Prepared for, and under the guidance of,
the Committee on the Exercise of the Inalienable Rights
of the Palestinian People

THE UNIFIED DEVELOPMENT OF THE WATER RESOURCES OF THE JORDAN VALLEY REGION

PREPARED AT THE REQUEST OF THE
UNITED NATIONS
UNDER DIRECTION OF
TENNESSEE VALLEY AUTHORITY
by CHAS. T. MAIN, INC.
BOSTON, MASS. CHARLOTTE, N. C.
1953

INTRODUCTORY NOTE

Towards the end of last year it was already clear that the United Nations Relief and Works Agency for Palestine Refugees in the Near East would shortly be entering into a Programme Agreement with the Government of the Hashemite Kingdom of the Jordan to reserve a very large sum of money for a scheme to use the waters of the Jordan and Yarmuk Rivers for irrigating the Jordan Valley and for establishing refugees there.

Although the main outlines of the scheme had begun to take shape, it was thought proper (in view of the importance of the funds to be committed) to examine all previous plans — of which there are many — for utilising the waters of the Jordan River and its tributaries, and to determine the extent to which the projects which the Agency might be called upon to finance were really economical and would not be rendered nugatory by other projects undertaken by other interests in the same watershed.

It was found upon examination that no comprehensive survey of all the various proposals had been previously prepared; the Director therefore decided, with the concurrence of the Advisory Commission, to place the responsibility for such an investigation in the hands of the Tennessee Valley Authority, which by reason of its experience was the most appropriate organization to carry out the work. The Director also took steps to have studied the legal issues involved in the development of this international river.

Many of the earlier plans were prepared when the present political boundaries did not exist. Partly for this reason, but principally in the interests of sound engineering practice, the Tennessee Valley Authority was invited to disregard political boundaries, and to prepare a report indicating the most efficient method of utilising the whole of the watershed in the best interests of the area.

This report is the outcome of the request made to the Tennessee Valley Authority.

I take this opportunity of expressing the appreciation of the Agency for the cooperation of the Tennessee Valley Authority and the engineers who collaborated in the preparation of this report.

LESLIE J. CARVER
Acting Director
United Nations Relief and Works Agency
for Palestine Refugees in the Near East

Beirut, Lebanon
August, 1953

TENNESSEE VALLEY AUTHORITY

KNOXVILLE, TENNESSEE

August 31,1953

THE DIRECTOR,
UNITED NATIONS RELIEF AND WORKS AGENCY FOR
PALESTINE REFUGEES IN THE NEAR EAST,
BEIRUT, LEBANON

Sir:

I have the honor to present to you herewith the report prepared at your request on, "The Unified Development of the Water Resources of the Jordan-Valley Region."

This report gives the results of an engineering office study as requested by the United Nations Relief and Works Agency for Palestine Refugees in the Near East. The Tennessee Valley Authority agreed to direct such a study. 1/ The services of Chas. T. Main, Inc. an eminent engineering firm of Boston, Massachusetts, with a long and varied experience in the specialized field of water resource development, were secured to undertake the detailed study. The main body of the report was prepared by the staff of that firm under the personal direction of Mr. W. F. Uhl, President. In accordance with the terms of this assignment, this study was based upon materials, reports and data made available to TVA and was made without field investigations. The TVA transmits this report with complete confidence in the reasoning and engineering judgment it reflects.

The essence of the report is this: As a problem of engineering the most economic and the quickest way to get the most use from the waters of the Jordan River System requires better organization of the headwaters on the Hasbani and in the Huleh area to serve the lands by gravity flow within that part of the Jordan watershed and use of Lake Tiberias as a storage reservoir for the flood flows of the Jordan and Yarmuk Rivers. From Lake Tiberias these waters would be made available by gravity flow to irrigate lands on the east and west sides of the Jordan Valley to the south. Gravity flow eliminates expensive pumping facilities. Storage reservoirs save flood waters for use in the dry months. Use of the natural reservoir afforded by Lake Tiberias takes advantage of an asset already at hand; there is no known alternative site, at any cost, for a reservoir that would effectively regulate and store the flood flows of the Jordan and its main tributary, the Yarmuk. A quantity of water is suggested for each area of use within gravity reach of the supply made available and at the lowest cost. In short, the engineer, observing and using the lay of the land and the natural and potential storage areas in the watershed, gathers, saves, adds to, and divides the available water of the system economically and lets water run to the areas where it can be made useful for human beings.

Thus the report describes the elements of an efficient arrangement of water supply within the watershed of the Jordan River System. It does not consider political factors or attempt to set this system into the national boundaries now prevailing. The assignment of the water to the various areas as listed in this report is in no sense intended as an allocation of water. It may be noted that when these various areas and the amounts of water which would be available from the river system are added up within present political boundaries, 416,000 dunams are in Israel, 490,000 dunams are in Jordan and 30,000 dunams in Syria, and 394 MCM of water would go to Israel, 774 MCM of water would go to Jordan and 45 MCM of water would go to Syria. It is recognized .that each of these countries may have different ideas about the specific areas within their boundaries to which these waters might be directed.

Boundary lines are not shown on the maps in this report, but for the purpose of depicting the relationship between boundary lines and the Jordan River System a transparent overlay has been added at the back of this volume. This overlay can be placed over the maps to show the Armistice and national boundary lines. Thus the reader may see the political setting in which the engineering plan must be visualized. The present location of national boundaries suggests that the optimum development and utilization of the water resources of the Jordan-Yarmuk watershed could only be achieved by cooperation among the states concerned.

In a region where water is life, and where more and mose souls are crowding a scant water supply, there is a tragic need to develop, conserve, and dispense the waters of the Jordan Valley on a unified and impartial basis.

It is true that many of the projects suggested in the unified plan will require extensive further engineering study before they are ready for construction. Others may be impossible of achievement unless political adjustments can be made to assure appropriate control of the flow of waters and adequate guarantees secured as to their continual flow. Fortunately, however, there are suggested specific projects that could be carried out in the near future as parts of the unified plan. These are justified as separate projects as well as parts of the larger scheme and can result in substantial early benefits to those dwelling in the Jordan's watershed.

Respectfully submitted,

GORDON R. CLAPP
Chairman of the Board
Tennessee Valley Authority

1/ The Tennessee Valley Authority, an *agency* of the United States Government, was able to provide such services to the United Nations Relief and Works Agency for Palestine Refugees, upon the request of the Department of State, pursuant to the authority of Section 304 of the Foreign Economic Assistance Act, 22 USC, Section 1556(b).

TABLE OF CONTENTS

LIST OF MAPS

LIST OF TABLES

Table of Equivalents and Abbreviations

Linear:	1 Meter (m)	+1000 millimeters (mm) = 3.28 Feet (ft). =39.37 Inches (in)
	1 Kilometer (km)	=0.6237 Miles (mi)
Area:	1 Dunam (D)	=1000 Square Meters (sq.m.) =1/4 Acre (A) - approx
	1 Square Kilometer (sq.km)	=0.3861 squire Miles (sq.mi.) = 1000 Dunames (D)
	1 Square Meter (sq.m.)	=10.764 Square Feet (sq.ft.)
Volume:	1 Cubic Meter (cu.m.)	=35.315 Cubic Feet (cu.ft.) = 1.308 Cubic Yards (cu.yds.or c.y.)
	1 Million Cubic Meters (MCM)	=810.7 Acre Feet (A.F.)
Flow:	1 Million Cubic meters per Year (MCM/yr.)	=1.12 Cubic Feet per Second (cfs) = 0.317 cubic Meters per Second (cms)
Time:	1 Year (yr)	31,536,000 Seconds (s) =8760 Hours (hrs.)
Power:	1 Kilowatt (kw0	= 1.341 Horse Power (hp) = 737.5 Foot-pounds per Second
Energy:	1 Kilowatt-Hour (kwh)	= 1.341 Horse Power Hours = 2,654,000 Foot Pounds

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THE UNIFIED DEVELOPMENT of the WATER RESOURCES of the JORDAN VALLEY REGION

Chapter I
OBJECTIVE, BASIS AND SCOPE

The assignment calls for an engineering office study outlining the utilization of the Jordan Valley's water resources without regard to political boundaries. It is recognized that a plan for the unified development of the water resources of any watershed could result in some conflict with the plans or interest of individual countries whose boundaries cut into or across the drainage line. Whether this be true for the countries within which the Jordan Valley lies is not for this report to analyze; the assignment at hand specifically puts this problem outside the scope of this report.

The specific nature of this assignment requires a basic study and report depicting the most efficient and economical use of the region's meager available water. With such a plan at hand, relationships therein to the political boundaries, present or future, can be considered with a clearer notion of their value or effect. Because this assignment is somewhat unusual, it is especially important that the objective, basis and scope of this study and report be clearly understood.

Objective

The objective of this report is to establish, in general terms, disregarding political boundaries, a broad plan for the effective and efficient use of the water resources of the Jordan Valley emphasizing, first irrigation and, second, the production of hydroelectric power. The determination of the stages of development of the plan, with the general area to be irrigated, and the hydroelectric power to be co nstructed in each stage is included.

It is recognized that the water resources of this region are limited, and that there is great need for an adequate, dependable water supply. The very nature of this assignment, calling for a study of these limited water resources without regard to political boundaries, demands a logical approach. Such an approach requires, first, a determination of how much water is available and, second, the development of an effective means to conserve and to use this water efficiently and economically. The basic principle followed in the approach to the problem in this report is fundamental in its concept. It is the utilization of the topography of the watershed advantageously to conserve the surface water yield by natural storage where possible, together with gravity transportation of irrigation water.

Basis

The material used as a basis for this study, as made available by the terms of the assignment, consisted exclusively of reports resulting from previous engineering investigations and topographic maps. This material is listed as follows:

1. Report on the Water Resources of Trans-jordan and Their Development, Incorporating a Report on Geology, Soils and Minerals by G. S. Blake. March 1939 *By M. G. lonides*
2. Report on Palestine Irrigation and Hydro Electric Power Project (Photostats). April 1945 *By }. L. Savage*
3. Preliminary Report — Proposed Overall Irrigation and Hydro Electric Development in Palestine, December 1945 *By James B. Hays*
4. TVA On The Jordan — Proposals for Irrigation and Hydroelectric Development in Palestine. A Report Prepared Under the Auspices of the Commission on Palestine Surveys. June 1948 *By James B. Hays*
5. Final Report of the United Nations Economic Survey Mission for the Middle East. December 1949 Part I — Final Report and Appendices Part I — The Technical Supplement
6. Preliminary Report on the Proposed Extension of Irrigation in the Jordan Valley. March 1950 *By Sir M. MacDonald and Partners*
7. Report on the Proposed Extension of Irrigation in the Jordan Valley. December 1950 *By Sir. M. MacDonald and Partners*
8. Prospectus: Yarmuk-Jordan Valley Project, Kingdom of Jordan. *— Not Dated By M. E. Bunger*
9. Information on the Yarmuk River Watershed (Proposed dam at Maqarin). *Not Dated By M. E. Bunger*
10. Topographic Maps: Hashemite Jordan, Scale 1:100,000 compiled from various surveys 1941-1944 Hashemite Jordan, Scale 1:50,000 compiled from various surveys 1941-1946 Syria, Scale 1:50,000 compiled from various surveys 1941-1946 Palestine, Scale 1:250,000 compiled from various surveys 1914-1944 Palestine, Scale 1:100,000 compiled from various surveys 1914-1945 Palestine, Scale 1:50,000 compiled from various surveys 1941-1945
11. United Nations Maps:

Palestine North Sheet, Scale 1:250,000 May 1949

Houle, Scale 1:50,000 September 1949 Jerusalem, Scale 1:10,000 May 1949

The information forming the basis for this report was limited to that secured as the result of an analysis and review of the reports and maps listed. No field survey or personal inspection of the region was made.

Scope of Report

This report relates solely to the problem of water resources development in the Jordan Valley. Its scope is denned in the following paragraphs:

1. Political boundaries have been completely ignored and legal limitations involving water rights have not been considered. The facts presented in this study should assist in solving these problems.
2. The water available has been assumed to be that originating within the drainage area of the Jordan River including the inflow to Lake Huleh and Lake Tiberias, and all tributaries and wadis entering the Jordan River. The actual amount of this total which is usable is somewhat less due to evaporation and other losses and the impracticability of storing all of the flood flows of the rivers.
3. The method of secondary water distribution for irrigation is beyond the scope of this report, but the general method of storing and transporting the water to irrigable areas is included.
4. The approximate magnitude of the expenditure involved in constructing the entire plan and each stage of development has been estimated. Accurate cost estimates of the individual parts can only be made after field surveys and preliminary engineering plans have been made.

Cost estimates in this report are costs for the work if it were located in the United States as of June 1953. There will have to be some adjustments made to obtain a true figure for the actual location in the Jordan Valley but experience in foreign work indicates that the magnitude of cost and the comparative relationship between costs will not be far different. Savings in labor costs would be offset by increased costs for heavy equipment operations.

The cost estimates in this report do not include the cost of power transmission and distribution, secondary irrigation distribution systems from the main canals, value of water rights, value of land, and interest during construction.

5. The overall development of irrigation and water power in this region has been assumed to be economically justified.
6. The general benefits of the broad plan as related to the Jordan Valley have been outlined.
7. The general areas it would be possible to irrigate with the water supply available have been shown. Indication of specific areas suitable for irrigation as well as the most suitable crops and the water requirements to produce these crops are all dependent upon the results of basic agricultural research and beyond the scope of this report. Approximate average figures for water requirements based on the referenced data have been used as a basis for this report.

Chapter II
SUMMARY

THE results of the engineering office study and the conclusions reached in the subsequent chapters of this report are summarized as follows:Unified Development of Water Resources *(See Figure 4)*

The studies which have been made to determine the most effective and efficient use of the water resources of the Jordan Valley region have conformed to the fundamental principle outlined in Chapter I and have resulted in a broad plan for irrigation of substantially all of the cultivable land in the Huleh area, the Galilee Hills and the Ghor (flat terrace areas on both sides of Jordan River below Lake Tiberias) which may be reached by gravity flow. This requires the entire usable water supply for distribution and use within the watershed area and utilizes the natural storage potential of Lake Tiberias which results in the minimum evaporation loss from the storage required by the plan. Hydroelectric power developments are also included.

The major features of this plan for the unified development of the Jordan Valley's resources are listed below: Irrigation Features *Hasbani Storage Dam.*
This dam on the Hasbani River will store and regulate the waters of that headwater stream. *Irrigation Canals from the Banyas River to the Galilee Hills area southwest of Lake Tiberias, and the Yavneel Valley irrigation system,* These canals will transport water from the headwaters of the Jordan River to irrigable areas in the Galilee Hills section. A well system will supply irrigation water for the Yavneel Valley.
Yarmuk Diversion Dam and Diversion Cana to Lake Tiberias.
This diversion dam on the lower Yarmuk River will direct the waters of that river into the eastern Ghor irrigation canal and also through a diversion canal into Lake Tiberias for storage.
Irrigation Canals on the east and west side of the lower Jordan River.
These main canals will carry water stored in Lake Tiberias southward by gravity to serve areas on both sides of river.
Irrigation of Huleh Area.
Drainage of the Huleh swamp will make this area available for irrigation and eliminate heavy water losses by evaporation and transpiration.
Construction necessary to raise Lake Tiberias. This construction will provide for storage requirements by raising of the water level approximately 2 meters above its present maximum level.
Construction of Control Works and Canals for the use of the Perennial Flows from the Wadis.
This construction is for the purpose of improving the present facilities to obtain more efficient use of the perennial flows.
Development of the Flood Flows of the Wadis and/or the increase in height of Maqarin Dam from about 58 meters, which is the initial height principally for power purposes, to approximately 95 meters.
Additional studies are necessary to determine the extent to which each of these methods is economical for obtaining additional irrigation storage.

Power Features

Tel Hai Power Plant and Power Canal from
Hasbani Dam.
This hydroelectric power development will take water from the Hasbani Reservoir as released for irrigation, develop power, and return it to the main irrigation canal.
Maqarin Dam, approximately 58 meters high with Adasiya Power Plant and Power Canal.
This project, located on the Yarmuk River, will take water from Maqarin Reservoir for the generation of power and return it to the Yarmuk River for irrigation. Although principally for power purposes this dam will provide some benefits to irrigation also.

Stages of Construction

An analysis of the plan of unified development clearly indicates that the first stage should be the construction of the Yarmuk Diversion Dam and the starting of the irrigation canal on the east side of the Jordan River. Starting of the west side canal and headworks, starting of the canal from Banyas River to the Galilee Hills section and drainage of the Huleh Swamp are also included in the first stage of development. This will provide irrigated land in the shortest possible time and with a minimum initial expenditure. It can also be accomplished with the minimum of preliminary engineering study. It is estimated that this first stage could be completed and placed in operation in from two to three years.
Subsequent stages in the overall plan will require further study, surveys, and field investigation before they can be started. An advantage of proceeding with this first stage of construction as indicated is that it will not conflict with the subsequent stages of development regardless of whether further study should indicate that modifications in the plans for those stages were required. From ten to fifteen years may well be utilized in carrying out the entire development.

Water Available

Figure 3, a map of the Jordan Valley region, shows the location and amount of the average volume of water including flood flows, annually available from the Jordan River and its tributaries. The usable flows, determined as a result of this study and forming the basis for the proposed plan of development, are somewhat less due to the impracticability of storing and using all of the flood flows. The estimated average annual amount of water available in the rivers at various locations is given in the following table. There are also included estimated perennial flows of the wadis, now assumed to be fully used, which are not included in the flows of the rivers. The flood flows of the wadis are included in the estimated river flows.

AVERAGE ANNUAL FLOWS

Rivers	Estimated Average Annual Flow MCM per `
Dan River	258
Hasbani River	157
Banyas River	157
Jordan River below Lake Huleh	640
Jordan River outlet from Lake Tiberias	538
Yarmuk River near junction with Jordan River	475
Yarmuk River at Maqarin Dam site	420
Jordan River at Allenby Bridge	1250

Wadis & Wells	Estimated Perennial Flow From Wadis Now Used MCM per Year	Estimated Recoverable Flood Flow From Wadis MCM per Year	Estimated New Wells MCM per Year
East Side of Jordan River below Lake Tiberias	123	45	10
West side of Jordan River below Lake Tiberias	145	29	10
Yavneel Valley	-	-	20
	268	74	40

Irrigation

Figure 5, a map of the region, shows the general areas it would be possible to irrigate by the proposed unified development of the water resources. Specific areas for irrigation, water duty, and type of crops best suited to meet the needs of the region are dependent upon agricultural research. The location of general areas of irrigable land, the area to be irrigated by the proposed development, the estimated water duty and estimated average annual net water requirements are given in the following tabulation:

UNIFIED DEVELOPMENT OF WATER RESOURCES IRRIGATED LAND AND WATER REQUIREMENTS

Location	Area Irrigated Dunams	Estimated Water Duty - Cubic meters Per Dunam per Year	Estimated Net Average Annual Wate Requirement MCM per Year		
			From Rivers (5)	From Wadis and Wells	To
Upper Huleh	71,000 1/	770	55	0	55
Ayelet Hashahar	30,000	890	27	0	27
Yavneel Valley	22,000	930	0	20	20
Lowe Galilee	113,000	780	88	0	88
Afula -Beit Alfa	91,000	930	86	0	86
North Section Western Ghor	107,000 3/	1330	53	89	142
North Section Eastern Ghor	85,000 2/ 3/	1330	44	69	113
Central Section Western Ghor	67,000 3/	1440	42	55	97
Central Section Eastern Ghor	127,000 3/	1440	112	71	183
South Section Western Ghor	98,000 3/	1860	141	40	181
South Section Eastern Ghor	95,000 3/	1860	138	38	176
Yarmuk Plateau	30,000 3/	1500	45	0	45
	936,000		831	382 4/	1213 4

1/ Does not include 7000 dunams now irrigated.
2/ Does not include 15,000 dunams now irrigated in Yarmuk Triangle.
3/ Includes area now partly irrigated by the perennial flows of the wadis.
4/ Includes 268 MCM perennial flows from the wadis now being used.
5/ These amounts allow for an average loss of *10%* in conveying water from the point of diversion to the land.

Dead Sea Level

If the water which is to be diverted from the Jordan River system for irrigation is not replaced, the inflow into the Dead Sea will be materially reduced. Assuming that the rate of evaporation will remain the same as it is at present, it is estimated that the level of the Dead Sea will fall until the surface area is reduced to a little more than half the present area. The lowering of the water level might continue over a period of two hundred years and would leave the surface possibly 85 meters below its present elevation.

The general magnitude of the amount of water to be replaced annually, after full development of the irrigation plan, in order to maintain the level of the Dead Sea at its present elevation is estimated to be about 990 MCM.

Lake Tiberias Level

The unified development of the water resources of the Jordan Valley calls for diversion of the waters of the Yarmuk River into Lake Tiberias and a portion of the water from the upper Jordan to be diverted for irrigation before reaching Lake Tiberias. As a result of its use for storage regulation, the maximum water elevation of Lake Tiberias will be raised approximately 2 meters above its present high water level.

The natural storage potential of this lake has been partially utilized in the past with a fluctuation in water level of about 3 meters. The plan of development will require a maximum fluctuation of approximately 5 meters, due to the long-period storage of the unusually high floods. The salinity of Lake Tiberias will not be increased.

Effect of Jordan River

The dry season flow of the lower Jordan River under the broad plan will be largely determined by the amount and variation of the return flow from irrigation. It is estimated that the dry-season flow will probably not be less than one-third of the present average dry season flow. The unused part of any perennial flows would be in addition to this amount but cannot be evaluated.

Water Power

Figure 6 shows the location of the water power projects included in this report as part of the broad plan for the unified development. Pertinent data relating to these hydroelectric power projects follow:

HYDROELECTRIC POWER

Project	Location	Proposed Installed Capacity Kilowatts	Estimated Average Annual Output Kilowatt-Hours	Gross Head meters
Tel Hai Power Plant	Hasbani River	27,000	76,000,000	289
Adasiya Power Plant	Yarmuk River	*38,000	134,000,000	250
	Total	65,000	210,000,000	

* Capacity for ultimate installation.

Relationship of the Maqarin Dam and Power Project on the Yarmuk River to the Broad Plan.

The Yarmuk Project presently being considered by individual countries in an effort to provide water for a segment of the watershed is large and expensive. It is estimated that it will require from five to eight years to plan and design properly, complete the construction and place such a project in operation. A project of such magnitude must have comprehensive engineering investigations and studies completed before it can be started. In any case this project, being primarily a power project, is not scheduled as part of the first stage of the broad plan.

A preliminary review, made in connection with this study, indicates that the proposed dam on the Yarmuk River at Maqarin Station should not be constructed to the proposed full structural height of 150 meters, which corresponds to a difference in water surface elevations of 128 meters. There is also doubt as to the justification of the proposed power plant at the dam if irrigation needs are given first priority and the water level of the reservoir is drawn down for that purpose, thus causing too great a fluctuation in the head available for power generation.

The results of the present study indicate that as part of the unified development of the Jordan Valley region the proposed project on the Yarmuk River at Maqarin is esentially a power project. If constructed to a structural height of approximately 58 meters it may be justified as a power project but would have very little irrigation value. Additional height might be justified for a dual purpose project providing for both power and irrigation. The maximum structural height for the combined-use project is estimated to be approximately 95 meters; further engineering study, using data from field investigations, might vary this figure.

Water from the Yarmuk River diversion, the upper Jordan and perennial flows from the wadis will supply the major part of the requirements for irrigation in the Ghor. The question of how the remaining comparatively small amount of water required may be economically obtained cannot be answered without further information. The part of the flood flows of the wadis which might be feasible to use is estimated to be 74 MCM per year. It is estimated that the Maqarin Project, constructed to a height of 95 meters, could provide an additional 56 MCM per year of water, from carryover storage supplementing the storage in Lake Tiberias. In the carrying out of the plan for the unified development as presented herein, there would be time for making the necessary investigations and arriving at an informed decision.

The broad plan includes both development of the wadis and construction of the Maqarin Dam to a height justified for power only. Later investigations may prove the additional height of the dam to approximately 95 meters as a part of the unified development, to be justified as a source of carryover storage for irrigation and additional power.

In the logical sequence of development of the region's water resources, there would appear to be no real need for completing this project to 95 meters on the Yarmuk River to obtain the relatively small additional dependable volume of water for irrigation purposes until after the supply available from the Yarmuk River diversion and Lake Tiberias is utilized. For this reason the project on the Yarmuk River at Maqarin should be planned in two stages as follows:

1. Construction of the power project, including the Maqarin Dam to about 58 meters in height and the Adasiya power plant and power canal from Maqarin Dam. The power plant and canal should be designed for possible ultimate construction of Maqarin Dam to about 95 meters in height.
2. Raising of Maqarin Dam to about 95 meters in height, if justified by further investigation.

Estimated Magnitude of Cost

The estimated magnitude of cost of the broad plan is tabulated below. These figures are as of June 1953, and in general for work if it were located in the United States. These do not include the cost of power transmission and distribution, secondary irrigation distribution system from the main canals, value of water rights and of land which must be acquired, and interest during construction.

The estimate identifies the cost chargeable to irrigation and power and also shows the cost of each stage of construction.

ESTIMATED MAGNITUDE OF COST OF STAGES OF CONSTRUCTION
Based on work in the United States — 1953
(For detail breakdown see Chapter XI)

	Irrigation	Power	Total
Stage 1			
Yarmuk Diversion Dam Eastern Ghor Canal (1st Section Western Ghor Canal Headworks Western Ghor Canal (1st section)* Lake Hulen Drainage Works Canal from Banyas River to Galilee Hills (1st Section) Yarmuk Plateau System Yavneel Valley System	$38,000,000	0	$38,000,000
Stage 2			
Eastern Ghor Canal Headworks Feeder Canal (to Eastern Ghor Canal) Yarmuk Diversion Canal (to lake Tiberias) Hasbani Storage Dam Tel Hai Power Project	$16,500,000	$11,000,000	$27,500,000
Stage 3			
Raise Lake Tiberias Dam Canal to Galilee Hills (Final Section) Eastern Ghor canal (Final Section) Western Ghor Canal (Final Section)* Development of Wells in Ghor Redevelopment of Perennial Flows of Wadis	$16,500,000	0	$16,500,000
Stage 4			
Development of Flood Flows of Wadis Maqarin Dam (Initial Height) Adasiya Power Project	$17,000,000	$22,000,000	$39,000,000
Total for Broad Plan	$88,000,000	$33,000,000	$121,000,000
Stage 5			
Raise Maqarin Dam (if found to be justified)	$7,000,000	$7,000,000	$14,000,000

* If rugged terrain makes this portion of the work impracticable, water from Lake Tiberias may be brought to the lower western Ghor by a syphon from the eastern Ghor Canal in the vicinity of Wadi Kafrinje.

On the basis of the above magnitude of cost the capital cost for the above principal irrigation work is $119 per dunam for the Galilee Hills and Huleh area and $86 per dunam for the lower Jordan Valley eastern and western Ghor.

Chapter III
HYDROLOGY OF REGION

THE Jordan Valley forms the northern portion of the Dead Sea drainage basin which lies in the great rift extending from the Gulf of Aqaba on the Red Sea to the mountains of Lebanon. The Jordan River, flowing southward within the rift, rises on the slopes of Mt. Her-mon, about 2000 meters above sea level, and ends its course in the Dead Sea, 395 meters below sea level.

In the upper valley the comparatively flat basin land above Lake Huleh is surrounded by high hills. Between Lake Huleh and Lake Tiberias, the land is high, and cut by the deep gorge of the river. South of Lake Tiberias there is a great similarity in the general topographic features of the country. Here the floor of the valley, lying between the high escarpments of the hills, is cut by the trough of the river called the Zor about 60 meters in depth, leaving a flat terrace on either side called the Ghor. The land in the Ghor slopes generally southward with a gentle rise from the edge of the Zor to the intersection with the hills. To the east, above the Ghor, there is a vast plateau through which the wadis draining the area have cut deep gorges on entering the Ghor. On the west rolling hill country extends to the coastal plains, and the streams enter the Ghor through similar deep channels.

Climate

The climate is typical of the Mediterranean area, with a wet winter season, and a dry, hot summer season. In the hills and in the plateau the winters are cold, and snow falls regularly in some areas. Mean annual temperatures here range between a minimum of 30°F and a maximum of 100° to 104°F. The winds are generally from the west and southwest, coming from the Mediterranean Sea, and have a moderating influence in the summer weather. Occasional winds coming from the south and east over the desert are cold and dry in the winter, and dusty and scorching in the spring.

In the lower Jordan Valley, the climate varies from subtropical to tropical, having hot summers and mild winters with very rare frosts. Here the mean annual temperatures vary between a low of about 39°F and a high of about

Rainfall

Basic rainfall data have been taken from the reference material which provided the annual average depth of rainfall throughout the region, correlated from various records for the period 1901 through 1930. The isohyetal map, Figure 2, shows the average amount and distribution of rainfall based on this information. The variation from north to south is very marked, with the northern section of the valley receiving by far the greatest rainfall. This is further illustrated by the average annual depth of rainfall over various sections of the watershed shown below:

RAINFALL

Drainage Area	Area Square Kilometers	Average Annual Rainfall Milimet
Upper Jordan above Dan	740	
Upper Jordan above Lake Huleh outlet	1400	
Upper Jordan above Yarmuk River	2740	
Yarmuk River	7250	
Jordan Valley aboe allenby Bridge	16730	

The variation in the annual amount of rainfall appears to be comparable to that found in similar areas, the rainfall for the minimum year being approximately 0.5 of the average, and for the maximum year, about 1.5 times the annual average. Practically all of the rainfall occurs in the winter months, the monthly percentages at Amman given below being typical of the region:

SEASONAL RAINFALL AT AMMAN

Month	Rainfall in Percentage of Annual Average
January	25
February	33
March	8
April	4
May	1
June	0
July	0
August	0
September	0
October	2
November	10
December	17

The River System

The boundary of the watershed of the Jordan River system is shown in Figure 1. From the mouth of the river at the Dead Sea, it runs westerly, to the summit of the Palestinian range; northerly, along the range, across the Plain of Jezreel, and along the Galilee Hills; northeasterly, along the divide of the Litani River watershed to the northern slope of Mt. Hermon; southward, across Mt. Hermon to the plateau; easterly, to the summit of Jebel Druse; southwesterly, passing just south of Amman, to the outlet of the river at the Dead Sea.

Within the basin the river system is composed of the Bareighit, the Hasbani, the Dan and the Banyas Rivers which come from the north to form the upper Jordan River above Lake Huleh. The principal tributary is the Yarmuk River, which comes from the east and joins the Jordan River just below Lake Tiberias. Wadis and springs drain the remaining tributary area. Among these, entering the Ghor south of Lake Tiberias, are the Wadis Arab, Ziqlab, Jurm, Yabes, Kafrinje, Rajeb, Zerka, Sha'eb, Kefrein and Rama on the east, and the wadis Faria, Auja and Qilt on the west. (See Table 3-1.)

The Hasbani River, the longest of the four tributaries in the north, drains the west slope of Mt. Hermon, and flows for much of its length at an elevation greater than 500 meters above sea level. It joins the other streams in the Huleh basin at an elevation of about 75 meters. Lake Huleh at an elevation of 70 meters above sea level has an area of about 14 square kilometers and is very shallow, being only about 3.5 meters deep at the center. North of the lake are marshes more than 30 square kilometers in area, and these with the lake are conducive to heavy water losses due to evaporation and transpiration.

A short distance below Lake Huleh, the Jordan River enters a deep gorge from which it emerges some 10 kilometers downstream to flow into Lake Tiberias, a body of fresh water about 166 square kilometers in area and at an elevation 212 meters below sea level. The outlet of Lake Tiberias is controlled by a dam which permits utilization of about 3 meters of its depth for storage.

The Yarmuk River drains the high plateau to the east through tributary wadis and springs, some of which have cut deeply below the general land surface. The river itself enters the Ghor through a deep narrow valley at an elevation of about 200 meters below sea level and joins the Jordan River about 5 kilometers below its outlet from Lake Tiberias.

Below its junction with the Yarmuk River, the Jordan River follows a winding course within the Zor (trough of the river), its channel depressed about 60 meters below the terrace land of the Ghor. Wadis enter from both the east and west sides, some having nearly uniform flows throughout the year, others variable. At a point about 188 kilometers south of its source, the Jordan River empties into the Dead Sea at an elevation about 395 meters below sea level.

The Jordan River system drains an area of about 17,300 square kilometers out of the total Dead Sea basin of 40,650 square kilometers. The watershed tributary to the outlet of Lake Tiberias is about 2700 square kilometers, and that of the Yarmuk River at its mouth is about 7250 square kilometers. Because of the hydro-logical and geological conditions in the region, direct comparison of runoff in various parts of the watershed cannot be made on the basis of drainage areas alone.

Runoff

The part of the total rainfall which reaches the channels of the streams is here considered as the runoff. It may come as direct surface flow, as outflow from springs, or as seepage from groundwater. As would be expected under the geological and hydrological conditions in the region, the characteristics of the small streams or wadis may vary widely.

The seasonal nature of the rainfall is typical of the entire region, and accounts for the heavy runoff from many streams during the winter months. Wadis which have access to large volumes of underground storage maintain very uniform flows throughout the year, the variation depending largely upon the portion of the total runoff supplied from surface and underground sources. That part of the runoff which originates from groundwater and flows throughout the year is called the perennial flow. This is the base flow of the wadis and is the approximate quantity of water which is available without storage. The part of the runoff which comes from direct surface flow during the rainy season, and is extremely variable, is called the flood flow. The winter flows include both the perennial flow and the flood flow.

Measurements of Runoff

Records of stream flow from established gaging stations are available for only a small number of the rivers and wadis within the region. Only the Jordan River at its outlet from Lake Tiberias and the Yarmuk River near its mouth have records of measurement of sufficient length to be representative of the average flow conditions. In general the information concerning the flows of the wadis consists of some records of systematic spot measurements made during the period of about one year, and estimates from various sources, without supporting data.

A summary of the available information on stream flows in the Jordan Valley region is given in Table 3-1. The table gives the approximate period of record, where known, and an explanation as to the type of flow measurement, whether from estimate, spot gaging, or from an established station rated by standard methods. The average annual runoff is given in millions of cubic meters per year and is the mean of the measurement for the period of record without any corrections. It should be noted that the runoff from some of the wadis includes only the perennial flows and is identified in the table.

(Please see attached Table 3-1 on page 17)

From the nature and extent of the records of flow, it is evident that the most reliable information is available for the Jordan and Yarmuk Rivers, with very meager data on the wadis. The wadis tributary to the river system above the junction of the two principal streams have their flows included in the long period measurements of the Jordan and Yarmuk Rivers. The flows of the wadis south of Lake Tiberias can be determined only from the information available, whether based on spot measurement or an • estimate. Where the perennial flows of the wadis are given, the spot measurements may furnish a good guide as to the magnitude of the flows because of their tendency toward uniformity.

It is believed that the recorded flows of the lower Jordan River at Allenby Bridge and at the Potash Works do not include the high flood runoff which overflows the banks of the normal channel and makes measurement difficult. There are, therefore, no reliable records of the flood flows at these points which would include the flood flows of the wadis.

Estimates of the Flows of the Wadis

The lack of satisfactory information on both the perennial flows and the flood flows of the wadis has led to the use of some rainfall-runoff relationship as a guide in estimating their magnitude. With the great variation in hydrological conditions within the valley; no general relation can apply to all sections. On the upper Jordan River above Lake Tiberias, the total runoff is estimated to be about 42 percent of the total rainfall on the area while for the Yarmuk River this figure is about 18 percent.

From studies of flow measurements and experiments described in the reference material, it was concluded that, for the area on the east side of the Jordan River, which included the watersheds of the Yarmuk River and all wadis to the south as far as Allenby Bridge, the runoff was about 15 percent of the total rainfall and was divided about equally between flood runoff and perennial flows. If this relationship were used as applicable to the entire area between Lake Tiberias and Allenby Bridge, the total runoff would be about 374 MCM, of which the flood flows and the perennial flows of the wadis would each be about one-half or 187 MCM per year. The perennial flows from this area taken from Table 3-1 total 232 MCM per year. This indicates the lack of agreement in the data available on the flows of the wadis.

The flow characteristics of the wadis in the valley are known to cover the entire range from those having an almost uniform flow throughout the year, to those whose flows consist almost entirely of the seasonal flood runoff. Since there are no complete records of measurement, figures are not available to show the variability of the wadi flows.

Streamflow Variations

In the case of the rivers, the flow records are more extensive, and some information on both seasonal and annual variations may be obtained. Records of flow measurement of the Jordan River at the outlet of Lake Tiberias, and of the Yarmuk River near its mouth, cover a period of 20 years, and should be representative of the flow conditions to be expected. Because of the regulation of Lake Tiberias, and the large evaporation losses which take place before measurement, the records do not show the natural flow variations of the Jordan River and there is insufficient information to make the necessary corrections. The Yarmuk River records are, therefore, the best available to give an indication of the flow variations of a stream in the region. Using these records as a basis, the following approximate variations appear applicable within the watershed:

STREAMFLOW VARIATION

Period of Flow	Ratio of Rate of flow to Average for 20-Year Period
Driest Year	0.53
Wettest Year	1.88
Driest Month	0.19
Average Dry Season	0.51

The shorter records of stream gaging at other points may be compared with the records of the Yarmuk River for the common period of observation. Such a comparison shows the annual variation of the Jordan River at Jisr Banat Yakov to be of the same order as that of the Yarmuk River. As would be expected, the seasonal variation differs slightly, probably because of the effect of Lake Huleh on the flow of the river below. The combined flows of the Banyas, Dan and Hasbani Rivers for the period of record show annual variations very nearly the same as those of the Yarmuk River; the resulting flow being more influenced by the variable Banyas and Hasbani than by the steady flow of the Dan.

Ground-water

Part of the rainfall seeps into the ground, where, upon reaching the water table, it moves as groundwater flow. After a period of time, the flows tend to stabilize, and where there is a large amount of underground storage, the rate may vary but little from year to year. Much of the groundwater appears as the perennial flow in springs and wadis. Where the geological formations are favorable, the groundwater may be obtained as a source of supply by pumping from wells. In order to be considered a gain in total water resources, the supply from ground-water thus obtained must be so located that it would not be

recoverable from the springs and wadis.
TOPOGRAPHY (Please see attached map)

Figure 1
RAINFALL (Please see attached map)

Figure 2

Chapter IV
WATER AVAILABLE

[THE] water resources of the Jordan Valley have been discussed in the preceding chapter, together with the records of flow measurements on which estimates of the amount of water available must be based. The sources of supply may be listed under the following divisions which apply to the magnitude of the source, its flow characteristics, and the extent of the flow records:

(1) The flow of the rivers;
(2) The perennial flow of the wadis;
(3) The flood flow of the wadis; and
(4) The well supply from groundwater.

In order to discuss and compare each potential source of water in the valley, it is necessary to arrive at some figure indicative of the amount of water which can be expected from that source each year. The longer period of record of gaging on the Jordan and Yarmuk Rivers, which includes a wide range in both wet and dry years, is more representative of average conditions than the short records of other streams. It is, therefore, necessary to make some adjustment in the flow measurement according to the nature of the period of record, whether the runoff was greater or less than the average.

The figures given for the average annual flow of the rivers in the watershed in Table 3-1 are the mean of all flows for the period of record. In order to make them more representative of long term average conditions these flows have been adjusted by comparison with the 20-year record of the Yarmuk River at its mouth.

There is so little basic information on the flow of the wadis that no attempt has been made to reconcile the various estimates given in the data forming the basis for this report. Table 4-1 summarizes the estimates of the average annual amount of water available in the Jordan Valley and accounts for the runoff in the watershed on the basis of the figures used. These figures are indicative of the magnitude of these water resources and must depend on subsequent field observations for final determination. The same general information is given in Figure 3, which shows the location of the water resources with respect to the whole region.

It is essential that there be a clear understanding of the meaning of the figures given and the nature of the flows available. The figures are for the estimated average amount available each year and are based on the mean of all flows of record including flood flows. For any one year the total annual runoff might vary from one-half to nearly twice the average, depending upon the rainfall. There is also the seasonal variation in flow, with the heavy surface runoff taking place in the winter months. The amount of water *available* is the quantity which it is possible to obtain each year at the location shown without regard to its utilization.

The *usable* part of the available supply is the amount which can be obtained where and as required for use. Whenever there is a conveyance loss between the source and the point of use, such as occurs in a canal from the point of diversion to the land to be irrigated, the remaining quantity is the net annual water applied directly to the land. The demand for irrigation water is greatest in the summer months and the usable water is determined by the amount available during that period, either from the natural stream flow or from the winter flows conserved by storage. The portion of the available water shown in Table 4-1 and on Figure 4 which can be utilized for irrigation depends, therefore, on the location in respect to the place of use and on the size and location of the storage facilities.

(Please see Table 4-1 on page 22-24)

River Flows

The-greatest potential source of water for irrigation in the Jordan Valley region is from the flows of the Jordan and Yarmuk Rivers. The long records of flow measurement of both streams just below Lake Tiberias give reliable data on the magnitude and the dependability of the flows available at this point. The shorter period records of the stream in the upper valley, used with the records of the Yarmuk River, form a substantial basis for estimating the water available in the area.

The water available at the junction of the Jordan and Yarmuk Rivers is given in Table 4-1 as 538 MCM and 475 MCM each year, respectively, for the two rivers. The total of 1013 MCM is the average annual amount available, with the flows subject to seasonal and annual variation. Since the regulating effect of Lake Tiberias on the flows of the Jordan River cannot be determined from available data, it has been assumed that the variations in flow are similar to those of the unregulated Yarmuk River.

The location of the two rivers in respect to Lake Tiberias and to land in the lower Jordan Valley is of major importance in determining the extent of utilization of the large river flows at this point. By use of the vast storage capacity of Lake Tiberias much of the available water from the heavy winter runoff could be made usable in the lower valley. Of particular importance is the fact that evaporation losses, always a major factor in the consideration of storage in the area, would be but little affected by such use of the lake. The amount of water available would be substantially the same as given, since the flow measurements were made after the evaporation losses in Lake Tiberias had taken place.

In the upper valley of the Jordan River, the three major streams enter the Huleh Basin not far apart and at an elevation well above large areas of cultivable land within the region. Gaging records of the streams are available for a period of about four years, a period too short to give a reliable indication of the average flow which might be expected. As has been previously discussed, the Dan River, having its source in the Tel el Qadi springs, shows a remarkably uniform flow for the period of record. The Hasbani and the Banyas Rivers show considerable variability in flow. A comparison of the combined flows of the three streams with the flow of the Jordan at Jisr Banat Yacov and with the Yarmuk at its putlet indicated that the annual variations followed the same general pattern. The average annual flows of these streams were therefore adjusted to the longer term record of the Yarmuk River to get the average available water.

The total average amount of water available from the Banyas, Dan, and Hasbani Rivers is given in Table 4-1 at 572 MCM per year. The location of so large a source of supply where it can reach large areas of land by gravity- conveyance makes it of great value. However, the amount of the available water which is usable is much less because of the lack of suitable sites for the large volume of storage required to regulate the variable stream flows.

The eight-year record of stream gaging at Jisr Banat Yacov gives a good basis for estimating the water available at this point. The annual variation of flow follows that of the Yarmuk River very closely, and the record has been adjusted by comparison to give the long period average. The difference in the amount of water available at Jisr Banat Yacov and from the three streams above is accounted for by using the estimated evaporation and transpiration losses which take place in Lake Huleh and the marshes, as given in the source material.

The part of the available water which could be used at Jisr Banat Yacov would depend upon the amount of storage which could be developed to regulate the variable runoff. As stated above, there is the possibility of very little storage in the upper valley. The land around Lake Huleh is considered of sufficient value to reclaim by drainage and probably should not be used for storage even if a good site existed. The nearby cultivable land is all at a higher elevation than the river and could not be reached by gravity diversion from this location. Between Jisr Banat Yacov and the outlet of Lake Tiberias, there are no flow records to indicate the contribution from this area. If the figure of 300 MCM per year, as given in the source material, is accepted as the amount of water lost by evaporation from Lake Tiberias each year, the accounting will be somewhat as indicated in Table 4-1. On this basis the total inflow to Lake Tiberias is about 838 MCM per year, with only 538 MCM per year available at the outlet.

It may be seen that, because of this evaporation loss, there is a limitation on the amount of water which may be used in the upper valley and still maintain Lake Tiberias in its present state. The evaporation loss will continue at about the same rate whether or not the lake is used for storage. It is estimated that such use would increase the annual evaporation by only about 7 MCM.

Wadi Flows

Below the junction of the Jordan and Yarmuk Rivers the flow records do not permit estimates of the water available with the same degree of dependability as do those above. The flows of the wadis have been taken from various sources, and it is doubtful if any consistent estimates can be made from the data available. The figures used are taken as indicative, only, of the magnitude of the wadi flows in the lower valley.

The records of measured flows of the Jordan River at Allenby Bridge and at the Potash Works appear to be inconsistent, and probably do not correctly include the flood flows. The five-year period of measurement 1939 through 1943 was selected as representative of the flow at Allenby Bridge and the 1250 MCM per year given in Table 4-1 is the average for this period.

In accounting for the flows of the wadis in the intermediate area, figures were used which are not strictly of the same category as those for the stream flows. The perennial flows of the wadis are given as the usable amount of water each year from this source, and it is assumed, from the information available, that all of this water is now used. Similarly the flood flows of the wadis are stated as the estimated amount of these flows which is recoverable. The remainder is the part unaccounted for, which will make the total flows balance.

The wadis in the area cover the full range of flow characteristics. There is very little information on the wadis on the west side of the river, but it seems likely that they are similar to those on the east. Here spot measurements indicate that perennial flows of some of the wadis are very constant, with little increase in flow from the winter runoff, while others are variable. It is understood that full use is now made of the estimated 268 MCM annual perennial flow of the wadis. Any use of the flood flows will require the development of storage and the 74 MCM per year is the amount which has been estimated to be recoverable by reasonable construction. The origin of the wadi supplies at an elevation above the Ghor insures that ample cultivable land may be served by gravity distribution.

The water available in the lower Jordan River, as indicated by the measurements at Al-lenby Bridge, is the sum of the flows of the Jordan and Yarmuk Rivers increased by any perennial and flood flows from the wadis reaching the river above the bridge. Use of water upstream from this point would subtract from the amount available. For any large part of the remaining water in the lower river to be usable, storage capacity would have to be provided in that area to conserve the heavy winter runoff. To obtain the large volume of storage necessary, the reservoir required would inundate extensive areas of cultivable land in the Ghor.

The purpose of this discussion has been to aid in the evaluation of the estimates of water available in the Jordan Valley region as given in Table 4-1 and in Figure 3. The amount of the water available which can be utilized for irrigation is so dependent upon the facilities for storage and their location in relation to the cultivable land that the importance of Lake Tiberias is evident.

AVAILABLE WATER (Please see attached map)

Figure 3

Chapter V
CULTIVABLE LAND AND WATER DUTY

IN the Jordan Valley the cultivable land in general lies largely within the area where the average annual rainfall is in excess of 200 millimeters (7.9 inches) with the exception of land in the southern part of the Ghor. The area includes the high plateau on the east side of the Jordan Valley and the hill country on the west, lying both within and adjacent to the Jordan River watershed.

Dry farming is practiced most extensively outside of the Ghor and a large part of the cultivable land is now in use. Since, within certain limits, the productivity of the land is in proportion to the amount of water it receives, much larger areas are necessary to support the population where there is low rainfall than where supply of water is ample. The occurrence of dry years makes the maturing of crops uncertain in areas fully dependent on rainfall.

Where so great a part of the cultivable land is utilized for dry farming, any large scale improvement in productivity can come only through irrigation. The rainfall in the area is now entirely utilized except for the part lost as direct surface runoff. In the southern part of the watershed this loss may amount to less than 10 percent of the total rainfall. Thus, except for some gain by improvement in methods of farming, the overall increase in production in dry farming areas by conservation of rainfall appears to be limited to about 10 percent. More intensive use of the land is possible by terracing the steep slopes where suitable soil is found, but this is considered a project for the individual land holder and can offer no large scale increase in production. The greatest benefits will result from the irrigation of land so situated that it can receive water from the resources of the Jordan and Yarmuk Rivers.

The location and area of the land assumed to be irrigable and the general scheme for supplying irrigation water have necessarily been taken from the reports which served as the basis for this study. Since the total area of cultivable land is not definitely known, the proportion which can be irrigated cannot be stated. There is some disagreement in the reports as to the exact extent of land in a particular section which can be irrigated and the area of land which is irrigated at present. The information given herein can be considered as indicative only of the general location and area of cultivable land which may be supplied from the water available in the Jordan Valley. More accurate data will have to be obtained from field studies to determine the extent and suitability of the land in specific areas.

Land in the Ghor *(Flat terrace area on both sides of river)*

The largest area of land which it is practicable to irrigate by gravity from the water resources of the Jordan Valley lies within the Ghor. In one reference report it was estimated that over 659,000 dunams (165,000 acres) of land are suitable for irrigation between Lake Tiberias and the Dead Sea. Of this estimated area, 355,-000 dunams are located on the east side and 304,000 dunams on the west side of the Jordan River. The figures are, of course, approximate and probably include some areas where the salinity of the soil is too great for use in its present condition.

Available information indicates that in general the soil in the Ghor is of equal quality to that found in other areas and varies from a true loam to a sandy or marly loam. The better soil is apparently found near the foot hills where the depth is greatest, the soil becoming thinner as the Zor is approached and is more apt to be saline. The climate ranges from sub-tropical to tropical. In addition to the freedom from frosts, the productivity in the area, according to reference data, probably surpasses that of any in the region.

As the Dead Sea is approached, the soil tends to be more saline. Actual reclamation and use of the land indicates that washing the soil is possible, and that good crops can be raised after proper treatment. Until more detailed surveys and studies are made it is not certain just how much of the saline land may be utilized. For the purposes of this report, it has been assumed that the land lying south of the Wadi Rama on the east and the Wadi Qilt on the west could not feasibly be developed to any greater extent than at present.

There is some land within the Zor (trough of the river) which is suitable for cultivation and could be irrigated from the Jordan River. The land lies in the flood plain of the river and is subject to frequent inundations under present conditions. It is probable that occasional flooding would occur under any plan of development. The land is not readily accessible and would require costly clearing before it could be used. Because of these reasons and the limited amount of land available, it has not been included as part of the irrigable area within the Ghor.

The situation of the land in the Ghor with respect to the available water supply is favorable for irrigation. Most of the land lies below the level of Lake Tiberias and slopes gradually to the south making gravity conveyance of the water practicable.

Land in the Huleh Basin

Land lying southwest of Lake Huleh and in the level area to the north is suited both as to soil and topography to receive irrigation water from the upper Jordan Valley. The land to the southwest has an area estimated at about 30,000 dunams, and in the north a total area of about 71,000 dunams. To make the latter area available, drainage of the lake and the marsh land to the north would be necessary as has been previously proposed. Large areas would have to be cleared of vegetation before the land could be put to full use for agriculture.

The rainfall in the general area is between 500 and 800 millimeters per year, well above the minimum for dry farming, but the distribution during the seasons makes supplementary irrigation necessary for maximum production.

Land in the Galilee Hills and Valley of Jezreel

There are some extensive areas of cultivable land in the high country on the west side of the Jordan River, lying southwest of Lake Tiberias. The water available in the upper Jordan Valley from the Banyas, Dan, and Hasbani Rivers is at sufficient altitude to reach a large part of this area by gravity flow. The rainfall, which averages between 400 and 600 millimeters per year in this section, reduces the supplementary water required for irrigation to an amount below that required in areas of lower rainfall.

In the Galilee Hills, the Yavneel Valley and the Valley of Jezreel, there is an area estimated at over 216,000 dunams which can be irrigated from the upper Jordan Valley waters. The extent of the land which could be irrigated from the water available in the upper Jordan Valley is limited by the lack of sites for the construction of storage facilities which would make more of the water supply usable.

Land in the Yarmuk River Plateau

There is very little information concerning land in the plateau near the Yarmuk River. One plan included in the reference material proposes to make use of the springs on the plateau in the Mzerib region, which are tributary to the Yarmuk River, to irrigate 30,000 dunams of land. From the topography of the land, it appears likely that the limitation on the amount of land which could be irrigated would be the lack of storage facilities necessary to utilize a large part of the water available.

Water Duty

In order to relate the water available and the area of the land which can be irrigated, it is necessary to have some information concerning the water requirements for use of the land in agriculture. The amount of water required annually per dunam of land, or "duty," varies with many factors, such as climate, season, rainfall, soil conditions, crops raised, crop rotation schedule, and method of irrigation. Duty, as used in this report, is denned as the average quantity of irrigation water which must be applied annually to the land to mature the crops, and is measured in cubic meters per dunam of irrigable land. The duty is in addition to rainfall and includes water used in the evapo-transpiration process, and loss by evaporation from the soil and water surfaces, percolation, seepage, and waste.

With the range in climatological and soil conditions found in the region, there will be a corresponding variation in duty. It is doubtful that, with the large number of factors involved, and the information available, any exact determination of duty is possible. For the purpose of this report it is considered only necessary to establish duties which approximate actual requirements, and which take into account the major differences in the rainfall and climate of the various sections of the region.

Estimates of duty given in the reference reports, forming the basis for this study, have been used with some modification because of the wide divergence of the estimates in certain areas. It is assumed that the land is used for forage, grains, green manure, potatoes and vegetables, and fruit orchards, in the best proportions for each locality. The schedule of use varies with the climate, ranging from less than 70 percent utilization in the high country to over 80 percent in the Ghor.

The water duty in various sections of the region is assumed as follows:

WATER DUTY

Location	Water Duty in Cubic Meters per Dunam Per Year
Lower Jordan Valley, North	1330
Lower Jordan Valley,Central	1440
Lower Jordan Valley, South	1860
Upper Hulen	770
Ayelet Hashahar	890
Lower Galilee	780
Yavneel Valley	930
Afula - Beit Alfa	930
Yarmuk Plateau	1500

The seasonal variation in the amount of water used varies with the locality, and the proportion of the land planted to crops with varying water requirements. For the schedule of land use which formed the basis for the duties given above, there was, of course, some variation in relation of the water used in any month to the total for the year. The variation was not large, and for convenience in considering the seasonal requirement for irrigation, the average has been used. The figures tabulated below are used as indicative of the monthly variation in demand for irrigation water throughout the region.

MONTHLY IRRIGATION DEMAND

Month	Per Cent of Total Annual Water Requirement
January	2
February	3
March	6
April	10
May	11
June	11
July	11
August	12
September	12
October	10
November	8
December	4

On the assumption that these figures may be used as representative of the rates of seasonal irrigation water demand, it may be seen that in the winter months the requirement may be only 25 percent of the average, while during the summer months it may reach about 150 percent of the average rate of demand. Since the stream flows do not follow the pattern of use, storage facilities are, of course, necessary for the regulation and maximum utilization of the available water.

The duties given for the various areas are the average estimated water requirements and their bases have been discussed. As previously mentioned the duty may be changed by the method of irrigation, whether by ditch or by sprinkler, and by the crops planted and their rotation. Furthermore, it is not possible with the best of data to establish exactly the amount of water necessary to mature a crop. For these reasons it has been assumed that a variation in duty 15% above or below the average would not measurably affect the crop production. The use of such a figure is necessary in estimating the usable part of the available water where the limited storage facilities make it impossible to obtain the same amount of water each year.

Chapter VI

PLAN FOR UNIFIED DEVELOPMENT

IN considering the information on the water available, the topography and location of the irrigable land, and the water requirements, discussed in the preceding chapters, the features which are essential to the formulation of a plan of development are evident. The major sources of water supply in the Jordan Valley are the flows of the Jordan and Yarmuk Rivers. Capacity for storage, so necessary for the utilization of the stream runoff exists in Lake Tiberias, strategically located both in respect to water supply and irrigable land. Additional storage capacity may also be developed on the Hasbani River. The topography is favorable to gravity distribution of irrigation water both in the upper and lower sections of the valley. There is the possibility of the further development of the water resources by more efficient use of the perennial flows of the wadis in the south and by recovery of some of the flood flows now wasted. Actual practice and tests have indicated that additional well supplies may be obtained in various parts of the valley.

Incidental to the primary use of the water resources for irrigation, the unique topographic features of the area make possible the development of a considerable amount of hydroelectric power. Construction of power stations in the upper Jordan Valley and on the Yarmuk River, will permit the utilization of the great differences in elevation in the irrigation system.

Domestic water supplies are expected to be obtained from local water resources, and no provision is made for their development.

Plan for Unified Development

The main features of the broad plan for the unified development of the water resources of the Jordan Valley are shown in Figure 4 and consist of the following:

1. The Hasbani Reservoir in the upper valley would be constructed for storage of the winter runoff of the river.
2. A canal would intercept the diverted flows of the Banyas, Dan and Hasbani Rivers, high in the valley, and convey by gravity substantially all of the usable flows to irrigate land in the Upper Huleh Basin, Ayelet Hashahar district, Galilee Hills, Yavneel Valley, and Valley of Jezreel.
3. The Yarmuk River would be diverted into the eastern Ghor irrigation canal and into Lake Tiberias, where its water with that of the Jordan River would be stored for use in irrigating the cultivable land in the Ghor.
4. Main canals would be located on the east and west sides of the Jordan River with regulating works at Lake Tiberias to convey water by gravity south as far as the Wadis Rama and Qilt. Construction necessary to raise Lake Tiberias 2 meters would be done.
5. Lake Huleh and the marsh area above would be drained and cleared for agriculture, with the water recovered from the present excessive transpiration and evaporation flowing into Lake Tiberias for storage.
6. Control works and canals for the more efficient use of the perennial flows of the wadis south of Lake Tiberias would be provided.
7. Reservoirs for the conservation of the flood flows of the wadis would be constructed to the extent shown feasible by detailed field studies, and/or raising Maqarin Dam above the initial height if further investigation shows this to be justified.
8. Wells would be used for supplementary irrigation water in areas where the development of such supplies is found feasible, as in the Ghor and the Yavneel Valley.
9. A power canal from the Hasbani Dam and a powerhouse near Tel Hai would be constructed for the utilization of the irrigation water in the generation of hydroelectric power.
10. Hydroelectric power facilities would be constructed on the Yarmuk River consisting of a dam at Maqarin, a power canal, and a powerhouse near Adasiya.

Description of the Work

Figure 4, "Plan of Unified Development," shows the general location of the proposed works and the areas in which it is proposed to provide water for irrigation. Main supply canals only are shown on this plan since the study of secondary canals is beyond the scope of this report.

The work required to carry out the proposed plan will require the construction of a wide variety of structures as indicated on Figures 4, 5 and 6. The following descriptions of the major features show the purpose, general type, approximate size or capacity of each.

1. The Hasbani River Storage Dam: This dam on the Hasbani River about 20 kilometers from its junction with the Jordan River is for the purpose of storing irrigation water. The dam, estimated to be about 90 meters high, would be of concrete or earth and rock, whichever is most economical, and it would have a storage capacity of about 165 MCM, while the average annual flow at the dam site amounts to about 130 MCM. It is proposed to store all of the flood flow of the river each year until the reservoir is full and release the water only during the 6 to 8 months when irrigation requirements are greatest. By this method of operation, the reservoir in effect acts as a partial regulator for the combined flow of the Banyas, Dan and Hasbani Rivers.

2. The Banyas River Dam: This dam, for the purpose of diversion only, is proposed at a point about 8 kilometers from the mouth of the Banyas River, its elevation being determined so that it can discharge the normal flow into the irrigation canal, which has its beginning at this location, and permit the water to be carried to the Galilee Hills area by gravity.

3. The Dan River Headworks: This structure will be located at the point where the irrigation canal crosses the Dan River and is for the purpose of diverting the Dan River and the flow from the Tel el Qadi Springs into the irrigation canal serving the Galilee Hills area.

4. Canal — Banyas River to Galilee Hills: This canal, for irrigation purposes only, will begin at the diversion dam on the Banyas River and extend about 2.7 kilometers to the Dan River, where the normal flow of that river and the Tel el Qadi Springs will be added. About 3 kilometers beyond the Dan River the canal will pick up the flow of the Hasbani River which is not diverted through the Hasbani power canal. At a point about 9.7 kilometers from the Hasbani River the discharge from the Hasbani powerhouse will enter the canal. The canal at this point will have a capacity of about 14 cubic meters per second and will then extend about 104 kilometers generally south, passing west of the Huleh swamp and Lake Huleh and supplying irrigation water to these areas. It will then be carried to a point about 5 kilometers west of the city of Tiberias, a total distance of about 120 kilometers from its beginning at the Banyas River. At this point it will divide into several smaller branches traversing through the Galilee Hills and the Jezreel Valley area and supply water to the adjacent lands. The length of these smaller canals totals about 110 kilometers and their capacities vary from about 8 cubic meters per second to 1 cubic meter per second. At various points throughout its length this canal system will require such structures as tunnels, syphons, flumes, drainage systems, outlets, road and railroad crossings, auxiliary dams and spillways at wadi and river crossings, as well as various minor items. Portions of the canal will be constructed in rock, although most of it will be in earth. It is expected that, in general, the canal sections will require concrete lining, to minimize leakage, prevent erosion or reduce head loss due to friction. Extensive field surveys, engineering and economic studies will be required to determine the location, size, slope and details of this canal system to secure the most feasible and beneficial project.

5. Yarmuk Diversion Dam: This dam on the Yarmuk River is for the purpose of diversion only. It should be located so that the pond formed by it will serve as the tailwater for the Adasiya Power Plant as well as the headwater for the eastern Ghor irrigation canal and for the diversion canal to Lake Tiberias. The dam should include control works for the diversion canal to Lake Tiberias, control works for the irrigation canal proposed for serving the eastern Ghor and a spillway of sufficient capacity to discharge the maximum flood to be expected without causing damage to the structure or the surrounding area.

6. Yarmuk Diversion Canal: This canal is proposed for the purpose of diverting a large part of the flow of the Yarmuk River to Lake Tiberias for storage. The diverted waters would consist of water not diverted southward into the eastern Ghor canal and, when the elevation of Lake Tiberias permits, water which cannot be stored in the Maqarin Dam after its construction. The capacity of this canal should be relatively large to enable it to carry flood flows of about 750 cubic meters per second, since its purpose is to permit conservation of flood flows for long period carryover in Lake Tiberias. The canal should be designed to conduct the water from the pool formed by the Yarmuk diversion dam to Lake Tiberias when the lake is at its proposed new maximum height.

7. *Eastern Ghor Canal:* This canal is for the purpose of irrigation only and will serve substantially the full length of the eastern Ghor of the lower Jordan by gravity flow. It will begin at the Yarmuk diversion dam (elevation about -200 meters) and have a capacity at this point of about 16 cubic meters per second. Either at the dam or at a suitable nearby point the canal must be provided with a drop so that it will be at the same elevation (about -215 meters) as the feeder canal from Lake Tiberias, which will provide a portion of the water for this canal. From its junction with the feeder canal, it will be carried generally south supplying secondary canals along its route as required and be provided with the necessary flumes, syphons, spillways, outlets, drainage, crossings, etc. Its total length will be about 100 kilometers and its capacity will be reduced gradually as the required flow is reduced by diversion to secondary canals. The slope of the canal and the type of construction to be used can be determined only from detail surveys and economic studies. For the purpose of this report it has been assumed that the canal will have an average slope of 0.25 meters per kilometer.

8. Eastern Ghor Headworks: This structure is for the purpose of regulating the discharge of tored waters from Lake Tiberias into the eastern Ghor feeder canal. Its location in the Lake Tiberias Dam will be dependent on the location of the feeder canal. The structure should be so designed that it will be able to discharge the maximum water requirements into the eastern Ghor canal within the contemplated limits of the fluctuation of Lake Tiberias.

9. Eastern Ghor Feeder Canal: This canal is for the purpose of carrying the stored irrigation waters by gravity from Lake Tiberias to the eastern Ghor canal. It is not contemplated that this canal will directly serve any irrigable lands or supply any secondary canals. Its total length will be about 12 kilometers and it will have a capacity of about 16 cubic meters per second. At the point where it crosses the Yarmuk River, it will be necessary to provide a flume, syphon or other suitable structure depending on the existing conditions. The usual drainage, road crossings, culverts and other minor structures must be provided as required. The minimum elevation of water at the beginning of this canal will be about -215 meters and its slope, size and type of design can be determined only from detail surveys and economic studies.

10. Western Ghor Headworks: This structure, for regulating the discharge of storage in the western Ghor canal, will be similar to the eastern Ghor headworks. It will operate under similar conditions.

11. Western Ghor Canal: This canal is for the purpose of irrigation only and will serve substantially the full length of the western Ghor of the lower Jordan by gravity flow. It will begin at the western Ghor headworks (elevation about —215 meters) and be carried generally south. The capacity of the canal at the head-works will be about 13 cubic meters per second and it will supply secondary canals along its route as required. It will be provided with the necessary flumes, syphons, spillways, outlets, crossings, etc. The total length of the canal will be about 100 kilometers. The slope of the canal and the type of construction can be determined only from detail surveys and economic studies. For the purpose of this report it has been assumed that the canal will have an average slope of 0.25 meters per kilometer. If the topography is too difficult for the construction of the northern section of this canal, an alternate scheme appears feasible. This scheme would provide for carrying the water for the western Ghor from Lake Tiberias to the vicinity of Wadi Kafrinje in the eastern Ghor canal and then by a syphon across the Jordan River to the western Ghor canal, a distance of about 4.5 kilometers.

12. Irrigation of Lake Huleh Area: The purpose of this work is to drain Lake Huleh and the marsh land north of it so that the land will be suitable for irrigation and the raising of crops. To accomplish this purpose it will be necessary to lower and enlarge the outlet of the lake and to provide drainage canals throughout the lake and swamp areas. As additional results of this work, the substantial elimination of the natural evaporation from the lake and the reduction of malarial conditions should prove to be of considerable value. The proposed drainage canal and outlet for the lake must be made of sufficient capacity to carry the flood flows of the contributing area, including the watersheds of the Banyas, Dan and Hasbani Rivers, since the capacity of the irrigation canal is insufficient for this purpose and floods may occur when the Hasbani Reservoir is full. Control works to maintain the proper level of water in the lake area should also be included.

13. Raise Lake Tiberias Dam: The purpose of this work is to permit raising the water surface level of Lake Tiberias to obtain additional storage capacity for irrigation water. It is proposed to raise the dam about 2 meters over its present height. Engineering reports made available as the basis for this study indicate the possibility of performing this work although no details of the extent or type of work required are given.

14. Control Works and Canals for Perennial Flow of Wadis: This construction will provide diversion dams, control works, concrete lined channels and other facilities as required to conduct the perennial flows of the wadis either to the main point of distribution or to the canal system, depending upon the local conditions. Its purpose is to give better control of the water and to permit more efficient use of this supply. No details of these features are available.

15. Dams, Reservoirs, and Structures for the Conservation of the Flood Flows of the Wadis: The facilities required for the recovery of the flood flows of the wadis will be developed only to the extent that such construction is shown to be economically feasible by actual field study. The construction will provide for the storage of the water and its conveyance in concrete lined channels to the main canal system. It is estimated that the maximum average annual amount of water which could be made available from the flood flows of the wadis is 74 MCM.

16. Well Supplies: Wells would be developed in areas where tests or actual experience have shown that such supplies can be obtained at costs comparable to those from other sources. The use would be either as a main source of supply or as supplementary to irrigation water from stream flow. It is expected that well supplies will be found in the Ghor and in the Yavneel Valley.

17. Yarmuk Plateau Irrigation: Cultivable lands located in the Yarmuk Plateau may be irrigated from water tributary to the Yarmuk River. It is estimated that the irrigation water required is about 45 MCM per year and, allowing for normal losses, 50 MCM per year is assumed to be diverted from the Yarmuk River before it reaches the vicinity of the Maqarin Reservoir site. It is also assumed that the rate of diversion throughout the year will vary in accordance with the monthly requirements for irrigation used in this report for other areas. No description of the work necessary for diversion and transportation of this water is included in this report, inasmuch as no data on this phase of the matter are available.

18. Yavneel Valley Irrigation System: Irrigation in this valley involves about 22,000 dunams of irrigable land. Pumping facilities for ground water only will be provided. The estimated cost included in this report covers the cost of the supply only.

19. The Hasbani Power Development: Development of power is proposed by utilizing the head between the outlet of the Hasbani Dam and the irrigation canal from the Banyas River to the Galilee Hills. A brief description of this development is included in Chapter VIII, "The Development of Water Power."

20. The Maqarin Dam and the Yarmuk Power Development: This development on the Yarmuk River is initially for power purposes but may be added to in a later stage for the purpose of storing water for irrigation use. This project is more fully described in Chapter IX, "The Maqarin Project on the Yarmuk River."

Storage and Water Distribution in Relation to the Plan

The essential function of storage and its importance to the full utilization of the water resources of the valley have been referred to repeatedly. The location of reservoirs in respect to the cultivable land largely determines the areas which can be irrigated by the water so conserved. These factors and their relation to the unified plan require further discussion.

Storage in Lake Tiberias: The great potential usefulness of Lake Tiberias cannot be ignored. It is located where its large storage capacity can be used to regulate the Jordan and Yarmuk Rivers, and where it can serve by gravity flow the largest single area of irrigable land in the Jordan Valley. The amount of water lost from its surface through evaporation will continue to be about the same whether or not the lake is used for storage. Its utilization would result in the least possible total loss of water for the storage capacity obtained.

Existing facilities provide over 500 MCM of storage in the lake utilizing a 3 meter range in surface elevation, and the low cost of increasing this capacity would make storage here by far the least expensive in the region. There is no comparable site in the area which is as strategically located both with respect to water supply and cultivable land.

A plan making most efficient and economical use of the water resources of the valley must fully utilize Lake Tiberias.

Water Distribution within the Region: Because of its position in the river system, any of the flows of the stream in the upper valley which are not used will reach Lake Tiberias. Under the unified development any unused water in the Yarmuk River will also flow ?«<•<> Lake Tiberias. Conditions are thus imposed on the irrigation of the land in the region: cultivable land in the upper valley and in the hill country can be irrigated by gravity only from the high water resources of the upper valley, while land in the Ghor can be so irrigated by water from both the upper and lower valley resources. The area of the cultivable land in the entire region being much greater than can be irrigated from the total water available, the plan must provide for the division of water within the region.

It is well recognized that a gravity system of water distribution is preferable to a system requiring extensive pumping. The initial cost of construction is usually lower and the heavy continuing operating and maintenance costs are avoided. It also makes unnecessary the employment of a highly trained technical staff which any large pumping system would require. However, the use of supplementary pumping, under certain conditions, makes it possible to supply water to land which could not be irrigated by gravity from the existing water resources, and requires consideration.

In the upper valley, the amount of water which could be diverted from the rivers to serve the high country by gravity is limited by the lack of suitable sites for storage. The construction of the Hasbani Reservoir will provide regulation of that river, and with the summer flow of the Banyas and Dan Rivers, it is estimated that an average of about 300 MCM per year could be diverted as needed for irrigation. If storage facilities were provided in the hills, some of the winter flows could also be diverted and stored for later use. Greater amounts of the summer flows could be obtained by pumping from remaining sources of supply found at a lower elevation.

To determine whether the additional water resources of the upper valley should be used in the hills or in the Ghor, a comparison would be necessary which would consider the cost of the required facilities, the duty requirements, and the productivity of each area. All of these factors cannot be evaluated, but it is possible to reach some conclusions from their general relationships. The advantage of lower cost water utilization, and the greater productivity in the Ghor must be compared with the lower water duty in the hills.

As a basis for comparison, it may be assumed that the cost of the additional water made available for use by the Hasbani Reservoir is determined by the cost of construction of the storage facilities. Using this cost and taking into account the difference in duty, the cost of supplying water to irrigate a dunam of land in the hills by pumping and in the Ghor by gravity is very nearly the same. If the basis of water cost had been the cost of storage facilities at Lake Tiberias, the irrigation cost would have favored the land in the Ghor.

The greater productivity of the land in the Ghor, and the disadvantages of pumping previously discussed, led to the adoption of a gravity system of water distribution. The cost of providing the additional storage facilities in the hills, even if the sites could be found, could not compete with the cost of equal storage in Lake Tiberias, and the diversion of water in the upper valley was limited to that available from the natural stream flow supplemented by storage in the Hasbani Reservoir.

Stages of Construction

Irrigation of the Jordan Valley region at the earliest possible time is assumed to be of prime importance. Although it is apparent that a plan of the magnitude proposed herein will require a number of years for its completion, it appears feasible to construct it in progressive stages so that some of the land can be irrigated within about two years from the start of construction work. Thereafter, the completion of other features of the plan from time to time will provide water for other lands, with the result that new lands can be brought under cultivation each successive year until the work is complete.

The power projects, however, are not so readily subject to construction by stages. Each includes, as a principal feature, a long power canal, or other water conduit, construction of which is feasible only as a complete unit. Installation of generating units and their auxiliaries in multi-unit plants can, of course, be deferred until required, but these may represent only a very minor part of the project.

Stage No. 1. In order to provide irrigation water to a considerable portion of the land at an early date, the construction of the Yarmuk diversion dam and the eastern Ghor canal should be started promptly. It is believed that this can be done with a minimum of field investigation and engineering study. A similar situation exists regarding the western Ghor canal and headworks, the diversion dams on the Banyas and Dan Rivers and the canal to the hill country. All of these items have been included in Stage No. 1. Various minor works for the Yarmuk Plateau and the Yavneel Val-ley, which are independent of other work and which it is understood will provide irrigable land and the necessary water with little delay, have also been included in Stage No. 1.

Stage No. 2, which of course may overlap Stage No. 1 in point of time, consists of the work necessary to divert the Yarmuk River flow into Lake Tiberias for storage, the construction of Hasbani storage dam and the Tel Hai power project. All of these items making up this stage are substantially extensions of the work in Stage No. 1. They will result in making additional water available for irrigation and in the production of a considerable amount of electric power.

Stage No. 3 will consist of the work necessary to complete irrigation systems for supplying water to the Galilee Hills and the Ghor of the lower Jordan River by the completion of all main canals and the raising of Lake Tiberias Dam. This stage will also include the development of some of the independent sources of irrigation water such as wells and perennial wadi flows.

Stage No. 4. This stage will consist of the development of flood flows of the wadis, the construction of the power features of the Yarmuk River and of the dam to its initial height. It is not intended that these projects should necessarily be constructed last. Construction of the Yarmuk River development is dependent upon both the need for and value of power and additional storage facilities for irrigation water.

Stage No. 5. This stage covers the raising of the Maqarin Dam to its ultimate height to develop its full power potential and to provide some storage to secure as part of the unified development, some carry-over storage for irrigation use, if feasible.

UNIFIED DEVELOPMENT OF THE WATER RESOURCES

Figure 4 (Please see attached map)

Chapter VII
IRRIGATION

A DEFINITE plan of development having been proposed, it is now possible to indicate in general the location and area of the lands which may be irrigated. The importance of storage on the amount of the available water which may be utilized has been emphasized, and with a knowledge of the storage facilities to be provided, a more accurate estimate of the quantity of usable water may be made.

In discussing the irrigation in each section of the region it is convenient to consider separately the upper valley, and the lower valley and to further distinguish the water supplied by the rivers from that supplied by other sources. The inter-relation between the irrigable land and the water supply requires that they be considered together in,the discussion which follows.

In the discussion of duty, it was assumed that the annual amount of water required for the irrigation of a given area could vary within certain limits and have no measurable effect on crop production. Thus in wet years some water in excess of the average could be fully utilized and in dry years the crops could mature with an amount of water somewhat less than the average. This would undoubtedly be true within the accuracy of the data from which the duty estimates were made. On such a basis, the average amount of usable water which could be obtained from a variable stream flow would be greater than if the same quantity were required each year. Therefore, to make all estimates comparable, the annual average is taken as the average amount of usable water per year which can be obtained in such a manner that the maximum and minimum annual rates of use will not be more than 15 percent above or below the median.

Irrigation in the Upper Jordan Valley

Large areas of cultivable land may be reached by a gravity canal from the river supply in the upper valley. The extent to which this land may be irrigated is limited by the amount of the available water which can be supplied as required. Of the total estimated 572 MCM of water available each year from the Banyas, Dan and Hasbani Rivers, only a little over 300 MCM will be usable for irrigation under the plan, making full use of the storage in the proposed Hasbani Reservoir. The remainder will flow down the Jordan into Lake Tiberias.

With only short term records of the stream flow in the upper valley, it has been necessary, as previously described, to utilize the 20-year records of the Yarmuk River to indicate the variations in stream flow to be expected. Use was made of the so-called mass curve in estimating the flow conditions after regulation with the best use of the 165 MCM Hasbani storage.

The use of the flow record of the Yarmuk River to simulate the long period stream flow in the upper valley might appear over-conservative, since included in the total flow is that of the Dan River which is purported to be nearly constant. However, the comparison with the record of flow at Jisr Banat Yacov, where the flow of the Dan is a substantial part, indicated that the annual variations there were similar to those of the Yarmuk River.

Complete regulation is, of course, not possible with the limited storage, and the natural low flows of the uncontrolled streams would occur at the periods of highest irrigation demand. With the average variation in seasonal requirements for irrigation as established for the entire region, it is estimated that a usable flow averaging about 300 MCM per year could be diverted from the upper valley streams.

The location, area, and designation of the irrigable land which may be supplied by gravity from the water resources of the upper valley have been taken from reference material serving as a basis for this study. About 7000 dunams of land in the Upper Huleh were estimated to be under irrigation. It has been assumed that the water used came from the river system and was not included in the measured flow of the streams. The tabulation below gives the area of the land irrigated, the duty and the gross water required from the river supply, which allows 10 percent for loss in conveyance from the point of diversion to place of use on the land. The land in the Yavneel Valley to be irrigated from well supply under the plan is also shown:

IRRIGATION - UPPER VALLEY

Location	Duty Cubic Meters per Dunam per year	Area irrigated Dunams	Water required MCM per year	
			From Wells	From River 1/
Upper Hulen	770	71,000		61
Ayelet Hashahar	890	30,000		30
Lower Galilee	780	113,000		98
Afula-Beir Alfa	930	91,000		95
		301,000		
Yavneel Valley	930	22,000	20	
		327,000	20	284
Upper Hulen Now Irrigated		7,000		No Data

190% of this amount is usable for irrigation directly on the land.

The location of the irrigated areas and the general arrangement of the main irrigation canal system is shown in Figure 4. It will be noticed that all of the land lies within the watershed of the Jordan River system, and that only 284 MCM per year of the 300 MCM per year of river water available for irrigation is required in the upper valley.

An accounting of the available water supply of the upper valley after the proposed diversion is as follows:

RIVER WATER SUPPLY —UPPER VALLEY

			Average Annual Flow MCM per y
Banyas River			157
Dan River			258
Hasbani River		157	
Evaporation Loss from Reservoir		-2	
			155
	Total		570
Less Upper Diversion			-284
Remaining Stream Flow			286

The nature of the major items of flow above should be particularly noticed. The 284 MCM diverted for irrigation is, of course, the average amount each year; and since it is slightly less than the maximum possible, it is estimated that the annual variation in the rate of diversion will be about 5 percent above or below the median. The flow of 286 MCM per year which is left to flow down the Jordan River is what remains after the uniform part of the stream flow has been diverted. This flow is, of course, extremely variable both seasonally and annually and becomes more so as greater amounts of the base flows are diverted. To make this irregular flow usable for irrigation in the lower valley, storage in Lake Tiberias becomes essential.

Irrigation in the Lower Jordan Valley from River Supply

Land in the Ghor will be largely irrigated from water taken from Lake Tiberias under the unified development. A part of the flow of the Jordan River will be used in the upper valley, and some of the flow of the Yarmuk River will be used in the plateau, but the remaining water of the upper Jordan River and of the Yarmuk River not diverted directly into the eastern Ghor canal will flow into Lake Tiberias for regulation as required for irrigation. The more important features of the unified development of the Region's water resources are discussed in more detail below.

The average annual usable supply at Lake Tiberias is made up as follows:

RIVER WATER SUPPLY — LOWER VALLEY

	Average Annual Flow MCM per Year

Remaining Flow from Upper Jordan River	286	
Recoverable Flow from Drainage of lake Huleh and Marshes	62	
Flow from Intermediate Jordan River Drainage Area	266	
Total Inflow from Jordan River		614
Measured flow of Yarmuk River	475	
Water used from Irrigation in Yarmuk Plateau	-50	
Total inflow to Lake Tiberias		425
		1039
Loss due to evaporation	-300	
Flood flows not utilized	-150	
		-450
Water Usable fro irrigation in Ghor		589

The location and area of land which will be irrigated from the river supply available in the Yarmuk plateau and at Lake Tiberias are given in the tabulation below. Allowance has been made for areas to be supplied from the other sources, the wadis and the wells. In the north section, on the east side of the Jordan River, there are said to be some 15,000 dunams already under irrigation. Since the information is incomplete, it is assumed that the water used comes from the river system, and is not included in the records of flow measurements:

IRRIGATION FROM RIVER — LOWER VALLEY

Location	Duty Cubic Meters per Dunam per Year	Area Irrigated Dunams	River Water Required MCM per Year
Yarmuk Plateau	1500	30,000	50
Eastern Ghor			
North	1330	33,000	49
Central	1440	78,000	124
South	1860	74,000	153
		185,000	326
Western Ghor			
North	1330	40,000	59
Central	1440	29,000	47
South	1860	76,000	157
		145,000	263
Jordan- Yarmuk Triangle in Eastern Ghor			
Now Irrigated		15,000	No data

190% of this amount is assumed usable for irrigation directly on the land.

Lake Tiberias Storage

Under the plan it is proposed to raise the dam at the outlet of Lake Tiberias in order to use a 5 meter range in the water level to regulate the remaining flows of the Jordan and Yarmuk Rivers. At present it is understood that the lake may be varied 3 meters for storage purposes. An increase of 2 meters in the height of the dam appears feasible, thus making available a total storage capacity of about 830 MCM.

The advantages of utilizing Lake Tiberias for storage have been discussed. Its key location in respect to water supply and irrigable land, the small amount of construction necessary for its use, and the low increase — estimated to be less than 7 MCM per year — in the total evaporation by such use, make this site the most economical in the area both in regard to cost and water conservation. The storage capacity is adequate for seasonal regulation and will provide for a substantial amount of carry-over storage.

The estimate of 300 MCM of water lost each year through evaporation from the lake surface annually must be accepted because of lack of data for verification. It is, of course, an average, and the actual evaporation would vary from year to year. The amount represents about 1.8 meters of depth on the lake surface and is well within the range of observed evaporation in similar areas. In view of the approximate nature of these figures, the 2 percent increase in the evaporation loss by use of the lake for storage is considered negligible. The accuracy of the estimate does not affect the estimates of water available since these were based on actual measurements of flow after the evaporation had taken place.

The variation of the inflow to the lake will be accentuated by the upstream diversions, where the winter flows pass nearly undiminished and most of the summer runoff is used. The amount of annual use in the upper valley will be determined by the low stream flows And will not necessarily be related to the flows in the lower valley which are more dependent on the winter runoff. Storage in Lake Tiberias must also take care of the water lost through evaporation, since the water thus lost arrives during the winter months and must be stored to provide for the heavy evaporation occurring in the summer and fall.

Analyses of mass curves of the inflow, based on the 20-year record of the Yarmuk River, taking into account the nature of the diversions and evaporation losses, indicate that with the 830 MCM of storage, an average of 150 MCM per year would be in excess of storage capacity and would have to be wasted downstream. From the record it appears that the actual losses would occur only three times in a 20-year period. It is doubtful, therefore, if the construction of any additional storage capacity could be justified to conserve this infrequent runoff unless the cost were very low.

Supply from the Jordan River: Of the figure given for the inflow from the Jordan River into Lake Tiberias, the remaining flow from the upper valley and the water recovered by drainage in the Huleh area have been explained. The inflow from the intermediate area, 266 MCM per year, was not measured but was derived from the records of flow, assuming that the estimated 300 MCM was the average annual evaporation from the lake surface.

Supply from the Yarmuk River: The 20-year flow records of the Yarmuk River show that an average of 475 MCM would be available each year. The plan provides for the use of an average of 50 MCM of water per year from springs tributary to the river for irrigation of land in the plateau. The remaining flow, 425 MCM per year, will be diverted either to the main eastern Ghor canal or to Lake Tiberias for storage. The capacity of the diversion canal is to be about 750 cubic meters per second, and this is expected to handle all but the extremely high floods. Without the necessary data for verification, it has been assumed that the peak flood flows which could not pass through the channel into the lake would occur during the infrequent periods when the storage capacity was exceeded, and only this loss has been allowed.

Irrigation in the Lower Jordan Valley from Wadi and Well Supplies

The irrigation in the Ghor from the wadis and wells does not have as a basis the long term records of observation which are available for the river supplies. It has been necessary to rely upon the reference reports forming the basis for this study for estimates of the extent of irrigation possible from these sources.

The water supply, in the case of the wells and wadis, has been given as the net amount of water usable for irrigation, whereas the river supplies were necessarily stated as the gross amount of water, from which deduction for losses had to be made.

In considering the land to be irrigated from the perennial flows of the wadis, it is important that the present use of this water be noted. The perennial flows are said to be now fully but inefficiently used for irrigation. Under the broad plan, the area irrigated from this source will actually be reduced because of a higher duty allowance. However, the more dependable supply, the elimination of waste and the resulting increase in productivity of the land should greatly benefit the area.

The necessity for field studies and investigation of the wadis with respect to the storage and use of the flood flows has been mentioned and must be re-emphasized. The meager data on which the estimates of the irrigation possible from this source of water are based are not sufficient to ascertain fully the feasibility of construction as a part of the plan for unified development. The figures must, therefore, be considered only as indicative of the extent of irrigation possible from this source of supply which awaits field confirmation.

The supply from wells is also somewhat uncertain. The estimates give the magnitude of the supply, based on the experimental data reported, which can be developed in the Ghor. The extent of the use of well water as a main supply or as supplementary to the winter flow of the wadis should be determined as the land is developed.

Irrigation from the Wadis: The estimated amount of water for irrigation to be obtained from the perennial flow of the wadis, 268 MCM per year, and that to be obtained from the flood flows, 74 MCM per year, are both net amounts assumed usable for irrigation. The details of irrigation from this supply are as follows:

IRRIGATION FROM WADIS - LOWER VALLEY (Please see attached table)

Tables page 52

Irrigation from Wells: The estimated supply from wells, 20 MCM per year, is the net usable amount and will be used for irrigation as follows:

IRRIGATION FROM WELLS —LOWER VALLEY **(Please see attached table page 52)**

Summary of Irrigation

The tabulation below summarizes the irrigation under the proposed plan for the unified development of the Region's water resources. It is divided into three sections to show more clearly the relative extent to which the used and unused resources will be developed. The first section shows the area of land which will be irrigated from unused water resources; the second section shows the area irrigated with water resources which are now fully, but inefficiently utilized; and the third section shows land which is reported to be now irrigated but for which data on the water supply is not known:

SUMMARY OF IRRIGATION

Nature of Proposed Irrigation	Source of Water Supply	Area Irrigated Dunams	Water Used MCM year
From Unused resources	Rivers	665,000	93
	Flood flow of Wadis	52,000	
	Wells	36,000	
From Sources now fully used	Perennial Flow of Wadis	183,000	
From undefined sources now used	No Data	22,000	No

190% of this amount is assumed usable for irrigation directly on the land.

IRRIGATION (Please see attached map)

Figure 5

Chapter VIII
WATER POWER

THE urgent need for water for irrigation has generally led to the conclusion that such use is of primary importance and the use of water for power generation should be, in all cases, of secondary consideration. In an arid region desperately in need of a dependable water supply to provide the people through agriculture with the basic necessities of life the reasons for this priority are obvious. However, it should be clearly realized that a supply of low-cost hydroelectric power, if available, would serve to complement irrigation, the first priority, by providing enlarged agricultural opportunities. In such a region hydroelectric power could well increase the total annual water supply by making possible a more complete utilization of the underground water resources as a supplement to the surface water runoff. It could also provide for the preservation of food and insure adequate sanitary domestic water supplies. Thus, both irrigation and power development add to the amenities of life and serve to strengthen the economy of a region. For this reason the development of hydroelectric power, either incidental to irrigation works or as independent projects, has been proposed in the past by engineers and agriculturists who have studied the water resources of the Jordan Valley region.

Among the most important hydroelectric projects previously proposed in this region are the following:

(1) The Hasbani River, at the irrigation storage dam.

(2) The Hasbani River near Tel Hai, by diversion canal from the storage dam.

(3) The Yarmuk River at the Maqarin Dam.

(4) The Yarmuk River near Adasiya.

(5) The Dead Sea Project, by diversion of the Mediterranean Sea water to the Dead Sea.

Preliminary engineering planning reports are available for projects (1), (2) and (5) .whereas no planning reports on projects (3) and (4) have yet been made. The following discussions of those projects for which reports are available indicate the engineering feasibility of the projects after giving primary consideration to the use of the available water for irrigation.

The existing Tel Or power development is also briefly discussed herein.

Hasbani Dam Development

This power development, as proposed in the reference reports, contemplates the installation of hydroelectric units in a power plant located at the Hasbani storage dam. Since, under the unified development the stored water is to be used primarily for irrigation, it will be held in the reservoir during the winter season when irrigation requirements will be at a minimum and will be released during the summer months when river flows are low and irrigation requirements are maximum. As a result of this reservoir regulation, there will be several months during the average year when no water will be released, and at times the reservoir will contain little or no water. Development of power at the dam itself is, therefore, not included as it is of doubtful economy to develop a hydro plant with the great variation of water level and power head available under these conditions.

Hasbani Canal Development

This proposed development contemplates the use of the water released from the Hasbani Reservoir under the conditions as described in the preceding section. However, it is proposed to locate the power plant at the end of a diversion tunnel and canal from the dam to a point near the village of Tel Hai, making possible the utilization of a fall of about 289 meters (950 feet) between the diversion canal and the main irrigation canal from the Banyas River to the hill country west of Lake Tiberias.

It is shown in Chapter IV that the average annual flow of the Hasbani River at the proposed dam site is about 130 MCM, and that, under the unified development, the flow released from the dam will be made during about eight consecutive months in the average year at a varying rate, with a maximum of about 31 MCM per month equivalent to a flow of 420 cubic feet per second.

The canal and tunnel will be about 20.7 kilometers (13 miles) long, terminating in a fore-bay and headworks from which a penstock will carry the water to the powerhouse located near the main irrigation canal. The location of this proposed project is shown on Figures 4 and 6.

Although power from this plant will be available only about eight months each year and will be suitable for the base load operation almost entirely, it will have considerable value due to the fact that the time and the amounts available both correspond with the large irrigation load anticipated for the general area under consideration.

A development having a capacity for utilization of a maximum of about 31 MCM per month on the basis of uniform rate of flow (11.9 cubic meters per second — 420 cubic feet per second), under a gross head of 289 meters (950 feet) will develop about 27,000 kilowatts of power.

The total energy output per average year will be about 84,000,000 kilowatt-hours gross or about 76,000,000 kilowatt-hours net.

The total expenditure for the power facilities, which does not include the dam, is estimated to be about $12,000,000.

The annual fixed and operating cost, assumed at *6}/2%* of capital cost, will be about $695,000 or 0.9 cents per kilowatt-hour.

The Maqarin Project on the Yarmuk River

This project is covered in detail in Chapter IX.

The Existing Tel Or Plant

Near the junction of the Jordan and Yarmuk Rivers is located the Tel Or hydroelectric plant with an installed capacity reported to be about 18,000 kilowatts. It was designed to use waters of both of these rivers, and to make use of Lake Tiberias for storage purposes.

The unified development of the Jordan Valley waters giving primary consideration to irrigation uses will result in diverting most of the Yarmuk and Jordan waters from the Tel Or plant and will make its operation entirely in-feasible. It is at present reported to be incapable of being operated, and its repair and replacement for permanent service seems to be entirely unjustified, if the overall plan herein proposed is to be followed. The plant might be repaired and used during the development period as a temporary source of power for construction purposes.

The Dead Sea Power Project

This report is concerned primarily with the utilization of the Jordan Valley region's water resources. However, utilization of the waters of the Jordan River for irrigation purposes by the unified development will greatly reduce the inflow to the Dead Sea. Unless this depletion is made up from some other source, the level of the Dead Sea will be substantially and permanently lowered. Such a lowering of the Dead Sea level may not be desirable or permitted, so that replacement of the diverted water may be necessary. For this reason a discussion of this matter in this report appears desirable.

Replacement of the water diverted from the Jordan Valley may be accomplished by bringing salt water from the Mediterranean Sea and, at the same time, utilizing the difference in elevation between the Mediterranean Sea and the Dead Sea (about 395 meters) for the development of power.

Such a power development has been proposed by a number of engineers for a number of years. Included in the early proposals were schemes suggested in 1920 by Albert Hjorth, a Norwegian engineer, and in 1925 by M. Pierre Gandillon, a French engineer. In most of the various plans suggested for the development and utilization of the region's water resources, this question of maintaining the water level of the Dead Sea was recognized as a major problem. The topography of the region made it inevitable that a hydroelectric power development be associated with and become an important part of the solution of this problem.

Among the engineering schemes proposed for development of power by the use of Mediterranean water, one proposing utilization of the entire difference in elevation between the Mediterranean Sea and the Dead Sea is described in reference reports. It proposes a development to replace the water diverted by its irrigation scheme in the amount of about 950,-000,000 cubic meters per year (equivalent to 30 cubic meters per second), the development to consist of the following principal features:

1. Improvement of the Qishon River channel near Haifa and construction of a feeder canal from the river southerly to a pumping plant, a total distance of about 12 kilometers.
2. A pumping plant equipped with electric pumps operating under a static head of about 42 meters, to pump the water into a canal at an elevation to permit gravity flow over the divide between the Mediterranean Sea and the Dead Sea.
3. A canal about 22 kilometers in length with a capacity of 40 cubic meters per second to a regulating pond.
4. A regulating pond about 6 kilometers west of Afula.
5. A deep-cut canal about 15 kilometers long across the Plain of Esdraelon, extending about 60 kilometers further to a regulating pond.
6. A large regulating pond, dam and head-works on the hillside near Wadi Abu Sidra.
7. Penstocks, pressure tunnels and surge tanks from the regulating pond to a powerhouse.
8. A powerhouse (No. 1) and substation near the mouth of Wadi Abu Sidra, with an installed capacity of about 100,000 kilowatts under a gross head of about 300 meters.
9. A regulating pond at the tailrace of powerhouse No. 1.
10. A canal about 53 kilometers long from powerhouse No. 1 to a regulating pond about 10 kilometers west of the northern end of the Dead Sea.
11. A regulating pond and headworks.
12. Penstocks, surge tanks and tunnels from the regulating pond to a power plant, a distance of about 7 kilometers.
13. A power plant (No. 2) and substation on the west shore of the Dead Sea about 10 kilometers from the northern end of the Dead Sea. The installed capacity of the power plant would be about 36,000 kilowatts under a gross head of about 110 meters.
14. Miscellaneous structures, such as syphons, flumes, culverts, wasteways, railway and highway crossings, transmission lines and other necessary features.

The scheme proposed appears to be fundamentally sound and has been used in this report as a basis, being modified only as necessary to utilize the amount of water estimated to be required to bring the Dead Sea to its natural level after completion of the unified development and to provide for base load operation rather than peak load operation.

In Chapter X, "The Effects of the Plan on Lake Tiberias, the Jordan River and the Dead Sea," it is indicated that at least 1420 MCM of water can be accounted for, which, in the average year, would flow down the Jordan River if no water were diverted for irrigation. Under the broad plan an estimated annual average of 150 MCM will be unusable and remain in the river. Return flow from irrigation reaching the lower valley if assumed at 25% of the water put on adjacent land would amount to about 280 MCM per year, but this quantity may not be established until many years after the completion of the irrigation works. Summarizing the foregoing it appears that about 1270 MCM (1420-150) will be the maximum amount of replacement required per year and that this amount will decrease over a period of years to about 990 MCM (1270-280) per year. Furthermore, if the Dead Sea power project were not constructed until several years after the construction of the major part of the irrigation works, the Dead Sea would be considerably lowered and the power plant would be

required to replace the accumulated deficiency. In view of these uncertain factors, a power development having a capacity of 1500 cubic feet per second (1340 MCM per year) is assumed for the purpose of this report.
Due to extremely long power canals required and the apparent absence of suitable locations for the development of necessary headwater and tailwater ponds, it is not considered feasible to develop this system for daily peak load operation. Therefore, it is proposed to construct the waterways, pumping facilities and power plants so that their maximum capacity would be 1500 cubic feet per second (42.5 cubic meters per second). Operation of this system should ultimately be for base load only; it would be capable of meeting the weekly or other long period fluctuations of load but not capable of meeting

DEAD SEA PROJECT —POWER & ENERGY

Plant	Static head meters	Operating head meters	Power: Used- Developed+ Kilowatts	Energy: Used- Available+ Kilowatt-hours per yea
Pumping Plant	-42	-45	-23,400	-205,00(
Abu Sidra Power Plant	300	292	+102,000	+747,00(
Dead Sea Power Plant	110	108	+36,000	+261,00(
Net Totals	368	355	+114,500	+803,00(

the usual daily peak loads, since the rate of flow in the system can be varied only at a slow rate through control of the pumping plant.
Each power plant should be equipped with facilities for bypassing water for use in case of shut-down of the turbine units; conduits and mechanical equipment should, of course, be constructed of material with high resistance to the action of Mediterranean Sea water.
The preceding table summarizes the principal statistics relating to the ultimate development proposed in this report and indicates the estimated amounts of power and energy available in the average year.
The scheme of development is not readily adaptable to the usual breakdown into several stages of construction. Since the salt water taken from the Mediterranean Sea should not be discharged at any point other than the Dead Sea, it will be necessary to construct the water conduits initially from the pumping plant to the Dead Sea. Furthermore, the canals, ponds and tunnels would be of such size and character that they should be substantially completed in the initial stage of this power development.
The estimate of the cost of construction of this project has been based on the estimate included in the reference report used as a basis for this study. Adjustment has been made to compensate for the changes in the capacities of the various features of the project and for the general increase in construction costs since the preparation of the reference report. It is estimated that the ultimate project would cost about $76,000,000 exclusive of interest during construction, cost of land, land rights and transmission lines not necessary for the interconnection of the pumping plant and power plants.
Based on the cost of the complete project the annual cost, including interest, amortization, taxes, insurance, operation, maintenance, repairs and supplies, is estimated to be about *61/2* percent or $5,000,000 per year; the resulting cost of energy available (803,000,000 kilowatt-hours) is about 0.63 cents per kilowatt-hour.
The proposed power development is feasible from an engineering and construction viewpoint ; how,ever, a field survey and a comprehensive engineering study based on the survey are essential. Such a study should determine, among other things, whether or not replacement of Jordan River water used for irrigation must be made up from other sources. In case it is found that the water diverted from the stream for irrigation need not be replaced in the Dead Sea, it appears that replacement for power development only would be justified, provided the study suggested verifies the available data serving as a basis of this report.

WATER POWER

Figure 6 (Please see attached map)

Chapter IX
THE MAQARIN PROJECT ON THE YARMUK RIVER

DEVELOPMENT of the Yarmuk River for power and irrigation as a separate project has recently been proposed. The scheme proposed includes an earth and rock fill dam with a structural height of nearly 150 meters (500 feet) at Maqarin Station and a powerhouse at the dam discharging into a canal to carry the water at contour level about 32 kilometers (20 miles) to a point on the hillside east of Adasiya where construction of a fore-bay pond is proposed; from this pond a penstock would carry the water to a second powerhouse near the Yarmuk River. The location of the second powerhouse would be suitable for diverting the water to an irrigation canal to serve the eastern Ghor of the Jordan Valley. The dam proposed would have a storage capacity of about 500 MCM (400,000 acre feet) and its purpose would be to provide water for irrigation in addition to the development of power. The average annual flow of the Yarmuk River at the proposed dam site is about 420 MCM based on 20 years of records of the flow at the mouth of the river. The gross head proposed for development of power at the Maqarin Dam would be dependent on the elevation of the water in the reservoir. It is understood that a fluctuation of 30 meters in the water level is proposed. The gross head proposed for the plant near Adasiya would be 250 meters (820 feet).
This proposed project, operated as a single reservoir for the storage of water essential to meet the requirements of irrigation, would apparently have certain limitations. With irrigation given first priority in the use of water, power from the project's generating plants would be available only when there was need for irrigation. Apparently there is no provision for storage of water discharged from the lower powerhouse either by creating storage facilities or by diversion of the discharge into Lake Tiberias for storage. Consequently, unless water is wasted, the ability of this recently proposed project to generate power will be limited to periods of irrigation and restricted by the amount of irrigation water required. This limitation could be removed with the provision of adequate storage facilities to conserve the water discharged from the lower power plant until needed for irrigation, thereby making it possible to meet the requirements of irrigation irrespective of the demand for power production.
In arid regions, where a dependable water supply is essential to agricultural production, some provision should be made to insure an adequate supply during the dry years, several of which, in the weather cycle, are apt to come in succession. Storage of water in excess of the bare annual requirements is the solution to this problem. Provision of this desirable carry-over storage solely by the project recently proposed, to fully meet the irrigation needs of the lower valley would appear difficult because of the storage limitations of its reservoir.
No comprehensive planning report has yet been made on the proposed development described; fundamental geologic data, runoff records and maps only, showing the location of the main features of the project, have been made available.
The Yarrnuk Development as Part of the Broad Plan The inclusion of a project on the Yarmuk River at Maqarin site in the broad plan has been studied to show what benefits can be expected, giving priority to its use for irrigation, and considering the power benefits as secondary. The bases of the study included consideration of the following factors:
1. Controlled storage of 5 meters of water in Lake Tiberias assumed to be in use.
2. Stream flow available at the Maqarin Dam site has been taken from reference data covering 20 years of record. The yearly flow has been reduced by an amount of 50 MCM for irrigation use in the Yarmuk Plateau at a rate of use varying throughout the year in accordance with the general

requirements of the Jordan Valley region.
3. Power and energy studies are based on an average year stream flow computed from the 20-year record; irrigation studies are based on the-full 20-year period rather than on an average year.
Lake Tiberias with its large capacity for storage and its accessibility to the flows of both the Jordan and Yarmuk Rivers is the key to the effective control of irrigation water. The use of water from an additional storage dam on the Yarmuk, as part of the broad plan, cannot be relatively as effective as Lake Tiberias storage since it will be useful only for storing extreme floods such as occur once in several years. This requires a large capacity for the storage of water, which, on the average, will be released in small amounts over a period of several years. Its annual benefits to irrigation are small and the storage becomes relatively much less valuable than the base storage provided by Lake Tiberias.
In analyzing the possible benefits to be derived from a project developed at the Maqarin site, as part of the broad plan, dams of varying height up to about 500 feet were studied. The cost of constructing the dam and installing power generating equipment, together with estimates of energy output and cost, and the increase in the yield of irrigation water with its estimated cost were calculated for each height of dam studied. Development of power at the dam itself was not included as it is of doubtful economy to develop a hydro plant with the great variation of water level and power head available.
Development of power by construction of a power canal from the Maqarin Dam to a point on the hill east of Adasiya and a powerhouse on the Yarmuk River near Adasiya was included with each of the dams studied. The results of these studies are shown in Table 9-1. This table gives in summarized form the estimated costs and benefits which would result from various heights of dams, if constructed at the Maqarin Dam site, as part of the broad plan for the unified development of water resources. It is important that this tabulated summary be clearly understood, for it provides a means of readily comparing the potentialities as well as of understanding the limitations of this site. From this table it may be noted that as the structural height of a dam located at this site is increased, the costs increase at even a more rapid rate. For example, the total estimated cost of a dam 95 meters in height and the power plant near Adasiya is $39 million while the dam 152 meters in height with the same power plant is estimated to cost $82 million or more than double the cost of the lower dam. The capital cost of providing each additional MCM of irrigation water per year from these same dams, as part of the broad plan, more than doubles, being estimated as $205,000 per MCM for~.the 95 meter dam and $478,000 per MCM for the dam 152 meters in height. The energy available per average year from each of these dams remains the same, 183,600,000 kilowatt-hours. The structural height of 95 meters for a dam at this location is, therefore, significant. A further review of the summarized tabulated results of these studies will lend emphasis to this fact. Each column in the tabulation is numbered and fully explained in the text immediately following.

TABLE 9-1 (Please see attached table page 64)

Explanation of Table 9-1
Column 1 shows the maximum reservoir surface elevations above sea level resulting from the approximate structural heights of dams listed.
Columns 2 and 3 show the estimated structural height for each dam (in both meters and feet) and includes 2 meters for free-board above the water surface and an allowance for the approximate depth of excavation necessary to secure a suitable dam foundation.
Column 4 shows the estimated cost of the complete dam structure, including the earth and rock fill, the spillway, outlet structures, railroad relocation, reservoir preparation, diversion of water, roads, miscellaneous items, engineering costs and contingencies.
Column 5 shows the estimated cost of the work for power only and includes the power canal, penstock, powerhouse, power equipment, auxiliaries, tailrace, engineering and contingencies.
Column 6 shows the total of columns 4 and 5.
Column 7 shows the estimated power capacity for which the plant should be designed to make the best use of the water available, giving due consideration to the fact that the water will be released at rates most suitable for use in irrigation. Although the full installed capacity is not strictly "firm power," it will be possible through the use of storage in Lake Tiberias to develop the full capacity for meeting seasonal or weekly peaks, without wasting water which later could be used for irrigation.
Column 8 shows the energy available at the plant in the average year after making allowance for station uses and reasonable losses. It should be noted that with a dam having a structural height of about 95 meters the full energy potential of this site has been reached.
Column 9 shows the approximate storage capacity of the reservoir for the various heights of dams.
Column 10 shows the computed dependable additional yield of irrigation water from the combined flow of the Yarmuk and Jordan Rivers made possible, in the broad plan, by the storage provided by dams of varying heights in addition to the storage to be provided in Lake Tiberias. It reflects the variation in the rate of flow for the 20-year period of record, the joint use of Lake Tiberias storage (5 meters), the varying rate of use for irrigation purposes throughout the year, the evaporation from the reservoir surface and the use of carry-over storage to insure a dependable amount of water each year.
Columns 11 and 12 show the allocation of the total capital cost to power and to irrigation. The dams indicated as having structural heights of 28 meters and 58 meters are essentially power darns although they provide some small irrigation benefit. This benefit is considered incidental only. The costs of the dams whose heights are indicated as 78 meters and 95 meters have been arbitrarily divided equally between power and irrigation since a more detailed study of the allocation is not justified at this time. For higher dams the increased costs have all been allocated to irrigation since the increase in height contributes no appreciable benefit to the power development.
Column 13 shows the estimated cost per kilowatt-hour of energy. It is based on the cost of the project allocated to power (Col. 11) and the assumption that the total annual costs will be about *61/2%* of the capital cost. The net energy output (Col. 8) is the amount used for this calculation.
Column 14 shows the capital cost per MCM of dependable yield of irrigation water made available annually. Based on the allocations made this cost is high because of the small annual additional yield which the Maqarin storage would provide when added to the large capacity of the Tiberias storage and because of the high cost of providing this storage.
Storage at Maqarin Dam as Part of the Broad Plan
Under the unified development, about 830 MCM of storage capacity will be provided by the use of Lake Tiberias. The value to irrigation of any additional storage made available by the construction of the Maqarin Dam can be determined only by considering its use in conjunction with that to be provided by Lake Tiberias. It appears appropriate in this connection to review the function of storage.
Storage, as has been stated, makes possible the conservation and use of water which would otherwise be wasted. As storage capacity is added beyond that required for seasonal regulation, its use becomes mainly to store the runoff of infrequent floods, and the gain in the annual yield becomes smaller with each increment of storage. A point will be reached where the addition of a large volume of storage results in an insignificant increase in the amount of usable water or yield. The construction of reservoirs also adds to the amount of water lost through evaporation, so that excessive storage becomes uneconomical both with respect to cost and water conservation.
The cost of providing storage at the Maqarin Dam as a part of the unified development is shown in Table 9-1, where the cost per million cubic meters of added annual yield is given. In contrast, the estimated cost of storage in Lake Tiberias on the same basis would be less than $10,000 for each million cubic meters of irrigation water made usable annually. For the Hasbani storage, the estimated capital cost would be a little over $100,000 per million cubic meters of added yield per year. Thus the provision of storage at the Maqarin Dam would permit the utilization of the last increments of available water supply to be used for irrigation, but at a very high cost. It should be constructed only after the need has been established, and investigation has shown such an expenditure justifiable. Certainly consideration should first be given to the possibility of obtaining greater storage in Lake Tiberias, either by further raising of the water level above the two meters included in the broad plan or by pumping from the lake below the elevation of the gravity canals during those infrequent periods when more storage would be needed.
Study of the Maqarin Dam and reservoir site maps and comparison of this dam with many existing large earth, or earth and rock dams raises a question

regarding the suitability of the reservoir for storage purposes although the Maqarin site may be satisfactory as a dam site. The following facts are pertinent to this matter:

(a) The ratio of the storage capacity of the proposed reservoir (500 MCM) to the volume of a suitable earth and rock dam is about 38:1.

(b) The comparable ratios for nine large earth and rock fill or earth and rock faced dams built in the United States vary from 62:1 to 680:1 and average 229:1.

Conclusions

The studies of this project indicate that it has sufficient merit to justify a comprehensive field survey and a preliminary engineering study based thereon. Since the usable irrigation water that can be made available by a storage dam at the site proposed will not, as a part of the broad plan, be required until after completion of the first stages of the unified development, construction of the dam for storage of irrigation water should be scheduled with this in mind for a later stage.

Additional studies, as suggested, may indicate that development of power at an early stage is justified. This could be accomplished by providing the necessary power facilities and a dam of (say) 58 meters in height, with provision for raising at a later date to such a height as would be justified by its contribution to power and irrigation requirements at that time.

Based on present available data and the results of studies given in Table 9-1 it appears that construction of a dam for development of power about 58 meters in height, to be raised to about 95 meters in height for irrigation storage may be justified, and estimates of cost have been based on these figures. The estimated amount of additional water made available for irrigation by the 95 meter Maqarin Dam is 56 MCM per year. Provisions for power facilities to meet the requirements for the higher dam should be installed initially. The estimated costs, allocated to power and irrigation, on the basis of the studies summarized in Table 9-1, are approximately as follows:

Stage	Height of Dam	Power Plant	Estimated Cost - Dollars Dam Power	Irrigation	Total
First	58 M	16,000,000*	6,000,000	3,000,000	25,000,000
Final	95 M	16,000,000	11,500,000	11,500,000	39,000,000

Chapter X

EFFECTS OF THE UNIFIED DEVELOPMENT OF THE REGION'S WATER RESOURCES ON LAKE TIBERIAS, THE JORDAN RIVER AND THE DEAD SEA

THE major changes in the regimen of the river system of the valley under the proposed plan for the unified development must be considered with respect to the resulting effects on Lake Tiberias, the Jordan River and the Dead Sea. Water from the Yarmuk River will become a part of the supply to Lake Tiberias, and large quantities of water which once flowed down the Jordan River will be used on the land for irrigation. The effect of the diversions on the salinity of the lake and the extent of depletion of the flows of the lower Jordan River is discussed in this chapter.

Return Flow

A part of the water used on the land for irrigation finds its way to the natural channels of the streams where it appears as surface flow. It results from leakage and waste from the distribution system and from water which seeps into the soil beyond the root zone and returns to the stream channel as groundwater. This is called return flow, and its magnitude depends upon the system of distribution, the soil conditions, the crops raised, and the general efficiency of operation.

Field studies of soil conditions throughout the area are, of course, essential to the development of the plan and will give some guidance in estimating the amount of the return flow. The progress and the extent of the development will be factors. In general, the quantity can only be determined from actual measurement, and the problem is further complicated by the fact that the conditions of equilibrium in return flow may not be established for a period of from 20 to 30 years.

Some idea of the general magnitude may be gained from measurements of return flow made in irrigated areas in California. Here the average annual return flows, expressed as percentages of annual gross diversions from streams, were estimated at about 42 percent in the Sacramento Valley, 35 percent in the San Joaquin Valley, 15 percent in the delta uplands, and 14 percent in the Mokelumne Valley. It was estimated that as much as 50 percent of the total originated from seepage through the soil. Seasonal variations in flow followed the rates of use closely.

As water percolates through the ground, it dissolves the soluble salts in the soil, and thus alters its quality and suitability for irrigation. The re-use of the return flow is dependent both upon its location and its salinity. In the upper valley, there appears to be but little saline land, and the return flow should be unaffected, whereas south of Lake Tiberias there are areas in the Ghor where the land is known to be saline, and the quality of the water would be in doubt.

Since all land irrigated under the plan lies within the watershed of the Jordan River system, it seems likely that a great part of the return flow will appear in streams or springs in the valley. Water returning in the area above Lake Tiberias will be held with the river flows for use in irrigating land in the lower valley. Whatever use is made of the return flow in the Ghor must be determined from actual field experience. If, as stated in the source material, the irrigated land will require no under-drainage, it seems likely that the return flow in this area will not be readily recoverable for re-use. With the uncertainties both as to the quality and quantity, no allowance for its re-use in irrigation has been made.

It does not appear feasible to attempt an estimate of the return flow to be expected from the irrigation proposed under the broad plan. The best that can be done in this respect is to consider what the magnitude of this flow might have been under the conditions observed in California. There the range reported was from 14 to 42 percent of the gross river flow. Considering only the area from which the return flow might reach the lower Jordan River, and excluding the Ayelet Hashahar and Upper Huleh areas, a net amount of about 1130 MCM of water per year will be used for irrigation which probably would have reached the river under natural conditions. In the California area, for which figures were given, the return flow might have been between 150 and 475 MCM per year.

Effect of Unified Development on Lake Tiberias

The raising of the level of Lake Tiberias about 2 meters above what is now understood to be its maximum height has been discussed. This will permit an operating range of 5 meters, making about 830 MCM of storage capacity available as needed. Because of the generally steep shoreline of the lake, a rise of 2 meters will cause only a small increase in surface area and the increase over the normal amount of loss due to evaporation is estimated to be less than 7 MCM annually. It has been assumed that the raising of the lake will not cause excessive damage to existing facilities.

The extent to which utilization of the full storage capacity will be necessary will depend upon the stage of development reached under the broad plan and upon actual experience in operating the system. Until the maximum irrigation demand is reached, the use of the full 5 meter range will be infrequent, since at that time it will be required only about 3 years out of 20. Satisfactory operation with the present 3 meter range for storage should be possible much of the time.

With the diversion of the Yarmuk River into Lake Tiberias for storage, the entire inflow will be extremely variable because of the use of a part of the base flow of both tributaries for irrigation. The storage provided will take care of all seasonal variations in flow and will supply reasonable annual regulation. The total quantity of water passing through Lake Tiberias under the plan for unified development will be controlled by the diversion dam on the Yarmuk River and can be always maintained at a rate at least equal to the present flow of the Jordan River alone. There is, therefore, no question of the ability to maintain the

lake in its present state.
The introduction of the water from the Yarmuk River into the lake raises the question of the effect on its salinity. Information available indicates that the salinity of the Yarmuk River and Lake Tiberias waters is 88 and 300 parts per million respectively. Assuming that the water flowing out of the lake will have its average salinity, and that conditions are at present nearly stable, it can be shown that the diversion of the Yarmuk River into Lake Tiberias and the use of the water under the plan will not increase the salinity.

Effect of Unified Development on the Jordan River

After the diversion of the water in the upper valley for irrigation, over half of the average stream flow will remain in the upper Jordan River. In addition, the drainage in the Huleh area will add an estimated 62 MCM per year, coming mostly in the summer months so that as the river passes Jisr Banat Yacov, nearly two-thirds of the original flow, on the average, will remain. There is probably little use made of the river water between that point and Lake Tiberias.
The major effects of the extensive use of the river water for irrigation will be felt in the lower Jordan River, where, except during periods of high runoff, there will be no direct flow from the outlet of Lake Tiberias or from the Yarmuk River. As the distance below the lake increases, the river will receive the flood flows of the small wadis which are not suitable for development and any of the perennial flows which cannot be utilized. The return flows reaching the river will increase in amount as larger areas of irrigated land become tributary and will be greatest in the lower reaches.
The nature of the runoff in the river, originating from these sources will, of course, be different than at present. The Jordan River flows are regulated to some extent by the natural storage in Lake Tiberias, and when the lake was used in connection with the hydroelectric plant at the junction with the Yarmuk River, much of the flood flow was released during the summer months. Water from the wadis will consist largely of the flood flows and will come in the winter months. The flows wasted from storage into the lower river will not occur uniformly each year, but will more likely be concentrated into a period of perhaps three years out of twenty. Return flows, following the irrigation cycle, will be largest in the summer and fall.
The dry season flow of the lower Jordan River under the proposed plan will thus be largely determined by the amount and variation of the return flow from irrigation. There are no available records of the flows in the lower river previous to the use of Lake Tiberias for regulation, so that it is expected that the dry season flows measured at Allenby Bridge are higher than for the natural stream. The average of the flows of the lowest month each year for the period of record is about 58 MCM per month. Assuming that the return flows follow the seasonal change in duty requirements, the average return flow under the conditions experienced in California would be from 16 to 52 MCM per month. If this is accepted as indicating the magnitude of the return flow, the minimum flow remaining in the river during the dry season would be at least approximately one-third of the present dry season flow. The unused part of any perennial flows would be added to this amount, but cannot be evaluated.
Considerable time might be required for the seepage from irrigation to fill the groundwater storage and to establish stable conditions of return flow. The detention of this water would be compensated by the natural flows, some of which would remain in the river channel until the development under the plan was completed.
The water of the Jordan River now increases in salinity in passing from Lake Tiberias to the Dead Sea. The quality of the remaining flows of the river after diversion cannot be anticipated, since it will depend largely upon the nature of the return flows and the amount of salt taken into solution in passing through the soil.

Effect of Unified Development on the Dead Sea

The Jordan River valley lies within the Dead Sea drainage basin and contributes a substantial part of the inflow to the sea. Since the only outflow is the water lost through evaporation, its rate relative to the inflow affects the level of the water surface. Any depletion of the runoff of the Jordan River such as the use of the water for irrigation would upset the existing conditions, and cause a gradual lowering of the Dead Sea. This would continue until the rate of evaporation from the reduced water surface area equaled the diminished rate of inflow, at which time conditions of equilibrium would be re-established. The effects on the sea if the water used were not replenished are discussed briefly.
The Dead Sea has a water surface area of about 1015 square kilometers and lies at an elevation of about 395 meters below sea level. The northern section, comprising about three-quarters of the area, has a maximum depth of approximately 400 meters, and the southern section has a depth of only 10 or 11 meters. The water has a density varying from 1.15 to 1.25 and in some places is nearly saturated with salt.
The annual runoff from the drainage area which reaches the Dead Sea can only be approximated. The total drainage area is 40,650 square kilometers, of which an area of about 23,000 square kilometers is in the south below the Jordan River watershed. From the reference material forming the basis of this study, it is estimated that the Jordan River contributes over four-fifths of the total runoff. If the figure given as the average flow at Allenby Bridge is used as the total flow of the Jordan River, the total inflow to the Dead Sea on this basis would be about 1600 MCM per year.
The relation between inflow and evaporation at the Dead Sea is not static. The records show that there have been long-period changes of at least 12 meters in the level of the sea, and for the twenty-year period 1924 through 1943, the water surface has lowered about 3 meters, indicating an apparent excess of evaporation loss over inflow averaging about 150 MCM per year. The evaporation is said to be about two meters of depth per year, or a total loss from the surface of the sea of about 2000 MCM per year. If, as has been indicated by the lowering of the water surface, the evaporation has exceeded the inflow by about 150 MCM per year, the average inflow on this basis would be about 1850 MCM per year. This is greater than the 1600 MCM, estimated on the basis of the flow of the Jordan River, but the figures are of the same general magnitude.
The amount by which the inflow to the Dead Sea will be depleted, under the proposed plan, is equal to the total amount of water used for irrigation which once flowed into the Jordan River system, less any return flow. Due to lack of basic data, no estimates of the amount of return flow to be expected have been made, and use of quantitative data has been in reference to measurements of flow in other areas. However, in discussing the conditions at the Dead Sea, it will be convenient to use a figure for the return flow, and this should be considered as an indication of the magnitude of these flows and not as an estimate.
Since there is very little information relative to the conditions at the Dead Sea, all figures used must of necessity be approximate. For the total amount of water utilized for irrigation, the estimates must include figures in various categories, not entirely comparable, such as gross river flows, net amounts for irrigation, and quantities based on land areas irrigated. Thus the net water used in irrigation from which return flow would be likely to reach the lower valley is about 1130 MCM per year. Using 25 percent of this as representative of the return flow gives an amount of about 280 MCM per year which would return to the river. The average waste from Lake Tiberias has been given as 150 MCM per year, and with the figure used for return flow would make an average total of 430 MCM per year which would reach the river channel after full development of the plan. From the figures used for land now irrigated and water available, it may be assumed that an average of at least 1420 MCM per year would flow down the Jordan River if none were used for irrigation. The depletion of flow would be, therefore, the 1420 less 430 or 990 MCM per year. As previously stated, the 990 MCM per year is to be considered only as indicative of the total reduction of the inflow to the Dead Sea under the broad plan.
In setting up such a figure for the total depletion of inflow, it must be tacitly assumed that the 150 MCM per year deficiency of inflow, which was shown to exist by the fall in the water level, was caused by the previous use of water for irrigation of which account is taken.
On the basis given, a depletion of the river flow amounting to 990 MCM per year would result in an excess of evaporation over inflow of the same amount, and the water level would fall. This would continue until the decreasing water surface area reduced the evaporation rate by 990 MCM per year, when the system would again be in equilibrium. Assuming a 2 meter per year rate of evaporation, a reduction in the water surface of 495 square kilometers would be necessary, and this could involve a drop of perhaps 85 meters in the water level, depending upon the area-depth relationship. The time when the sea level ceased to fall would probably be in the order of two hundred years. The south end of the sea, below the peninsula would, of course, be dry.
An analysis of the general problem shows that calculations of the change of level of the water surface, such as those given above, are greatly affected by the rate of evaporation. Since this rate, as well as many of the other conditions, had to be assumed, the figures must be considered only as indicative of the magnitude of the changes resulting from the diversion. Actually the rate of runoff reaching the Dead Sea and the rate of evaporation would vary from year to year, but data on these and other important factors were not available.
The development of hydroelectric power as described in Chapter VIII, "Water Power," would provide for the maintenance of the water level of the Dead Sea by taking water from the Mediterranean Sea to make up for the depleted runoff.

Chapter XI

MAGNITUDE OF COST

THE estimate of cost of the work under the plan for unified development is for the purpose of determining the *magnitude* of cost only. Although figures are given showing the estimated cost of each of about twenty separate items of work, it should be understood that neither working drawings nor preliminary drawings are available for any of these items.

The cost figures in general are intended to represent the cost as of 1953 for similar work performed in the United States. It is believed that the cost of the whole plan constructed in the Jordan Valley will be of the same magnitude as if constructed in the United States. This, of course, may not be true of each individual item; relatively small operations that can be economically carried out by hand labor with local materials should cost less in the Jordan Valley. Similar operations involving large quantities may require the use of imported construction equipment and equipment operators to permit completion of the specific item within a reasonable length of time; the cost of such work may conceivably be greater than if performed in the United States. .

Basis for Estimates

The bases used for the figures given for specific items were obtained from the following sources:

1. *Estimates of other engineers* contained in the reference reports used as a basis for this study. These estimates have been revised to reflect the general increase in construction costs between the time such reports were prepared and 1953, and adjusted to apply to structures of different capacity or size.
2. *Current unit prices* for work in the United States applied to estimated quantities or quantities derived from the reports of other engineers.
3. *Estimates Contained in Reports of the United Nations.*
4. *Lump sum estimates* based on experience in case none of the foregoing could be used.

Cost estimates are intended to cover the cost of construction, engineering and construction overhead. The cost of land, water rights and interest during construction have not been included.

Estimated Costs:

The following list of items and estimated costs are numbered to agree with the description of these items included in Chapter VI, "The Plan for Unified Development."

ESTIMATED MAGNITUDE OF COSTS

Please see attached tables page 76, 77 and 78

Tables

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Maps

jordan.pdf