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Ground Water Resources of Az Zāwiyah Area, Tripolitania, United Kingdom of Libya

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International Development Mission to Libya

Open File Report

Ground Water Resources of the Az Zāwiyah Area, Tripolitania, United Kingdom of Libya

by

William Ogilbee and R. C. Vorhis
U.S. Geological Survey

and

Hadi Ali Tarhuni
Nazarat of Agriculture
Province of Tripolitania

Tripoli, Libya

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William Ogilbee, H. C. Vorhis

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Abstract

A study of the ground-water resources of Az Zāwiyah area, Tripolitania, shows that water levels are declining in the area and that contamination of aquifers by salt-water encroachment is a current (1962) threat.

The area studied comprises about 190 sq. km. along the southern coast of the Mediterranean Sea. The land surface of the area slopes generally northward to the sea, which is bordered by consolidated coastal sand dunes. Between the coastal dunes and a belt of semi-active dunes along the southern border of the area, is a zone of flatter land about 5 km wide interspersed with stabilized dunes. Because of the widespread presence of dune features and low runoff, no coherent stream pattern exists in the area. Water from rain collects in depressions between the dune ridges and percolates into the ground. The climate is semiarid and is characterized by low precipitation (254 mm per year at Az Zāwiyah), high evaporation, and wide temperature range.

Most present farming in this agricultural area is restricted to the flat-land zone between the coastal dunes and those farther inland. Agricultural development depends largely upon ground water for irrigation, although some dry-land farming is practiced.

Az Zāwiyah area is underlain by northward dipping Quaternary and Miocene limestone, sand, and clay which presumably overlie Mesozoic rocks. Quaternary sand and limestone aquifers yield most of the ground water currently used in the area.

Ground water occurs under unconfined to semiartesian conditions throughout the area. The water-table slopes generally northward to the sea. Dug wells tap the shallow ground water in the Quaternary deposits at depths generally less than 15 meters. Most of the bored wells tap a deeper aquifer in the Quaternary but few attain depths greater than 60 meters. The water generally has fair to good chemical quality and is suitable for agriculture and domestic use. Artesian water is also present in deep Miocene and Mesozoic aquifers but poor chemical quality may preclude use of water from such aquifers for many purposes.

Recharge to the Quaternary aquifers is both by infiltration from local precipitation and by underflow from the south. The deeper Miocene aquifers, however, are probably recharged by underflow alone. Withdrawals by pumps of about 18 million cubic meters annually together with the natural discharge exceed the recharge, at least in the developed area; consequently, the water level in the developed area is declining currently (1962) at about 0.2 to 0.4 meter per year. Salt-water encroachment is imminent near the sea.

The southern part of the area is suggested as most suitable for new development of the shallow ground water in the Quaternary deposits. Exploration for deeper aquifers, especially in the middle and lower Miocene rocks, is also recommended. The trend toward overdevelopment of the shallow ground water near the coast needs to be monitored by observation wells for water levels and chemical quality. Also pumping tests to evaluate hydraulic characteristics of the aquifers are needed.

Introduction

Purpose and scope

This report summarizes the results of an investigation of the ground-water resources of Az Zāwiyah 1/ area, Tripolitania. It is one of a

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1/ Transliteration of most of the geographic names used in this report conforms to the system adopted by the U.S. Board on Geographic Names, BGN/PCGN system. (U.S. Dept. of Interior, 1958). Some familiar names are left in their conventional forms.

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number of reports on areal investigations made as examples of methods and techniques of hydrologic studies; also the areas have been selected so as to provide data for development planning.

The United Kingdom of Libya is currently undergoing a period of rapid economic development following the discovery of fairly large petroleum reserves. Much of the anticipated revenue from the exploitation of this important resource is to be used for further development of agricultural lands and water resources. Informed individuals in Libya however, realize that water is among the chief limiting factors in the economic growth of the country.

The demand for additional water for agricultural use, industry and public supplies has resulted in an alarming decline of water levels in many of the developed areas. Much of the additional demand for water has arisen from the increasingly efficient pumps, increased availability of electric power, and improved markets for agricultural products. Also concern over the decline of water levels in a number of developed areas is now becoming widespread.

The present report is based on field work carried on intermittently by the writers and technical personnel of the Government of Libya during 1959-62. The report illustrates the application of established methods of field inventory of wells and of other hydrologic features and the compilation and interpretation of the resulting data. Information is given on depth to water, changes in water levels, depths of wells, chemical quality of water, and other pertinent hydrologic phenomena. Test drilling, geophysical studies, and pumping tests to determine hydraulic characteristics of aquifers, however, were not a part of the work.

Location of the area

The area discussed in detail in this report comprises about 190 sq km (square kilometers) in the vicinity of the town of Az Zāwiyah (Zavia), in the Province of Tripolitania (Wilāyat Ṭarābulus), Libya. Reference is made, however, to geologic and hydrologic conditions in the adjoining region that pertain also to Az Zāwiyah area. The area lies between 12°40' and 12°50' east longitude and is bounded on the north by the Mediterranean Sea and on the south by 32°40' north latitude. The town of Az Zāwiyah, which is centrally located in the area, is about 43 km (kilometers) west of Tripoli (Ṭarābulus) along the coastal highway to Tunisia (fig. 1).

Figure 1.--Map of Mediterranean region showing location of area of study.

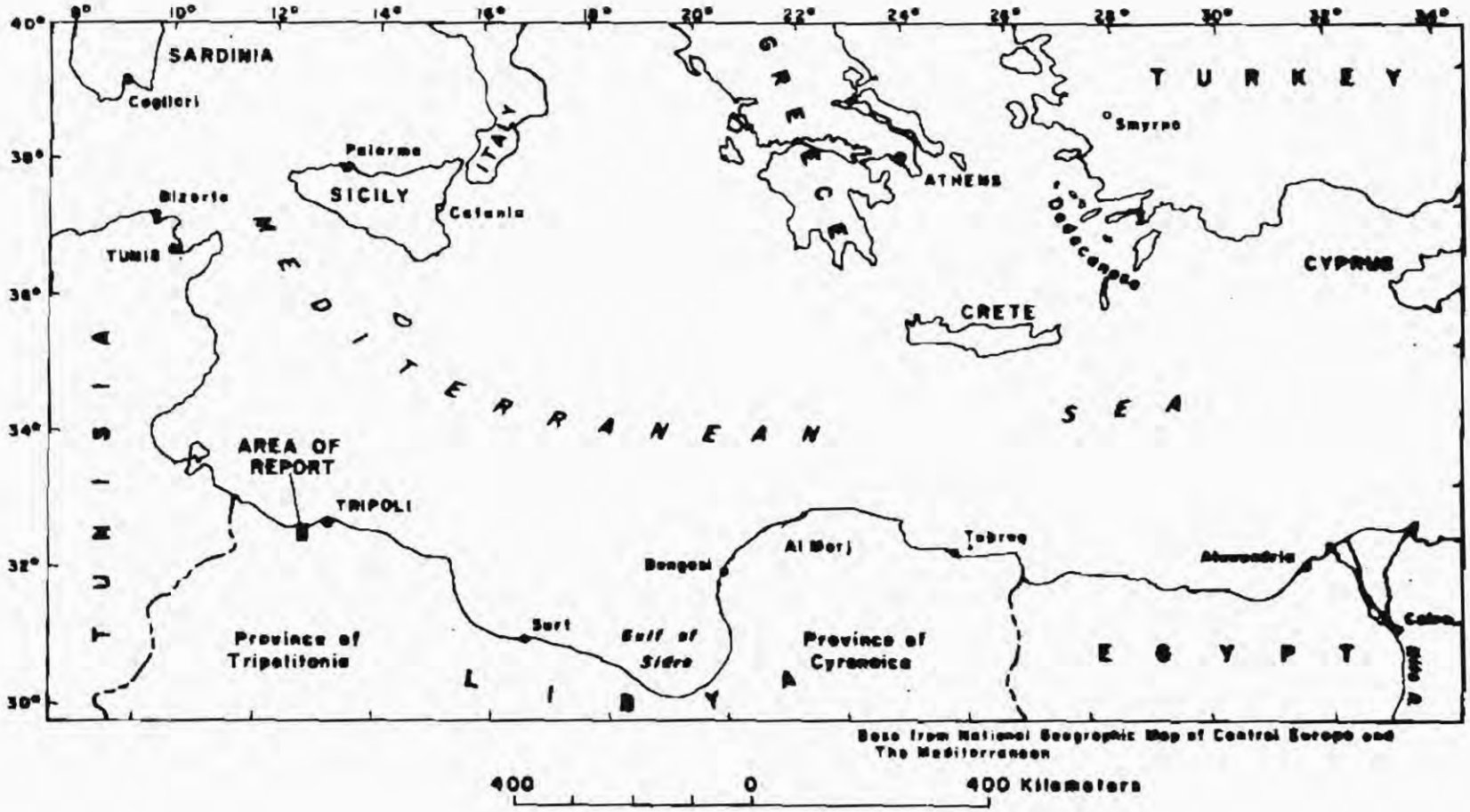

Figure 1.--Map of Mediterranean region showing location of area of study.

Description of well-numbering system

The wells described in this report are assigned identification numbers based on the latitude and longitude of the well site. All of Libya is situated in north latitude and east longitude. Each well number describes the location of the well within rectangles of 1 minute or 5 minutes of latitude and longitude. The first unit of four numbers describes north latitude, and the second unit, separated by a hyphen, describes east longitude. This number is the latitude and longitude of the southwest corner of a rectangle that contains the well. This rectangle has dimensions of either 1 minute by 1 minute or 5 minutes by 5 minutes. The 5-minute rectangle is designated by the addition of the numeral 5 separated from the other units by a hyphen. The last number, also separated by a hyphen, represents the serial number of the well within the rectangle. For example, well 3245-1246-1 is the first well described in a rectangle 1 minute on a side and bounded by 32°45' and 32°46' north latitude and 12°46' and 12°47' east longitude (fig. 2).

Figure 2.--Map of Az Zāwiyah area showing location of water wells.

Other well-numbering systems have been used in the past by the Italians and others. Many of these previously assigned numbers have been cross-indexed and are on file in the ground-water investigations offices of the Government of Libya.

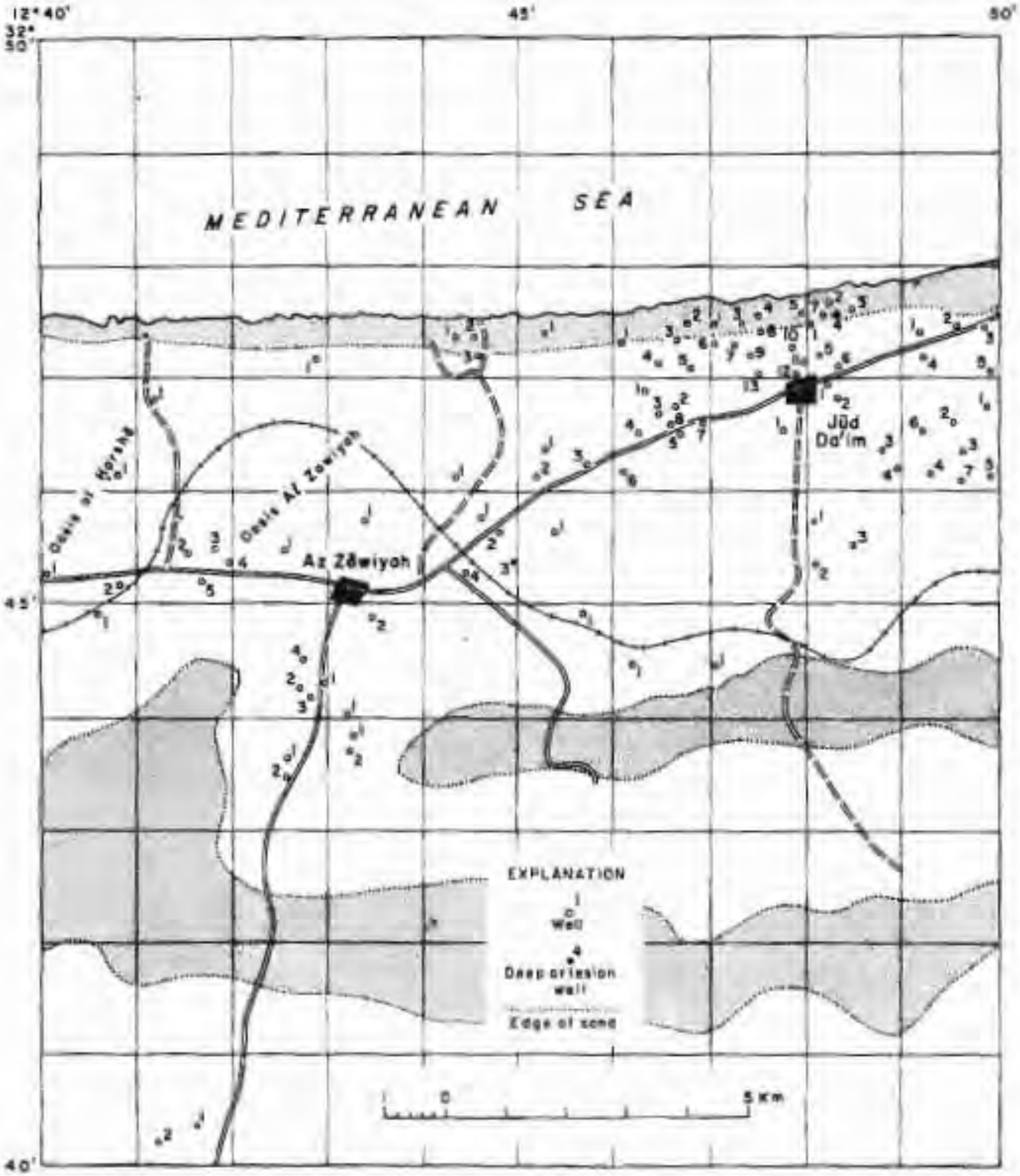

Figure 2.--Map of As Zāwiyah area showing location of water wells.

Previous investigations

Information on the ground-water hydrology of Libya is not extensive, however, many significant contributions bearing on ground-water conditions were made by Italian geologists prior to 1940. The description of the geology of Tripolitania by Bernet (1912) was probably the first of these contributions. Parona (1915) discussed the formations exposed along the Tripolitanian coast in "Geomorphic Notes on the Gefara." Zacagna (1915) published a general report on geohydrologic studies in western Tripolitania and in 1919 published some measured sections along the Jabal escarpment. Desio (1939) compiled a geologic map of Libya. Floridia (1939) published measured sections and geologic map of the Homs (Al Khums) area.

In a more recent study, Borgognoni (1946) gave a generalized discussion of the ground water of Tripolitania. In 1955 Christie published on the geology of the Garian area. Hill (1960) published a paper on the ground-water resources of the Gefara. Cederstrom (1960) prepared a ground-water report on the Tripoli area that contains much information applicable to Az Zāwiyah area. Stuart (1960) presented the results of pumping tests conducted in various parts of the Gefara. Vorhis (written communication) provided a good compilation and review of the geologic history of northern Tripolitania.

Acknowledgments

The study at Az Zāwiyah was made with the help and cooperation of the Nazir of Agriculture of Tripolitania, other Provincial and local government officials, and farmers. The work was undertaken as part of the joint program of the Government of Libya and the United States Agency for International Development Mission to Libya (USAID/L). Most of the field work was done by trained Libyan technicians under the guidance of U.S. ground-water advisors.

Geography

Az Zāwiyah area lies within the physiographic unit known as the Gefara, which is a coastal plain sloping gently northward from the escarpment of Jabal Nafūsah to the Mediterranean Sea. The Gefara, which is relatively flat land interspersed with sand dunes, extends along the coast from southern Tunisia eastward to Al Khums (Homs) where it pinches out between the sea and the Jabal Nafūsah. A chain of oases extends along the coast from Zuwarah to Al Khums in a narrow belt about 5 to 10 km wide. These oases lie between fossil dunes along the present coast and an active sand dune belt, several kilometers wide, that begins about 5 to 10 km south of the coastline. The Jabal Nafūsah forms the southern boundary of the Gefara. The Jabal, an erosional scarp which rises some 400 m (meters) above the Gefara, consists principally of interbedded limestone, sandstone, and gypsum.

In the northern part of Az Zāwiyah area a long chain of fossil dunes, which rises about 15 to 25 m above sea level, parallels the coast. A belt of irrigated land about 5 km wide lies inland and parallel to the coastal dunes. This belt includes the oasis (wāhat) Az Zāwiyah (altitude 15-20 m), the oasis Al Ḫarshā (altitude 10-15 m) and a cultivated tract (altitude 25-50 m) near Jūd Dā'im. South of this belt is a zone of semi-active sand dunes about 4 km wide which is gradually being put into cultivation by dune-stabilization methods.

Climate

The climate of Az Zāwiyah area is characterized by low precipitation, high evaporation, and a wide range in daily and annual temperature. The average annual rainfall for Az Zāwiyah for the period of record, from 1925 to 1940 and 1950 to 1961, is 254.5 mm (millimeters) (table 1). During these years the measured annual rainfall ranged from 90 mm in 1935 to 475 mm in 1925. The period of record, however, is too short to evaluate any long-term trends or cyclic effects that may be present.

Rainfall in Az Zāwiyah area, as in most of coastal Tripolitania, is seasonal with the maximum precipitation in the winter months and little or no rain during the summer. Monthly averages, which range from 60.9 mm in December to 0.1 mm in July, tend to give a false impression of the temporal distribution, as the actual rainfall is quite erratic. For example, recorded rainfall for December has ranged from 0.8 mm in 1935 to 165.1 mm in 1928.

Az Zāwiyah area lies within the general farming zone described by J. H. Stewart (1960, p. 30) (fig. 3). Crops such as barley, wheat, millet,

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Figure 3.--Map of northern Tripolitania showing average annual rainfall, in millimeters.

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olives, almonds, melons, and winter vegetables can be grown successfully in the area without supplemental irrigation.

Table 1.--Rainfall at Az Zāwiyah, 1925-40 and 1950-61, in millimeters.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1925	127.8	25.3	106.2	1.5	2.0	9.5	0.0	0.0	7.0	125.8	42.4	27.1	474.6
1926	52.1	22.1	31.8	25.0	2.0	7.3	0.0	0.0	3.1	1.5	30.4	40.4	215.7
1927	87.7	23.5	25.4	0.0	0.0	0.0	0.0	0.0	0.0	7.5	7.0	3.6	154.7
1928	159.5	81.1	4.7	2.7	0.0	0.0	0.0	0.0	0.0	2.0	53.1	165.1	468.2
1929	120.4	47.6	17.8	3.2	0.5	17.0	0.0	0.0	25.2	5.5	29.0	8.4	274.6
1930	28.9	42.3	4.9	12.5	8.3	0.0	0.0	0.0	0.0	4.3	45.3	37.2	183.7
1931	29.7	52.1	0.0	0.0	7.6	0.0	0.0	0.0	78.6	6.5	5.5	51.1	231.1
1932	91.6	20.6	8.2	1.7	0.0	0.0	0.0	0.0	20.3	76.0	29.8	35.5	283.7
1933	17.4	51.6	223.3	1.4	0.4	0.7	0.0	0.0	0.0	0.0	10.9	97.2	402.9
1934	178.9	42.6	7.4	0.0	0.9	0.0	0.0	0.0	0.0	16.6	55.1	33.8	335.3
1935	60.0	8.2	6.8	5.9	0.0	0.0	0.0	0.0	1.5	0.8	6.5	0.8	90.5
1936	16.3	6.3	1.8	0.0	10.7	0.0	0.0	1.6	0.0	59.4	42.8	141.4	280.3
1937	14.7	42.9	0.5	9.1	0.2	9.0	0.0	0.0	3.7	29.4	17.0	37.4	154.9
1938	104.9	90.4	47.8	51.6	0.3	0.0	0.0	0.0	0.0	5.0	44.0	122.7	466.7
1939	62.7	5.8	19.0	12.7	6.0	0.0	0.0	0.0	0.5	0.0	29.4	62.4	198.5
1940	18.2	0.0	10.0	6.8	0.0	0.0	0.0	0.0	0.0	7.4	15.9	143.3	201.6
1950	51.4	28.3	68.9	4.3	9.8	0.0	0.0	0.0	0.0	28.3	75.9	26.3	293.2
1951	61.9	0.5	5.8	0.0	8.5	0.0	3.3	0.0	33.5	27.5	23.8	99.6	264.4
1952	46.3	81.5	0.0	1.5	0.0	0.0	0.0	0.0	38.0	3.5	47.3	54.8	272.9
1953	79.7	2.9	12.0	0.6	3.0	0.0	0.5	1.8	0.0	55.0	114.0	84.1	353.6
1954	7.3	6.0	7.2	5.2	0.0	8.5	0.0	0.0	0.0	36.8	30.5	60.3	161.6
1955	1.5	35.7	0.0	45.5	0.0	0.0	0.0	0.0	0.0	53.0	17.0	74.0	226.7
1956	9.5	18.5	30.5	0.0	0.0	0.0	0.0	0.0	7.0	40.8	3.0	107.8	217.1
1957	89.3	0.0	0.5	36.0	13.0	0.0	0.0	0.0	0.0	55.0	46.0	56.0	295.8
1958	2.0	3.0	29.2	0.0	0.0	0.0	0.0	0.0	0.0	19.5	61.5	37.5	152.7
1959	28.5	18.0	5.0	10.3	1.5	0.0	0.0	0.0	0.0	14.5	12.0	12.5	102.3
1960	4.0	2.5	0.0	17.0	0.0	0.0	0.0	0.0	50.0	0.0	56.0	66.5	196.0
1961	33.5	11.0	35.5	34.5	7.0	0.0	0.0	0.0	11.0	14.0	0.0	19.0	165.5
Average	56.6	27.5	25.4	10.3	2.9	1.5	0.1	0.1	10.0	24.9	34.0	60.9	254.2

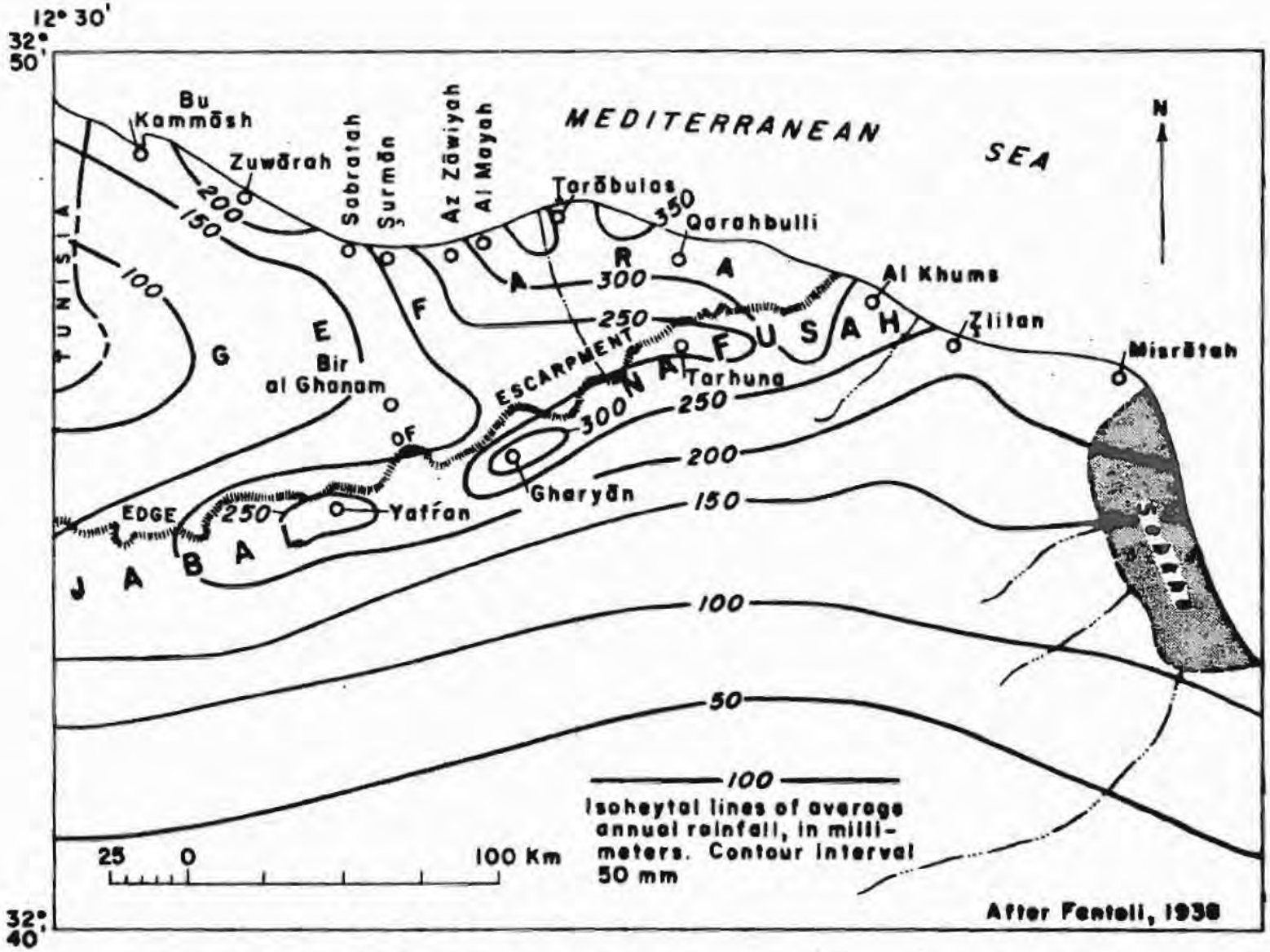

Figure 3.--Map of northern Tripolitania showing average annual rainfall, in millimeters.

The frequency as well as the amount and distribution of rains is a very important factor in the pattern of cultivation in this area. Optimum conditions for growth of barley and other cereals require a sequence of moderate rains beginning in late October and extending through March with few extended dry periods. Variations from these conditions greatly affect the yield of the winter cereals and the grazing conditions that are especially important to the semi-nomadic inhabitants of the southern part of Az Zāwiyah area.

Agricultural development

Farming in Tripolitania and Az Zāwiyah area was originally centered near the oases that lie near the coast. In these oases where the water table is generally shallow, extensive groves of date palms have been cultivated for many centuries. Probably many of the ancient groves were originally subirrigated from a high water table and the palms were essentially phreatophytes. More recently in the oases, date culture has been supplemented by subsistence-type gardens irrigated from water lifted by animal power and mechanical pumps from dug and bored wells. As has been the case since time immemorial the southern part of Az Zāwiyah area is inhabited by semi-nomads who follow their herds most of the year but carry on some dry-land cultivation of cereals dependent on the winter rains.

The economy of Az Zāwiyah area, as of much of Libya, is based largely on agriculture. Most agricultural production in the area comes from the narrow belt about 5 kilometers wide near the sea. The principal crops are peanuts, alfalfa and other fodder crops, barley, wheat, maize, dates, olives, potatoes, tomatoes, and other vegetables. South of the coastal belt the principal crop is barley and grazing of livestock is important. The 1960 census of agricultural statistics lists 955 hectares of peanuts planted with a yield of 15,821 quintals (qtls.); 754 hectares of alfalfa and other fodder crops yielding 35,235 qtls; 21,031 hectares of cereals with a yield of 15,569 qtls. Production figures are not available for dates, olives and citrus fruits, however, these crops contribute substantially to the commercial exports of the area. In addition to crops listed above, some 26,364 head of livestock, 4,891 poultry and 1,145 rabbits were raised which yielded for human consumption and use 651 liters of milk, 417 qtls. of wool, and 360,600 eggs. Agricultural development in Az Zāwiyah area is largely based upon ground-water irrigation, but dry-land cultivation of barley, grapes, and olives also is practiced.

Stratigraphy

Rocks exposed in northern Tripolitania range in age from Triassic to Recent (table 2). Existing (1962) drilled wells in Az Zāwiyah area have not actually penetrated formations older than Miocene. The older formations are described herein because they may be explored and developed for water in the future.

The rocks of the region consist of a sequence of sedimentary formations that dip gently and thicken gradually toward the sea from near the foot of the Jabal Nafūsah; thus they are not only thicker toward the sea but also lie at greater depth than inland. The process of deposition did not occur evenly, as some formations at places were either eroded away prior to burial by younger beds or were not deposited. Post-depositional faulting and folding also affects some of the beds.

Mesozoic rocks

The oldest formation exposed in northern Tripolitania is the Ras Hamia Formation of Middle Triassic age (Burollet, 1960, p. 44). The type section exposed near Al Azīzīyah consists of some 74 m of dark-red, fine-grained, micaceous sandstone, red and green silty clay and claystone, and vari-colored siltstone. Only the uppermost part of the formation is exposed at the type locality and the total thickness may be several hundred meters.

Table 2.--Generalized section of geologic formations for northwestern Tripolitania.

(After Christie, 1955)

System	Series	Group or Formation	Thickness (meters)	Lithologic Description	Water-bearing Character
Quaternary	Recent			Loess, wind-blown sand	
	Pleistocene	Garagaresc calcarenite	0-30+	Loosely cemented coquinoid calcareous sandstone	Yields some potable water locally but quality soon deteriorates with use owing to proximity to sea
		Gefarico silt with intercalations of marine deposits	50+	Calcrete, silty sand, loosely cemented sandstone, limestone and clay	Upper strata yield small to moderate amounts of water wells. Lower strata yield moderate to large amounts. Principal aquifers of the area
		?	?		
Tertiary	Pliocene		?	May be present but not identified in subsurface	
		Unconformity			
	Miocene		560±	Marine limestone, sandstone, and clay found in subsurface in northern part of Gefara	Middle sandstone strata yield moderately saline water, but little known about quality and quantity. Basal sandstone strata yield large quantities of brackish water
Cretaceous	Upper (Cenomanian to Turonian)	Gasr Tigrinna Formation	87		Yields small to large amounts of potable water. Many springs flow from the Ain Tobi and Chicla Formations
		Garian dolomite	55		
		Nefusa Group Jefren Marl Ain Tobi Limestone	79	Limestone, dolomite, marl, sandstone, clay and conglomerate that are exposed on the front of Jabal Nafusah and may also underlie the Miocene near the coast	
	Lower (Wealden)	Chicla Formation	0-65		
Jurassic		Bir el Ghnem Group	100±	Gypsum and limestone with beds of clay and sandstone. Not identified in the subsurface near the coast	Not considered a source of potable water
		?			
		Bu Scebba Formation			Yields moderate amounts of slightly saline water to wells. Supplies water for irrigation near Bir al Ghanam
Triassic	Upper (Kueper)		165±	Sandstone, conglomerate, clay, and some gypsum	
	Middle (Muschelkalk)	Azizia Limestone	110	Limestone and chert, exposed near Azizia	Not considered a source of water
		Ras Hamia Formation	800±	Micaceous sandstone, silty clay, claystone	Reported to yield large amounts of water for irrigation near Al Aziziyah

The Azizia Limestone overlies the Ras Hamia Formation (Christie, 1955, p. 4-6). In the type section at Al AzīzĪyah 61 m of light to dark-grey compact fossiliferous limestone with bands and nodules of chert is exposed. The Azizia is used as road metal and as an ornamental building stone.

The Bu Sceba Formation (Christie, 1955, p. 15-16; Burollet, 1960, p. 10) has been described as Late Triassic to Early Jurassic in age. The formation comprises about 165 m of red to brown sandstone, pebble conglomerate, white sandstone, red and green clay, and minor amounts of gypsum.

The Bi'r el Ghnem Group of Jurassic age consists of about 100 meters of gypsum and limestone with thin beds of clay and sandstone.

Five stratigraphic units of Cretaceous age have been identified (Christie, 1955, p. 17-20) from their exposures in the Jabal Nafūsah escarpment. They consist of limestone, dolomite, marl, clay, sandstone and conglomerate.

Rocks of Mesozoic age have not been reached by borings in the report area, although they probably underlie it at depths of several hundred meters. Sedimentary rocks older than Miocene were penetrated from 412 to 750 m in a test hole at Umm al Ḥashahān, about 15 km east of Az Zāwiyah. Although the age of these rocks was not definitely established, they probably are of Cretaceous age.

Tertiary rocks

Miocene rocks consisting chiefly of limestone, clay, marl, quartz sand and sandstone overlie the Mesozoic rocks. The Miocene attains a thickness of approximately 560 meters in the coastal Gefara according to Desio (1940) and 500 meters or more in Az Zāwiyah area. The Miocene strata dip northwesterly at about 15 m per kilometer.

Quaternary deposits

Quaternary deposits most of which are unconsolidated form the surface rocks of Az Zāwiyah area and adjacent parts of the Gefara. These deposits are of eolian and marine origin and range in thickness from 40 meters near Tripoli to 130 meters at Ṣabratah. In the vicinity of Jūd Dā'im the deposits are probably about 100 meters thick.

The lower part of the deposits consists of loosely cemented silty sand, some limestone, and clay, whose overall permeability appears to be much greater than that of overlying beds. The upper part of the deposits consist of unconsolidated eolian sand; loess, calcrete and some loosely cemented sand.

The Gargaresc calcarenite, a coquinoid fragmental calcareous sandstone, is exposed in a series of loess-covered cemented dunes extending from Tripoli westward along the coast at least as far as the Tunisian frontier. The calcarenite deposits are limited to the coast and have not been found inland. They are used extensively for building stone.

Ground water

Source and occurrence

The source of most fresh water on the earth is precipitation. The process of evaporation, condensation, and precipitation known as the hydrologic cycle, (Fig. 4) is continuous and has no beginning or end.

Figure 4.--The hydrologic cycle.

Water evaporated from the land and water surfaces, is borne as vapor into the atmosphere where it condenses and falls back to the earth as rain. Some of the precipitation sinks into the ground, some runs off into streams, and some is evaporated back into the atmosphere. The water that sinks into the ground flows underground and reappears at the surface as springs or enters the ocean directly. The water in the streams flows to the ocean where it is again evaporated into the atmosphere thus completing the hydrologic cycle.

Water, which occurs naturally as rain, falls on the surface of the ground and percolates downward through the pore spaces of the soil and forms the zone of saturation. The upper surface of the zone of saturation is known as the water table. The water in the zone of saturation, sometimes referred to as "phreatic water", moves by gravity flow towards areas of discharge.

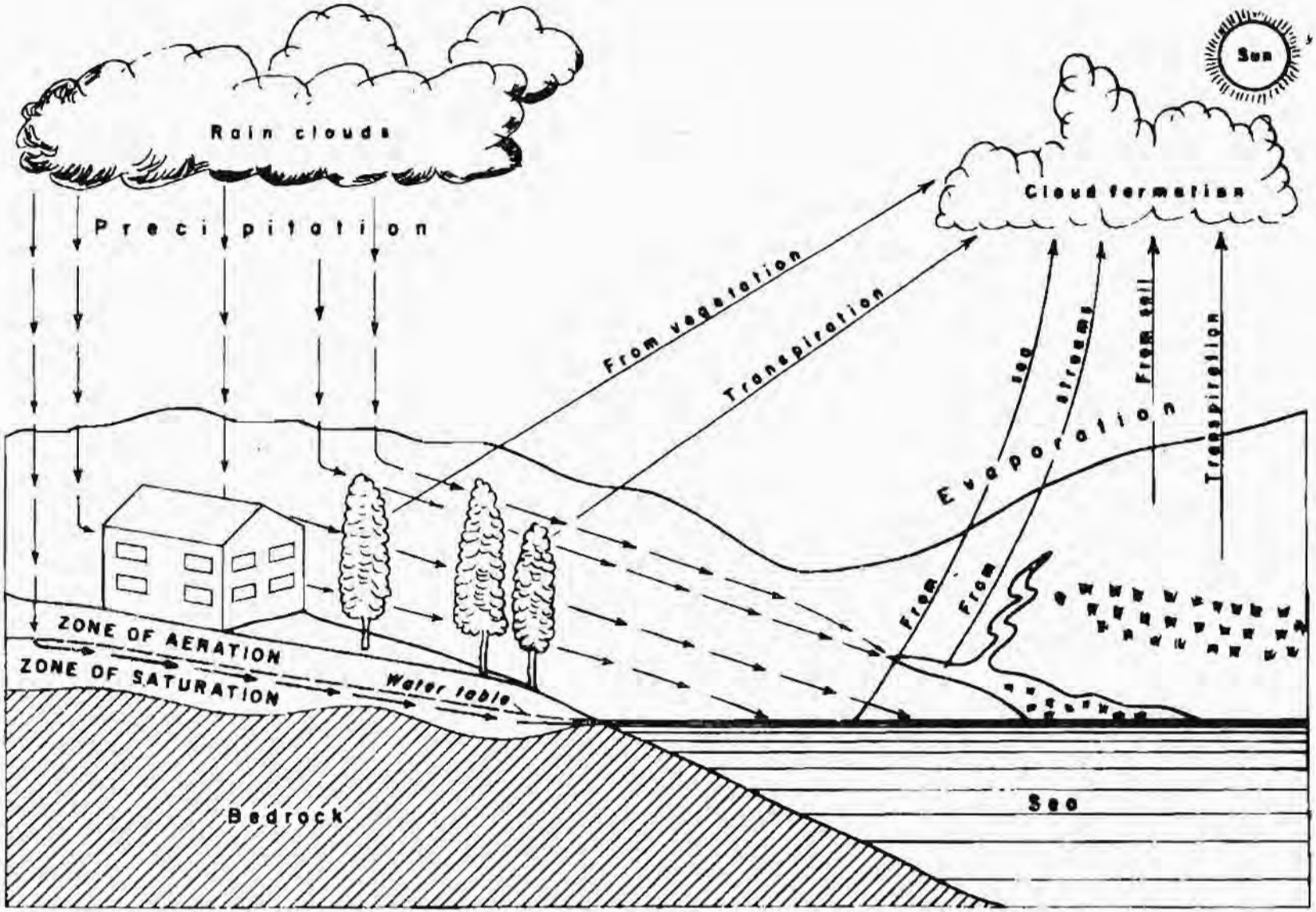

Figure 4.--The hydrologic cycle.

Ground water also occurs as confined or artesian water. A gross over-simplification of the origin of an artesian aquifer is described below. As water moves through a formation by gravity flow the water-bearing strata commonly pass beneath overlying impermeable beds which restrict vertical flow. If the bed beneath the water-bearing formation is also impermeable, the water-bearing formation is said to be confined or artesian. As the water continues to flow through this confined formation it acquires a hydrostatic pressure proportional to the vertical distance between the elevation of the point of confinement and the top of the confined bed at any point.

Ground water is stored in the earth in the pore spaces of the different types of rocks in which it is found. All granular material in the earth contains openings between the grains or particles, but the openings differ in number, size, and shape. In materials such as clay and silt, the open spaces are very small, and therefore, do not readily yield water to wells. Sand, gravel, and fractured massive rocks may have large interconnected spaces through which water can flow freely. The size and amount of the voids or open spaces of the water-bearing formation affect the ability of the formation to transmit and store water.

Water-bearing formations

Mesozoic rocks

The oldest water-bearing formations known in northern Tripolitania are the Ras Hamia, Azizia and Bu Sceba of Triassic to Jurassic age. Useable water in these aquifers is tapped at depths ranging from 100 to 325 m near Bi'r al Ghanam and Al Azīzīyah. For example, a test hole drilled 2 km south of Al Azīzīyah encountered a very permeable aquifer in the Ras Hamia at a depth of 324 m. A few wells of low yield also tap water-bearing zones in the Azizia near the type locality. Permeable beds in the Bu Sceba yield water rather freely to wells at Bi'r al Ghanam. Potable water is also obtained from springs issuing from the Cretaceous rocks, notably the Ain Tobi Limestone, of the Jabal Nafūsah to the south of the report area. Presumably, all these formations underlie Az Zāwiyah area but probably at considerable depth. The water contained in these formations, however, probably would be salty or brackish beneath the report area.

Tertiary rocks

Rocks of Miocene age attain a thickness of 500 meters or more in the coastal zone adjacent to Az Zāwiyah area. Exploratory wells put down in or adjacent to the report area have penetrated to the basal Miocene and each has encountered several water-bearing zones in the Miocene (table 4). Also each well has encountered three fresh-water aquifers in the middle Miocene section. For example in well 3247-1248-4 (OPDL well no. 21) at Jūd Dā'im, aquifers in the Miocene were penetrated at depths of 140, 239, 254, 280, 344, 426, 437, and 496 m. Unfortunately, the water from the wells was not checked systematically for quality or quantity, for interest at the time the wells were put down was solely in flowing artesian water. In well 3247-1256-2 (OPDL well no. 16) at Mayah, the first aquifer was encountered at 141 meters, the second at 191 meters, and the third at 223 meters. The reported chemical quality of water from the aquifer at 223 meters suggests that the water, though slightly brackish, could be used for irrigation. Water of similar quality was also obtained from an aquifer at 254 meters in well 3247-1248-4. These aquifers were also encountered in a test hole, well 3243-1255-2, at Umm al Hashshān drilled by the predecessor US AID in 1956. The Miocene aquifers thus may contain a potential source of water for future utilization in Az Zāwiyah area that could be used to supplement the declining supply from Quaternary aquifers in the present agriculturally developed tracts. Test holes, however, need be drilled to determine the extent and thickness of these aquifers in Az Zāwiyah area. The test holes should be properly logged and the quality and quantity of water should be determined systematically by analyses, electrical logging, and pumping tests.

Sandstone aquifers in the basal Miocene yield flowing water to wells along the coast from Ṣabrātah to near Al Khums. The water, however, is both hot and highly mineralized and contains hydrogen sulphide (H_2S). The water from these wells generally has proved unsatisfactory for irrigation. Analyses of water from wells penetrating the basal Miocene strata suggest that the quality of the water improves inland or up dip. If this conclusion is correct, it may be possible to obtain water of quality suitable for irrigation in the southern part of Az Zāwiyah area from aquifers in the basal Miocene and at depths which become progressively less to the south.

Quaternary deposits

Quaternary deposits overlying the Miocene contain the principal aquifers in the Gefara of Tripolitania. The deposits range from unconsolidated sand to loosely cemented sandstone and limestone. The thickness ranges from 40 meters near Tripoli to 130 meters at Ṣabratah and is probably about 100 meters near Jūd Dē'im.

The lower beds in the Quaternary deposits, locally referred to as the second aquifer, furnish most of the water for irrigation and public supply in coastal Tripolitania as well as in Az Zāwiyah area. The water-bearing materials are loosely cemented permeable sandstone and limestone intercalated with impermeable layers of clay. The aquifer is considered to be semiartesian, that is, it is hydraulically continuous over a large region but locally, vertical movement of water may be impeded by less permeable beds. Consequently, when the lower beds are penetrated by a well, the water will rise in the well to the level of the water table. The permeable beds in the second aquifer are highly lenticular and any particular bed may lens out in a relatively short distance. The overall permeability of the lower beds appears to be considerably greater than that of the upper beds which constitute the first or water-table aquifer. The average depth of the wells penetrating the second aquifer in the lower beds of the Quaternary is about 60 meters, increasing somewhat to the west.

In Az Zāwiyah area, the first and second aquifers in the Quaternary deposits appear to be directly interconnected in many places. Consequently, the shallow dug wells tapping the first aquifer may go dry shortly after nearby deeper drilled wells begin pumping. Since 1959 a large number of dug wells have been deepened or replaced with drilled wells.

The Gargaresc calcarenite deposits are extremely permeable and locally yield small supplies of potable water. Owing to their proximity to the sea, however, they are subject to salt-water contamination.

Hydraulic characteristics

Under natural conditions and over a long period of time, the hydraulic system in a water-bearing formation is essentially in balance, that is, the natural discharge is equal to the recharge. Water in transit between the area of recharge and the discharge area is said to be in storage. When this natural balance is upset by a withdrawal of water, as from an irrigation well, an adjustment takes place which results in a decline in the water level. When water is withdrawn from a well that penetrates an aquifer, the direction of flow of the water in the vicinity of the well is changed. The withdrawal causes a lowering of the water level around the well in the form of an inverted cone, the well being at the center. As the cone expands and deepens, water flows to the well from all directions. (Fig. 5). The rate of decline of the water level and the outward spread

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Figure 5.--Diagram showing movement of ground water around a cone of depression of a pumped well near sea level.

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of the cone depend on the hydraulic characteristics of the formation as well as the rate of pumping. The magnitude of the decline in water level varies directly as the rate of withdrawal of water, and increases with the logarithm of time that has elapsed since withdrawals began.

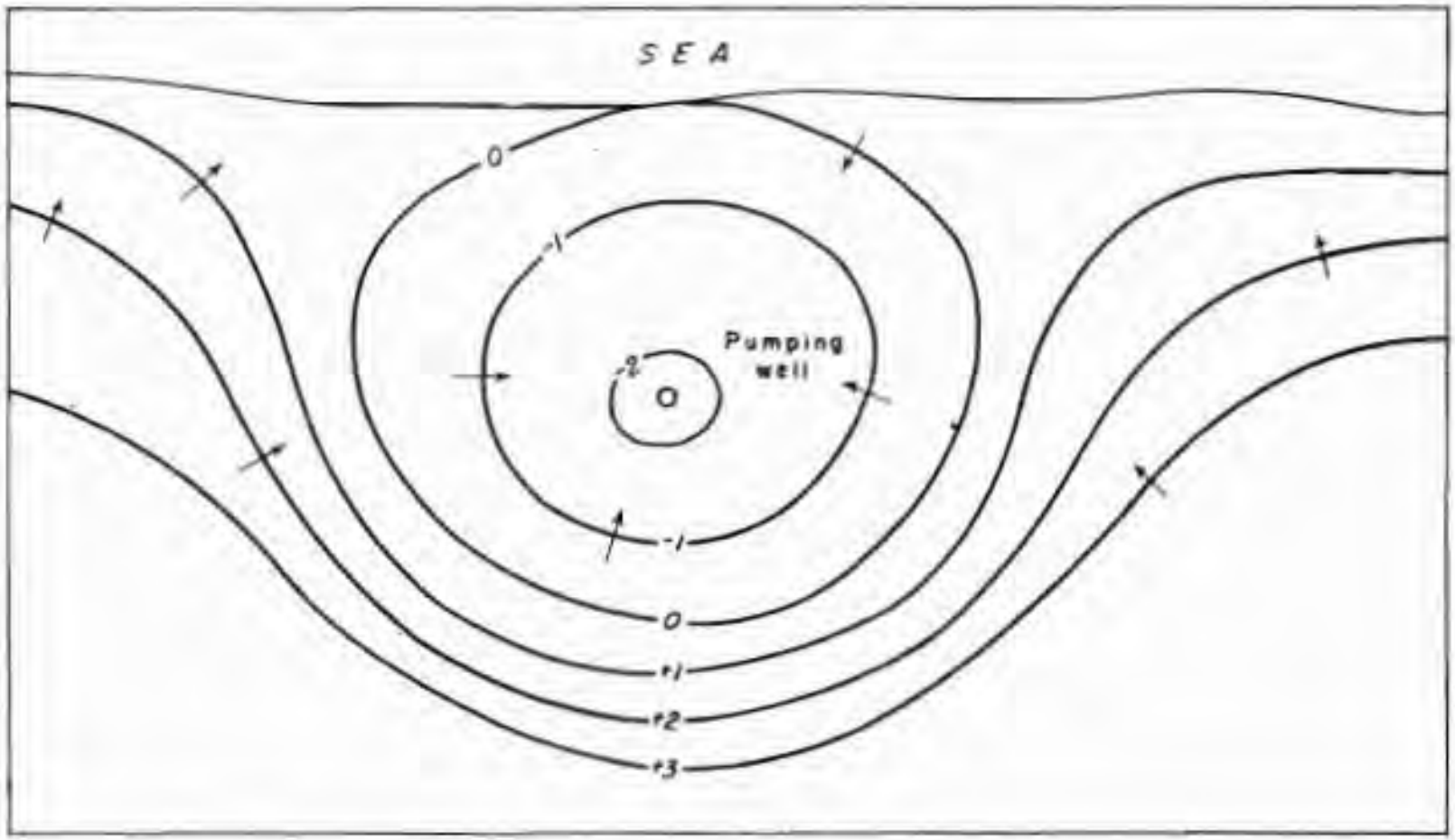

Figure 5.--Diagram showing movement of ground-water around a cone of depression of a pumped well near sea level.

Two of the hydraulic characteristics of water-bearing formations which affect the rate of decline of water levels in wells are the ability of the formation to transmit water, and the capacity of the formation to yield water from storage. These are known as the coefficient of transmissibility and the coefficient of storage. The coefficient of transmissibility is defined as the rate of flow of water, in gallons per day, through a vertical strip of the aquifer one foot wide, extending the full saturated thickness of the aquifer under a hydraulic gradient of one foot drop in head in one foot of flow distance. The coefficient of storage is defined as the volume of water an aquifer releases or takes into storage per unit surface area of the aquifer per unit change in the component of head normal to that surface.

The hydraulic coefficients of storage and transmissibility of the aquifers in Az Zāwiyah area are not available owing to the lack of pumping tests. Tests were conducted however, in the Bianchi (Az Zahra) area by W. T. Stuart (1960). The aquifers at Az Zahra are believed to be sufficiently like those at Az Zāwiyah that their hydraulic characteristics are comparable. In Az Zahra tests the coefficient of transmissibility was determined to be 37 cubic meters per hour per meter (68,000 U.S. gallons per day per foot) and the coefficient of storage was found to be 0.0016.

The figures obtained in Az Zahra tests indicated a moderate ability of the water-bearing formations to transmit water to wells. The figures may have been low owing to lack of complete penetration by the pumped wells of the water-bearing formations.

Recharge and discharge

Recharge to the aquifers in Az Zāwiyah area is either from direct infiltration of water from precipitation or from the runoff in ephemeral streams of the region. Much of the recharge comes from local rainfall that percolates down into the ground-water reservoir, however, it is difficult to predict how much recharge will occur in any one year. During drought years the recharge may be small or nil, but during periods of heavy rainfall a high percent of the precipitation may enter the ground-water reservoir as recharge. Information is not available to evaluate the rate of recharge that occurs in relation to the amount of rainfall. Correlation of rainfall and recharge would be difficult to determine because water is being withdrawn continuously for irrigation causing an overall decline in the water level that masks the effects of ground-water fluctuations due to natural causes. Detailed recharge studies therefore, were beyond the scope of this report.

Recharge also moves into Az Zāwiyah area from the south as shown in figure 6. The contour lines in figure 6 are drawn through points

Figure 6.--Map showing configuration of the water table in a part of the central Gefara, 1959-60. (After Vorhis).

of equal altitude on the water table and were constructed from water levels in wells measured during 1959-60. The map shows that the water table slopes northerly toward the sea. A ground-water mound marked by the 95-meter contour in the Bi'r al Ghenam area and another south of An Nāṣiriyah marked by the closed 90-meter contour suggest that these two areas may be primary recharge zones. This tends to substantiate the conclusion that much of the recharge for the aquifers of the Gefara comes from the runoff of ephemeral streams draining seaward from the Jabal Nafūsah. During periods of heavy rainfall on the Jabal, the runoff is high. The water flows northward from the steep wadis of the Jabal front and disappears into the ground along the wadi channels in the southern Gefara. Generally, very little runoff originating in the Jabal reaches the sea. Recharge from local direct infiltration of rainfall on the southern part of the Gefara also occurs but diminishes southward with decreasing rainfall.

There also may be interformational recharge in Az Zāwiyah area and other areas along the coast, but this has not been evaluated.

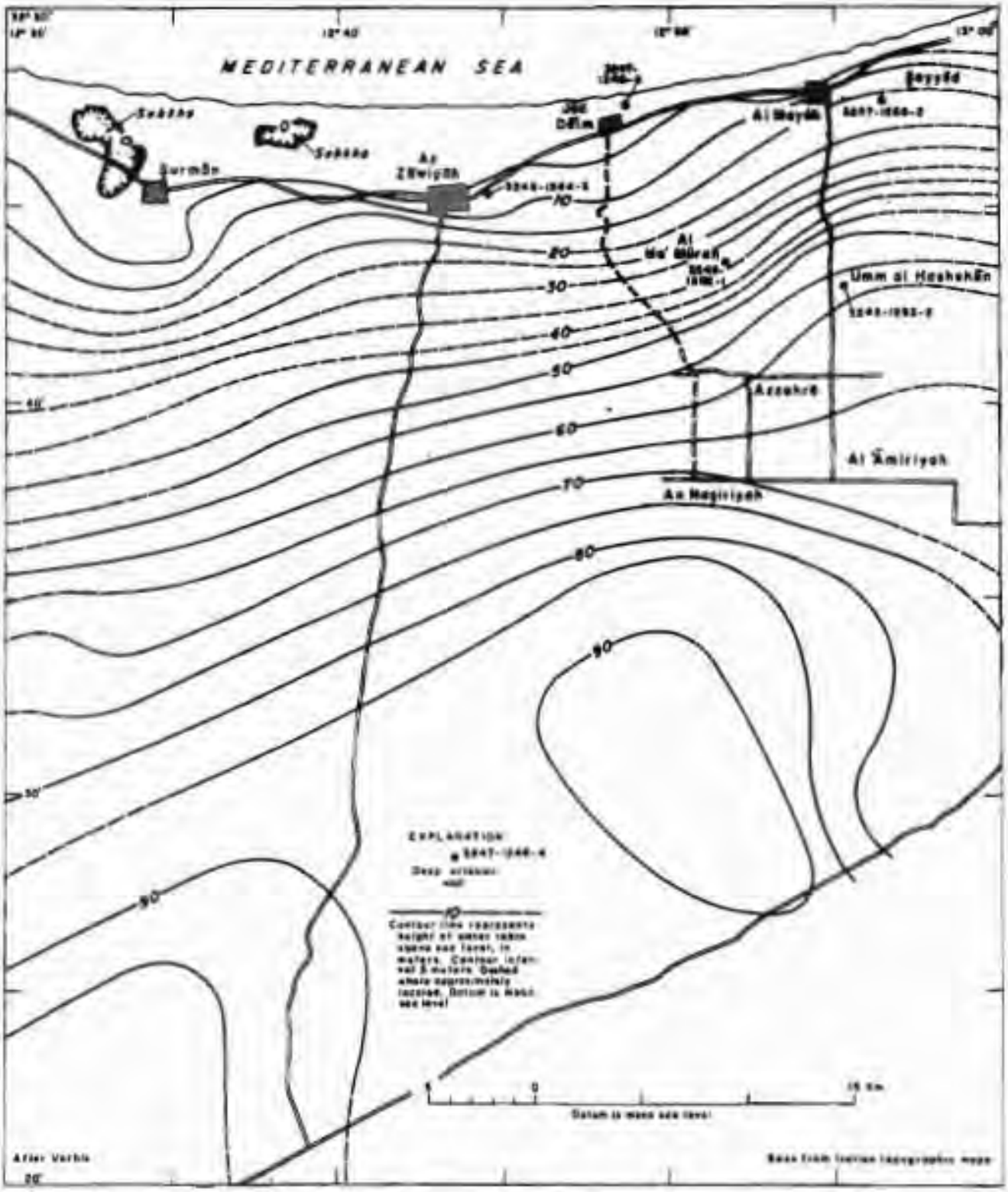

Figure 6.--Map showing configuration of the water table in a part of the central Gefara, 1959-60. (After Vorhis).

Ground-water discharge in Az Zāwiyah area occurs both by natural and artificial means. Water is discharged naturally from ground-water reservoir by submarine outflow, spring flow, and evapotranspiration. Submarine outflow below sea level may form an important part of the natural discharge in Az Zāwiyah area. Discharge by evapotranspiration is substantial near the sea where the water table is near the surface.

Most of the ground-water discharge in Az Zāwiyah area is through wells used for irrigation and domestic supply. The total annual withdrawal from wells in Az Zāwiyah area was computed by estimation methods. The data were supplied in part by the owners and the rest was acquired from other sources. Table 3, lists the reported yield, crops, and number of hectares irrigated. Irrigation requirements given by Casadio (Lewis, p. 55, 1954) and by Fred M. Tileston (1961, written communication) were used to estimate the annual withdrawal from those wells for which the crops and hectares irrigated were available.

In order to obtain a more precise base for estimates of withdrawals from wells, an inventory in Az Zāwiyah area was made in 1958-59 with additional information collected in 1960-61. The inventory of wells, listed in table 3, was not complete, however, but most of the deeper wells of substantial discharge were visited and described. Information received in 1961 from the Mudir of Az Zāwiyah District listed 2,550 additional wells most of which are shallow dug wells.

Using the computed consumption from the inventoried wells plus an estimate for the newer reported wells, a total consumption of 18 million cubic meters per year was derived. Consumptive figures for domestic and stock use were not computed per se, however, the estimated figure for the reported dug wells includes water used for these purposes.

Well yields

The yields of individual wells in Az Zāwiyah area range from about 1 cubic meter per hour (m^3/hr) from an average dalu well to about 60 m^3/hour (250 gpm) in a drilled well. About 150 wells yield from 15 to 60 m^3/hour (67 to 250 gpm). An additional 450 wells may have a pumping capacity of 5 to 10 m^3/hour, however, they are pumped only for short periods of time to irrigate small Arab gardens. There are also about 2,100 dalu-type wells reported in Az Zāwiyah area that individually yield about 1 m^3/hour.

Most of the drilled wells _/ in this area use centrifugal pumps set in an "avampozzo", which is a dry well dug to a point just above the water table. A minimum distance must be maintained between the pump and the dynamic water level, for the maximum effective lift of a centrifugal pump is about 8 meters (28 feet). The amount of water that a well can pump is controlled somewhat by the specific capacity of the well (the yield of the well per unit of drawdown). If the specific capacity of the well decreases or is low, the rate of discharge cannot necessarily be augmented by increasing the pumping rate or size of the pump.

The yields of many of the wells in this area could be increased if they were developed properly by modern water-well construction methods. Most of the drilled wells are not properly cased and screened and rarely are developed properly. Few of the wells completely penetrate the water-bearing formation. It is common practice to case only the upper part of the well and to leave the lower part of the well open. This practice subjects the well to failure by sanding.

_/ A drilled well in this area is one that has been put down mechanically including rotary and motor or hand-powered percussion methods.

Present and potential development

In the past, agricultural development in the report area has been concentrated in the oases of Az Zāwiyah and Al Hārana, near the town of Az Zāwiyah. The shallow water-table aquifer has long been drawn upon by dug wells to irrigate farms in Arab-type gardens of 1 hectare or less, customarily by dalus _/. The use of motor-driven pumps in deeper wells on some of the larger farms has caused water levels to decline below the bottoms of many of the nearby dug wells. Therefore, owners of the dug wells have had to deepen their wells and install small centrifugal pumps. This trend has accelerated since 1959. A further increase in ground-water withdrawals in this area will accelerate the rate of decline of the water table and the consequent encroachment of salt water from the sea. For this reason further development of irrigated agriculture in this area should be discouraged.

_/ A dalu is a skin, or commonly today rubber, bag which is raised from and lowered to water by rope, pulley with a camel or yoke of bullocks for power.

East of Az Zāwiyah, near Jūd Dā'im, the Italians established a large farming community about 1938 where the land surface is generally more than 25 meters above sea level. Most of the wells penetrate and draw from the lower or second aquifer in the Quaternary deposits and are equipped with centrifugal pumps set in "avampozzos". Some new farms have been developed south of Az Zāwiyah and Jūd Dā'im in recent years. The water table in this part of the area is 5 meters or more above sea level and rises gradually to the south (fig. 6). The position of the water table is thus sufficiently high to minimize the immediate hazard of salt-water intrusion from the sea. Therefore, even though the pumping lift increases to the south, new ground-water development preferably should be in this direction.

Additional problems in the southern part of the area are shifting sand that has to be controlled by dune-stabilization methods and the necessity for land leveling or sprinkler irrigation. These problems, moreover, apply to most of the Gefara.

Water levels in the Quaternary aquifer of Az Zāwiyah area as well as in other parts of the Gefara have been declining steadily for the past 10 years or more. Eventually, if these declines continue the quality of the shallow ground water will be affected in Az Zāwiyah area. Serious consideration needs to be given, therefore, to the possibility of utilizing water from deeper artesian water-bearing formations. Water-bearing middle Miocene strata were encountered at depths between 140 and 275 meters in test holes drilled by the OPEL and USAID at points in and near the report area. Water samples from wells at Jūd Dē'im and Al Mayah suggest that this water has quality suitable for irrigation. If these intermediate aquifers yield water of quality and quantity suitable for irrigation in Az Zāwiyah area, they could be tapped to supplement the diminishing shallow-water supplies. Water from the basal Miocene sandstones may also be usable, as the chemical quality of the water may improve southward with proximity to the recharge area.

A government project for land development and resettlement in an area comprising about 55,000 hectares south of Az Zāwiyah is under consideration (1962). The project would be based on irrigation. Large withdrawals from the shallow aquifers of this area are certain to intercept a large part of the underflow that recharges the shallow aquifers of the developed agricultural belt nearer the coast. Too little is known, however, of the deeper aquifers to predict the magnitude of effects of pumping from them. Az Zāwiyah area is adjacent to the proposed project and would probably be involved, in time, in a regional drawdown of water levels that would result from large-scale pumping.

Water levels

Water levels in wells are one of the most important indices used in evaluating the water supply of an area. Changes in water levels resulting from discharge of water are a measure of the overall effect of discharge upon the aquifer. If the static water level fails to return to its original level after cessation of extended pumping, then this fact suggests that the water is being withdrawn faster than it is being replenished. During the period of minimum withdrawal, in the winter months, the water levels are generally at their highest level. It is during this time that static water levels for year to year comparison and evaluation are usually measured.

The general configuration of the water table in Az Zāwiyah area and adjoining areas is shown in figure 6. As indicated, the water table slopes toward the north at an average of about 4 meters per kilometer. The water levels are only slightly above sea level near the shore line. North of the highway between Jūd Dā'im and Az Zāwiyah the water levels are less than 5 meters above sea level, being from 1 to 3 meters above sea level in much of the area. These areas are subject to salt-water encroachment from the sea if the ground-water reservoir is overpumped. South of Az Zāwiyah, the altitude of the water table rises well above sea level, but the slope of the land surface is greater than that of the water table and consequently the depth to water increases southward as shown in figure 7.

Figure 7.--Map showing depth to water in Az Zāwiyah area, 1961.

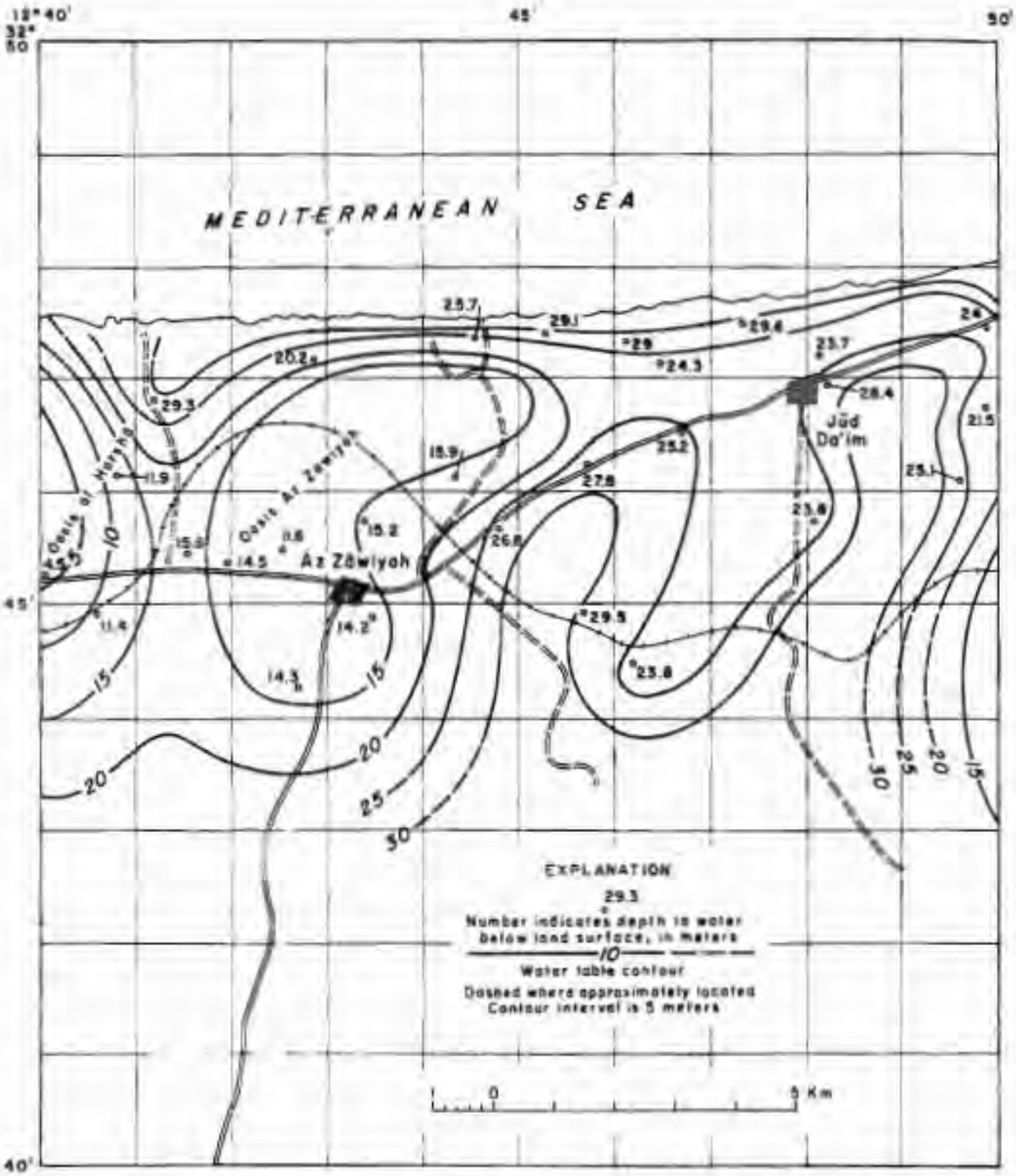

Figure 7.--Map showing depth to water in Az Zāwiyah area, 1961.

The depth to water is of great importance to farmers using ground water for irrigation, for as the depth to water becomes greater the cost of lifting water to the surface increases. If the farmer uses a dalu, he must pump water for a longer period or purchase a pump, or if a pump is already installed, he must use more power which will increase the cost of operation. However, the increase in pumping cost may be partly offset if expansion of the new power system in Tripoli makes electric power available.

North of Az Zāwiyah very few comparative water-level measurements are available. West of Az Zāwiyah measurements made about 1938 and again in 1960-62 show a decline in static water level of about 2.5 to 4.0 meters (fig. 8). Recent measurements made in 1960-62, as in wells 3245-1241-4

Figure 8. Map showing water level declines in Az Zāwiyah area.

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and 5, suggest that the present rate of decline of the water level is about 0.25 to 0.3 meters per year.

If the water levels in the aquifer north of Az Zāwiyah continue to decline at the rate of 0.25 to 3.0 meters per year, wells near the sea may yield salty water within 10 years. A large number of pumps installed in this area can only accelerate the rate of decline of the water level, and consequently, the rate of contamination by sea water would also increase.

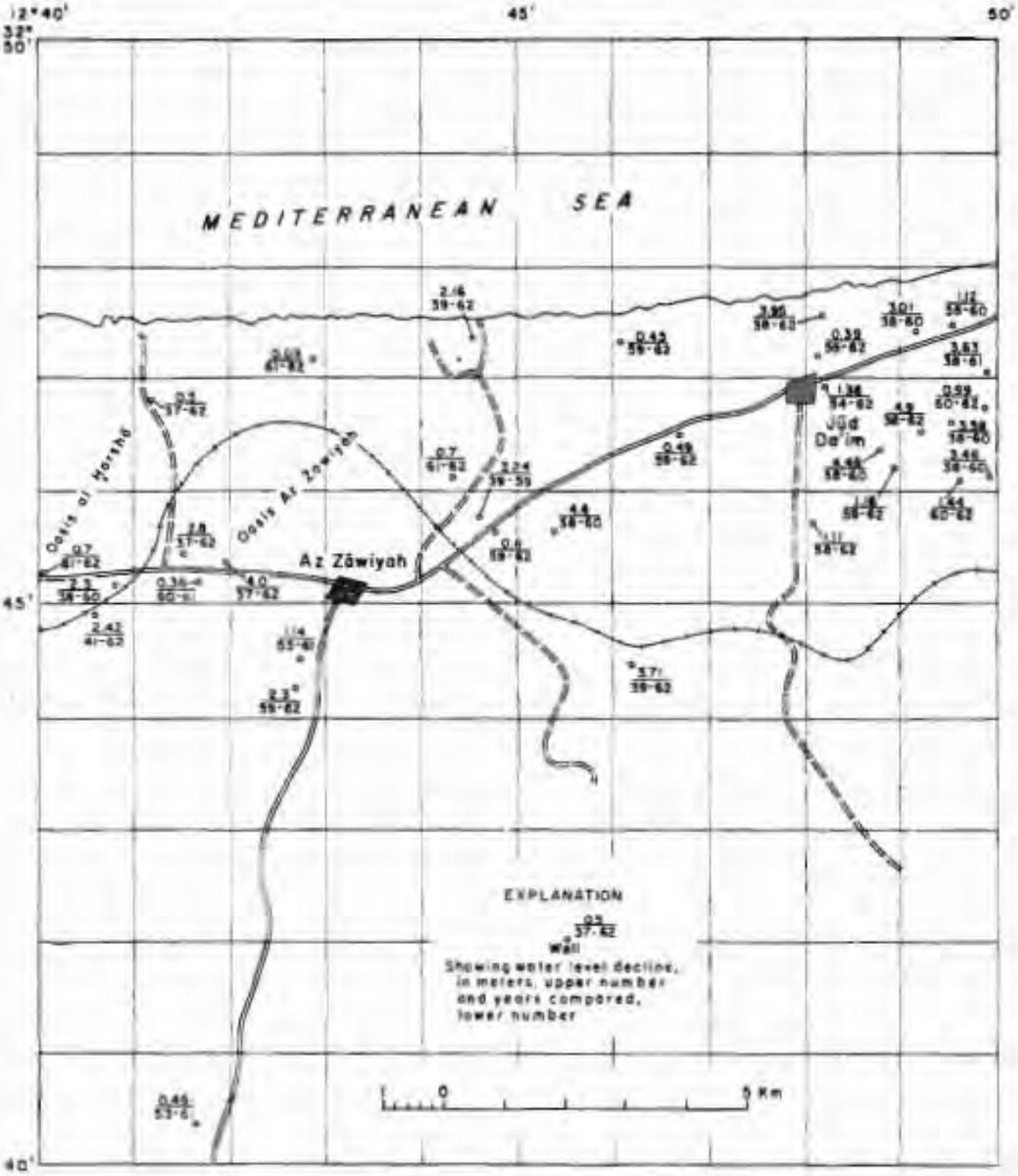

Figure 9.--Map showing water-level declines in Az Zāwiyah area.

In the agricultural developed tract near Jūd Dā'im there are many more comparative water-level measurements (fig. 8). The measurements show a decline in static water level of over 4 meters since 1938. Recent measurements made in 1960-62 indicate that the rate of decline of the water level is currently (1962) about 0.4 meters per year in this tract.

In the vicinity of the sea the fresh water of the ground-water reservoir is in contact with salt water along an interface or zone of diffusion. It is important that the hazard of salt-water contamination from the sea and from the sebkha be recognized and that the relationship between salt water and fresh water in the coastal zone be understood. This relationship, known as the Ghyben-Herzberg principle, results from the fact that the specific gravity of water increases with the amount of dissolved minerals in the water. Fresh water, containing less dissolved minerals, is lighter and will float on salt water. In the coastal zone, the depth to which fresh water occurs below sea level is determined by the head of the fresh ground water above sea level and the difference in specific gravities of the two waters. Under conditions of equilibrium, 1 meter of fresh-water head above sea level will balance approximately 40 meters of fresh water below sea level. This means that if 1 meter of fresh-water head is lowered by pumping or other means, the fresh water-salt water interface will rise approximately 40 meters. To avoid salt-water contamination, substantial withdrawals from wells should not be made adjacent to the coast and water levels in pumping wells should not be depressed below sea level for prolonged periods.

The water table in Az Zāwiyah area, as in other parts of the Gefara, declines during the summer months and recovers during the winter when irrigation is at a minimum. As the water table approaches sea level the danger of salt water encroachment increases. If, during the summer, the water table, because of heavy pumping for irrigation, declines below sea level, the ground-water gradient or slope will be reversed and salty water can then move into the wells (fig. 5) and thus contaminate the water, making it useless for most purposes.

Quality of water

General features

All ground water contains dissolved minerals but the content varies through a wide range. Water from some wells in the Az Zāwiyah area contains as little as 371 parts per million (ppm) of dissolved solids, whereas water from other wells contains as much as 5,877 ppm (table 5). Useful limits of water are difficult to determine, for although waters containing large amounts of dissolved solids are not considered to be potable, they may be useful for other purposes such as livestock or industry. As the mineral content increases, however, the usefulness of the water decreases markedly.

Quality of water determinations are generally expressed in concentrations of individual ions for those substances known to be dissociated in solution. Determinations commonly made in water analyses include cations, anions, and certain more general chemical and physical properties such as acidity (pH), hardness, specific conductance, and dissolved solids. The number of chemical determinations of an analysis is usually governed by the nature of the investigation.

Dissolved solids is a measure of the total quantity of matter carried in solution by the water. Dissolved solids have a direct relationship to the specific conductance (conductivity) of the water and can be easily estimated from the conductivity. Specific conductance, an electrical property, which is used as an index of the total salinity of the water, can be measured easily and accurately in the laboratory and in the field.

Table 5.--Chemical analyses, in parts per million, of water from typical wells in Az Zaviyah area.

Well No.	Depth of Aquifer (meters)	Date of Collection	Temperature (°C.)	Silica (SiO_2)	pH	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Specific conductance (micromhos at 25°C.)	Dissolved solids at 180°C.	Hardness as $CaCO_3$	Sodium absorption Ratio (SAR)
3240-1241-1	33.8	May 26, 1959	-	14	-	58	16	51	5	135	37	64	-	643	443	212	1.56
3240-1241-1	33.8	Aug. 27, 1960	-	12	7.4	54	19	56	6	157	61	66	76	705	426	215	1.52
3243-1242-1	23.9	June 4, 1959	-	14	7.6	54	14	48	3	151	49	76	33	585	371	194	1.09
3243-1242-2	35.4	June 9, 1959	-	-	-	-	-	-	-	-	-	57	-	-	-	-	-
3244-1240-1	-	June 21, 1961	-	-	7.5	48	22	63	5	168	67	92	30	680	404	203	1.93
3244-1242-1	42	June 9, 1959	-	-	-	-	-	-	-	-	-	275	-	-	-	-	-
3244-1242-3	40	June 9, 1959	-	-	-	-	-	-	-	-	-	120	-	-	-	-	-
3244-1243-1	-	June 9, 1959	-	-	-	-	-	-	-	-	-	294	-	-	-	-	-
3244-1245-1	34	June 20, 1959	-	16	7.6	75	31	96	8	194	100	160	-	1111	630	322	2.33
3244-1246-1	40	May 27, 1961	-	12	7.7	62	28	64	3	220	74	96	23	702	472	268	1.69
3245-1241-5	37.9	June 21, 1961	-	-	7.2	39	17	68	5	218	54	39	40	585	386	168	2.30
3245-1242-1	14.3	June 20, 1961	-	-	7.3	39	23	66	5	238	35	72	16	630	382	194	2.02
3245-1243-1	16.3	June 20, 1961	-	-	7.1	310	229	614	33	281	1222	1132	115	5610	4034	1735	6.69
3245-1244-3	572	1940	55	-	-	-	-	-	-	-	-	1920	-	-	-	-	-
3245-1249-4	29.2	Oct. 14, 1957	-	-	-	59	21	-	-	165	97	59	-	772	517	232	1.59
3246-1246-1	13.7	June 20, 1961	-	-	7.4	43	41	93	6	217	57	151	14	980	52[illegible]	27[illegible]	2.[illegible]
3246-1246-1	16	June 20, 1961	-	-	7.5	59	36	114	8	182	112	186	30	1050	634	294	2.[illegible]9
3246-1245-2	49	Aug. 3, 1959	-	-	-	-	-	-	-	-	-	135	-	877	545	260	-
3246-1245-3	51.3	June 15, 1961	-	-	7.9	55	33	86	7	199	71	129	36	910	519	247	2.39
3246-1246-1	39.5	July 30, 1959	-	-	-	-	-	-	-	-	-	115	-	912	492	-	-
3246-1246-2	33.3	June 15, 1961	-	-	7.6	60	31	104	6	192	93	166	38	1070	610	279	2.69
3246-1246-4	-	June 15, 1961	-	-	7.8	57	21	70	5	169	57	116	36	790	458	227	2.02
3246-1246-7	12.9	June 21, 1961	-	-	7.4	58	18	116	8	260	54	147	-	940	546	221	3.39
3246-1246-8	13.5	June 21, 1961	-	-	7.6	45	25	75	6	201	52	116	-	795	481	218	2.20
3246-1249-2	35.7	June 19, 1961	-	-	7.6	60	28	91	5	174	121	126	-	940	489	267	2.42
3246-1249-2	36.3	June 20, 1961	-	-	7.4	106	71	193	11	195	329	326	71	1850	1254	557	3.56
3246-1249-3	35.3	Dec. 3, 1958	-	13	7.7	67	23	79	4	174	102	110	46	877	566	263	2.13
3246-1249-3	35.3	June 19, 1961	-	-	7.7	60	23	86	4	177	99	113	-	820	519	242	2.39
3246-1249-4	65.8	June 19, 1961	-	-	7.6	62	23	90	5	181	100	124	-	880	543	249	2.48
3247-1242-1	36	1957	-	-	-	132.8	72	-	-	193	691	376	-	2340	1765	629	4.34
3247-1246-4	39.3	June 15, 1961	-	-	7.7	56	27	104	6	198	91	148	36	1030	593	254	2.93
3247-1247-6	584	Oct. 9, 1940	44	25	7.1	650	178	1270	-	353	2030	1870	-	7663	6420	2475	11.42
3247-1247-10	46	July 15, 1959	-	17	-	68	26	79	4	183	91	135	44	877	565	276	2.04
3247-1248-2	44	July 21, 1959	-	13	8.3	72	34	104	8	181	117	181	39	1029	688	322	2.54
3247-1248-3	57	June 19, 1961	-	-	7.6	71	29	112	5.9	191	101	190	-	1110	666	297	2.85
3247-1248-4	254	Sept. 29, 1937	-	7	7.4	106	160	469	-	-	731	479	-	2960	2458	890	6.71
3247-1249-3	270	Sept. 24, 1937	-	-	7.4	146	112	-	-	-	965	478	-	-	2486	830	-
3247-1249-4	299	Dec. 21, 1939	-	-	-	-	-	-	-	-	-	723	-	-	-	970	-
3247-1248-4	344	Dec. 21, 1939	-	-	-	-	-	-	-	-	-	1353	-	-	-	1400	-
3247-1249-4	374	Jan. 3, 1940	-	-	-	-	-	-	-	-	-	1518	-	-	-	1560	-
3247-1249-4	426	Jan. 27, 1940	-	-	-	-	-	-	-	-	-	1550	-	-	-	2150	-
3247-1249-4	500	Feb. 10, 1940	-	-	-	-	-	-	-	-	-	1295	-	-	-	2100	-
3247-1248-4	496	Feb. 23, 1940	40	-	-	-	-	-	-	-	2064	1425	-	-	-	-	-
3247-1248-4	496	Apr. 19, 1940	40	8	7.6	628	164	1048	121	111	2262	1447	-	-	5977	2250	9.64
3247-1249-2	36	June 29, 1959	-	12	8	131	70	244	12	217	397	411	40	2223	1473	609	4.31

The cations ordinarily present in significant concentrations in groundwater are calcium, magnesium, sodium, and potassium. Calcium, magnesium and potassium are essential plant foods; however, although sodium is used by many plants it is not as essential as the other nutrients and may be toxic to some plants.

The more important anions in irrigation water include carbonate, bicarbonate, sulfate, chloride and nitrate. Sulfate and nitrate are essential nutrients in optimum concentrations. Chloride in high concentrations is toxic to many plants.

The precipitation of sodium carbonate, resulting from evaporation of irrigation waters containing high bicarbonate ion concentrations, forms a "black alkali" deposit which has a deleterious effect upon soil structures. This condition is not prevalent in the report area because the bicarbonate ion concentrations of the waters are relatively low and the soil has good drainage.

Ground water in the area of study is used principally for domestic supply, irrigation, and livestock. The quality of water for these purposes can vary through a wide range. The preferred upper limits, in parts per million, for total dissolved solids and other common chemical constituents in drinking water as prescribed by the United States Public Health Service (1961) is shown in the table below. Water which contains much higher concentrations, however, is used in many parts of the United States as well as other parts of the world.

	ppm		ppm
Chloride	250	Dissolved solids	1,000
Sulfate	250	Nitrate	44
Magnesium	125	Flouride	1.5

Most of the common constituents in drinking water are objectionable only when the concentrations are high enough to be noticeable to the taste. Because of differences between individuals, objectionable concentrations are difficult to state. Water containing 400-600 ppm chloride is salty to the taste of the average person. People can become accustomed to an objectionable taste if no other source of water is available.

The nitrate content of water from well 3245-1243-1 of 115 ppm is far above the limits suggested by the U.S. Public Health Standards. Because this well is shallow it is possible that the excess nitrate may be the result of surface pollution from fertilizer on irrigated farms or from local cesspool. Detrimental effects from drinking water with high nitrate content have been reported in the United States. High concentrations of nitrates in drinking water are believed to cause methemoglobinemia or cyanosis in infants (Comly, 1945).

The quality limitations in water for livestock are not as stringent as for human consumption. The upper limits of dissolved solid concentrations in stock waters are reported to range from 5,000 to 15,000 ppm. If the animals are accustomed to highly mineralized water, upper limits of 10,000 to 12,000 ppm dissolved solids can be used as shown in the table below.

	ppm		ppm
Poultry	2,860	Cattle (Dairy)	7,150
Pigs	4,290	Cattle (Beef)	10,000
Horses	6,430	Adult Sheep	12,900

For the best growth and development of the animals, however, water of quality better than the upper limits indicated is desirable. It is common belief that camels have higher tolerance for salts than do most animals.

The concentration and composition of dissolved constituents in a water determine its quality for irrigation use. Also quality of water is an important consideration in any appraisal of salinity or alkaline conditions of the soil in an irrigated area. The chemical characteristics of an irrigation water that appear to be most important in determining its quality are: (1) total concentration of soluble salts; (2) relative proportion of sodium to other cations; (3) concentration of boron or other elements that may be toxic; and (4) under some conditions, the bicarbonate concentration as related to the concentration of calcium plus magnesium.

The total concentration of soluble salts in irrigation waters can be adequately expressed for purposes of evaluation and classification in terms of electrical conductivity (specific conductance). The conductivity is useful because it can be readily and precisely determined. In the classification of irrigation water, conductivity is the measure of the salinity hazard.

In determining the salinity hazard, the waters are divided into four groups with respect to conductivity. The limits or dividing points of the classes were determined to be at 250, 750, and 2,250 micromhos/cm (fig. 9). These class limits were selected in accordance with the

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Figure 9.--Diagram for the classification of irrigation waters. (U. S. Salinity Laboratory, 1954).

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relationship between the conductivity of irrigation waters and the saturated extract of the soil. Most waters used for successful irrigation have conductivity values of less than 2,250 micromhos/cm, however, water of higher conductivity can be used in some instances where the soil is well drained and a large percentage of gypsum is present in the soil.

It has been shown that the water-transmission and drainage properties of the soil and the salt tolerance of the crop to be grown are important factors in appraising irrigation waters with respect to total salt concentration.

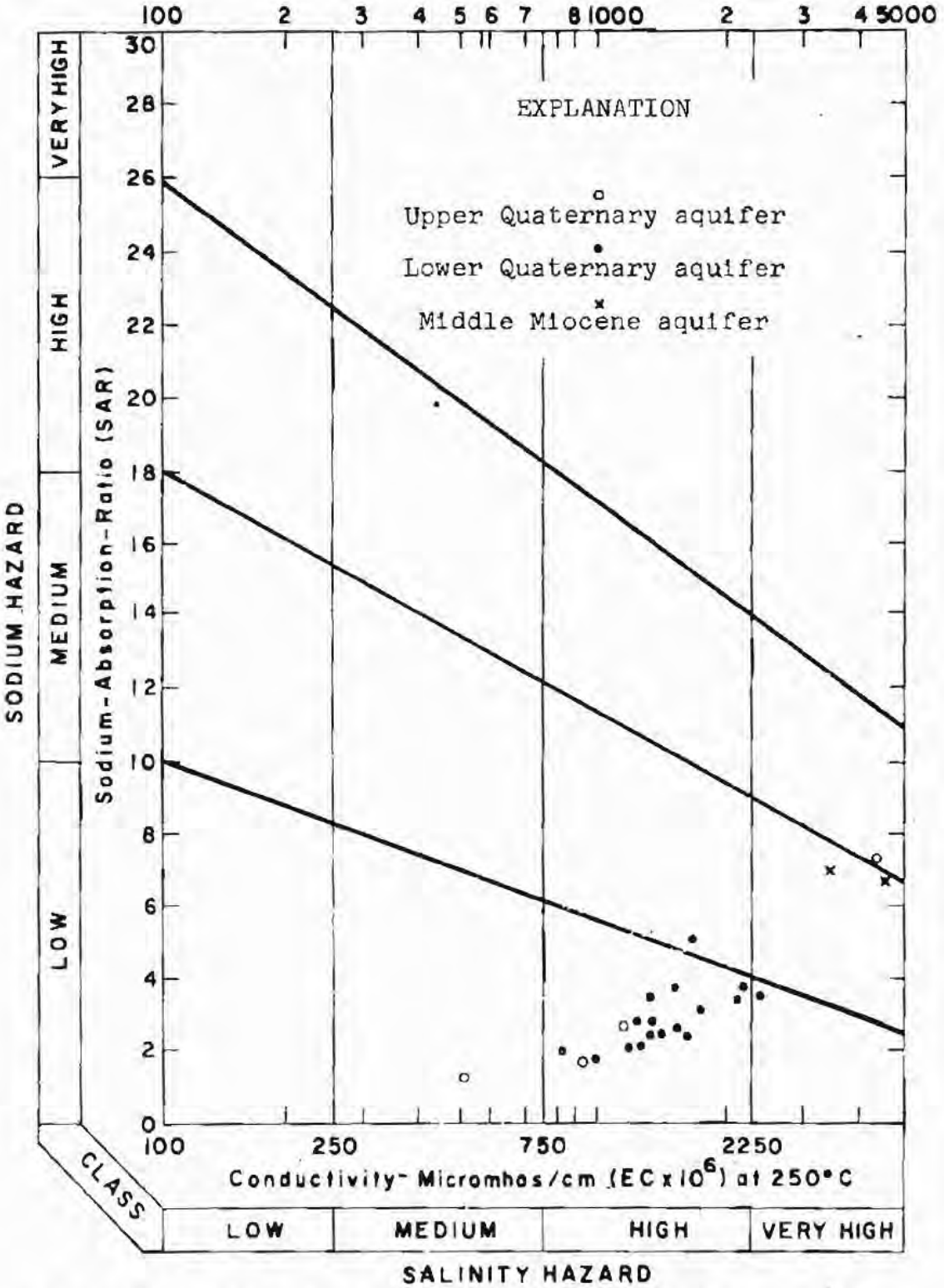

Figure 9.--Diagram for the classification of irrigation waters. (U.S. Salinity Laboratory, 1954).

The soluble inorganic constituents of irrigation waters react with soils as ions. The alkali hazard involved in the use of a water for irrigation is determined by the absolute and relative concentrations of the cations. The sodium-adsorption-ratio (SAR) of a soil solution is related to the adsorption of the sodium by the soil. This ratio is used as an index of the sodium of alkali hazard of the water. The ratio is defined by the empirical equation:

$$SAR = \frac{Na^{++}}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}$$

where sodium (Na^{++}), calcium (Ca^{++}), and magnesium (Mg^{++}) represent the concentrations in milliequivalents per liter of the respective ions.

The significance and interpretation of the quality-class ratings on the diagram for the classification of irrigation waters (fig. 9) are summarized below:

Conductivity

Low-salinity water	- can be used for irrigation with most crops on most soils, with little likelihood that a salinity problem will develop. Some leaching is required, but this occurs under normal irrigation practices except in soils of extremely low permeability.
Medium-salinity water	- can be used if a moderate amount of leaching occurs. Plants with moderate salt tolerance can be grown in most instances without special practices for salinity control.
High-salinity water	- cannot be used on soils with restricted drainage. Even with adequate drainage, special management for salinity control may be required, and plants with good salt tolerance should be selected.
Very-high salinity water	- is not suitable for irrigation under ordinary conditions but may be used occasionally under very special circumstances. The soils must be permeable, drainage must be adequate, irrigation water must be applied in excess to provide considerable leaching, and very salt-tolerant crops should be selected.

The classification of irrigation waters with respect to SAR is based primarily on the effect of exchangeable sodium on the physical condition of the soil. Sodium-sensitive plants may, however, suffer injury as a result of sodium accumulation in plant tissue when exchangeable sodium values are lower than those effective in causing deterioration of the physical condition of the soil.

Low-sodium water	- can be used for irrigation on almost all soils with little danger of the development of harmful levels of exchangeable sodium. However, sodium-sensitive crops, such as stone-fruit trees and avocados, may accumulate injurious concentrations of sodium.
Medium-sodium water	- will present an appreciable sodium hazard in fine textured soils of high cation-exchange-capacity, especially under low-leaching conditions, unless gypsum is present in the soil. This water may be used on coarse-textured or organic soils that have good permeability.
High-sodium water	- may produce harmful levels of exchangeable sodium in most soils and will require special soil management--good drainage, high leaching, and additions or organic matter. Gypsiferous soils may not develop harmful levels of exchangeable sodium from such waters. Chemical amendments may be required for replacement of exchangeable sodium, except that amendments may not be feasible with waters of very high salinity.
Very-high sodium water	- is generally unsatisfactory for irrigation purposes except at low and perhaps medium salinity where the solution of calcium from the soil or use of gypsum or other amendments may make the use of these waters feasible.

Soils may become saline from use of irrigation waters if the drainage is inadequate or water is applied too sparingly. Plant roots take in water but absorb very little salt and evaporation removes the soil water and leaves the salt, consequently an excess amount of salt may accumulate near the base of the root zone and the growth of crops may be curtailed.

This may be controlled by leaching of the soil by the use of excessive irrigation water if the soil drainage is good.

The control of increased exchangeable sodium, or alkali, resulting from irrigation waters high in sodium content may require special management practices. As the proportion of exchangeable sodium increases, the physical and chemical conditions of the soil become detrimental to the growth of plants. This can be prevented at times by the addition of gypsum ($CaSO_4$ $2H_2O$) to the water or to the soil. If the soils are highly calcareous or gypsiferous the irrigation water may dissolve sufficient calcium from the soil to decrease and control the sodium hazard.

Evaluation of water analyses

Most of the chemical analyses of water from Az Zāwiyah area, when plotted on the SAR diagram for classification of irrigation waters (fig. 9), exhibit a very low sodium hazard with a medium to high salinity hazard. This type of water has proved to be satisfactory for irrigation of most crops in this region. All of the analyses of water from wells penetrating the lower or second Quaternary aquifer plot within this classification.

Water from wells 3247-1242-1 and 3247-1249-2 when plotted on the classification diagram fell into the medium sodium hazard and high to very high salinity hazard classification. These wells, which penetrate the upper Quaternary aquifer , are located very close to the sea and may be subject to salt-water contamination. They should be checked in the future for increased salinity.

Chemical analysis of water from well 3245-1243-1 proved the water to be of poor quality when compared with the rest of the water analyzed in Az Zāwiyah area. The water contained over 4,000 ppm of dissolved solids, which is of marginal quality and may cause alkaline soil conditions with prolonged use. This well is situated in the low-lying area north of the town of Az Zāwiyah. Additional analyses of the water in this area should be made to determine the cause or source of the poor quality water and to determine whether salt-water contamination is prevalent.

Water from an aquifer at 254 meters in well 3247-1248-4 (table 5) was classified as medium sodium hazard and very high salinity hazard water. The water was obtained from a middle Miocene aquifer and is believed to be of suitable quality for irrigation of a large number of crops in the sandy, gypsiferous soils of this area if controlled leaching is practiced.

Waters from the deep Italian test wells that penetrated the basal Miocene sands contained over 6,000 ppm of dissolved solids and were considered unsuitable for irrigation. The wells were capped and abandoned.

Most of the waters used in Az Zāwiyah area have a relatively low sodium content; therefore, the danger of toxic effects to plants and permanent damage to the soil structure is small. The higher sodium hazard waters found in some wells may be offset by the high gypsum content that is reported in the soils of Tripolitania. If the amount of gypsum in the soil is not sufficient then additional amounts may be added to the water or the soil.

The soils in Az Zāwiyah area, as in most of the Gefara, are predominantly sandy and thus provide good drainage of the soil. Under these conditions control of salinity can be readily attained by leaching of the soil with additional irrigation water. Some of the crops grown in this area are sensitive to both sodium and salinity. Stone-fruit trees, such as peaches, are reported to be sodium-sensitive. Citrus fruit, almonds and potatoes have a low salinity tolerance, whereas figs, grapes, olives, alfalfa, barley, peanuts, and tomatoes have a moderate to high salinity tolerance. Date palms and tobacco have a high salinity tolerance. Most of the crops grown in this area appear to have a moderate to high tolerance to salinity. The irrigation waters, except in the very shallow wells, do not present problems that cannot be ameliorated by judicious irrigation management and leaching procedures.

Few, if any, wells in this area tap deeper artesian aquifers that might contribute highly mineralized water to the shallow aquifers. Such contamination, however, takes place in many other parts of the Gefara. Near the coast many of the shallow wells penetrating the first aquifer in the upper beds of the Quaternary are reportedly becoming salty. This suggests the possibility of salt-water encroachment from the sea. The increased salinity, however, may be due in some cases to contamination of the shallow ground water by irrigation return from the land surface.

Conclusions and recommendations

Ground water has been used for irrigation in Az Zāwiyah area, probably for many centuries. During much of this stretch of time the ground-water reservoir was probably in an approximate state of equilibrium, that is, the recharge was equal to discharge. Date culture was supplemented by cultivation of figs, olives, peppers, and other crops with low water requirements. With the introduction of crops of large water requirement, such as peanuts, alfalfa, potatoes and tomatoes during the past 25 years the draft on the ground-water reservoir has increased substantially. Installation of power pumps and cultivation of additional land also have materially increased withdrawals. Consequently, water levels have declined and salinity of water has increased at some places.

The chemical quality of the ground water in the area is generally satisfactory for domestic use and irrigation. A few shallow wells show relatively high mineral content, but this is believed due to contamination from irrigation return or possibly from the sea.

Water-level measurements in Az Zāwiyah area show that the water level at some places has declined more than 4 meters between 1938 and 1960. The estimated rate of decline in the oases near Az Zāwiyah is currently about 0.25 to 0.3 meters per year. This decline is general in most of the developed tracts (fig. 8) of the Az Zāwiyah area and if continued, wells near the sea may become salty within 10 years.

Artesian water was encountered in middle Miocene strata at 254 meters in well 3247-1248-4 (OPDL no. 21) at Jūd Dā'im. The quality of the water is believed to be suitable for irrigation of a large number of crops in the sandy, gypsiferous soils of this area with controlled leaching practices. Moderate to large yields of water of acceptable chemical quality also may be obtained in wells tapping these aquifers at depths of 150 to 300 meters

elsewhere in Az Zāwiyah area.

With these conclusions in view the following recommendations are made.

New large withdrawals of water, such as for irrigation or industrial use from the Quaternary aquifers should be restricted to the area south of the towns of Az Zāwiyah and Jūd Dā'im where the altitude of the water table is 5 meters or more above sea level.

Ground-water withdrawals should be kept at a minimum, and further agricultural expansion should be discouraged in the northern part of the area to lessen the danger of contamination from the sea and sebkha.

Representative wells should be selected and periodic observations made of changes in water levels and chemical quality of the water. It may be necessary to drill wells for the specific purpose of observing fluctuations in water levels if suitable unpumped wells cannot be found. Fluctuations of water levels are used to evaluate the effects of pumping and to appraise the long-term availability of water. Data from the observation wells will also show whether the danger of salt-water contamination is increasing and the location of the susceptible areas.

The Miocene aquifers should be drilled and tested to determine if they can produce water of suitable quality and quantity to supplement or replace the diminishing supply in the Quaternary aquifers of the coastal belt.

Several pumping tests should be made to measure the hydraulic characteristics of the various aquifers. Such information, together with data on pumpage and water levels, is necessary for quantitative evaluations and of the ground-water supply of the area. With such data valid estimates of the amount of water taken from storage and of recharge can be made.

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Notes to accompany Table 3.

1/ The spellings of the cabilas and owners' names follow those of the field notes.

2/ Dr, drilled. All drilled wells in this report are put down in dug wells that extend to a short distance above the water table.

3/ Chemical analyses are given in table 5. Conductivity = specific conductance in micromhos at 25°C.

4/ See bottom of page.

5/ Aquifer, upper (1) or lower (2) Quaternary deposits tapped by well.

6/ Irr, irrigation; Dom, Domestic or public supply; S, stock.

Table 1.--Records of typical wells in the Zawiyah area.

WELL NUMBER	LOCATION AND OWNER 1/	ELEVATION ABOVE SEA LEVEL (meters)	DEPTH (meters)	TYPE OF WELL 2/	YEAR CONSTRUCTED	AQUIFER 3/	DEPTH TO WATER BELOW LAND SURFACE (meters)	DATE OF MEASUREMENT	(m^3/ha) EXPECTED YIELD	HECTARES IRRIGATED	CROPS IRRIGATED 4/	USE 5/	ANNUAL DISCHARGE (m^3)	REMARKS 6/
3240-1241-1	Az Zawiyah-Bir Mamour Public Well	50.55	7.97	Dug			5.98 6.45	25 Sept 53 5 Apr 61				Dom. S		Chemical analysis
3240-1241-2	Az Zawiyah (Near Bir Mamour)		45	Dr.	1940				18			Unused		
3243-1242-1	Az Zawiyah-Ulad Sagur Mesaghi Benini	26.897	23.66	Dr.	1950	2	4.53	4 Jan 59	36	6	Al, Fe	Irr.	80,000	Chemical analysis
3243-1242-2	Az Zawiyah-Ulad Ashag Amor Bardisi Ali		38.45	Dr.	1958	2	4.23	9 June 59	40	7	Fe,To,Pp	Irr.	85,000	Chemical analysis.
3243-1243-1	Az Zawiyah-Ulad Mamed Mohamed Geladi		39 +	Dr.		2	10.07	7 Apr 62	25	4	Al	Irr.	45,000	
3243-1243-2	Az Zawiyah-Ulad Mamed Mohamed Geladi		40	Dr.		2				8		Irr.	60,000	
3244-1240-1	Harecia Zawiyah Sheikh Mohamed Yusef	30.07		Dr.	1940	2	9.00 12.44 11.98 11.42	21 Mar 41 31 May 60 21 June 61 28 Mar 62	35	14	Be,Fe,To	Irr.	140,000	Chemical analysis.
3244-1242-1	Az Zawiyah-Ulad Mamed Kalifa Kashem		42	Dr.	1958	2	16.5	9 June 59	38	8	Al,Fe,To	Irr.	94,000	Chemical analysis.
3244-1242-2	Az Zawiyah Ibrahim Ruto Mustaker	27.856	26.89	Dr.	1957	2	11.95 14.29	9 June 59 26 Mar 62	80	18	Ol, Fe	Irr.	126,000	
3244-1242-3	Az Zawiyah Caradine Mirzaro		40	Dr.	1951	2	25	9 June 59	60	6	Al, Fe	Irr.	85,000	Chemical analysis.
3244-1242-4	Az Zawiyah Sheikh Kalifa		17.6	Dug		1	14.20 15.34	25 Sept 53 23 Feb 61				Irr.	3,000	
3244-1243-1	Az Zawiyah-Ulad Ba Sheikh Suagela Kura		29.69	Dr.	1941		12.40	4 June 59		15	Al,Fe,Pp	Irr.	150,000	Chemical analysis.
3244-1243-2	Az Zawiyah Mohamed Ramadan		19.95	Dug		1	13.91 13.62	20 June 61 9 Apr 62		1	Ve	Irr.	3,000	
3244-1245-1	Az Zawiyah-Lot 20 Clemente Balbi	30.651	34	Dr.	1936		29.60	20 Apr 60	60	10	Fe, To	Irr.	110,000	Chemical analysis.

y/ = Pe - Peanuts; Po - Potatoes; Pp - Peppers; Be - Beans; Al - Alfalfa; Ol - Olives; Da - Date Palm; Or - Oranges; On Onions ; Ba - Barley; To - Tomatoes; Co - Corn; Ve - vegetable

Table 3.--Records of typical wells in Az Zāwiyah area cont'd.

WELL NUMBER	1/ LOCATION AND OWNER	ELEVATION ABOVE SEA LEVEL (meters)	DEPTH (meters)	2/ TYPE OF WELL	YEAR CONSTRUCTED	3/ AQUIFER	DEPTH TO WATER BELOW LAND SURFACE (meters)	DATE OF MEASUREMENT	(m^3/hr) REPORTED YIELD	HECTARES IRRIGATED	4/ CROPS IRRIGATED	6/ USE	ANNUAL DISCHARGE (m^3)	3/ REMARKS
3244-1246-1	Az Zawiyah-Lot 20 Nestore Balbi		39.10	Dr.	1939	2	20.10 23.40 23.81	20 Apr 39 20 Apr 60 9 Apr 62	40	5	Be, Pe	irr.	55,000	Chemical analysis
3244-1247-1	Az Zawiyah-Lot 20 Clemente Balbi		37.50	Dr.	1939	2	6.08	29 Apr 39				Unused		
3245-1240-1	Az Zawiyah-Cabila Hadara Hamed Ben Kalife		22.94	Dr.	1958	2	4.39 4.46	20 May 61 26 Mar 62	16			irr.	25,000	
3245-1240-2	Harscia Zawiyah Sheikh Mohamed Yusef		25.90	Dr.	1937	2	8.8 11.10	23 Jan 38 31 May 60	60	11	Pe,Be,Al	irr.	125,000	
3245-1241-2	Harscia Zawiyah Antonio Licari	19.792	32.00	Dr.	1936		12.52 16.30 15.62	4 July 37 31 May 60 26 Mar 62	60	2	Ol, Pe	irr.	25,000	
3245-1241-3	Az Zawiyah-Ulad Sagar Ernesto Paganini		48.40	Dr.	1939	2	16.87 19.75	7 Apr 39 21 May 60	35	10	Ol, Co	irr.	20,000	
3245-1241-4	Az Zawiyah-Ulad Sagar Beshir Ben Salem Shebani		36.60	Dr.	1934	2	10.50 14.06 14.50	6 Apr 39 21 May 60 26 Mar 62	16	2	Or, Ol	irr.	20,000	
3245-1241-5	Az Zawiyah-Ulad Sagar Belgasem Ahmed		37.90	Dr.		2	12.29 15.00 15.36	15 Apr 37 21 May 60 21 June 61	40	12	Pe, Be	irr.	100,000	Chemical analysis.
3245-1242-1	Az Zawiyah-Ulad Sagar Taher Hassen		14.3	Dug		1	11.76 11.64	20 June 61 26 Mar 62		1	Ve	irr.	3,000	Chemical analysis.
3245-1243-1	Az Zawiyah Bir Mresh		16.3	Dug		1	15.95 15.17	20 June 61 26 Mar 62		½	Ve	irr.	2,000	Chemical analysis; Salty water.
3245-1244-1	Az Zawiyah-Lot 20 Clementi Balbi		32.77	Dr.	1937	2	18.40 21.64	18 Aug 39 15 June 59	40		Or, Ol	irr.	80,000	
3245-1244-2	Az Zawiyah-Lot 20 Clemente Balbi	32.788	45.9	Dr.	1938	2	26.20 26.38 26.80	15 June 39 27 Mar 61 9 Apr 62	40			irr.	80,000	

4/ • Pe - Peanuts; Po - Potatoes; Pp - Peppers; Be - Beans; Al - Alfalfa; Ol - Olives; Da - Date Palm; Or - Oranges; On Onions; Ba - Barley; To - Tomatoes; Co - Corn; Ve - Vegetable

Table 1.--Records of typical wells in Az Zāwiyah area cont'd.

WELL NUMBER	LOCATION AND OWNER 1/	ELEVATION ABOVE SEA LEVEL (meters)	DEPTH (meters)	TYPE OF WELL 2/	YEAR CONSTRUCTED	AQUIFER 3/	DEPTH TO WATER BELOW LAND SURFACE (meters)	DATE OF MEASUREMENT	REPORTED YIELD (m^3/hr)	HECTARES IRRIGATED	CROPS IRRIGATED 4/	USE 5/	ANNUAL DISCHARGE (m^3)	REMARKS 3/
3245-1244-3	Az Zawiyah Clemente Balbi	40 ±	528	Dr.	1940				73			Unused		GWDL #66; chemical analysis; Drillers log.
3245-1244-4	Az Zawiyah-Ulad Siag Sheikh Mohamed Ben Yahia		11.1	Dug		1	7.50	4 Aug 53				Irr.	3,000	
3245-1245-1	Az Zawiyah-Lot 20 Clemente Balbi		50.8	Dr.	1935	2	24.40 29.00	18 Aug 37 20 Apr 60	50			Irr.	100,000	Chemical analysis.
3245-1248-1	Jud Dain Ali Serreg	32.280	46.67	Dr.		2	22.72 23.43 23.83	3 Dec 56 27 Mar 61 15 Apr 62	80	19	Pe,Al, Or, Po	Irr.	225,000	
3245-1248-2	Jud Dain Ali Serreg		29.26	Dr.			24.85	3 Dec 58		2	Or	Irr.	19,000	Chemical analysis.
3245-1248-3	Jud Dain-Podere 10 Antonio Masalao		35.20	Dr.	1938		25.82	4 July 59	18	1½	Pe,Or,Ve	Irr.	20,000	
3246-1240-1	Az Zawiyah-Castle Ulad Abu Hamsita Sheikh Ali Nase		13.7	Dug		1	12.02 11.68	20 June 61 7 Apr 62		4	Ve	Irr.	3,000	Chemical analysis.
3246-1241-1	Az Zawiyah Girolamo Ancona		47.35	Dr.	1935	2	23.8 24.90 24.30	8 Sept 39 9 June 60 26 Mar 62	60	9	Pe, Al,	Irr.	100,000	
3246-1244-1	Az Zawiyah Dila Mohamed Ben Ali		16.0	Dug		1	15.15 15.85	20 June 61 1o Apr 62		½	Ve	Irr.	2,500	Chemical analysis.
3246-1245-1	Jud Dain-Podere 45 Mohamed Ben Ali		28.44	Dr.	1937	2	30.78	3 Aug 59	28	4	Pe,Or,Be	Irr.	40,000	
3246-1245-2	Jud Dain-Podere 44 Evariste Secco		48.34	Dr.	1941	2	24.43	3 Aug 59	50	10	Pe,To,Al	Irr.	125,000	
3246-1245-3	Jud Dain-Podere 46 Bartolo Secco		51.80	Dr.	1958	2	27.64	3 Aug 59	46	6	Pe,Or,To	Irr.	72,000	Chemical analysis.
3246-1246-1	Jud Dain-Podere 26 Giovanni Gallizzo		38.50	Dr.	1937	2	24.62	30 July 59	30	6	Pe,Al,Ve	Irr.	72,000	Chemical analysis.
3246-1246-2	Jud Dain-Podere 53 Saadi Gadban		33.8	Dr.	1937		21.42	30 July 59	25	4	Pe, Al	Irr.	50,000	Chemical analysis.

4/: Pe - Peanuts; Po - Potatoes; Pp - Peppers; Be - Beans; Al - Alfalfa; Ol - Olives; Da - Date Palm; Or - Oranges; On Onions ; Ba - Barley; To - Tomatoes; Co - Cotton; Ve - Vegetable

Table 3.--Records of typical wells in Az Zāviyah area cont'd.

WELL NUMBER	LOCATION AND OWNER 1/	ELEVATION ABOVE SEA LEVEL (meters)	DEPTH (meters)	TYPE OF WELL 2/	YEAR CONSTRUCTED	AQUIFER 5/	DEPTH TO WATER BELOW LAND SURFACE (meters)	DATE OF MEASUREMENT	REPORTED YIELD (m^3/hr)	HECTARES IRRIGATED	CROPS IRRIGATED 4/	USE 6/	ANNUAL DISCHARGE (m^3)	REMARKS 3/
3246-1246-3	Jud Daim-Podere 51 Giuseppe Croce			Dr.	1949		30.53	30 July 59	32	2	Pe, Or	irr.	24,000	
3246-1246-4	Jud Daim-Podere 50 Vittorio Bruti			Dr.	1937			3 Aug 59	30	4	Pe,Al,Be	irr.	45,000	Chemical analysis.
3246-1246-5	Jud Da'im, Podere 54 Massimo Pescador	26.43	32.30	Dr	1937	-	22.73 22.77 23.22	14 July 59 27 March 61 11 April 62	22	4	Pe,Ve,Be	irr.	43,000	
3246-1246-6	Jud Da'im, Podere 56 Giuseppe Bordin	-	44.00	Dr.	-	-	33.56	3 August 59	40	10	Pe,Be,To, On	irr.	90,000	
3246-1246-7	Jud Da'im-Gabila Gubail Bir Mgazen	-	12.85	Dug	-	1	12.69	21 June 61	-	-	-	dom,Stk	1,000	Chemical analysis
3246-1246-8	Jud Da'im-Gabila Ishab ben Mariam Ismail Kubar	-	13.5	Dug	-	1	13.37	21 June 61	-	1/2	Ve	irr.	2,000	Chemical analysis
3246-1247-1	Jud Da'im, Podere 21 Salem Mehedded	-	54.86	Dr	1937	2	38.49	30 June 1959	20	3	Pe, Ve	irr.	34,000	
3246-1248-1	Jud Da'im Government	32.0	36.00	Dr	-	-	27.00 28.36	29 November 54 11 April 62	-	-	-	ps	-	
3246-1248-2	Jud Da'im, Podere 35 Ferigo Lino	-	35.75	Dr	1934	-	23.00 30.59	13 July 60 4 July 38	40	7.5	Pe,Be	irr.	75,000	Chemical analysis
3246-1248-3	Jud Da'im, Podere 13 Alfonso Laudeaddio	-	63.09	Dr	1937	2	33.87 35.07	2 July 59 11 May 60	40	4	Pe,Al,Ve	irr.	48,000	
3246-1248-4	Jud Da'im, Podere 14 Serafino Bruni	-	70	Dr	1938	-	31.59 32.75	21 July 59 12 April 62	35	8	Pe,Or,Ve	irr.	93,000	

4/ • Pe - Peanuts; Po - Potatoes; Pp - Peppers; Be - Beans; Al - Alfalfa; Ol - Olives; Da - Date Palm; Or - Oranges; On Onions; Ba - Barley; To - Tomatoes; Co - Corn; Ve - Vegetable

Table 1.--Records of typical wells in Az Zawiyah area and [illegible]

WELL NUMBER	LOCATION AND OWNER 1/	ELEVATION ABOVE SEA LEVEL (meters)	DEPTH (meters)	TYPE OF WELL 2/	YEAR CONSTRUCTED	AQUIFER 3/	DEPTH TO WATER BELOW LAND SURFACE (meters)	DATE OF MEASUREMENT	REPORTED YIELD (m^3/hr)	RECTANGULAR INDICATED	CROPS IRRIGATED 4/	USE 5/	ANNUAL DISCHARGE (m^3)	REMARKS 6/
3246-1249-1	Jud Daim-Podere 17 Giuseppe Zampon		29.17	Dr.	1937	2	18.30 21.46 21.90 22.49	12 July 38 2 July 59 11 May 60 12 Apr 62	30	4½	Pe,Al,Ve	irr.	59,000	
3246-1249-2	Jud Daim-Podere 16 Giovanni Codoro		36.30	Dr.	1937	2	22.02 25.73 25.90	16 July 38 2 July 59 14 July 60	30	6	Pe,Al,Ve	irr.	70,000	Chemical analysis. Salty ?
3246-1249-3	Jud Daim Ali Serrag		30.35	Dr.			19.35	3 Dec 58	70	16	Pe, Or, Be, Al	irr.	160,000	Chemical analysis.
3246-1249-4	Jud Daim-Podere 8 Antonio Ciferno		65.8	Dr.	1938	2	26.70 30.97 29.40	17 July 38 21 July 59 11 May 60	31	5	Pe, Ve	irr.	60,000	Chemical analysis.
3246-1249-5	Jud Daim-Podere 9 Raffaele Otiobuni		36.30	Dr.	1937	2	16.79 20.20 20.25	19 July 38 21 July 59 11 May 60	40	5	Pe,To,Ve	irr.	60,000	
3246-1249-6	Jud Daim-Podere 15 Jad El Affar		57.0	Dr.	1937	2	31.58 35.75 36.48	8 July 38 29 May 60 12 Apr 62	32	4	Pe,Al,Ve	irr.	45,000	
3246-1249-7	Jud Daim-Podere 4 Sebastiano [illegible]		37.7	Dr.	1937	2	23.65 25.09	11 May 60 12 Apr 62	36	3½	Pe,Al,To	irr.	41,000	
3247-1242-1	Az Zawiyah-Cabala Bou Hamaira Mohamed Ben Abdalla Kalifa		36	Dr.	1936	2	20.19 20.72	9 Mar 61 10 Apr 62	25	4	Pe,Al,Be	irr.	49,000	Chemical analysis.
3247-1244-1	Az Zawiyah District		19	Dug		1	11.00	6 Dec 54				irr.	3,000	
3247-1244-2	Az Zawiyah-Marra Bili Angelo Tolino		45	Dr.	1938	2	23.04 24.81 25.30	23 Mar 39 11 June 60 10 Apr 62	36	9	Pe, Al,	irr.	127,000	
3247-1244-3	Az Zawiyah District		13	Dug		1	10.00	6 Dec 54				irr.	3,000	

4/ Pe - Peanuts; Po - Potatoes; Pp - Peppers; Be - Beans; Al - Alfalfa; Ol - Olives; Da - Dam Palm; Or - Oranges; On Onions; Se - Barley; To - Tomatoes; Co - Corn; Ve - Vegetable

Table 3.--Records of typical wells in Az Zāwiyah area cont'd.

WELL NUMBER	LOCATION AND OWNER 1/	ELEVATION ABOVE SEA LEVEL (meters)	DEPTH (meters)	TYPE OF WELL 2/	YEAR CONSTRUCTED	AQUIFER 5/	DEPTH TO WATER BELOW LAND SURFACE (meters)	DATE OF MEASUREMENT	REPORTED YIELD (m^3/hr)	HECTARES IRRIGATED	CROPS IRRIGATED 4/	USE 6/	ANNUAL DISCHARGE (m^3)	REMARKS 3/
3247-1245-1	Az Zawiyah Mohammed Tahher Sumih		54.6	Dr	1938	1	11.0	6 Dec 54	16			Dom., irr.	3,000	
3247-1246-1	Jud Daim-Podere 27 Rhil Ben Ahmed El Gdery		57.6	Dr.	1937	2	28.56 29.01	29 July 59 11 Apr 62	30	4	Pe,Al,Be	Dom., irr.	48,000	
3247-1246-2	Jud Daim-Podere 19 Mohamed Ramadan		56.7	Dr.	1951	2	30.69	29 July 59	25	4	Al, Be, Pe, Or	Dom., irr.	48,000	
3247-1246-3	Jud Daim-Podere 22 Elio Cappelletto		53.7	Dr.	1938	2	29.75	29 July 59	33	6	Pe,Al,Be	irr.	76,000	
3247-1246-4	Jud Daim-Podere 21 Sasy Kubasi		39.3	Dr.	1937	2	22.60	30 July 59	33	10	To, Be, Pe, Co	irr.	115,000	Chemical analysis.
3247-1246-5	Jud Daim-Podere 17 Livio De Bernardo		55.3	Dr.	1937	2	28.44	15 July 59	28	5	Pe, Be, To, Al	irr.	65,000	
3247-1247-1	Jud Daim-Podere 16 Alfredo Gianferrari		32.4	Dr.	1937	2	30.20	15 July 59	31	22	Pe, Al, Co, Be	irr.	72,500	
3247-1247-3	Jud Daim-Podere 13 Eugenio Freschi		29 +	Dr.	1937	2	29.80	15 July 59	25	4	Pe, Al, Or	irr.	50,000	
3247-1247-4	Jud Daim-Podere 10 Mohamed Abdalla Glueds		59.4	Dr.	1937		27.48	15 July 59	35	7	Pe,To,Al	irr.	75,000	
3247-1247-5	Jud Daim-Podere 6 Michele Previtera		53.7	Dr.	1937	2	25.57	15 July 59	30	4	Pe, To	irr.	52,000	
3247-1247-6	Jud Daim OPDL #84		584.0	Dr.	1940		+ 42	1940	270			Unused		Chemical analysis; Drillers log.
3247-1247-7	Jud Daim Ismail Dacrum		42.7	Dr.	1938	2	29.39	15 July 59	27	4½	Pe, Be	irr.	52,000	
3247-1247-8	Jud Daim-Podere 11 Mohamed Salem El Dib		40.6	Dr.	1938	2	20.42	15 July 59	33	5	Pe,To,Al	irr.	65,000	
3247-1247-9	Jud Daim-Podere 12 Ali Ben Omer		53.2	Dr.	1937	2	22.17	14 July 59	27	8	Pe, Al, To, Be	irr.	96,000	
3247-1247-10	Jud Daim-Podere 9 Giuseppe Scarfia		46.5	Dr.	1937	2	19.21	14 July 59	33	5	Pe, To, Al	irr.	64,000	

4/ Pe - Peanuts; Po - Potatoes; Pp - Peppers; Be - Beans; Al - Alfalfa; Ol - Olives; Da - Date Palm; Or - Oranges; On Onions ; Ba - Barley; To - Tomatoes; Co - Corn; Ve - Vegetable

Table 3.- Records of typical wells in As Sāwiyah area cont'd.

WELL NUMBER	LOCATION AND OWNER 1/	ELEVATION ABOVE SEA LEVEL (meters)	DEPTH (meters)	TYPE OF WELL 2/	YEAR CONSTRUCTED	AQUIFER 3/	DEPTH TO WATER BELOW LAND SURFACE (meters)	DATE OF MEASUREMENT	AQUIFER YIELD (m^3/hr)	HECTARES IRRIGATED	CROPS IRRIGATED 4/	USE 5/	ANNUAL DISCHARGE	REMARKS 3/
3247-1247-11	Jud Daim-Podere 61 Mushah El Arwal		50	Dr.	1938	2	25	11 July 59	33	6	Co,Pe, Al, Be	Irr.	70,000	
3247-1247-12	Jud Daim-Podere 61 Giuseppe Cammarata		39	Dr.	1938	2	22.76	11 July 59	20	4½	Pe,To,On	Irr.	52,000	
3247-1247-13	Jud Daim-Podere 58 Mohamed Ben Zieri		45.4	Dr.	1939	2	17.27	14 July 59	33	6.7	Pe,Be,Ve	Irr.	63,000	
3247-1248-1	Jud Daim-Podere 7 Gaspare Cantone		42.5	Dr.	1938	2	22.78	11 July 58	33	5	Pe,Be,Al	Irr.	60,000	
3247-1248-2	Jud Daim-Podere 4 Francesco La Cava		44.1	Dr.	1937	2	27.65	29 July 59	28	3½	Pe, To	Irr.	50,000	Chemical analysis.
3247-1248-3	Jud Daim-Podere 3 Ali Fituri		57.4	Dr.	1936	2	30.02	29 July 59	27	8	Pe,To,Be	Irr.	85,000	Chemical analysis.
3247-1248-4	Jud Daim Sedeg El Tif	38 ±	500	Dr.			30.7					Unused		Chemical analysis; Drillers log; OPDL #21
3247-1248-5	Jud Daim-Podere 63 Bruno Ferreresa	26.583	44.7	Dr.	1938	2	23.38 23.50 23.77	11 July 59 27 Mar 61 11 Apr 62	25	3	Pe, Or, Ol	Irr.	36,000	
3247-1248-6	Jud Daim-Podere 46 Giuseppe Sanin		31.9	Dr.	1935	2			12	3	Pe,Al,Ve	Irr.	37,000	
3247-1248-7	Jud Daim-Podere 58 Antonio Milardo		63.9	Dr.	1937	2	33.97 36.62 37.28 37.91	15 May 58 18 Sept 58 27 Apr 60 14 Apr 62	32	5	Pe, Be, Or, Ve	Irr.	50,000	
3247-1249-1	Jud Daim-Podere 48 Fortunato Mestellaro		52.73	Dr.	1937	2	33.34 36.32 36.35	30 June 58 18 Sept 58 27 Apr 60	25	4	Pe,Or,Ve	Irr.	38,000	
3247-1249-2	Jud Daim-Podere 49 Luigi Zarzan		36.97	Dr.	1936	2	29.38 30.59 30.50	18 May 58 18 Sept 58 20 Apr 60	32	5	Pe,Or,	Irr.	58,000	Chemical analysis.
3247-1249-3	Jud Daim Geronimo Errera		48.6	Dr.	1938	2	23.50	29 June 59	20	5	Pe,Al,Or	Irr.	58,000	

3/ : Pe - Peanuts; Po - Potatoes; Pp - Peppers; Be - Beans; Al - Alfalfa; Of - Olives; Da - Date Palm; Or - Oranges; On Onions ; Be - Barley; To - Tomatoes; Co - Corn; Ve - Vegetable

Table 3.--Records of typical wells in Az Zāwiyah area cont'd.

WELL NUMBER	LOCATION AND OWNER 1/	ELEVATION ABOVE SEA LEVEL (meters)	DEPTH (meters)	TYPE OF WELL 2/	YEAR CONSTRUCTED	AQUIFER 5/	DEPTH TO WATER BELOW LAND SURFACE (meters)	DATE OF MEASUREMENT	REPORTED YIELD (m^3/hr)	HECTARES IRRIGATED	CROPS IRRIGATED 4/	USE 6/	ANNUAL DISCHARGE (m^3)	REMARKS 3/
3247-1249-4	Jud Daim Gerolemo Errera		42.8	Dr.	1930	2	31.11	29 June 59						
3247-1249-5	Jud Daim-Podere 29 Ugo Miccolina		38.71	Dr.	1938	2	30.72 33.85 34.35	11 July 38 1 Oct 60 27 Apr 61	30	4	Pe, Be,	irr.	41,000	

4/ : Pe - Peanuts; Po - Potatoes; Pp - Peppers; Be - Beans; Al - Alfalfa; Ol - Olives; Da - Date Palm; Or - Oranges; On Onions; Ba - Barley; To - Tomatoes; Co - Corn; Ve - Vegetable

Table 4.--Logs of deep drilled wells in Az Zāwiyah area.

(Translated from records of the Italian Administration)

Well 3245-1244-3
(OPDL well no. 86) Near Az Zāwiyah

Lithologic Description	Thickness (meters)	Depth (meters)
Sand	7	7
Sandstone, soft	19	26
Sandstone, soft, with thin beds of sand	3	29
Sandstone, more or less hard	80	109
Clay	209	418
Conglomerate, soft	27	445
Conglomerate, soft	35	480
Limestone, sandy. Water; temp. 28°C.	4	484
Sandstone, hard. Water at 492 m	13	497
Limestone, hard to soft	73	570
No record. Water from 572 to 578 m, flow 73 m^3/hr; temp. 53°C.	8	578

Table 4.--Logs of deep drilled wells in Az Zāwiyah area cont'd.

(Translated from records of the Italian Administration)

(Well 3247-1247-6) Near Jūd Da'im

Lithologic description	Thickness (meters)	Depth (meters)
Sand	1	1
Sandstone with beds of limestone. Water at 28 m; temperature 26.5°C.	23	24
Clay with clayey sand	32	56
Limestone, fractured. Water at 56 m	33	89
Conglomerate, fossiliferous	51	140
Limestone, gray with flaky clay beds	52	192
Sand, fine, quartz	4	196
Limestone, gray with beds of clay	44	240
Clay, plastic	235	475
Conglomerate, white and gray, fossiliferous. Water from 475 to 496 m; flowing; temp. 31°C.	7	482
Clay, sandy, green	4	486
Conglomerate with quartz sand	36	522
Pebbles	1	523
Conglomerate with quartz sand	28	551
Conglomerate, as above with beds of sand	6	557
Conglomerate, as above with clay beds	6	563
Conglomerate with pebbles. Water from 563 to 584 m; static water level 42 m above land surface; flow 270 m^3/hr; temp. 44°C.	7	570
Conglomerate with hard and soft beds	14.6	584.6

Table 4.--Logs of deep drilled wells in Az Zāwiyah area cont'd.

(Translated from records of the Italian Administration)

Well 3247-1248-4
(OPDL well no. 21) Near Jūd Da'im Altitude 28 m.

Lithologic Description	Thickness (meters)	Depth (meters)
Sand, quartz, limy, reddish, with beds of white quartz sandstone. Water at 18.3 m----------	56.3	56.3
Sand, quartz, pink, with large nodules of white quartz sandstone----------	22.7	80
Sand, quartz, pure, white, with strata of pink sandstone----------	5.5	93.5
Sand, quartz, white, with strata of white sandstone----------	7.5	101
Limestone, marly soft, white, weathered--------	5	106
Limestone, cherty, porous, white-yellow--------	6	112
Limestone, powdery, slightly marly, weathered--	5	117
Marl, limy, soft, yellow----------	3	120
Marl, limy, white-grey----------	20	140
Limestone, marly, white-grey. Water from 140 to 147 m; static water level 14.5 m---------	20	160
Marl, clayey, grey----------	13	173
Limestone, marly, grey----------	2	175
Marl, grey----------	15	180
Limestone, marly, sandy, grey----------	10	190
Marl, clayey, grey----------	10	200
Clay, marly, grey-pink-brown-green----------	14	214
Sand, grey-green----------	9	223
Clay, marly, varigated with wood ochre---------	2	225

Table 4.--Logs of deep drilled wells in As Zāwiyah area cont'd.

(Translated from records of the Italian Administration)

Well 3247-1248-4
(OPDL well no. 21) Near Jūd Da'im Altitude 28 m.

Lithologic Description	Thickness (meters)	Depth (meters)
Clay, slightly marly, green----------	8	233
Clay, lightly sandy----------	6	239
Limestone, marly, sandy, white-grey. Water; static water level at land surface----------	2	241
Clay, green----------	9	250
Marl, limy, fossiliferous----------	4	254
Marl, greenish. Water from 254 to 258 m; flow 43 m^3/hr----------	6	260
Limestone, marly, powdery, whitish, sandy near the bottom----------	12	272
Clay, marly, sandy, green----------	1	273
Marl, limy, greenish with dysters----------	3	276
Clay, marly, and clayey fossiliferous marl----	12	288
Clay, dark-green, slightly sandy, with strata of sand. Water from 280 to 303 m; flow 1.8 m^3/hr----------	15	303
Clay, marly, dark-green----------	19	322
Marl, limy, green, fossiliferous----------	3	325
Clay, lightly marly, green----------	19	344
Sand calcareous, hard, with a little clay. Water, salty; flow 1.0 m^3/hr----------	4	348
Marl, limy, slightly sandy, green, fossiliferous----------	11	359

Table 4.--Logs of deep drilled wells in Az Zāwiyah area cont'd.

(Translated from records of the Italian Administration)

Well 3247-1248-4
(OPDL well no. 21) Near Jūd Da'im Altitude 28 m.

Lithologic Description	Thickness (meters)	Depth (meters)
Clay, sandy, grey----------	25	374
Sand calcareous, with pebbles. Water, salty; flow 16.2 m^3/hr----------	5	379
Clay, grey----------	15	394
Clay, very slightly marly, plastic----------	32	426
Sandstone, friable, with calcareous sand. Salty water from 426 to 429 m and 437-444 m; temp. 36°C.----------	18	444
Clay, grey----------	9	453
Clay, dark-grey, with quartz sand----------	3	456
Sandstone, siliceous (quartzite ?) friable----	42	498
Gravel with siliceous sand and fossils. Water from 496 to 500 m; flow 138 m^3/hr; temp. 40°C.----------	2	500

ويعزز هذا التقرير على ان القسم الجنوبي من هذه المنطقة هو مدانفاً جداً لايجاد انماء جديد في المياه الجوفية الفصلة التابعة للرواسب الرباعية . كما يوصي باجراء التنقيب عن طبقة مائية اكثر عمقاً خاصة في الصخور التابعة الى العهدين المايوسيني الاوسط والاسفل . اما الاتجاه نحو المبالغة في تنمية المياه الجوفية الفصلة بالقرب من الشاطئ يوجب ايجاد اماكن لمراقبة مستوى سطح المياه ونوعيتها الكيماوية . ويجب ايضاً اجراء عمليات للسحب التجريبي لتقدير الميزات الهيدروليكية في طبقات المياه .

محصورة الضغط . وتنحدر الطبقة المائية بوجه عام باتجاه شمالي نحو البحر . وتنتج الآبار المحفورة باليد المياه الجوفية الضحلة المتخزنة في الرواسب الرباعية من اعماق تقل عامة عن ١٥ متراً . اما قسم كبير من الآبار المحفورة بآلة الحفر تسحب المياه من الطبقات الرباعية باعماق اكثر انما قليل منها يتجاوز الـ ٦٠ متراً عمقاً . تتراوح نوعية المياه الكيمائية بوجه عام من معتدلة الى حسنة وهي صالحة للاستهلاك الزراعي والمنزلي . ومن الارجح ايضاً ان تتوفر المياه الارتوازية في طبقات المياه العميقة في صخور المايوسيني والميزوزوي اما نوعيتها الكيماوية الضعيفة يمكن ان تمنع استعمال المياه من هذه الطبقات لمعظم الحاجات .

تتخزن المياه في الطبقات الرباعية عن طريق ارتشاح مياه الامطار المحلية ومن المجاري الجوفية المتسربة من الجنوب . ومن الارجح ان تتخزن طبقات الميوسيني العميقة بمياه المجاري الجوفية فقط . وقد يفوق معدل سحب المياه بالضخات الذي يبلغ نحو ١٨ مليون متر مكعب بالسنة ومعدل التغذية الطبيعي معدل كمية المياه التي تتخزن في الطبقات وذلك على الاقل في المناطق العامرة . بناءً على ذلك فان مستوى سطح الماء في المناطق العمرة ينخفض بمعدل حالي (١٩٦٢) يتراوح بين ٢ ، و ٤ ، المتر بالسنة . اما تسرب المياه المالحة فهو وشيك الحدوث بالقرب من البحر .

رمال شبه متحركة يمتد على طول الطرف الجنوبي من المنطقة بقدر ارض مسطحة يبلغ عرضها خمسة كيلومترات ويتخللها كثبان رملية مستقرة . وبسبب وجود الاودية الكثبانية على نطاق واسع ومياه سطحية بكميات قليلة فان مجاري المياه الطبيعية لا تقع على نظام واضح التماسك . تتجمع مياه الامطار في الاحواض الطبيعية بين الكثبان ثم ترشح في داخل الارض . اما حالة الطقس فهي شبه جافة يتميز بقلة وقوع الامطار (٢٥٤ ميليمتر بالسنة في منطقة الزاوية) وشدة التبخر واتساع مدى معدل الحرارة .

تنحصر اكثر المزارع الحالية في هذه المنطقة الزراعية في المنطقة المنبسطة الواقعة بين كثبان الرمل الساحلية والكثبان الابعد منها نحو داخل البلاد . ويتوقف الانماء الزراعي كثيراً على المياه الجوفية لري المزروعات مع انه يجري زرع الاراضي الجافة .

تقع منطقة الزاوية جيولوجياً على تكوين رباعي وميوسيني نحو الشمال يتألف من حجر الكلس والرمل والغرين ويحتمل ان يقع فوق صخور العهد الميزوزوئي . وتخرج طبقة الرمل وحجر الكلس التابعة الى العصر الرباعي نسبة كبيرة من المياه الجوفية المستعملة حالياً في هذه المنطقة .

تقع المياه الجوفية في سائر المنطقة بحالة تتراوح بين غير محصورة الى

موارد المياه الجوفية لمنطقة الزاوية في ولاية طرابلس

المملكة الليبية المتحدة

وضع

وليم أوجلبي ورابرت ڤورس
وهادي علي طرحوني

ملخص

تدل الدراسة التي اقيمت على موارد المياه الجوفية في منطقة الزاوية بولاية طرابلس الى وجود انخفاض في مساوي مياه المنطقة ويبدو ان تلويث الطبقة المائية الناتج عن تسرب المياه المالحة يشكل تهديداً حالياً (١٩٦٢) .

ويشمل هذا التقرير منطقة تبلغ مساحتها نحو ١٩٠ كيلومتر مربع وتقع على الشاطئ الجنوبي من البحر الابيض المتوسط . وتنحدر ارض هذه المنطقة بوجه عام باتجاه شمالي نحو البحر الذي يحده كثبان الرمل الساحلي والمتماسكة . ويقع ما بين الكثبان الساحلية ونطاق من

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موارد المياه الجوفية لمنطقة الزاوية
في ولاية طرابلس
المملكة الليبية المتحدة

وضع

وليم أوجلبي ورابرت ڤورس
من مصلحة المساحة الجيولوجية الأمريكية

وهادي علي طرهوني
من نظارة الزراعة، ولاية طرابلس

[illegible]لس، [illegible]بيا
تشرين الأول (نوفمبر) ١٩٦٢

الولايات المتحدة الأمريكية
وزارة الداخلية
مصلحة المساحة الجيولوجية

موارد المياه الجوفية لمنطقة الزاوية
في ولاية طرابلس
المملكة الليبية المتحدة

أعد هذا التقرير بالتعاون مع الحكومة الليبية
وتحت رعاية بعثة وكالة التنمية الدولية الأمريكية إلى ليبيا

تقرير مفتوح