge measurements at Nabaa el Leben were made. These are listed below:



Nabaa el Aassel
Existing improvements constructed by the Government of Lebanon.

Nabaa el Leben
Base flow at the end of the 1955 dry season.

Sanitized Copy Approved for Release 2011/06/21 : CIA-RDP80T00246A003400510001-7

Date	Discharge (Liters per second)
August 8, 1955	51
October 13, 1955	22
November 30, 1955	182

Nabaa el Kana and Nabaa el Mogharah. Nabaa el Kana is about 4,000 meters northeast of the village of Harjel at an elevation of about 1,585 meters. Nabaa el Mogharah is about 600 meters southeast of the village at an elevation of about 1,230 meters. The elevation of Harjel is about 1,330 meters.

Nabaa el Kana issues from the intersection of two crossing faults in the marly limestones of the upper part of the Aptian (2cb) member and the lower part of the fissured limestones of the Albian (C3) member of the Cretaceous formation. On December 2, 1955 the flow from the spring was measured at 57 liters per second.

The rising point of the spring is now obscured by talus and debris. It is suggested that the spring be cleared of this cover and that a drain be dug across the fault deep enough to reach the lower level of the spring. The water now wasted under the talus and in the lower crushed zone of the fault may then be collected and conveyed to a storage basin.

Nabaa el Mogharah flows from a fault zone in which hard fissured basalt is brought into contact with the limestone of Jurassic age. It is suggested that the spring be cleared of talus and loose overburden and a drain be dug across the plane of the fault about 3 or 4 meters in length in order to collect the water now lost through the overburden and cracks of the fault. On January 12, 1956 the measured discharge from Nabaa el Mogharah was 75 liters per second.

Ain el Souane and Ain el Tannour. In and about the village of Mayrouba there are several small springs that are used for drinking water and to irrigate gardens. Of these, the two largest are Ain el Souane, measured as flowing 1.5 liters per second on November 29, 1955; and Ain el Tannour, measured as flowing 3.0 liters per second on the same day. The springs are both at about elevation 1,240 meters. Mayrouba is on steeply sloping ground ranging from 1,250 to 1,295 meters in elevation.

Both springs issue from the basalt and basaltic tuffs of Upper Jurassic age. It is suggested that each of these springs be cleared of overburden and provided with a proper catchment basin or storage reservoir.

Nabaa Sannine. This spring is about 6,000 meters eastsoutheast of the village of Beskinta and is at an elevation of about 1,645 meters. It issues from an east-west fault that ranges through the valley south of Beskinta into the high plateau at the crest of the Lebanon Mountains. The formations adjacent to the spring are Lower Aptian (C2a) in contact with the arenaceous deposits at the base of the Cretaceous formation (C1).

Other springs appear in the talus of the fault below the principal point of outflow. On August 12, 1955 the main spring was measured at 26.3 liters per second; and on October 10, 1955 it had dropped to 14.5 liters per second.

It is suggested that this spring be improved by cleaning the spring zone to a depth of 2 or 3 meters to reach the water now lost under the talus, and by constructing a drain 12 to 15 meters in length transversal to the fault plane to collect the discharge and convey it to a suitable storage basin.

Nabaa el Membourkh. The spring is about 2,500 meters south of the village of Beskinta and has an elevation of about 1,630 meters. It is in a valley traversed by a fault that disturbs the limestones and marly limestones of the Cenomanian (C4), Middle Cretaceous formation.

The Government of Lebanon has begun the development of this spring by digging a tunnel parallel to the fault.

Anna Bakich Group. This group of small springs is about 3,000 meters north of the village of Beskinta and is at an elevation of about 1,810 meters. These springs issue from the talus of the Lower and Middle Cretaceous formation, Aptian (C2b), Albian (C3), and Cenomanian (C4). Remnants of an ancient irrigation canal are still visible in the vicinity of the springs. On January 9, 1956 the largest spring of Anna Bakich Group was flowing 7.5 liters per second, and nearby Nabaa Delbi was flowing 2.8 liters per second.

It is suggested that the area around each spring be cleared of talus and that a drain at right angles to the springflow be constructed to collect the water now lost under the talus and to convey it to a central storage basin.

Nabaa Jafer. This spring is about 4,000 meters northnortheast of Beskinta and north of the Anna Bakich Group of springs. The elevation of Nabaa Jafer is about 1,770 meters. On January 9, 1956 the flow from the spring was measured at 7.5 liters per second.

The spring is covered by talus and debris. It is suggested that the spring zone be cleared and a suitable catchment basin be constructed to collect the water now lost under the talus.

Nabaa el Jozat. This spring is in the valley of the Nahr Jafer about 2,000 meters east of the village of El Toute. Its elevation is about 1,450 meters.

The spring issues from a fault that disturbs beds of the Jurassic formation, and the Lower and Middle Cretaceous formations, before continuing into the high Cretaceous plateau above Sannine. There are several springs along this fault plane. On January 13, 1956 Nabaa el Jozat was measured as discharging 141 liters per second.

The Government of Lebanon is currently developing the spring to supply drinking water to the villages of Kfar Aqab, Ain el Karm, Kfartaiy, and others.

Nabaa es Sakie. This spring is about 2,500 meters east of the village of Kalaa and at an elevation of about 1,700 meters. It issues from a jointed rock zone that was caused by a fault passing about 150 meters northwest of the spring and its rising point is presently covered by talus. It is suggested that this talus be cleared away and a suitable drain be constructed to utilize all of the water coming from the spring.

On December 6, 1955 the measured discharge from the spring was 27.0 liters per second.

Nabaa el Rhabate. This spring is about 500 meters east of Nabaa el Aassel and at an elevation of about 1,620 meters. On January 12, 1956 it was discharging 11.0 liters per second.

The water rises from talus, and much of it is now wasted. It is suggested that a drain be constructed to save and collect the water now escaping.

Jeita Spring. This spring is near the bottom of the valley of the Nahr el Kelb at about elevation 60 meters. It is currently used as the principal source of water for the city of Beirut. The geology of the spring will be discussed more fully under the Jeita Unit in the following paragraphs. Three measurements of the spring discharge are available.

Date	Discharge (Liters per second)
December 8, 1952	1,786
November 5, 1953	1,674
October 18, 1955	1,117

Proposed Nahr el Kelb Development

Hardoun Unit. This unit would collect the surface water derived from rain and snowmelt, and the water issuing from the springs along the edge of the high Cretaceous plateau at the crest of the Lebanon Mountains, and convey it to the proposed Hardoun Penstock and Power Plant to be built on the upper reaches of the Nahr es Salib. All of the proposed engineering features in this unit would be relatively small. Each feature would be constructed on the hard limestones, marly limestones, and sandstones near the base of the Cretaceous formation or the dolomitic limestones at the top of the Jurassic formation, except for a section of the canal or conduit in the vicinity of Nabaa el Aassel where talus and debris would present problems in earth sliding.

Fakra Diversion Dam and Canal Sites. The initial structure in this unit would be a small concrete dam across the Nahr es Samm at about elevation 1, 632 meters. This elevation would place the site above the major east-west trending fault in this vicinity and provide a foundation of hard fossiliferous limestone of Upper Aptian (C2b) age, which should be adequate for the small diversion dam proposed. The conduit, which may be constructed as an open canal, would convey the water about 960 meters to the gorge of the Nahr el Leben. The conduit would traverse beds of the Upper Aptian formation consisting of hard limestone, marly limestone, and some sandstone.

Nahr el Leben Diversion Dam Site. The site of this low diversion structure is in a narrow, steep gorge of massive limestone which contains many large boulders and blocks of limestone that have fallen from the canyon walls. At elevation 1, 537, the right abutment of the tentative axis would be formed by one of these massive blocks. The left abutment would be a sheer wall of massive limestone.

The diversion structure planned for this site would be low and it would impound little or no water. The weight and volume of the massive slide block is estimated to be sufficient to form a satisfactory abutment for a simple structure of this design. The streambed in the vicinity of the site is essentially free of fine grained alluvium, although some clearing of the larger boulders will be necessary.

El Leben Conduit Site. This conduit would carry water from the Nahr el Leben Diversion Dam a distance of about 2, 160 meters to a point just below Nabaa el Aassel, and would have the most doubtful foundation of any of the engineering features in the Hardoun Unit.

A small fault ranges along the right side of the Nahr el Leben which the conduit must cross. Nearly midway in its length, the conduit would enter an area of marly talus that shows evidence of previous sliding. Some of the marly talus may be avoided by constructing a short tunnel through a knoll near the edge of the talus deposits. In all cases the thickness of the talus overburden should be investigated to determine the depth to bedrock so that the final alinement may be shifted, where possible, to obtain a firm footing.

El Aassel Diversion Dam Site. Outcrops of hard limestone of the Upper Aptian (C2b) formation appear in the bed of the Nahr el Hassen a short distance downstream from the present outlet of Nabaa el Aassel. These beds provide the best foundation for a low diversion structure in this vicinity. Both sides of the valley above these outcrops are covered by an earthlike marly talus that is subject to sliding and slumping, particularly when wet.

El Aassel Conduit Site. This conduit will carry water from the El Aassel Diversion Dam at about elevation 1, 526 meters to the stream crossing below Nabaa Chabrouka at about elevation 1, 519 meters. It would be about 2, 200 meters in length and would be built on deposits of Upper Aptian (C2b) age. The most conspicuous member of this formation is a massive bed of limestone that forms an escarpment along this side of the valley.

The strike dips along the alinement of the conduit are to the east. This condition would permit the first 600 to 800 meters of the conduit to be built over the upper surface of the massive limestone bed; but at some point the conduit would have to be brought down across the face of the cliff formed by the outcrop and then carried along its base to the stream crossing at elevation 1, 519 meters. Except for special support structures along the face of the cliff, the construction of this conduit would encounter no important foundation problems.

Chabrouka Diversion Dam Site. The site of this low diversion structure would be in beds of hard limestone near the top of the Upper Aptian (C2b) formation. These beds would form an adequate foundation for the structure proposed.

Charbrouka Conduit Site. This conduit would carry the water collected from the Charbrouka Crossing to the intake of the proposed Hardoun Penstock at about elevation 1, 513 meters. It would be approximately 2, 400 meters in length and would run along the base of a cliff formed by massive limestone. There is some talus along the base of the cliff; but this talus cover is believed to be shallow and the foundation along most of the proposed alinement would be limestone beds in the upper part of the Lower Aptian (C2a) formation.

Hardoun Conduit Site. A low diversion structure would be constructed across the steep, narrow gorge below Nabaa el Kana at about elevation 1, 523 meters. Here, massive beds of limestone of the Upper Aptian (C2b) formation outcrop in the streambed. The elevation of the proposed structure may be varied within limits to take advantage of one of these beds as a foundation.

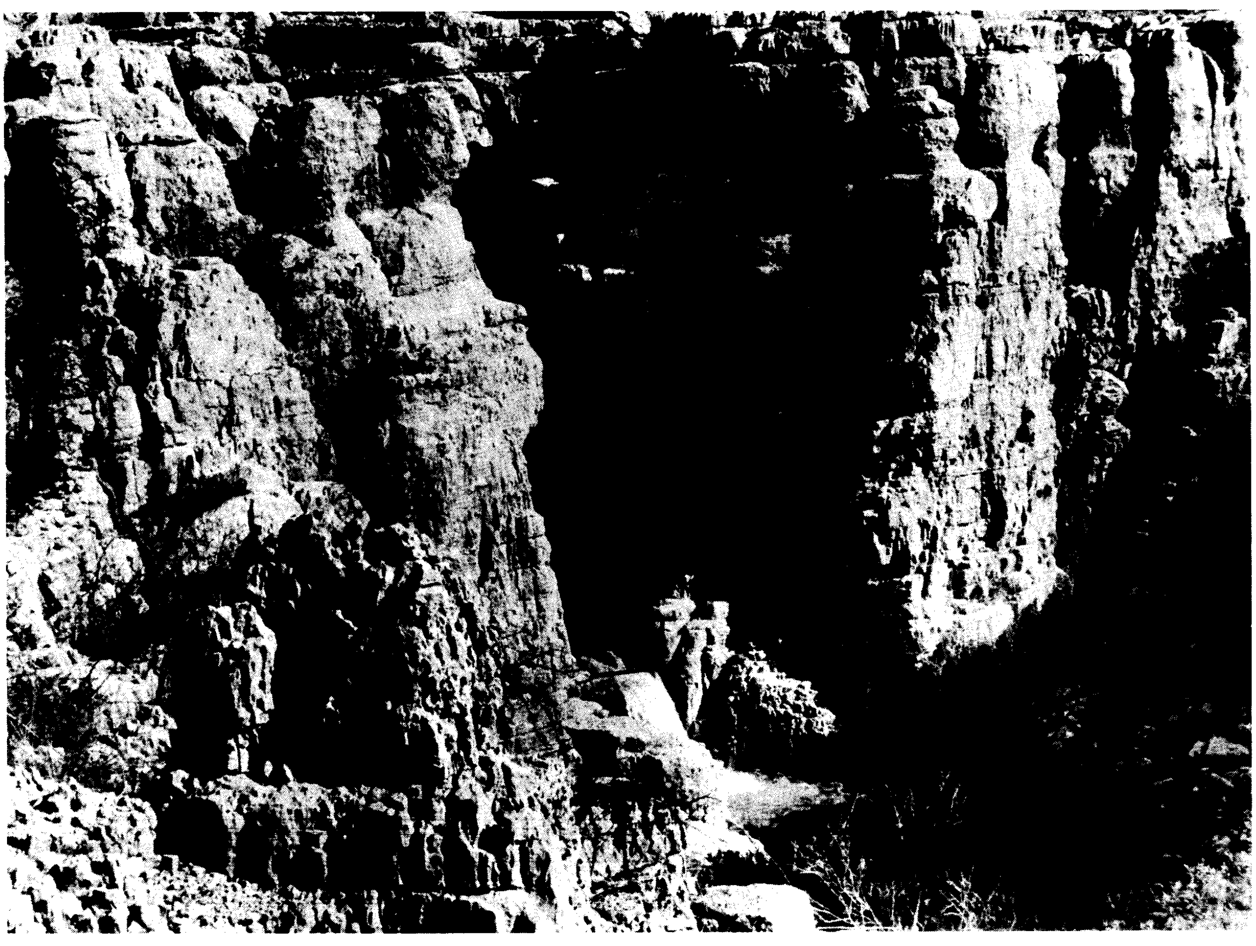
The Hardoun Conduit would be about 1, 900 meters long, and the alinement would follow the base of a cliff to the penstock intake. Here again, some marly talus would be encountered, but the foundation would be the firm limestone beds of the Upper Aptian (C2b) formation.

Hardoun Penstock and Power Plant Sites. At elevation 1, 513 meters the Hardoun Penstock Gate Structure and a small collecting basin would be founded on hard limestone of the Upper Aptian (C2b) formation. The penstock would be built over and through the limestones, marly limestones, and sandstones of the Lower Aptian (C2a) formation, the iron oxide-stained sandstones at the base of the Cretaceous formation, and the hard limestones and dolomites in the upper part of the Jurassic formation. None of these beds exhibit evidences of structural defect. The cuts or short tunnels, that would be required because of grade changes along the penstock, would probably be confined largely to the limestones and dolomites of the Jurassic formation. These deposits should present no unusual construction problems. The power plant also would be founded in these rigid deposits of Jurassic age, and they would form a suitable platform for the structure. Along the alinement of the penstock, particularly in the area of Jurassic outcrop and at the site of the proposed power plant, there are large blocks of limestone talus, some of which would require removal by blasting.

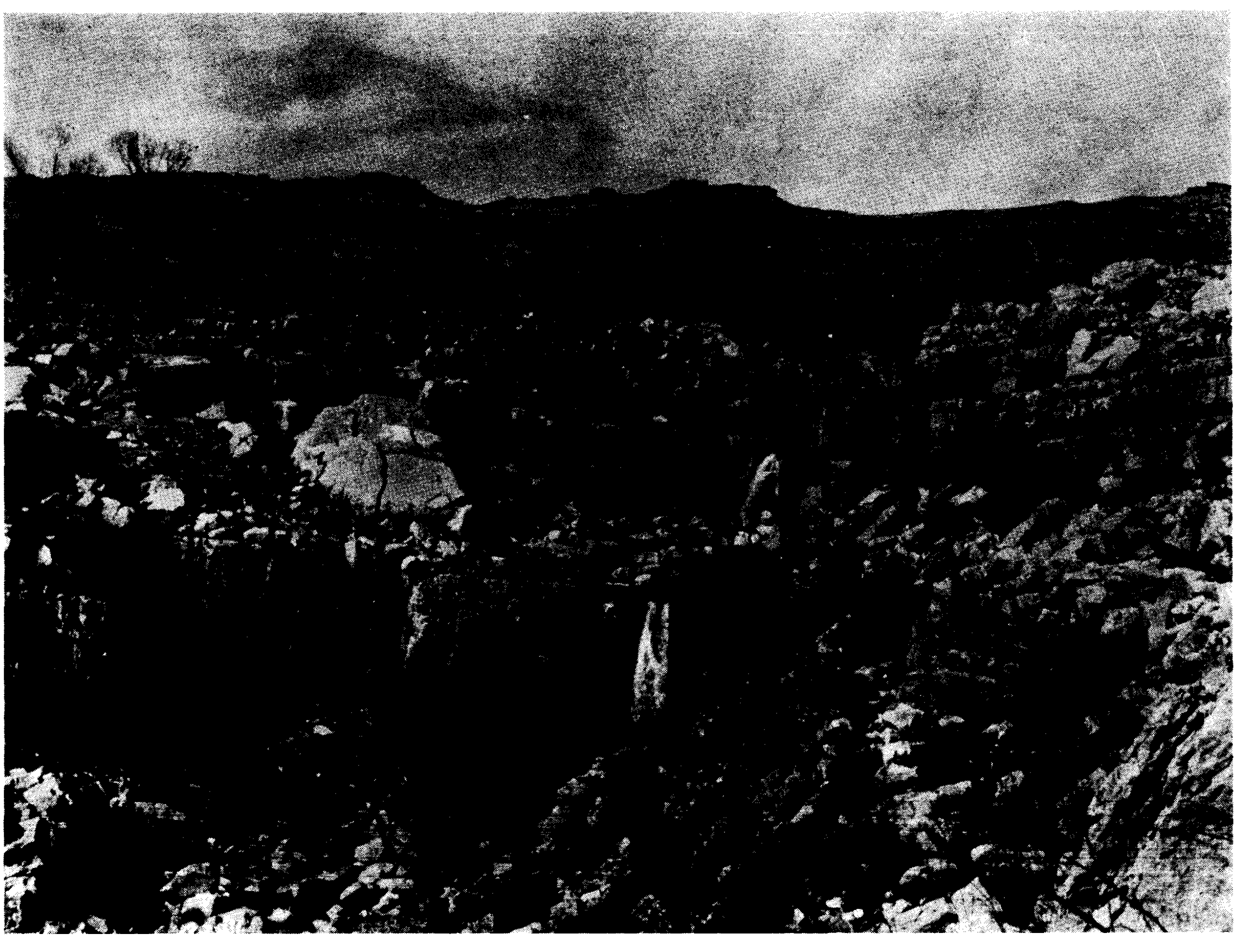
Mayrouba Unit

Mayrouba Dam and Reservoir Sites. The site of the proposed Mayrouba Dam is in a U-shaped gorge eroded in massive, dense limestone and dolomite of Jurassic age. The alluvium in the canyon floor, composed of limestone gravel and boulders of small diameter, appears to be relatively shallow, probably not more than 2 meters in thickness. The dip of the strata that would form the foundation and abutments of the proposed dam is nearly horizontal. At the right abutment the river has undercut the wall of the gorge creating a shallow overhang. A reconnaissance Geologic Profile, constructed on a surveyed cross section of the site, is shown on Plate IV-3. As a whole, this site appears to be suitable for the concrete arch structure proposed.

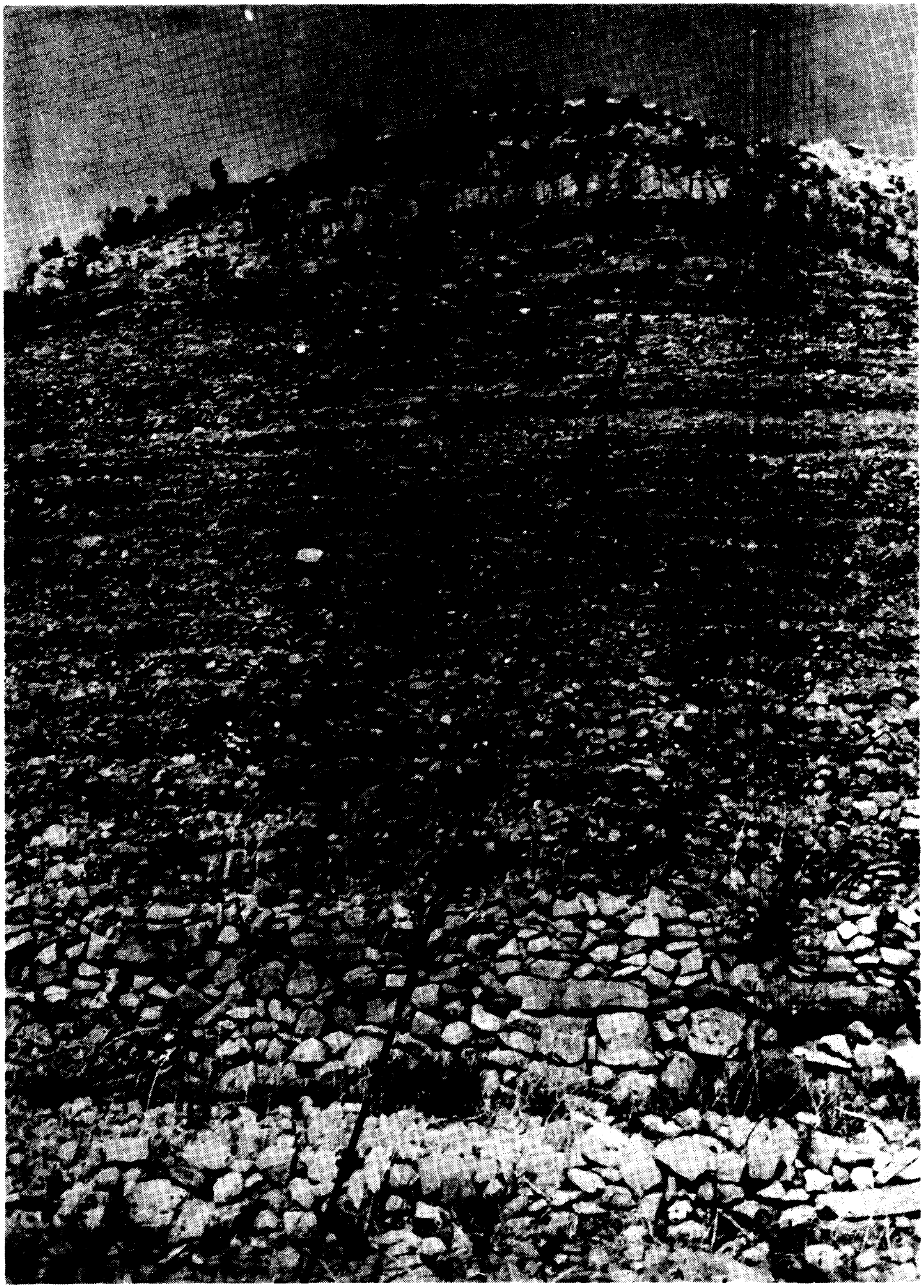
A short distance upstream from the proposed dam site, the gorge of the Nahr es Salib widens to form a topographic basin with a capacity of more than twenty million cubic meters. In general, this basin has been eroded in massive beds of Jurassic limestone and dolomite exhibiting a definite secondary fracture pattern. These fractures, or fissures, would result in appreciable losses through seepage of any water that might be impounded in the basin.



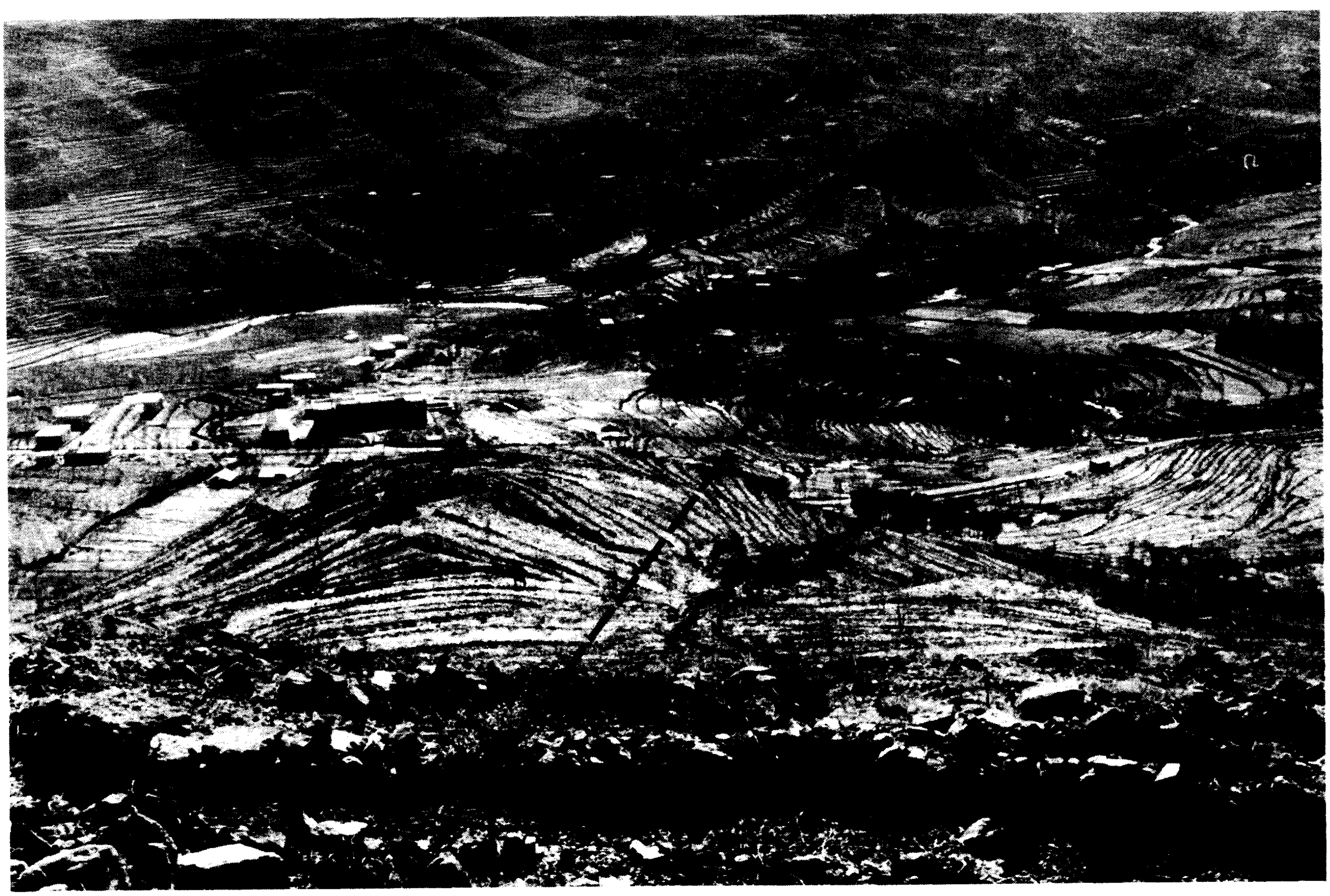
Chabrouka Diversion Dam Site
Hard limestone forms the foundation for the dam in the gorge of the Ouadi Chabrouka.



Hardoun Diversion Dam Site
Talus obscures the foundation for this structure located at the edge of the pool below the lower falls.



Hardoun Penstock
Upper section of Penstock alinement Gate Structure
would be at the base of the escarpment.



Hardoun Penstock
Lower section of penstock alinement. The upper end of the Mayrouba reservoir would occupy the valley in the distance.

Sanitized Copy Approved for Release 2011/06/21 : CIA-RDP80T00246A003400510001-7

About 1,250 meters upstream from the proposed dam site, the wedge of a V-shaped fault extends into the reservoir area; and about 700 meters above this point, a second fault bisects the basin. The crushed zone in each of these fault planes ranges from 1 to 2 meters in width. The limestone and dolomite beds between the two fault zones, and for a distance of about 800 meters upstream from the second fault, have localized areas of intense fracturing. These areas display prominent joint systems with the major fracture planes striking northwest. From the dam site to the V-shaped fault the Jurassic strata are nearly horizontal, but in the vicinity of the faulting these beds begin to dip to the east at angles ranging from 7° to 12°. A bed of coarse-grained, altered basalt extends along the north side of the basin from the village of Mayrouba to Ouadi Hardoun, and continues down the south side of the basin to the vicinity of the village of Et Talle. This bed also may be expected to absorb large quantities of water upon saturation.

The topographic forms in the Nahr es Salib Basin, notably the Natural Bridge below Nabaa el Leben and at other places in the Nahr el Kelb Basin, promote the inference of a cavernous condition of unknown size and extent below the valley floor, and point to the general solubility of the limestone strata.

These are the adverse factors effecting the proposal to store water in the Mayrouba Reservoir Site. They emphasize the need for extensive investigation of the proposed reservoir before its feasibility can be finally established. The investigation of this reservoir should be completed before constructing any of the power features proposed downstream from the Mayrouba Dam Site. At a minimum, this investigation should include a detailed geologic map of the reservoir area, core drilling in the valley floor to detect the existence of subterranean caverns, and water pressure testing in the localities of intense fracturing. The water pressure testing is required both to determine the seepage losses that may be expected and as a guide for future grouting.

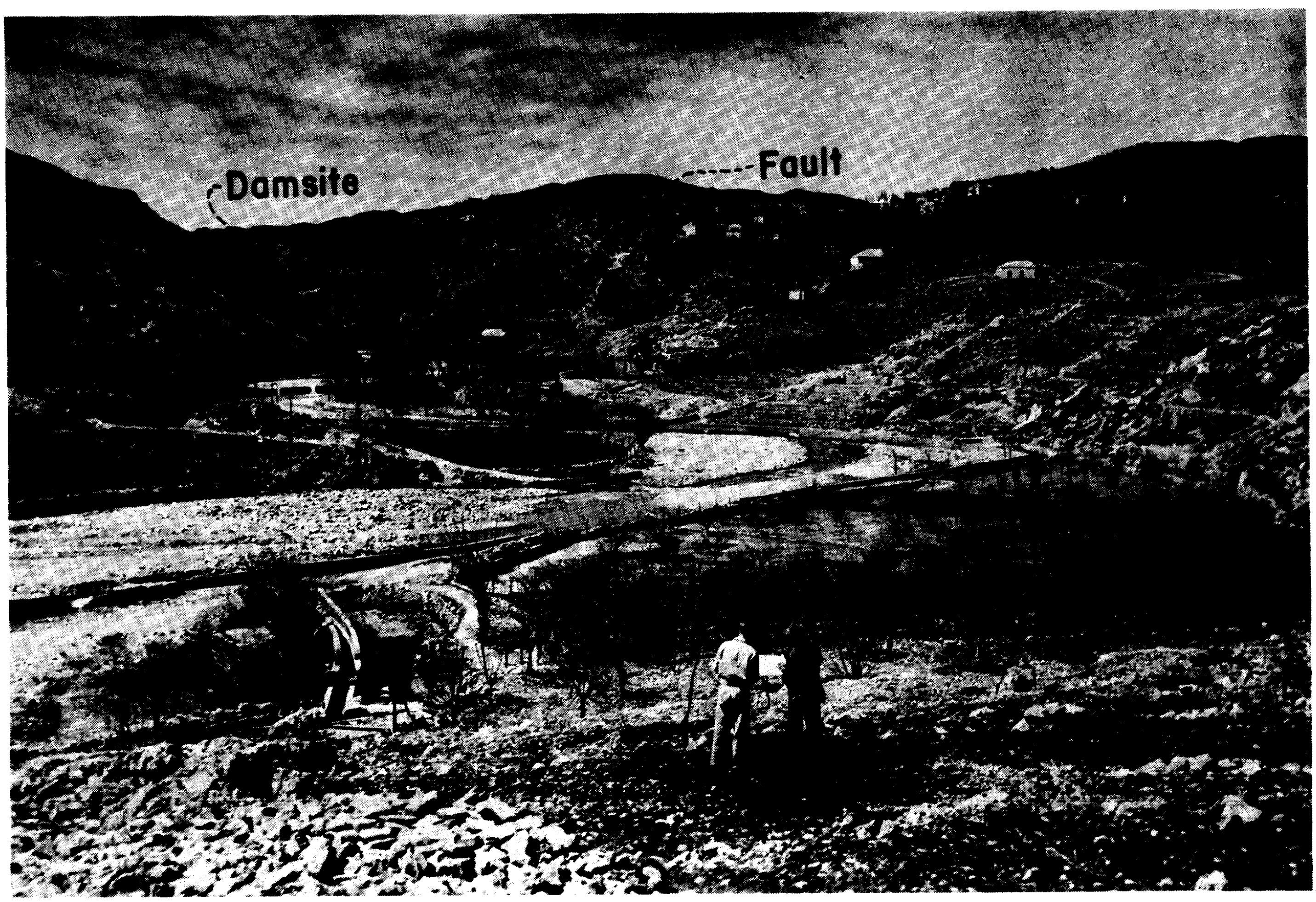
The value of water storage at this elevation is so great, both for power generation in the Nahr el Kelb basin and for future water supply to the growing city of Beirut, that the basic problem becomes not "will this reservoir hold water?" but rather, "can this reservoir be made to hold water?" This report fully recognizes that the proposed Mayrouba Reservoir would normally sustain large seepage losses. The proposed plan of power generation and operation has been controlled and modified by this assumption. It anticipates a full reservoir at the end of the winter rainy season and a nearly empty reservoir at the end of the summer dry season. The calculated depletions include normal water releases, losses through evaporation, and large seepage losses.

If the detailed geological and drilling investigation recommended above indicates that the seepage losses through the intensely fractured localities would be within tolerable limits, or that there are no sinkholes or extensive caverns below the alluvium, this proposed plan of operation would permit annual inspection of the upper, or most critical part, of the reservoir area to locate and administer corrective treatment to newly developed localities of seepage.

The drainage area above the proposed reservoir contains much marly talus. The water impounded during each rainy season would probably carry a large sediment load originating from these deposits. As the reservoir refills each year, most of this sediment load would be dropped at the upper end of the reservoir in the most critical seepage area. These sediments might plug the fracture planes and develop a natural corrective filter that would materially reduce the anticipated seepage losses.

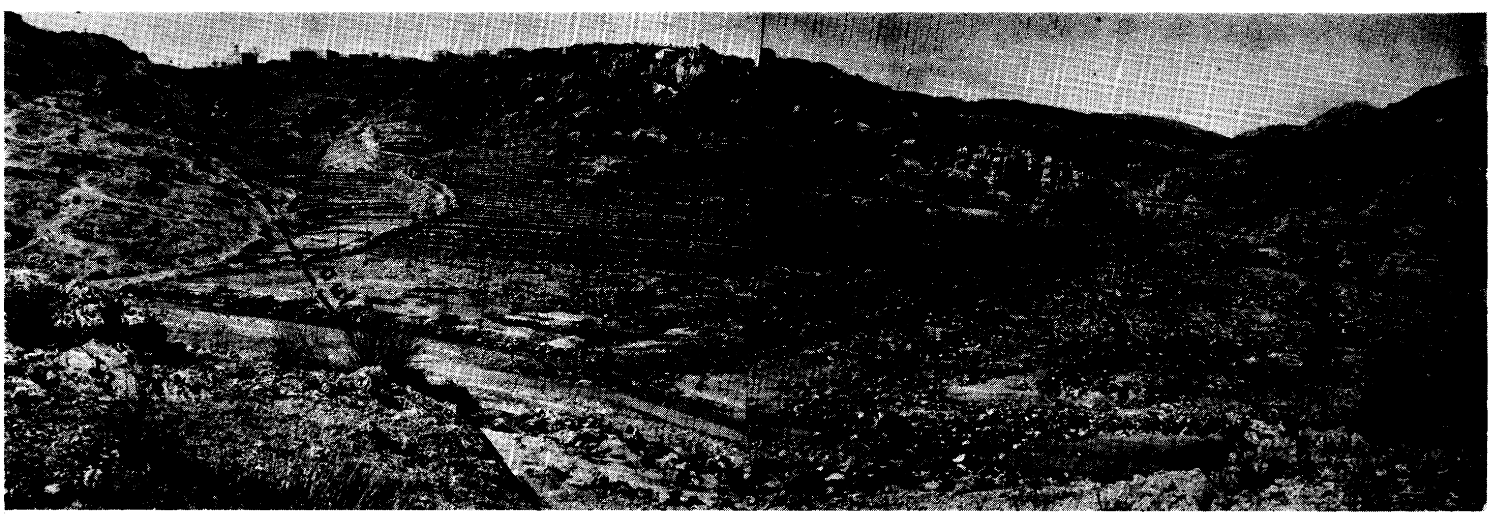
The floor of the river valley now contains a layer of fine-to-coarse-grained alluvium that may be 2 to 3 meters in thickness. An estimated thirty percent of this alluvial material is silt size or smaller. In potentially pervious reservoirs this natural cover should not be disturbed except to administer corrective measures in known localities of seepage, or along the fault planes where seepage may be anticipated with confidence.

Basalts, limestones, the crushed zones in fault planes, and ordinary jointed rock often carry water underground for such long distances that the existing flow may



Proposed Mayrouba reservoir site view from upper end of reservoir looking downstream. Note Alluvium in valley floor.

Proposed Mayrouba reservoir site. Looking upstream into Mayrouba reservoir from about 1250 meters above Damsite.



Proposed Mayrouba reservoir site. Intersecting faults in Mayrouba reservoir about 1250 meters upstream from damsite. J = Jurassic, b = basalt or basaltic tuffs, C1 = base of Cretaceous.

Sanitized Copy Approved for Release 2011/06/21 : CIA-RDP80T00246A003400510001-7

never be found or recognized. The critical condition to be determined is whether erosion and enlargement of the seepage channels is occurring, and at what rate. Inflow-outflow storage records should be kept so that a study may be made to determine the elevation at which water losses start, and surveys of the reservoir floor should be made at all times of low water to locate possible sinkholes. The inflow-outflow storage studies and the detailed reservoir geological map will help to determine the possible locations of water loss so that timely corrective measures can be undertaken. This process should be repeated through several cycles of reservoir operation, or until all localities of leakage are found.

Standard methods of treating pervious reservoirs include earth blanketing, grouting, and lining or paving the localities of greatest seepage with concrete, soil cements, or other materials. In the Mayrouba Reservoir the use of an earth blanket appears impracticable because of the scarcity of suitable material in the vicinity. Concrete lining would be expensive, and the cost of even blanket grouting might be excessive depending upon the extent of the localities to be treated.

From the standpoint of providing a future water supply for the city of Beirut, the time may come when almost any expense to render this reservoir impervious is justifiable. But before extensive corrective treatment is undertaken, the costs should be compared with the expense of providing water, either by pipeline or by conduit, from some alternate source - perhaps the Nahr Ibrahim or the Nahr Bisri.

Mayrouba Tunnel Site. This combination of tunnels, conduits, and canals would carry water along the left side of the Nahr es Salib Valley a distance of about 5,100 meters from the Mayrouba Reservoir to the intake of the Mayrouba Penstock. It would be constructed through deposits of limestone and dolomitic limestone of Jurassic age for most of its length. The strike dips of these strata range from nearly horizontal to 4° to 6° east and are essentially free of structural deficiencies, except for relatively minor secondary fracturing and fissuring. Final alinement may reduce the overall length of tunneling to 1,800 to 1,900 meters, with the remainder of the conveyance constructed as open canals or conduits. The lower 1,000 meters of the conduit will cross an area of altered and weathered basalt. Although this material is less rigid than the calcareous deposits, it will provide an adequate foundation.

Mayrouba Penstock and Power Plant Site. At the proposed site of this power plant, the canyon of the Nahr es Salib is V-shaped and has been cut into Jurassic limestone and dolomite. On the lower sections of the penstock slope, there are accumulations of talus from 2 to 5 meters in depth. The power plant site would require stripping to reach the firm limestone bedrock, which is free of faulting and would provide an excellent foundation. The penstock slope to the bottom of the canyon would be steep and rocky but with very little overburden, except for the talus accumulation at the foot of the slope.

Qlayaat Unit

Qlayaat Diversion Dam Site. The site of this diversion dam would be a short distance downstream from the Mayrouba Power Plant at about elevation 795 meters. The foundation for this structure would be similar to that for the Power Plant. Some stripping of the talus at the abutments would be required, but this would not be excessive since outcrops of bedrock are visible along the sides of the stream. The alluvium in the streambed is probably shallow, because the stream gradient is steep and rushing water has kept the bedrock relatively clean except for numerous waterworn boulders of varying size.

Qlayaat Tunnel Site. This tunnel would range along the right side of the river valley and would deliver water to the Qlayaat Penstock. It would be approximately 2,300 meters in length and would be constructed through Jurassic limestone and dolomite. A fault of low displacement containing a zone of jointed rock about 5 meters wide crosses the tunnel alinement. Aside from this minor structural break, the construction of the tunnel should encounter no unusual problems.

Qlayaat Penstock and Power Plant Sites. The U-shaped canyon of the Nahr el Kelb below the confluence of the Nahr es Salib and the Nahr Hardoun, has been eroded into beds of massive Jurassic limestone and dolomite. The strike dips of these strata range from 14° to 16° west, or downstream; but they are otherwise free of structural defect, except for minor fracturing and fissuring. The floor of the canyon contains many waterworn limestone boulders 2 meters or more in diameter, in addition to a thin layer of fine-grained alluvium.

It would be necessary to excavate a recess in the sheer canyon wall for part of the power plant foundation. Preparing the foundation will also involve clearing the larger boulders from the canyon floor.

The penstock gate structure and other appurtenant structures at the outlet of the Qlayaat tunnel would be in the disturbed zone of the Balloune-Durayak Fault that extends to the vicinity of the Jeita Spring. This is not a sharply defined fault plane with a distinctive crushed zone, but a series of step-faults of low displacement about 300 meters wide. The upper part of the penstock would cross this disturbed zone and continue through undisturbed massive limestone and dolomite for the rest of its length. It might be desirable to construct the lower 90 to 100 meters of the penstock as a tunnel because of the sheer canyon walls near the streambed.

Balloune Unit

Balloune Diversion Dam Site. The canyon of the Nahr el Kelb about 1,000 meters below the confluence of the Nahr es Salib and the Nahr Hardoun, is also U-shaped. The valley floor is strewn with large waterworn boulders and blocks of massive limestone that have fallen from the canyon walls. The layer of fine-grained alluvium in the streambed is probably not more than a meter deep, but there is evidence that the river carries considerable sediment during flood stage.

The walls of the canyon are about 50 meters apart. The axis of the proposed dam may be shifted upstreamor downstream to reduce the amount of blasting and stripping that would be required to clear the foundation. Aside from the necessity of superficial cleaning, the foundation at the Balloune Diversion Dam Site is sound and free of structural defects.

Balloune Tunnel and Conduits Sites. The distance between the Balloune Diversion Dam Site and the intake of the proposed Balloune Penstock at elevation 338, is approximately 5,000 meters. The topography along the right side of the Nahr el Kelb will permit this conduit to be built in about equal lengths of tunnel and circular concrete pipe. The material over and through which this conveyance would be built is Jurassic dolomitic limestone and limestone, occasionally covered by thin deposits of limestone talus. The strike dips of these strata range from 11° to 23° west, with the steepest dips near the penstock intake.

Balloune Penstock and Power Plant Sites. The penstock location has been carefully selected to follow a fairly uniform slope just south of a fault ranging along the north side of the river valley, and east of a zone of intense secondary fracturing. The upper part of the penstock slope would be gradual and free of obstructions, but the lower 150 to 200 meters would cross outcrops of massive Jurassic dolomitic limestone that will require some excavating.

The power plant would be founded on massive Jurassic dolomitic limestone which lies under a thin cover of alluvium and talus.

Jeita Unit. One of the natural wonders of Lebanon is the "Grotte de Jeita," which consists of a spring of sparkling blue water issuing from a system of caverns and galleries into the Nahr el Kelb at about elevation 60 meters. The caverns have been explored by a group of speleogists who are said to have penetrated a distance of from 5 to 6 kilometers and to have remained in the system of galleries over a period of 4 or 5 days.

Jeita Spring and Inlet of Canal leading to
the Hrach Power Plant.

Sanitized Copy Approved for Release 2011/06/21 : CIA-RDP80T00246A003400510001-7

A member of the group making the current reconnaissance investigation entered the cavern by boat early one morning and returned late in the afternoon of the same day. He believes that he followed the interconnecting caverns a distance of about 4 kilometers. Approximately one kilometer from the entrance he encountered the largest known of several small subterranean lakes. He estimated this lake to be 150 meters wide and 300 meters long. He also observed several sinkholes, or funnels, particularly in the first kilometer beyond the entrance, where water from the stream disappeared.

About one hundred meters upstream from the main cavern, a second spring issues from under a large rock in the riverbed. At times when the Nahr el Kelb is muddy, the clear water boiling up from this spring creates a striking effect. All existing evidence indicates that this spring is directly connected with the Jeita Cavern System, and may be the outlet for the water lost in one or more of the sinkholes mentioned above.

Approximately 150 meters downstream from the main cavern, a third spring issues from a small cavern eroded in the steeply inclined dolomite and dolomites limestone beds of upper Jurassic age. This spring may be a part of the Jeita cavern system, but it is more probably a separate spring fed by a large fault along the south side of the river valley. The water accumulated along this fault plane has probably found release along the contact of individual limestone beds, and with time, dissolved out a suitable passage. This spring often flows muddy water within a few hours following a heavy rain, indicating that the cavern system is relatively new or that the source of spring recharge is relatively nearby, or both.

The Jeita Caverns are related to three fault planes. One ranges along the river valley, another extends from just below the cavern to the village of Ajeltoun, and the third extends from just above the spring through Balloune and Darayah to Labougha. It is possible that the underground cavern system has developed a connection with the large fault near the village of Mayrouba, and that the water flowing from the spring has traveled a considerable distance through an extensive gallery system before reaching the surface.

The Jeita Cavern System should be carefully investigated with the object of improving the spring flow. It is possible that the sinkholes, or funnels, might be plugged, thus saving the water now probably lost to the sea. Also, the channels between the subterranean lakes might be widened and deepened, to establish a more uniform flow.

Jeita Diversion Dam Site. This site is a short distance downstream from the Balloune Power Plant at about elevation 60 meters. It is above the Balloune-Darayah Fault in massive Jurassic dolomitic limestone dipping downstream at angles of 23^{o} to 26^{o}. The stream channel contains many large waterworn boulders and a thin veneer of fine-grained alluvium. The foundation will require cleaning of this alluvial debris, but is otherwise structurally suitable for the type of structure proposed.

Hrach Flume and Jeita Conduit Sites. The clear water from the Balloune Power Plant would be diverted by the Jeita Diversion Dam and joined with the discharge from Jeita Spring. It would then be conveyed by the existing Hrach Flume a distance of about 350 meters to a new concrete flume or conduit along the right side of the river valley. This new conduit would carry the water about 1, 400 meters to the intake of the Jeita Penstock Structure, above the existing Beirut Water Supply Intake Structure.

The slopes through this reach of the valley are steep, but they are adequate to permit the construction of a concrete flume or conduit. The conveyance would cross the bevelled edges of a complete section of the local expression of the Cretaceous formation. These strata dip sharply downstream at angles ranging from 24^{o} to 72^{o} west. The right side of the river valley is essentially free of faulting.

Jeita Penstock and Power Plant Sites. The penstock would be constructed along an abrupt but relatively uniform slope in the alternating beds of limestone and marly limestone of upper Cretaceous Cenomian (C6) age. These deposits are structurally sound.

The power plant would be founded on deposits of similar age and character. They should provide a satisfactory foundation for the structure proposed.

SECTION V

IRRIGATION DEVELOPMENT

Irrigation has probably been practiced in the Nahr el Kelb Basin since ancient times. In the mountainous headwater areas, canals have been constructed to carry water from a number of major springs and to supply water for villages several kilometers distant from such springs. Part of this water has been used along the routes of these canals for irrigation of terraced lands and the balance for domestic consumption. In some instances canals have been constructed from such springs exclusively for irrigation. However, the size of the canals, the water conveyed by them, and the individual tracts of land irrigated are relatively small. The operation of these mountain systems is of prime importance to the village lands which they serve, and of considerable importance to the Nahr el Kelb Basin as a whole.

Unfortunately, there are no sizable additional areas of arable land within or adjacent to the Nahr el Kelb Basin which could feasibly be irrigated. Although there is a surplus of water, future irrigation development in the basin must be confined to minor expansions of existing systems in the mountains. For this reason, no land classification or other detailed irrigation studies have been made for the basin.

Existing Irrigation Development - Coastal Area

The steep slopes of the Lebanon Range extend to the sea in the vicinity of the Nahr el Kelb, and the river is confined to a narrow canyon for most of the lower reaches. Nearby, a small area of coastal plain lies between the mountains and the sea; the practical limit of this area which can be irrigated is about 80 hectares; it is completely developed.

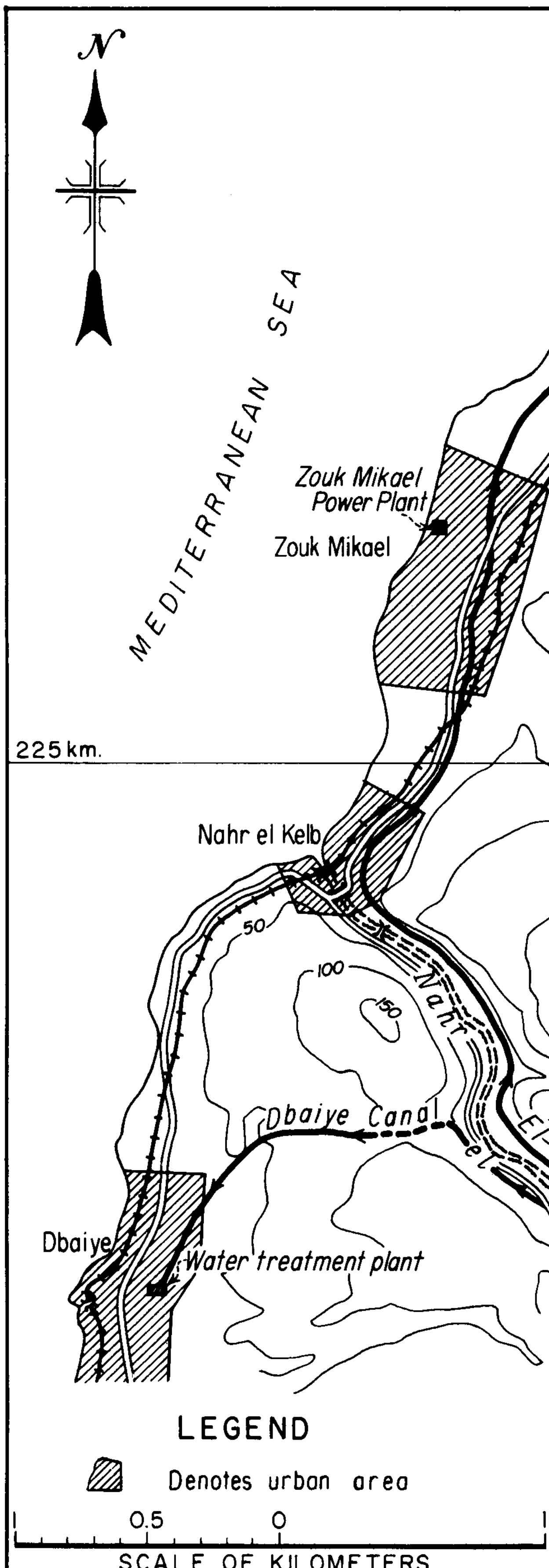
The existing irrigation system has a single supply canal known as the El Wata Canal. It is over 200 years old, having been originally established by the Princess Oomaali to furnish power for a grist-mill. The canal was extended in succeeding generations and its function gradually changed to irrigation supply. At present it is reported by local farmers to have a water right of 26,000 cubic meters per day. In addition to irrigation, a small amount of water is diverted from the canal at Zouk Mikael for use in the power plant boilers.

A second canal, the Dbaiye Canal which supplies domestic water to the city of Beirut, has its diversion a short distance below that of the El Wata Canal. It furnishes a very small amount of irrigation water in the Nahr el Kelb canyon and irrigates some gardens in the village of Dbaiye. Locations of the existing irrigation canals are shown on Plate V-1.

El Wata Canal. The El Wata Canal originates about 3.2 kilometers upstream from the mouth of the Nahr el Kelb. The diversion structure is very rudimentary, consisting of a crude dike of piled stones. The canal is located on the right bank of the river and begins as an unlined ditch. About 200 meters downstream a well constructed masonry section with a side overflow wasteway protects the canal from excessive flows. A short distance farther downstream the El Wata Canal passes the diversion works for the Dbaiye Canal, and here a gate is provided for diverting water into the Dbaiye system. The next kilometer is an unlined ditch excavated in earth and rock. For the final kilometer within the canyon, the canal is an old aqueduct supported on masonry arches.

Near the highway bridge across the Nahr el Kelb, the canal turns northward and follows a course above the highway until it passes under the highway at the village of Zouk Mikael. Just past the crossing a new turnout supplies water to the Zouk Mikael Power Plant.

The most intensive irrigation noted along the course of the canal occurs between Zouk Mikael and the outskirts of Jounieh. Here the canal is of rectangular section, concrete lined, with turnouts and distribution laterals of concrete. The gardens are orderly and well arranged, with crops of vegetables and citrus orchards. Most of the acreage of



UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
WATER RESOURCES RECONNAISSANCE

EXISTING IRRIGATION SYSTEM
NAHR EL KELB

DR. M.J.	SUBMITTED William T. Walter
TR. J.M.K.	RECOMMENDED L. A. Kolb
CH. WTW	APPROVED L. J. Snyder
BEIRUT, LEBANON NOV. 28, 1955	OA - 10 - 848

PLATE V - I

the project lies in this area, and if good soil were available above the canal it would logically have been developed for pump irrigation. Unfortunately, the higher elevations are practically all rock.

The Coastal Plain and the El Wata Canal end at a cliff near Jounieh. At this point a wasteway discharges the excess water into the sea.

The total length of the canal is 7.6 kilometers. It is estimated that the flow varies between 0.4 cubic meters per second and 1.0 cubic meters per second, depending on the stage of the river and the amount of water required for the Dbaiye Canal which furnished the Beirut water supply. The upper reaches of the canal are in poor condition, though no major leaks were noted in the canyon. The canal is lined and generally in good condition throughout its length along the coastal plain.

Dbaiye Canal. The Dbaiye Canal is a modern, concrete lined canal with headworks and a diversion dam which diverts the entire flow of the Nahr el Kelb during the dry season. This canal carries the domestic water supply for the city of Beirut. The capacity is about 3.0 cubic meters per second. It takes Nahr el Kelb water after the El Wata Canal has diverted its share; however, through purchase of a mill which had a water right of 14,000 cubic meters per day from the El Wata Canal, the Dbaiye Canal was enabled to take over that right. This water is transferred by means of a gate between the two systems located in the Dbaiye diversion works. A small amount of irrigation in the Kelb canyon is furnished from the Dbaiye Canal. The village of Dbaiye contains approximately 40 hectares of irrigated gardens which use 0.03 cubic meters per second of water from the Dbaiye Canal before it enters the water treatment plant.

Project Operation. The El Wata Canal is an inheritance from ancient times. There is, for the canal, no concession or governmental control other than the general laws concerning the waters of Lebanon. The water users have an organization known as the "Committee for Distribution of Nahr el Kelb Water." The committee is derived from those landowners using the water and is headed by one of their number. The present committee was formed in 1949.

No written laws govern operation and maintenance, but when problems arise the committee meets and makes decisions. It maintains the canal and appoints guards. When repairs are necessary, they are made and the costs are divided fairly among the water users.

Existing Irrigation Development - Mountain Area

A considerable area of land above the Coastal Plain, in the mountainous area of the Nahr el Kelb Basin, is being irrigated. Most of the irrigation water comes directly from springs scattered throughout the basin. The areas irrigated are generally relatively small in area, noncontiguous, and have varying amounts of water available. Some have full water supplies; others have only a partial supply. They are served generally by small canals which were either poorly constructed, or have been allowed to deteriorate through lack of maintenance. Water use efficiency is low, and canal losses are high. Usually water is diverted into the canals as long as it is available. No attempt at regulation is made, even though reduced quantities of water may be required for irrigation or other uses. This results in a great waste since only a portion of the water wasted from the canals returns to the steams for use downstream.

The aggregate of the mountain areas receiving irrigation water is considerable and is a significant factor in the economy of the basin. Because of the difficulty in surveying and evaluating each of the many individual areas, and the greater importance of the coastal areas in regard to future developments, a survey of the mountain section has not been made. Often these irrigation systems are connected or closely related with domestic water supplies, therefore, any future irrigation development should be made in conjunction with domestic water supply studies and investigations.

Proposed Irrigation Development

The El Wata Canal now carries water at a rate varying from 0.4 cubic meter per second to 1.0 cubic meter per second. This is much more than the available land requires. Due to the steepness of the hills close to the sea, and the lack of soil cover, it would be impossible to economically develop any further irrigation from this canal.

It is proposed, therefore, that the irrigation of the coastal area be confined to the existing project. Since a flow of 0.1 cubic meter per second should be ample for irrigation, a study should be made to determine whether or not the wasted water could be saved for other purposes, such as the Beirut domestic water supply.

Consideration should also be given to the probable expansion of trade and recreational establishments along the route of the new coastal highway being constructed. Commercial growth of the area could absorb the excess water if the Beirut water system does not require it.

The water users realize that the canal is wasting water; they estimate approximately 40 percent of their rightful 26,000 cubic meters per day is lost by seepage. It is possible that aid could be offered them in the form of a canal lining program, which would alleviate their fear of water shortage in case of closer control of their diversion practices.

Diversion to this canal should be regulated much more accurately than at present. The water users claim as their right only 0.3 cubic meter per second. Obviously even this difference could be well used by the Dbaiye Canal without resorting to a reduction in the El Wata rights.

No attempt has been made to fully evaluate the additional irrigation potentials of the mountain area. As in the mountainous areas of other river basins, mountain irrigation in the Nahr el Kelb Basin is accomplished by a large number of small projects using the water supply of springs and streams. No large scale unified projects are feasible in the mountains because of both land and water limitations. Some expansion of existing systems would be possible. Present systems are antiquated and wasteful of water. Future development of these areas should therefore be based on better use of existing water supplies, rather than additional diversions or major construction projects. If losses in canals and on the farms were reduced to a practical minimum, and if the water were used more carefully, considerable additional land, where available, could be brought under irrigation with no increases in the water being diverted at present.

It is proposed, therefore, that irrigation on the terraced land of the mountains be expanded where possible by rehabilitation of existing works to reduce waste. The water users should also be given instruction and guidance in the proper techniques of irrigated agriculture. With good use of the water, it is estimated that 25 percent or more additional land could be irrigated with the same amount of water that is being used at present. With proper guidance and encouragement much of the rehabilitation work needed could be done by the landowners and farmers themselves. Canals are small in most cases and could easily be repaired with little or no cost for materials, and a minimum of labor.

SECTION VI

POWER DEVELOPMENT

General

In the past, little consideration was given to the development of hydroelectric power in the Nahr el Kelb Basin. The principal reasons for this were: other basins in Lebanon appeared to offer better possibilities for hydroelectric power production; the upper reaches of the basin contain numerous tributaries which have confluences with the Nahr el Kelb at low elevations close to the mouth of the river; at the higher elevations the numerous tributaries cannot be readily collected and diverted to a common point; all spring water in the upper reaches of the basin is used during the summer months for domestic supplies and for irrigation of terraces; the central area of the basin contains porous formations which reduce the surface flow and form large springs near the coastal region; and the coastal springs were developed to supply Beirut and other towns with domestic water and to irrigate small areas on the coastal plains.

Due to these conditions, the development of hydroelectric power in the Nahr el Kelb Basin is restricted to the production of fuel replacement power during the months of December through May, unless sufficient reservoir capacity is developed to store part of the February through May flows for use during the months of June through January. The development plan of this report proposes the construction of a 20 million cubic meter storage reservoir near the village of Mayrouba.

Field reconnaissance surveys were made of all sites of the proposed features considered for development. Investigation and studies were made of the available water and of the geologic conditions encountered at the sites to determine the general feasibility of constructing the proposed features. The power development proposed herein is believed to be physically sound and economically justifiable. The economic feasibility of some of the power features would be improved if storage in the proposed Mayrouba Reservoir is also used for supplying domestic water to Beirut and nearby communities, since the costs for conveyance structures from the Mayrouba dam could then be opportuned between power and domestic water uses.

Existing Power Development

There are three small hydroelectric power plants existing in the Nahr el Kelb Basin. The largest of these is known as the Mar Elias Power Plant. It is located on the right side of the Nahr el Kelb, about 1, 500 meters downstream from the Jeita Spring and about 400 meters upstream from the diversion dam for the Beirut water supply. This plant has two generating units with a total installed capacity of 160 kilowatts under a head of about 11 meters. It was constructed about 1925 and is operated by the Jounieh Electricity Company.

The next plant, known as the Tahoun el Khoury Power Plant, is on the left side of the Nahr el Kelb about 250 meters downstream from the Jeita Spring. This plant has an installed capacity of 100 kilowatts and utilizes a head of about 9. 5 meters. It was constructed about 1952 at the site of an abandoned flour mill and is also operated by the Jounieh Electricity Company.

The smallest hydro power plant on the Nahr el Kelb Basin is located just below the spring known as Nabaa el Aassel. It has a capacity of about 20 kilowatts, which is used by nearby hotels, restaurants, and private homes.

The two larger power plants, operated by the Jounieh Electricity Company, are shown on Plate VI-1, "Existing Power Development, Nahr el Kelb." The location of the small 20 kw. power plant may be found on Plate II-1, "General Map, Nahr el Kelb Basin."

Tahoun el-Khoury Power Plant
Achouche Spring is located under the cliff immediately below the Power Plant.

Prior Power Development Schemes

The only plan which has been previously proposed for the development of hydroelectric power from the waters of the Nahr el Kelb Basin is a minor power plant totaling 2, 900 kilowatts between the Jeita Spring and the Beirut water supply diversion dam. This development is proposed by interests from the village of Bikfaya which is located about 2. 5 kilometers from the river. The development will consist of the Hrach Power Plant, now under construction, and a future Tamiche Power Plant. Plate VI-1 shows the general location of these power plants.

The Hrach Power Plant is about 500 meters below the Jeita Spring. It will contain an installation of 2, 000 kilowatts for the production of 7 million kilowatt-hours of energy in an average water year. It is planned that the entire flow from the main grotto of the Jeita Spring will be utilized at this plant at a head of approximately 20 meters. This plant is a redevelopment of an old uncompleted installation at this site.

The Tamiche Power Plant will be constructed near an abandoned flour mill on the left side of the river. The exact location is still unsettled. One plan would locate this plant about 600 meters below the Hrach Plant, where it would utilize the flow from the Hrach Plant at a head of about 9 meters. For this location an installation of about 900 kilowatts is proposed for the production of about 3 million kilowatt-hours of energy in an average water year.

Proposed Power Development

The proposed hydroelectric power development for the Nahr el Kelb Basin would consist of the Hardoun, Mayrouba, Qlayaat, Balloune, and Jeita units. The Hardoun Unit is independent of the other units and could be constructed and operated alone. The water available for this unit is limited to the winter and spring flows. The Mayrouba, Qlayaat, Balloune, and Jeita Units would depend upon the construction and operation of the Mayrouba Dam and Reservoir and their efficient operation would require close coordination of these units. A small alternate Jeita Unit should be considered in conjunction with the proposed improvements to the Beirut Water Supply System. The development plan proposed herein does not include costs or benefits of this alternate Jeita Power Unit.

For this reconnaissance study a 69-kilovolt transmission line was assumed to connect the units and transmit the power to the principal load center at Beirut. A 35-kilovolt transmission system was assumed for distributing power to towns and villages in and adjacent to the Nahr el Kelb Basin. Final determination of the transmission system voltage levels should be left for future detailed investigations.

The Hardoun Unit would have an installed capacity of 10, 000 kilowatts and would be a run-of-the-river plant. The water for the other power units would be regulated by releases from the Mayrouba Reservoir. The Mayrouba Unit would have an installed capacity of 29, 000 kilowatts, The Qlayaat 34, 000 kilowatts, the Balloune 26, 000 kilowatts and the Jeita 4, 200 kilowatts. The small alternate Jeita Power Plant would have an installed capacity of 2, 000 kilowatts.

This basin development has been based upon reconnaissance-type field surveys and investigations, and data obtained from the Beirut Water Company and the Ministry of Public Works, Government of Lebanon. Detailed field surveys, more extensive investigations, and additional geologic and hydrologic data are required before the exact location, and final sizes and capacities of the various features proposed in this development can be determined. The tentative locations selected for the various features are shown on Plate VI-2. Their pertinent elevations are shown on Plate VI-3. A summary of the estimated construction costs of these units is shown in Table VIII-1 of Section VIII - COSTS AND BENEFITS. All costs include contingencies, engineering supervision, and interest during construction.

Hardoun Unit. This unit is on the upper reaches of the Nahr es Salib, the largest and northmost tributary of the Nahr el Kelb. It consists of the Hardoun Penstock Gate Structure, Penstock, Power Plant at the upstream end of the proposed Mayrouba

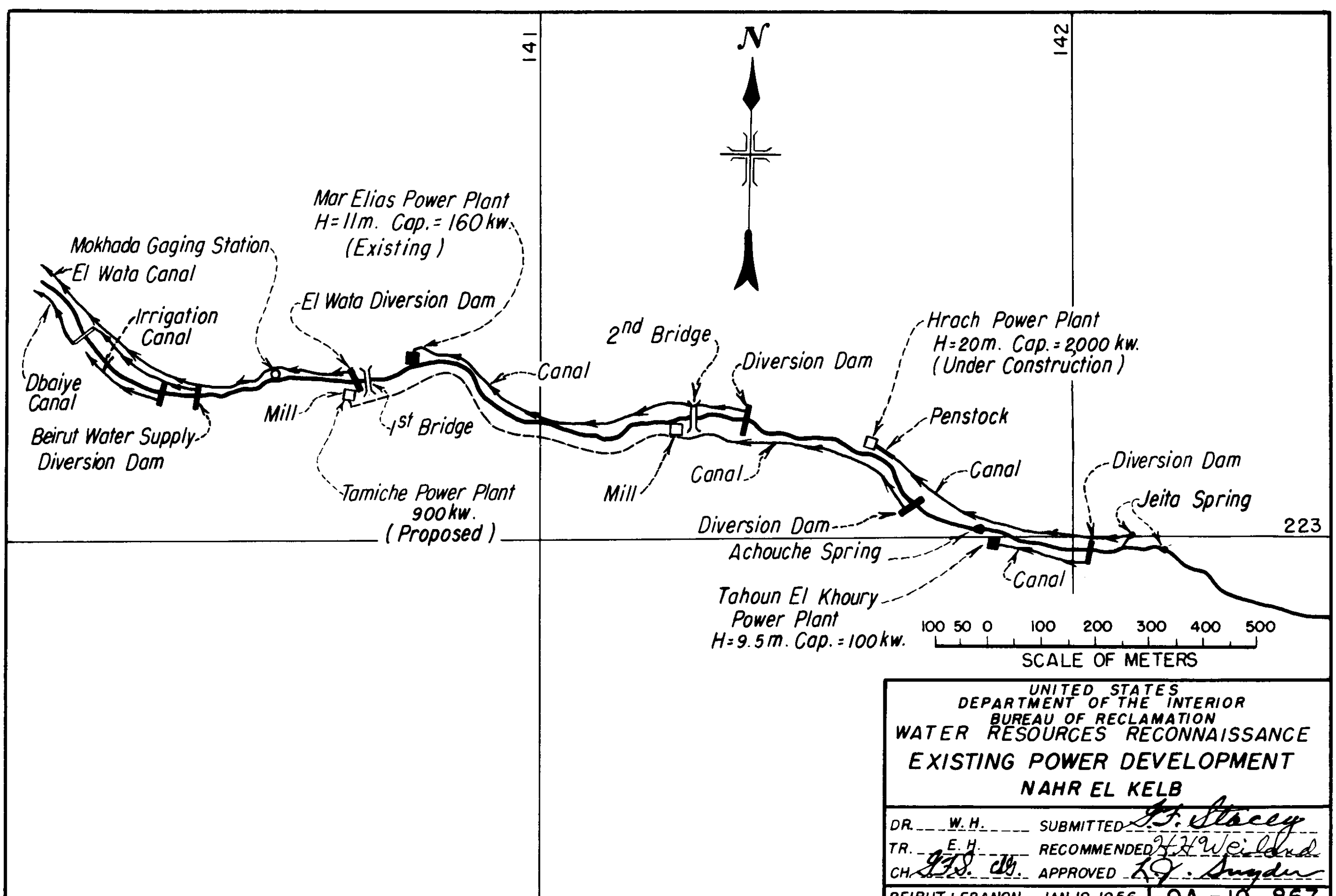
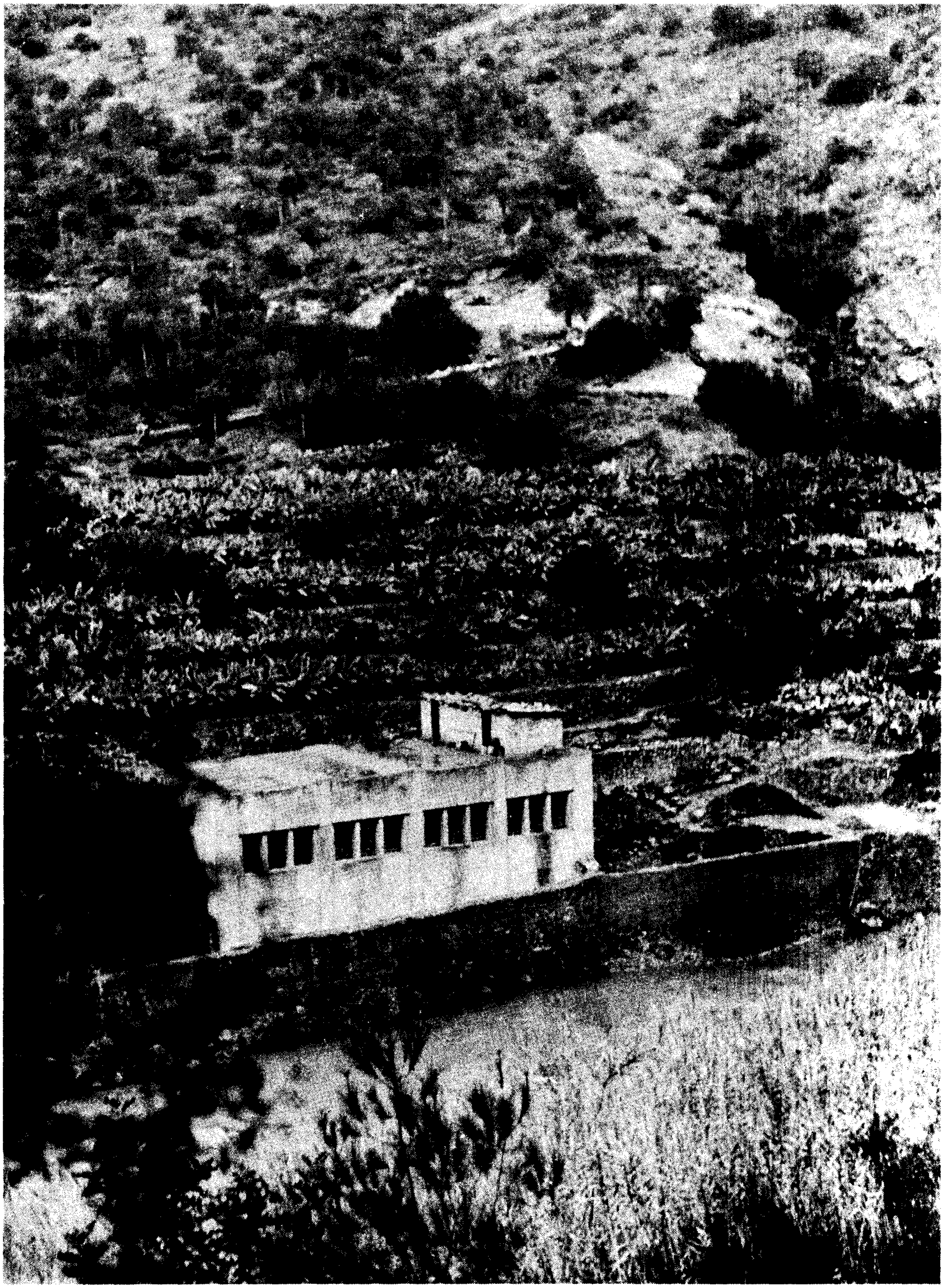


PLATE VI-I

Sanitized Copy Approved for Release 2011/06/21 : CIA-RDP80T00246A003400510001-7



Hrach Power Plant (Under Construction)

Sanitized Copy Approved for Release 2011/06/21 : CIA-RDP80T00246A003400510001-7

Reservoir, five diversion dams (Fakra, El Leben, El Aassel, Chabrouka, and Hardoun), and a series of conduits which would collect the water from four tributaries of Nahr es Salib, one tributary of Nahr es Samm, and numerous small springs and streams along its route.

Fakra Diversion Dam, a small concrete structure with a crest elevation to 1,632 meters, would be constructed across the Nahr es Samm just below Nabaa es Sakie. This site was selected so that the canal which begins at the dam and which will divert water from the Nahr es Samm to the Nahr es Salib Basin, would have a minimum length and be in terrain suitable for construction of an open canal. Cost estimates were based on a 4-cubic meter per second capacity, concrete lined canal 960 meters long. The capacity of the canal is believed ample to carry the high flows occurring for short periods following heavy rainfall and snowmelt. These flows would greatly exceed the expected normal streamflow during the winter and spring months. The canal would terminate at the crest of the ridge between the Nahr es Samm and Nahr el Leben (a tributary of Nahr es Salib), from where the water would flow into Nahr el Leben through a small ravine.

A low diversion dam with a crest elevation at about 1,537 meters would be constructed across the narrow canyon of Nahr el Leben to divert the normal flow of water into the collection conduit. Excess floodwater from Nahr el Leben, plus that diverted from Nahr es Samm, would pass over the spillway for storage in the Mayrouba Reservoir.

The water supply for the Hardoun Unit would be obtained from various sources and would be conveyed to the inlet of the penstock by two conduits. One conduit would collect the divertable runoff from Nahr el Leben, Nabaa el Aassel, Ouadi Chabrouka, and other small streams and springs along its route. The initial capacity of the conduit at Nahr el Leben would be 2.0 cubic meters per second. Capacity would be gradually increased to a maximum of 4.0 cubic meters, and the conduit would terminate at the Hardoun Penstock Gate Structure at about elevation 1,513 meters. The conduit would have a total length of about 6,760 meters.

The collecting conduit would cross Nahr el Hassen just below Nabaa el Aassel where there has been a large amount of work undertaken over a period of years. This work includes a tunnel for improving the spring, collection works, bifurcation structure, headworks, flumes, and retaining walls. Most of these structures would have to be rebuilt, or modified, to obtain a compact collection and distribtuion system capable of handling the many functions required by the present and future canals and pipe systems leading from this site. El Aassel Diversion Dam would be a small concrete structure a short distance downstream from Nabaa el Aassel. The crest elevation would be about 1,526 meters.

In addition to the diversion dams on the Nahr es Samm, Nahr el Leben, and Nahr el Aassel, a small concrete diversion structure would be constructed on Ouadi Chabrouka. The diversion structure would be constructed above the collection conduit siphon that is required for crossing the steep, narrow canyon of Ouadi Chabrouka. The water from the structure would be conducted to the collection conduit by a steel pipeline constructed along the left side of the canyon. Approximately 20 small structures would be required to collect the divertable water from small streams and springs that occur along the conduit route.

The second conduit would begin at a small concrete diversion dam on Ouadi Hardoun at about elevation 1,525. This conduit would be about 1,900 meters long and would also terminate at the Hardoun Penstock Gate Structure. It would have a uniform capacity of 1.5 cubic meters per second. No difficult problems are anticipated in the construction of this conduit.

Cost estimates of the two conduits were based on a reinforced concrete circular section varying from 1 to 1.7 meters in diameter. Further studies may show that construction could be facilitated and costs reduced by using some sections of open canals or bench flumes. The estimates also include the costs of a short tunnel section near Nabaa el Aassel, a short siphon across Ouadi Chabrouka, special protection through a slide area near Nabaa el Aassel, special structures for supporting the conduit for a short distance along the face of a cliff, access roads, and rights-of-way. The estimated cost of the collecting system not including diversion dams, is LL. 2, 840, 000. The estimated cost of the five diversion dams is LL. 700, 000. The total estimated cost of the entire collecting system is LL. 3, 540, 000.

The Hardoun Penstock Gate Structure would be constructed at the junction of the collecting conduits at elevation 1,513 meters. The gate structure would consist of a small basin containing an emergency penstock control gate, bypass gates, and an overflow spillway section from which a short chute would be constructed to divert the overflow into a small nearby ravine that discharges into Ouadi Hardoun.

The Hardoun Penstock would be a single steel pipe about 1, 400 meters long, with an average diameter of 1. 1 meters for a designed capacity of 4 cubic meters per second. It would have an invert elevation of 1,513 meters at the gate structure and an invert elevation of about 1,217 meters at the Hardoun Power Plant. The penstock would be located over terrain which has several fairly sharp, grade changes. This would require several deep cuts, one trestle which would cross a highway, and several small horizontal angles. No other unusual problems are anticipated during construction of the penstock. The estimated cost of the Hardoun Penstock including excavation of the deep cuts and construction of the trestle, is LL. 1, 300, 000.

The Hardoun Power Plant would be located at the junction of Ouadi Hardoun and Nahr es Salib at about elevation 1,217 meters. The water from the power plant would discharge directly into Nahr es Salib just above the maximum high water surface of the Mayrouba Reservoir. No unusual problems are anticipated during the construction of the power plant. The geology of this site is discussed in Section IV - GEOLOGY.

The power plant would have an installed capacity of 10, 000 kilowatts in one direct-connected unit. It is recommended that either double-overhung, double-jet impulse turbines or a single, vertical impulse turbine with three or more jets be used. This plant would have a gross head of about 296 meters and is expected to produce about 33 million kilowatt-hours of energy in an average water year. The power plant switchyard would be located adjacent to the power plant. A description and cost estimate of the switchyard and transmission system are discussed in this section under "Transmission System". The estimated cost of the Hardoun Power Plant is LL. 3, 900, 000.

The total estimated cost of the Hardoun Power Unit exclusive of the switchyard and transmission system, but including contingencies, engineering, supervision, and interest charges during construction, is LL. 8, 740, 000. The cost estimates for features of the Hardoun Power Unit are shown in Table VIII-1 and are discussed in Section VIII - COSTS AND BENEFITS.

Mayrouba Dam and Reservoir. This reservoir would be a dual-purpose feature of the Nahr el Kelb Basin development. The reservoir would store rainy season runoff to supply domestic water to Beirut and nearby communities during the dry season. It would also store water for generating peak power at the hydroelectric plants downstream from the dam.

The dam site, at streambed elevation 1, 154 meters, is about 1. 2 kilometers southwest of the village of Mayrouba. The dam and reservoir sites are accessible by foot trail leading from the Reyfoun - Kafirdebiane Highway Bridge about one kilometer south of the dam site. Plate VI-2 shows the general location of Mayrouba Dam and Reservoir.

The reservoir would be about 3. 5 kilometers long, covering an area of about 125 hectares at the normal reservoir water surface elevation of 1,213.5 meters. At this level the usable reservoir storage capacity would be about 20 million cubic meters. Dead storage of 500, 000 cubic meters would be provided below the power tunnel inlet structure at elevation 1,170 meters.

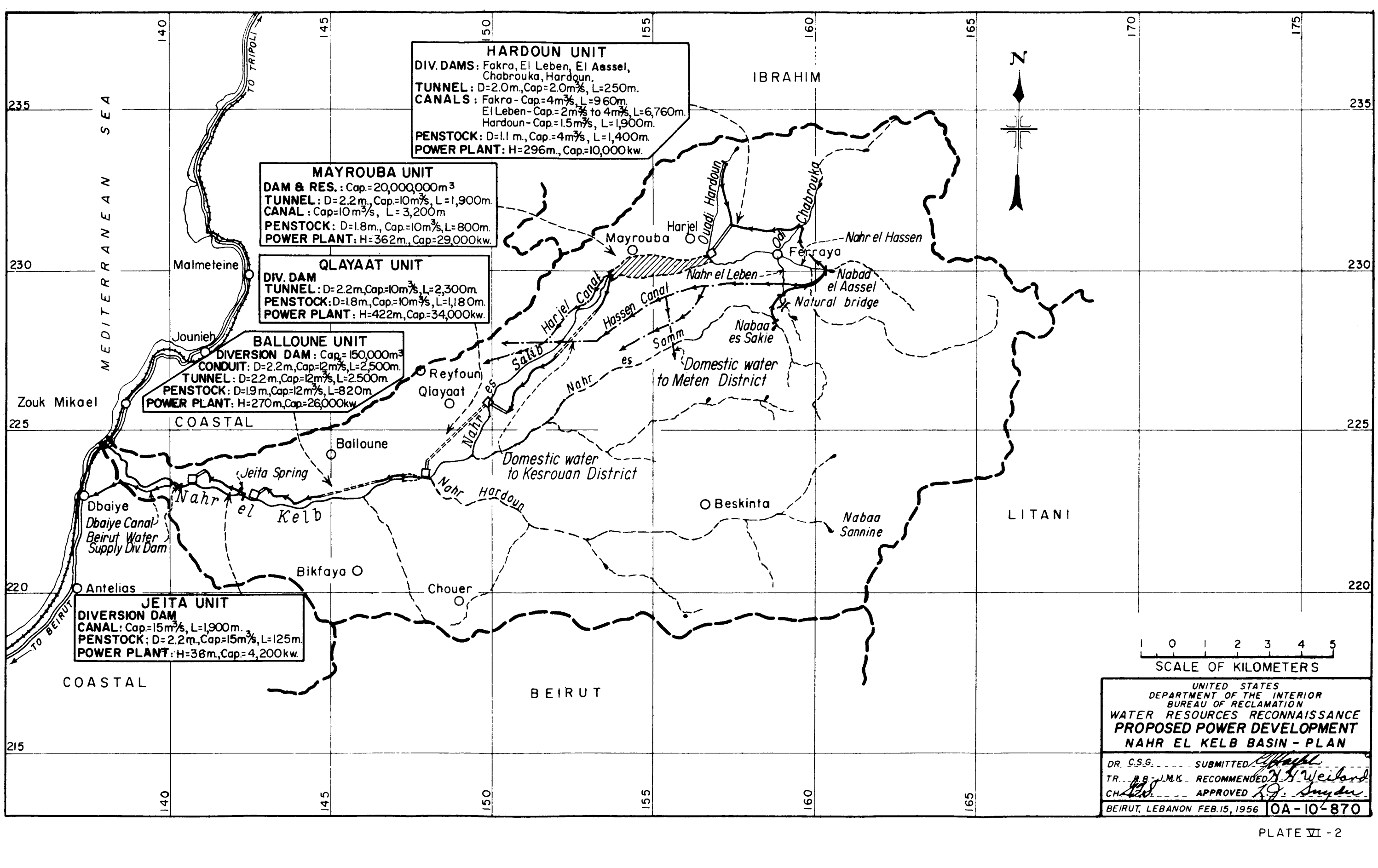
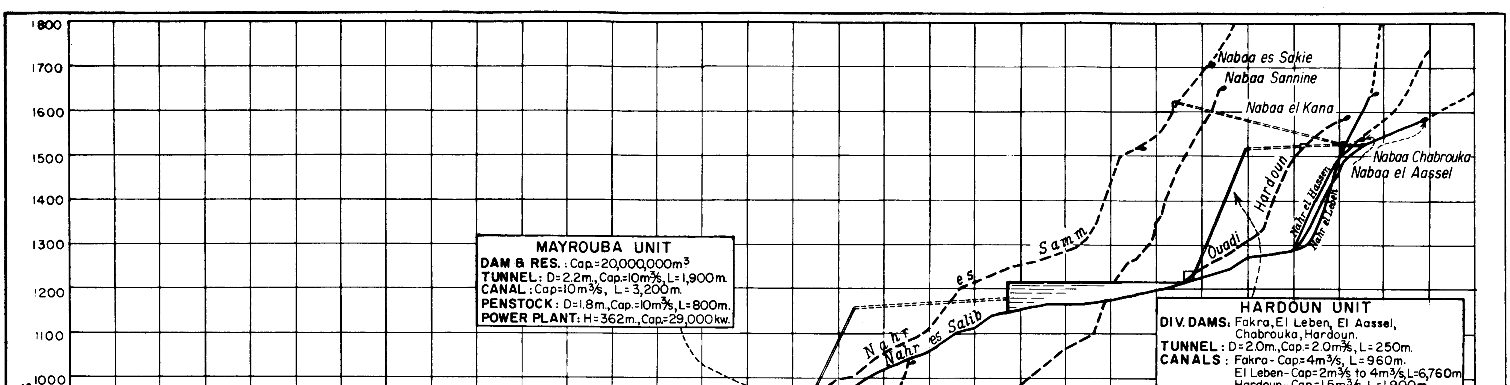

HARDOUN UNIT
DIV. DAMS: Fakra, El Leben, El Aassel, Chabrouka, Hardoun.
TUNNEL: D=2.0m., Cap.=2.0m³/s, L=250m.
CANALS: Fakra - Cap.=4m³/s, L=960m.
El Leben - Cap.=2m³/s to 4m³/s, L=6,760m.
Hardoun - Cap.=1.5m³/s, L=1,900m.
PENSTOCK: D=1.1 m., Cap.=4m³/s, L=1,400m.
POWER PLANT: H=296m., Cap.=10,000 kw.
MAYROUBA UNIT
DAM & RES.: Cap.=20,000,000m³
TUNNEL: D=2.2m., Cap.=10m³/s, L=1,900m.
CANAL: Cap.=10 m³/s, L=3,200m
PENSTOCK: D=1.8m., Cap.=10m³/s, L=800m.
POWER PLANT: H=362m., Cap.=29,000kw.
QLAYAAT UNIT
DIV. DAM
TUNNEL: D=2.2m., Cap.=10m³/s, L=2,300m.
PENSTOCK: D=1.8m., Cap.=10m³/s, L=1,180m.
POWER PLANT: H=422m., Cap.=34,000kw.
BALLOUNE UNIT
DIVERSION DAM: Cap.=150,000m³
CONDUIT: D=2.2m., Cap.=12m³/s, L=2,500m.
TUNNEL: D=2.2m., Cap.=12m³/s, L=2,500m.
PENSTOCK: D=1.9m., Cap.=12m³/s, L=820m.
POWER PLANT: H=270m., Cap.=26,000kw.
JEITA UNIT
DIVERSION DAM
CANAL: Cap.=15m³/s, L=1,900m.
PENSTOCK: D=2.2m., Cap.=15m³/s, L=125m.
POWER PLANT: H=36m., Cap.=4,200kw.
140
145
150
155
160
165
170
175
235
230
225
220
215
N
TO TRIPOLI
TO BEIRUT
MEDITERRANEAN SEA
IBRAHIM
COASTAL
LITANI
BEIRUT
Malmeteine
Jounieh
Zouk Mikael
Dbaiye
Dbaiye Canal
Beirut Water Supply Div. Dam
Antelias
Jeita Spring
Nahr el Kelb
Balloune
Reyfoun
Qlayaat
Nahr es Salib
Hariel Canal
Hassen Canal
Nahr es Samm
Domestic water to Meten District
Domestic water to Kesrouan District
Nahr Hardoun
Mayrouba
Hariel
Ouadi Hardoun
Chabrouka
Ferraya
Nahr el Hassen
Nahr el Leben
Nabaa el Aassel
Natural bridge
Nabaa es Sakie
Beskinta
Nabaa Sannine
Bikfaya
Chouer
0 1 2 3 4 5
SCALE OF KILOMETERS
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
WATER RESOURCES RECONNAISSANCE
PROPOSED POWER DEVELOPMENT
NAHR EL KELB BASIN - PLAN
DR. C.S.G.
TR. B.B.-I.M.K.
SUBMITTED
RECOMMENDED
APPROVED
BEIRUT, LEBANON FEB.15, 1956
OA-10-870

PLATE VI - 2



ELEVATION IN METERS
DISTANCE IN KILOMETERS ABOVE MOUTH
JEITA UNIT
DIVERSION DAM
CANAL : Cap.= 15m³/s, L=1,900m.
PENSTOCK: D=2.2m., Cap.=15m³/s, L=125m.
POWER PLANT: H=36m., Cap.=4,200kw.
BALLOUNE UNIT
DIVERSION DAM - Cap.=150,000m³
CONDUIT : D=2.2m., Cap.=12m³/s, L=2,500m.
TUNNEL . D=2.2m., Cap.=12m³/s, L=2,500m.
PENSTOCK : D=1.9m., Cap.=12m³/s, L=820m.
POWER PLANT: H=270m., Cap.=26,000kw.
QLAYAAT UNIT
DIVERSION DAM
TUNNEL: D=2.2m., Cap.=10m³/s, L=2,300m.
PENSTOCK: D=1.8m., Cap.=10m³/s, L=1,180m.
POWER PLANT: H=422m., Cap.=34,000kw.
MAYROUBA UNIT
DAM & RES. : Cap.=20,000,000m³
TUNNEL: D=2.2m., Cap.=10m³/s, L=1,900m.
CANAL : Cap.=10m³/s, L=3,200m.
PENSTOCK : D=1.8m., Cap.=10m³/s, L=800m.
POWER PLANT: H=362m., Cap.=29,000kw.
HARDOUN UNIT
DIV. DAMS: Fakra, El Leben, El Aassel, Chabrouka, Hardoun.
TUNNEL : D=2.0m., Cap.=2.0m³/s, L=250m.
CANALS : Fakra-Cap.=4m³/s, L=960m.
El Leben-Cap=2m³/s to 4m³/s, L=6,760m.
Hardoun-Cap=1.5m³/s, L=1,900m.
PENSTOCK: D=1.1m., Cap.=4m³/s, L=1,400m.
POWER PLANT: H=296m., Cap.=10,000kw.
Beirut Water Supply Diversion Dam
Nahr el Kelb
Nahr es Salib
Nahr es Samm
Nahr Hardoun
Ouadi Hardoun
Nahr el Hassan
Nahr el Leben
Nabaa es Sakie
Nabaa Sannine
Nabaa el Kana
Nabaa Chabrouka
Nabaa el Aassel
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
WATER RESOURCES RECONNAISSANCE
PROPOSED POWER DEVELOPMENT
NAHR EL KELB BASIN - PROFILE
DR. C.S.G.
TR. J.M.K.
SUBMITTED
RECOMMENDED
APPROVED
BEIRUT, LEBANON MAR. 22, 1956
OA - 10-873

PLATE VI - 3

The dam site is in a U-shaped canyon of dense Jurassic limestone. The site is topographically and geologically suited to the construction of a symmetrical, concrete, arch structure. The maximum height of the dam would be about 67 meters. The top of the dam, at elevation 1,217 meters, would be 4 meters thick with a length of 150 meters along an arc of 65 meters radius to the upstream face. This reconnaissance estimate assumed a constant center, circular, arch dam with a vertical upstream face, and a uniform downstream face sloping 0.2 units horizontal to one unit vertical.

An uncontrolled, overflow spillway, with a length of 60 meters would be constructed at the center of the dam to permit discharge of 910 cubic meters per second with the reservoir at the level of the spillway crest at the beginning of the 12-hour, 7.9 million cubic meter, inflow design flood. This discharge was determined by routing the two inflow design floods, of which, the short duration, high intensity flood was found to give the more critical spillway discharge. A ski-jump type chute on the downstream face of the dam would deflect the spillway discharge a sufficient distance downstream to prevent scour damage to the dam foundation. An emergency river outlet works would be constructed adjacent to the spillway section. Outlet works for the Mayrouba Power Unit would be constructed in the southeast abutment.

The diversion works for the existing Harjel (English) Canal and the first portion of the canal itself will be inundated by the reservoir. It will, therefore, be necessary to construct outlet works in the northwest abutment of the dam to supply water to this canal.

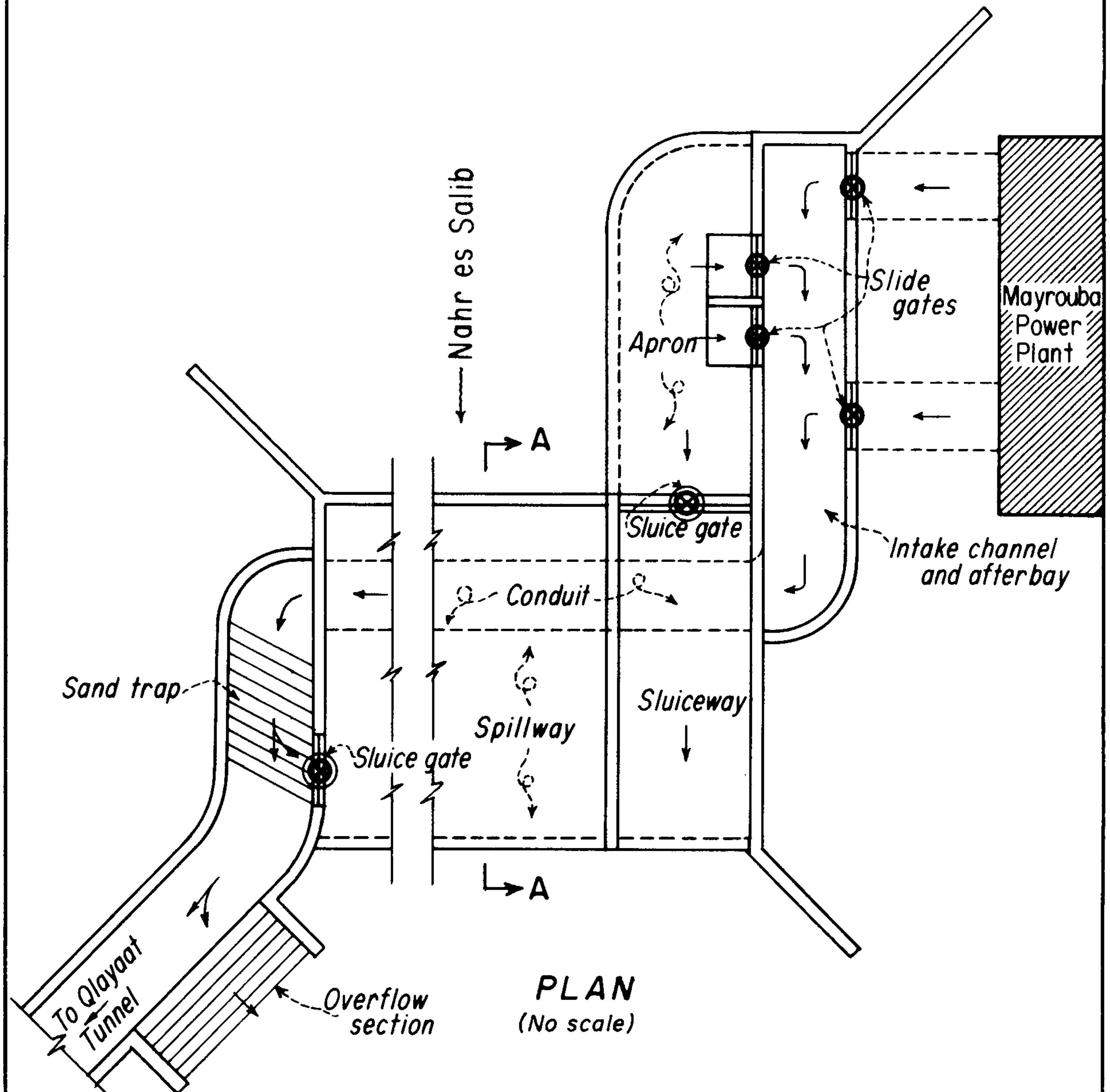
Principal construction quantities for the dam would include about 80,000 cubic meters of mass concrete and 20,000 cubic meters of foundation excavation. The estimated cost of the dam and reservoir including a lump sum of LL. 2,000,000 for investigating and treating the reservoir foundation, contingencies, engineering, supervision, and interest during construction is LL. 14,700,000.

Mayrouba Unit. This unit would be located below the Mayrouba Dam along the south side of the Nahr es Salib and would be supplied with water from the Mayrouba Reservoir. It would consist of the Mayrouba Canal, Tunnel, Penstock, and Power Plant.

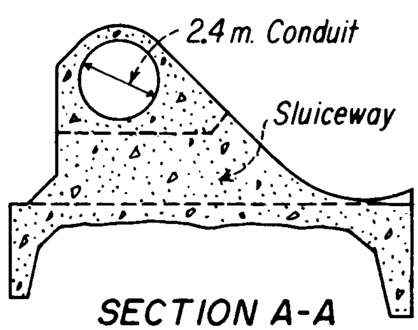
The inlet of the Mayrouba Tunnel would be 1,000 meters downstream from the Mayrouba Dam outlet works, connected to it by a canal or bench flume constructed along the left side of the canyon. The tunnel would be a free-flow, concrete lined, horseshoe-shaped tunnel with a diameter of 2.2 meters, and a length of 1,900 meters. This tunnel diameter was selected as the minimum size which would be the most economical to construct. It would have a designed capacity of 10 cubic meters per second which is adequate for the optimum operation of the unit in an average water year. A canal with a capacity of 10 cubic meters per second and a length of 2,200 meters would convey the water from the tunnel outlet to the penstock. To facilitate the operation of the power plant, a small forebay of 25,000-cubic meter capacity would be required near the penstock inlet. This forebay could be obtained either by constructing a small basin or by enlarging the lower end of the canal. No unusual problems are anticipated during construction of the tunnel or canal. The estimated cost for the tunnel, canal, forebay, and penstock control gate is LL. 3,930,000.

A single steel penstock with an average diameter of 1.8 meters would convey the water from the canal to the power plant. The penstock would be about 800 meters long and have a designed capacity of 10 cubic meters per second. It would have an inlet elevation of 1,160 meters and an elevation of 797 meters at the power plant. The upper half of the penstock would be over terrain having a fairly flat slope, while the lower half would have a very steep slope. The estimated cost for the penstock is LL. 2,100,000.

The Mayrouba Power Plant would be located on the left side of the Nahr es Salib at about elevation 797 meters and about 1,500 meters upstream from the junction of Nahr es Salib and Nahr es Samm. At this point the canyon has adequate width for construction of the power plant without excessive hardrock excavation from the canyon wall. The excavation of considerable talus will be required. The geologic formation at this site is discussed in Section IV - GEOLOGY.



PLAN
(No scale)



SECTION A-A
(No scale)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
WATER RESOURCES RECONNAISSANCE
QLAYAAT DIVERSION DAM
GENERAL PLAN AND SECTION
NAHR EL KELB BASIN

DR. H.H.W.-R.J.H. SUBMITTED [signature]
TR. J.M.K. RECOMMENDED [signature]
CH. [signature] APPROVED [signature]

BEIRUT, LEBANON APR. 5, 1956 OA-10-875

PLATE VI-4

The power plant would discharge into a tailrace constructed slightly above and along the streambed adjacent to the power plant. The tailrace would be a component part of the proposed Qlayaat Diversion Dam and would contain the diversion dam's outlet works and control gates for the Qlayaat Unit. The outlet works would be arranged so that the clear water supplied from the Mayrouba Reservoir and discharged by the power plant could be conveyed to the Qlayaat Unit (ultimately through other units to the intake of the Beirut Water Supply System) without mixing with the water flowing in the Nahr es Salib, which is occasionally very muddy during heavy winter rainfalls. During periods of normal runoff the control gates could be operated so that the water from the Nahr es Salib would be diverted to the Qlayaat Unit along with the water discharged from the power plant. See Plate VI - 4.

The Mayrouba Power Plant would have an installed capacity of 29, 000 kilowatts, consisting of two 14, 500 kilowatt units direct-connected to impulse turbines. It is recommended that either double-overhung, double-jet horizontal impulse turbines, or single vertical impulse turbines with three or more jets each be used. This plant would have a gross head of about 362 meters and is expected to produce about 54 million kilowatt-hours of energy in an average water year. The power plant switchyard would be located adjacent to the power plant. A description and cost estimate of the switchyard and transmission system are discussed in this section under "Transmission System". The estimated cost of the Mayrouba Power Plant, not including the tailrace which is included in the cost for the Qlayaat Diversion Dam, is LL. 8, 400, 000.

The total estimated cost of the Mayrouba Power Unit, exclusive of the Mayrouba Dam and Reservoir, switchyard, and transmission system, but including access roads, rights-of-way, contingencies, engineering, supervision, and interest during construction, is LL. 14, 430, 000. The cost estimates for features of the Mayrouba Power Unit are shown in Table VIII-1 and are discussed in Section VIII - COSTS AND BENEFITS.

Qlayaat Unit. The site for this power unit is along the north bank of the Nahr es Salib from the Mayrouba Power Plant to the Junction of the Nahr es Salib and the Nahr Hardoun. The unit would consist of the Qlayaat Diversion Dam, Flume, Tunnel, Penstock, and Power Plant. The general plan and profile of this unit are shown on Plates VI-2 and -3, respectively.

The diversion dam would be an uncontrolled concrete ogee section 20 meters long, with a crest elevation of 795 meters. A general plan and section of the Qlayaat Diversion Dam is shown on Plate VI-4.

A rectangular, concrete basin constructed at the upstream side of the left abutment, would serve as the tailrace for the adjacent Mayrouba Power Plant as well as being part of the Qlayaat Intake Structure. A 2. 4-meter diameter concrete conduit passing through the ogee crest would connect this tailrace to the Qlayaat Flume on the opposite side of the stream. In this manner, during periods of high streamflow, the relatively sediment-free water passing through the Mayrouba Power Plant would be conveyed into the Qlayaat Unit without mixing with the muddy water of the Nahr es Salib. During such operation, all of the streamflow at the diversion dam would pass over the spillway or through the sluiceway.

At the right abutment (northwest side) of the dam, a short, concrete, rectangular open channel (the Qlayaat Flume) would convey diverted water to the Qlayaat Tunnel. The streamside of this flume would serve as a training wall for the diversion dam spillway. The flume would also include a sand trap, sluice gate, and side channel overflow spillway.

When the Mayrouba Power Plant cannot supply adequate quantities of water to the Qlayaat Unit, the Nahr es Salib would be diverted through slide gates at the left abutment, into the tailrace, and into the conduit leading to the Qlayaat Flume. Desilting of the streambed immediately upstream from the dam would be accomplished by surging water through a slide gate and sluiceway constructed in the left end of the spillway and under the transverse conduit within the crest.

The estimated construction cost of the Qlayaat Diversion Dam, including the tailrace for the Mayrouba Unit, control works, and flume, is LL. 400, 000.

The Qlayaat Tunnel would be about 2, 300 meters long and would convey the water from the outlet flume of the diversion dam to the penstock gate structure. It would be a free-flow, concrete lined, horseshoe-shaped tunnel with a diameter of 2. 2 meters and a designed capacity of 10 cubic meters per second. The tunnel would have an inlet invert elevation of 792 meters and an outlet invert elevation of 786 meters at the penstock gate structure. Due to its short length no adits are proposed, but, if desired, several adits would be readily available. No unusual problems are anticipated in construction of this tunnel. The estimated cost of the tunnel is LL. 3, 040, 000.

The penstock gate structure would be constructed at the outlet of the Qlayaat Tunnel and would include an emergency penstock control gate, bypass gates, and a spillway section and chute. Water from the gate structure would be conveyed to the Qlayaat Power Plant by a single steel penstock, 1. 8 meters in diameter and about 1, 180 meters long. It would have a designed capacity of 10 cubic meters per second and would have an invert elevation at the gate structure of 786 meters and an invert elevation of 367 meters at the power plant. The upper two-thirds of the penstock would be located over terrain having a fairly flat slope while the bottom third would be over terrain having a very steep slope. The estimated cost for the penstock is LL. 3, 300, 000.

The Qlayaat Power Plant would be located on the left side of the Nahr el Kelb in a fairly narrow canyon just below the junction of the Nahr es Salib and Nahr Hardoun at a river elevation of 362 meters. Considerable hardrock and talus excavation will be required. No other unusual problems are anticipated. The geology of this site is discussed in Section IV - GEOLOGY.

The power plant would discharge into a tailrace constructed with a bottom elevation of 364 meters, the maximum operating high water elevation of the proposed Balloune Forebay. A concrete flume would be constructed from the tailrace to the right abutment of the proposed Balloune Diversion Dam. A chute along the lower right wingwall of the Balloune Diversion Dam would be required to convey the water from the flume to a proposed bifurcation structure at the downstream end of the diversion dam outlet works. Control gates would be provided in the tailrace so that the water from the power plant could be discharged into the Balloune Forebay or diverted into the flume for delivery to the bifurcation structure. When the Nahr el Kelb becomes muddy following heavy rains, the system could be operated, so that only the clear water from the Qlayaat Power Plant would be diverted to the Balloune Unit and ultimately into the Beirut Water System. The muddy Nahr el Kelb water would be discharged through the large sluiceways in the Balloune Dam.

The power plant would have an installed capacity of 34, 000 kilowatts, consisting of two 17, 000-kilowatt units direct-connected to impulse turbines. It is recommended that either double-overhung, double-jet horizontal impulse turbines, or single vertical impulse turbines with three or more jets each be used. This plant would have a gross head of 420 meters and is expected to produce about 68 million kilowatt-hours of energy in an average water year. The power plant switchyard would be located downstream and slightly above the power plant. Considerable rock excavation will be required to form a level switchyard area. A description and cost estimate of the switchyard and transmission system are discussed in this section under "Transmission System". The estimated cost of the Qlayaat Power Plant is LL. 9, 500, 000 excluding the cost of the flume leading from the tailrace. The cost of this flume is included in the cost of the Balloune Unit.

The total estimated cost of the Qlayaat Unit, exclusive of the switchyard and transmission system, but including contingencies, engineering, supervision, and interest charges during construction, is LL. 16, 240, 000. The cost estimates for features of the Qlayaat Unit are shown in Table VIII-1 and are discussed in Section VIII - COSTS AND BENEFITS.

Balloune Unit. This unit would be located along the north side of the Nahr el Kelb, between the confluence of Nahr es Salib and Nahr Hardoun and the Jeita Spring. It would consist of the Balloune Diversion Dam and Forebay, Conduit, Penstock Gate Structure, Penstock, and Power Plant.

A diversion dam would be constructed across the Nahr el Kelb Canyon about 1, 000 meters below the confluence of the Nahr es Salib and Nahr Hardoun. The dam would form a small reservoir (150, 000 cubic meters) which would be used as an afterbay for the Qlayaat Unit and as a forebay for the Balloune Unit. The cost estimate was based on a concrete gravity-type dam with a maximum height of 15 meters above the streambed. The dam would have a crest length of about 50 meters and a spillway crest elevation of 364 meters. The outlet works would be placed in the right abutment. A chute would be constructed along the lower right wingwall to convey the water from the flume leading from the Qlayaat Power Plant. Large sluiceways with sluice gates would be constructed near the bottom of the dam to facilitate the removal of sediment from the reservoir. Special desilting devices should be provided when constructing the dam. These could consist of an electrically operated winch mounted on rails placed in each abutment and in the bridge over the spillway section. The winch would be used to pull a drag line running on cables attached to the dam and to anchors placed at the upstream edge of the maximum high water elevation of the reservoir. The cost estimate of the dam including cost of special desilting devices, is LL. 1, 700, 000.

A short conduit would be constructed from the diversion dam outlet works at elevation 355 meters to a bifurcation structure located below the right abutment. The bifurcation structure would contain additional control gates, sand traps, measuring devices, an overflow spillway section, and a stilling basin for the chute conveying the water from the Qlayaat Power Plant.

The Balloune Conduit would start at the bifurcation structure and would consist of sections of reinforced concrete, circular pipes and horseshoe-shaped tunnels. The conduit would have an invert elevation of 354 meters at the bifurcation structure and an invert elevation of 336 meters of the penstock gate structure. It would be designed as a free-flow conduit with a capacity of 12 cubic meters per second. Both the circular pipe and the horseshoe-shaped tunnel sections would have a diameter of 2. 2 meters. Cost estimates were based on 2, 500 meters of circular, concrete pipe sections and 2, 500 meters of tunnel sections. The final lengths and locations of these sections would depend upon detailed surveys. Detailed surveys may also indicate that the construction cost could be reduced and construction time decreased by using open canals or bench flume through sections of favorable terrain. The estimated cost of the Balloune Conduit including the bifurcation structure and the flume and chute from the tailrace of the Qlayaat Power Plant is LL. 4, 440, 000.

A single steel penstock would convey the water from the conduit to the Balloune Power Plant. It would have a designed capacity for 12 cubic meters per second with an average diameter of 1. 9 meters. It would have an invert elevation of about 336 meters at the gate structure and about 63 meters at the power plant. The penstock would be about 820 meters long and would be located on terrain having a fairly uniform, flat slope for the upper two-thirds and a steep slope for the lower one-third of its length. A penstock gate structure would be constructed at the junction of the top of penstock and the end of the conduit. It would include an emergency penstock control gate, bypass gates, overflow spillway, and a chute leading to a small ravine that discharges into the Nahr el Kelb. The estimated cost of the penstock including the penstock gate structure, is LL. 1, 800, 000.

The Balloune Power Plant would be on the right bank of the Nahr el Kelb about 200 meters upstream from Jeita Spring at an elevation of 63 meters. The same system as used for the other upstream units, to control the water discharged from the power plant and diverted from the Nahr el Kelb, would be constructed at this power plant. This would enable the clear water supplied from the Mayrouba Reservoir to reach the intake of the Beirut Water System without mixing with muddy water flowing in the Nahr el Kelb after heavy rains.

The power plant would have an installed capacity of 26,000 kilowatts, consisting of two 13,000-kilowatt units direct-connected to impulse turbines. It is recommended that either double overhung, double-jet horizontal impulse turbines, or single vertical impulse turbines with three or more jets each be used. This plant would have a gross head of 273 meters and is expected to produce about 100 million kilowatt-hours of energy in an average water year. The power plant switchyard would be located adjacent to the plant. Considerable excavation will be required to level the switchyard area. A description and cost estimate of the switchyard and transmission system are discussed in this section under "Transmission System". The estimated cost of the Balloune Power Plant is LL. 7,300,000.

The total estimated cost of the Balloune Power Unit, exclusive of the switchyard and transmission system, but including contingencies, engineering, supervision, and interest charges during construction, is LL. 15,240,000. The cost estimates for features of the Balloune Power Unit are shown in Table VIII-1 and are discussed in Section VIII - COSTS AND BENEFITS.

Jeita Unit. This unit would be located along the north side of the Nahr el Kelb between Jeita Spring at elevation 60 meters and the Beirut Water Supply intake structure at elevation 23 meters. Two plans of development for this unit were considered. The first plan which is here proposed for adoption, would disregard the existing power plants and pertinent features, except the canal for the Hrach Power Plant which would be modified and used as a component part of this unit. The proposed unit would consist of the Jeita Diversion Dam, Canal, Penstock Gate Structure, Penstock, and Power Plant. This plan would also include a collection system for intercepting the flow of the several springs in the Jeita Spring Area.

The second plan considered would develop the hydroelectric potentialities between the Hrach Power Plant and the Beirut Water Supply Intake Structure. It would disregard the other two existing very small power plants, but would not alter the existing or proposed features of the Hrach Power Plant. This alternate plan should be given detailed consideration in the event it is desired to immediately improve the Beirut Water System by utilizing only the clear water from Jeita Spring.

What is locally called Jeita Spring is really a group of springs geologically connected as discussed in Section IV - GEOLOGY. The proposed Jeita Diversion Dam would be constructed upstream from the highest point of discharge from this group of springs. Consideration was given to a plan where the diversion dam would be constructed downstream from the lowest point of discharge from this group of springs, but this would require a fairly high dam which would result in considerable back pressure on the springs. As a result, the flow of the spring might be caused to break out further downstream. Additional geologic investigations should be made before the final site is selected.

The diversion dam would consist of a low, concrete ogee spillway section with pertinent sluiceways, abutments, and wingwalls. The spillway section would have a crest elevation of 60 meters and a length of about 40 meters. A flume conveying the water discharged from the Balloune Power Plant would be constructed along, and form a component part of, the right abutment and wingwalls. The inlet gates would be installed in this flume so that the water flowing in the Nahr el Kelb could be diverted to the Jeita Unit or discharged through the diversion dam sluiceway. Thus, the clear water from the Balloune Power Plant could be conveyed to the Beirut Water System along with the water from Jeita Spring, without being mixed with the muddy water flowing in the Nahr el Kelb following heavy rains. The estimated cost of the diversion dam including the flume from the Balloune Power Plant, is LL. 400,000.

A system of underground galleries and drains would be constructed to collect the water from the secondary springs situated in the riverbed just below the dam. This water would be conveyed to a sump from which it would be pumped into the flume proposed for construction between the diversion dam and the principle source of Jeita Spring. The cost estimate for this system including pumping equipment, is LL. 100,000.

The flume leading from the diversion dam to the principle source of Jeita Spring would be 200 meters long, constructed of reinforced concrete, and designed for a capacity of 15 cubic meters. It would be connected to the existing Hrach Power Plant Headworks and Flume located just below the principle source of Jeita Spring.

The existing Hrach Power Plant Flume is 350 meters long and has an invert elevation at Jeita Spring of 58. 3 meters and 57. 1 meters at the end of the flume. The flume would be enlarged to a 15-cubic meter per second capacity by either increasing its width or depth. As this flume was constructed of concrete plastered masonry, it is believed that enlargement would be best accomplished by removing and rebuilding the downhill wall.

A concrete flume 1, 400 meters long would be constructed from the end of the Hrach Flume to the Jeita Penstock Gate Structure situated in the Nahr el Kelb Canyon above the Beirut Water Supply Intake Structure. It would be designed for a capacity of 15 cubic meters per second and would have an invert elevation of 56 meters at the gate structure. A small siphon would be required to cross a small ravine near the end of the flume. The estimated cost of the Jeita Conduit, including modifications of the existing Hrach Flume and the sections of flume between the Balloune Power Plant, Jeita Diversion Dam, and the intake of the Hrach Flume, is LL. 1, 300, 000.

The Jeita Penstock Gate Structure would be constructed at the end of the Jeita Flume. It would include an emergency penstock gate, bypass gates, overflow spillway section, and chute. The chute would convey to Nahr el Kelb the water discharged by the bypass gates and spillway. A single steel penstock with an average diameter of 2. 2 meters would convey the water from the gate structure to the Jeita Power Plant. The penstock would have an invert elevation of 56 meters at the gate structure and 22 meters at the power plant. It would be 125 meters long and would be constructed over terrain having a fairly uniform slope. No unusual problems are anticipated during the construction of the penstock. The estimated cost of the Jeita Penstock is LL. 150, 000 complete with the gate structure.

The Jeita Power Plant would be located on the Nahr el Kelb about 100 meters upstream from the Beirut Water Supply Intake Structure. The power plant will discharge into a tailrace that would be connected directly to the inlet structure for the Beirut Water Supply System. Thus, water discharged from the Jeita Power Plant could be diverted into the Beirut Water Supply System without mixing with water flowing in the Nahr el Kelb.

The power plant would have an installed capacity of 4, 200 kilowatts in one or two units direct-connected to reaction type turbines. This plant would have a gross head of 35 meters and would produce about 19 million kilowatt-hours of energy in an average water year. The power plant switchyard would be a short distance downstream from the power plant. The generators are planned for a voltage of 5. 5 kilovolts for direct connection with the local distribution system. A description and cost estimate of the switchyard and transmission system are discussed in this section under "Transmission System". The estimated cost of the Jeita Power Plant is LL. 2, 500, 000.

The total cost of the Jeita Power Unit, exclusive of the switchyard and transmission system, but including contingencies, engineering, supervision, and interest charges during construction, is LL. 4, 350, 000. The cost estimate for features of the Jeita Power Unit are shown in Table VIII-1 and discussed in Section VIII - COSTS AND BENEFITS.

Canal, leading from Jeita Spring to the Hrach Power Plant.

Sanitized Copy Approved for Release 2011/06/21 : CIA-RDP80T00246A003400510001-7

TABLE VI-1

PERTINENT DATA - PROPOSED HYDROELECTRIC POWER DEVELOPMENT
NAHR EL KELB BASIN

Feature	Hardoun Unit	Mayrouba Unit	Qlayaat Unit	Balloune Unit	Jeita Unit
Dam and Reservoir	(5 dams)				
Crest Elevation	1521-1632m.	1, 217 m.	795 m.	363 m.	60 m.
Storage Capacity	Nil	$20x10^6m^3$	Nil	$150,000m^3$	Nil
Tunnel	Free-flow	Free-flow	Free-flow	Free-flow	
Diameter	2. 0 m.	2. 2 m.	2. 2 m.	2. 2 m.	--
Length	250 m.	1, 900 m.	2, 300 m.	2, 500 m.	--
Conduit					
Diameter	--	--	--	2. 2 m.	--
Length	--	--	--	2, 500 m.	--
Canal					
Capacity	$1.5\text{-}4m^3/s$	$10m^3/s$	--	--	$15m^3/s$
Length	9, 620 m.	3, 200m.	--	--	1, 900m.
Penstock					
Diameter	1. 1 m.	1. 8 m.	1. 8 m.	1. 9 m.	2. 2 m.
Length	1, 400m.	800m.	1, 180m.	820 m.	125 m.
Power Plant					
Gross Head	296 m.	362 m.	422 m.	270 m.	36 m.
Turbines	Impulse	Impulse	Impulse	Impulse	Reaction
Generators	1-10, 000kw.	2-14, 500kw.	2-17, 000kw.	2-13, 000kw.	1-4, 200kw.
Total Capacity	10, 000 kw.	29, 000 kw.	34, 000 kw.	26, 000 kw.	4, 200 kw.
Annual Generation (Million KWH)	33	54	68	100	19

Capabilities of the Hydroelectric Development

It is estimated that the proposed Hardoun, Mayrouba, Qlayaat, Balloune, and Jeita Power Plants can produce a total of about 113 million kilowatt-hours of energy in a minimum water year, and 274 million kilowatt-hours of energy in an average water year. One of the principle features of this development is the proposed Mayrouba Reservoir with 20 million cubic meters of usable storage. Without this reservoir the downstream power plants could generate only during the months of January through May, a time when all other potential hydro developments in Lebanon are at their best, thus producing only fuel replacement power. With this reservoir it is possible to store water during the spring months and release it during the summer and autumn months, thereby permitting dependable peaking capacity throughout a minimum water year. Also, this type of reservoir operation is particularly beneficial for the supply of domestic water to Beirut and various villages where there is a water shortage during the summer months of dry water years.

As a result of hydrologic studies, it is estimated that the quantity of water shown to be available in a minimum water year is sufficient to provide dependable peaking capacity of 80, 000 kilowatts for a load peaking at 145, 000 kilowatts. Table VI-2 shows probable monthly generation at each plant for minimum and average water years.

TABLE VI-2

PROBABLE MONTHLY GENERATION
HYDROELECTRIC POWER PLANTS
NAHR EL KELB BASIN

(in millions of kilowatt-hours)

Month	Hardoun Min. Year	Hardoun Avg. Year	Mayrouba Min. Year	Mayrouba Avg. Year	Qlayaat Min. Year	Qlayaat Avg. Year	Balloune Min. Year	Balloune Avg. Year	Jeita Min. Year	Jeita Avg. Year	Total Min. Year	Total Avg. Year
Jan.	2.0	4.3	3.4	9.1	4.2	12.0	4.7	16.0	0.9	2.6	15.2	44.0
Feb.	2.8	5.9	0.4	6.5	1.0	8.8	4.8	16.3	1.0	2.8	10.0	40.3
Mar.	4.6	7.3	0.4	5.2	1.0	7.5	4.8	17.3	1.1	3.0	11.9	40.3
Apr.	5.9	7.1	0.4	5.5	1.2	7.4	7.0	15.0	1.5	2.8	16.0	37.8
May	1.1	5.2	0.4	5.9	0.8	6.9	3.4	9.9	0.9	2.1	6.6	30.0
June	0	1.4	1.4	3.3	1.6	3.9	2.3	5.6	0.7	1.3	6.0	15.5
July	0	0	1.4	3.0	1.5	3.4	1.0	3.7	0.4	1.0	4.3	11.1
Aug.	0	0	1.8	1.9	1.9	2.0	1.3	1.4	0.4	0.5	5.4	5.8
Sept.	0	0	2.0	2.0	2.1	2.1	1.4	1.4	0.4	0.4	5.9	5.9
Oct.	0	0	2.4	2.7	2.9	3.0	1.9	1.9	0.4	0.5	7.6	8.1
Nov.	0.1	0.3	2.9	3.3	3.4	3.9	2.2	2.9	0.5	0.7	9.1	11.1
Dec.	0.8	1.8	3.9	5.7	4.8	7.1	4.5	8.0	0.9	1.4	14.9	24.0
Total	17.3	33.3	20.8	54.1	26.4	68.0	39.3	99.4	9.1	19.1	112.9	273.9

Nahr el Kelb Thermal Power

A thermal electric power plant would be required to firm the power produced by the proposed hydroelectric development, as this hydroelectric development would only produce peaking capacity throughout a minimum water year and during the summer and fall months of an average water year. The most probable location for this plant is at the site of the Zouk Mikael Steam Power Plant now under construction by the Beirut Electricity Company. The Zouk Mikael Plant, also known as the Chamoun Plant, is planned to have an ultimate installation of 90,000 kilowatts. The first unit of 15,000 kilowatts is now completed. This first 15,000 kilowatt unit is necessary to firm the existing hydro installations on the Beirut system; the remaining 75,000 kilowatts has been proposed in the Nahr Ibrahim Basin Report to be used to firm that hydro development. It should be possible either to install additional capacity in the Zouk Mikael Plant to firm the Nahr el Kelb development or to construct another thermal plant on the coast between the Zouk Mikael Plant and Beirut.

It is estimated that the proposed Nahr el Kelb hydroelectric development would require 65,000 kilowatts of thermal electric generating capacity to properly firm the hydroelectric output in a minimum water year. For the purposes of this report this thermal power plant is assumed to be located near Dbaiye. The load, located principally in the Beirut area, which would best utilize this hydro and thermal capacity is estimated to have a peak requirement of about 138,000 kilowatts and an annual energy requirement of about 620 million kilowatt-hours. Considering probably transmission losses, it is estimated that the hydro and thermal power plants would have to be capable of producing a peak of about 145,000 kilowatts and annual energy of 645 million kilowatt-hours. It is estimated that the thermal power plant would have to produce about 532 million kilowatt-hours in a minimum water year and about 371 million kilowatt-hours in an average water year.

The estimated construction cost for a 65,000 kilowatt thermal electric generating plant is LL. 42,500,000 at the generator bus. This plant would be connected to the proposed 69-kv. transmission system. Features of this transmission system are discussed in this section under "Transmission System". Estimates of the annual cost of operation of this plant are discussed in Section VIII - COSTS AND BENEFITS.

Hydro Thermal Operation

Available reservoir capacity in the Nahr el Kelb Basin is very limited. On the Nahr Hardoun and Nahr es Samm branches, reservoir capacity is practically nonexistent. It would be useful if sufficient reservoir capacity could be found on these streams to regulate the peak discharges during storms. On the Nahr es Salib there is a topographical site near Mayrouba which is proposed to be developed for a storage of 20 million cubic meters. Above Mayrouba, at the Hardoun Dam Site it is not possible to obtain even sufficient storage for daily pondage, except by construction of an artificial reservoir. At the Balloune Dam Site, on the Nahr el Kelb below the junction of the three branches, it is possible to obtain sufficient capacity for daily pondage which would permit the regulation of peaking discharges from the Mayrouba and Qlayaat Power Plants.

In the operation studies it was assumed that there would be sufficient pondage in the forebay and canals leading to the Hardoun Power Plant to permit its operation on the peak of the load curve in December of a minimum water year. It was assumed that the Mayrouba Reservoir would be operated to store most of the flow from February through May and to release these flows from July through January. Furthermore, these flows would be released in a manner to permit the Mayrouba and Qlayaat Power Plants to be operated on the peak of the load curve most of the time. The forebay at Balloune would permit this plant to be operated on the 16-hour portion of the load curve during times of low water flow. It was assumed that the canal feeding the Jeita Power Plant would be able to reregulate the flows from the Balloune Plant during times of low flow. The results of this operation are given in Table VI-2.

The proposed Nahr el Kelb hydroelectric installation, when operated in conjunction with a thermal power plant of 65,000-kilowatts capacity, is estimated to be able to supply a load peaking at 145,000 kilowatts. The estimated monthly energy distribution as generated at the hydro and thermal power plants in both a minimum and average water year is shown in Table VI-3. This table was prepared from data obtained from Plates A-8,-9, and -10 in Appendix A - POWER MARKET STUDY - LOAD AREA I.

TABLE VI-3

ESTIMATED HYDROELECTRIC AND THERMALELECTRIC
MONTHLY ENERGY DISTRIBUTION
NAHR EL KELB BASIN

(capacity in kilowatts, energy in millions of kilowatt-hours)

	Load Requirements		Average Water Year		Minimum Water Year	
Month	Capacity	Energy	Hydro Energy	Thermal Energy	Hydro Energy	Thermal Energy
Jan.	138,800	58.7	44.0	14.7	15.2	43.5
Feb.	137,000	52.3	40.3	12.0	10.0	42.3
Mar.	135,700	55.5	40.3	15.2	11.9	43.6
Apr.	134,100	51.6	37.8	13.8	16.0	35.6

TABLE VI - 3 (Continued)

Month	Load Requirements		Average Water Year		Minimum Water Year	
	Capacity	Energy	Hydro Energy	Thermal Energy	Hydro Energy	Thermal Energy
May	130, 200	52.9	30.0	22.9	6.6	46.3
June	124, 000	51.6	15.5	36.1	6.0	45.6
July	122, 200	51.0	11.1	39.9	4.3	46.7
Aug.	120, 400	51.0	5.8	45.2	5.4	45.6
Sept.	115, 600	49.6	5.9	43.7	5.9	43.7
Oct.	119, 000	52.9	8.1	44.8	7.6	45.3
Nov.	127, 200	55.5	11.1	44.4	9.1	46.4
Dec.	145, 000	62.5	24.0	38.5	14.9	47.6
Total	145, 000	645.1	273.9	371.2	112.9	532.2

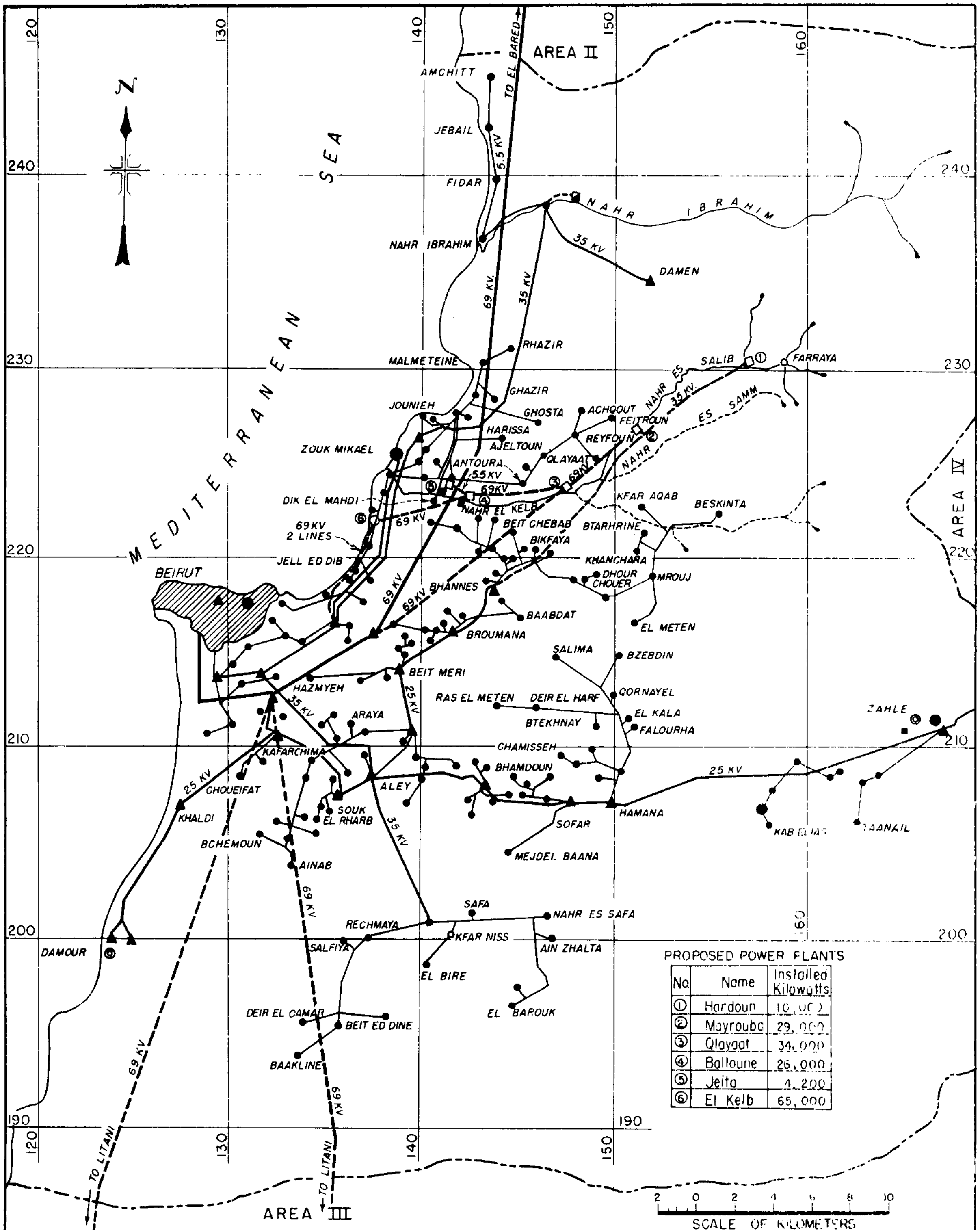
Transmission System

Although final determination of the transmission voltages should be made in future detailed studies, these investigations assumed a 69-kilovolt transmission system to connect the hydro and thermal plants of the Nahr el Kelb Basin development and would extend to the load center at Beirut. The general location of this system is shown on Plate VI-5. This reconnaissance study also assumed that a 35-kv. transmission line would be constructed to interconnect the Hardoun Power Plant with the 69-kv. system at the Mayrouba Power Plant; and continue to Bhannes to connect with a 25-kv. line from Beirut, which is expected to be changed to 35-kv. in the near future. The existing 5. 5-kv. village transmission system would be interconnected with this system at the Jeita Power Plant and at substations on the proposed 35-kv. transmission system. Bureau of Reclamation standard designs for wood pole, H-frame construction with ACSR conductors and steel overhead ground wires would be used for all 69-kv. lines in the system, and single pole construction for the 35-kv. lines.

It is estimated that 40 kilometers of 69-kv. line and about 20 kilometers of 35-kv. line would be required. This includes 2 lines from the thermal plant to Beirut, one line from the hydroplants to the thermal plant, and one line from the Qlayaat Plant direct to Beirut. Construction costs for these transmission lines, including contingencies, engineering, and supervision are estimated at LL. 25, 000 per kilometer, or LL. 1, 000, 000 for the 69-kv. lines; and LL. 15, 000 per kilometer, or LL. 300, 000 for the 35-kv. lines, making a total of LL. 1, 300, 000 for all of the transmission lines required.

The substations and switchyards for the 69-kv. system would be the outdoor type, with an indoor control station and station service equipment. The double-bus, single circuit breaker scheme of connections with one transfer breaker would be used. American practice for substation and switchyard connections uses one main and one auxiliary bus, while European practice uses two main busses. Construction costs of both arrangements are about equal. Since substations and switchyards presently installed in Lebanon follow the European practice, this system has been adopted and is shown on the single line diagram on Plate VI-6.

All transformers would be of the three-phase type, oil-immersed, and with natural cooling. The transformers for use with the generating units would be of the two-winding type with delta connection on the low voltage side and a grounded wye connection on the high voltage side.



PROPOSED POWER PLANTS

No.	Name	Installed Kilowatts
①	Hardoun	10,000
②	Mayrouba	29,000
③	Qlayaat	34,000
④	Balloune	26,000
⑤	Jeita	4,200
⑥	El Kelb	65,000

LEGEND

	Existing	Under Cons.	Proposed
Hydro Power Plant	■	▣	□
Thermal Power Plant	●	◕	○
Substation 25 kv. or larger	▲	▲	△
Substation 5.5 kv. and village	•	•	○
Transmission lines 25 kv. or larger	———		— — —
Transmission lines 5.5 kv.	═══		- - - -
Village (other than shown with Sub)	◎		

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
WATER RESOURCES RECONNAISSANCE

TRANSMISSION SYSTEM
LOAD AREA I
NAHR EL KELB DEVELOPMENT

DRAWN C.S.G. SUBMITTED C. J. Gysland
TRACED E.A.H. RECOMMENDED
CHECKED APPROVED
BEIRUT, LEBANON FEB. 1953 OA - 10 - 874

PLATE VI - 5

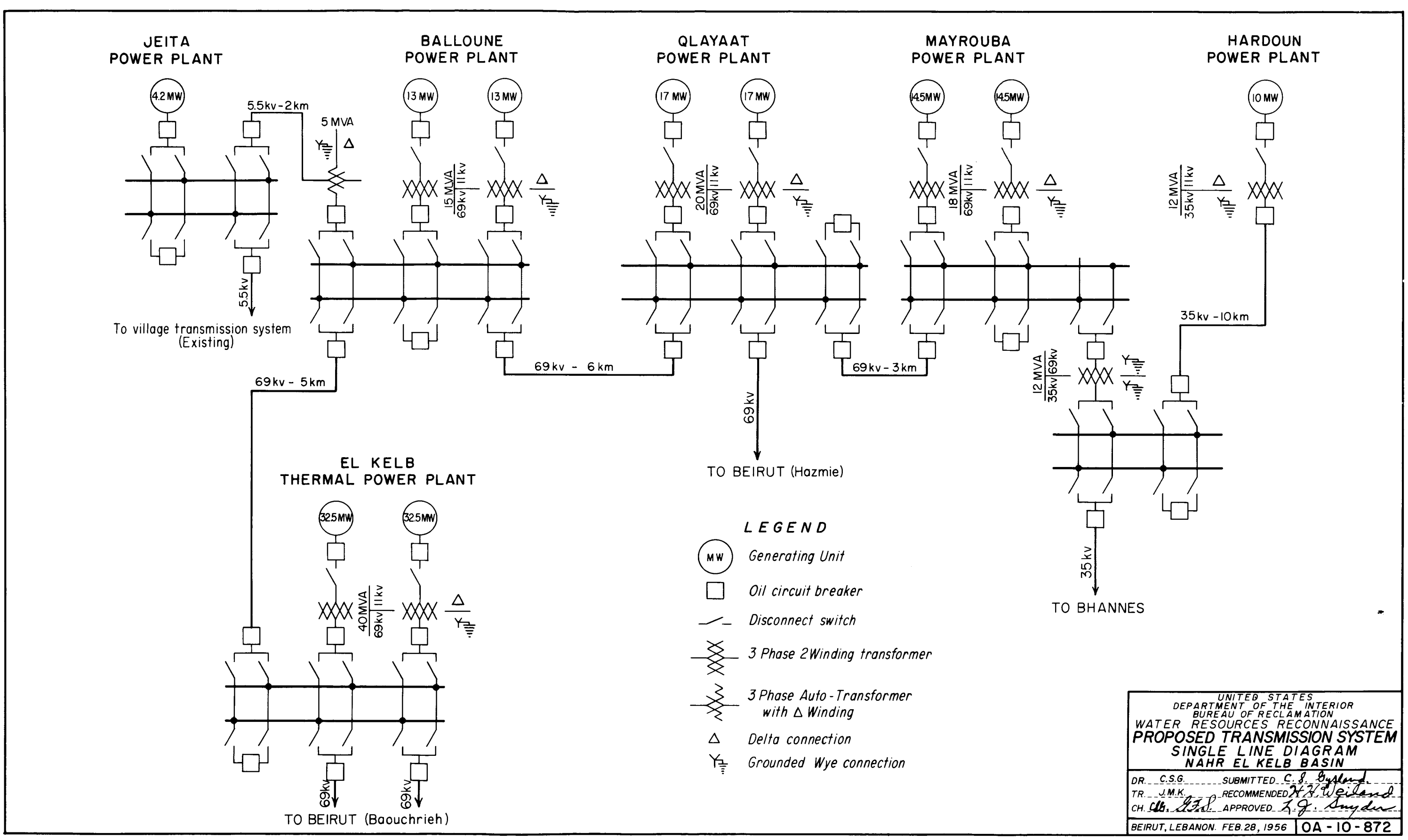

JEITA POWER PLANT
BALLOUNE POWER PLANT
QLAYAAT POWER PLANT
MAYROUBA POWER PLANT
HARDOUN POWER PLANT
4.2 MW
5.5kv - 2km
5 MVA
13 MW
13 MW
15 MVA 69kv/11kv
17 MW
17 MW
20 MVA 69kv/11kv
14.5 MW
14.5 MW
18 MVA 69kv/11kv
10 MW
12 MVA 35kv/11kv
5.5kv
To village transmission system (Existing)
69kv - 5km
69kv - 6km
69kv - 3km
35kv - 10km
12 MVA 35kv/69kv
69kv
TO BEIRUT (Hazmie)
EL KELB THERMAL POWER PLANT
32.5 MW
32.5 MW
40 MVA 69kv/11kv
69kv
69kv
TO BEIRUT (Baouchrieh)
35kv
TO BHANNES
LEGEND
MW Generating Unit
Oil circuit breaker
Disconnect switch
3 Phase 2 Winding transformer
3 Phase Auto-Transformer with Δ Winding
Δ Delta connection
Grounded Wye connection
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
WATER RESOURCES RECONNAISSANCE
PROPOSED TRANSMISSION SYSTEM
SINGLE LINE DIAGRAM
NAHR EL KELB BASIN
DR. C.S.G. SUBMITTED C. S. Gyllend
TR. J.M.K. RECOMMENDED H. V. Weiland
CH. APPROVED L. J. Snyder
BEIRUT, LEBANON FEB. 28, 1956
OA-10-872

PLATE VI-6

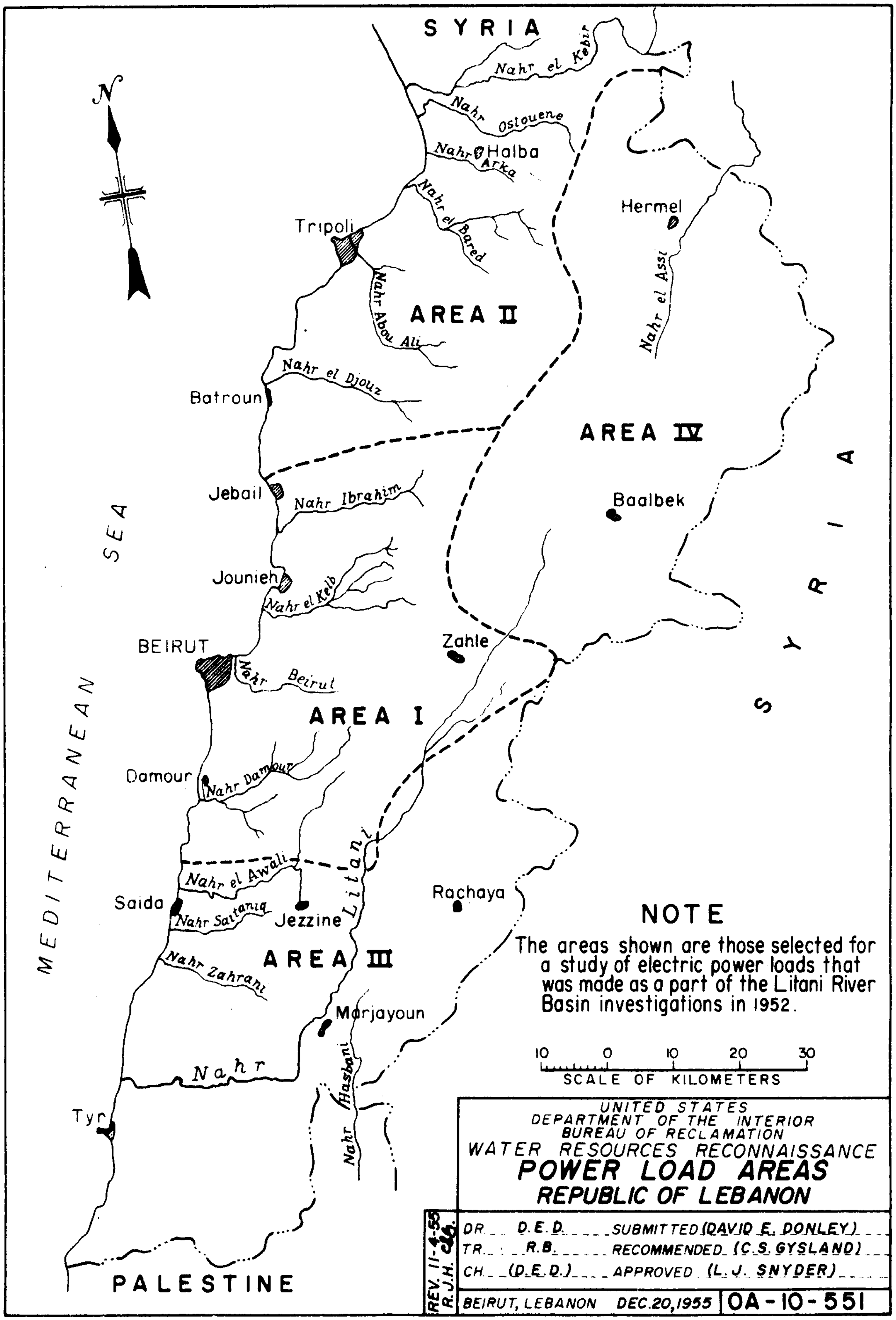

SYRIA
N
Nahr el Kebir
Nahr Ostouene
Nahr Halba Arka
Nahr el Bared
Tripoli
Hermel
Nahr el Assi
Nahr Abou Ali
AREA II
Nahr el Djouz
Batroun
AREA IV
Jebail
Nahr Ibrahim
Baalbek
SEA
Jounieh
Nahr el Kelb
SYRIA
BEIRUT
Zahle
Nahr Beirut
AREA I
MEDITERRANEAN
Damour
Nahr Damour
Nahr el Awali
Litani
Rachaya
Saida
Nahr Saitaniq
Jezzine
AREA III
Nahr Zahrani
Marjayoun
Nahr Hasbani
Nahr
Tyr
PALESTINE
NOTE
The areas shown are those selected for a study of electric power loads that was made as a part of the Litani River Basin investigations in 1952.
10 0 10 20 30
SCALE OF KILOMETERS
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
WATER RESOURCES RECONNAISSANCE
POWER LOAD AREAS
REPUBLIC OF LEBANON
REV. 11-4-55 R.J.H.
DR. D.E.D. SUBMITTED (DAVID E. DONLEY)
TR. R.B. RECOMMENDED (C.S. GYSLAND)
CH. (D.E.D.) APPROVED (L.J. SNYDER)
BEIRUT, LEBANON DEC. 20, 1955
OA-10-551

PLATE VI-7

Circuit breakers would be the outdoor type, oil-filled with arc controlling devices such as oil-blast, deion grids, etc. An interrupting rating of 1,000 MVA would be used for the 69-kv. breakers with an interrupting time of 8 cycles. Disconnecting switches would be motor operated. Complete protection of substations and switchyards would be provided by means of lightning arrestors, protective relays, and fire extinguishing equipment. Telephony and telemetering between all substations and the dispatching station would be provided by means of carrier-current equipment.

The construction costs for 69-kv. substations and switchyards are dependent upon the number of transformers, circuit breakers, disconnect switches, etc., and upon the MVA capacity of the transformers. Therefore, the required substations and switchyards have been divided into bays to facilitate the estimating of construction costs. The cost of a 69-kv. power transformer bay, complete with transformer, circuit breaker, and associated switchgear, is estimated at LL. 320,000 plus LL. 24,000 multiplied by the MVA capacity of the transformer. The cost of a 69-kv. line, or bus-tie bay, complete with circuit breaker and associated switchgear, is estimated at LL. 180,000. Each of these bays would be complete with its foundations, structures, footings, fittings, connectors, conduit, bus and grounding copper, control panel and cables, miscellaneous accessories, and its share of battery plant and carrier-current equipment. The cost of the complete substation or switchyard has been obtained by combining the cost of the various bays. The following tabulation shows the estimated cost of the switchyards and substations required for the 69-kv. system:

<u>Switchyards</u>		
Hardoun Plant	LL.	350,000
Mayrouba Plant		2,700,000
Qlayaat Plant		2,330,000
Balloune Plant		2,220,000
Jeita Plant		100,000
El Kelb Thermal Plant		3,300,000
TOTAL:	LL.	11,000,000
<u>Substations</u>		
Beirut Substations	LL.	5,400,000

The 35-kv. village transmission system would require about 5 step-down substations, each with a capacity of 500 KVA for transforming 35-kv. to 5.5-kv. Each of these substations would cost about LL. 20,000 for a total cost estimate of LL. 100,000.

The estimated cost of the entire transmission system, including contingencies, engineering, supervision, and interest charges, is LL. 17,800,000.

Power Market Study - Load Area I

A study of the existing and potential power markets in Lebanon was made as a part of investigations for the "Development Plan for the Litani River Basin"4/. To facilitate the study of loads and their characteristics, Lebanon was divided into four principle load areas based upon such factors as natural geographical separations, locations of existing power systems, boundaries of political subdivisions, and boundaries of concessionary load areas. These areas were designated Areas I, II, III, and IV, and their boundaries are shown on Plate VI-7. Area I contains the Nahr el Kelb Basin as well as the basins of the Nahr Ibrahim, the Nahr Beirut, and the Nahr Damour. The results of the power market study for Load Area I are contained in Appendix A.

<u>Sequence of Development.</u> The Development Plan for the Litani River has been adopted by the Lebanese Government, and construction of the Litani River Project is expected to start during 1956. The schedule of development for the Litani Project has been arranged so that this project with the existing developments will supply all of the electric energy required in Lebanon until about 1980. It appears, therefore, that further

second; but only 70.8 liters per second are available. Therefore, an additional 21.2 liters per second are needed. (See Table VII-2.)

power development on the Nahr el Kelb need not be undertaken during the next 15 to 25 years, providing that the Litani Project is constructed on schedule and as proposed in the Development Plan for the Litani River Basin. This will provide ample opportunity to collect and analyze the additional data necessary to develop detailed plans for the multiple purpose use of the water resources of this basin.

It may become desirable to construct the Mayrouba Reservoir to provide an additional domestic water supply for Beirut and certain villages in this area, before the time that increased power loads develop to require construction of the proposed Nahr el Kelb power development. If such is the case and the Mayrouba Reservoir is constructed primarily for domestic water supply, it may then be desirable to construct certain of the proposed Nahr el Kelb power units and reschedule the construction of remaining units of the Litani Project. The problem of deciding a schedule for construction of the various potential hydroelectric power plants in Lebanon is complex and will require considerable

TABLE VII-1

MISCELLANEOUS SPRING FLOW MEASUREMENTS
NAHR EL KELB BASIN

Name of Spring	Location by Map Coordinates	Date Measurements Taken	Discharge Measurements (Liters per Sec.)
Nabaa el Assal	230.0 N - 160.4 E	Nov. 20, 1938	362.0
" "	" "	Oct. 3, 1939	262.0
" "	" "	Oct. 1, 1940	287.0
" "	" "	July 30, 1947	462.0
" "	" "	Oct. 21, 1948	201.0
" "	" "	Aug. 14, 1951	312.0
" "	" "	Oct. 22, 1951	219.0
" "	" "	Nov. 2, 1951	220.0
" "	" "	July 4, 1952	500.0
" "	" "	Oct. 13, 1955	218.0
" "	" "	Nov. 29, 1955	532.0
Nabaa Membourkh	220.3 N - 157.6 E	June, 1925	30.0
Jeita Spring	223.0 N - 142.2 E	Dec. 8, 1952	1786.0
" "	" "	Nov. 5, 1953	1674.0
" "	" "	Oct. 18, 1955	1117.0
Nabaa el Jozat	225.8 N - 156.7 E	Jan. 13, 1956	141.0
Nabaa el Jamajeme	221.5 N - 156.7 E		
Nabaa el Leben	228.5 N - 159.5 E	Aug. 8, 1955	51.0
" "	" "	Oct. 13, 1955	22.0
" "	" "	Nov. 30, 1955	182.0
Nabaa el Kana	233.7 N - 157.6 E	Dec. 2, 1955	57.0
Nabaa el Mogharah	230.4 N - 156.8 E	Jan. 12, 1956	75.0
Nabaa Chabrouka	232.5 N - 160.0 E	Dec. 2, 1955	27.0
Nabaa es Sakie	228.2 N - 157.6 E	Dec. 6, 1955	27.0
Nabaa Nakich } Anna	225.0 N - 158.5 E	Jan. 9, 1956	7.5
Nabaa Delbi } Nakich Gr.	" "	Jan. 9, 1956	2.8
Nabaa Jafer	225.8 N - 158.4 E	Jan. 9, 1956	7.5
Nabaa Ghabieh	229.9 N - 161.0 E	Jan. 12, 1956	11.0
Nabaa Sanine	222.8 N - 161.0 E	Aug. 12, 1955	26.0
" "	" "	Oct. 10, 1955	14.5
Achôuche Spring	223.0 N - 142.1 E	Dec. 8, 1952	479.0
" "	" "	Nov. 5, 1953	263.0
Ain el Souane	230.7 N - 154.2 E	Nov. 29, 1955	1.5
Ain Tannour	231.1 N - 154.7 E	Nov. 29, 1955	3.0

TABLE VII-2

POPULATION AND WATER REQUIREMENTS of VILLAGES RECEIVING WATER FROM NAHR EL KELB BASIN

Villages in Kesrouan District Receiving Water From Nabaa el Aassel

Name of Village	Elevation 1/	Population Summer 2/	Population Winter 3/	Domestic Water Needs 4/ (Lit/Sec)	Present Sources and Quantity Available: Nabaa el Aassel (Lit/sec)	Present Sources and Quantity Available: Other (Lit/sec.)	Additional Water Needed: Amount (Lit/sec.)
Ferraya	1350	2,000	940	3.48			
Harjel	1350	3,000	1,199	5.21			
Mayrouba	1350	1,400	500	2.43			
Ain el Jorn	1450	300	300	0.52			
Mazrat Kfar-debiane	1350	3,000	2,800	5.21			
Faitroun	1260	2,000	565	3.48			
Reyfoun	1170	1,600	740	2.78			
Qlayaat	1100	1,200	879	2.08			
Darayah	750	350	300	0.61			
Ajeltoun	920	5,000	3,000	8.69			
Balloune	800	215	115	0.37			
Sohaile	680	500	414	0.87			
Jita	450	860	805	1.41			
Ain Tehili	380	330	280	0.57			
Antoura	300	450	550	0.96			
Mosbeh	220	546	750	1.30			
Zouk Mikael	50	2,000	2,204	3.48			
Sarba	250	(See Jounieh)					
Jounieh & Vicinity	150	20,000	21,000	36.5	Total Allocated equals 52.10	18.70	
Sahel Alma	50	(See Jounieh)					
Malmeteine	50	150	300	0.52			
Achqout	1070	3,000	990	5.21			
Bzoumar	950	266	175	0.46			
Achqout el Quala	750	350	350	0.61			
Morhrab	830	360	360	0.63			
Ghosta	800	2,000	1,568	3.48			
Daraoun	650	1,600	1,338	2.78			
Harissa	650	225	167	0.39			
Batta	650	232	275	0.43			
TOTALS:		52,934	42,840	92.00	52.10	18.70	21.20

1/ Possible Reservoir Elevation - Taken from Map, Scale 1/50,000.
2/ Populations Estimates taken from 1953-54 "Villages Economic Survey" made jointly by the Ministry of National Economy and USOM/Lebanon.
3/ Official Populations supplied by GOL Ministry of Interior.
4/ Maximum Population x 150 liters / 86,400 sec. = Liters per Second

TABLE VII-3

POPULATION AND WATER REQUIREMENTS
OF
VILLAGES RECEIVING WATER FROM NAHR EL KELB BASIN

Villages in Meten District Receiving Water from
Nabaa el Aassel and Nabaa Membourkh

Name of Village	Elevation 1/	Population: Summer 2/	Population: Winter 3/	Domestic Water Needs 4/ (Lit/sec.)	Present Sources and Quantity Available: Nabaa el Aassel & Membourkh (Lit/sec.)	Present Sources and Quantity Available: Other	Additional Water Needed: Amount (Lit/sec.)
Beskinta	1350	5,260	5,260	8.69	23.4 liters/sec.from Nabaa el Aassel; 11.4 liters/sec.from Nabaa Membourkh	1.2	
Mrouj	1270	1,400	555	2.43		(Local Springs)	
Khanchar	1100	3,120	1,820	5.42			
Jouar	1000	310	150	0.54			
Chouer	1200	6,500	3,600	11.30			
Sefsaf	1190	220	220	0.38			
Ain Sindiani	1150	350	250	0.61			
Dhour Chouer	1275	200	180	0.35			
Mar Chouaya	1070	200	140	0.35			
Bikfaya	1000	4,200	2,755	7.30			
Bahr Saf	1000	2,300	1,350	4.00			
Jeita	780	550	520	0.90			
Wadi Chahin	700	400	400	0.70			
Beit Chebab	780	4,000	3,635	6.95			

1/ Possible Reservoir Elevation - Taken from Map, Scale 1/50,000
2/ Populations Estimates taken from 1953-54. Village Economic Survey made jointly by the Ministry of National Economy and USOM/Lebanon.
3/ Official Populations supplied by GOL Ministry of Interior.
4/ $\frac{\text{Maximum Population x 150 liters}}{\text{86,400 sec.}}$ = Liter per Second

TABLE VII-3 (Continued)

Name of Village	Ele- vation 1/	Population Summer 2/	Population Winter 3/	Domestic Water Needs 4/ (liters/sec.)	Present Sources And Quantity Available: Nabaa el Aassel & Membourkh (liters/sec.)	Present Sources And Quantity Available: Other	Additional Water Needed: Amount (liters/sec.)
Beit Rhaiam	580	310	310	0.54	23.4 liters/sec. from Nabaa el Aassel 11.4 liters/sec. from Nabaa Membourkh		
Fraike	580	400	310	0.70			
Qornet el Hamra	400	550	500	0.96			
Mazrat Yechou	430	400	400	0.70			
Qornet Chahouane	680	1,220	1,000	1.74			
Ain Aar	700	500	225	0.87			
Dik el Mahdi	360	160	215	0.37			
Ain Sefsaf	1000	220	220	0.38			
Khaly	1100	150	150	0.26			
Daouar	1200	2,600	600	4.51			
Mar Moussa	1000	160	160	0.28			
Mazrat ech Chaar	370	400	400	0.70			
M'Taileb	390	160	160	0.28			
Bannes	1000	500	300	0.87			
Baabdat	850	1,500	750	2.61			
Broumana and Ghabie	800	5,260	1,700	9.14			
Nbaye	550	750	750	1.30			
Roumie	700	1,600	850	2.78			
Beit Meri	750	10,000	3,000	17.35			
Ain Saade	700	1,500	700	2.61			
Ain Kafra	650						
El Mansouryet	420	850	850	1.48			
M Kalles	200	400	385	0.70			
Totals:		58,600	37,060	101.40	34.8	1.2	65.40

TABLE VII-6

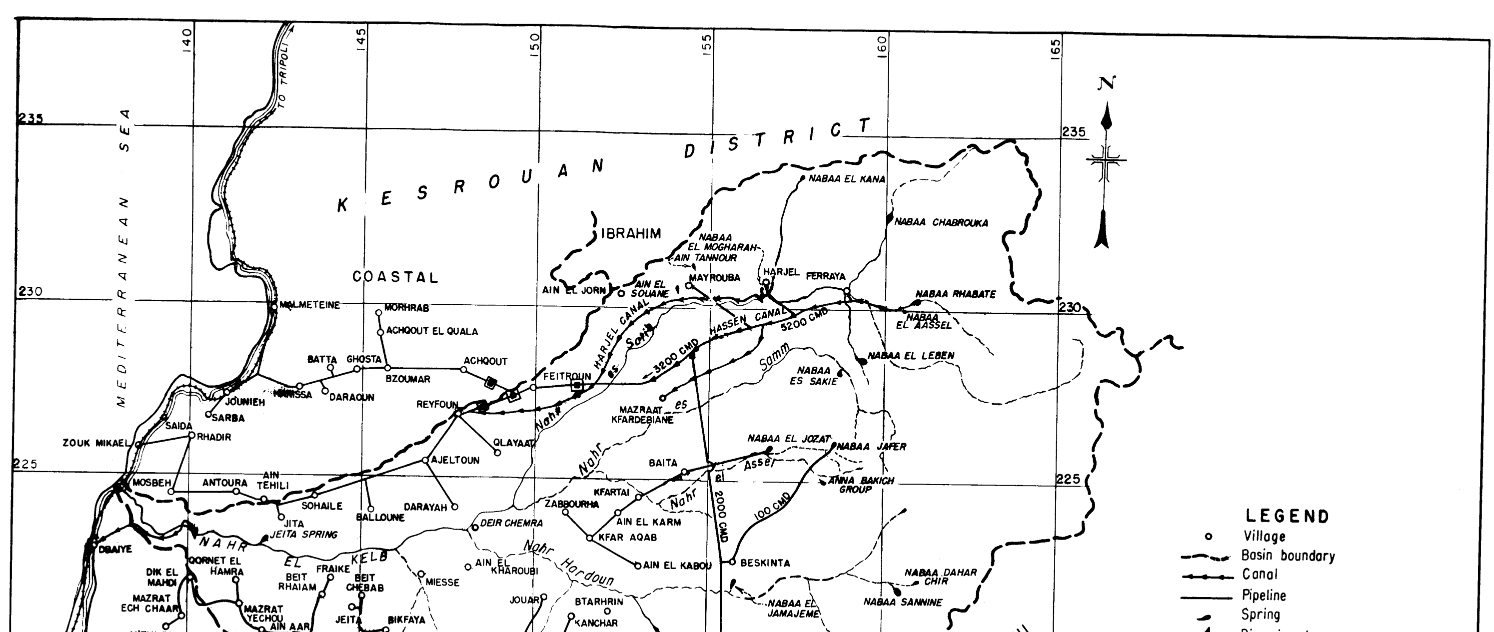
~~FUTURE~~ DOMESTIC WATER NEEDS AFTER COMPLETION OF PROJECTS UNDER CONSTRUCTION

System	Description 1/	Number Villages Served	Population Served	Domestic Water Needs 2/	Domestic Water Available 2/	Domestic Water Available 3/	Additional Domestic Water Needed 2/
A	Villages in Kesrouan District served by Nabaa el Aassel	29	52,934	92.00	70.8	115	21.2
B	Villages in Meten District served by: Nabaa el Aassel, Nabaa Membourkh, Nabaa el Jamajeme and Jeita Spring..	40	61,600	106.6	100.8	141	None for near future
C	Villages in Meten District served by: Nabaa el Jozat	6	2,626	4.56	4.63	152	None for near future
D	City of Beirut and: several coastal villages served by: Jeita Spring	5	572,320	993.50	1244 Minimum	188	None for near future

1/ All of the above systems are in existence or scheduled for completion during 1956.

2/ Liters per second.

3/ Liters per capita per day.



N
KESROUAN DISTRICT
MEDITERRANEAN SEA
TO TRIPOLI
TO BEIRUT
COASTAL
IBRAHIM
NABAA EL KANA
NABAA CHABROUKA
NABAA EL MOGHARAH
AIN TANNOUR
AIN EL JORN
AIN EL SOUANE
MAYROUBA
HARJEL
FERRAYA
NABAA RHABATE
NABAA EL AASSEL
NABAA EL LEBEN
HARJEL CANAL
HASSEN CANAL
5200 CMD
3200 CMD
2000 CMD
1000 CMD
100 CMD
Nahr es Salib
Samm
NABAA ES SAKIE
MALMETEINE
MORHRAB
ACHQOUT EL QUALA
BATTA
GHOSTA
BZOUMAR
ACHQOUT
FEITROUN
JOUNIEH
HARISSA
DARAOUN
SARBA
REYFOUN
MAZRAAT es KFARDEBIANE
SAIDA
RHADIR
ZOUK MIKAEL
OLAYAAT
AJELTOUN
NABAA EL JOZAT
NABAA JAFER
Nahr
BAITA
Assel
ANNA BAKICH GROUP
MOSBEH
ANTOURA
AIN TEHILI
SOHAILE
JITA
BALLOUNE
DARAYAH
KFARTAI
ZABBOURHA
DEIR CHEMRA
NAHR EL KELB
JEITA SPRING
AIN EL KARM
KFAR AQAB
AIN EL KABOU
BESKINTA
DBAIYE
QORNET EL HAMRA
DIK EL MAHDI
BEIT RHAIAM
FRAIKE
BEIT CHEBAB
MIESSE
AIN EL KHAROUBI
Nahr Hardoun
NABAA DAHAR CHIR
MAZRAT ECH CHAAR
MAZRAT YECHOU
AIN AAR
JEITA
BIKFAYA
JOUAR
BTARHRIN
KANCHAR
NABAA EL JAMAJEME
NABAA SANNINE
M'TAILEB
ANTELIAS
JELL ED DIB
QORNET CHAHOUANE
BAHR SAF
CHOUER
DHOUR CHOUER
AIN SINDIANI
SEFSAF
MROUJ
NABAA MEMBOURKH
LITANI
COASTAL
BHANNES
DAOUAR
AIN SEFSAF
KHALY
NBAYE
MAR MOUSSA
BEIRUT
BAABDAT
ROUMIE
BROUMANA
GHABIE
METEN DISTRICT
AIN SAADE
BEIT MERI
TO MKALLES
AIN KAFRA
EL MANSOURYET
LEGEND
Village
Basin boundary
Canal
Pipeline
Spring
Diversion dam
Reservoir
CMD Cubic meters per day
Diversion box
SCALE OF KILOMETERS
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
WATER RESOURCES RECONNAISSANCE
EXISTING DISTRIBUTION SYSTEM
DOMESTIC WATER SUPPLY
NAHR EL KELB BASIN
DR. A.E.W. SUBMITTED
TR. E.A.H. RECOMMENDED
CH. APPROVED
BEIRUT, LEBANON FEB. 7, 1956 OA-10-869

PLATE VII - 1

The water available to individual villages from local springs is not known except for a few villages, but the total quantity available has been estimated as insufficient to appreciably alter the domestic water needs calculated above.

Nabaa el Jozat Water System - Meten District. Nabaa el Jozat, one of the larger springs in the Kelb Basin, is the source of domestic water for six small villages in the central part of the basin. Nabaa el Jozat has a recorded flow of 141.0 liters per second, of which 4.63 liters per second have been allocated to the six villages. As the total estimated domestic water needs for the six villages are only 4.56 liters per second, the quantity provided is believed to be adequate. This system has recently been completed. If additional water is needed it can probably be obtained by taking more water from Nabaa el Jozat, or one of the springs in the Anna Bakich area. (See Table VII-4.)

Jeita Spring Water System. Jeita Spring, the largest spring in the Nahr el Kelb Basin, is the principal source of domestic water for Beirut and several coastal towns between the source and Beirut. Jeita Spring has a recorded minimum flow of 1,117 liters per second, but it is believed that the flow will be less than this at times. According to the Government of Lebanon records, the total flow of the spring has been allocated for power development and domestic water supply, except for 300 liters per second which have been allocated to the El Wata Canal for irrigation purposes. Due to excessive leakage and poor irrigation practices, recorded flows of 370 to 1,040 liters per second have been released to the El Wata Canal during the irrigation season. Therefore, during the summer months the water available for domestic water supply is appreciably reduced. (See Section V - IRRIGATION DEVELOPMENT.)

Jeita Spring flows from a large cavern approximately five kilometers upstream from the mouth of the Nahr el Kelb and from several smaller outlets in the river bed near the cavern. Immediately below the source the flow is diverted into three canals by a system of diversion dams, and passes through two small hydro power plants. Then, the water is returned to the stream. The locations of the diversion dams and power plants are shown on Plate VI-1.

Immediately below the Mar Elias Power Plant a low diversion dam diverts the water from the stream into the El Wata Canal. A short distance downstream from the El Wata Division is the Beirut Water Supply Diversion Dam which diverts water into the Dbaiye Canal. This canal conveys the water to Beirut's modern municipal water treatment plant in the village of Dbaiye. The designed capacity of the canal is 3,000 liters per second. During winter months when flows in the canal are at a maximum, part of the water is used to operate a hydraulically powered pump. This pump is a supplement to the diesel and electrically powered pumps that are used to deliver treated water to the storage reservoirs in Beirut.

The first of a two phase expansion program is now under construction at the treatment plant, and when completed, the plant will have a treating capacity of 860 liters per second. The new plant improvements include clarification by mechanical up-flow type units, filtration by a combination of high and slow rate filters, and sterilization by chlorine gas. This construction program is believed to be adequate for the present daily water consumption; but Beirut's rapid population growth, as well as an anticipated industrial expansion, will require the implementation of Phase Two in the near future. The additional future expansions that are planned for Phase Two will increase the treatment capacity to 1,500 liters per second. The present daily water consumption of Beirut is approximately 800 liters per second, which severely overloads the present plant and nearly equals the planned capacity of the remodeled plant.

From the water treatment plant, the water is pumped through cast iron mains to two large concrete reservoirs in Beirut. From there it flows by gravity to all parts of the city. On the route between the treatment plant and the reservoirs, the cast iron mains pass through several coastal villages, each of which is furnished water from the mains.

Flow measurements taken at Jeita Spring on October 18, 1955 showed a flow of 1,117 liters per second, which is believed to be nearly the minimum flow of this spring. On the same date, flow measurements made on the Nahr el Kelb immediately above the

Beirut water supply diversion dam and in the El Wata irrigation canal showed a flow of 830 liters per second in the stream and a flow of 770 liters per second in the canal. The sum of these two flow measurements gives a total minimum flow of 1, 600 liters per second above the Beirut Diversion Dam. This is 483 liters per second more than the minimum recorded flow of Jeita Spring. This increase in flow below Jeita Spring is attributed to Achouche Spring and to several smaller sources of inflow.

The 1, 600 liters per second flow, less the amount diverted to the El Wata Irrigation canal and 56 liters per second allocated for the Meten District, is available for the domestic water supply of Beirut. If the amount of water diverted for irrigation is reduced to the 300 liters per second allocated for this purpose, there should be a minimum of 1, 244 liters per second available for use in Beirut.

Development Plans

Two new domestic water supply projects are under construction, which when complete, will furnish an additional 65 liters per second to the villages in the Meten District. The proposed distribution system that will serve the villages in the Nahr el Kelb and adjoining basins after completion of these projects is shown on Plate VII-2. This plate also shows the location of proposed power plants, diversion dams, and the Mayrouba Reservoir as described in Section VI - POWER DEVELOPMENT.

The large Nabaa el Aassel - Nabaa Membourkh Distribution System has been considered as two separate systems, each designated herein by a letter of the alphabet for easier discussion and study of the effects of development work underway. The number of villages and the population served, the estimated domestic water requirements, the quantity of water available from each system's source, and the additional quantity of water required by each of the systems are shown on Table VII-6. Development plans for each of the systems are discussed separately below.

System "A" - Source Nabaa el Aassel. The domestic water allocated by the Government of Lebanon to the 53, 000 inhabitants of the 29 villages in the Kesrouan District is sufficient to furnish each inhabitant an average of 115 liters per capita per day. This is believed to be adequate for present needs but provides nothing for future growth. Unfortunately, there are deficiencies in the distribution system, such as leaks in the canals and pipes, undersized piping in some areas, and frequent breakages by irresponsible persons, that prevent an equal distribution of the allocated water. Rehabilitation of the system and development of the spring to capture water escaping through talus, should eliminate the present deficiencies and supply sufficient water from some future village growth.

Another approach would be to improve Nabaa el Kana. It is well located geographically for development as a supplementary supply to Nabaa el Aassel. These spring improvements are discussed in Section IV - GEOLOGY.

The construction of the Mayrouba Reservoir will make it possible to provide an adequate supply of domestic water for all villages served by this system. This reservoir is discussed in Section VI - PROPOSED POWER DEVELOPMENT.

To get the most beneficial use of the water from Nabaa el Aassel and other springs and streams in the high country, as much water as possible should be used for power production prior to its diversion for domestic use. Therefore, before detailed plans are prepared for power production and domestic water systems, a complete economic study of the entire basin development should be made comparing the cost against income to determine the most economical place for diverting the domestic water from the proposed power system.

It is believed that the demand for domestic water will increase greatly in the lower villages served by this system, due to the construction of the Beirut-Malmeteine Highway. The Zouk Mikael - Jounieh - Malmeteine Area, and the villages as far from the highway as Feitroun, will probably grow as they become more readily accessible to tourists and summertime residents from Beirut. The Jounieh area is one of the beauty spots of Lebanon. Plans are now underway to make it one of the country's main tourist centers. Plans for supplying additional water to this area should be prepared and implemented as soon as possible.

System "B" - Sources Nabaa el Aassel, Nabaa Membourkh, Nabaa el Jamajeme and Jeita Spring. The existing Nabaa Aassel-Nabaa Membourkh Systems furnish an average of 53 liters per day to each of the 58,600 inhabitants of 37 villages in the Meten District. At present the Meten District receives 2,000 cubic meters per day from Nabaa Aassel; 1,000 cubic meters per day from Nabaa Membourkh; and in addition, the village of Beskinta receives approximately 100 cubic meters per day from Nabaa Jafer. Upon completion of two projects now under construction, an additional 5,600 cubic meters per day of domestic water will be supplied to the area. The new projects will also serve the villages of Btarhrin, Ain el Kharoubi, and Miesse, which have an aggregate population of 3,000 persons and which are not served by the central system.

The larger of the two projects under construction will have a new high-lift pumpline and two pumping stations that will take 4,800 cubic meters of water per day from Jeita Spring and lift it approximately 1,000 meters to a new reservoir near Bhannes. Pipelines from the new reservoir will connect to the existing system at Bhannes and Bahr Saf, as shown on Plate VII-2.

The second and smaller of the two projects is a new pipeline that will carry 800 cubic meters per day from Nabaa el Jamajeme to a reservoir above Beit Chehab The discharge line from this reservoir will serve the villages of Beit Chehab and Jeita. Any excess water can be discharged into the existing system at a point west of Bahr Saf.

At the completion of the Jeita Spring and Nabaa el Jamajeme Projects, there will be a total of 8,700 cubic meters per day available for the 61,600 inhabitants of the 40 villages served. This quantity of water will make available an average of 140 liters per capita per day.

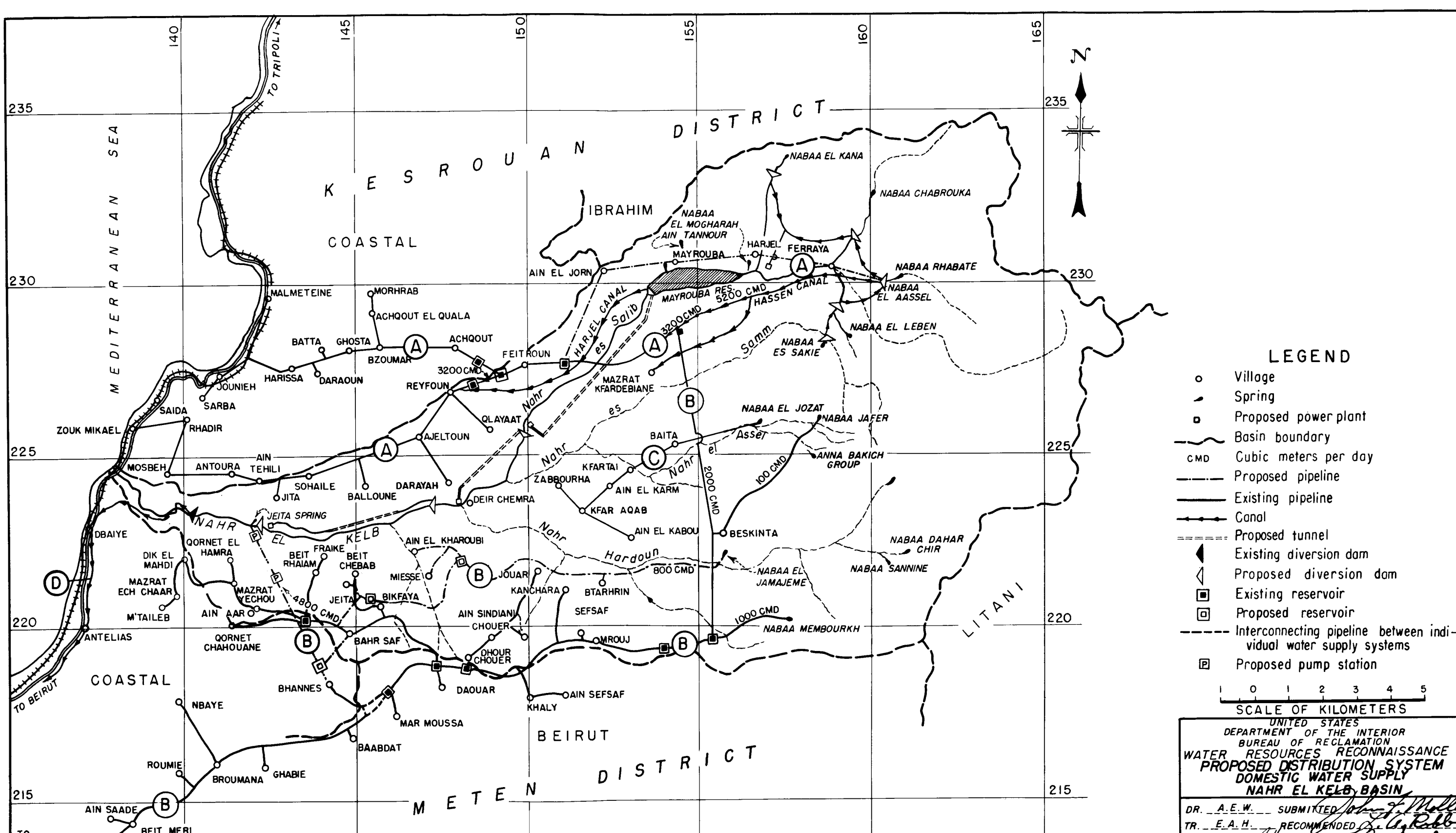
Plate VII-2 illustrates the manner in which the projects now under construction will connect to and improve the distribution of water in the existing system. The villages served by this system will have available sufficient domestic water for their present and near future needs, unless there is an unexpectedly large increase in population.

System "C" - Source Nabaa el Jozat. This is a recently completed system. Table VII-6 shows that an average of 152 liters per capita per day is provided for each person served by the system, and that this quantity is believed to be adequate for present and near future needs. In the event there is a large increase in population, it should not be difficult to obtain additional domestic water from Nabaa el Jozat. The quantity of domestic water now being taken, 4.63 liters per second, is small compared to the total spring flow of 141.0 liters per second.

System "D" - Source Jeita Spring - Beirut Water Supply. Rehabilitation of the El Wata Irrigation Canal to eliminate excessive leakages and an improvement in present irrigation practices would make available an additional 70 to 740 liters per second flow for the Beirut domestic water supply and the project in the Meten District now under construction. This quantity of water being lost by wasteful irrigation facilities and practices is over and above the 300 liters per second flow which canal owners claim is allocated for irrigation. The actual irrigation requirement, as shown in Section V - IRRIGATION DEVELOPMENT, is only 100 liters per second.

The completion of the proposed Nahr el Kelb Basin power development, discussed in Section VI - POWER DEVELOPMENT, would make available at the tailrace of the Jeita Power Plant a total flow of 2,000 liters per second for use by the city of Beirut in a minimum year. This is approximately twice Beirut's present average summertime daily water consumption.

The existing Dbaiye Water Supply Canal, with a reported capacity of 3,000 liters per second, is more than adequate to transport the 2,000 liters per second flow from Jeita Power Plant to the water treatment plant, but the treatment capacity of the water



KESROUAN DISTRICT
IBRAHIM
COASTAL
MEDITERRANEAN SEA
TO TRIPOLI
TO BEIRUT
TO MKALLES
BEIRUT
METEN DISTRICT
COASTAL
LITANI
NAHR EL KELB
Nahr es Salib
Nahr es Samm
Nahr el Asset
Nahr Hardoun
HARJEL CANAL
HASSEN CANAL
MAYROUBA RES.
3200 CMD
5200 CMD
2000 CMD
100 CMD
800 CMD
1000 CMD
4800 CMD
NABAA EL KANA
NABAA CHABROUKA
NABAA EL MOGHARAH
AIN TANNOUR
MAYROUBA
HARJEL
FERRAYA
NABAA RHABATE
NABAA EL AASSEL
NABAA EL LEBEN
NABAA ES SAKIE
NABAA EL JOZAT
NABAA JAFER
ANNA BAKICH GROUP
NABAA DAHAR CHIR
NABAA SANNINE
NABAA EL JAMAJEME
NABAA MEMBOURKH
AIN EL JORN
MALMETEINE
MORHRAB
ACHQOUT EL QUALA
BATTA
GHOSTA
ACHQOUT
BZOUMAR
FEITROUN
REYFOUN
HARISSA
DARAOUN
JOUNIEH
SARBA
SAIDA
RHADIR
ZOUK MIKAEL
MAZRAT KFARDEBIANE
QLAYAAT
AJELTOUN
MOSBEH
ANTOURA
AIN TEHILI
SOHAILE
JITA
BALLOUNE
DARAYAH
DEIR CHEMRA
JEITA SPRING
BAITA
KFARTAI
ZABBOURHA
AIN EL KARM
KFAR AQAB
AIN EL KABOU
BESKINTA
DBAIYE
DIK EL MAHDI
QORNET EL HAMRA
MAZRAT ECH CHAAR
M'TAILEB
BEIT RHAIAM
FRAIKE
BEIT CHEBAB
AIN EL KHAROUBI
MIESSE
JOUAR
MAZRAT YECHOU
JEITA
BIKFAYA
KANCHARA
BTARHRIN
AIN AAR
AIN SINDIANI
SEFSAF
CHOUER
MROUJ
ANTELIAS
QORNET CHAHOUANE
BAHR SAF
DHOUR CHOUER
DAOUAR
AIN SEFSAF
KHALY
BHANNES
NBAYE
MAR MOUSSA
BAABDAT
ROUMIE
BROUMANA
GHABIE
AIN SAADE
BEIT MERI
AIN KAFRA
EL MANSOURYET
LEGEND
Village
Spring
Proposed power plant
Basin boundary
CMD Cubic meters per day
Proposed pipeline
Existing pipeline
Canal
Proposed tunnel
Existing diversion dam
Proposed diversion dam
Existing reservoir
Proposed reservoir
Interconnecting pipeline between individual water supply systems
Proposed pump station
SCALE OF KILOMETERS
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
WATER RESOURCES RECONNAISSANCE
PROPOSED DISTRIBUTION SYSTEM
DOMESTIC WATER SUPPLY
NAHR EL KELB BASIN
DR. A.E.W. SUBMITTED
TR. E.A.H. RECOMMENDED
CH. APPROVED
BEIRUT, LEBANON FEB 14, 1956
OA-10-871

PLATE VII - 2

plant will need to be increased from its present design capacity of 860 liters per second to 2,000 liters per second before the additional quantity of water can be utilized. As mentioned previously, plans have already been made to expand the capacity of the water treatment plant to 1,500 liters per second whenever the need arises and additional water is available. Prior to making any future expansion of the treatment plant it would be advisable to restudy the design of the plant facilities, and if a sufficient quantity of water is or becomes available, the plant units should be redesigned and constructed with sufficient capacity to treat the expected 2,000 liters per second flow.

Technical Assistance Program

The United States Operations Mission to Lebanon and the Lebanese Government signed Project Agreement No. 68-52-036 (formerly 68-12-036), "Village Water Supply", on October 1, 1953. Another agreement replacing the first was signed on March 31, 1955. The agreements provide authority and funds for a joint technical cooperation project whereby individual works may be planned and constructed for village water supply. The agreements enumerate the districts for which domestic water systems are to be studied and constructed where preliminary reports are favorable to such development. They also provide for a joint reconnaissance investigation and report on each of the districts; and where such reports recommend development, the preparation of Memoranda of Understanding outlining the work to be accomplished.

Under the present agreement there are no village water supply districts in the Nahr el Kelb Basin. However, it is possible that this agreement could be amended in the future to include villages within this basin.

SECTION VIII

COSTS AND BENEFITS

Construction Costs

The estimates of construction costs in this report are based upon material and labor conditions in Lebanon. Due allowances have been made for variations in wages and in the classes of labor required for different kinds of work and in the working conditions at the various locations. Allowances have also been made to cover rights-of-way and access roads wherever applicable. Local costs have been taken into consideration where appropriate, and have been correlated with United States cost data where conditions are at considerable variance with normal local experience. Where no local data were available, United States cost averages were adjusted for the differential in current labor rates in the two countries.

All estimates of costs include allowances for engineering, administration, general expense and supervision during construction, amounting to from ten to seventeen percent, depending upon the type of feature to be constructed. All estimates include additional sums for contingencies, varying from fifteen to twenty percent, depending upon the hazards involved and the completeness of the design data available. Also, all estimates include an allowance for interest during the construction period. This period has been assumed to be the time necessary to place a particular feature in operation after construction was started. This allowance was based upon an average money value of six percent. Cost estimating data, obtained during the preparation of the Development Plan for the Litani River 4/, has been used in determining probable construction costs.

The Mayrouba Dam will be a moderate size dam of concrete arch construction. The work is considered as outside the usual scope of experience of local contractors. The estimate of cost for this dam is based upon unit costs near United States average costs for such work.

All of the diversion dams proposed for construction are relatively small and are considered within the scope of experience of local contractors. Concrete or masonry construction is planned for each of the dams, and no particular construction difficulties are anticipated.

Tunnel and canal work in Lebanon is much cheaper than in the United States because of the extensive use of hand labor at low wage rates. Construction costs have been adjusted to take this into account as well as the geologic condition of the rock, the probable water conditions, and other difficulties which might be encountered. All the tunnels proposed for construction are in relatively good tunneling material, with only moderate water difficulties, and may be undertaken by local contractors using hand labor. Likewise, the construction of the canals, and conduits is not expected to result in any unusual difficulties and may easily be handled by local contractors.

The steel penstocks will have to be procured in a foreign market. They may be fabricated in Lebanon if suitable facilities are constructed for this purpose. It is expected that prices for furnishing and installing the penstocks will be similar to those in the United States. Back-filling and restoring terraces along penstock lines would be an ideal job for local contractors.

Materials and equipment costs for hydroelectric power plants have been based upon an analysis of quotations received from internationally known manufacturers, and upon United States cost estimating data. Labor costs for construction and installation were found to be generally lower in Lebanon than in the United States. Hydroelectric power plant construction cost estimates have been prepared after consideration of the above data and upon the assumption that equipment used would be furnished principally from European manufacturers. Expected construction costs are summarized on Plate VIII-1. The curves on this plate show costs estimated for the construction of a complete hydroelectric power plant in Lebanon, including structures and improvements, turbines and generators, and accessory electric and miscellaneous power plant equipment. No allowance has been included in the costs shown by these curves for a power plant switchyard, since this cost has been included in the estimates for the transmission system.

The estimated investment costs for the construction of modern steam-electric power plants in Lebanon have been based on current costs, supported by the basic information contained in detailed engineering cost reports submitted to the Federal Power Commission of the United States. These data have been modified after consideration of the estimated cost for the 90, 000-kilowatt Zouk Mikael steam-electric power plant now under construction, as determined by the former Electricity Company of Beirut from tenders received for this plant. Expected construction costs are summarized on Plate VIII-2. These estimates are for the construction of oil burning, steam-electric power plants in Lebanon. They include structures and improvements, boiler plant equipment, turbo-generator units, accessory electric and miscellaneous power plant equipment. No allowance has been included in the costs shown for the power plant switchyard, since this cost has been included in the estimates for the transmission system.

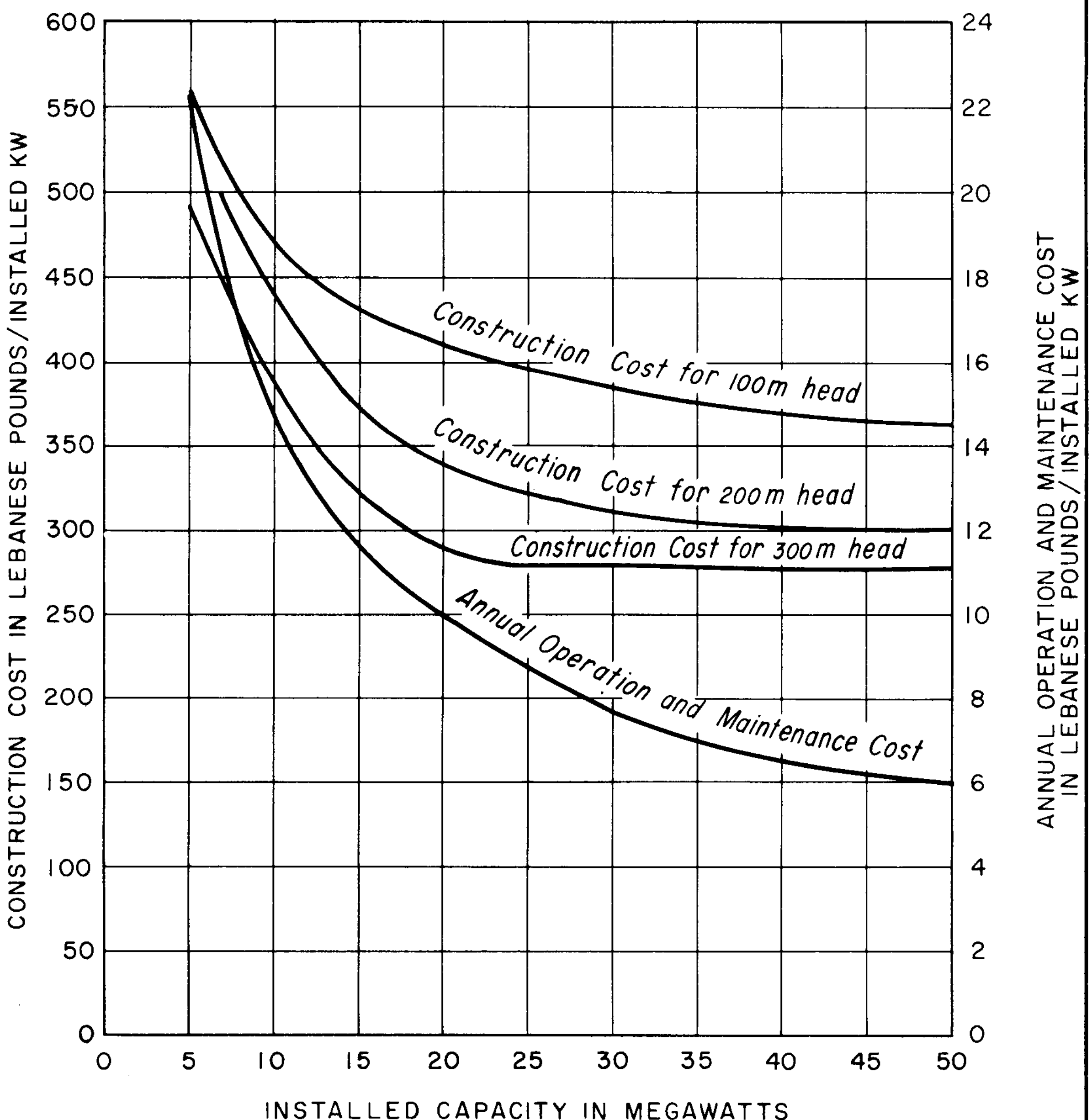
The transmission system has been assumed to be designed for 69, 000 volt, 50-cycle, 3-phase alternating current operation. Transmission line estimates have been based upon wood pole H-frame construction with steel structures assumed to be used at dead-ends. The lines will be exposed to lightning during the rainy season and the extent of overhead ground protection depends in part upon the cost of this type of construction compared to its value. The switchyards and substations have been assumed to be double bus, single-breaker stations with one transfer breaker. They would be the outdoor type, with indoor control stations and station service equipment. Construction and equipment costs have been derived from Bureau of Reclamation and Federal Power Commission data, and checked against local suppliers and quotations from the United States and Europe. Cost estimates have been prepared for each station on the basis of the equipment to be installed rather than on a flat rate per kilovolt-ampere.

Table VIII-1 shows the estimated construction cost of each unit of the proposed development. These have been separated into elements which, in general, have similar operation, maintenance, and replacement requirements.

TABLE VIII-1

SUMMARY OF POWER DEVELOPMENT COSTS
(In thousands of Lebanese Pounds)

Feature	Construction Cost	Annual Costs: Operation and Maintenance	Annual Costs: Interest Insurance Amortization Replacements	Annual Costs: Total Annual Cost
Hydro Power Development				
Hardoun Unit				
Diversion Dams	700	10	43	53
Canals and Conduits	2, 840	1	175	176
Penstocks and Gates	1, 300	2	83	85
Power Plant	3, 900	150	266	416
Unit Total:	8, 740	163	567	730
Mayrouba Dam & Reservoir	14, 700	50	910	960
Mayrouba Unit				
Tunnel and Canal	3, 930	2	241	243
Penstock and Gates	2, 100	3	134	137
Power Plant	8, 400	230	572	802
Unit Total:	14, 430	235	947	1, 182



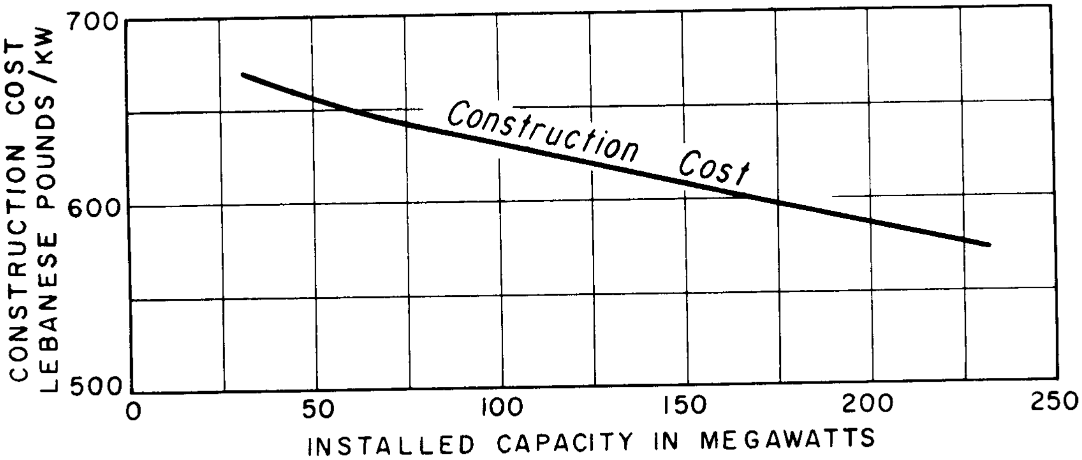
NOTE

Construction costs shown include plant structure and complete power plant equipment. Annual costs include complete plant operation, and costs of lubricants and of minor repairs. All are based upon data from Bureau of Reclamation Manual, modified to fit conditions in Lebanon.

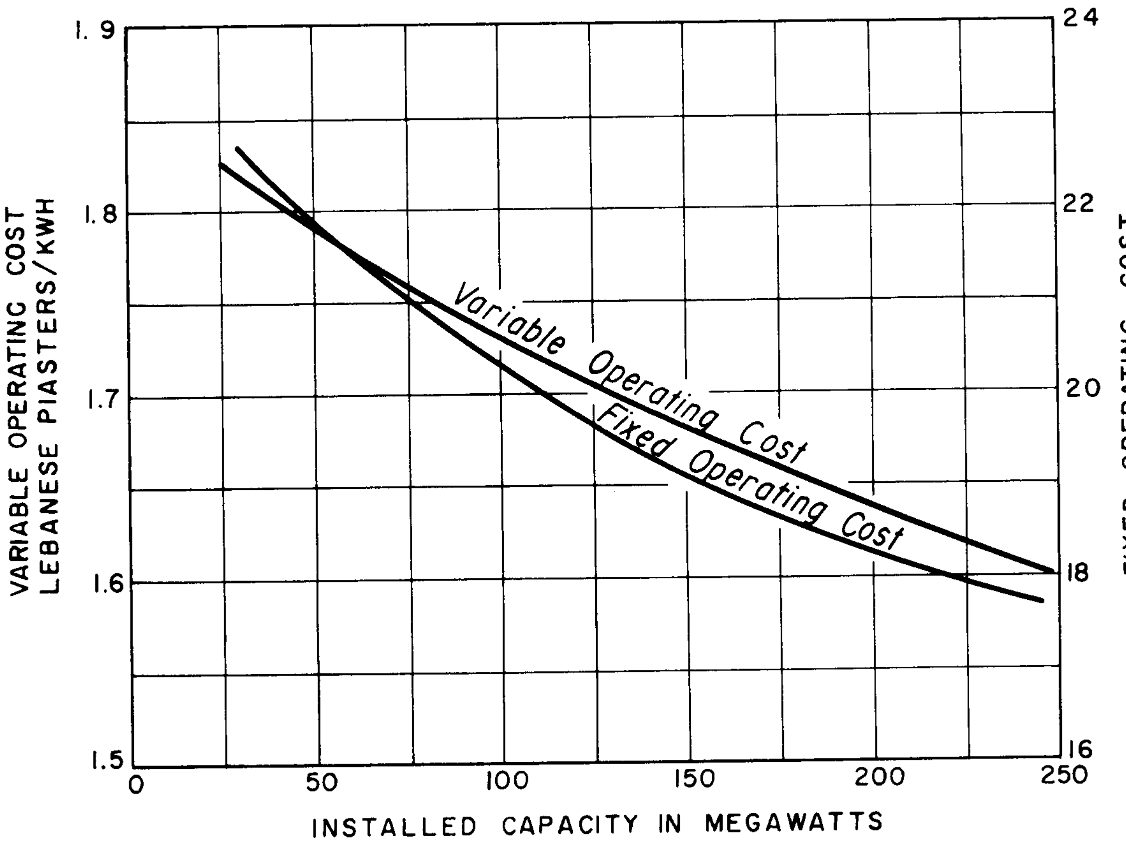
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
WATER RESOURCES RECONNAISSANCE

COST ESTIMATING DATA
HYDRO ELECTRIC POWER PLANTS

DR. C.S.G.	SUBMITTED C. I. Gyllard
TR. J.M.K.	RECOMMENDED H.K. Weiland
CH. CSG.	APPROVED L. J. Snyder
BEIRUT, LEBANON MAR. 3, 1955	OA-10-556



CONSTRUCTION COST



OPERATING COSTS

Notes: All above costs are for a steam-electric power plant only and are effective at the generator bus.
Fuel oil is assumed to cost L.L. 54.50 per meter ton or L.L. 1.37 per milion B.T.U.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
WATER RESOURCES RECONNAISSANCE

COST ESTIMATING DATA
THERMAL-ELECTRIC POWER PLANTS

DR. C.S.G. SUBMITTED C. S. Gysland
TR. R.B. RECOMMENDED H. V. Wayland
CH. CSG APPROVED L. J. Snyder

BEIRUT, LEBANON MAR. 21, 1955 | OA-10-557

PLATE VIII-2

TABLE VIII-1 (Continued)

Feature	Construction Cost	Annual Costs: Operation and Maintenance	Annual Costs: Interest Insurance Amortization Replacements	Annual Costs: Total Annual Cost
Qlayaat Unit				
Diversion Dam	400	2	25	27
Tunnel	3,040	2	187	189
Penstock and Gates	3,300	3	211	214
Power Plant	9,500	240	647	887
Unit Total:	16,240	247	1,070	1,317
Balloune Unit				
Dam and Reservoir	1,700	3	105	108
Tunnel and Canal	4,440	2	272	274
Penstock and Gates	1,800	3	115	118
Power Plant	7,300	224	497	721
Unit Total:	15,240	232	989	1,221
Jeita Unit				
Diversion Dam	400	2	25	27
Canal	1,300	1	80	81
Penstock and Gates	150	0	10	10
Power Plant	2,500	100	170	270
Unit Total	4,350	103	285	388
Thermal Power Development				
El Kelb Thermal Power Plant	42,500	7,930	3,115	11,045
Transmission System				
Switchyards and Substations	16,500	370	1,239	1,609
Transmission Lines	1,300	11	88	99
Unit Total:	17,800	381	1,327	1,708
Total Power Development Costs:	134,000	9,341	9,210	18,551

Operation and Maintenance Costs

The costs, which have been estimated for operation and maintenance of the various project features, have been determined on the assumption that adequate personnel would be provided to perform all operating requirements, and that a preventive maintenance program would be adopted that would minimize the need for early replacements of equipment. Costs used as a basis for determining the proper operation and maintenance charges, are in accordance with United States Bureau of Reclamation practices, and have been modified to suit local labor conditions.

Annual operation and maintenance charges for the Mayrouba Storage Dam and Reservoir have been assumed to be LL. 50,000 to include an annual sum for reservoir treatment as might be found necessary to reduce leakage. For diversion dams and forebays a flat charge of LL. 2,000 each has been assumed. Approximate annual operation and maintenance charges for tunnels,, canals, and conduits have been determined by multiplying the construction cost of these features by a factor of 0.0005. Annual operation and maintenance charges for penstocks have been approximated by a charge of LL. 0.42 per square meter of their inside and outside surfaces.

Annual operation and maintenance charges for hydroelectric power plants have been obtained by use of the curve shown on Plate VIII-1. Annual operation and maintenance charges for the steam-electric power plants have been obtained by use of the curves shown on Plate VIII-2. The fixed operation and maintenance costs shown are dependent upon the size of the power plant, and include the cost of the operation and maintenance personnel, the fixed fuel costs necessary for standby operation, and normal maintenance expenses. The variable operation and maintenance costs are principally dependent upon the amount of fuel consumed in generating the required kilowatt-hours of energy, and to a small degree upon the additional maintenance required. This latter factor varies with the amount of energy generated.

Annual operation charges for the power plant switchyards, and main substations have been estimated at LL. 20,000 for each station, plus 1.5 percent of their estimated construction cost. Annual operation and maintenance charges for the transmission lines have been estimated at LL. 185 per kilometer of 69-kv. line, and LL. 165 per kilometer of 35-kv. line.

Table VIII-1 shows the annual operation and maintenance charges estimated for each feature of the proposed project.

Interest, Amortization, Insurance, and Replacement Costs

The method of financing this development remains to be determined, and the source and cost of capital are indefinite. It is believed that capital may be obtained partly by Lebanese Government participation, partly by private financing, and partly by loans from international banking organizations. In order to compare annual costs with expected benefits, to determine the financial feasibility of the proposed development, it has been assumed that an annual interest rate of six percent will be charged on all capital required to be invested. A sinking fund for amortization and replacement, using six percent interest, has been provided for each feature of the proposed development. This fund has been determined as that necessary to amortize the capital investment for each feature within its estimated useful life, and to provide for interim replacement for short-life features. No allowance has been made for taxes. An allowance of 0.12 percent for self-insurance against unusual losses was made for all dams, tunnels, canals, hydro-electric power and pumping plants, and transmission systems. A similar allowance of 0.30 percent has been made for the proposed thermal-electric power plant.

The useful life of the several features has been based upon estimated useful lives published in "Bulletin F", U.S. Treasury Department, and are shown in Table VIII-2.

TABLE VIII-2

USEFUL LIFE OF DEVELOPMENT FEATURES

Feature	Percent of Feature	Useful Life (Years)
Dams and Reservoirs	10	45
	90	100
Tunnels and Canals	100	100
Penstocks and Gates	50	45
	50	75
Hydroelectric Power Plants	25	75
	75	35
Thermal-Electric Power Plants	25	50
	75	30
Switchyards and Substations	7	45
	93	28
Transmission Lines	40	33
	60	50

Table VIII-3 shows the factors used for each feature of the proposed development to obtain the sinking fund for amortization, replacement, interest, and self-insurance, as well as the resulting overall factor to be applied to investment cost. The resulting interest, amortization, replacement, and insurance charges for each of the features are shown in Table VIII-1. The addition of the operation and maintenance charges to these charges gives the expected total annual cost for each of the items in the proposed development. These are shown in Table VIII-1.

TABLE VIII-3

INTEREST, AMORTIZATION, REPLACEMENT, AND INSURANCE FACTORS

Feature	Sinking Fund for Amortization and Replacements	Interest	Self-Insurance	Overall Factor
Dams and Reservoirs	0.0006	0.0600	0.0012	0.0618
Tunnels and Canals	0.0002	0.0600	0.0012	0.0614
Penstocks and Gates	0.0027	0.0600	0.0012	0.0639
Hydroelectric Power Plants	0.0069	0.0600	0.0012	0.0681
Thermal-Electric Power Plants	0.0103	0.0600	0.0030	0.0733
Switchyards and Substations	0.0139	0.0600	0.0012	0.0751
Transmission Lines	0.0062	0.0600	0.0012	0.0674

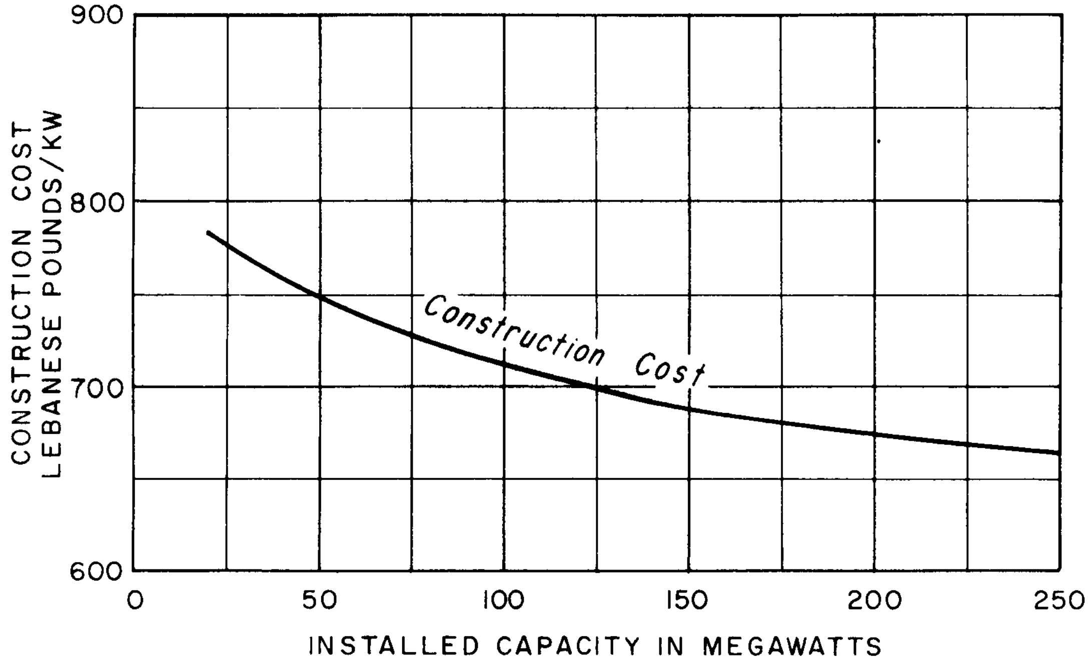
Evaluation of Existing Development

No evaluation was made of the existing development since it has a total installed capacity of only 280 kilowatts. The 2,000-kilowatt Hrach Power Plant now under construction, would be superseded by the proposed 4,200-kilowatt Jeita Power Plant. No separate evaluation was made of the alternate plan which would retain the Hrach Power Plant and substitute the alternate Jeita Power Plant of 2,000 kilowatts for the proposed Jeita Power Plant.

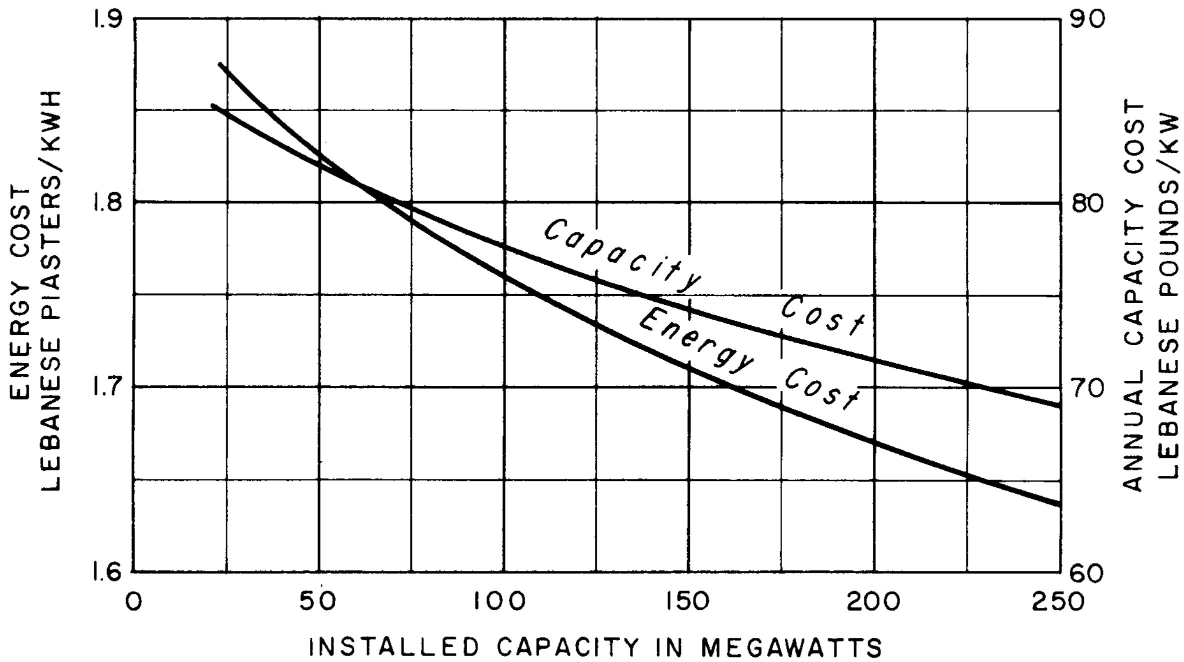
Power Benefits and Costs

The proposed plan of development combines hydro energy and thermal energy into an interconnected system to meet the entire estimated energy demand. This combined system has the advantage over an all-hydro system of essentially utilizing all the hydro energy that can be produced, instead of using only prime energy and wasting secondary or dump energy. The combined operation results in hydro power supplying only peaking energy in certain low-water years and months, with the remaining load carried by the thermal plants. In high-water years and months the reverse is true, with the hydro plants carrying the base of the load and the thermal plants carrying the peaking energy. It is estimated that the proposed development would meet power and energy requirements amounting to approximately 145,000 kilowatts of power and 645 million kilowatt-hours of energy annually, assuming an average annual load factor of about 50 percent and deducting all transmission losses.

The primary benefits of power produced by a project are the value of the power to the users as measured by the amount that they would be willing to pay for such power in the absence of the project. A measure of these benefits may be obtained from the cost of equivalent power from the alternative source of power that would most likely be utilized in the absence of the project. Summarized cost factors, shown on Plate VIII-3, were used to obtain the annual cost for an equivalent all-thermal power development. These curves indicate that an all-thermal power plant that would serve a load demanding 145,000 kilowatts of power and 645 million kilowatt-hours of annual energy measured at the power plant, would require an investment of about LL. 100,000,000, including the necessary transmission system, Annual costs for this alternative development are estimated at LL. 10,800,000 for capacity and LL. 11,100,000 for energy - a total annual cost of LL. 21,900,000. This is a measure of the primary power benefits to be expected by the construction of the proposed project and modification of the existing development. Annual



CONSTRUCTION COST



PRODUCTION COSTS

Note: Construction costs include steam-electric plant, plant switchyards, 11 km of transmission line, and stepdown substation at load center. Production costs include cost of fuel oil at L.L. 1.37 per million B.T.U., interest on investment at 6 per cent and amortization of plant after average life of 30 years.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
WATER RESOURCES RECONNAISSANCE

CAPACITY AND ENERGY COSTS
THERMAL-ELECTRIC POWER PLANTS

DR. C.S.G. SUBMITTED C. I. Gysland
TR. J.M.K. RECOMMENDED N. N. Weiland
CH. Clb APPROVED L. G. Snyder

BEIRUT, LEBANON MAR. 3, 1955 OA-10-558

PLATE VIII-3

costs for the proposed power development are shown in Table VIII-1 to total LL. 18,551,000. An overall benefit to cost ratio of 1.2 to 1 is estimated for the proposed development including the 65,000-kilowatt thermal power plant.

Annual costs of the 65,000-kilowatt thermal firming power plant when producing 371 million kilowatt-hours of energy, are found to be LL. 5,200,000 for capacity of LL. 6,680,000 for energy -- a total annual cost of LL. 11,880,000 including transmission as obtained from Plate VIII-3. A measure of the value of the hydro power plants alone, may be obtained by subtracting these annual costs from the annual costs for the 145,000-kilowatt alternative thermal power plant discussed in the previous paragraph. This operation results in an estimated capacity value for the complete hydro installation of LL. 5,600,000 or LL. 70 per kilowatt of dependable peaking capacity, and an estimated energy value for the complete hydro installation of LL. 4,420,000 or LL. 16,130 per million kilowatt-hours of energy generated in an average water year. Using these values an estimate was prepared to indicate the individual benefit to cost ratios for the individual hydro power developments. In preparing these ratios the estimated switchyard costs were used, and transmission line and substation costs were prorated according to the proportion of the dependable peaking capacity of each plant to the total peaking capacity of the entire system. The cost of the Mayrouba Dam and Reservoir was divided among those plants situated below the dam according to the proportion of the total head utilized by the particular plant. The results of this calculation are shown in Table VIII-4.

The benefit cost analyses for the proposed Nahr el Kelb development, considering only the direct benefits from the sale of electricity, show an economically justifiable development. The benefits from domestic water supplies provided by the Mayrouba reservoir would justify an allocation of a portion of the costs of this reservoir to be paid from domestic water revenues, thus further increasing the power benefit to cost ratio as calculated above. The current annual charge to the sanitary water consumer in Beirut is LL. 60 for a daily supply of one cubic meter. The 20 million cubic meters of Mayrouba storage would be sufficient to supply about 740,000 persons with 150 liters per day per capita during the dry season of an assumed six month duration. Present use of domestic water averages about 50 liters per capita in Beirut. The normal operation of the Mayrouba Reservoir for maximum power benefits is expected to conform substantially to the requirements for domestic water, except possibly during the months of December and January which will require releases for power but probably will not require releases for domestic water.

TABLE VIII-4

BENEFIT TO COST COMPARISONS FOR INDIVIDUAL HYDROELECTRIC UNITS

Feature	Costs in LLx1,000		Dependable Plant Capacity (December) Kw.	Average Year Generation KwHx10^6	Estimated Hydro Benefits LLx1,000			Hydro Benefit to Cost Ratio
	Total Construction Costs	Total Annual Costs			Capacity Value	Energy Value	Total Benefits	
Hardoun Unit	9,370	791	6,000	33	420	530	950	1.20
Mayrouba Unit	23,310	1,858	29,000	54	2,030	870	2,900	1.56
Qlayaat Unit	25,850	2,026	34,000	68	2,380	1,100	3,480	1.72
Balloune Unit	21,530	1,690	9,000	100	630	1,610	2,240	1.33
Jeita Unit	5,040	434	2,000	19	140	310	450	1.04
Total:	85,100	6,799	80,000	274	5,600	4,420	10,020	1.48

SECTION IX

ADDITIONAL INVESTIGATIONS NECESSARY

This reconnaissance investigation of the water resource potentialities of the Nahr el Kelb Basin has been limited to stream gaging, preliminary hydrologic investigations, reconnaissance-type field surveys, geologic investigations, a review of existing plans, proposals, and projects, and to proposed developments for electric power and domestic water. These investigations indicate that further detailed investigations are required to provide additional data before a development plan for the Nahr el Kelb Basin can be finally prepared. This section outlines a number of the additional investigations deemed necessary to secure the data required for the preparation of such a plan.

Mapping Program

Existing maps covering the Nahr el Kelb Basin consist of topographic quadrangle sheets on a scale of 1:50,000 having a contour interval of 10 meters. These sheets were prepared by the Institue Geographique National Ministere Des Travaux Publics et Des Transports, Paris, France from field surveys made in 1936. The horizontal control for these maps is a rectangular grid calibrated in units of one kilometer and has its origin located at 34^{o} 39' North Latitude and 37^{o} 21' East Longitude with assumed coordinates of X = +300 kilometers and Y = +300 kilometers. A primary triangulation network was established and adopted by the French Army in 1923 and appears to have been used in the preparation of these quadrangle sheets.

Two datum planes have been used by the Government of Lebanon in the vertical control system. In 1920 the French Cadastral Department established a temporary bench mark on the estimated mean sea level of the Mediterranean at Beirut. This is known as the Cadastral Department Datum. In 1926 a new datum was established on the true mean sea level of the Mediterranean at Beirut. This one is known as the Army Geographic Service Datum. This new datum is 0.730 meters lower than the earlier one. It appears to have been used in the mapping for the existing quadrangle sheets. However, Cadastral Department surveys and maps drawn prior to 1926 have not been corrected to the new datum.

A number of checks have been made on the data shown on the guadrangle sheets for the Nahr el Kelb Basin. Although there are a number of minor discrepancies in details, these sheets have been found sufficiently accurate for general use. However, the following field surveys should be completed before definite plans for the over-all development of the Nahr el Kelb Basin are undertaken: A first order line of levels should be run along the Nahr el Kelb and the Nahr es Salib, and permanent bench marks established near the site of each proposed feature. Profiles should be obtained for the rivers and streams, along which developments are planned. Second or third order horizontal control should be extended from the existing Syrian-Lebanese Rectangular Coordinate System to cover all the areas under consideration for development.

A topographic map should be made of the Mayrouba Reservoir Site as early as possible to obtain an accurate area-capacity table or curve. Detail topography should also be obtained for all diversion sites and all proposed sites for the power production features.

The preparation of a detailed plan of development will require extensive mapping of sites for the structures proposed and for other data required. Recently the Cadastral Department awarded a contract to have aerial photographs made for a part of Lebanon. It is suggested that the Government of Lebanon give consideration to the mapping of the remainder of the country by aerial photographic methods. Such mapping would provide much better basic data, with considerable saving in cost and time, than the usual ground stadia method. Topographic mapping should be accomplished in the next few years and be made available for use in the detailed investigations required for the development of this basin.

Hydrologic Data Collection

Additional hydrologic data must be collected before a detailed development plan can be undertaken for the multiple purpose use of the water resources in the Nahr el Kelb Basin. Available hydrologic data are discussed in Section III-HYDROLOGY, and consist of 11, 7 and 6 years of rainfall records at Qlayaat, Bikfaya and Qornel Chahouane, respectively; about 6 years of streamflow records at El Mokhada. A few miscellaneous spot measurements have been made for canal diversions. No records are available for consumptive water use, or for snowfall over the higher parts of this basin.

A country-wide program for hydrologic data collection in Lebanon has been prepared and submitted to the Ministry of Public Works, Government of Lebanon. This program provides for the installation of additional precipitation stations, stream gages, and snow survey courses in the Nahr el Kelb Basin, as well as in other areas of Lebanon. It also provides for additional discharge measurements on the Nahr el Kelb its principal tributaries, and the principal springs in the basin. Flows in the principal canals existing in the basin, would also be measured to determine the quantity of water now diverted and the consumptive use of such water.

Sediment measuring stations should be established for the collection of data which would be needed in the design and maintenance of reservoirs, tunnels, conduits, power plants, and domestic water supply.

The exact locations for the several hydrologic stations and snow courses required can only be determined by field reconnaissance. However, from a study of existing topographic maps, approximate locations have been selected for use in planning the program. These tentative locations are shown on Plate III-1.

Ten years constitutes the minimum period during which such a program should be operated before sufficient data would be available upon which to base a final plan of development for the water resources in the Nahr el Kelb Basin. Continued operation of a data collection program, after the end of the 10-year period, is essential for the improvement of development planning and to provide data for the operation of the water use projects after they are constructed.

Analysis of Hydrologic Data

Investigations necessary for the preparation of a final plan of development will require detailed analysis of basic information obtained through a hydrologic data collection program. Office activities at that time should include detailed studies to determine consumptive use and irrigation requirements, sedimentation, storm and runoff studies to determine infiltration rates, unit hydrographs, maximum storm potentialities, flood frequencies, and snowmelt rates, all of which are necessary to determine spillway capacities and diversion requirements during construction.

The office studies should also include investigation of comparative monthly power operation to establish economic reservoir, tunnel, and power plant capacities and to eliminate competitive alternate developments; supply and requirements for village water systems; and water rights. The meager hydrologic data available for the Nahr el Kelb Basin has necessitated the estimation of all such factors for this reconnaissance investigation.

Geologic Exploration

Mayrouba Dam and Reservoir Sites. The proposal to store 20,000,000 cubic meters of water in the Mayrouba Reservoir is the most critical undertaking in the proposed power development of the Nahr el Kelb Basin. The feasibility of the entire plan presented in this report is based on the ability of this reservoir to capture and store water over the minimum period required. Therefore, a careful and detailed surface and subsurface investigation of this reservoir should be completed before any of the other features in the proposed program are started.

At the outset, a detailed geologic map of the reservoir area should be made giving particular attention to the alinement of the three major fault planes and the various areas of intense fracturing. The exact elevation of the absorbent deposits, such as the altered basalts and basaltic tuffs, should also be established.

Following the preparation of the geologic map, a program of subsurface borings in the valley floor should be undertaken to ascertain that no sizable cavities or interconnected galleries exist under the alluvium. Double-packer pressure tests should be made in drill holes in the various localities of intense fracturing and along the planes of the three faults to establish the rate of seepage that may be expected. These tests will also be of value in providing the basic data to be used in future grouting programs.

A moderate number of test pits or core holes should be put down at the Mayrouba Dam Site to ascertain the extent of weathering and the bearing capacity of the underlying bed rock.

General Statement. The steeply eroded terrain and the thin soil cover in the Nahr el Kelb have resulted in an abundance of formational outcrops and bedrock exposures, which when coupled with the relative monotony of the lithologic character of the geologic column, permit interpretations to be made from surface investigations with a high degree of accuracy. For this reason, future subsurface investigation at each of the other dam and power plant sites, and along the several tunnels, canal lines, and penstocks, may be limited to that normally required to assure the designer that the strata at the various sites are structurally sound and capable of supporting the loads to be superimposed upon them, with the following exceptions.

El Leben Conduit. Over a large part of its length, this conduit would cross a marly talus that exhibits considerable evidence of past sliding. The thickness of this overburden should be investigated by test pits or hand auger holes to determine the depth to bedrock and to obtain samples for laboratory analysis of the shear strength and other engineering characteristics of the materials.

Jeita Unit. The Jeita Grotto should be extensively explored with the object of ascertaining the best method of plugging the various sinkholes, or funnels, and improving the flow of the water held in the various small lakes or sumps in the cavern. The vicinity of the Jeita Grotto should be carefully investigated, both upstream from the outlets, by surface observation and borings to ascertain the exact nature of the cavern system and to establish that no additional caverns exist under the Jeita Diversion Dam Site or the canyon floor.

Power System Operations

Power system capability determination is one of the first studies that should be undertaken after hydrologic data become available. It should be made on a detailed basis, to check the generating capabilities of existing and proposed hydro plants, and the capacity of the thermal plant required to firm the hydro-produced power. It is also required to determine the economic capacity of each proposed plant, to provide the data required to check the size and number of generating units selected, and to check the size and capacity of the related hydraulic structures proposed.

Power system performance studies would be required in order to integrate the power to be produced in the Nahr el Kelb Basin into the country-wide power system. Also, transmission system voltage levels should be studied in detail to determine the levels to be used for the country-wide system, as well as for the Nahr el Kelb system.

Financial operation studies, based upon detailed cost estimates, should be made in connection with the economic analysis necessary to determine the final benefit-cost ratio for each development. An over-all repayment study should be made, including expected costs and revenues of each feature of the project. A revision of the power market study should be undertaken to incorporate the additional available power use data.

Domestic Water Supply

The Ministry of Public Works has under construction water systems and improvement of existing systems that will provide an adequate water supply to all small villages receiving water from the Nahr el Kelb Basin. These are shown on Plates VII-1 and VII-2.

In the forseeable future Beirut's present water supply will be inadequate to take care of the city's rapid expansion. The construction of the proposed power development would alleviate this shortage.

In order to conserve water discharged from the proposed Jeita Power Plant during the peaking periods, a small reservoir would be required immediately above the intake to the Dbaiye Canal. This could be accomplished by raising the Beirut Water Supply Diversion Dam about two or three meters. Detail surveys and geologic studies along with right-of-way problems should be made on this site.

Costs and Benefits

When more definite plans for the project have been delveoped, costs should be refined and brought up to date. Careful studies of current construction costs of other works in Lebanon should be made in order to make cost estimates as accurate as possible. Operation and maintenance costs would be made on the basis of personnel, equipment, and material requirements. Benefits accruing to the project should be similarly refined and adjusted to reflect current prices and other economic conditions.

SECTION X

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

It is concluded as a result of this water resource reconnaissance investigation that:

1. It is economically justifiable to develop the water resources of the Nahr el Kelb Basin for expansion of domestic water supply and for additional hydroelectric power. Such power can be produced without interference with existing irrigation or domestic water supply;

2. The existing irrigation system in the coastal plain section requires rehabilitation and the improvement of operation and maintenance practices;

3. Improved operation, maintenance, and water use practice in irrigation adopted in the mountain section will conserve water urgently needed for village water supply;

4. Five hydroelectric plants with a total installed capacity of 103,200 kilowatts, and a thermal plant with an installed capacity of 65,000 kilowatts, constitute the proposed power development that is economically justifiable;

5. Existing electric energy production in Lebanon, that is expected from the Litani River development soon to be constructed, and that proposed herein for the Nahr el Kelb development, is estimated to be absorbed within 25 to 35 years, provided that no other major electrical power developments are completed within that time;

6. A detailed project investigation is required to determine the exact location, the structural details, and more definite costs for the power units included in the proposed development. This investigation will require a minimum of 10 years of hydrologic data, as well as additional detailed geologic investigations, site surveys, repayment analyses, market studies, etc;

7. An investigation is required to determine the necessity and benefits of developing the potential municipal water supply storage in the Nahr el Kelb Basin for use in metropolitan Beirut and neighboring areas.

Recommendations

It is recommended that:

1. The plan proposed herein for the rehabilitation of the existing irrigation system, development of potential hydroelectric power, and expansion of the domestic water supply, be adopted by the Government of Lebanon as a preliminary plan for the development of the water resources of the Nahr el Kelb Basin;

2. Detailed investigations, including the collection of 10 years of additional hydrologic data, additional surveys, geologic data, extensive foundation investigations of the Mayrouba Reservoir Site, comparative preliminary designs for Mayrouba Dam, power market studies, repayment analyses, and additional data on all phases of the proposed power development, be undertaken and completed before final design and construction of the proposed power development be undertaken;

3. The additional power development proposed herein for the Nahr el Kelb Basin be studied in detail for construction as soon as market conditions warrant and sufficient data are available as a result of the detailed project investigations proposed herein, provided that no other major power developments, other than that of the Litani River Project, are authorized before the Nahr el Kelb development;

4. Final determination of the transmission system voltage levels should be left to future detailed transmission studies of the entire country, which should include consideration of all the potential hydroelectric developments;

5. Investigations be undertaken to determine the necessity and benefits of developing the potential municipal water supply storage in the Nahr el Kelb Basin for use in metropolitan Beirut and neighboring areas;

6. The Ministry of Public Works expedite their development program for village water supply, and that it be expanded to include all of those villages in the Nahr el Kelb Basin whose present water supply is inadequate;

7. The Government of Lebanon **establish** a program to educate and train water users in the proper use of irrigation water and modern agricultural practices.

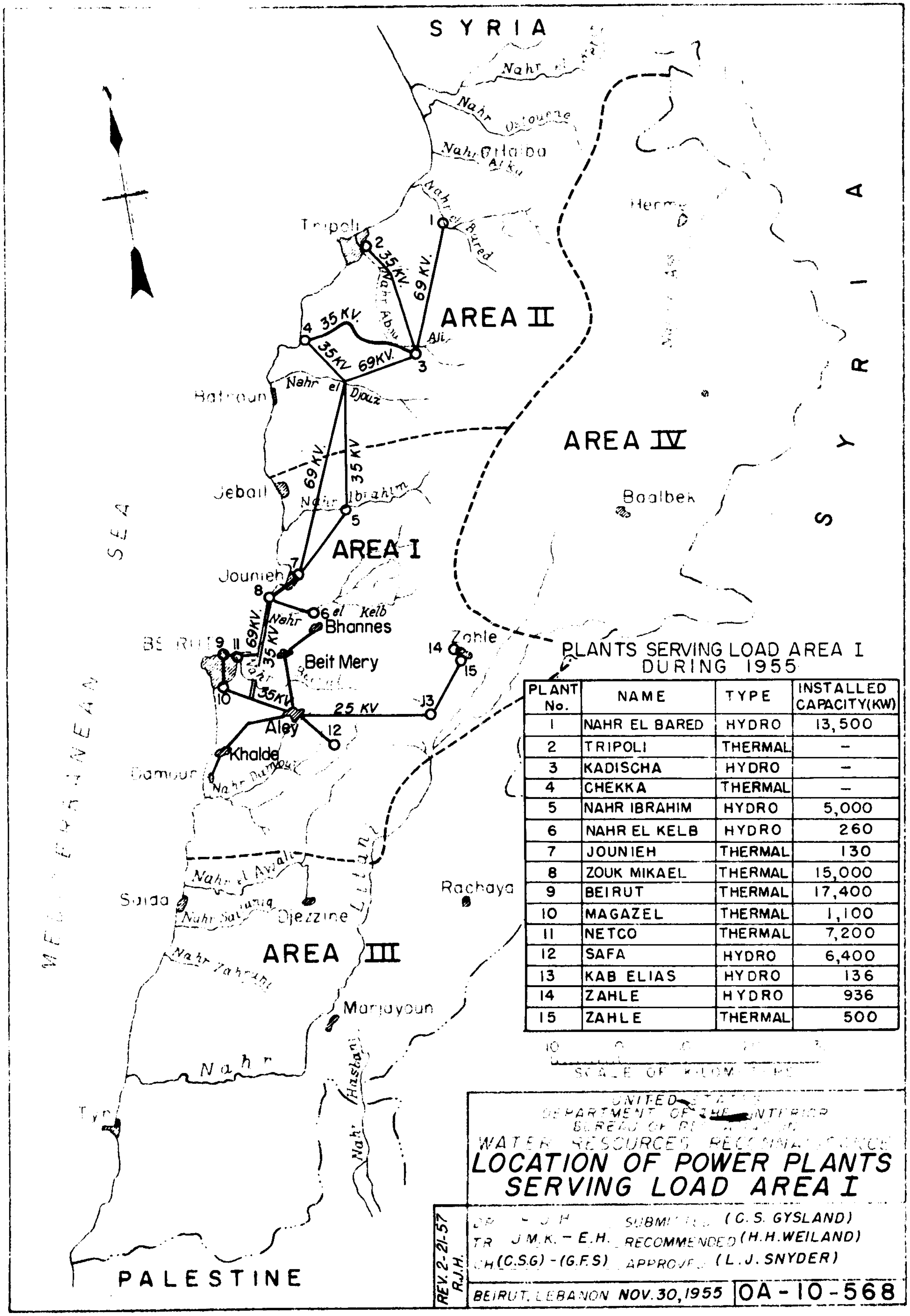
APPENDIX

POWER MARKET STUDY - LOAD AREA I

Description of Power Supply Facilities

Electric power is generated in Load Area I by one large Government-owned company and about six comparatively small privately-owned companies. Early in 1953 the Government of Lebanon entered into the operation of the largest of these companies, the Electricity Company of Beirut, which was then a privately-owned corporation. The Government appointed three Directors to manage it. This arrangement was expected to remain in effect for one year, but instead, it culminated in the Government's purchase of the company. The Electricity Company of Beirut owns and operates the 6,400-kilowatt Safa Hydroelectric Plant near Rechmaya and a 12,400-kilowatt diesel power plant in Beirut. It has constructed a 5,000-kilowatt gas turbine power plant in Beirut and is constructing a 90,000-kilowatt steam power plant at Zouk Mikael which is on the coastline about 11 kilometers northeast of Beirut. The initial 15,000-kilowatt unit was placed in operation in December 1955.

The National Engineering Trading Company owns and operates a 7,000-kilowatt steam power plant in Beirut. All of its power is sold to the Electricity Company of Beirut. The Magazel Company owns and operates a 400-kilowatt diesel power plant just south of Beirut. Its power is sold to the Electricity Company of Beirut. The Phoenician Company of the Hydroelectric Powers of the Nahr Ibrahim, known locally, and hereafter referred to as the Nahr Ibrahim Electricity Company, owns and operates a 5,000-kilowatt hydroelectric plant on the Nahr Ibrahim. It sells most of the power generated to the Electricity Company of Beirut and the remainder to the Electricity Company of Jebail. The Nahr el Kelb Electricity Company operates two small hydro plants on the river and a diesel power plant in Jounieh aggregating a capacity of 400 kilowatts. This power is distributed in the town of Jounieh. The Kab Elias Electricity Company owns and operates a hydroelectric power plant of 136-kilowatt capacity, and distributes this power in the town of Kab Elias. The Zahle Electricity Company owns and operates small hydro and diesel power plants aggregating 950 kilowatts in capacity, and distributes this power in the town of Zahle. The Nahr el Bared Electricity Company, which is located in Load Area II north of Tripoli, owns and operates a 9,000-kilowatt hydroelectric power plant on the Nahr el Bared. The energy produced is sold to the Electricity Company of Beirut. In addition, the Chekka Cement Company and the Kadischa Company located in Load Area II sell a small amount of energy to the Electricity Company of Beirut during peak load and emergency periods. Table A-1 shows power plants which served Load Area I in 1954, together with the type of power plant and the energy produced in that year. Location of the above power plants which serve Load Area I are shown on Plate A-1.



PLANT No.	NAME	TYPE	INSTALLED CAPACITY (KW)
1	NAHR EL BARED	HYDRO	13,500
2	TRIPOLI	THERMAL	–
3	KADISCHA	HYDRO	–
4	CHEKKA	THERMAL	–
5	NAHR IBRAHIM	HYDRO	5,000
6	NAHR EL KELB	HYDRO	260
7	JOUNIEH	THERMAL	130
8	ZOUK MIKAEL	THERMAL	15,000
9	BEIRUT	THERMAL	17,400
10	MAGAZEL	THERMAL	1,100
11	NETCO	THERMAL	7,200
12	SAFA	HYDRO	6,400
13	KAB ELIAS	HYDRO	136
14	ZAHLE	HYDRO	936
15	ZAHLE	THERMAL	500

PLATE A - I

TABLE A-1

INSTALLED CAPACITY AND ENERGY PRODUCTION
POWER PLANTS SERVING LOAD AREA I DURING 1954

Plant	Principal Load	Year Installed	Installed Capacity (kw)	Energy (kwh x 10^6)
Hydro:				
Safa	Beirut	1932	6,400	39.8
Nahr Ibrahim	Beirut	1950-54	5,000	21.8
Nahr el Kelb	Jounieh	1925-54	270	0.4
Kab Elias	Kab Elias	1930	136	0.3
Zahle	Zahle	1925	550	2.5
Nahr el Bared 1/	Beirut	1954	9,000	8.5
	Subtotal hydro:		21,356	73.3
Thermal				
Beirut	Beirut	1924-50	12,400	47.1
Magazel	Beirut	-	400	3.9
NETCO	Beirut	1954	7,000	1.2
Zahle	Zahle	1952	400	0.3
Jounieh	Jounieh	-	130	0.2
	Subtotal thermal:		20,330	52.7
	Total:		41,586	126.0
Kadischa & Chekka Systems 1/	Tripoli Chekka		-	4.7
	Grand Total:		41,586	130.7

1/ Plants located in Load Area II

The principal power transmission lines for Load Area I are 25-kilovolts, 35-kilovolts, and a recently constructed 69-kilovolt line from the Nahr el Bared Power Plant to Beirut. The primary distribution circuits are for the most part at a nominal voltage of 5,500. The secondary distribution voltage which predominates throughout Lebanon is 190/110, although a distribution voltage of 380/220 is used in some localities. All power plants in Lebanon operating at the end of 1954 generated at a frequency of 50 cycles per second.

Past and Present Production. An analysis of the past and present electrical load is an important consideration in estimating the magnitude and characteristics of the future load for use in planning power resource development. The analysis should include the projection of the findings into the future applying load influencing factors which are known, or which can reasonably be forecast.

Load Area I is supplied by the Electricity Company of Beirut and eighteen comparatively small concessionaires. Fifteen of these concessionaires distribute electrical energy purchased wholesale from the Electricity Company of Beirut. Two companies have small power plants to supplement purchases from the Electricity Company of Beirut. Each of the villages of Kab Elias, Jounieh, and Zahle are supplied by their own small, nearby hydroelectric plant supplemented by small diesel plants. These plants are not interconnected with the Beirut Electric Company system. Energy generated by them amounts to only about 2-1/2 percent of the total produced in Load Area I. The Electricity Company of Beirut system extends east as far as Zahle, some 45 kilometers from Beirut.

In the ten-year period ending in 1954, power consumption more than quadrupled on the Electricity Company of Beirut system. The average annual increase was nearly 16 percent. If the installation of new generating capacity had kept up with the actual requirements, the increase in consumption would have been even higher. The Electricity Company of Beirut has limited the demands of each new residential and commercial customer to 10 amperes by means of a company-owned entrance circuit breaker. Since the installation of the 15,000-kilowatt unit at the Zouk Mikael Plant in December 1955, the company is relaxing these demand restrictions and is permitting the installation of larger entrance circuit breakers upon request.

In 1951 the peak load supplied by the Electricity Company of Beirut was 21,600-kilowatts; whereas, by estimating the reduction attained by cutting off industries and reducing the voltage, calculations show that the unrestricted demand would have been 29,500-kilowatts. Without the depressing effect caused by discouragement of residential and commercial uses in past years, the 1951 peak demand would have been higher than the above estimate. Despite the limitations imposed upon the power demands, the annual energy consumption in the Beirut interconnected area increased from less than 80 million to more than 130 million kilowatt-hours from 1950 to 1954. This is an average annual growth of about 14 percent.

Plate A-2 indicates the month by month operation of the various power plants in the Beirut interconnected load area during 1950 and 1951. This graph is also indicative of the operation during 1952 and 1953. It does not show the effect of the new power plants at Nahr el Bared and the NETCO which were placed in operation in 1954. The loads shown on this graph constitute approximately 97-1/2 percent of the total in Load Area I; therefore, the monthly energy distribution and peak demands shown are representative for this entire load area. The practically equal monthly peak demand prior to November 1950 is misleading. It does not represent the actual demand for power, but rather the maximum power which the existing facilities were able to supply.

The first units of the Nahr Ibrahim Power Plant were placed in operation in November 1950. This increased the peak loads from 17,000 to 20,450-kilowatts by December 1950. The drop in peak power production for November 1951 was caused by a shutdown of a 3,200-kilowatt unit at Safa for repairs. This, together with low water conditions at Nahr Ibrahim, necessitated curtailment of service during November 1951 daily peaks to fit the load to the available dependable capacity of 17,800-kilowatts. During December 1951 the peak rose to 21,600-kilowatts, when both units at Safa were in operation and there was enough flow in the Nahr Ibrahim to permit practically full capacity generation.

The Nahr Ibrahim Hydroelectric Plant is a run-of-the-river plant with no pondage, while the Nahr el Bared Hydroelectric Plant has sufficient pondage for daily peaking. The Electricity Company of Beirut utilized the Safa plant to the extent of its water supply, and purchases the Nahr Ibrahim and Nahr el Bared output when available and required.

During the wet months of the year, the hydro plants are operated on the base load. The thermal units supply the remaining load, including the peak load. From June to December the stream flow to the hydroelectric plants is greatly reduced, and the larger part of the required energy must therefore be furnished by the thermal plants.

Present Load Characteristics. Studies were made of the present electrical load characteristics in Lebanon to serve as a basis for estimating the future load characteristics. Typical of a system with a relatively heavy lighting load, the daily load curves for the Beirut system show a prominent peak during the early hours of darkness. The annual load factor for 1950 was 44.4 percent, and for 1951, 48.5 percent. These load factors are low when compared with systems having a well developed industrial load or with residential systems having substantial water heating, cooking, space heating, and refrigeration loads. However, they would have been even lower had it not been for measures taken to limit peak demands. The Beirut load has grown in recent years to such an extent that the power company has not been able to meet the peak demands, although the energy use and peak demand are far short of those of a European or American city of similar size. Some of the power company's diesel equipment is capable of being operated for only a short time during the day, and the company has found it necessary to adopt various restrictions to limit demand. It is estimated that the annual load factor of the Beirut system would be about 40 percent if all demands could be met. It is this inherent load factor which must be considered in power development planning. On Plate A-3 is shown typical December load characteristics for Load Area I.

Present Power Production Costs. In 1954 electric power was supplied to the Beirut load center principally by three hydroelectric power plants -- Safa, Nahr Ibrahim, and Nahr el Bared; and by three thermal power plants -- Beirut Diesel, NETCO Steam, and Magazel Diesel. The average production cost for the energy generated by the hydroelectric power plants was 2.8 piasters per kilowatt-hour in 1952, and it increased to 3 piasters in 1954 with partial operation of the El Bared Plant. The thermal plants produced energy in 1954 for an average of about 7 piasters per kilowatt-hour. The average cost for all energy produced in 1954 was about 5 piasters per kilowatt-hour at the 5,500 volt distribution primary in Beirut.

Table A-2 shows the production costs in 1954 for the various hydro and thermal power plants supplying the Beirut Load Area, and the expected production costs for additional thermal power plants completed during 1955.

TABLE A-2

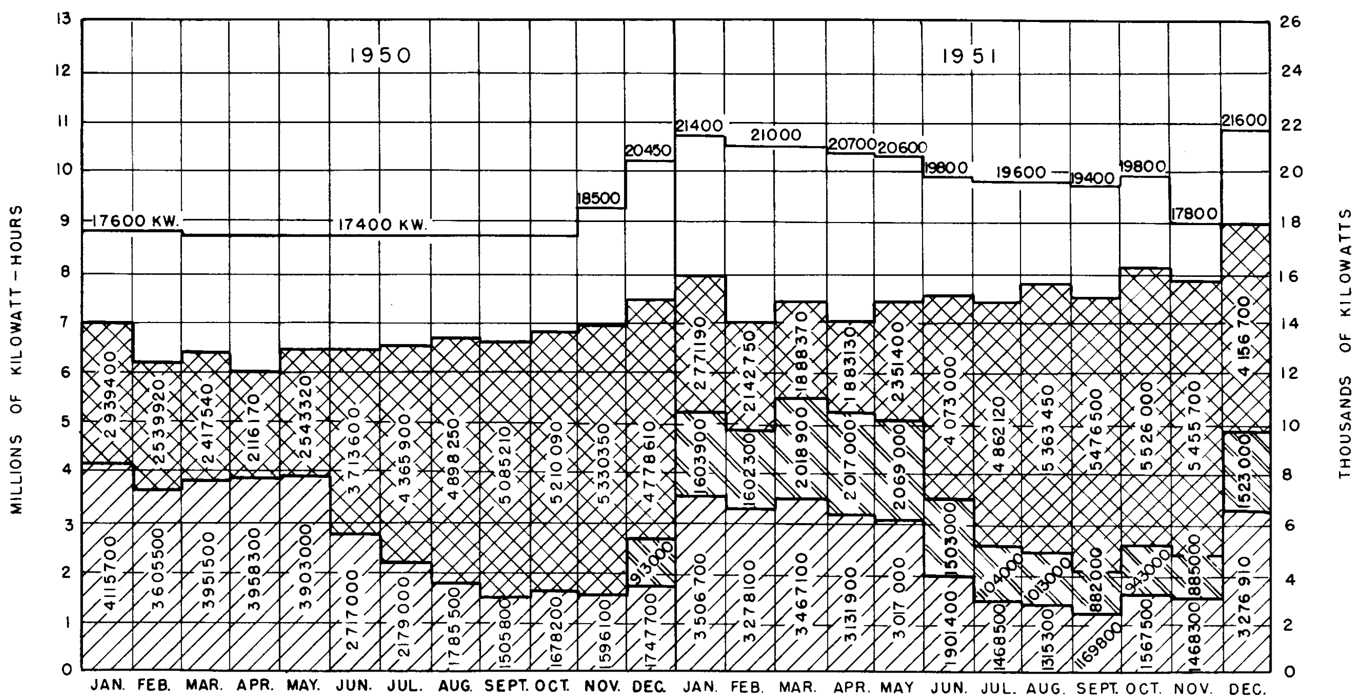
PRODUCTION COSTS - HYDRO AND THERMAL POWER PLANTS
BEIRUT LOAD AREA

Plant	Installed Capacity (Kilowatts)	Year of Initial Operation	Cost per kwh at the 5.5-kv. Distribution Primary (Lebanese Piasters)
Safa	6,400	1932	2.0
Nahr Ibrahim	5,000	1950-1954	4.2
Nahr el Bared	9,000	1954	5.0
Beirut Diesel	12,400	1925-1949	7.5
Magazel Diesel	400	1954	7.0
NETCO Steam	7,000	1954	6.5
Zouk Mikael Steam	15,000	1955	4.5
Beirut Gas Turbine	5,000	1955	5.0 to 6.0

The production costs given here for the first 15,000-kilowatt unit at Zouk Mikael is an estimate based upon the expected initial utilization. As the utilization improves, this production cost is expected to decrease to about 3.5 piasters per kilowatt-hour. The production cost given here for the Beirut Gas Turbine Power Plant is an estimate based upon its being operated essentially as a peak load plant. All estimates of production cost for the privately-owned power plants which sell their energy to the Beirut Electricity Company are actually the net cost to the Beirut Electricity Company. The basic data for all of the above estimates of production costs for hydro and thermal power plants were supplied by the Ministry of Public Works, Government of Lebanon.

Present Electricity Rates. Maximum electric rates in Lebanon are fixed by government decree in accordance with the circumstances and the requirements of each concessionaire. The general tendency is for the concessionaire to charge the maximum permitted, so the actual rates closely correspond to the maximum rate permitted by the governmental decree.

The rates, as defined by the Government, come under one of three general forms. In one form, the subscriber pays for the number of kilowatt-hours used -- the rate per kilowatt-hour depending upon the purpose for which the power is to be used. This type of rate has the disadvantage of requiring a meter for lighting and another meter for motors and other use. A second rate form is based upon the number of hours of utilization of the power subscribed for. The subscribed power is determined by the size of the meter and entrance breaker in many cases, but some concessionaires actually record the highest fifteen minutes integrated demand in a month and base the amount of subscribed power on that. The number of kilowatt-hours used is divided by the amount of subscribed power to arrive at the number of hours of utilization. The rate per kilowatt-hour is then based upon the number of hours of utilization--the more hours of utilization, the lower the rate



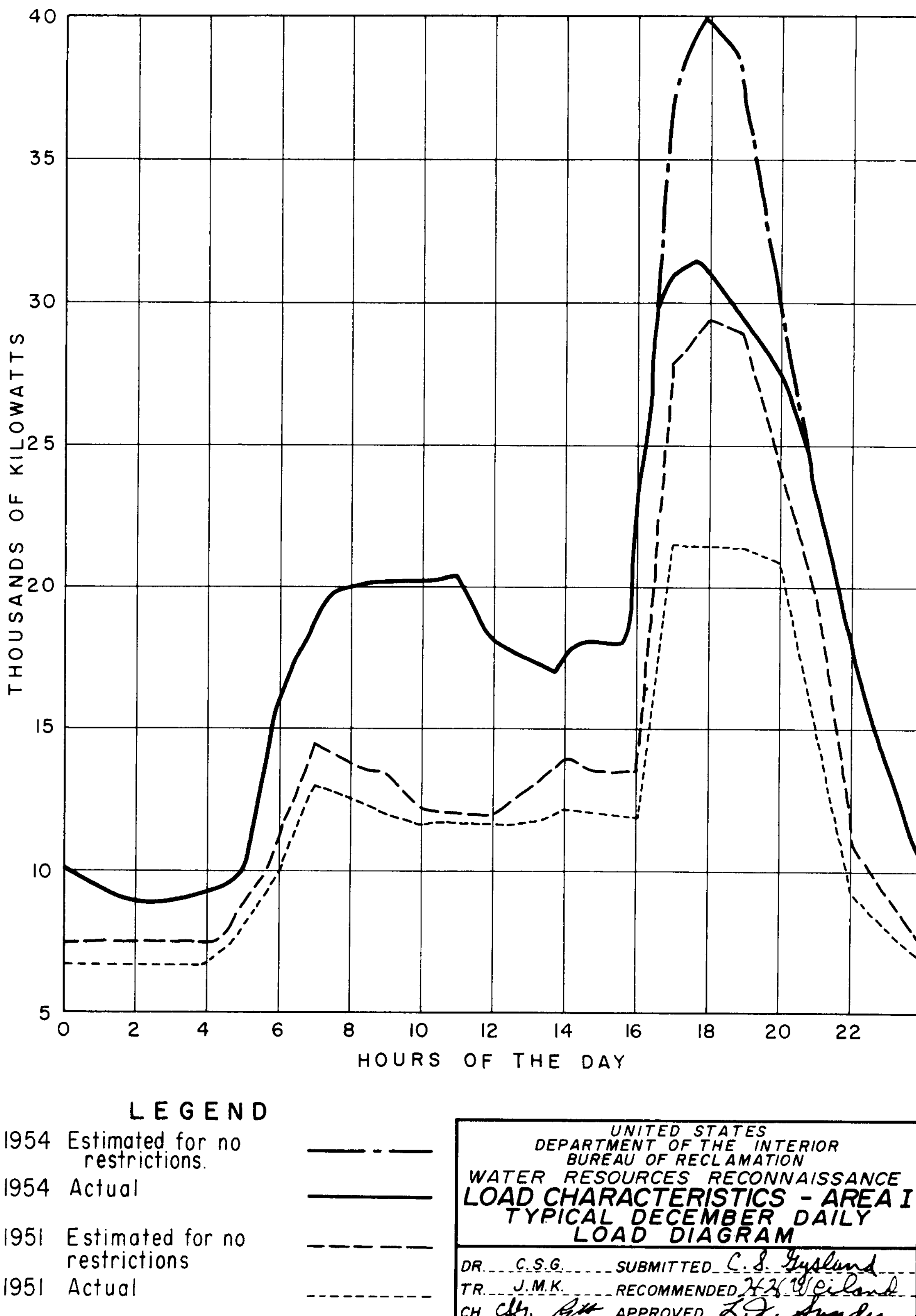
	1950	1951
Safa Hydro	32,744,100 Kwh.	28,568,510 Kwh.
Nahr Ibrahim	1,018,000 Kwh.	17,164,100 Kwh.
Diesel	45,938,310 Kwh.	45,950,310 Kwh.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
WATER RESOURCES RECONNAISSANCE

BEIRUT INTERCONNECTED LOAD AREA
POWER AND ENERGY GENERATION
1950-1951

DR. C.S.G. SUBMITTED C. S. Gysland
TR. E. H. RECOMMENDED H. H. Weiland
CH. [illegible] APPROVED L. J. Snyder
BEIRUT, LEBANON NOV. 23, 1955 | OA - 10 - 566

PLATE A-2



UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
WATER RESOURCES RECONNAISSANCE

LOAD CHARACTERISTICS - AREA I
TYPICAL DECEMBER DAILY LOAD DIAGRAM

DR. C.S.G.	SUBMITTED C. S. Gysland
TR. J.M.K.	RECOMMENDED H. H. Weiland
CH. [illegible]	APPROVED L. J. Snyder
BEIRUT, LEBANON OCT. 31, 1955	OA-10-560

PLATE A-3

per kilowatt-hour. The above two rate structures are applicable to industrial users, commercial establishments, schools, churches, hotels, cafes and theaters. Under these rates are penalties (defined by Governmental decree for each month of the year) which are assessed for use of power for machinery during the peak hours of the day, as well as for the use of low power factor equipment by the subscriber. There is also a difference in rate depending upon whether the subscriber takes the power at high voltage (5,500 volts) or low voltage (190/110 volts).

The third rate structure is applicable to residential and small commercial subscribers. The maximum rate per kilowatt-hour is applicable to the first block of energy. In Beirut and Tripoli the first block ranges in size between 20 and 70 kilowatt-hours per month, depending upon the size of the meter and entrance breaker. The minimum is charged for all energy used in excess of the first block during a given month.

The 1956 decreed rates for electrical energy are shown in Table A-3.

TABLE A-3

DECREED ELECTRICAL ENERGY RATES
(Piasters per kilowatt-hour)

Location	Residential and Commercial	Industrial	
		Low Voltage	High Voltage
Beirut Load Area	Maximum 16.5 Minimum 10.0	Maximum 11.0 Minimum 8.0	Maximum 10 1/ Minimum 5.5
Tripoli Load Area	Maximum 16.5 Minimum 7.0	Maximum 9.0 Minimum 8.0	Maximum 6.5 Minimum 3.0
Other Localities	Maximum 35.0 Minimum 18.5	- -	- -

1/ Energy used during the peak hours, as defined by the Governmental decree, for motive power is charged for at the rate of 16.5 piasters per kilowatt-hour.

Rates charged by the large companies, such as the Beirut Electric Company, for energy delivered to concessionaires for distribution and resale, are not shown in Table A-3. This energy is delivered to the concessionaires at 5,500 volts for rates ranging from a minimum of 3,5 piasters to a maximum of 9.5 piasters per kilowatt-hour. This maximum rate is applied to on-peak deliveries.

The rates for electric energy in the urban centers of Lebanon appear to be reasonable if one compares these rates and the above production costs for thermal and hydroelectric power with the corresponding rates and production costs for electric power in parts of the United States and Europe. Furthermore, these rates if applied to the entire country should not be detrimental to the growth of the load.

Future Power Requirements

Factors Influencing Future Load Development. The major factors influencing present and estimated future electric power requirements in Lebanon are the physical features of the power market area, natural resources, population, income, principal economic activities, and electric rates.

The 1952 annual personal income was evaluated at approximately LL. 700 ($220) per capita in Lebanon. The estimated annual per capita income of families using electricity was approximately LL. 1100 ($340).

Table A-4 shows the estimated population in Lebanon by load area for the period 1932 to 1975.

TABLE A-4

ESTIMATED POPULATION IN LEBANON
(In Thousands)

Load Area	Description	1932	1951	1955	1960	1965	1970	1975
I	Beirut	115	400	468	548	630	705	782
I	Towns & Villages	1/	304	324	354	391	432	481
I	Total Area	1/	704	792	902	1,021	1,137	1,263
II	Total Area	1/	255	270	292	313	334	353
III	Total Area	1/	247	250	258	262	269	271
IV	Total Area	1/	98	100	103	105	107	109
	Grand Total:	793	1,304	1,412	1,555	1,701	1,847	1,996

1/ Data not available

Trade and services provide the largest share of the national income, followed by agriculture and industry. Manufacturing on a modern scale has developed in Lebanon during the past twenty-five years. The estimated capital investment in Lebanese industry is estimated at 200 million Lebanese Pounds, which includes a working capital of 50 million Pounds. The annual output of this industry is estimated at 130 million Pounds. There is an industrial labor force of approximately 21,000 which earns 34 million Pounds annually.

The electric rates in effect at present are not as important a factor in holding down load growth as the lack of facilities to meet the present demand. It is not within the scope of this report to establish retail rates, but future rates must be designed to yield an adequate revenue to the power system, and at the same time, they must be designed to meet the competition of alternative sources of energy. When, in the future, a load-building policy is necessary, rates more favorable to the 40-60 hour commercial week should be adopted, and more incentives should be given to off-peak uses of energy.

Future Load Growth. Electrical energy consumption in Lebanon increased at an average annual rate of 9 percent between 1925 and 1939. Since World War II the use of electrical energy has increased at an average rate of nearly 16 percent per year. This increase has been particularly pronounced in the urban Areas I and II. In Area I, the rate of increase has been dampened by the effects of restrictions on the use of electricity even to the extent of mandatory blackouts of districts in Beirut and its suburbs during the evening peak hours. Realizing that some time in the future the power market will approach saturation, an effect should be made to present conservative predictions. The estimates derived in this survey and presented on the graph, Plate A-4, are based upon an assumed rate of annual increase of 11 percent until 1965, and a 6 percent increase thereafter throughout the development period of the Litani River Project. Two factors having a bearing on load growth in a region are the normal increase in population and the increase of per capita use of electricity. Estimates of the population trend in Lebanon have been presented, and on Plate A-5 comparisons are made of the per capita consumption of electrical energy in Lebanon with that of other countries in the world. When comparing the per capita usage of electrical energy in Lebanon with various representative countries of the world, it was found that each country assumed a certain trend of increase, that the trends followed almost similar patterns, and that Lebanon follows the general trend.

The residential energy sales estimated for the future, as shown on Table A-5, are based on continuation of residential electric rates in Beirut at substantially the same rates as are presently in effect. Except for the possible introduction of a low off-peak energy rate for such uses as water heating, reductions in the Beirut residential rate do not appear likely.

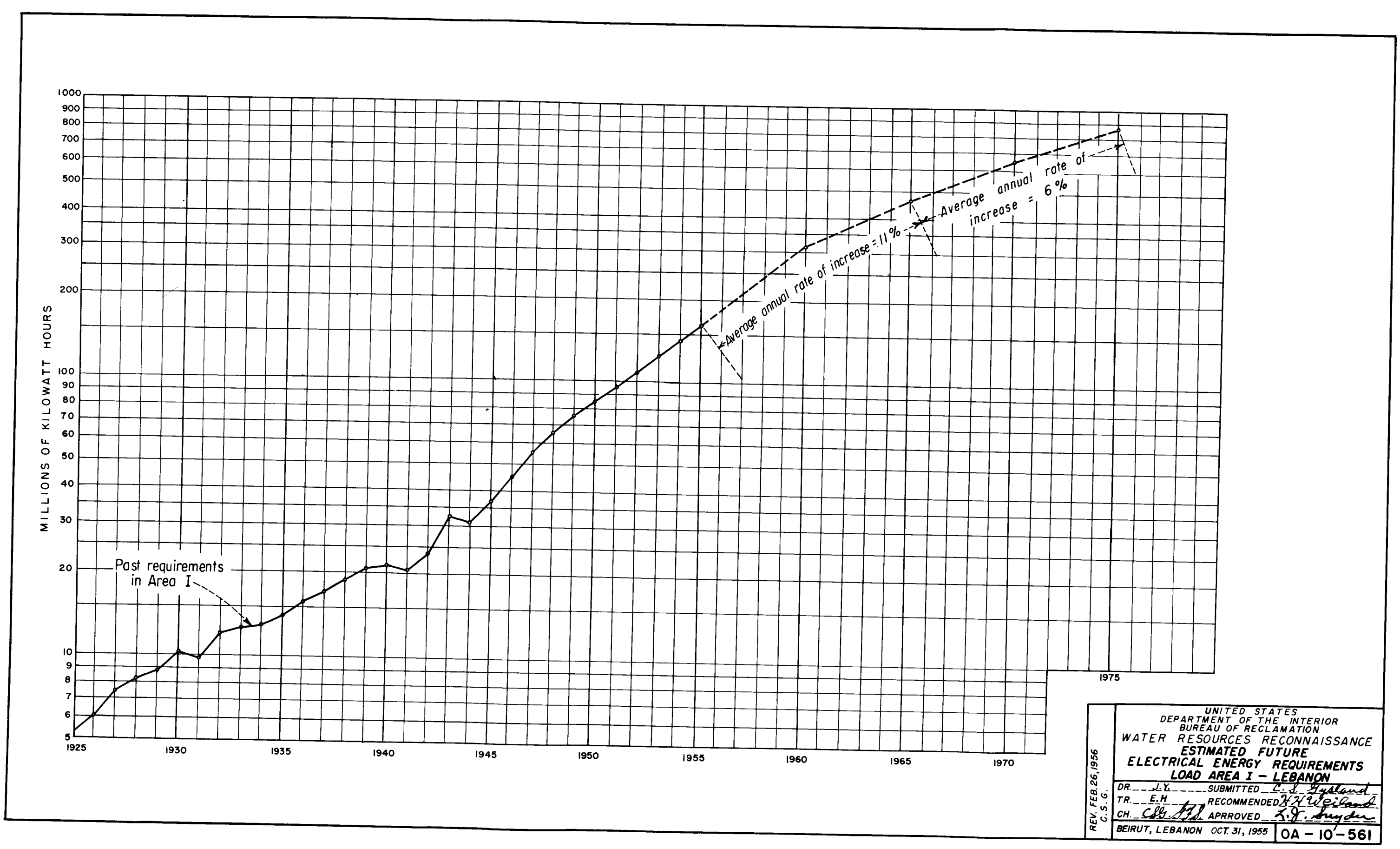

MILLIONS OF KILOWATT HOURS
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
Past requirements in Area I
Average annual rate of increase = 11%
Average annual rate of increase = 6%
REV. FEB. 26, 1956 C. S. G.
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
WATER RESOURCES RECONNAISSANCE
ESTIMATED FUTURE
ELECTRICAL ENERGY REQUIREMENTS
LOAD AREA I – LEBANON
DR. J.Y.
SUBMITTED
TR. E.H.
RECOMMENDED
CH.
APPROVED
BEIRUT, LEBANON OCT. 31, 1955
OA – 10 – 561

PLATE A-4

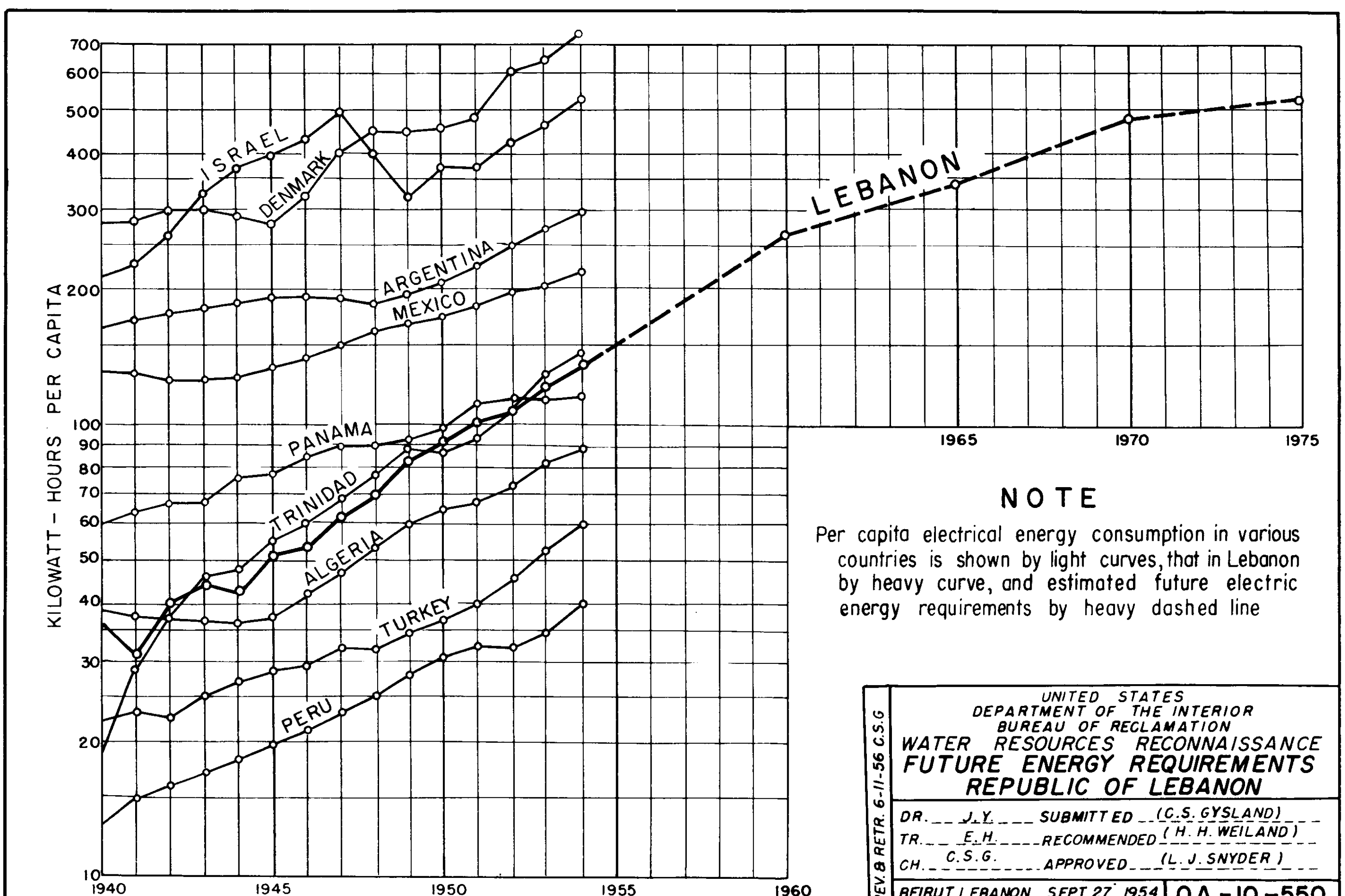

KILOWATT - HOURS PER CAPITA
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
1940
1945
1950
1955
1960
1965
1970
1975
ISRAEL
DENMARK
ARGENTINA
MEXICO
PANAMA
TRINIDAD
ALGERIA
TURKEY
PERU
LEBANON
NOTE
Per capita electrical energy consumption in various countries is shown by light curves, that in Lebanon by heavy curve, and estimated future electric energy requirements by heavy dashed line
REV. & RETR. 6-11-56 C.S.G.
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
WATER RESOURCES RECONNAISSANCE
FUTURE ENERGY REQUIREMENTS
REPUBLIC OF LEBANON
DR. J.Y. SUBMITTED (C.S. GYSLAND)
TR. E.H. RECOMMENDED (H. H. WEILAND)
CH. C.S.G. APPROVED (L. J. SNYDER)
BEIRUT, LEBANON SEPT 27, 1954
OA-10-550

PLATE A-5

TABLE A-5

FUTURE RESIDENTIAL ELECTRICAL ENERGY REQUIREMENTS
BEIRUT

Year	No. of Residential Meters	Population (Thousands)	Percent Using Electricity	Persons per meter	Requirements per meter (kwh)	Total Requirements (Thousand kwh)
1932	7,000	115	60	10	275	2,000
1940	17,500	240	65	9	390	6,800
1947	25,043	320	70	9	400	10,000
1951	47,361	400 1/	75	6.5	474	22,400
1955	64,000	468 1/	83	6	800	51,500
1960	94,000	548 1/	91	5.5	1,000	94,000
1965	117,000	630 1/	93	5	1,200	140,000
1970	148,000	705 1/	94	4.5	1,300	192,000
1975	186,000	782 1/	95	4	1,400	260,000

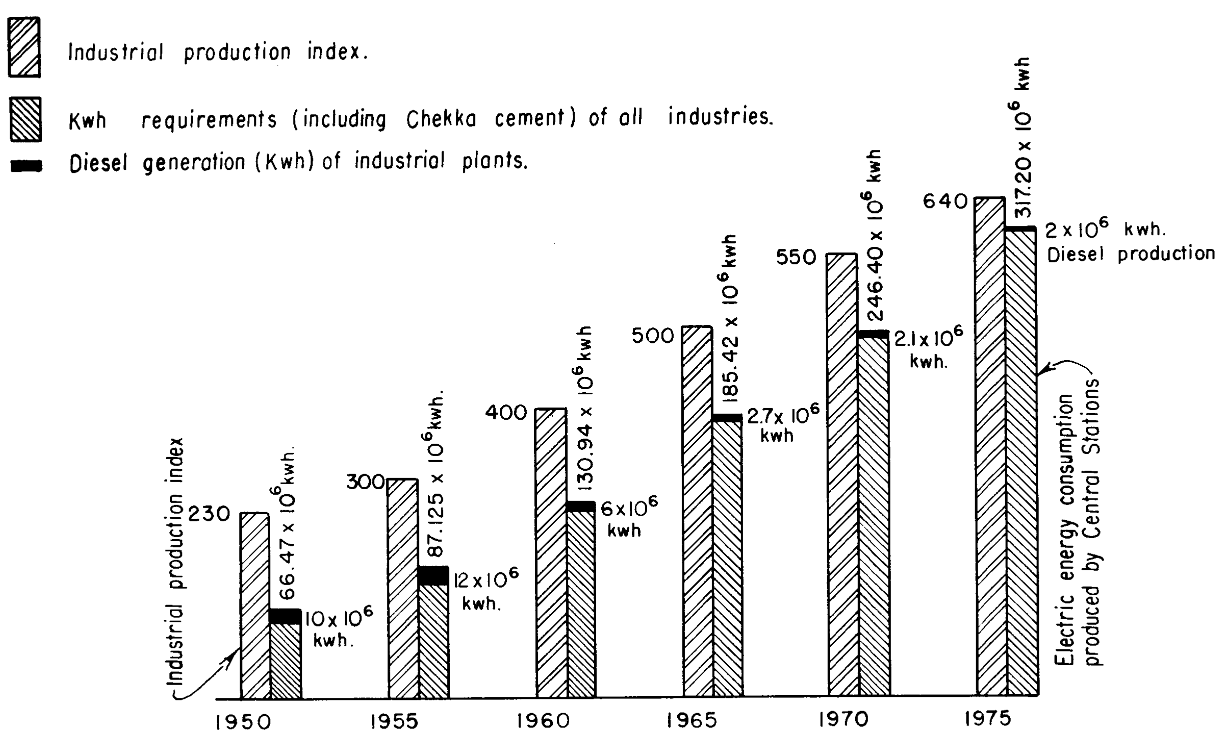
1/ Estimated. (See preceding population discussion).

If the reversible heat pump can be made available at a cost acceptable to the average income group, it should find wide acceptance as its use is ideally suited to Beirut's mild climate. The lower cost air-to-air design may be used and approximately the same capacity will be needed for either the summer cooling or winter heating cycle. There is a considerable demand in Beirut for summer cooling of offices, restaurants, shops, and other commercial establishments. It is believed that when the dual feature of the heat pump has been demonstrated (enabling heating in the winter with the same equipment that is used to provide cooling in the summer), the demand for this equipment will be instantaneous, especially for use in residential apartment buildings in the city. Estimates indicate that it will be possible to operate a heat pump in Beirut for even less than it costs to heat with fuel oil, based on the present rates for both electricity and fuel oil.

Many of the offices and shops in Lebanon have inadequate lighting facilities, and are lacking sufficient display windows and neon signs. A similar situation exists in schools and hospitals which also need air conditioning and heating. Furthermore, hotels, restaurants, and night clubs are in need of air conditioning during the summer months when most of these lose their patrons to other establishments possessing air conditioning facilities.

Although there were restrictions imposed by the Electricity Company of Beirut to curtail commercial consumption due to its inability to meet the demand, the annual rate of increase for this category has gone from 8.5 percent in 1945 to 13 percent by 1952. Future commercial Electrical Energy requirements for Beirut are shown on Table A-6.

FUTURE ELECTRICAL ENERGY REQUIREMENTS FOR INDUSTRIES IN LEBANON



OA-10-562

NOV. 30, 1955 C.S.G.

PLATE A-6

TABLE A-6

FUTURE COMMERCIAL ELECTRICAL ENERGY REQUIREMENTS
BEIRUT

Year	Number of Commercial Customers	Commercial Energy Requirements per Customer (kwh)	Population (Thousands)	Commercial Energy Requirements per Capita (kwh)	Ratio Residential to Commercial Requirements	Total Annual Commercial Energy Requirements (kwh x 10^3)
1932	-	-	115	-	-	-
1940	-	-	240	-	-	-
1944	-	-	300	-	-	-
1948	4,050	1,082	330	12.2	2.96	4,400
1951	5,765	1,295	400	18.5	3.00	7,400
1955	10,000	1,750	468	37.5	3.00	17,500
1960	14,200	2,200	548	57.0	3.00	31,000
1965	17,000	2,800	630	76.0	3.00	48,000
1970	20,000	3,200	705	91.0	3.00	64,000
1975	25,600	3,450	782	112.0	3.00	88,000

Lebanon's geographic position, together with its sea and airports and its good highway system, make it a branch point of communications with each of the Middle Eastern countries and an important link in the trade route between European, African, and Asian countries. So far, these countries have transported through Lebanon their requirements from foreign markets. With the growth and development of Lebanese industry, it is hoped to replace a portion of such goods in transit by competitive items of local manufacture. Future development beyond the next five years will depend largely on the availability of electrical energy. Assuming future availability of a dependable power supply, it is expected that new industries will be set up. The element of risk pertaining to the setting-up of industries such as automobile assembly plants, cement factories, drydocks, iron ore mining, etc., is apt to introduce considerable error in any forecast of the future industrial power requirements.

Another factor which will affect the future load is the purchase of electrical energy by industries now producing their own energy. According to a joint survey made by the Ministry of National Economy and the Industry and Transport Section, USOM/Lebanon of 1,000 industrial establishments, it was found that most of the industrial energy used in Lebanon is supplied to the industries by their own power units. It is assumed that, in 15 or 20 years, 80 or 85 percent of the industries producing their own energy would want to shift to a central power source. Some industries, notably the olive oil industry, would convert from direct diesel power and hand-driven machinery to electric motive power. Plate A-6 shows the estimated future electrical energy requirements in industries for the entire country, the energy produced by the industries, and the estimated future industrial production indices for the years 1955 to 1975.

Electrical energy requirements for other miscellaneous loads such as tractions, municipal lighting, domestic water pumping, irrigation, and losses must be considered in estimating future requirements. Future electrical energy requirements under the classification "Traction" are for the operation of the tram cars in Beirut. At present there are no electrified railroads in Lebanon, although the electrification of mainlines has been proposed. The estimated future electric energy requirements for traction is based on the assumption that the tramway system in Beirut will be modernized and expanded sufficiently to maintain adequate service. At present the antiquated tram cars are nearly always crowded beyond capacity. The 1965 electrical energy requirements for traction are estimated at 30 million kilowatt-hours and the 1975 requirements at 48 million kilowatt-hours. The current trend in other countries is to replace tram cars with electric-trolley busses and expand the transportation facilities to cover a wider area of the city and suburbs. This is reflected in the estimates for future years which are given in Table A-7 and on Plate A-7.

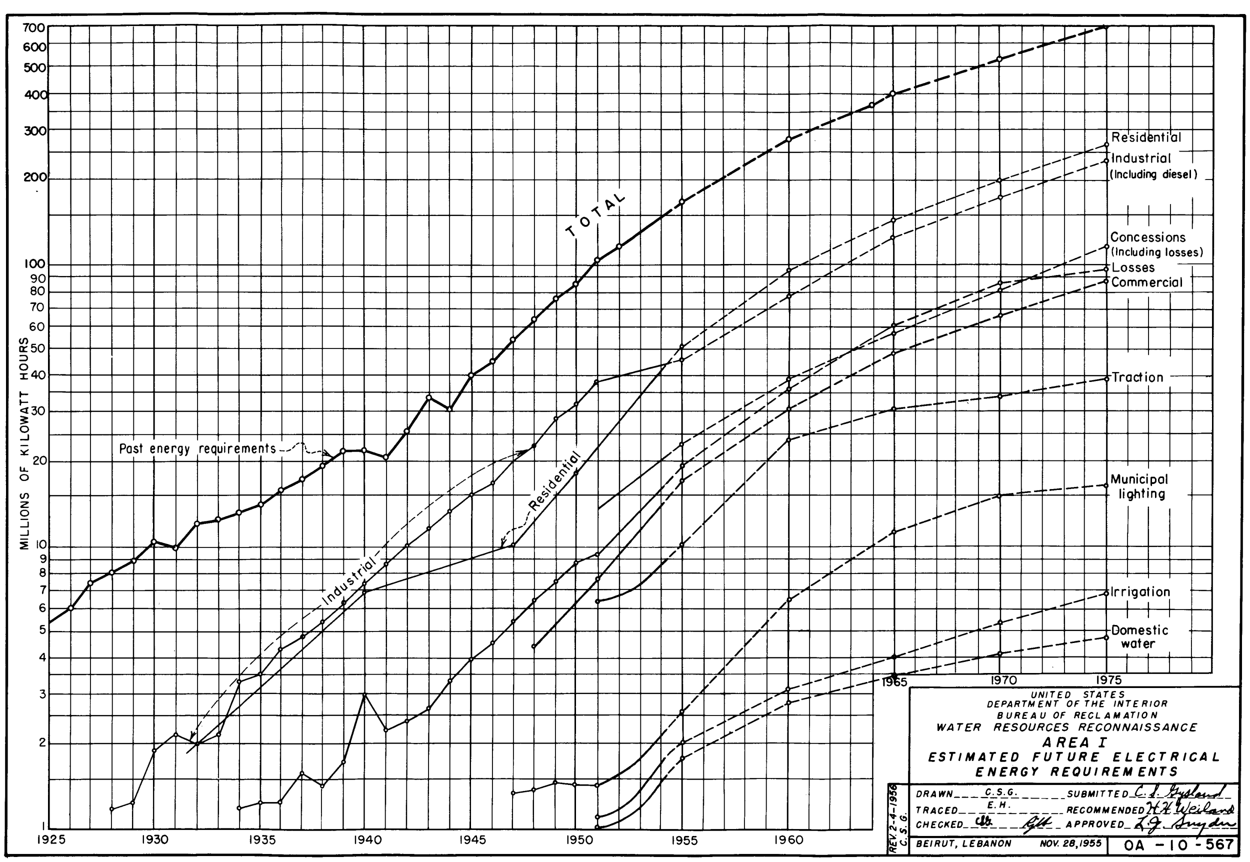

MILLIONS OF KILOWATT HOURS
TOTAL
Past energy requirements
Industrial
Residential
Residential
Industrial (Including diesel)
Concessions (Including losses)
Losses
Commercial
Traction
Municipal lighting
Irrigation
Domestic water
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
WATER RESOURCES RECONNAISSANCE
AREA I
ESTIMATED FUTURE ELECTRICAL
ENERGY REQUIREMENTS
DRAWN C.S.G.
TRACED E.H.
CHECKED
SUBMITTED
RECOMMENDED
APPROVED
REV 2-4-1956 C.S.G.
BEIRUT, LEBANON
NOV. 28, 1955
OA -10-567

PLATE A-7

TABLE A-7

ESTIMATED FUTURE ENERGY REQUIREMENTS
LOAD AREA I
(All values in millions of kilowatt-hours)

Use Classification	1951	1955	1960	1965	1970	1975
Beirut (City)						
Residential	22.4	51.5	94.0	140.0	192.0	260.0
Commercial	7.4	17.5	31.0	48.0	64.0	88.0
Concessions	9.5	19.3	36.5	54.5	79.5	111.5
Industries	39.5	46.0	75.0	122.0	170.0	232.0
Other Area I Loads						
Traction	6.3	10.0	24.0	30.0	40.0	48.0
Municipal Lighting	1.3	2.7	6.5	11.0	15.0	16.0
Domestic Water	1.0	1.9	2.7	3.5	4.2	4.8
Irrigation	1.0	2.0	3.0	4.0	5.4	6.8
Losses	13.6	22.9	38.0	58.1	82.2	94.5
Total Electrical Energy Requirements:	102.0	173.8	310.7	471.1	652.3	861.6

Electrical energy for public street and highway lighting are closely related to population and increasing demands of the population for additional municipal services.

The ultimate electrical energy requirements for pumping domestic and industrial water were based on the assumption that the presently planned projects would be constructed, and that the Beirut system would be enlarged about 50 percent by 1975.

Agriculture throughout most of the country is generally dependent on irrigation for its success. In areas where gravity water is not available, pumping from streams or underground water supplies can be done if electric energy is supplied at a reasonable cost. A large part of the existing pump primemover capacity is comprised of small diesel motors. To arrive at the future electrical energy requirements for irrigation, an estimate was made of the area of land which could reasonably be expected to be irrigated and which could not be served by gravity.

The sum of all of the foregoing classes of use gives the total load at the point of delivery. Transmission and distribution losses, and energy which cannot be accounted for, must be added to this total to obtain the total load on the generating facilities. In estimating the losses in future years it was concluded that the percent of losses would decrease due to expected improvements in the distribution systems.

The total electrical energy consumption for Load Area I in 1951 was about 94 million kilowatt-hours, increasing to 130 million kilowatt-hours, in 1954. This figure is expected to increase by 1965 to about 400 million kilowatt-hours -- over four times the 1951 consumption -- and to about 700 million kilowatt-hours by 1975 -- over seven times the 1951 consumption. These estimates were used in determining the future electrical energy deficiencies for Load Area I. Estimated future electrical energy requirements by classified use for Load Area I are shown on Plate A-7 and Table A-7.

Characteristics of the Future Load. The future characteristics developed and presented here are for use in coordination studies for the purpose of matching the potential hydro- and thermal-electric power supply to the future loads of various magnitudes. The future load characteristics will change with expected gradual improvement of the daily, monthly, and annual load factors and with changes in monthly distribution of the annual energy. The latter will result from an expected gradual decrease in the annual rate of energy consumption as load saturation is reached in the future.

Because it is impracticable to predict the load characteristics precisely year by year, the required characteristics were derived for expected average conditions from the present to 1965, and for those beyond 1965. The set of characteristics for each of these two average conditions consists of monthly distribution of the annual energy, monthly peak demands, monthly and annual load factors, and load duration and peak percentage curves for the months of December and March. These months are critical in properly coordinating the hydro- and thermal-electric supply on the future loads. December is the month of annual peak demand, and March is the month of maximum streamflow with corresponding maximum total energy generation from existing and potential hydroelectric plants. These characteristics as shown in this section are presented on a percentage basis. As actually used in coordination studies in following sections of this report, these characteristics are converted to a kilowatt and kilowatt-hour basis to represent loads of the required magnitude.

The following factors were considered in the derivation of the above-mentioned characteristics. The efforts made to curtail peak demand have had the effect of holding down kilowatt demand at the same time that the kilowatt-hour consumption was increasing. Thereby, the load factor is greater than would have been the case if all demand had been satisfied and the load factor had been permitted to seek its level in accordance with the load actually being served. A study of the load factors in the past twenty years shows that, following the installation of power supply facilities adequate to meet the load, the annual load factor always dropped sharply and then increased as the demand began to overtake the supply. This was especially true when restrictive measures were applied to limit the peak.

The increased use of electricity in the home for refrigeration, water heating, cooking, and other non-lighting purposes have led to a gradual improvement of the load factor for residential loads. The proportion of industrial use with a high load factor is not expected to increase appreciably compared to the overall load.

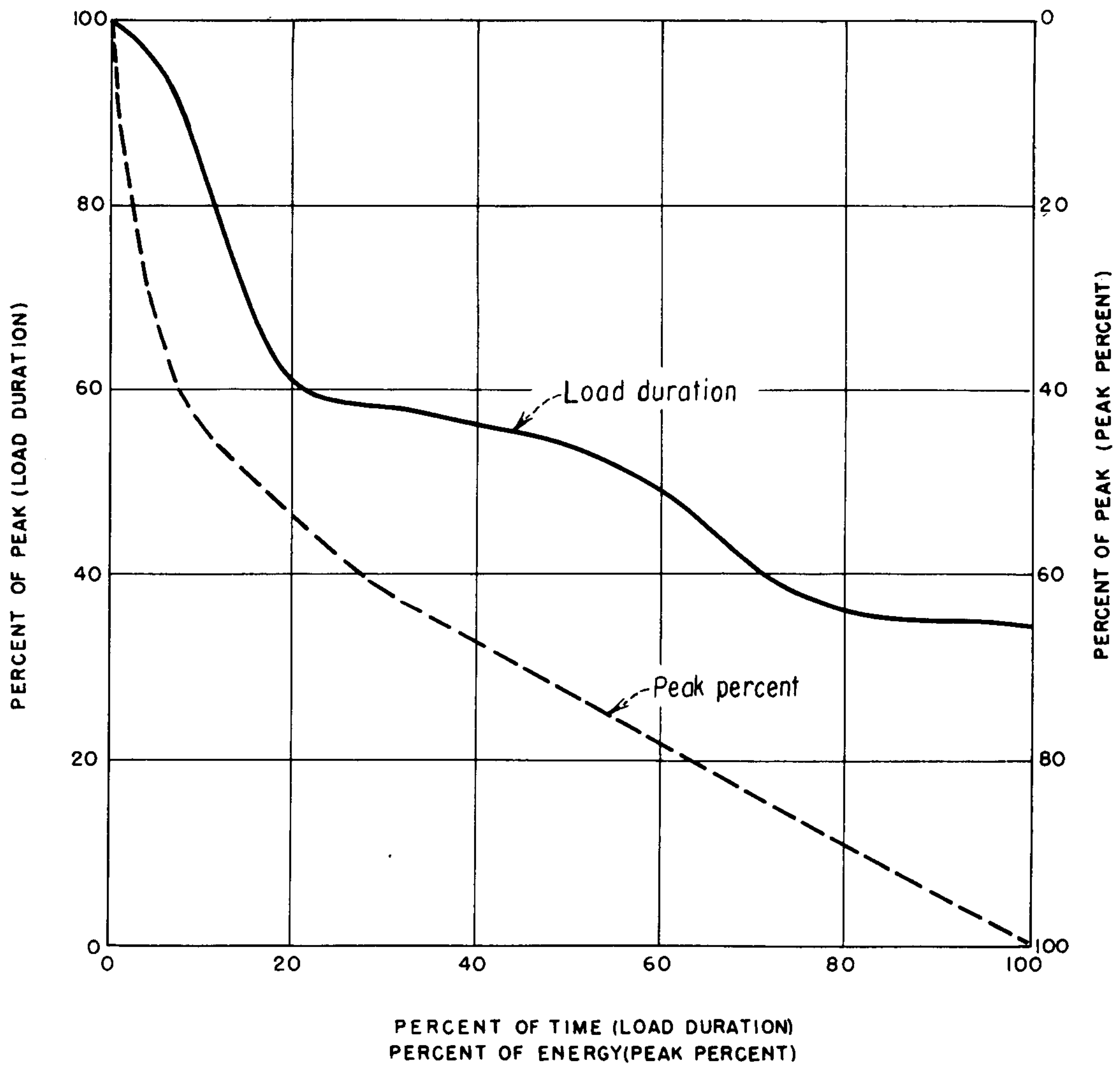
This power market survey has not revealed information upon which to base a prediction that the combined system load factor in the future will improve rapidly. However, there are indications that an annual load factor on the order of 50 percent may be expected by 1975. The shape of the daily load curve follows a characteristic pattern through a long period of time. Plate A-8 shows the drived load duration curve for a future month of March, and Plate A-9 shows a similar curve for a future month of December. These curves are of the composite load in Lebanon and have been drawn up assuming an interconnected system. The general characteristics of the load have not undergone a pronounced change from past to present, which would lead to a forecast that the shape of the load duration curves would be drastically different in the future. The daily load factor, however, is expected to improve because of additional cooking, water heating, refrigeration, air conditioning, water pumping, and other applications which extend the use of electric power "around-the-clock". Adoption of low rates for off-peak uses would be especially helpful in this regard. Improvement of the daily load factor will bring with it an improvement of the monthly and annual load factors.

The present load characteristics were used as a basis for determining a monthly distribution of the annual energy consumption and peak demands. The monthly distribution is not expected to change appreciably except for future changes in the annual load growth. No disproportionately large seasonal future loads, such as air conditioning, summer water pumping, electric heating in the winter, or seasonal industrial load, were discovered in this power market study. The history of electric power in Lebanon has been a record of power shortages, restrictions on use, "brownouts", and below-average service, particularly in the Beirut area which has consumed over 70 percent of the energy generated in the country. In spite of this, the load has grown at the rate of about sixteen percent per year during the past nine years, and at a long-time rate of eleven percent per year.

It was brought out in the preceding discussion of future load growth that the load is expected to increase at ten percent per year until about 1965. Beyond that time a rate of six percent per year has been assumed. Plate A-10 shows the monthly energy and peak demand characteristics for a year with a six percent load growth.

Retirement of Existing Power Facilities. The estimate of the power deficiency in Lebanon must take into account the retirement of existing generating facilities. Equipment is being operated which, under the usual considerations, should have been retired

MARCH CONDITIONS
1965 - 1975

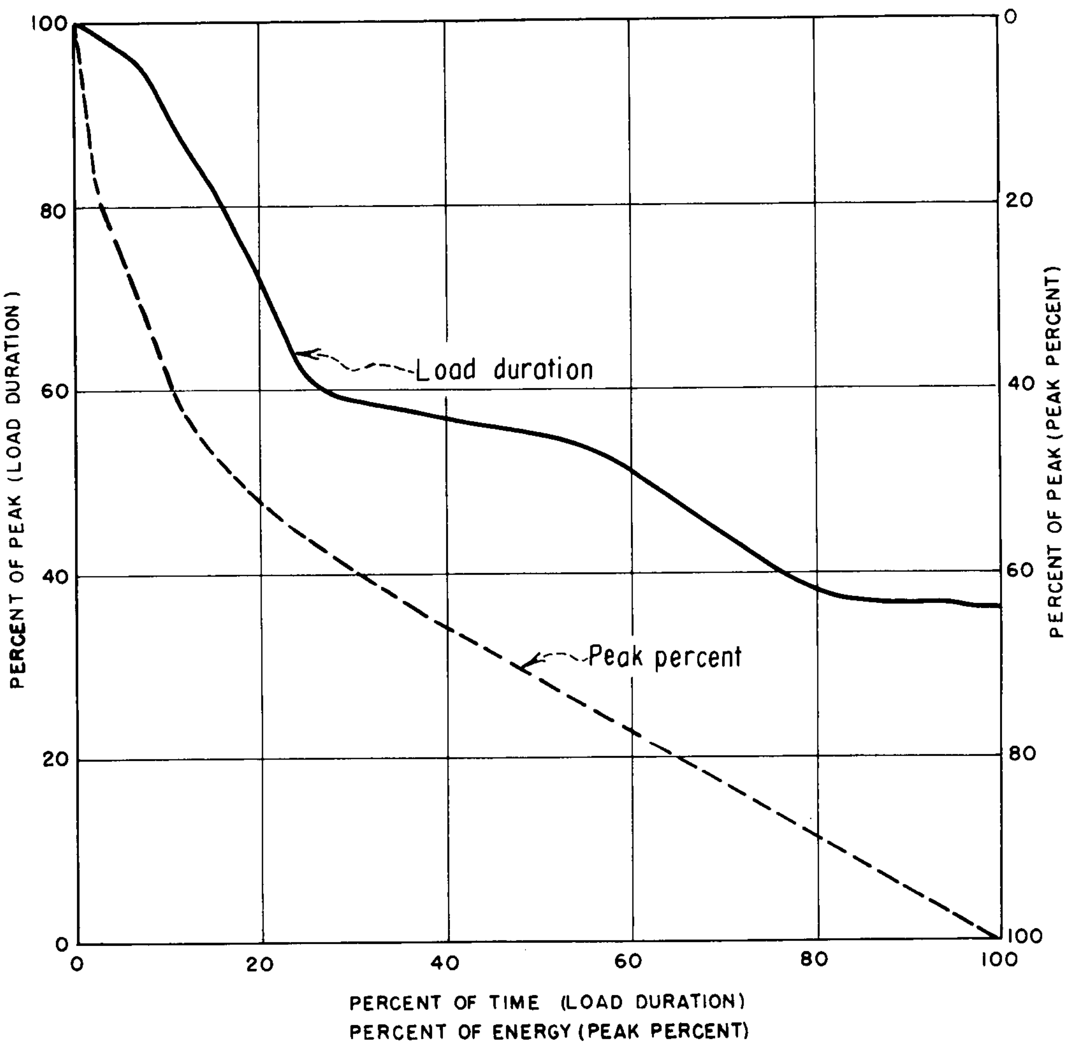


UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
WATER RESOURCES RECONNAISSANCE
FUTURE LOAD CHARACTERISTICS
LOAD DURATION AND PEAK PERCENT CURVES
MARCH CONDITIONS-1965-1975

DR. C.S.G.	SUBMITTED C. L. Gysland
TR. E.H.	RECOMMENDED H. H. Weiland
CH. [illegible]	APPROVED L. G. Snyder
BEIRUT, LEBANON NOV.18,1955	OA-10-563

PLATE A-8

DECEMBER CONDITIONS
1965-1975



UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
WATER RESOURCES RECONNAISSANCE

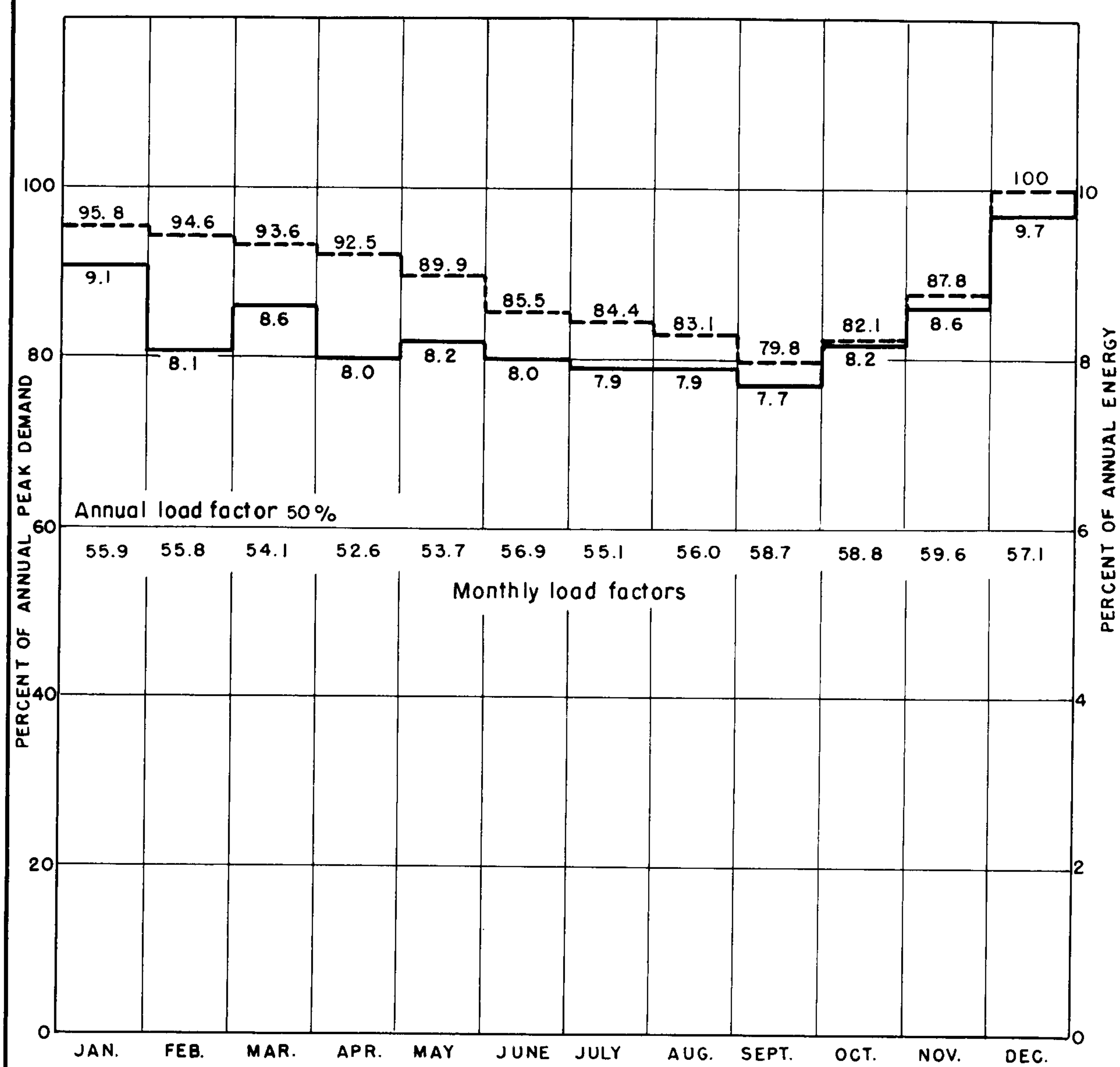
FUTURE LOAD CHARACTERISTICS
LOAD DURATION AND PEAK PERCENT CURVES
DECEMBER CONDITIONS - 1965-1975

DR. C.S.G. SUBMITTED C. S. Gysland
TR. E.H. RECOMMENDED H. K. Weiland
CH. G.H. APPROVED L. G. Snyder

BEIRUT, LEBANON NOV. 18, 1955 OA-10-564

PLATE A-9

1965 TO 1975 LOAD CHARACTERISTICS IN LEBANON



6 % ANNUAL LOAD GROWTH

—— Percent monthly energy of annual energy
– – – Percent monthly peak of annual peak demand

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
WATER RESOURCES RECONNAISSANCE

FUTURE LOAD CHARACTERISTICS
MONTHLY DISTRIBUTION
6 % ANNUAL LOAD GROWTH

DR. C.S.G. SUBMITTED C. S. Gysland
TR. E.H. RECOMMENDED H. H. Weiland
CH. [illegible] APPROVED L. A. Snyder

BEIRUT, LEBANON NOV. 18, 1955 OA-10-565

PLATE A-10

long ago. The Electricity Company of Beirut has three diesel units which at present can be operated only a few hours a day. One of these is a 400 kilowatt unit installed in 1925; two are 1,200 kilowatt units, one installed in 1929 and the other in 1921. If it were possible to operate the system without these machines they would have certainly been retired by now due to the high operation and maintenance costs resulting from their excessive wear and obsolete design.

Although the Tripoli area appears to have, at present, a small power surplus, the country taken as a whole is deficient in power supply. The installation of the first 15,000 kilowatt unit at Zouk Mikael in December 1955, and the second Zouk Mikael 15,000 kilowatt unit assumed ready in 1957, should relieve the power deficiencies in Lebanon until the completion of the first unit of the Litani River Project.

Realizing that during a power deficiency any equipment that can operate at all should not be retired, and that no capacity can be designated as reserve, a probable schedule of retiring existing equipment is presented. Such factors as age and condition of machines, and physical location of the power plants, are taken into account. Equipment located in the Tripoli area will probably be retired while it is in better condition than equipment located in the Beirut area, where every kilowatt of generating capacity is badly needed. This probable schedule is: Abou Ali Steam Turbine Unit, 1,630 kilowatts and Beirut Diesels, 3 units, 2,800 kilowatts, retired in 1956. In addition, there are 1,850 kilowatts in small diesel units at towns such as Saida, Tyr, Zahle, Nabatiye, Merjayoun, and Baalbek. At least half of these should be retired, and the rest placed in reserve, as soon as transmission facilities are extended from future power projects to bring a less costly and more dependable power supply to these vicinities. For the purpose of estimating the future power deficiency, this is assumed to occur by 1960. Retirement of existing power facilities is shown in Table A-8.

TABLE A-8

RETIREMENT OF EXISTING POWER FACILITIES

Name and Location of Equipment	Type	Year of Initial Operation	Capacity (kw)	Estimated Date Retired
Abou Ali	Steam	1908	1,630	1956
Beirut Diesel	Diesel	1925	400	1956
Beirut Diesel	Diesel	1929	1,200	1956
Beirut Diesel	Diesel	1931	1,200	1956
Scattered small plants	Diesel	--	925	1960

Future Reserve Capacity. The designation of equipment which can be classified as reserve capacity is difficult during a power shortage such as the one indicated in this market survey. For example, the 2,168-kilowatt hydro unit which was recently installed in the Abou Ali Power Plant, and the 1,000-kilowatt hydro unit which was recently installed in the Nahr el Djouz Power Plant, can be used as reserve units for emergency operation in the event of a breakdown of another unit in the same plant. Under most circumstances, however, the available water would not permit their operation to replace a unit in another power plant. For this reason these units are not considered as system reserve.

The only existing capacity of any consequence which can be relegated to reserve is in the diesel units at the Chekka Cement Works and at the Beirut Central Power Station. The Chekka diesel of 2,640-kilowatts, while actually serving only the load at the cement plant, can be considered reserve in that the cement plant can be dropped from an outside supply and the capacity which had been serving the cement plant's requirements can be used to cover an outage on the Kadischa system or the ultimate interconnected system. The four newest Beirut diesels (9,600-kilowatts) are assumed to be reserve units now that the Zouk Mikael 15,000-kw. unit is in operation. In addition there are the 925 kilowatts of diesel capacity at scattered locations, as explained in the paragraph, "Retirement of Existing Power Facilities", which are placed in the reserve category.

Additional reserve capacity is required in the future, and in the deficiency study it is assumed to exist. Table A-9 considers only the capacity known to be installed at present.

TABLE A-9

FUTURE RESERVE CAPACITY

Location and Type of Equipment	Year of Initial Operation	Year Relegated to Reserve	Reserve Capacity (Kw)
Beirut Diesel			
4 units	1946-1948	1956	9,600
Chekka Diesel			
3 units	1948-1953	1956	2,640
Miscellaneous Diesel	-	1959	925
		TOTAL:	13,165

Power facilities Under Construction. In determining future requirements, it is necessary to consider scheduled additions to the power supply facilities. In the Beirut area, the Government of Lebanon has taken over the completion of the Zouk Mikael Steam Power Plant. Construction of this plant was initiated by the Beirut Electric Company at a costal site about 11 kilometers north of Beirut. The ultimate size of this installation will be 90,000 kilowatts. The initial unit, placed in operation in December 1955, consisted of a 15,000-kilowatt unit with boiler capacity for a second unit of the same size. The second unit is scheduled for completion in 1957.

The Development Plan for the Litani River Basin has been adopted by the Lebanese Government and construction is expected to start during 1956. The completion of the power plants in this development is expected to follow the construction schedule presented in the report on the "Development Plan for the Litani River Basin".

GPO 851963