CYPRUS.

REPORT

UPON THE

WATER SUPPLY OF CYPRUS

BY

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Report upon the Water Supply of Cyprus.

The following contents are based upon observations made during several weeks study of the water problem of Cyprus by Mr. A. Beeby Thompson in April, 1926.

GEOLOGY.

Aided by the valuable geological and other reports by Bellamy and Jukes Brown, Cullis and Edge, Clement Reid and Ellis, it was an easy matter to acquaint oneself with the main geological features. The conclusions drawn conformed with the views of others in considering that the conditions are unfavourable for obtaining important natural (artesian) flows of water, although in several regions there are chances of obtaining moderate artesian flows. One can positively affirm that there is no justification for the popular belief that water reaches Cyprus from the mainland to the north, and geological considerations discourage the hopes of obtaining fresh water from deep wells. There are, however, large areas where moderate and regular supplies of water might be obtained by drilling.

As in other countries the ancients, whether Greek, Roman or Turkish, confined their energies to the development of surface and shallow water sources, and the most obvious and promising areas of Cyprus have been skilfully and successfully developed by works that must command the admiration of all hydrologists.

The so called chains of wells are merely headings driven along water bearing beds on a gradient that will ensure a regular flow. The conduits are usually constructed along river valleys where the surface gradient is steeper than that necessary to induce a flow, so that they become progressively deeper in an upstream direction. About 70 ft. appears to be the limit of depth, as shafts have to be sunk at close intervals to ensure ventilation and assist in the removal of debris during construction. This form of work has been rendered possible by the consolidated nature of the strata which hold up without support.

Briefly summarised the geology can be described as consisting of six main groups of rocks. The oldest sedimentaries are the Trypanian limestones (Cretaceous and Eocene) succeeded unconformably by a group of sandy shales and fine-grained sandstones locally termed the Kythrean (Oligocene). These are conformably overlain by the Idalian group of chalky marls and limestones, which in turn are covered unconformably by shelly limestones and calcareous sands and sandstones of Pliocene age. Large intrusions of igneous rocks occurred in Idalian (Miocene) times and have left their influence on the sedementaries as zones of disturbances and metamorphism. The attached table of geological succession is based on Bellamy and Jukes Brown's works.

GEOLOGICAL SEQUENCE, CYPRUS,
(After Bellamy and Jukes Brown).

	Pleistocene 50 ft. + −	Alluvial deposits, sands, conglomerates and gravels as river terraces, raised beaches, valley fills, etc.
		Unconformity.
	Pliocene 100/200 ft.	Shelly limestones, calcareous sands, grits, sandstones. All compacted or lightly cemented and horizontal.
		Unconformity.
Miocene.	Idalian 1,400 ft.	Upper 1,000 ft. white chalks, shelly and chalky limestones and marly chalks with flint bends.
		Lower 400 ft. grey and yellowish marls with beds of gypsum.
Oligocene.		*Supposed to be conformable, but uncertain.*
	Kythrean 1,500 ft.?	Highly folded often overfolded group of felspatchic sands and sandstones and sandy shales. Well-laminated beds generally exhibiting appearance of salts on surface with marine sandstones at base and conglomerates near faulted junction with Trypanian.
Eocene.		*Unconformity and fault.*
		Upper 1,100 ft. greenish shales and limestone bands.
	Trypanian 6,000 ft.?	Lower grey massive crystalline limestones with dolomites and marbles near intrusions of igneous rocks. Mainly vertical, sometimes showing laminations.
Cretaceous.		Igneous rocks which have intruded into or influenced all beds to Idalian.

The Trypanian limestones are mainly developed in the northern mountain range of Cyprus where they extend for 90 miles and reach an altitude averaging 2,000 ft. Most of the central plain is probably underlain by Kythrean strata, but these beds are mainly exposed on the southern flanks of the northern range. The greatest exposure of the Idalian is on the south of the Troödos range in Paphos, but outcrops are widely distributed elsewhere where the Pliocene beds have been denuded.

Pleistocene beds occur as valley deposits, river terraces and raised beach formations in restricted areas.

As sourses of water supply the various groups of strata present contrasts of note. The faulted and fractured crystalline limestone of the Trypanian series are often dolomitic and cavernous and they yield large springs of water at points where conditions favour its outflow. The Kythrean spring is a notable example where fissures in the limestone are associated with cavernous conditions and water travels laterally for long distances before a suitable exit is found at a point where a steep gully has reached the limestone. Water follows tortuous courses in these limestones and it is difficult to predict results at any point.

The Kythrean group of unfossiliferous, well-laminated rocks, is not hopeful as a usuful source of water, although sands and sandstones are plentifully distributed in the series between beds of clay and sandy clay. All the sands are, however, compact and are obviously not suitable reservoirs for water, moreover they are charged with soluble salts which render the contained water saline. The outcropping sands almost everywhere show efflorescences of salts which transmit objectionable properties to the waters. To complicate matters further, this distinctive series of beds has been severely flexured and contorted so that dips are very steep sometimes actually vertical and often reversed. This high angle of dip enables a single stratum to be traced for long distances on the surface. Some of the very massive sandstones might yield water of useful quality where the conditions favoured the leaching out of salts, and there may be fractured zones in the vicinity of faults where fair quality water could be obtained under certain favourable circumstances.

The Idalian series presents more encouraging prospects for water, especially the upper portion of shelly and coralline limestones. It is, however, likely that the middle portion of chalks with flint bands will prove productive of water. Everywhere this series of rocks is characterised by clearly defined bedding planes, and the series is sufficiently flexured and fractured to admit water into any porous strata outcropping at low angles over wide stretches of country. This series is only badly distorted in the vicinity of igneous intrusions and in the mountains; over large areas it is nearly horizontal. Extensive beds of gypsum are found in the lower part of the Idalian which consists mainly of greenish marls unsuitable for water supplies.

One final series of sediments constitutes a very important source of water supply, namely the Pliocene formation which, in many areas, unconformably covers all the older series of rocks. Sometimes it constitutes a mere veneer above the older strata: at other times it reaches a thickness of several hundred feet, but it is always horizontal, having escaped the severe earth movements which caused the sharp flexuring of the older beds. This series consists of calcareous grits and sands and sandy limestones which readily absorb water, and at various depths free-yielding aquifers may be struck under structural conditions that ensure moderate and regular supplies of good quality water.

Mention should be made of the igneous rocks which occupy a large section of the Island south of the western Mesaoria and form the source of the main water supplies of the Island. As the gathering ground for considerable masses of snow which may last into the month of May, they have a great and valuable influence on the country's water problem. Rising to an altitude of over 6,400 ft. at Troödos they cause a large area of heavy precipitation in the form of rain or snow. Only one small section on the Kyrenia range has a rainfall equal to that of some 200 sq. miles round Troödos.

All the rivers of Cyprus originate in the southern massif of igneous rocks, and the decomposed surfaces and valley deposits constitute an important check on surface drainage. In this connection the value of forest growth in retaining water and encouraging rain cannot be too strongly stressed. The activities of the Forest Department in planting and protecting vegetation on the mountain slopes cannot fail to benefit the whole Island.

There may be places where the decomposed surface of the igneous rocks would yield usuful quantities of water if penetrated to some depth, but their essentially basic character is against their value as containers of economic supplies of water.

THE DEVELOPMENT OF SUB-SOIL WATER.

Clement Reid has appropriately and correctly described the drainage of water in Cyprus as essentially superficial. The outstanding exception is the northern range of upturned limestones and dolomites which absorb large volumes of water, much of which descends deeply and, eventually escapes to the sea without emerging at the surface. If its value justified the cost much water could doubtless be obtained by tunnelling into the limestones at the head of some of the many gullies that stretch to the plain. Even boring at strategic points might locate important fissure systems that could be usefully developed. More detailed studies would be necessary before embarking on any project of this nature.

In the past all water investigations were based on impounding schemes or the search for artesian supplies, and scanty consideration was apparently given to the utilization of subsoil water which did not rise to the surface unaided. Perhaps the striking success of chains-of-wells had distracted attention from sources calling for mechanical means of lifting water, although the importance of bullock-driven bucket pumps must have been noted. Possibly, in addition, the difficulty of making farming profitable under the old and simple conditions unfavourably influenced initiative. Certainly the increasing demands for semi-tropical produce at highly attractive prices has stimulated interest and may make it possible to employ methods that were formerly too costly.

That water can be mechanically raised with profit has been amply demonstrated at Famagusta where over 1,000 windmills, besides oil engines are being used to lift water for orange, pomegranate and potato cultivation. Elsewhere similar efforts have been made with varying results, but the success of forced cultivation aided by fertilisers is now appreciated by agriculturalists, and it is clear that wherever the soil is light and fertile and water exists the process will be extended.

Subsoil water of acceptable quality and quantity is not everywhere available, but there are large areas where useful supplies can be developed. Many native efforts have been only partially successful as the inhabitants have not the means of proceeding deeper than the first aquifer struck, usually within 100 ft. of the surface, and this often fails in the dry season. In many cases it is possible by drilling to tap water-yielding strata at a depth which will ensure regular supplies throughout the whole year. Only by drilling can such deeper supplies be cheaply and expeditiously reached, and although the rate of yield of a borehole may be relatively small it has many advantages over open shafts.

On the attached plan, areas showing promise of development by drilled wells are indicated. Paphos has been quite neglected as it presents few difficulties and did not come within the scope of this investigation. The divisions shown on the attached map are purely approximate as the detailed geology has not been worked out, and often little is known about the thickness of certain beds. The Island could be roughly divided into four classes :—

(*a*). Areas where little or nothing can be gained by drilling.
(*b*). Areas where the prospects are very poor.
(*c*). Areas where the prospects are favourable.
(*d*). Areas where test drilling is justified.

It must be understood that within the areas marked there are strips where it would be futile to drill, but without a detailed geological map these could not be separately indicated. For instance, one would avoid areas where the lower Idalian (gypseous) series outcropped or the vicinity of igneous intrusions, or where the Kythrean beds were only covered by a thin deposit of Pliocene beds. In many cases drilling alone will disclose the information which would condemn or commend a locality. Apart from mere thickness there is also the factor of lateral variation of beds to consider, for strata of the same age may change in general character within short distances.

As development with wells progresses favourable areas and regions where economic supplies do not exist will be determined. In order to fix these limits it will be necessary to sink prospect wells even at the risk of failure, for often underground conditions can only be explored by drilling. It was many times stated that the inhabitants are prepared to pay for successful bores, but they want some guarantee of results before accepting liability. It does not appear an altogether unreasonable obligation for the Government to assume. Under qualified advice absolute failures will probably be somewhat rare, but there are certain areas where exploration with its attendant risks should be faced as in the event of success the benefits to all would be considerable.

The little drilling undertaken in the past has been considered very disappointing mainly because the search was confined to flowing (artesian) water. A number of wells have been drilled and good quality water has evidently been struck in some, but the boreholes were never tested for quantity with a pump, and practically nothing is known as to their capacity. In some cases salt water was struck at depth, and in others only a very small flow resulted when the bore was tapped at some depth below the water level by a tunnel. As already explained the conditions are not favourable for deep drilling, for unless large quantities of water can enter outcropping rocks at an elevation and flush out the aquifers by sheer force of pressure no important circulation is likely to occur much below sea level. Unless the Trypanian dolomitic limestones are struck it is improbable that the potable waters will be found at a depth much below sea level, solely on account of this apparent absence of extensive reservoir rocks.

It is unlikely that boreholes will give large yields except in some few favourable locations where gravels or porous limestones are struck, but they can be relied upon to give regular and consistent yields for long periods. Proof is afforded of their capacity to yield freely by the bore at the Famagusta Stud farm, where 4,000 gals. hourly were pumped with a depression of only 6 ft. in a well 170 ft. deep. Sir Wm. Willcoks also drilled outside the Famagusta city gate and struck abundance of water at no great depth, but well below sea level. More recently a well drilled at Salamis has struck what appears to be a fair supply of water at about 60 ft. near sea level.

In most cases it will be found an advantage to use a few lengths of perforated casing to cover the aquifer, otherwise the free inlet of water around and under the shoe may be restricted. At times some advantage might be obtained by employing screens which hold back sands having a tendency to run in and choke the bore. This is not, however, likely to be a common phenomenon and need not be provided for in the early stages of the work.

AVAILABLE SOURCES OF WATER SUPPLY.

When considering the quantity of water available, rainfall must be kept in mind. On some of the plateaux the beds would be fed only by rainfall which might be as low as 10 inches in a year. Allowing for evaporation and other losses the amount percolating into the earth may not exceed 3 inches or say about 300 tons per acre. Intensive and wide spread pumping would soon exhaust a year's admission, but fortunately only restricted areas would require water, and in many cases the land receives a greater watering by irrigation and floods than is derived by rainfall. This particularly applies to the western end of the Messaoria where for months the Pliocene beds are heavily watered by canals leading from the many rivers which debauch into the plains from the Troödos range. As the rainfall is low in this district, especially around Morphou, the influence of such irrigation must be important.

In the eastern Messaoria large areas of the flood belt are covered by impervious silts which prevent free percolation into the lower beds, but even here irrigation is practised and in the rainy season water is conveyed outside the silty zone and over strata more receptive for water. The fact that water is successfully impounded in large reservoirs at several places in the eastern Messaoria illustrates the impermeable character of the valley floors. Many perennial springs discharge their water into the plains from the northern range. At Kythrea one spring flows 3,000,000 gals. daily the whole year, and at Dikomo another gives 1,000,000 gals. daily, a collective supply of about 5,500,000 cub. metres a year, consequently these two springs alone furnish a supply of water equal to a rainfall of 12 inches over 5,000 acres, or say about 8 square miles. All this water is derived from country where no cultivation is practised, and certainly an appreciable proportion finds its way into porous strata for subsoil circulation, especially as the water is widely spread by an irrigation system covering some 2,000 acres in the plain.

Unquestionably the run off is rapid in Cyprus owing to the steep gradient of the river courses and the frequently heavy rate of precipitation, especially from narrow and high mountain ranges, but the springs of the northern limestone range and the snows of Troödos are a balancing factor of great importance, and one that will be materially aided by systematic afforestation.

A system which might be worth practising in Cyprus, and one followed in some countries where somewhat similar conditions prevail, is to dam up water courses in the mountains at selected spots with rough masonry, thus forming barriers against which the wash of the stream collects and over which the water cascades. These barriers hold up water and delay its progress downstream and also afford strips of alluvium for plantations. In the re-afforestation of the Bulgarian mountains this procedure was widely and successfully followed.

Whilst in no way desiring to disparage the value of the " chains-of-wells " which are such a feature of Cyprus water supply, we do wish to draw attention to the unavoidable waste of water occasioned by such works. It is suggested that this policy should be extended with extreme caution, for although it affords a cheap and easy way of securing large supplies of water it enables subsoil water to be drained off at a dangerous rate and may reduce the value of land from which the tunnels are fed. The flows in these underground conduits cannot be controlled, and in the rainy season when the ground supplies are being naturally replenished and subsoil water is not needed for the crops, the percolating water is drained off at an enormous rate and wasted, thus prematurely depressing the water table over wide areas. In the past there was probably enough water and to spare for both town population and farms, but with the growth of population and the advance of intensive cultivation the matter assumes a quite different aspect.

The evils of the conduit system are best seen in the Pedias valley south-west of Nicosia, where a wide expanse of rich, heavily-cultivated valley alluvium and pervious beds are literally honeycombed with conduits conducting water to the city of Nicosia, to mills and to irrigated areas. During April 1926, when unusual rains had rendered the employment of much additional water unnecessary, conduits could be seen flowing full and performing little useful purpose. One such aqueduct employed for running a saw mill was flowing at a rate in excess of 3,000,000 gals. daily, whereas later in the year when the water was really wanted the supply would fall off to perhaps one-fourth or one-fifth of this quantity.

Curious water rights of ancient origin may preclude the enforcement of any useful restrictions, but the numerous abuses engendered by the system may themselves cause a demand from the people for some method of control. The original chains-of-wells supplying Nicosia were apparently owned by the Mosques, and surplus water was permitted to be taken by the city. At various times individuals were allowed to make connections for taking "measures" of water on condition that they added new wells to the system. Thus perpetual right to "Massouras" were secured by families in the city. What a "Massoura" constituted is not clear as it represented an aperture which would naturally give different yields, under different heads, but it is taken at approximately 1.2 gallons a minute.

The system of tunnelling in a region where no exclusive water rights were recognised or reserved, and land is much cut up into small holdings very naturally led to abuses, as likewise the town system. Many connections have been made surreptitiously in the city, and in one length of aqueduct examined at Larnaca no less than 40 unauthorised connections were discovered. Wells are sunk indiscriminately about the valley where the aqueducts run, and the yield of the latter can be greatly reduced without any injuction being obtained. Near the city where the main aqueducts rise above the water table of the district, the seepage losses are very large, and it is regular practice to sink shafts as near as possible to the conduits to drain off the water and increase the seepage by locally lowering the zone of saturation.

It is clear that the system in use is far from satisfactory, for the construction of the conduits does not prevent admission of earthy matter and ingrowth of tree roots which need cleaning out at regular intervals. The seepage losses are not in themselves a disadvantage as the water is not wasted, but used to replenish ground near the city where it is being recovered by numerous private installations upon which reliance is placed for garden watering and sometimes drinking and culinary purposes: ground too, which but for the chains-of-wells might have continued to yield bounteously to a much later period of the year, if not the whole year. The conduits are, however, wasteful in draining ground water off at a rate far in excess of that which would result from normal subsoil movement, and at a time too when the water should be carefully conserved for the dry season supply.

In a modified form the chain-of-wells system might be deprived of its objectionable features by using an iron pipe from the point where the tunnels rise above the lowest water table of the district. Water could then be released by valves as and when required and the beds thereby allowed to fill up when it was not required, but without some measure of control over the supply the waste might be just as great as at present.

If dry-season crops are to be encouraged and intensive cultivation stimulated, all sources of fresh water will have to be carefully preserved and utilised to compensate for the rapid run off. This raises the question of pumping on a large scale as distinct from the local development of gardening water. Two areas call for especial notice in this direction viz., the fresh water lake near Famagusta and the Morphou Bay area.

The fresh water lake near Famagusta is a low lying basin which receives the drainage of a moderate area over the Peninsula south of Famagusta. It has been a source of considerable annoyance to the district, as, in the hot season, it became a favourite breeding place for mosquitoes which, it is said, are blown by a prevailing night wind to Famagusta. A canal has been made to the sea but the fall is insufficient to drain off the water rapidly, and some 75,000,000 to 110,000,000 gals. of water have to be pumped out annually. This water is all wasted, and at comparatively little additional expense it could be lifted to an altitude which would enable a fair area of good land to be watered in the immediate vicinity. The quantity which could be stored and held for use when the rains ceased would be sufficient to give four 3-inch waterings to about 300 to 400 acres of ground, where flax, cotton, potatoes or fruit could be grown.

Enormous quantities of water reach Morphou Bay where many of the chief rivers of the Island discharge their waters. Observations in this area encourage the belief that large areas of porous alluvial material underlie part of this belt at near sea level thus providing a huge reserve of water which could be utilised when all surface water had disappeared. Rich lands with fairly gentle slope seawards and at no great elevation could be watered if such supplies exist and the results will repay the cost of pumping. A series of experimental bores along the coastal strip and in the river valleys would quickly settle the question of supplies, but for studying irrigation problems it would be necessary both at Morphou Bay and at Famagusta to have contoured plans prepared covering any promising ground indicated by the Agricultural Department. Meter contour intervals would probably suffice for the initial work.

Another lake at Sotira where much water accumulates in the rains is worth studying with the same object in mind. It is now drained by a canal and tunnel which conducts the water into the sea to the north-west near Paralimni. It was not examined from this point of view, but its reputation as a salt lake is probably due solely to capillary evaporation in the dry season after the disappearance of the water.

An area justifying prospecting for subsoil water in quantity lies north of Salamis along the coastal strip. Great quantities of flood water reach the sea in this region and if the underlying strata are very porous large yields of water might be obtained from wells striking a suitable stratum. A few bores sunk along this strip in low lying country would quickly settle the matter.

Naturally these pumping schemes depend upon the value of water to the farmer. It is certain that means could be found to combat the malarial menace at the Famagusta lake if profitable use could be made of the water. Such a lake can be no worse than the reservoirs already in existence. Some approximate costs are given on page 15 and they show that water could be raised to the hundred foot contour above sea level for something in the neighbourhood of 0.12 penny per ton or say one shilling per acre inch of water. Four 3-inch waterings would, therefore, cost about 12*s.* per acre. The above calculations are based on using units of 20,000 to 40,000 gallons per hour capacity say 65,000 to 130,000 tons monthly, equivalent to 650 to 1,300 acre inches of water. The larger sized pump would drain the Famagusta lake in from three to four months. The costs are based on oil engines of the high-compression type.

As labour and stone is cheap in Cyprus, it might come cheaper to raise the water by stages into aqueducts at different levels rather than pipe the water to a distance.

The inhabitants of Cyprus have little to learn in the matter of harnessing surface water. Wherever water courses show visible water it is led away in canals over the lands at suitable spots where the gradient admits. At Lefka where the river bed is very deep the irrigation channels are carried for miles along the steep sides for orange cultivation. Some of the larger river valleys of the western Messaoria should, however, be prospected by the drill, for it is possible that areas may be found where the gravels are very thick and extensive when it might be possible to syphon water under control from boreholes through pipes to suitable lands downstream. This saves the cost of pumping water on to land, whilst avoiding the waste occasioned by chains-of-wells.

DRILLING FOR WATER.

A certain amount of drilling has been done in the past with somewhat antiquated machinery; consequently, the results cannot be considered satisfactory. Although the wells were carried down to considerable depths, the time occupied was far too long. The following deep wells have been drilled :—

Location.	Feet above sea level.	Depth of well.	Level water from surface. feet.	Dia. of casing.	Remarks.
Nicosia, (Printing Office)	508.	761	15	6 in.	Jan., 1905 to Jan., 1907. Water salt (2.4%) but abundant.
Nicosia, (Prison)	475.5	875	15		Jan., 1907 to Mar., 1909. Fresh water at 312 ft. but only clay below.
Prastion, (Mesaoria)	63.	1100		8 in. to 273 ft. 6 in. to 955 ft.	All white and blue clays after 75 ft.
Prastion, (Morphou 1.)	82.	950	16	8 in. to 335 ft. 6 in. to 790 ft.	Nov., 1912 to Dec., 1914. Water to 375 ft.
Prastion, (Morphou 2.)	57.	1100		?	After 250ft. all blue clay under conglomerates, etc. with water.
Koutrapha 1	4 ?.	480	60	?	Crystalline limestones 205 ft. to 350 ft. with water rising to 60 ft. from surface. Marls below, coarse gravels above.
Koutrapha 2	485.	605	Flow	?	At 504 ft. salt water (0.5%) rose to 3 ft. 10 in. above surface and flow at surface 4 gals. in 38 mins. year later 4 gals. in 20 secs. Igneous rocks at 470 ft.
Famagusta	33.	250	37	8 in.	Water in sands and limestone yield 4,000 gals. per hour.

About two years seem to have been taken to drill 700 to 1,000 ft. whereas a suitable modern rig would do the same work in one to three months.

The original Isler rig is a heavy cumbersome plant expensive to run and only allowing of painfully slow progress. It is only an expense and burden and should be scrapped at once. Composed as it is of a number of separate parts its dismantling, transport and re-erection is a long and costly operation. Fuel consumption is very high which, when considered with the time element is a serious item.

The recently purchased Canadian Spudding rig is an improvement on the Isler plant, but it is unsuitable for the local conditions. In the first place the Spudding mechanism is clumsy entailing excessive rate of wear and tear besides limiting the size of the hole. It is driven by an underpowered oil engine which, in addition to giving trouble, slows down the rate of drilling. A 4-inch bailer could only be raised at an absurdly slow speed, even when the engine was struggling. Only one speed of running is possible, a very serious hindrance to efficient drilling, and only one size of bit is included. Quick and efficient drilling can only be accomplished with a big reserve of power and provision to drill a number of sizes of holes to suit varied conditions. For instance, it may be necessary at times to exclude upper objectionable or unwanted water, or to shut off strata which are impeding deeper drilling by caving or swelling. Where large volumes of water are needed fairly large diameter wells are necessary and a rig for Cyprus should embody the following features :—

(*a*). Portability.

(*b*). Ample power and provision for speed fluctuations.

(*c*). Capacity to drill wells up to 12-inch diameter and to 1,000 ft. in depth.

(*d*). Means of handling casing up to 12-inch diameter.

(*e*). Apparatus for testing and rapid cleaning operations.

The "Star" portable drilling rig satisfies all these requirements, and the one ordered (No. 22) is suitable in all respects if furnished with supplementary tools which we have already enumerated. It is generally agreed that the use of steam power is objectionable when coal is scarce or expensive, but although oil engines are used they are a constant source of trouble unless a highly skilled Mechanic is always on hand to give them attention. Anyone of ordinary ability can fire a boiler and handle a steam engine, consequently we advocate the retention of steam power.

Drilling in Cyprus will generally be easy, although in some districts difficulties may be anticipated, but if delays are to be avoided it is essential that a stock of suitable casing should be carried. We have recommended the following standard sized California casing for lining the wells, as representing a happy medium between excessive strength and therefore weight, and dangerously light material which would not resist moderate punishment in use.

Nominal diameter.	External diameter.	Thickness of metal.	Weight per ft.	Length of coupling	No. of threads per inch.
10 in.	$10\frac{3}{4}$ in.	.348 in.	40 lbs.	$8\frac{1}{8}$ in.	10
$8\frac{1}{4}$ in.	$8\frac{5}{8}$ in.	.304 in.	28 lbs.	$8\frac{1}{8}$ in.	10
$6\frac{1}{4}$ in.	$6\frac{5}{8}$ in.	.28 in.	19.5 lbs.	$7\frac{5}{8}$ in.	10

As a rule it will not be necessary to insert any special device for restraining the admission of sand, but as there may be cases where much trouble would be avoided by the use of some arrangement, we recommend the ordering of a limited quantity of perforated pipe and sand screens. The casing is specified in random lengths not exceeding 12 ft. in order that the boreholes can be lined as drilling proceeds when found advisable, and to simplify the handling of strings of casing by the rig. This entails some additional expense which should be recouped in saving of time during drilling and in transport.

We certainly advise the engagement of a skilled driller to operate the Star drills. Although the natives may, in course of time, acquire a considerable measure of skill and, perhaps, eventually qualify for the senior post, it would be unwise to leave the work in their hands at present. Provided ample work is in hand to keep them fully engaged it has everywhere been found that the engagement of skilled, if expensive, men is well repaid by results. It is anticipated that a suitable operator will be found for a salary of about £50 monthly, but we generally recommend the addition of a bonus to hasten progress. If possible a man should be engaged with a mechanical training so that he can fix up any pumping machinery that is subsequently required.

With suitable plant and operators, speeds of 25 to 50 ft. daily should be possible in many parts of the Island.

VALUE OF WATER.

It is not easy to appraise the value of water to the Cyprus agriculturalist. Water rights are jealously guarded and any attempts to interfere with existing conditions are regarded with deep suspicion and resentment. All the most serious offences dealt with by the Courts are said to arise from quarrels over water supplies. As a result of this attitude it will be much easier to deal with new sources of supply than to attempt a more equitable distribution of existing sources, however wasteful present methods may be. The type of cultivation and the nature of the crops vary with the location of the land. Fertile hillsides are planted with vines, lands well watered by irrigation are devoted to the growing of beans, onions, vetches, flax, cotton, tobacco, cereals, mulberry and oil seeds. Lands dependent almost solely upon rainfall are planted with cereals and the crops are consequently precarious and may prove a dismal failure. Market gardening and fruit growing are practised where the soil is light and water is within reach of the surface and can be raised by windmills, bullock-driven bucket wheels or small oil engines. Olives and carob may thrive where the ground is too rocky for ploughing. Most crops suffer in consequence of abnormal conditions. Late rains when the harvest is in progress may cause serious damage by beating down ripe corn and washing away drying grain on the threshing floors. Late floods may do much damage to cultivation. In 1925 the cotton planted on the dry bed of the Kouklia reservoir was destroyed by an early flood.

Holdings are small in Cyprus, the average being probably between 3 to 4 acres per family, and as living is cheap, families are comfortably supported by this area of land. In the seasons when there is little to occupy the people on the land the families busy themselves with weaving, spinning cotton, wool, or silk, making lace or embroidery, and unquestionably this assists in the support of families.

It is said that the need of an average family is about £50 a year, consequently, the land must yield around £15 per acre unless substantial subsidiary income is earned. Additional income is earned in many cases by the breeding or feeding of stock, labour on public works, silkworm culture and the activities of the woman in weaving, etc.

With the aid of waters and fertilisers figures show that very large yields per acre can be obtained. Fruit and potatoes give especially large returns. An acre of oranges, for instance, in the Lefka district produces about 50,000 oranges in a season and with a selling price of 60*s.* to 70*s.* per 1,000 on the trees, the revenue represents between £159 and £175 per acre and the profit £129 to £156 per acre.

In the Famagusta district somewhat similar conditions prevail, and even if the price of oranges falls to its old level of 30*s.* to 40*s.* per 1,000 the revenue represents £75 to £100 per acre. Matured orange gardens with water rights have been sold, it is said, for £600 per acre.

Potatoes from imported seed produce 50 tons per acre in suitably watered soil and yield a revenue of about £120 per acre. Cotton it is calculated will give a net revenue of about £50 per acre. Flax can be grown at a profit of from £15 to £30 per acre if well watered, but may result in a loss if water fails. The sale of seed is said to pay the whole cost of planting and farming flax, about £6 per acre. Mr. Classen, the adviser on flax cultivation to the Government, claims that both flax and cotton can be grown on the same soil in succession in one year. Flax is reaped in May leaving the ground in a suitable condition for planting cotton which matures in September and October. The combined yield is thus £65 to £80 per acre. The table attached prepared by Mr. Zarifi gives a fair idea of the possibilities of certain crops.

Nature of Crops.	Yield per acre. okes.	Cost of prod. pounds per acre.	Selling price per oke.
Potatoes	6,000	£27 0*s.* 0*cp.*	1½ to 2 *cp.*
Cotton	240 to 600	8 5 0	15 to 18 *Pt.*
Flax..	450	4 10 0	2½ to 3 ,,
Aniseed	450	4 10 0	6 to 8 ,,
Cumin	600	6 0 0	5 to 6 ,,
Tobacco	600	15 0 0	7 to 8 ,,
Oranges	50,000 (*number*)	21 0 0	£3 to £4 10*s.* per 1,000 on trees.
Pomegranates ..	12,000	7 10 0	1½ to 2 *Pt.*

It is clear from the foregoing that provided water is made available to prevent a failure of crops through lack of rain such provision is a valuable insurance and justifies any reasonable expenditure on works which ensure that end. As the success of practically all Cyprus crops is mainly dependent upon water, there are few which would not benefit from articially applied water in most years. At present much ground is left fallow and as such it is always a nuisance in permitting the growth of weeds which scatter their seeds to cultivated ground. With water at hand, as required, fertilisers can be applied and crop rotations can be arranged which will remove the need for leaving land fallow.

Long stretches of country covered by a nearly unbroken horizontal bed of limestone are left for grazing. Much of such ground is merely a crust formed by the capillary leaching of lime from calcareous beds beneath, and when broken a depth of loose earthy material is exposed. Such areas can be reclaimed with the aid of water.

The somewhat precarious character of crops in Cyprus, on account of erratic rainfall, has, in the past, it is said, led to the farmers getting into the hands of money lenders who extorted usurious terms. Certain legislation framed to prevent the forced sale of land has relieved the situation, but the dangers of the system have been generally recognised and an agricultural bank has been recently formed to assist the agriculturalists. The bank is endeavouring to extend the formation of co-operative groups in which those participating, singly and jointly, guarantee interest and capital on cash advances made for the purpose of farming the land on modern principles. This system can be most appropriately applied to the development of water supplies without which fertilisers cannot be properly applied and the success of the crops is dependant entirely upon rainfall.

METHODS AND COSTS OF RAISING WATER.

Where shallow water is found outside the range of springs and aqueducts and irrigation channels it is artificially raised by various methods such as :—

(*a*). Bucket pumps and horse or bullock gear.

(*b*). Chain pumps.

(*c*). Windmills.

(*d*). Centrifugal or other pumps worked by engines.

A. The first named method is very popular as it is in Egypt and elsewhere as it permits the use of plant which can be made and repaired by the peasant themselves, and it can be operated by horses or bullocks when unoccupied on other duties. Large volumes of water can be thus raised at low cost from shallow shafts. In order to economise the use of water and ensure its flow to a distance the water as with other systems is run into a concrete or masonry tank of 100 to 500 tons capacity, placed high enough to ensure a quick travel of water to the most remote part of the field.

B. The chain pump is another simple device for raising shallow water economically and is being increasingly used. Its efficiency is low but as it is simple and understood by all, it has become popular. It may be worked by animals or an engine.

C. The windmill has proved an unqualified success in Cyprus, and it is said that there are about 2,500 in operation mainly in the Famagusta district where fruit culture is practised and there is no surface water. The 14-ft. windmill on 40 to 60 ft. tower is favoured, working a 4 to 6-inch diameter pump barrel with stroke of 6 to 12 inches. When operating on wells up to 70 ft. deep one mill will just about water one acre. In a good breeze they will throw up to 1,000 gallons per hour, or say 50 tons of water daily in 10 to 12 hours running, equal to half acre-inch of water. A 14 ft. windmill costs about £90 complete on site. Naturally the velocity of the wind and its regularity varies with the seasons and the location, and some advantage may be secured by being near the sea, but the general use of windmills by the railway and farmers and houses all over the country is the most convincing proof of their value in Cyprus.

D. Power driven pumps are in use to some extent and mention was made of one 24 HP pumping set in use on the Kyrenia Road for cotton irrigation. Many smaller installations are in use. No actual statement of results could be obtained, but it is obvious that if the equivalent of the annual rainfall, or even double the quantity can be placed on the land in the dry season at a cost considerably below the increased value of the crops reaped, pumping projects should be officially encouraged and free technical aid granted.

Only certain lands are topographically suitable for irrigation, and the combination of a plentiful supply of reasonably shallow water and convenient fertile land may not be general. Cheap labour, however, enables long distance conduits to be constructed above or below ground if it is found necessary to lead water some considerable distance. There are certainly wide expanses of country where water could be transferred to fertile land that now depends entirely upon rainfall, and the main problem is to evolve means of financing pumping stations and canal systems in a manner acceptable to the farmers.

As the capital cost per HP diminishes with the size of the engine, large units have some advantage over small, but in Cyprus it will probably be found that small or moderate sized units will best suit the local conditions. Twenty HP units with water lift of about 100 ft. will irrigate rather more than 200 acres with a monthly 3-inch watering.

The cost of power is mainly dependent on fuel which is very scarce in Cyprus. As imported coal is expensive steam power is rarely employed. Fuel oil for high compression engines would not cost more than £6 a ton so that the fuel oil for a 20 HP engine would be about 240 lbs. say one-tenth of on daily.

Depreciation on plant is a low figure when calculated at 10 per cent. per annum. Assuming the installations to cost £400 and a 20 HP engine to work for 6 months in the year and produce some 400,000 tons, say 4,000 acre-inches of water, the cost would not exceed 1*s.* per acre-inch, or say 12*s.* per 12-inch watering per acre.

As the fuel constitutes the chief charge for water it is desirable that the cheapest source of energy should be used. Suction gas installations generate power at the lowest cost and will consume almost any kind of combustible material. In Cyprus charcoal could be so used in which case the fuel costs could be reduced to a nominal figure, and consequently, the water costs. Unfortunately these engines are less reliable in action than other forms of power and hesitation is felt in recommending their use where skilled mechanics are not readily available to repair defects.

SUMMARY OF CONTENTS AND CONCLUSIONS.

In the attached report an endeavour has been made to explain how greater use can be made of the water resources of Cyprus. Although the geological conditions of the Island generally disfavour the chance of striking important Artesian flows of water by deep drilling, large areas will yield ground (subsoil) water at depths which render its economic recovery feasible. Regions of promise are mentioned where tests should be made for subsoil water, but certain districts as Morphou and Salamis call for especial notice, as very large volumes of water reach the sea both above and below ground at these two extremes of the central plain.

Attention is directed to the dangers of extending systems at present in use which result in the subsoil water being drained at a rate which imperils the future progress of certain areas of concentrated development. The opinion is stressed that the increase of population and the innovation of intensive cultivation must modify past ideas and lead to different methods which involve conservation. The topography of Cyprus encourages the rapid run-off of most of the rainfall, and any measures which artificially hasten that process in the wet season are inimical to the country's prosperity.

Any interference with existing water rights could only be accomplished by very delicate handling, as ancient customs have established hereditary rights which would not be readily relinquished ; consequently, it is appreciated that for the moment attention must be mainly directed to sources of supply hitherto left untouched by the inhabitants.

Included in the report are figures obtained by officials of the Agricultural Department showing that the response of land to irrigation will well repay the expense of lifting water mechanically. Only by having reserves of stored or ground water can certain crops in Cyprus be saved from those periodical failures due to erratic rainfall. Any important extension of the irrigation system of the Island can only be secured by artificial methods, and the estimates submitted indicate that the farmer can well afford to pump water for certain classes of crops. As there are no very suitable sites for surface reservoirs, and little satisfaction is felt over those already in use, it is upon ground (subsoil) water reserves that future reliance must be placed.

That land can be very profitably worked with mechanically-raised water has been amply demonstrated by the many small installations and windmills in use and upon which the crop is often entirely dependent. These installations are confined to small holdings in limited areas where the conditions are unusually favourable for one reason or another. More ambitious projects involve an outlay beyond the means of individuals and co-operative action is essential to enable the necessary funds to be raised. If the Government grants free technical advice and undertakes surveys and prospecting works the result will be virtually guaranteed.

Definite recommendations are made concerning the type of drilling machinery and accessories which should be ordered to conduct a methodical drilling programme. If the water resources of Cyprus are to be properly and exhaustively explored some risks must be run, and it is submitted that this is a legitimate risk the Government might assume in view of the possible benefits to the whole community.

The larger pumping schemes necessitate contour surveys as well as test drilling and trial pumping and several areas are initially indicated as worthy of immediate attention.

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