CYPRUS WATER DEVELOPMENT

BEFORE 1960

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by

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1. ANCIENT TIMES TO 1878

The story of water development in Cyprus is as old as the history of its first inhabitants, even though their problems in the early days may have been simple by present-day standards. Their villages would have been sited near natural springs or at places where water was close to the surface and could be reached by shallow hand-dug wells without difficulty.

However from about 1,000 B.C. the many invasions from surrounding lands led to the establishment of large seaports and towns requiring reliable and permanent supplies of water which could often best be obtained from inland springs. It was probably in this period that the first masonry aqueducts were built and they would have brought water to the ancient Greek cities of, among others, Soli, Paphos, Curium, Citium and perhaps the greatest of them all, Salamis. It was for Salamis, near Famagusta, that the first known major water development was undertaken in Cyprus. It was the great Roman aqueduct which supplied the city from the Kythrea spring, some 45 kilometres away.

This aqueduct was built in the early years of the Christian era and was severely damaged by earthquakes in A.D.334 and A.D.345, after which it appears to have been repaired and to have continued in use until the destruction of Salamis by the Arabs in the 7th century. Parts of the aqueduct were in the form of a lined masonry channel at or near ground level but long sections were of arches above ground. Near the terminal point in Salamis there was a capacious storage reservoir. Ruins of these works are still to be seen, as can the traces of many others of smaller size which once brought water from springs in the hills to cities and villages throughout the Island. Also to be seen are the remains of many masonry or rock-hewn cisterns once used for storing rain and spring water.

The Romans lost their influence in Cyprus in A.D.364 when their empire was divided into East and West, and the control of Cyprus passed to the Eastern or Byzantine half. For the next thousand years or more when the Island was controlled in varying degree by the Byzantines, the Lusignan Dynasty and the Venetians there was little change in the methods used of obtaining and supplying water. Where springs existed, masonry aqueducts or earth channels usually led to towns or villages, bringing water for domestic use and for irrigating cultivated fields. Much reliance was also placed on village or household wells from which water was drawn by hand or by primitive mechanical devices. It is probable that towards the end of this period animal power was first used to lift water by means of the Persian Wheel in which the chain of buckets was then comprised of earthenware pots and later of metal containers. By these means water could be raised from a well from depth of as much as 10 metres.

Under the Turkish occupation, beginning in the sixteenth century, some changes occurred, devised no doubt from Turkish experience on the mainland in Arab countries, and further east. Perhaps the most effective innovation at that time was the chain-of-wells, know elsewhere as the Qanat, Karez or Falaj, which came into frequent use for draining off shallow groundwater to the surface by gravity flow. Head wells in Cyprus were as deep as 25 or 30 metres and the length of the chain was sometimes as much as about 5 kilometres. The tunnels connecting the wells were only as large as necessary for a man to crawl through and they were sometimes lined with rough masonry and sometimes left unlined.

These chains-of-wells proved of immense value both for irrigation and domestic water. For irrigation they were built in many places throughout the island, though perhaps they were most numerous and of greatest value in extracting water from the gravels of river valleys descending to the Western Mesaoria. The chief cities were almost all supplied with domestic water from chains-of-wells of which one of the best known is the Arab Ahmad built by a pasha of that name for the supply of the old city of Nicosia soon after the Turkish occupation. It is still in use in the twentieth century having been repaired and extended from time to time.

The system of measurement of water by means of the saccoraphi system of small orifices and weirs was probably introduced in this period and was ingenious and effective and, in the absence of meters and other modern appliances, was of great value to the community in providing an even distribution of both domestic and irrigation water and also in enabling the ownership of the water to be identified, recorded and traded among registered owners.

Towards the end of the Turkish occupation the first known rainfall measurements were recorded. They were made between 1863 and 1869 by British consular officials acting chiefly under advice from the Scottish Meteorological Society. At about the same time what was probably the first description of the geology of the Island was made by Professor Gaudry of Paris.

2. EARLY BRITISH OCCUPATION 1878-1918

In the early years of the British occupation, which began in 1878, very few new water schemes were attempted but a programme of repairs and extensions was undertaken to improve the many chains-of-wells, aqueducts, small irrigation works and distribution systems of domestic water in towns and villages. Such works were then mostly suffering from lack of maintenance.

Various engineers and geologists from Britain reported on the possibility of large-scale works and a start was made on the study of the geology and the gauging of springs. Emphasis was given to the possibility of obtaining water by deep drilling in the Mesaoria and to the impounding of water in reservoirs after the style that had been very successful on a large scale in India.

At about the turn of the century four impounding works were built at Kouklia, Syngrasi, Akhna and Akhyritou but these met with little success and, apart from Kouklia reservoir, were soon abandoned, or almost abandoned.

Some noteworthy reports that were made during this period, up to the outbreak of war in 1918, are commented upon in the following sections.

RUSSELL 1880

A report entitled "The Existing Water Supply of the Island of Cyprus and on the Probability of Procuring an Additional Water Supply from Artesian Wells" was prepared by Mr R Russell of the British Geological Survey in August 1880 after an eleven week visit. It is probably the first printed report on the Island's water supplies. Mr Russell gave an excellent description of the domestic and irrigation water supplies as existing at that time and he described the geology as well as he could in the absence of known earlier geological work. He made spring gaugings throughout the island, probably the first quantitative measurements on record, and his report gave chemical analyses of the waters. He mentions repair works proceeding at that time in different places including improvements and extensions of Nicosia's Arab Ahmad chain-of-wells.

His recommendations were not very clear but appear to have been chiefly the following:-

a) He urged the Government to take control of all rivers and springs under a Central Department or Water Board with a qualified engineer to superintend works.

b) In a general sense he recommended the construction of reservoirs and irrigation channels and the sinking of wells.

c) He proposed that deep borings should be made in the Mesaoria envisaging depths down to about 3000 feet, with the object of obtaining artesian water for which he said conditions were favourable though success could not be guaranteed.

The first of the above recommendations, (a), can perhaps be taken as the earliest proposal on record for the formation of a Water Development Department, though it was not acted upon at the time. As regard to (b), a certain amount of action was taken though the results were not spectacular. This report is perhaps best remembered for (c), his recommendation for deep drilling, a subject that gave rise to popular discussion for many years to come, though perhaps not in a way that would have been supported by Mr Russell. A favourite theory was that water percolating under the sea from Anatolia would be available either by pumping or, hopefully, by artesian pressure. An alternative was that an "underground river" from the Nile might flow beneath the Mesaoria. In order to prove or disprove these theories it was often suggested, with public support, that drillings should be made to a depth of 5,000 feet or more. However as better knowledge of the geology of the Island was acquired less attention was given to ideas of this sort, and no planned programme of deep drilling was ever attempted, though from time to time in later years holes were drilled to more than 1,000 feet below ground.

<u>MEDLICOTT 1897-1902</u>

Mr J Medlicott, an engineer from India was engaged in about 1897 as "Director of Irrigation Works". His designation of "Director" perhaps indicates that an organisation in the nature of an Irrigation Department existed at that time.

His work was concerned chiefly with the Mesaoria where he surveyed many reservoir sites and made recommendations for the construction of a large number of impounding reservoirs some of which were started almost at once. In a report dated 4th February 1889, at a time when works at Syngrasi were nearing completion, he appeared to be optimistic of success and made recommendations to Government for at least a dozen or more irrigation works, mostly impounding reservoirs, considered major schemes at the time. Three of these, Syngrasi (then under construction), Kouklia and Akhyritou were completed but the other proposals appear to have been abandoned either early in construction or even without being started.

Kouklia continued in use but both Syngrasi and Akhyritou were virtually out of action and silted up when reported upon twenty years later by another engineer from India, Colonel Ellis (see following pages). Mr Medlicott soon realised that in most years there was insufficient water to fill the reservoirs and, to provide more water for them, he proposed a major diversion from rivers of the Western mesaoria, a proposal that was later abandoned because of cost and also perhaps because the water could be fully utilised in the Western Mesaoria itself without diversion.

Perhaps Mr Medlicott's chief problem was the absence of hydrological information. There were, of course, no flow or discharge measurements upon which he could base his calculations, and comparisons with run-off conditions in India, with which he was familiar, would not have been a reliable guide. He may also have not realised how large a proportion of flood water was already absorbed by small irrigation channels throughout the plain, leaving only an insufficient surplus to fill the new reservoirs except in years of heavy rainfall.

Mr Medlicott left the Island in 1902.

CLEMENT REID 1908

Mr Clement Reid, a senior geologist of the British Geological Survey visited the Island in May and June 1908 to examine "the possibility of increasing the water supply of Cyprus from artesian boring or otherwise, particularly for drinking purposes in Nicosia". His visit perhaps arose because the recommendations for deep drilling in the central plain made 28 years earlier, in 1880, by Mr Russell were still remembered and had a measure of popular support. They appeared to offer an easy solution to many of the Island's water problems.

At the time of Mr Reid's visit no geological survey of the Island had yet been made but he stated "it has been of great advantage in the enquiry to have an excellent topographical map to work on and to have so good a geological sketch-map as that completed by Mr Bellamy". The topographical map was probably prepared by Lord Kitchener who was then a serving officer in the Royal Engineers. The geological sketch map was probably prepared by Mr Bellamy only a year or two earlier.

Mr Reid's view on the subject of deep drilling in the Mesaoria was unequivalent and in his report he states that he considered "the search for artesian water over the greater part of the central plain to be hopeless".

His advice for action towards increasing water supplies generally was rather vague but he did favour extensions and improvements to local works, including wells and chains-of-wells and also systematic afforestation to limit floods and prolong the flow of springs.

For the improvement of the Nicosia water supply his recommendation was for a tunnel "to tap the springs in the cavernous limestone of the Kyrenia mountains", and following his advice an adit was later driven into the hills near Fileri, where the result was inconclusive. An attempt was then made at Sykari where, by 1937, a small but useful flow of water was obtained and, a few years later, was piped to Nicosia at a rate of about 650 m^3/day. Work then appears to have stopped until the 1950's when the potential of the limestone as a large natural storage reservoir, as visualised by Mr Reid, was again recognised and the adit was included with only small modification as one of the sources of the Greater Nicosia water supply scheme. In 1959, after being closed in winter, the adit produced without pumping a summer yield for Nicosia of about 2,500 m^3

per day, a quantity that might have been sufficient in Mr Reid's day to solve the city's water problems if added to the sources then in use.

In general Mr Reid's assessment of the possibility of obtaining new water sources was sound. He stated "the position of the villages, of the chain-of-wells, and of the valuable cultivated lands depends mainly on the occurrence of water within easy reach of the surface. The Cypriot, however, has little to learn as to the position of the waters. By a method of trial and error he has already, in the course of many centuries, located most of the superficial sources". These "superficial sources" would usually be within about 30m of the ground surface, the maximum depth from which they could be drawn off by a chain-of-wells. Mr Reid made no recommendation for drilling a little deeper to the "second" and "third" waters between say 50m and 100m, of the type which proved so useful in the late 1940's and thereafter. This was probably because at the time of his report (1908) there were no borehole pumps in Cyprus and few internal combustion engines or electric motors.

3. BETWEEN THE WARS 1918-1939

In the years before the two world wars there was only slow progress in the field of water development. This may have been because of shortage of money and also, perhaps, because of disillusionment over the lack of success of the Mesaoria impounding reservoirs, which were large projects by the standards of the time.

Another reason for the slow progress arose from the nature of the Government works organisation which included responsibility for water supplies among the duties of the Public Works Department. The PWD met that responsibility by appointing special officers to attend to water problems as they occurred, having regard to their priority in relation to its many other commitments including the very pressing need for roads and bridges for motor traffic then making its first appearance on the Island. For the busy PWD the difficult and time-consuming task of finding sources of water and undertaking water schemes was too easily set aside for what seemed more urgent matters.

To overcome these difficulties consultants from outside were engaged to examine the water situation, among them Colonel Ellis who was concerned chiefly with irrigation, and Mr Beeby Thompson who advised on groundwater exploitation. Their advice, which is reviewed in two later sections of these notes, had considerable influence in the shaping of water development policy over the next few years.

The need for more water for a rising population with higher standards continued to make itself felt both as regards irrigation and domestic use and thoughts were turning persistently towards the possibility of finding more groundwater. While Colonel Ellis, for his part, recommended the sinking of more wells for irrigation, Mr Beeby Thompson showed that large quantities of "second" and "third" water could be tapped at below the level of the superficial or "first" water, already drawn from wells or chains-of-wells. The percussion drilling rigs available at that time had no difficulty in drilling down to 100 metres or more if necessary to reach water which usually rose some of the way to the surface under artesian pressure and could be pumped economically by borehole pumps powered by internal combustion engines then coming into fairly common use.

The search for drilling sites to find "second" and "third" waters was a geological matter and accordingly, in 1937, a capable geologist was appointed to the department. He was Dr Raeburn (later Sir Colin Raeburn) and it was he who took over responsibility for the Island's water supplies under the designation of "Water Engineer". Dr Raeburn had strong ideas about how his work should proceed, particularly as regards the "little waters" of the numerous small irrigation works already existing throughout the Island, and in 1939 he was appointed head of a new Government department called the Water Supply and Irrigation Department.

The advent of the new and independent department relieved the Public Works Department of a troublesome burden of responsibility and it set the scene for the sustained and accelerating progress in water development which took place over the following years, first by the new department as named above and as from July 1954 as re-named the Water Development Department.

ELLIS 1922

Colonel Ellis, a former Chief Engineer of the Madras Presidency in India was engaged in May 1921 as Irrigation Adviser to the Government to advise, in effect on (a) measures to improve the then existing irrigation works at Kouklia, Syngrasi and elsewhere and (b) on any new works that could be undertaken profitably. He spent about six months on the Island.

As regards (a) he examined the scheme for diversion of water from the Western to the Eastern Mesaoria and although he appeared to consider it possible he did not recommend its construction, probably on economic grounds. He did not recommend any particular improvement works but seemed to think that benefits could be had by taking care to reduce wastage of water.

On the subject of (b) he was of the opinion that "the best means of bringing about the extension of irrigation is by encouraging the sinking of wells for the purpose and by giving advances towards the cost of the works or towards the cost of improvements to existing works". He did not recommend the construction of reservoirs chiefly because of the cost and he thought the best method of conserving water was by afforestation.

It will be noted under (b) that his main recommendation, viz the sinking of wells and the improvement of existing works, was in effect the successful policy of the Department in the early years of its life, though the "wells" were mostly deeper boreholes and the improvement works were supplemented by many new schemes of similar character.

BEEBY THOMPSON 1926-1928

Mr Beeby Thompson was engaged in 1926 to study the water problems of Cyprus. His firm had already had considerable practical experience in drilling for water in Greece and the Balkans and he was thus more concerned with groundwater than with other water sources. By this time some progress had been made by geologists in establishing the nature and sequence of the main geological features of the Island and Mr Beeby Thompson was thus soon able to recognise most of the essential facts and to make recommendations for a drilling programme.

He realised that there were large areas where water could be obtained from below the depth of the many existing wells and he considered "that there are some areas from which large volumes of water could be pumped the whole year if suitable works were undertaken". He was of the opinion "that the Morphou district alone in the Mesaoria offers any respectable prospect of finding extremely large quantities of water the whole year".

He put forward a drilling programme in June 1927 for two drilling rigs, one a "Canadian" rig and the other a "Star". The former was to sink relatively shallow holes in the Famagusta area while the latter was to drill to greater depths in the Western Mesaoria. He did not specify the exact number or depths of the wells to be drilled.

These recommendations appear to have been more or less implemented in the ensuing few years by encouraging more drilling in the Western Mesaoria. This was an important advance at that time and although the programme was small by present standards it led the way for similar work on a larger and increasing scale to continue right through to the 1950's when many of the free-yielding areas were being pumped to their limits and in some places beyond acceptable limits.

It is noteworthy that the Government of the day had its doubts about the economics of pumping water for irrigation, having fears that the cost would outweigh the benefits even though good cultivable land might exist around the well head. In 1927, no doubt on Mr Beeby Thompson's recommendation, Government started a subsidised drilling scheme whereby a landowner could have a borehole drilled on his land for a fixed nominal charge of £20. It seemed that by 1928 there was still some doubts about the wisdom of the scheme and Mr Beeby Thompson had to spell out his case at great length in his report of November 1928 to show that water, where found, could be used profitably despite the cost of pumping. His case appears to have been convincing, for the subsidised scheme continued and was still in force with minor modification thirty years later, in the 1950's, when the charge had risen to £32/10/-. By then all doubts about the economy of using pumped borehole water for irrigation had long since disappeared and Government's problem was rather to restrain pumping to within the safe capacity of the aquifers.

4. REMARKS ON EARLY GEOLOGICAL STUDIES

From the beginning of the British occupation the search for both irrigation and domestic water by drilling was handicapped by a lack of knowledge of the geology and hydro-geology of the Island. The first geologists were probably concerned more with minerals than with water and there was little geological mapping of the sort that would help in discovering and developing groundwater sources.

The earliest geological studies appear to have been made by Professor Gaudry of Paris in the 1860's or 1870's before the British occupation and according to Dr Raeburn, who was Water Engineer from 1939 to 1947, Professor Gaudry gave "a full and accurate account".

In 1880, about two years after the British occupation, the geology in relation to water supply was examined by Mr R Russell of H.M. Geological Survey, who may have been both an engineer and geologist. Mr Russell described the "Geological Structure of the Central Part of the Island" in some detail after an eleven week visit reporting on the broad aspect of water supplies. Among his findings was a recommendation for deep drilling down to 3,000 feet, which caused much discussion and controversy in later years. It is possible that if Mr Russell had had the benefit of more carefully prepared geological information, or if he had been able to spend more time studying it himself, he would not have made that recommendation.

The next significant geological report appears to have been made by Mr Bellamy in 1906 or 1907 and he was followed soon afterwards in 1908 by Mr Clement Reid an eminent geologist of the Geological Survey of the United Kingdom. Mr Clement Reid acknowledged the work of Bellamy with the words "... it has been a great advantage ... to have so good a sketch map as that compiled by Mr Bellamy". Mr Clement Reid's visit to Cyprus in May and June 1908 was short and he did not himself go into geological details in his report. However he saw enough to advise strongly against the deep drilling recommended by Mr Russell 28 years before.

In the 30 years or so following Clement Reid's visit interest in the geology of the Island continued and according to Dr Raeburn in his General Report of 1945 "notable advances were made by Bellamy and Jukes Brown, Cullis and Edge, Romnes, Cowper Reid and others so that in a general way the hydro-geology of the Island was known". Dr Raeburn also says "the geological map prepared by Bellamy and Jukes Brown, although on a small scale, is useful to show the extent of the various formations and considering the date of its compilation fairly accurate".

The first comprehensive geological map of Cyprus was prepared during the war, in 1940, by Messrs RV Browne and F McGinty of the South African Engineering Corps. In it were incorporated the works of Bellamy, Cullis and Edge. This map remained in general use as the standard geological map of Cyprus for the next 20 years at least.

A good explanation of "The Geology in Relation to Water Supply" is given by Dr Raeburn in his General Report of 1945, by which time the wide knowledge acquired indicated that future geological work, to be spread over many years, would consist mostly of detailed studies of particular areas and of geophysical surveys, rather than of general geological mapping.

In 1952 Dr Burdon, the Assistant Water Engineer, made a very full review of the position in his report on "The Underground Water Resources of Cyprus". He was able to put forward a programme and estimate for future drilling and his report, the most comprehensive to date, became a handbook at the time. He estimated that with careful development some 40,000 million gallons (181 million cubic metres) could be recovered each year from wells, chains-of-wells, and boreholes. It still remains to be seen to what extent this figure can be considered a realistic upper limit.

5. WATER SUPPLY AND IRRIGATION DEPARTMENT 1939-1948

During this period the department established its identity as an independent Government department. It completed many small works and discovered many new sources of groundwater in spite of difficulties caused by the war. The head of the department was Dr C Raeburn (later Sir Colin Raeburn) and his official designation was "Water Engineer".

Irrigation works were on a village scale and, according to Dr Raeburn in his report "Water Supply in Cyprus" of 1945, "official action was directed towards the multiplication of small schemes to be managed and maintained by the irrigators themselves ... ". Works were of simple character and built with local materials by foremen with traditional skills largely inherited from ancient times. They worked from sketches without formal plans. Masonry water storage tanks, irrigation channels, small aqueducts, diversion weirs and the like were solidly built and of pleasing appearance. The stonework was set in lime mortar or, as modern cement became available in lime-and-cement mortar. A typical scheme would consist of a small diversion weir in a stream bed, a lined masonry channel of up to, say, a kilometre in length and perhaps a storage tank holding up to about 500 m^3. Sometimes a spring or possibly a chain-of-wells drawing water from a river bed, would form the source instead of diversion weir.

Some small masonry dams were built in hill river beds during this period, the two highest being a Kalkhoria Klirou and Galini respectively, both being about 11 m in height with the former storing 82,000 m^3 of water and the latter 23,000 m^3. They were built of masonry set in lime-and-cement mortar with only the minimum aid from mechanical plant. Although they were trifling in size compared with those that followed they were remarkable in being the first dams for upper valley storage.

The cost of irrigation schemes was usually borne in part by the beneficiaries and in part by Government, the former paying between a fifth and a third of the total, sometimes in cash but more often partly by free labour and partly by Government loan at a low rate of interest. Upon completion the works were operated by the villagers themselves with guidance if required by the Department or the District Administration.

Collectively the small irrigation schemes brought great benefits to local communities, particularly in the hill villages, and much newly irrigated land was brought under cultivation. They were very popular and they enabled the irrigation section of the department to achieve considerable success.

Many village domestic water schemes were carried out during this period and they were much sought after by the villagers even though most were only improvements to old systems. Improvements usually consisted of protection works at the source, of repairs to old aqueducts and channels or, if pipes could be obtained, of replacement by new pipes. Covered storage tanks and public fountains or watering places were built in masonry. At this stage no individual house connections were made in villages. Entirely new water schemes were not usually possible because of the shortage of pipes in war time. Half the cost was usually paid by Government and the remainder by the villagers who were given Government loans at low interest rates. Sometimes part of the village share was given in cash or in the equivalent value of free labour.

As regards town water supplies, routine repairs and maintenance were attended to as well as possible under war conditions but few new works could be attempted because of the shortage of staff and equipment, including pipes and pumping machinery. Just before the war a scheme was prepared for major improvements in Nicosia, which was badly in need of more water, but the plan was never implemented. In the early stages of the war a pipe was laid from the Sykari Adit to give some relief to the Nicosia Water Commission's sources which consisted mainly of the Arab Ahmad and Silikdar chains-of-wells. This new pipe delivered about 650 m^3 per day.

In Larnaca the old Abu Bekir aqueduct, built in about 1745, and its distribution system were replaced by asbestos cement pipes ordered before the war. This work was completed in 1941 increasing the yield to about 4,000 m^3/day an average of more than 300 litres per person. It was divided among consumers by a "saccoraphi" system that was then satisfactory.

The plight of the other towns, as explained below was recognised and some ideas were formulated about future improvements but unfortunately little could be done under the prevailing wartime conditions.

The town of Limassol obtained its summer water mostly by pumping from the Chiftlikoudhia chain-of-wells but in winter it was able to obtain gravity water from the Ayia Irinia spring and the Kitromli chain in the Garillis river bed. These two chains-of-wells dated back to the days of the Turkish administration. All three sources were unreliable in summer, Chiftlikoudhia because of a tendency to become brackish through infiltration of sea water and the other two because of diminishing quantity. The pumping station on the Chiftlikoudhia chain was installed by the town authorities at about the turn of the century but was repaired and improved from time to time with the pumps and engines being renewed probably in the early 1940's. By this time the quantity supplied to the town in summer was of the order of 1500 m^3/day or 75 litres per person but in dry years it could well have been much less.

Famagusta received its water from the Panayia spring by means of an ancient 15 km aqueduct and from wells and boreholes belonging to the Municipality in the Stavros quarter and on the Ramparts. There was concern about pollution and increasing salinity and, in the case of the Panayia aqueduct, about theft and leakage. In general the total water was inadequate in quantity, particularly in summer.

In Paphos water was obtained from several small sources near the town and was under the control of the Municipality. The combined total quantity in summer amounted to only about 300 m^3/day or 60 litres per person.

The Kyrenia water came from three small chains-of-wells within the town boundaries and they yielded together a minimum flow of about 100 m^3/day or 40 litres per person.

Drilling for water in the Mesaoria and elsewhere continued steadily throughout the war with four rigs inherited from the Public Works Department operating in 1939, six in 1946 and eleven in 1948, including five on loan from the British Army. A total of around 600 holes were drilled in this period (1939-48), some for prospecting purposes for Government and the War Department but most, about 60%, for private individuals. The average depth was about 60 m and most were sited to penetrate into the Pliocene deposits of the Western Mesaoria, with the object of tapping the then abundant "second" and "third" and subsequent waters. About half of the boreholes drilled for water was classed as "successful", yielding upon test more than 45 m^3/hour.

A subsidised drilling scheme encouraged landowners to have boreholes drilled on their land. This scheme had been in operation since 1927, after the visit of the consultant, Mr Beeby Thompson, and it enabled a landowner to have a hole sunk in any reasonable place for a very small charge, first at £20 but increased to £32/10/- in about 1946. The balance of the cost was met by Government. At first very little advantage was taken of this scheme because there were so few drilling rigs and also because irrigation with pumped borehole water was considered expensive. However as more bores came into use, more were sunk, and there was soon a long waiting list of applicants. The low first cost to the owner enabled him to ascertain if he had useful quantities of water under his land and thereafter he, himself, could meet the cost of pumping machinery and channels to complete his own small irrigation works. Irrigation with pumped groundwater was soon found to be highly profitable in many parts of the Mesaoria and the practice then became firmly established.

As regards hydrological information, at this period the department took intermittent measurements of the discharge of the main springs but, no doubt through shortage of staff, not of the flow of streams in the hills, or of flood discharges of the rivers, or of changes in the levels of groundwater, or of the quantity pumped from groundwater. There was thus a lack of hydrological data with which to plan both for the present and future.

Mechanical equipment was difficult to obtain. Although the department carried out almost all its construction by direct labour, with minimum assistance from contractors, it possessed very little construction plant, except the drilling rigs which were maintained by the Public Works Department. It got by mainly by using hand tools only, and by hiring small plant from the market place or by borrowing from the P.W.D. which also kept its workshops available for such things as, for instance, the fabrication of small sluice gates, or the perforation of borehole casing pipes. This way of operation was perhaps only possible because works were kept simple and were built only by traditional methods.

In 1946 a ten-year programme of development for Cyprus was published setting out accepted schemes in many fields and including irrigation and domestic water supply. The money provided was in effect sufficient for the continuance of work at the then existing rate for the following ten years. Irrigation was to be on a village scale which had become so popular and it was given top priority. It included subsidised drilling which made possible pumped irrigation from boreholes, by then accepted as economic. As regards domestic water the aim was to provide every village with a "proper" supply of 15 gallons (or 67.5 litres) per head per day, within 5 years and money was provided with this end in view. However the shortage of pipes, and also staff, made such a time-schedule impossible and in the event the programme was slow in getting under way. It was expected that the scheme would meet the requirements of the villages for the next forty years. Town water supplies were discussed in the report but they were then primarily the responsibility of the municipalities and so no funds were included within the programme though it appeared to assume that Government loans would be offered in due course.

In general, during the 1939-1948 period only limited progress was made in domestic water supplies because of the shortage of staff and of pipes and materials. On the other hand good progress was made in the construction of small irrigation works within the accepted policy of developing the "little waters". This was done with little mechanical equipment other than hand tools. As regards drilling for water the department was fortunate in having the use of a number of drilling rigs throughout this period and it was thus possible to tap much new groundwater and to show the way ahead for wider expansion in that field.

Shortage of staff was always a problem. For most of the time the only qualified officer was Dr Raeburn himself though at first he was assisted by Mr T W Longridge, an engineer, and in 1945 he obtained an assistant, Mr A Cawley, a geologist. Dr Raeburn left in 1947 leaving Mr Cawley in charge until 1948 when he departed and Mr Ward arrived. The qualified staff was again only one officer, though this time an engineer instead of a geologist. Until 1948 the emphasis was chiefly on the geological side of water development and although there was much progress in irrigation and some in domestic water supply it can be said that the main thrust had been towards the search for groundwater rather than towards works. However although officers with academic qualifications were lacking, there were several extremely competent Cypriot superintendents and inspectors and also a wealth of highly skilled foremen without whom the department could have achieved very little, neither at that time nor in subsequent years. Many of these men continued to serve until the 1950's and beyond, until retirement.

6. DEVELOPMENTS 1948-1959

From 1939 to 1954 the department responsible for water development in Cyprus was named the Water Supply and Irrigation Department and the head of the department was designated "Water Engineer". Until 1947 the Water Engineer was Dr C Raeburn (later Sir Colin Raeburn) and he was succeeded in 1948 by Mr I L Ward. In 1954 the name of the department was changed to "Water Development Department" and its head became the Director of Water Development. The objectives and responsibilities of the department remained unchanged.

The engineering and geological side of all Government water development work was in the hands of the Department of Water Development whose duties included the search for new sources, the conservation and development of supplies for irrigation, domestic and industrial use and the problems connected with river training flood protection and land drainage. The administration of village Irrigation Divisions and Associations and domestic Water Commissions was supervised by the District Commissioners. Disputes over water rights were handled by the Commissioners in consultation with the Law Officers, the Department of Lands and Surveys and the Department of Water Development. Soil conservation and the agricultural problems involved in the economic use of water were the responsibilities of the Department of Agriculture.

POSITION AT END OF 1948

At the end of 1948, following the war years, the fortunes of the Department of Water Supply and Irrigation were at a low ebb although there was promise for the future.

The Water Engineer still had no qualified assistants though he had a capable Superintendent of Water Supplies to help him plus several Inspectors and some 65 foremen to supervise work. Although an active programme of building and improving small irrigation works was in progress the methods of construction belonged to the previous century and needed modernisation. There was an urgent need for more domestic water in both towns and villages but this could not be remedied at the time, even had there been more staff, because of the post-war shortage of pipes and other materials. Plans for new water supplies were needed in the chief towns, particularly Nicosia, Famagusta and Limassol, but as yet not even the new sources had been selected. There was little quantitative information about water resources, surface or underground, because regular measurements were not being taken, except for gaugings of some of the larger springs. The department possessed no workshops and, apart from its drilling rigs, no mechanical construction plant.

On the credit side there were clear programmes of work ahead for both irrigation and drilling for water, and also for village domestic supplies once staff and materials became available. These programmes were of a type highly popular in the villages and very suitable for their time. Money was available for fast progress in these fields.

As regards legislation, the various laws existing in 1948 were generally sufficient and suitable for the work then in hand but it soon became necessary to modify them and to add others with changing circumstances on the following years. In 1948 the chief water laws were:-

1. Government Waterworks Law (1928). This vested most underground water and all waste surface water in Government and provided machinery for ascertaining the nature of water rights and making surveys to determine the practicability of undertaking waterworks.
2. Irrigation Divisions Law (1938). Means were provided for landowners to combine together for the purpose of undertaking irrigation works.
3. Wells Law (1946). This provided that no well or borehole could be sunk without permission.
4. Water (Domestic Purposes) Village Supplies Law (1948). Provision was made for the setting up of Village Water Commissions to supply domestic water to villages.

Among the changes and additions found necessary in the next 10 years were the following:-

(a) Irrigation (Private Water) Association Law (1949). This law was somewhat similar to the Irrigation Divisions Law but it applied to the owners of "private" water rather than "common" water and enabled them to combine together in Associations to manage it. In practice it enabled them to enjoy the benefits of Government assistance, both financial and technical, in improving their irrigations works.

(b) Water Supply (Municipal and Other Areas) Law 1951, which made provision for the setting up of Water Boards in the chief towns. There were minor amendments in 1952 and 1954.

(c) Wells (Amendment) Laws. The Wells Law (1946) was amended twice, in 1951 and 1953. The first of these amendments provided measures for the protection of groundwater in special areas where the water levels were falling or the salinity of the water increasing. The second provided for the licensing of drillers and the compulsory submission of drilling samples to the Water Engineer.

(d) The Water (Development and Distribution) Law 1955 by which privately owned water could be acquired, upon compensation, for the common good as, for instance, when part of the Kythrea spring was taken by Government for domestic use in 13 dry villages on the plain.

(e) Nicosia Water Supply (Special Provisions) Law 1959. This provided for the temporary reconstitution of the Water Board of Nicosia with powers to manage and control all water undertakings for the supply of the Greater Nicosia area, including those then operated by Government. This law was due to expire on 31st December 1960.

A bill for a Land Drainage Law was considered in 1957 but was not enacted at that time. The objects were to facilitate the maintenance of improvement of rivers and streams, the execution of river training works and the prevention of pollution.

The immediate requirement for work at the end of 1948 was to press on with the small and simple irrigation schemes in the hills and elsewhere and with the subsidised drilling programme. Village water supplies were to receive attention as pipes could be obtained, and possible sources for town water had to be examined and selected to enable schemes to be prepared. At the same time a start had to be made in the collection of hydrological data for improved assessment of both surface and underground water for the future planning of larger schemes. Mechanical plant for construction had to be accumulated and a workshop established for its maintenance and for construction requirements.

Progress made in the above various activities in the years 1948 to 1959 is described, and other relative information is given, in the following sections of these notes.

IRRIGATION

From December 1951 onwards the irrigation section of the department was under the control of Mr A P H McLaughlan, Senior Engineer.

The many irrigation works undertaken in this period were mostly small in accordance with the policy of the time and they were mostly in traditional style though modified by new methods and techniques.

They can be classified in the following groups:-

(a) Excavation of springs to increase yield.

(b) Diversion of stream flows.

(c) Lining channels with concrete to prevent leakage.

(d) Construction of infiltration galleries otherwise known as chains-as-wells.

(e) Construction of reservoirs for night storage.

(f) Construction of masonry concrete and earth dams.

(g) Installation of pumping plant on wells and boreholes.

The general nature of these works can be understood from Appendix 1 of these notes, which is copied from an appendix of the annual departmental report for 1955, entitled "Description of Certain Irrigation Schemes".

Additional water was made available by the development of old and new sources. In the case of small springs this was achieved by the process of "excavating and building" the sources and then drawing off the water without loss in concrete channels or pipes, or in lined tunnels. River or stream intakes, which in the past were usually simple brushwood and earth structures easily destroyed by floods, were replaced by permanent concrete or masonry weirs and intakes of various types, or sometimes by concrete pipes laid in and below the river bed gravels. Weir foundations could frequently be taken down to bed rock to form "sub-surface" dams which prevented water going to waste along the stream bed under the intake. Pumping machinery became easily available for the first time in the Island's history and its frequent use enabled groundwater to be used on a scale hitherto unknown.

Many old chains-of-wells were repaired and extended and numbers of new ones were built by improved methods using standardised precast concrete linings in the tunnels large enough for a man to crawl through but small enough to be economic in cost. Perforations or open joints in the upper part of the lining permitted water to enter the tunnel while a sealed lower part prevented the water from escaping. The use of compressed air both for working rock drills and for ventilation greatly facilitated the driving of the tunnels.

Perhaps the most successful means of saving water was by the simple process of lining irrigation channels with concrete, eg. in the case of the Kythran spring it was estimated in 1959 that the water saved by lining 35 kilometres of channels was very much greater "than 25% of the total flow at source". In this particular case, as in many others, the irrigators were quick to recognise the benefits and they were not slow in asking for more channels to be lined in the same way. The lining was usually laid in 15 foot lengths of standardised reinforced concrete sections, cast in inter-changeable sections of formwork and jointed with plastic or bitumen to prevent leakage between sections.

In earlier days irrigators had difficulty in conveying water in channels across streams or dry river beds, or around precipitous hillsides and there was therefore considerable demand for small aqueducts over stream beds, pipe syphon crossings under river beds, channels cut in rock around hillsides, all of which were not difficult to construct with the mechanical equipment that by this time had become available.

Storage of water at night for use in the day was in the past a problem as the old masonry tanks usually lost much water by leakage. Also they were mostly too small, particularly after extra water was made available by the improvement of sources, lining of channels, etc. Consequently there was a considerable demand for properly jointed and sealed masonry or concrete storage tanks holding about 8 hours flow from a small source. For storage over longer periods it usually became necessary to consider the possibility of building dams in river valleys, which were relatively costly and involved engineering problems. Eight such dams of heights up to about 30 metres were built between 1948 and 1959 and about 18 others, some slightly larger, were planned for the future but at that time heights much greater than these were not considered feasible economically.

The Department, at its 1959 strength, was still not in a position to complete the construction of more than one dam a year because of its other commitments.

Gravity irrigation works such as those described above were extremely successful and very popular but in terms of both total area irrigated and of cost to Government they were eclipsed by new pumped irrigation, which resulted chiefly from the subsidised drilling programme whereby a borehole was drilled by the department at a nominal cost of only £32/10/- to the landowner. If the borehole was successful the landowner himself built the irrigation works at his own expense. These usually consisted of an oil engine and pump, a small storage tank and some lined channels leading to his gardens. He had, of course, also to pay the cost of pumping, an expense spared to his colleagues who used gravity water.

The following paragraphs show approximately the extent of the increase in both gravity and pumped irrigation in the period under review.

Progress was generally classified in the annual reports of the department under three heads, eg. (a) Gravity irrigation (perennial), (b) Gravity irrigation (seasonal), and (c) Pumped irrigation, and the area of new irrigation achieved each year was recorded. Expenditure was shown under only two heads, eg. (a) Gravity Irrigation and (b) Subsidised drilling which for practical purposes was the amount spent by Government on pumped irrigation. The following figures have been obtained by adapting this information from the annual reports. One donum = 0.33 acres = 0.134 hectares (approx).

Increase in Irrigation 1949 - 1959

Perennial Gravity	23,500 donums	)	
		)	74,500 donums
Seasonal Gravity	51,000 donums	)	
Pumped	99,000 donums	)	

A number of gravity schemes completed was 742 and the number of boreholes drilled for irrigation was 1826. The total cost of the gravity works to Government, excluding the village contributions was £1,517,000 or say £20.4 per donum and the total cost of pumped irrigation (ie. subsidised drilling) to Government was £149,000 or say £1.50 per donum. Government expenditure on irrigation over the 11 year period was, from the above figures roughly £151,000 per annum.

Though these figures are necessarily only approximations they serve to show that the irrigation works were of very good value economically. An indication of their popularity is that at the end of 1959, in spite of the completion of so many schemes over the 11 years, there was still a waiting list of 115 schemes ready to be started and there were many more applications awaiting attention.

GROUNDWATER AND DRILLING

This section of the department was administered by the Assistant Director who was Dr David Burdon from 1949 to 1952 and thereafter until 1960 by Mr David McGregor.

In 1948 the requirements of a programme for the utilisation of groundwater by drilling were reasonably clear. By that time the chief areas where water was likely to be found and to be used were known in a general way though their potential for extension had yet to be proved. Increased agricultural production that would result from irrigation with pumped groundwater was clearly of great economic value and there was a very pressing need for more water for both town and village domestic supplies.

Concurrently with the drilling programme care would have to be taken not to over-exploit the aquifers by drawing off more water than could be replenished year by year naturally by rainfall or possibly in some cases by artificial recharge. There was also a very real danger of increasing salinity. Little was known of the quantity of groundwater actually used at that time and there had been scarcely any measurements of the effect of pumping upon water levels or salinity.

It was therefore necessary not only to drill boreholes to produce water for irrigation and domestic purposes as fast as practicable but also to undertake studies leading to an assessment of the quantities likely to be available in the long term and of the resulting changes in groundwater conditions.

At the end of 1947 there were eleven departmental drilling rigs in operation and by 1958 their number had increased to sixteen and there were also some twenty privately owned rigs, locally made for light work, but used only spasmodically.

The average number of holes drilled by the Department increased from 68 per year in the five years prior to 1948 to 264 in the five years following 1953. The average depth was 57 metres.

By 1959 the total volume of water available from the holes drilled by the Department was of the order of 600,000 m^3/day but the quantity actually used was much less if averaged over a whole year. It was estimated that, including old wells, chains-of-wells and private drilled boreholes the total quantity of underground water pumped in Cyprus for irrigation, domestic use and industry amounted to about an average of 350,000 m^3/day or say 130 million m^3/year.

As a result of this increased rate of pumping there was, by 1959, a general lowering of water levels in most pumping areas and a marked increase in the salts content of the water, making it abundantly evident that the high rate of expansion could not be continued everywhere and that in some places it would have to be reduced if the aquifers were not to become exhausted.

The first scientifically prepared estimate of the total quantity of groundwater likely to be obtained in the Island by regular pumping was made by Dr David Burdon who was Assistant Water Engineer for 2½ years for 1949 to 1952. In his report of 1952 "The Underground Water Resources of Cyprus" he estimated, in an attempt to find a target figure for groundwater development, that in each year "with careful development some 40,000 million gallons (181 million m^3/year) should be recoverable from wells, chains-of-wells and boreholes". The quantity actually pumped in 1959, as stated above, was of the order of 130 million m^3/year or about 72% of Dr Burdon's target figure. Having regard to the fact that there were still a few areas not yet fully examined and there were the possible benefits of artificial recharge to consider it would seem that Dr Burdon's figure, was not too far from a realistic upper limit.

The danger to the aquifers from over-exploitation was recognised in the early 1950's when falling groundwater levels and increased salinities began to threaten town water supplies in Nicosia, Famagusta and Limassol. Systematic measurement of the extent of the changes began in 1950 when nine special observation boreholes were sunk. By 1959 there were 57 similar holes being observed regularly and much additional information was being obtained from pumped wells and boreholes, many of them privately owned. The areas causing greatest concern in 1959 were Phrenaros, upon which the water supply of Famagusta was dependent, and Kokkini Trimithia, which supplied a good proportion of Nicosia's water. At Morphou Bay, in the area that was about to supply Nicosia with additional water there was also a depressed water table. In all coastal areas there were signs of the encroachment of sea water.

In order to provide better control over the threatened areas the Wells Law of

1945 was amended in 1951 and 1953, as mentioned above, and by 1959 some nine areas had been declared under the revised law as meriting special attention. In these particular places the driller was required to obtain a licence before attempting to sink or deepen a well or borehole and to submit records of his work and drilling samples to the Director of Water Development. In giving or with-holding his concurrence to the issue of a licence the Director had to have regard to the extent to which the general water situation in the areas or the requirements of prior users would be affected.

By the end of 1959 the great benefits of the drilling programme were clearly visible in the extensive use of pumped water both for domestic purposes in towns and villages and for irrigation. The gainful effects of perennial irrigation were readily seen in agricultural development and improved agriculture economy. Where previously the summer landscape was bare and arid, citrus groves and vegetable gardens were being extended year by year at the remarkably low cost to Government of only about £1.5 per donum. However the need to sustain output with a falling water table and increasing salinity in some regions posed problems for the future.

VILLAGE DOMESTIC WATER SUPPLIES

The officer in charge of Village Water Supply Works until December 1951 was Mr V Levonian and thereafter mostly Mr V C Toundjian, Superintendent of Works.

The Ten Year Programme of Development of 1946 provided for a satisfactory supply of piped water in each of the 627 villages of Cyprus. A "satisfactory" supply was considered to be 15 gallons, or 75 litres per person per day, and on this basis about 547 villages needed attention, the remaining 100 at that time being "satisfactory".

As time passed, however, living standards rose and many villages were not content with only 15 gallons per person per day and the rate was usually increased (unofficially) to about 20 gallons (or 90 litres). They also frequently asked for individual house connections to supplement the traditional street "fountains". These improved standards led to a requirement of many more village schemes than the original 547. The schemes actually completed or partially completed in the eleven year period to 1959 numbered more than 600 and it was then estimated that a further 216 schemes were still required including 145 which needed replacement or major alterations or repairs.

A village water supply scheme usually comprised the development and protection of the source, the laying of a main pipe line to the village, and the installation of a piped distribution system including storage tanks and public street "fountains". A "fountain" is a combined standpipe, trough and drainage pit. Usually no house connections were included. The source could be a spring, chain-of-wells, borehole or well from which the water would sometimes be used for irrigation as well as for domestic purposes. Frequently a single source and main pipe line would be shared by several villages, particularly where long pipe lines were necessary.

Storage tanks were of a standard reinforced concrete circular design, replacing the traditional square masonry tanks and were built in fixed sizes of 1,000 gallons, 2,000 gallons, etc., up to 50,000 gallons or 225 m^3. Timber transportable moulds, made in the departments workshops, were used for the tanks and also for village fountains and other small structures. For elevated tanks standard reinforced concrete trestles of different heights were designed. Such mass production enabled work to proceed smoothly, quickly and at low cost and individual designs for particular villages were seldom needed.

In general there were few technical problems in these simple village schemes and progress in completing them in large numbers was limited only by the number of staff and the materials and money available having regard to the department's other commitments. The large quantity of pipes needed, sometimes up to 200 miles in a single year, limited progress in the post war years up to 1950 but thereafter was not a great problem.

Three of the more noteworthy village schemes of the 1948-59 period were the following:-

<u>Appidhes</u> This scheme supplied 23 villages from the Appidhes spring in the Paphos Forest. There were 99 miles of pipes, 27 storage tanks and 185 street fountains. It was completed in 1954 at a cost of £132,000 of which under half was paid by the villagers.

Dry Villages of Eastern Mesaoria Thirteen villages in the plains were supplied from the Kythrea spring. There were 63 miles of pipes, 8 storage tanks at ground level, 4 elevated storage tanks and 170 fountains. It was completed in 1956 at a cost of £90,000 of which half was paid by the villagers. Additionally, in compensation for the water taken from the spring under the Water (Development and Distribution) Law 1955, the department lined 18 miles of irrigation channels with concrete at a cost of about £60,000. While only 5% of the flow of the spring was diverted to the dry villages, more than 25% was saved from wastage by lining the channels.

Karpas Two boreholes near Ayios Andronikos were used to supply 3 villages in the first stage and four more later. Works consisted of a pumphouse with a 30,000 gallon storage tank, 6,500 feet of rising main, a 100,000 gallon storage tank, 11½ miles of distribution pipes, three village storage tanks and 42 street fountains. The first stage of the scheme was nearing completion at the end of 1959.

Some other typical village water supply schemes are described in detail in Appendix 2 which is a copy of Appendix 13 of Department's annual report for 1955.

TOWN WATER SUPPLIES

From May 1953 the officer in charge of the Town Water Supplies section of the department was Mr R S Wood, Senior Engineer.

The administrative control of water supplies to the chief towns in this period was under various authorities but technical advice was usually given by the Department of Water Development which also usually undertook the planning and construction of works. The position in each of the towns was as shown in the following paragraphs. Where there were Water Boards, as in Nicosia, Famagusta and Limassol, the six members of each were nominated half by Government and half by the respective municipalities. The Government nominees were the District Commissioner (chairman), the Accountant-General, and the Director of Water Development (members).

Nicosia in 1948 the water supply of Nicosia outside the city walls was in the hands of some 12 or more private companies while within the walls it was administered by the

Nicosia Water Commission, a body comprised of representatives of Government, the Municipality and the influential Turkish organisation Evcaf. The water sources were all wells or chains-of-wells around the town, except for a small pipeline from the Sykari adit in the Kyrenia hills. Within the city walls the water was not under pressure but was supplied by gravity through ancient aqueducts and divided and distributed by a "saccoraphi" system.

A Water Board was formed in 1951 with a duty to provide water within a newly defined area of supply which included the whole of the municipal area and some of the suburban villages. It assumed control of most of the private companies in 1953, but not the Nicosia Water Commission.

Two large improvement schemes were carried out by the Department of Water Development in the period 1952-1959, the first for the Water Board in 1952-55 and the second, the Greater Nicosia Scheme, directly for Government in 1956-1959. Construction of a third scheme, the Morphou Bay Scheme, also directly for Government, began in 1959.

The 1952-1955 works provided additional water chiefly from boreholes at Kokkini Trimithia and Laxia and from the upper Arab Ahmad and Makedonitissan chains-of-wells and it included the Strovolos reservoir, a ring main around the outside of the walls and a pressure distribution system outside the walls but only within the Board's area of supply. In 1956-1959 the Greater Nicosia scheme brought in water from Sykari, Dhikomo and Dhali and included the Engomi, Mandres and Lakatamia reservoirs and a pressure distribution system in suburban villages outside the Board's area of supply. It also delivered pressure water in bulk to the Board's system of pipes. At this stage the total quantity of water supplied to Nicosia and suburban villages amounted to about 14,000 m^3/day.

The Morphou Bay scheme included a 39 kilometre pumping main rising 245 metres, and it was designed to bring in 18,000 m^3/day from boreholes in the Morphou area. The first stage of this scheme (9,000 m^3/day) was carried out by the Department of Water Development in 1959 and 1960 with the help of consulting engineers (Messrs Howard Humphrey and Sons) and the Public Works Department which built the main pumping station. At that time there was still no pressure supply within the city walls though plans for it had been prepared.

The administration of water supplies in Nicosia remained confused and was still a cause for concern. Responsibilities were divided among the Government itself, the Nicosia Water Board and the Nicosia Water Commission. Attempts to combine these three into a single enlarged Board had not succeeded, mainly because of the disturbed political conditions in the period leading up to Independence.

In 1948 the average consumption in Nicosia was probably of the order of 50 to 100 litres per person per day. By 1959 it had increased to around 150 litres with restrictions at the height of summer, or if without restrictions, to probably 250 litres per person per day. By then the total population served was approaching 100,000 and so, to meet all demands, a total quantity of about 25,000 m^3/day was needed.

This fast rise in both per capita consumption and in total population, combined with the unpleasant fact that some of the existing sources were showing signs of partial failure through falling groundwater levels, made it clear that a reliable supply to satisfy all summer requirements could not be achieved easily and certainly not without the expenditure of large sums of money.

At the beginning of 1960 the incoming Government and the officers of the Department of Water Development thus faced a severe problem as regards Nicosia water supply and although some relief could be expected from the new Morphou Bay scheme no complete solution was likely for a number of years.

Famagusta Responsibility for the town water supply rested with the municipality until 1951 when it was taken over by a newly formed Water Board.

The town then received its water from wells and boreholes in the Stavros quarter and on the Ramparts while an additional small quantity came from the Panayia spring by means of an ancient aqueduct. Excessive pumping had caused the wells and boreholes to become slightly brackish through the infiltration of sea water.

The Department of Water Development carried out two schemes for the Water Board. The first, in 1951-1952, drew water from new boreholes near Phrenaros and included an 8 kilometer pipeline and a storage tank at Stavros.

This was followed in 1953-1955 by the development of a new pumping field at Phrenaros North, main pipe lines, two more main storage tanks and a completely new pressure distribution system within the town. The old Venetian aqueduct from the Panayia spring, after serving Famagusta faithfully for more than four hundred years was leaking badly and was no longer suitable for a twentieth century waterworks. It was replaced in 1958 by a 13 kilometre pipeline.

These new works and other minor improvements were capable of supplying the town with about 4000 m^3/day and it was found that a further 500 m^3/day from the old slightly brackish wells could be mixed with the new water without harm so that in all the waterworks in 1959 could supply about 4,500 m^3/day. This was almost sufficient to meet summer requirements though it was still sometimes advisable to turn off the water for short periods at night.

However the water table at Phrenaros was falling rapidly at about 80 cm per year, without appreciable recovery after winter rains, and it was unlikely that the boreholes could survive heavy pumping for many years. Moreover both the per capita rate of consumption and the population of Famagusta were increasing rapidly and it was clear that additional water would soon be needed. For this purpose a scheme was prepared in 1956 to bring in 9,000 m^3/day from some 10 boreholes in the Liopetri and Xylophagou areas through a 16 kilometre pipeline. Some of the materials for this scheme were ordered in 1958 but the works did not proceed because of the troubled political conditions.

Other schemes were also considered, including the possibility of using winter water from the Kythtrea spring, where large quantities were not fully utilised between November and February each season. If these were piped to Phrenaros they could have been used partly for re-charging the boreholes and partly for supplying the town directly with winter water. This would have enabled the Phrenaros boreholes to accumulate a reserve in winter so as to be capable of producing more water in summer according to the practice already adopted successfully at the Chiflikoudkia chain-of-wells in Limassol.

Limassol The water supply was managed by the municipality until 1951 when a Water Board was formed and took over control.

Before 1953 Limassol obtained most of its water from the Chiflikoydhia chain-of-wells by means of an old pumping station installed at about the turn of the century. The machinery was renewed probably in the early 1940's when, at about the same time, an elevated steel water tank was erected. The wells were over-pumped and the water became brackish because of the infiltration of sea water.

In 1952 - 1955 the Department of Water Development undertook a new scheme for the Water Board bringing good quality water to the town through some 31 kilometres of pipes from three mountain springs, Kephalovryso, Kria Pighadia and Mavromata, near Khalasa and building a new reservoir near Ayea Philia and a completely new pipe distribution system. These three springs more than satisfied winter demand and the surplus was then discharged into the old chain-of-wells where it accumulated for use in summer. This re-charge operation thus revived the old wells which then acted as a seasonal storage reservoir of large capacity yielding sweet water in summer when it was most needed. It brought the total summer supply to the town up to about 7,000 m^3/day in an average year or 200 litres per person per day, enough to avoid summer restrictions for several years to come.

To provide more water for the expanding population and for higher future standards of living, investigations were made by means of geophysical seismic surveys and trial borings for obtaining supplies from the gravels of the Kouris, Garillis and Yermasoya river basins. By the end of 1959 the most promising of them appeared to be the Yermasoya area where new boreholes seemed capable, after testing, of supplying another 4,000 or 5,000 m^3/day.

Larnaca In 1959 the water supply of Larnaca still came from an old chain-of-wells constructed in about 1745 by the Turkish Pasha Abu Bakir and it was still managed by the Turkish organisation Evcaf. In 1941 the old open aqueducts were replaced by pipes but the "saccoraphi" system of distribution by shares remained. The water in summer varied between about 2,250 m^3/day in a dry year to 4,500 in a good year and by 1959 was sufficient in an average summer to provide about 200 litres per person per day to a population estimated at 19,000. Although this overall rate was reasonably satisfactory local shortages occurred in the higher parts of the town because there was no reservoir and no satisfactory zoning of the street mains into distribution areas.

An outline scheme to remedy these distribution defects was prepared, but not then implemented because, perhaps, the urgency was not great and money was scarce. However in some areas the "saccorophi" system was replaced by water meters and by 1959 some 20% of the water was sold by volume.

For additional water, which would soon be needed for a growing population, no suitable groundwater sources near Larnaca were available having regard to higher priorities for irrigation and also for Famagusta water supply. Some consideration was given to an impounding reservoir on the Tremithios river but no firm plans were prepared.

Paphos Two small schemes for supplying Ktima and Kato Paphos were carried out by the Municipality in 1952 and 1958 under the supervision of the Department of Water Development. These increased the existing supply, which came from several small sources, by additional borehole water and provided a reservoir and a new metered pipe distribution system. The total water then available in an average year amounted to about 700 m^3/day or 100 litres per person. In a dry season it would be less, and so more water was needed to meet the summer requirements of an expanding population. A proposal under consideration included bringing water from the Trozena springs near Yerovasa and from wells or boreholes in the Dhiarias river gravels, through a 40 kilometre pipe line.

Kyrenia The three small chains-of-wells belonging to the Municipality had become insufficient by the early 1950's. In 1953 the Department of Water Development was successful in locating some artesian water by sinking a borehole in the Boghaz pass between Nicosia and Kyrenia, and in 1954 the water was piped to the town. This work was followed in 1955 by the construction of a small collecting tank and a pipe line from the Platanos springs and from another, older borehole. In 1958 the total supply amounted to about 400 m^3/day or 100 litres per person of a population estimated to be approaching 4,000. At that time it was considered that additional water, when needed, would have to be obtained by the acquisition of part of the flow of the Lapithos or Karavas springs.

HYDROLOGY

In 1948 very little factual information of the Island's water resources was available, apart from somewhat spasmodic measurements of the flow of the chief springs taken over the previous ten years or so. Of particular importance as regards groundwater was the need for facts about falling groundwater levels resulting from the rapidly expanding drilling programme and, as regards surface water, about the quantity available for irrigation from rivers and springs. Without such facts it was impossible to plan wisely for the best future use of the Island's limited resources.

With only a small staff to attend to such matters, progress was at first necessarily slow. However by 1951 regular measurements of water level were being made in some 56 key boreholes and a comprehensive report had been prepared on the "Underground Water Resources of Cyprus" by Dr David Burdon, Assistant Water Engineer. Regular measurements were being made of the flow of 143 springs and the measurement of flood discharges in rivers was begun by the installation of two automatic water level recorders, one on the Pedias at Nicosia and the other on the Serakhis near Morphou.

From 1952 onwards the Department's annual reports contained records of water levels in control boreholes and from 1953 there were annual summaries of hydrological conditions under the heading "Hydrological Notes". There were also monthly reports for office use containing details of measurements.

In 1954 an engineer-hydrologist (Mr Michael Grehan) was appointed to the department and he took charge of a new hydrological section formed for the purpose of studying

(a) Run-off in rivers and streams

(b) Spring discharges

(c) Run-off in different types of catchments

(d) Quantity of water drawn from wells and boreholes

(e) Changes in groundwater levels

(f) Annual recharge of aquifers

(g) Chemical and bacterial analyses of water

(h) Special problems in certain groundwater areas

He prepared a comprehensive report in 1958 taking into consideration all information collected by the Department over the previous decade and earlier. Each catchment was described in detail with an estimate of the yield and replenishment of groundwater areas and of the run-off. In the same year a technical paper on "Hydrology and Water Development in Cyprus" was prepared in the department jointly by the Director, Assistant Director, and the Engineer-Hydrologist and presented to the Institution of Civil Engineers, London.

By 1959 the Hydrological activities of the Department had increased to the extent shown in the following paragraphs:-

(a) Automatic water level recorders were installed at 34 sites, mostly on streams and rivers to observe flood discharges. Many were fixed at specially constructed measuring weirs.

(b) The discharges of 109 springs were recorded regularly, involving 1785 measurements during the year.

(c) A total of 57 specially drilled observation or control boreholes were observed regularly in order to determine changes in the levels of groundwater.

(d) Chemical analyses were made of 1549 water samples by the Government Analyst and bacteriological analyses of 183 samples were made by the Government Pathologist. They showed the extent of change in the composition of water resulting from over-exploitation or contamination of sources and they were made with the object of protecting the users of both domestic and irrigation supplies.

(e) Special intensive studies of groundwater conditions in the Phrenaros area, which was the chief source of the Famagusta town supply, and in the Kokkini Trimithia and Morphou Bay areas which were of particular importance to the Nicosia town supply. These studies involved special observations not only of the regular control boreholes but also of some 2,000 privately owned wells and boreholes, many of which were equipped with water meters. The meters were used for groundwater studies and also as a means of measuring the quantities of water used in general practice at different times of the year, for irrigating various agricultural crops.

The hydrological services described in the foregoing paragraphs were proving themselves of great value both for the long term, in collecting data for the eventual planning of major schemes, and in the short term in providing information for the design of small works and facts about the effects of heavy pumping upon natural groundwater reservoirs.

In the disturbed political conditions of the years immediately preceding Independence in 1960, it was not found possible to publish a printed year book with all the hydrological information described above, nor could interpretations of the information be fully presented. However, the importance of preserving all facts and figures for future attention was well recognised and was attended to by recording them in detail in monthly reports kept for departmental use, and also to some extent in annual summaries contained in the "Hydrological Notes" of the departmental annual reports.

WORKSHOPS

The officer in charge of the workshops was Mr Antronig Karoglanian, Senior Inspector of Works. From its inception in 1939 until 1960 the department carried out most of its own construction work without the help of contractors except for the supply of materials and transport. Until the early 1950's works were in the traditional style requiring little mechanical equipment other than hand tools. Building was mostly in masonry set in lime mortar. Construction plant such as excavators, compressors, even concrete mixers were seldom needed and there was very little pumping plant or machinery to install and maintain. The maintenance of drilling equipment was done mostly by the Public Works Department which also supplied what little construction plant was necessary.

As the nature and volume of the work changed with the increasing use of concrete for the construction of tanks and reservoirs, of pumping for both irrigation and domestic water, and of more sophisticated methods for town water supplies it became necessary for the department to operate and maintain its own mechanical plant. Accordingly workshops were established and gradually extended to become a very effective part of the department's activities. Much of the success of the workshops was due to the exceptional abilities of Mr Antronig Karoglanian.

By 1959 the workshops, including stores, consisted of a workshop office, garage, fitters shop, plant maintenance bay, precast concrete yard, welders shop, smithy, moulding shop, a water-meter testing room and three store buildings. In addition there were two open storage sites, one of 1½ donums mostly for inter-changeable timber formwork and one of 12 donums for pipes.

These workshops attended to the maintenance of all departmental plant and in addition served all sections of the department in respect of such matters as the building of forms for concrete work, carpentry,~~the supply of precast concrete work, carpentry~~, the supply of precast concrete products, concrete testing, the installation of pumping plant, the fabrication of special pipe connections and steel sluice gates, the cutting the bending of steel reinforcement, the slotting and perforation of pipes and the drilling of casing, etc etc.

Heavy transport was all hired from contractors though a few light vehicles were kept chiefly for personnel and for the transport of light tools. However a low loader and tractive unit provided for the movement of heavy machines. Among the larger mobile plant were some 15 drilling rigs, 8 excavators and bulldozers, 11 compressors, 4 deep well testing units, and three trenching machines.

This section of the department distinguished itself by its initiative in expanding to meet requirements and by its readiness to undertake all types of work often in emergency or at short notice. The close contacts which its personnel kept with the officers supervising construction contributed greatly to the overall progress of the department.

STAFF AND LABOUR

Between the end of 1948 and the beginning of 1959 the technical staff, including foremen, increased in numbers by 62%, from 84 to 136. The numbers in the various grades were as shown:-

	1948	1959
Director	1	1
Assistant Director	-	1
Senior Engineers	-	3
Engineer Hydrologist	-	Recently vacated
Executive Engineers	-	6
Geologist	-	1
Superintendent of Works	1	3
Senior Inspectors	1	7
Inspectors	5	9
Technical Assistants	11	29
Foremen	65	79
Total	84	136

The average number of labourers employed was 805 in 1948, increasing to 1740 in 1953 and then declining as mechanical equipment came into use to 760 in 1959.

In the latter part of this period six students were sent to the U.K. to obtain university degrees and by 1959 three had completed their courses successfully and another three were still studying. Of the three who returned two were appointed Executive Engineers and the third Geologist. One of the Executive Engineers was Mr C A C Konteatis (now Dr Konteatis) who later became Director (1967-1979) and the geologist was Mr Yangos Hudjistavrinou who became Director of the Geological Survey Department from 1965 until his untimely death in 1978.

The staff listed above was responsible for all the work of the department which included planning, design, administration and supervision of works by direct labour as well as the study of hydrological and geological data and technical advice to Water Boards and village committees as required. No help was received from outside consultants or contractors except in one instance when, in 1958, consultants were engaged for the main domestic water pumping station at Morphou Bay and the pipe line to Nicosia.

With so few technical officers to undertake the many tasks set before them it is fair to say that the department was badly under-staffed, a condition that persisted to the end of the decade and beyond.

By 1959 the Water Development Department had grown to be a strong and influential force in the Island. It was staffed by capable, enthusiastic and efficient Cypriot officers under the leadership of expatriates, working together in close co-operation as a very effective team. Despite being overworked and having to contend with difficult political conditions they achieved a very fine record of progress as will have been seen from the foregoing sections of these notes. For this they deserve the highest praise.

Special mention may be made of some of the long-serving members of the staff some of whom had been working continuously in Government since the early 1920's when they first joined the Public Works Department. Among these were Messrs V C Toundjian MBE and J K Karapetian BEM. Mr A H P McLaughlan began as far back as 1920 though with a six year break gaining overseas experience. Mr V Levonion was with the Water Development Department until the end of 1957 when he left after 39 years of outstanding service in Government to become manager of the Nicosia Water Board.

Among those who joined in the 1930's, before or about the time the new Water Supply and Irrigation Department was formed were Messrs Douglas, Karoglanian, Piyotis, Karakannas and Toufexis. Other long-serving officers who joined a little later were Messrs Theocli, Yiannokou, G Haralambous, Pantelides and Santi.

The Services of these experienced men were of the greatest value and many of them perhaps deserved more advancement than they received though that was not possible under Government regulations because of their lack of academic qualifications.

A number of experienced specialist expatriate officers took up senior positions in the 1950's. Mr David McGregor, who was a geologist, became Assistant Director in December 1952 and later, from July 1959 acted as Director for a year after the departure of Mr Ward. Mr R S Wood, who had specialist experience of water supplies in Britain was appointed a Senior Engineer in May 1953 and took charge of the town water supply work until he left in August 1959. Mr Michael Grehen occupied the post of Engineer-Hydrologist from October 1954 until August 1958.

7. CONCLUDING REMARKS

The facts and figures of these notes were obtained from many old reports, including the departmental annual reports and they were supplemented at times from the writer's memory of events in the eleven years he was in Cyprus closely involved in the establishment and early growth of the Water Development Department.

The story covers practical water development in Cyprus from its earliest days up to 1959, by which time the Water Development Department was firmly established and had reached what might be termed "the end of the beginning" of its life. It is now fifty years since it began as the modest Water Supply and Irrigation Department and it seems appropriate that an account of its early life should be placed on record, even though it may be overshadowed by the greater and more spectacular achievements that followed.

With the coming of Independence the British expatriates mostly returned home and for an interval the department lost its momentum and suffered from lack of direction, the only pause in a long record of steady and accelerating progress. However a number of Cypriot students had become qualified in Britain or were being trained overseas and some had already returned to take up positions of authority and eventual control, and they were followed by others. They soon proved to be extremely capable and their success rapidly became evident in the great works that took shape throughout the Island in the succeeding years up to the present time, about 30 years after Independence and 50 years after the beginning of the department.

The writer is now only a distant observer of present-day Cyprus but is glad to be able to keep up some contacts with his old friends. He finds it a great pleasure to offer his congratulations to the staff of the department who have done so well over the years and, in particular, to the first Cypriot director, Dr C A C Konteatis and to his successor, the present director, Mr C St Lytras.

APPENDIX 1

DESCRIPTION OF CERTAIN IRRIGATION SCHEMES

This is a copy of Appendix 6 of the 1955 Annual Report of the Department of Water Development written by J Karapetian B.E.M., Senior Inspector of Water supplies.

(*A*) *Perapedhi.*—This scheme consists of a dam 60 feet above river bed level impounding 11 million gallons of water on the Kryos river, half-way between Platres and Perapedhi. The work was undertaken as a measure of compensation to the Irrigation Division of Kilani and Perapedhi, for the quantity of water drawn by Government from the upper sources of the river for domestic purposes in the Troodos area.

It was estimated that the total requirements on Troodos in future would be of the order of about 10 million gallons during the summer season, and the reservoir was therefore designed to hold about an equal quantity of water, which could be stored in winter, when there was plenty of water in the river and drawn off at a slow rate for irrigation during the summer. In addition to storage in the reservoir, the stream in late summer flows at a minimum rate of about ½ cusec.

The dam was built in two stages : the first stage was completed in the summer of 1954 and consisted of the foundations and the undersluice section up to level 8 feet above river-bed. The average depth of foundation below bed-level was 7 feet and the width at foundation level is 52 feet. The foundations were cast in concrete mainly in the proportion of 1 : 2 : 4 and the total volume of concrete in the first stage was about 500 cubic yards.

The second stage of the scheme proceeded in 1955. Excavation work of the abutments started in spring and the main work of concreting commenced in June and was completed at about the end of September. The reservoir first filled on 16/12/55, when surplus water began to flow over the crest.

The core of the dam was built all in 1 : 3 : 6 cement concrete and the outer faces to a width of 4 feet with 1 : 2 : 4 cement concrete. Concrete was cast in 2-foot lifts in blocks with vertical construction joints at 40-foot intervals rendered in a bituminous mixture with copper strips near the upstream face. Stone displacers or " plums " were embedded in the concrete in the core of the dam in the proportion of about 15% of the volume of the concrete. Aggregate was brought to the site by lorry from the coast near Limassol and Episkopi, a distance of 20 miles, the last two of which were along a specially made mountain access track. From a flat space about 100 feet above the stream bed the aggregate was discharged through steel pipes directly into a concrete mixer standing on the top of the partly completed dam raised periodically upon the completion of each lift of concrete. In about three months a total of about 5,000 cubic yards of concrete was poured.

A circular 15" diam. penstock gate was installed at the mouth of the undersluice gallery with a screw spindle that can be operated from the crest. The draw-off arrangement consists of a vertical perforated inlet pipe fixed on the upstream side of the dam, a 6-inch sluice valve operated by a spindle and wheel from the top of the dam, and a 6" steel delivery pipe cast in the dam at 2 feet above bed level, discharging into the river at the downstream end. The valve is fitted at the lower end of the perforated pipe.

This dam is the first in Cyprus to be built of concrete, the usual practice in the past having been to build in masonry with lime or cement mortar. The total cost was £25,000.

(*B*) *Kandou.*—The first stage of the scheme was carried out in 1953–54. It consisted of intake works and distribution channels and a small dam of 15 feet in height, on the " Tabakkos " valley which was built mainly for experimental purpose to find out if the rock at the site of the dam was sufficiently impervious to hold water.

When the experimental dam had proved successful, a new scheme for raising the dam to 40 feet was put in hand and completed in 1955. The storage capacity of the new reservoir is 8 million gallons.

The new dam encloses the first experimental dam within itself. It is built in rubble masonry in cement mortar of proportion 1 : 4 and all stone used for the work was extracted from near the site. A great deal of excavation had to be made into both abutments, to find a solid and impervious rock, free from cavities and fissures.

The width of the dam at foundation level is 32 feet and the crest length between abutments is about 200 feet. The total volume of masonry completed in 1955, was 3,000 cubic yards. It was built in lifts of one foot and vertical contraction joints joined by copper strips were allowed at 32-foot intervals. The downstream face was built in steps cast in cement concrete and the upstream face was plastered in cement mortar. A 2′ × 2′ penstock operated from the top of the dam was installed at the mouth of a 3′ × 4′ undersluice gallery and a draw-out pipe is controlled with a 4″ diam. valve in a manhole immediately below the downstream toe of the dam.

The total cost of the scheme including the first stage works was £21,500 towards which the Irrigation Association Committee contributed the sum of £5,500.

The total area commanded is 600 donums out of which 400 donums can be irrigated in summer.

(C) *Kilani.*—This is a typical scheme of reinforced concrete lined irrigation channels which has proved very popular especially in hill villages, for preventing the waste of irrigation water.

The scheme consists of three weirs and one groyne-intake at successive intervals in the bed of the river with channels either on one or both flanks conducting the water to terraced gardens mostly planted with apple-trees.

The original irrigation scheme for Kilani was carried out by the Department in 1943, and some improvement works were continued in subsequent years. The lack however of properly lined irrigation channels was very badly felt, and the present scheme of linings and supplementary intakes has satisfied a long felt need in the village.

A total length of 8,000 feet of channels has been lined including some lengths of pipe distribution branches and crossings where necessary. The total cost of the scheme was £5,400 out of which the villagers contributed one-third or £1,800. The total area benefited with summer irrigation is 105 donums.

(D) *Pyrgos (Ll.).*—The scheme was carried out for an Irrigation Association known as " Moulos " in the village of Pyrgos, Limassol.

The scheme consists of a subsurface weir and reinforced concrete channel. The weir is one of the largest of its type undertaken in Cyprus and has a total length of 250 feet maximum depth of 18 feet below lowest river bed level. The profile of the bed rock was first determined by trial wells and boreholes and the subsurface flow was determined by test-pumping.

Before the execution of the scheme there was very little if any water flowing on the river surface in summer and the members of the Association had to content themselves with water for winter and spring irrigation only. Following the construction of the subsurface weir a flow of about 100,000 gallons per day was brought to the surface and made available for summer irrigation. This was according to the original forecast.

The scheme, which includes lining of some 3,500 feet of channels in reinforced concrete was first estimated in 1953 at £3,000 out of which the Association was to contribute 52% of the cost (i.e. £1,560). Due, however, to the increase of wages of labourers, field allowances, etc., the cost of the scheme was £6,400 which is by £3,400 above the original estimate. The difference in cost was, therefore, borne by Government. Total area commanded is 200 donums out of which 100 donums is irrigated in summer.

(E) *Gypsos.*—This is a scheme for the control and impounding of flood waters for irrigation purposes. It consists of an earth dam 1,700 feet long and 16 feet high, across a valley north of Gypsos at the locality " Vathys ". The storage capacity is 30 million gallons and the area of the bed is 400 donuns. The object of the dam is to retain spate water flowing from the surrounding hills, from which the water runs off at a high rate for a short period of time. By impounding the water in the reservoir it is brought under control and can be released at a slow rate and be used with greater advantage.

The work was commenced in 1954, when the relief spillway was constructed with two 100-foot long spill-weirs, built in series. The spillway is 600 feet long and each weir is 100 feet wide and 4 feet deep. Excess water over and above the capacity of the reservoir is discharged into an adjacent stream. The draw-out arrangements were also completed in 1954. These consist of an intake channel leading to a vertical perforated pipe 8" diam. which delivers into a valve tower rising above the flood water level. An outlet pipe 8" runs from the valve tower under the dam into the irrigation system below the reservoir. Draw-off control is effected by means of a penstock gate operated by a wheel and spindle mounted at the top of the outlet pipe. A foot-bridge has been provided leading from the embankment to the top of the tower for easy access.

The construction of the earth dam was started and completed in 1955. A total of about 25,000 cubic yards of earthwork was involved in the scheme. All work was done by machinery supplied on loan by the Department of Agriculture and other Government departments, or hired from contractors.

The spoil used for the construction of the embankment was taken from a wide borrow-pit immediately above and alongside the embankment. The foundation of the bank was excavated to an average depth of 2 feet and earth was placed and properly consolidated in layers of about six inches. The construction was carried out in three main sections with stepped joints between sections. The machinery used was mainly a scraper, traxcavator and rollers. Water for consolidation was brought through a pipeline from a distant well which was sunk for the purpose.

The total cost was £7,545, of which £1,750 was contributed by the beneficiaries. An area of 740 donums of cereals can be irrigated.

(F) *Mamonia Chiftlik.*—A supplementary scheme of works was carried out in 1955. This consists mainly of lining in reinforced concrete all the length of the main channel which conveys water from the river at the village of Ayios Yeoryios to the lands of the chiftlik. This supply is required only for winter and spring irrigation, as the river flow in summer is very small. The summer irrigation supply to the chiftlik is provided by a pumping installation which is part of the first scheme completed in 1954.

The present works will, apart from benefiting the chiftlik, which is a public utility project, also benefit private owners of lands in the Ayios Yeoryios area, who will enjoy irrigation water, as they did in the past through an improved system of lined channels.

The total area benefiting from the scheme including the chiftlik area is 720 donums, out of which 273 donums are private holdings. The total length of reinforced concrete channels constructed in 1955 was 11,800 lin. feet and the total cost £7,400. The scheme will be completed in 1956.

(G) *Akaki.*—Improvement works to an old chain-of-wells at the "Merika" locality were commenced in September, 1954, and completed in early August, 1955.

The works carried out consist of the cleaning and regrading of old tunnels, the extension of these works by sinking 22 new wells and the driving of 1,100 feet of tunnels and the excavation of 400 feet of cutting.

In order to prevent leakage the tunnels were lined with reinforced concrete precast oval blocks and the channels, for some 4,370 feet, with reinforced concrete cast in place.

The surface water which was formerly flowing in the river bed has been intercepted and collected by the extension of the tunnels and is now most effectively utilized for the irrigation of some 270 donums under various seasonal crops. The sum of £8,000 was spent on the execution of the necessary improvement works, towards which the beneficiaries contributed 50%.

APPENDIX 2

DESCRIPTION OF CERTAIN VILLAGE WATER SUPPLY SCHEMES

This is a copy of Appendix 13 of the 1955 Annual Report of the Department of Water Development written by V C Toundjian M.B.E. Superintendent of Waterworks.

(*A*) *Dhali* (*Nicosia*).—This is a pumping scheme from a public well located on the bank of Yialias river which passes along the northern outskirts of Dhali. A pumping unit was installed and housed after the well was deepened and lined to a depth of 56 feet. Its yield on test late in summer was over 8,000 gallons an hour.

A turbine pump driven by a diesel engine 13.5 H.P. pumps the water through a 4" main 0.3 mile in length at the rate of 6,000 gallons an hour against a total head of 120 feet to a set of three R.C.C. circular storage tanks of 10,000 gallons capacity each, built on a commanding hill on the N.E. end of the village.

The water is distributed by means of 19 public fountains, which are built to the standard type complete with troughs, drains and soak-pits. A reticulation covering almost all the streets in the village for a house-to-house service was also installed. The total length of galvanised pipes up to 4" diameter laid was 5.0 miles of various sizes, fitted with the required specials for house connections.

The scheme was commenced in February and completed in October, 1955, at a total cost of £8,500, or an average cost of £4.3 per head of the population which, according to the 1946 census, was 1965.

(*B*) *Karavas* (*Kyrenia*).—Karavas is a rural municipality. Although it is fortunate in having a potential source of supply known as " Kephalovrysos " with a flow fluctuating between 540,000 and 1,400,000 gallons a day, yet it lacked a proper piped distribution system.

By an arrangement with the owners of the spring, which is mainly used for irrigation, one-fifteenth of the flow was acquired and a distribution box for this purpose built at the source. The share thus acquired is conveyed in a 2½" steel main 0.7 mile in length to twin storage tanks of 10,000 gallons capacity each, built on a commanding site above the village.

Water is distributed by means of 31 public fountains including two at the school yard built in the form of small 4' × 4' × 4' tanks. A reticulation for a house-to-house service was also installed, complete with fittings for house connections. The total length of galvanised pipes laid in the village is 6.3 miles (sizes up to 3" diameter).

Work was commenced in April and completed in September, at a total cost of about £8,500 or an average cost per person of £4. The population is 2,156 as per 1946 census.

(*C*) *Arsos* (*Larnaca*)–*Vatili–Strongylos* (*Famagusta*).—This is a combined gravity scheme from an underground source known as the Arsos chain-of-wells, located about three quarters of a mile S.S.W. of the village, whence it derives its name.

The section of the tunnel which lies in water bearing stratum (1,630 feet in length) was lined in masonry with precast R.C.C. slabs and the mouth-tops of the shafts built and sealed. An asbestos-cement 6" pipeline 3,700 feet in length (partly laid in the dry section of the tunnel and partly in the deep cutting beyond the tunnel outlet, viz. 1,800 feet and 1,900 feet respectively) conveys the flow (maximum = 64,000 gallons a day and minimum = 32,000 gallons) to a distribution box built on top of a new 6,000 gallons R.C.C. circular storage tank at Arsos.

The water at this box is divided between the three villages in proportion to their population. The share of Arsos is discharged into the storage tank underneath the box and the remaining water of the two other villages is conveyed in a galvanised common pipeline partly 4" diameter and partly 3" for 3½ miles to a second distribution box built on top of one of the twin 10,000 gallons storage tanks by the main roadside at Vatili. Here again, after Vatili's share is discharged into the twin tanks, the remaining water is conveyed in a 2" galvanised pipeline 2¼ miles in length to a 3,000 gallons R.C.C. circular storage tank at Strongylos.

The distribution at the villages is effected by means of public fountains fed from the storage tanks mentioned above. The total number of fountains built to standard type is 45, including four at the school yards in the form of small 3' × 3' × 3' tanks. The total length of reticulation pipes laid is 4.4 miles and of sizes varying between 4" and 1" diameter.

Work commenced in July and was completed towards the end of December, at a total cost of about £24,500 or an average cost per person of £7.7. The combined population of all three villages was 3,156 in 1946.

(*D*) *Kondea–Sinda–Kouklia* (*Famagusta*).—The source of supply of this combined pumping scheme is borehole No. 40/54 located about two miles S.W. of Kondea. A pumping unit of 5,000 gallons an hour turbine driven by a 13½ H.P. diesel engine was installed and housed in a masonry building. Water is first pumped into a set of four R.C.C. circular storage tanks of 10,000 gallons each, built at a distance of about 100 yards from the pump-house, and thence gravitated in a galvanised composite main (3" and 2½" diameter 2 miles in length) to a distribution box built on top of a newly constructed 10,000 gallons storage tank at Kondea.

At this box the water is divided between the three villages in proportion to their population. After Kondea's share is discharged into the storage tank immediately underneath the box, the remaining water is conveyed in two independent pipelines to the new storage tanks at Sinda (10,000 gallons) and Kouklia (3,000 gallons)—the respective lengths of the mains being 4.4 miles of 3" and 2½" and 2¼ miles of 1½" and 1¼" galvanised pipes.

Water is distributed at the three villages by means of public fountains (standard type), of which 53 in all were built, including two in the form of small tanks at the school yard. The total length of reticulation pipes laid is 5½ miles and the diameters are 1" to 4".

Work was commenced in April and the whole scheme completed by the end of August, at a total cost of about £23,000 or an average cost of £10 per head of the combined population (2,268 in 1946.)

(*E*) *Paramytha–Spitali–Palodhia* (*Limassol*).—This is a combined gravity scheme, having as its source of supply two springs known as "Marammenos", which are located near the 15th milepost of the Limassol–Agros road. These springs were acquired for £800 and work on their excavation and building commenced in September 1954.

The flow, which fluctuates between 32,000 and 16,000 gallons a day, is conveyed in a main galvanised pipeline of 1½" diameter and of 7¼ miles in length, laid along the Agros road, to a distribution box built on a commanding site about half a mile S.E. of Paramytha. The water at this box is divided between the three villages in proportion to their population and thence conveyed in independent pipes (total length 2.1 miles, diameter 1¼") to the newly constructed R.C.C. circular storage tanks of 2,000 gallons capacity each at the villages.

The distribution at each village is effected by means of public fountains (standard type) fed from the aforementioned storage tanks. The total number of fountains erected is 11 and the length of reticulation pipes laid 0.7 miles (galvanised steel 1½" and 1" diameter).

(F) Emba–Lemba–Kissonerga (Paphos).—This is a combined gravity scheme from " Stavlisma " spring, located at about half a mile to the N.E. of Trimithousa village. After excavating and building the source, its flow (fluctuating between 50,000 gallons a day in spring and 16,000 gallons in autumn) was conveyed in a composite steel main of 3" and 2" diameter, two miles in length, to a distribution box on the eastern outskirts of Emba.

The water at this box is divided between the three villages in proportion to their population. After Emba gets its share, the remaining water is proportionately piped in independent pipelines to Emba (1.3 mile of 1½") and Kissonerga (2.1 miles of 2" and 1½").

The distribution at the villages is effected by means of public fountains (standard type), of which 33 in all were erected (including three in the form of small 3' × 3' × 3' tanks). These are fed from R.C.C. circular storage tanks (four with a total capacity of 24,000 gallons). The total length of galvanised reticulation pipes laid is 4.6 miles of various sizes 2½" down to 1".

The headworks were commenced in September, 1954, and the whole scheme completed in April, 1955, at a total cost of about £13,000 (including £3,024 for the acquisition of the spring). The average cost *per capita* is £8.1 calculated on the combined total population of 1946, which was then 1,597.

APPENDIX 3

STAFF OF WATER DEVELOPMENT DEPARTMENT 1959

(adapted from official staff list)

Appointment	Name	Date of Birth	Date of First Appointment
Director	I L Ward C.B.E	30/10/06	19/07/48
Assistant Director	D P McGregor	29/9/04	4/8/52
Senior Engineers	R S Wood	29/3/11	23/5/53
	AHP McLaughlan	13/2/03	1/12/51
	OJE Gething	27/10/115	9/6/58
Engineer Hydrologist	M Grehan	1/6/13	26/10/54
Executive Engineers	ARH Deverill	5/6/27	23/12/56
	L C Mock	1/3/24	30/1/57
	T E Scales	7/5/29	4/7/57
	H S Suphi	5/7/31	16/9/57
	AJB Staveley	23/9/30	9/2/58
	C F Sayer	10/9/28	8/4/58
Geologist	R D Morris	22/1/34	5/9/57
Superintendents of Works	V C Toundjian M.B.E.	7/2/01	8/3/29
	J K Karapetian B.E.M.	17/6/99	1/2/22
	H P Karakannas B.E.M.	3/12/18	17/6/39
Senior Inspectors of Works	A F Butler	8/9/07	17/4/51
	D Th Piyitis B.E.M.	9/3/03	11/4/39
	P Pantelides	6/2/19	1/5/47
	A Karoglanian B.E.M.	1/7/19	1/1/39
	C G Papadakis	13/4/15	7/4/51
	G A Douglas	28/7/14	1/3/37
	E Santi	19/4/14	23/12/46
Inspectors of Works	C Theocli B.E.M.	31/1/00	1/1/44
	N Yiannakou	21/4/20	1/1/44
	N Chr Toufexis	2/3/17	1/9/39
	G Haralambous	30/3/22	13/3/44
	S Giragassian	25/8/30	1/5/52
	S Chr Haji Pavlou	15/4/29	1/2/51
	A Josephin	17/12/31	1/11/53
	C Georghiou	21/1/32	1/11/53

Chief Foremen	Ch Loakim	10/6/10	1/1/47
	M Andreou	21/1/07	1/1/47
	Y Serghides	25/4/18	1/5/52
	Chr Stylianou	1/6/22	1/7/49
Administrative Assistant	O G Loizides	13/6/06	1/10/27
Accounting Officer	N Georghiou	20/1/23	1/5/46
Principal Clerk	HA Theodossiades	10/2/02	1/10/19

Two officers whose names are not shown on the above list should also be mentioned. They are Dr D Burdon, Assistant Water Engineer from 1949 to 1952, and Mr V Levonian, Superintendent of Works, who served for 39 years from 1917 to 1956 and thereafter became manager of the Nicosia Water Board.