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# Brief Résumé of Ground-Water Conditions in Libya

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by

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## Introduction

In response to a recent request for information to be forwarded to the Development Council I submit a brief résumé of what is known by the technicians of the Ground Water Geology project regarding the availability of ground water in Libya.

Generally speaking, the information is presented on the basis of Districts (Mutasarifias) in each of the Provinces.

No effort has been made to go into detail although a few illustrative data are given. The compilation of a detailed report would require many uninterrupted man-months of work and should, in fact, be the end product of the project.

A few general statements regarding the occurrence of ground water and some physical principals governing it should be made.

All water that is of economic importance to the people of Libya has originated as precipitation--that is, rain or snow. Some of it has been in the ground for a very long time. For example~~s~~, much of the ground water available in Fezzan fell as rain or snow during wet periods at the time much of Europe was covered by glaciers, 10,000 years and more ago.

The surface of ground water that is unconfined is called the water table. Ground water under water-table conditions does not rise above the level at which it is encountered during the drilling of a well. Generally speaking, the water has entered the ground rather close to where it is found. Usually the water levels respond quickly to precipitation.

Water which is confined is called artesian; it rises above the top of the layer in which it is encountered during drilling. Commonly it has entered the ground at some distance, in rare instances hundreds of kilometers, from where it is withdrawn from wells or springs. Artesian wells flow if the water pressure is sufficiently great, but more commonly the water stands below land surface. For practical purposes recharge to large artesian systems can be ignored in computations of long-term yield.

Because salt water is heavier than fresh water, at many places fresh water floats on salt. The difference in weight between the two fluids is such that rather a delicate balance exists between fresh and salt water. In nature, the interface between them is curved, with the shape depending on the altitude of the fresh water above the sea. Generally speaking, for each meter of fresh water above sea level, there are from 20 to 40 meters of fresh water below sea level and above the salt water. If the surface of the fresh water is drawn down 1 meter by pumping, the upper surface of the salt water below rises between 20 and 40 meters. The relationship may be compared to that between a piece of ice and the water in which it floats. As the piece of ice melts, the top comes closer and closer to the level of the water. At the same time the bottom of the ice rises closer and closer to the level of the water.

Because only one-seventh of the ice rises above the water and six-sevenths are submerged, the bottom rises during melting six times as far as the top declines.

This relationship explains why the danger of salt-water intrusion is so great near the coasts. Even as far inland as Benina, because the water surface is but slightly above sea level, the danger of contamination from below is great if pumping rates are high.

When any well is pumped or allowed to flow, the water level at the well declines. Water can enter a well only by running downhill; therefore a depression in the water surface is a normal, indeed an absolutely necessary, accompaniment of pumping or flow. With cessation of discharge, the water surface tends to return to its former position. It is only when a decline is more or less permanent that alarm over the supply of water is in order.

The significance of declines in water levels varies with circumstances. Decline of the water table is serious because it represents actual dewatering of the aquifer. Decline of the artesian water levels reflects loss in pressure, not dewatering of the aquifer. This is important with regard to pumping costs, but does not mean serious depletion of the supply available. It should be pointed out that for a given quantity of water removed from the ground, the decline in water level is far greater under artesian conditions than under water-table conditions. Where fresh water floats on salt, decline in water level commonly indicates rise of salt water from below.

In no area of Libya do we have all the information that should be collected. New information in any area, especially that regarding deeper aquifers, might warrant important changes in our opinions.

In no area is the ground water an inexhaustible resource. In fact, in most districts, especially the more heavily settled ones, at least locally dangerous situations exist. This is particularly true along the coast where infiltration of saline water may be induced. Not only is this apt to happen with increased withdrawals but it may, and at places already has, happened where water is withdrawn at fairly low rates by the dalu method. This has been true in Tripolitania, for example, near Misurata Marina. Withdrawals for municipal supply by the relatively safe gallery method and from wells of small yield have brought about increasing salinity at such places as Zliten, Sirte and Mrassas.

It should be noted that water of "inferior" or even "highly mineralized" quality has been used successfully in Libya for irrigation of some plants and on some soils. This matter should be investigated so that potential use of water can accurately be estimated.

Near-exhaustion of supply has taken place at Guarsha, where the watering of vegetable gardens by dalus was formerly widely practiced.

At Fonduq ben Gashir the water level is declining about 50 centimeters a year because of heavy pumping for irrigation. In the vicinity of El Guea the artesian head of a flowing well has dropped a reported 15 meters in 7 years.

It is rumored that new intensive irrigation is planned in the Zavia district adjacent to an area that has been recently developed. It is certain that declines of water levels will result. Whether this will be damaging beyond the cost of increased pumping lifts is not yet known.

So far, in the Gefara damages from declines have been chiefly financial, because of increased lifts, deepening of avampozzos, and the like. Probably for many years to come sufficient water will remain in the rocks to provide water for the present discharge and possibly more. However,the costs of lifting the water will increase and cut profits and ultimately put farmers, expecially those operating on a small scale or inefficiently, out of business.

In the Gefara about one-third of the annual discharge apparently comes from storage--conversely only two-thirds is replaced each year. This means that with present pumpage there is no possibility of water levels rising over any long period of time. It is possible that artificial recharge might be accomplished at some places, but it is improbable this would ever amount to anything like a third of the discharge.

The above comments indicate the need for conservation methods and control. Full utilization of water could result in a large decrease in the water required for the present area irrigated. However, the irrigated areas may be extended and additional needs, such as for food processing, will arise. Therefore, it is doubtful if even full utilization would halt the decline in water levels, although it might slow the rate of the decline.

Legal controls to prevent waste and require beneficial use are essential at least to slow the rate of decline. I believe that first simple enabling legislation, which can permit control in areas known to be critical, is urgently required. The details of regulation could be worked out later, if necessary on an area-by-area basis.

Certainly not all available water is now utilized or known. Much water that might be used now escapes to the sea. Studies should be made to permit salvaging of such water. Studies at some places might disclose areas where water could be withdrawn before it becomes so full of mineral matter as to be of little or no use. The bad water also should be studied because of its influence on levels and quality of fresher water and of its possible future use with improvement of demineralization methods.

No special comment has been made regarding water for agricultural processing or other industrial use. All too commonly chemical or physical properties of water are controlling factors for such uses.

I add a plea that the government give very serious consideration to an early decision regarding an organization to make the studies necessary. There seems to be no conception of the effort, and especially the time required, to make such studies. Some of the personnel required must be highly trained. Organization and recruitment of such a body will be slow.

I urge that this résumé together with the general comments made above be translated and widely distributed among government officials at federal and provincial levels as well as to many USOM technicians.

Cyrenaica

Mutasarifia Agedabia

Generally speaking, with the exception of the oases along the Twenty-ninth Parallel, water in the Agedabia Mutasarifia is scarce and of poor chemical quality. Little of it is suitable for human consumption and much is unfit for animals.

In the vicinity of Agedabia most wells are rather shallow and yield water of poor chemical quality. Wells are characterized by large fluctuations of water level (e.g. 2 meters in a year) and of chemical quality. These water-table wells quickly respond to rain by rising water levels and improved quality of water.

At Sidi Sultan a well is known to yield potable water from a depth of 14 meters.

Marsa Brega typifies the northern part of the Mutasarifia in having shallow but small supplies of very poor water.

The vicinity of El Agheila is similar with regard to ground water.

Shallow wells at Zuetina tap water which has fallen as rain in the immediate area. The water is of quality adequate for irrigation, but of limited quantity ~~quality~~. Moderate yields have been obtained from individual wells.

The prospects of obtaining major supplies of water suitable for irrigation in the areas described above are nil.

In the"Twenty-ninth Parallel oases" prospects are much better. Certainly more water is available at each of the oases than is now used. The water loss between well and plant is fantastically high; reduction of this loss would

result in the availability of much more water from the existing wells with only the present amount of labor. Deepening of many wells would make available more water with less pumping lift. A common problem is the high, and probably increasing, mineral content of the water. It is suggested that detailed studies might indicate where water of better quality could be obtained within or near the oases.

At Marada and neighboring parts of the Marada depression artesian wells, some of which flow, and springs supply water for irrigation. The water generally has a high mineral content, much of it being magnesian. Certainly more water could be produced, but any great increase in discharge would cause water levels to decline. This would necessitate the installation of pumps in flowing wells and springs and increase the lifts in non-flowing wells.

In the rest of the Marada muderia a few scattered wells are known, most of which yield highly mineralized water. To the north of Jebel Zelten deep wells yield water of very poor quality from very loose abrasive sand. Pumps last only a few hours, so lift is by compressed air.

At Jalo (El Ergh, El Lebba, and Esh Sherruf) water is available in quantity sufficient for the present cultivation pattern. Large increase in withdrawals should not, however, be made without detailed prior study. The water is rather highly mineralized, containing as much as 2,000 parts per million chloride. Nevertheless, the water is successfully used for irrigation, probably owing to the extremely sandy nature of the soil. The best water in the oasis proper is reported to be in the northern part of Esh Sherruf.

The best water in the general area is found at Bir Buttafal, whence it is transported for sale at El Lebba and El Ergh, some 40 kilometers to the WNW. Water of fair quality (about 500 parts per million chloride) is found at about one meter below the surface.

At Augila irrigation is practiced successfully with rather saline water. The vegetative pattern suggests that water may be available for extension of the cultivated area.

Jikherra is similar to Jalo.

Mutasarifia Benghazi

Prospects for appreciable supplies of fair to good water in this mutasarifia are best in the general area Benghazi-Benina-El Kuefia, a part of the coastal plain. The plain as far south as Giardina offers appreciably poorer prospects, and from there to the Mutasarifia Agedabia still poorer prospects.

Problems are low yields, high pumping lifts and, above all, poor chemical quality of water. It should be borne in mind, however that water of a quality considered elsewhere as unsuitable has been used successfully for irrigation in Libya.

In the vicinity of Benina several wells yield the municipal supply for Benghazi. Pumping lifts are about 75 meters. Investigation by LAJS has disclosed a deeper source of water of fair chemical quality that was previously unknown and has brightened the prospects of the area. Much further work, chiefly by test drilling, should be done between Benina and the sea. Care should be taken not to over-develop the area to the detriment of the municipal supply. The chief problem is salt-water intrusion.

In the Benghazi area infiltration of salt water is a threat, even though most wells are of low yield. Commonly, wells with power pumps yield water of poorer quality than those with dalus. Galleries and wells used during the Italian administration are disused because of increased salinity. Deep testing by the Italians and the United States Army have virtually eliminated hope of deep sources of good water.

At Er Regima the depth to the static water level is expected to be about 300 meters. The present small supply of good water is from springs.

Guarshia was formerly a prosperous garden area. The aquifer there has been largely de-watered and many wells are now dry or seasonally so. Test holes in the area disclosed but little water and that salty. The ditch En Nejila offers a possibility for irrigating a few hectares but its permanence for such high yield is questionable.

The area between Benina and Giardina contains some fair to good water at depths ranging from 36 to 56 meters. The highest yield of good water found by LAJS was only about 14 cubic meters per hour.

Further study in the southern coastal plain area is required. Probably water suitable for small-scale irrigation will be found at a few places, but large supplies are unlikely.

The vicinity of El Kuefia contains water moving through openings in limestone. Some of this water probably can be used for irrigation. The relationship of water there to that at Benina should be determined, lest development at either area be detrimental to the other. A test hole at El Kuefia yielded water of fair quality in moderate amount. A test hole only 4 kilometers away yielded very salty water. Salt-water intrusion would be a serious danger.

Water of fair quality is available at some places between El Kuefia and Tocra. In one test hole good water was replaced by salty water after only a few hours of pumping at a moderate rate. This illustrates the danger of salt-water infiltration everywhere in the coastal plain.

Mutasarifia Barce (El Marj)

The dream of irrigation water for the Barce plain seems shattered by the partly completed test-drilling program of LAJS. Elsewhere in the mutasarifia prospects seem even dimmer, with most areas characterized by great depths to water. Supplies sufficient for more than domestic use and livestock have not been demonstrated in the area by test holes up to 187 meters in depth. The chemical quality of the water is generally good. The area is characterized by cisterns. Several wells together yield an inadequate municipal supply for Barce. The best test hole near the town yielded nearly six cubic meters per hour. The static water level was 31 meters below land surface. Other test holes and wells in the Barce plain indicate that lower yields and higher pumping lifts prevail.

The municipal well at Batta, drilled by LAJS, appears capable of yielding at least 25 cubic meters per hour, but the static water level is 99 meters. Economics preclude the use of this well for irrigation.

At Bayada a test hole in which drilling was interrupted had not reached water at a depth of 142 meters.

Small supplies of water are available in the wadi bottoms at Tekness and Jerdes el Abid.

Between the Jebel Akhdar and the sea, notably at Tolmeita, water of poor quality is yielded to dug wells in small to moderate quantities. The vast cistern, capacity about 6,500 cubic meters, constructed in ancient times, points up the scarceness of good ground water.

Mutasarifia Beida

Italian, British, and LAJS studies show that many springs, a few of large yield, flow an impressive amount of water when considered in aggregate. However, with few exceptions, they are not so situtated as to be usable for irrigation works of any useful size. Two or three springs, such as Ain Shahat, could be utilized, but only at high cost. Wells are scarce and of small yield. The water is generally of good chemical quality.

For opinions on the feasibility of spring utilization in the Jebel Akhdar, it is suggested that personnel of the LAJS irrigation project be contacted.

Mutasarifia Derna

The comments made on the Beida area apply also to most of the Derna Mutasarifia.

A few wells in Wadi bottoms, notably at Gubba, yield small to moderate supplies.

The springs at Ain Mara yield considerably more water than can be applied to irrigable land there. Some surplus of spring water is available at Lathroon. Much spring water is used for municipal and irrigation supply at Derna.

Shallow wells in wadi bottoms yield small to moderate amounts of good water in the vicinities of Martuba and Um er Rezzem.

At Timimi small amount of good to brackish water are available from the wadi bottom. The municipality gets an inadequate supply from a collecting gallery. Careful investigation, including test drilling, might reveal more water available near Timimi. Large, or even moderate, withdrawals, if physically possible, might induce salt-water intrusion.

Mutasarifia Tobruk

High salinity is the outstanding characteristic of ground water in the Tobruk Mutasarifia.

Numerous test holes in the Tobruk-El Adem area have indicated the uselessness of further drilling for sweet water. Few of the wells have yielded large quantities even of poor water and depths are great. Commonly a thin layer of fresh water floats on the more saline water below.

Fair water in small quantity is obtained by galleries in two wadis.

At Mrassas, a collecting gallery supplies part of the domestic water for Tobruk, 40 kilometers to the east. The gallery collects water which falls on a small area of sand dunes by the sea. Some water is probably also received from runoff of a very small area inland.

Six springs at Ain Ghazala yield perhaps 100 cubic meters a day of salty water. Shallow wells yield salty water.

At Bardia small to moderate yields of good water are obtained from wells in the Wadi fill. Test drilling in depressions a few kilometers inland between Bardia and Tobruk might be fruitful.

Mutasarifia Kufra

This vast desert area has at some places rather abundant supplies of water available at shallow depth. Most of these places are inhabited.

Much of the water is under water-table conditions in surficial sand or in the upper layers of sandstone or limestone bedrock. This water comes from infrequent rains.

The Nubian sandstone is at the surface or overlain by a thin mantle of wind-blown or stream sediments over much of the area. At Kufra in particular, some phenomena suggest that the formation may contain artesian water. Deep borings into this formation in Egypt have been completed as wells of high yield, some of which flow.

Each of the inhabited areas could safely yield more water than is now being withdrawn, although water levels would decline somewhat. Other than through conservation measures, additional water could best be obtained by deepening existing wells.

At Kufra, Rebiana, and Bzeima water of from poor to good quality is available from the Nubian sandstone or overlying unconsolidated materials. Depths to water are generally less than 7 meters and commonly less than 5. At Tazerbo most of the wells yield from poorly cemented sand or from limestone.

At several places within a few kilometers of Bir Harrash (about 180 kilometers NW of Kufra) fair water is available at shallow depths. Long-term yields might be sufficient to support irrigated farming on a village scale.

Predesert Area

Little is known about ground water in the predesert area. A test hole was drilled by LAJS a few kilometers S. of Kharruba. Artesian water encountered at about 257 meters below land surface rose to 213 meters. The quality of the water was fair.

Giarabub

Giarabub is notorious for the poor quality of its water, from both shallow and deep wells.

## Fezzan

Broadly speaking, the Fezzan is blessed with the best supplies of ground water in Libya with regard both to quantity and quality. In most oases adequate yields are available from dug wells and in some areas copious supplies of flowing water can be easily obtained. At few places is the available water fully developed. In the Ghat-Berkat area and particularly the Shati Valley flowing water is wasted to a shocking degree.

Water conservation and not new production is the first problem of the Fezzan.

### Mutasarifia Sebha-Ubari

The majority of wells in the mutasarifia obtain their supplies from sandstone beds occurring between the clays and shales of the Nubian formation. The Nubian may contain large quantities of yet undiscovered artesian water. This possibility is suggested by several wells drilled by the LAJS at Sebha and Temmenhint and by a French test hole at Fort Leclerc. The Temmenhint well flows 5 cubic meters per hour, but yields freely ~~by~~ to pumping.

The water table in the Sebha area ranges from very near land surface to as much as 12 meters below ground level. Most of the water from this source is suitable for agriculture, but in some limited areas is salty. Normally, the yield from water-table wells is not great.

In the El Bawanis area and at Semnu and Zliten most of the water is withdrawn from the water table. The yields are generally limited, but sufficient for dalus and small pumps. The quality of water is suitable for agriculture. A LAJS test hole at Semnu was dry at 80 meters.

The water-table aquifer supplies almost all of the ground water to wells in the Wadi Ajal. Locally it may be salty, but generally the quality is

within limits acceptable for agricultural use. Only a few wells penetrate to bedrock and the majority are within the wadi fill. The French drilled a 350-meter test hole near Ubari that penetrated several aquifers; none were under sufficient pressure to flow at land surface. A 36-meter LAJS well at Goddua yielded 20 cubic meters per hour; static water level was 2.6 meters below land surface.

Mutasarifia El Shati

From Eskghida at the eastern end of the Shati Valley to Idri 150 kilometers to the west, flowing artesian water is encountered in Devonian sandstones at depths ranging from 60 to 130 meters. Artesian water flows also from numerous springs along the entire valley. The Italians initiated the drilling of flowing wells. This work was continued by the French and today is carried on by private contractors and the LAJS. All wells drilled so far yield water of chemical quality suitable for agriculture although it is usually high in iron and sulphate.

A very serious conservation problem exists in the Wadi Shati. Except for the wells constructed by the Italians, the French and more recently by the LAJS and a few enlightened private individuals, none are built to allow the restriction of flow. Consequently, great quantities of water go to waste down the wadis and subsequently also salt up the soil. Due to indiscriminate waste of water, the pressure head is being dissipated to no useful purpose and already several springs and wells have ceased to flow.

At and near Idri ground water ascends through natural openings and forms springs. However, at El Hatia, to the north, a 150-meter deep test hole drilled by the French failed to flow.

In spite of the abundance of flowing water in the Shati, many farmers utilize water from water-table aquifers. This water is generally of suitable quality for agriculture though in some places restricted as to quantity.

Mutasarifia Murzuk

In general, all of the exploited ground water in this area occurs within the Nubian formation or the thin blanket of sediment that overlies the Nubian. With the exception of the flowing wells at Traghen, the springs at Tmessa and the deep test holes in the Hofra-Cherguya Valley, all of the ground water is obtained from the water table.

Beds of Tournasian and Devonian age crop out southeast of Gatrun on the northwestern flank of the Tibesti mountains. This is the same sequence of sediments that occurs north of the Shati Valley; accordingly, the possibility exists that flowing water would also occur in this area. However, it is doubtful if the expense of exploring this possibility would be justified at this time.

In the Hofra-Cherguya Valley deep test holes have been drilled from Agar Atha in the west to Umm el Araneb to the east by the French and LAJS. With the exception of the three flowing wells at Traghen, all have static levels below land surface and require pumping to exploit their generally large yields.

At Tmessa large springs supply some water utilized for agriculture.

Traghen is situated in a depression; consequently, wells drilled there by the French were sufficiently low to intersect the piezometric surface and flow. Lack of drainage away from the farmed areas supplied by these wells has brought about salting of the soil from constant evaporation of irrigation water. The water is of good quality, but even low chloride water will form salt deposits where there is lack of drainage.

Dug water-table wells only a few meters deep yield most of the ground water in this mutasarifia. Water from this shallow source is generally of good quality.

Mutasarifia El Jufra

Muderia Hon

Hon lies in a geological unit that is bounded by faults (breaks in the rock). These faults control the occurrence and movement of ground water within the unit and tend to isolate it hydrologically.

At Hon the Italians drilled a well to a depth of 446 meters. This well yields highly mineralized hot water from a major artesian aquifer below a depth of 400 meters. Higher water-bearing strata of low yield or even poorer water were cased off. The highly mineralized water can be used for irrigation only because of the good drainability of the local soil.

Wells drawing from the water table yield small supplies of poor quality.

Muderia Uaddan

Uaddan lies in the same fault-bounded unit as Hon. The same artesian aquifer probably underlies Uaddan, but at still greater depth. Very valuable crops would be required to justify the cost of drilling so deep a well on the basis of irrigation.

The quality of shallow water in the area is almost everywhere very poor. Notable is the present-day use of fogarras (horizontal wells, similar to Persian ~~Q~~ganats).

Muderia Zella

Water-table wells, a few fogarras, and a few springs supply the oasis of Zella. The quality of the water is fair and yields are generally low to modera Thick clay beds cropping out in the lower part of the area indicate the very low probability of finding useful quantities by deep testing.

At El Fogaha seven springs issuing from fractured limestone supply most of the water. Clay underlying the limestone prevents the downward escape of the water.

Drilling by oil companies indicates low probability of successful wells in the Jebel Uaddan.

Muderia Socna

Socna lies to the west of the structure containing Hon and Uaddan.

Ain Hammam is a spring of large yield. Its hot mineralized water suggests either that the spring is associated with the volcanism that formed the basaltic Jebel Soda to the west or with the nearby faults that bound the Hon structure.

Dug wells in the area are generally shallow and of low yield, although some wells tapping a second stratum have higher yields.

Bir Waska, in a Wadi 45 kilometers southwest of Socna, yields excellent water. Probably an igneous dike crossing the wadi acts as a dam concentrating the water.

Mutasarifia Ghat-Berkat

Ground-water conditions in the two oases are the same. Shallow artesian wells may be drilled or dug into Cambro-Ordovician sandstone that underlies the area. Flows may be obtained at many places. Artesian springs discharge from the sandstones.

Generally speaking the water is not fully utilized. Rehabilitation of wells and springs is an important means of increasing water production.

Muderia Serdeles-El Aweinat

Serdeles lies in a large valley on the western edge of the Murzuk basin. A well drilled by the French at Serdeles to a depth of 105 meters flows from Devonian sandstones. This and other flowing wells drilled by an oil company demonstrates the similarity of conditions to those in the Wadi Shati. Flowing wells are obtainable in a large area of the valley both north and south of Serdeles.

Elsewhere in this area shallow dug wells supply a small amount of water to irrigation, herds, and caravans.

Mutasarifia Tripoli

The boundaries of the area considered here are those of Cederstrom's "Tripoli Quadrangle." 1/ Present (1960) demands seem to be doing little damage to the supply right at the city. However, there is a rumor that one or more of the municipal wells has become salty. In a few years the loss of recharge by flood waters of the Wadi Megenin owing to control by the LAJS - constructed dams will probably become apparent.

Cederstrom estimated the discharge, chiefly for irrigation, of what he calls the "Tripoli Quadrangle" (which includes parts of Suk el Giuma and Zavia districts and the Gasr ben Gashir-Suani area) to be about 103,000,000 cubic meters per year. This does not take into account a few deep flowing wells which yield water of inferior quality and which, in some cases, are actually damaging the water in shallow aquifers.

In the Fonduq ben Gashir area water levels have declined as much as 15 meters since 1930. Lesser, but significant, declines have occurred elsewhere. Continuing observations demonstrate no lessening of the downward trend.

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1/ Cederstrom, D.J. and Bertaiola,Mario, 1960, Ground-Water Resources of the Tripoli Area, Libya: U.S. Geological Survey Open-file report.

Mutasarifia Suk el Giuma

Quality problems are becoming more acute, especially near Suk el Giuma proper. They have also been noted farther east along the coastal highway where contamination of wells of large yield has become serious after only a few years of use. Contamination has been from sebkhas, from artesian wells, and from the sea at various places.

Very little is known of the district away from the coast.

Mutasarifia Garian

The water supply for the Garian district is obtained from springs and scattered wells of low yield. Much of the water for the town of Garian is obtained from small springs, among them Ain Turk with an average flow of about 100 cubic meters per day and Ain Tobi which flows about 15 cubic meters per day. The water is collected in reservoirs or galleries and pumped to the town. A well drilled by LAJS at Ain Turk to a depth of 140 meters yielded 1.7 cubic meters per hour; the static water level was 131 meters. Another LAJS test hole was dry at a depth of 293 meters. An Italian test at Ain Tobi encountered no water in a total depth of more than 200 meters. Prospects for additional large supplies are poor.

Mutasarifia Mizda

Very little is known about the water in this district. Depths to water in several existing wells in the area are from 30 to 50 meters. Some dry holes have been drilled as deep as 370 meters. Yields are reported to be low. The two chemical analyses on file show a high sulfate content. Best prospects for water are in wadi fill. It is improbable that water in quantity and quality for irrigation will be found.

One native reports that the paucity of wells is due more to sparse population than to scarcity of water.

Mutasarifia Jefren

Springs and scattered wells of low yield, chiefly near the jebel scarp or in wadis, supply water in the mutasarifia. Shallow wells and springs at Rumia, where a system of galleries collects water for the town of Jefren, are the most notable concentration of water sources in the area. Two test holes drilled south of the town encountered very little water; two other holes were dry.

The largest spring in the Zintan area yields about 2 cubic meters per hour. Springs and wells supply water for the town, livestock, and caravans, yielding no surplus for irrigation.

Mutasarifia Nalut

Scattered springs and wells, chiefly in wadi bottoms, yield sparsely for people, livestock, and very limited agriculture. Nalut and Cabao have rather meager supplies. The yield of the Cabao well, for example, is about 4 cubic meters per hour. In the vicinity of Tiji and Josh some springs provide water for small irrigated areas. Highly mineralized water characterizes the Gefara. For example, at El Uotia salty water (7,000 parts per million chloride) was encountered at about 20 meters below land surface. Further prospecting along the base of the Jebel might be rewarding.

Mutasarifia Ghadames

Near Ghadames artesian water is available at depths ranging from 147 to 370 meters. The flow of water is reported to be diminishing, but the cause is not known. Cleaning and deepening of wells have increased yields in the past. Artesian flow is available also at Derj. No estimate is available of the potential yield of artesian water. Shallow wells and springs of low but consistent yield are found near Ghadames, Sinauen, and Derj.

Mutasarifia Zavia

The Zavia Mutasarifia probably has the greatest underdeveloped groundwater potential of Tripolitania.

Tests suggest that although lifts would be high, the area south and west of ~~Zavia~~ Azizia, at least as far west as Bir Ghnem, might yield large quantities of water suitable for irrigation. Test drilling is necessary to prove or disprove this.

Increasing development of pump irrigation near the coast must be carefully watched because of possible salt-water intrusion.

Water levels in the irrigated districts as far south as Bianchi have dropped through the years. The rocks in Bianchi are less permeable than those around Fonduq ben Gashir, which affects the yields of individual wells and ultimately that of the area as water levels decline over large areas.

Westward from Bir Ghnem the quality of the water in the Gefara becomes poorer.

Some water-level declines and deterioration of chemical quality of water have been noted along the coast. Near the coast in this district some of the deeper waters seem of better quality than those to the east or west.

Of several strongly flowing artesian wells more than 500 meters deep, the deepest 872 meters, is at Agelat; the water from these wells is highly mineralized.

Mutasarifia Zuara

In sand dunes along the coast, small quantities of water of fair quality are available. The combined yield of the collecting gallery and well fields at Zuara is about 100 cubic meters per day. Inland from the sebkhas at some places a small yield has been obtained of fair water that is floating on water of very poor quality. Near the jebel water of very poor quality has been reported. A well at Zuara reported to be 502 meters deep flows strongly at land surface, yielding highly mineralized water that is objectionably sulfurous.

Mutasarifia Homs

The almost continuous oasis between Homs and Zliten yields water of fair quality at shallow depth. The danger of salt-water intrusion is great. It is not known whether the quality is now worsening, but the introduction of power pumps would most certainly induce salt water from the sea.

Water in the vicinity of Kussabat is very scarce and at depths of as much as 200 meters.

The El Guea area is unusual in the availability of artesian water of useful quality at moderate depth. Several flowing wells are used for irrigating. These conditions apply to a restricted area with undescribed geologic boundaries. The artesian head is declining rapidly and at an increasing rate with the drilling of new wells. Additional pumps will soon be required. A decline in pressure of 15 meters in 7 years is reported.

Mutasarifia Zliten

In the area of palm cultivation rather salty water is available, generally at depths of 6 to 8 meters. Most of the water is unsuitable for municipal supply. The most likely source for municipal supply is the Wadi Kaam area where water with a minimum of 700 parts per million chloride has been found. Whether much more water can be developed at Wadi Kaam remains to be seen.

The water is reported as becoming more salty with time. Some abandonment of irrigated farms may have resulted from this. The installation of pumps which would produce more drawdown than do the dalus now used would hasten the rate of salt-water intrusion.

Test drilling to much greater depths than reached by existing wells, or on the higher ground (in other words, tapping older rocks), might yield better water. However, three deep wells (184, 356, and 650 meters) at Nahima yielded highly mineralized water.

Mutasarifia Misurata

The situation in the Misurata district is similar to that around Zliten. Near Misurata Marina irrigation has been stopped at places because of increasing salinity of the water. It is reported that at one farm a power pump drew in salt water the first year it was used. For a municipal supply it was necessary to go to older rocks several kilometers inland from Misurata.

Deep wells have yielded water of quality marginal to unsuitable for irrigation at Gioda and Crispi. At some places artesian pressure is sufficient for deep wells to flow. Water pressures have decreased considerably with time.

Nothing is known of the situation inland except that a few wells have been dug in wadi fills.

Mutasarifia Sirte

Sweet water is in very short supply in the Sirte district even for livestock and people. Some fairly good water is available from dunes along the coast. Wadi fill yields some sweet water at Bu Hadi. The Bu Hadi area is presently being examined by LAJS. The probability of finding any appreciable supply of water suitable for irrigation seems very slight.

Mutasarifia Tarhuna

The Italian municipal well at Tarhuna was reported to yield 150 cubic meters per hour of water of good chemical quality. The well was 42 meters deep and had a static water level of 17 meters below land surface. Near Tarhuna a spring maintains a flow for a few kilometers near the headwaters of the Wadi Ramla.

Mutasarifia Beni Ulid

Near Beni Ulid a well 418 meters deep yielded water unfit for human consumption. The static water level was more than 100 meters below land surface. In the Wadi Soffegin and its tributaries, as at Bir Schmech, it is apparently possible to obtain water at 85 meters or less. The wadi should be explored by test drilling.